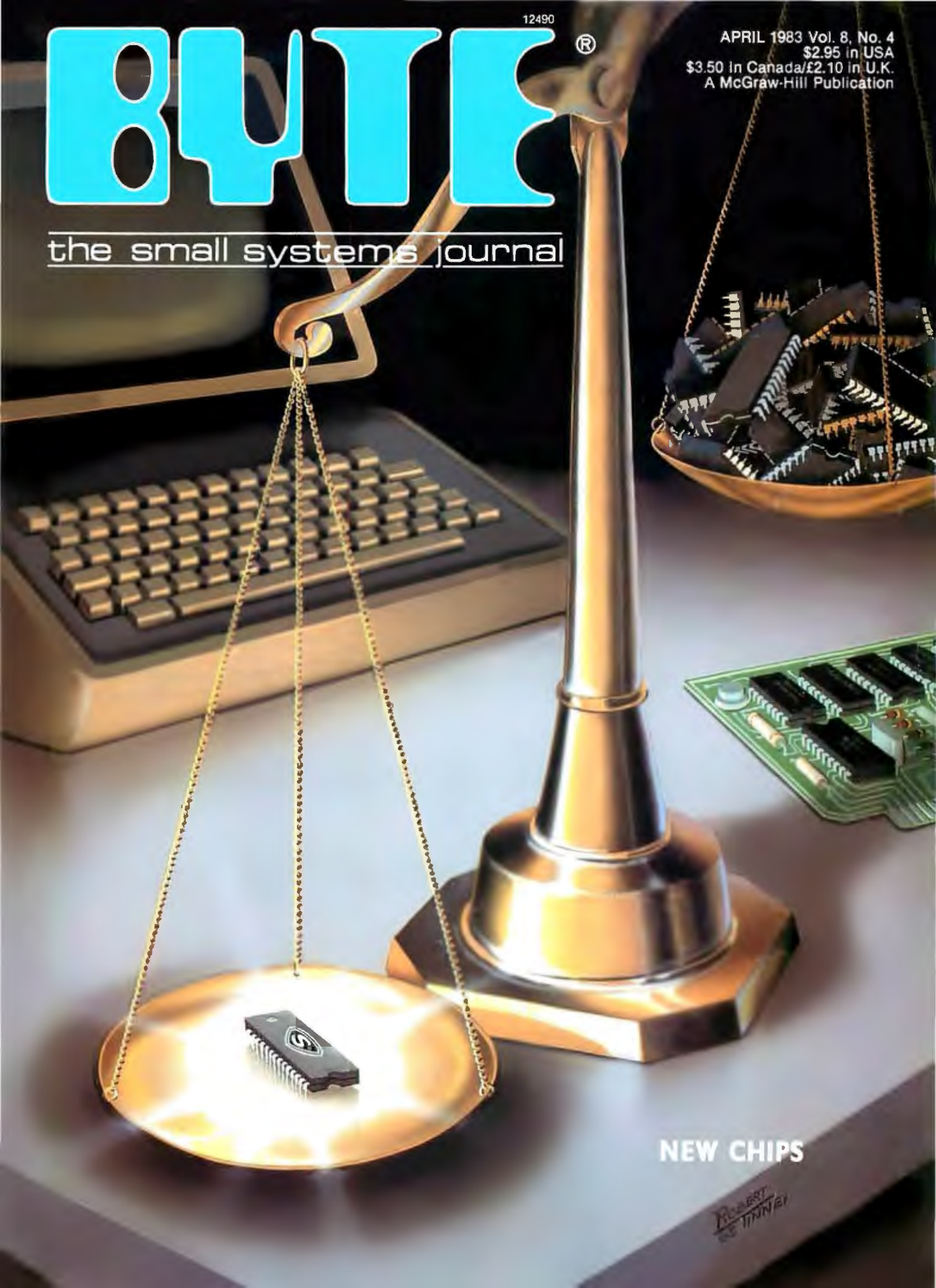


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Inside Apple

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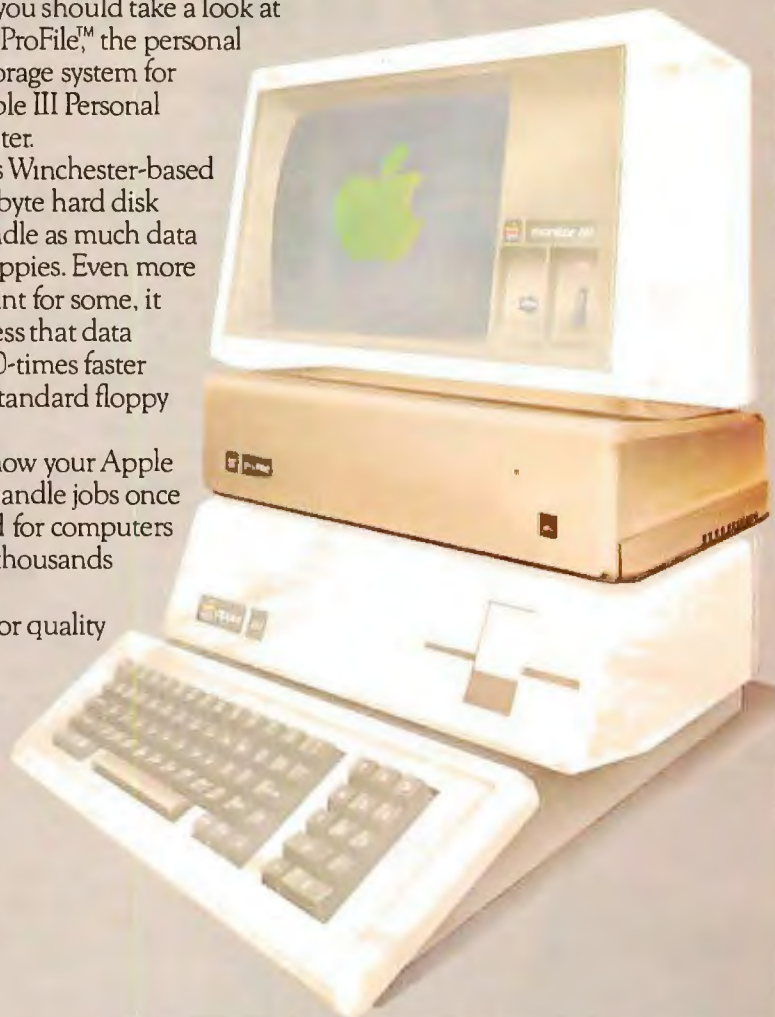
This Winchester-based 5-megabyte hard disk can handle as much data as 35 floppies. Even more important for some, it can access that data about 10-times faster than a standard floppy drive.

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Features

28 **Build an RS-232C Breakout Box** by Steve Ciarcia / This diagnostic tool can help you make working serial connections.

53 **The National Semiconductor NS16000 Microprocessor Family** by Glenn Leedy / The 16000 brings to microcomputers features formerly available only on much larger systems.

70 **Design Philosophy Behind Motorola's MC68000, Part 1** by Thomas W. Starnes / This 16-bit processor with multiple 32-bit registers is considered by many experts to be the most powerful, yet easy-to-program microprocessor available.

96 **The CRT 9007 Video Processor and Controller** by Brian Cayton and Mort Herman / Explore the heart of a smart terminal.

110 **New Japanese Microcomputers** by Phil Lemmons / A first look at the new wave of advanced computers.

132 **Intel's 80186: A 16-Bit Computer on a Chip** by Tony Zingale / The 80186 is the first integrated circuit that attacks the cost problem in 16-bit microcomputers.

154 **The Intel 8087 Numerics Processor Extension** by R. B. Simington / This chip lets you perform mathematical operations with 18 decimal digits of accuracy.

176 **Super Graphics Hardware from NEC** by Steve Levine / The NEC 7220 GDC is a new item of sophisticated graphics hardware for microcomputers.

190 **NAPLPS: A New Standard for Text and Graphics, Part 3: Advanced Features** by Jim Fleming / NAPLPS can draw irregular lines, compress repeated code segments, define new text characters, and divide the display screen into separate fields.

210 **Virtual Memory for Microcomputers** by Stephen Schmitt / A brief review of virtual-memory concepts, including an examination of four new memory-management chips.

242 **BYTE West Coast: Hard Choices for Software Houses** by Phil Lemmons / Advances in hardware, specifically microprocessors and storage devices, are forcing software houses to make some far-reaching decisions.

258 **50 and 100 Years Ago in BYTE** / The microcomputer industry has made great strides in the past 100 years. Read about what the industry looked like just a short century ago.

260 **The Enhanced VIC-20, Part 3: Interfacing an MX-80 Printer** by Joel Swank / How to connect a parallel-port printer to the VIC-20.

304 **Building a Hard-Disk Interface for an S-100 Bus System, Part 2: The Hardware** by Andrew C. Cruce and Scott A. Alexander / This installment covers choosing the disk drive, the disk controller, and the power supply and building the host computer adapter.

324 **User's Column: Terminal Solutions, Manual Madness, BASIC Bits, and Info Helpers** by Jerry Pournelle / Terminal concerns for Wordstar users, BASIC comments, and a bunch of useful utilities are reviewed by the lord of Chaos Manor.

360 **Build This Memory, Part 2: Constructing the Memory Card** by Cameron Spitzer / Take advantage of the low cost of dynamic memory.

385 **Modula-2** by Joel McCormack and Richard Gleaves / Niklaus Wirth, creator of Pascal, brings us a general-purpose systems implementation language based on modules.

398 **The Design of an Advanced Logic Simulator** by Robert M. McDermott / Macrocircuits and time-saving features make this new simulator easy to use.

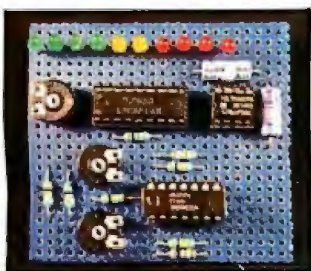
442 **Information Hiding: A Brief Example** by Gregg Williams / Consider this helpful alternative to structured programming and modular design.

Review

290 **Two Ways to Use CP/M-80 on the IBM PC** by Phil Lemmons

Nucleus

- 6 Editorial: The New Generation of Human-Engineered Software
- 12 Letters
- 457 BYTELINES
- 461 Clubs and Newsletters
- 463 Ask BYTE
- 466 Event Queue
- 477 Books Received
- 478 BYTE's Bits
- 479 Software Received
- 484 What's New?
- 541 Unclassified Ads
- 542 BOMB, BOMB Results
- 543 Reader Service



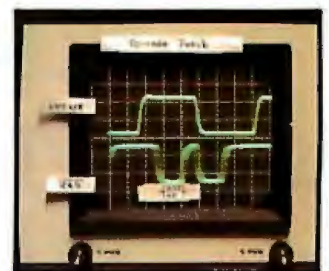
Page 28



Page 110



Page 304



Page 360

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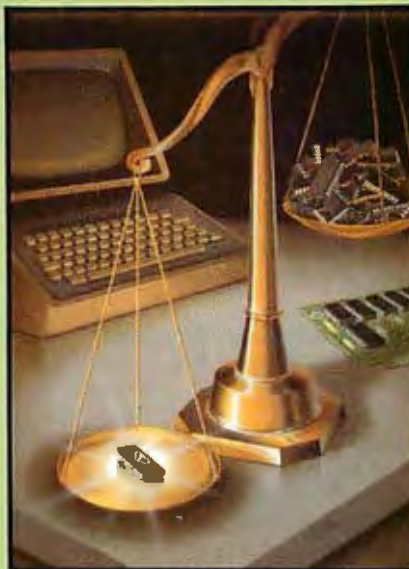
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In This Issue

Innovations in microprocessor and support chips are closing the gap between the speed and power of minicomputers and that of micros. As Robert Tinney's cover illustrates, the scales are tipped in favor of the 16-bit chips. "The National Semiconductor NS16000 Microprocessor Family" by Glenn Leedy introduces you to the NS16032 processor and its related chips. "Design Philosophy Behind Motorola's MC68000" by Thomas W. Starnes begins a multi-part study of the heart of machines such as the Lisa and the Radio Shack Model 16. In "Intel's 80186," Tony Zingale describes this new chip that combines the functions of the 8086 and several support chips in one device. "The CRT 9007 Video Processor and Controller" by Brian Cayton and Mort Herman discusses a sophisticated chip that greatly simplifies the design of smart terminals. Steve Levine looks at "Super Graphics Hardware from NEC." "The Intel 8087 Numerics Processor Extension" by R. B. Simington describes the theory and use of this coprocessor chip to speed up numeric computations on 8086/8088-based computers. In the first BYTE West Coast report, Phil Lemmons brings us news of the way in which software houses are responding to the new advances in hardware. Steve Ciarcia tells you how to "Build an RS-232C Breakout Box." Plus our regular features.

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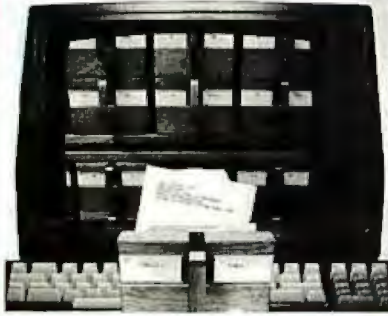
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PRO TEM

Editorial

The New Generation of Human-Engineered Software

Gregg Williams, Senior Editor

Apple's new Lisa epitomizes the state of the art in computer sophistication and ease of use. Its integrated software and mouse make this machine a harbinger of what's in store for microcomputers. These new advances mean serious business.

Software companies, for one, appear to be staking their future on products that feature video windows, which allow various projects to appear on the video screen simultaneously, and the mouse, a hand-held box-shaped device that provides an alternative to the computer keyboard. Many new products announced in the past few months are incarnations of what has become known as integrated software. The microcomputing industry is at the threshold of a new trend in user-friendly, human-engineered software—a trend spurred by new technologies and rising product development costs.

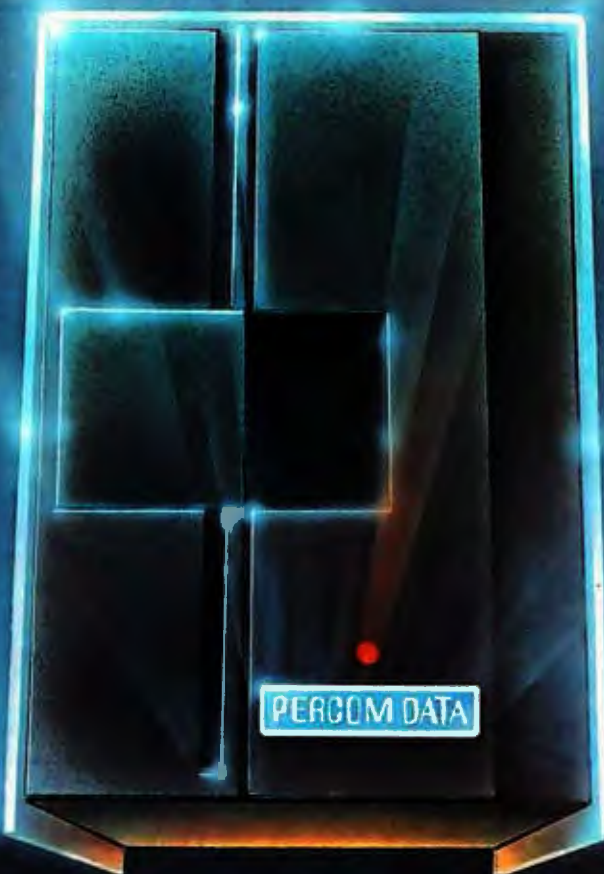
New technologies, particularly 16-bit processors and inexpensive computer memory, make more sophisticated software possible. Increased sophistication, however, means higher development costs, which are inevitably passed on to the consumer. Manufacturers, however, see a solution in easy-to-use software. By making such software, they expect to reach a boarder market base; with more potential buyers, the price per unit remains generally affordable.

Why Human-Engineered Software?

This move toward easy-to-use software is the result of a chain of events and influences. We begin with the 16-bit microprocessors, which have been around for several years. Their main contribution is that they have given the ambitious programmer some elbow room. Eight-bit processors are inherently limited by their 64K-byte address space and this in turn imposes restrictions on a programmer's creativity. Granted, clever hardware design and programming can often get around this storage problem, but only up to a point. On the other hand, with 16-bit (and larger) microprocessors capable of addressing millions of bytes of data, programmers have ample room in which to do their work.

The second link in this chain of events is the decreasing cost of mass storage devices and, in particular, computer memory. Only within the last year has memory become inexpensive enough to be used without manufacturers worrying too much about how additional memory will increase the price of the unit. Now that larger memories are affordable and are becoming standard, software companies must decide how they'll use the extra memory to its maximum potential. This brings us to the third link in this chain, which involves a choice to be made by software developers: they can create either computationally more powerful programs or easier-to-use programs. Both options have their advantages, but most companies are going with the latter for one reason: they are courting the average person who is being introduced to computers and their many uses through advertisements on television and in the print media. These people are the new computer users.

Why is this new computer user so important? First of all, the general public is just becoming aware of software and how it can make a computer work for them. Thinking that a lucrative software market is



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Editorial

beginning to open, each company understandably wants to get its foot in the door first with these new users. These companies are hoping that once people buy one of their packages, they are likely to consider them for their future software needs.

The far more compelling reason for courting this new user via easy-to-use software is cost. As the complexity of software goes up, so do the costs associated with designing, programming, testing, and documenting it. To keep these added costs from increasing the product's price and decreasing its potential market, software houses have realized that they must expand their market. Programs using current software technology will sell to only those people who currently use microcomputers. If, on the other hand, software designers use this extra power to make programs that are both powerful and easy to use, they can expect to sell to the potentially huge market of "software-hungry" users, thus vastly increasing the market for their product. The extra production costs would (they hope) be spread over such a large group that the extra cost per program sold would rise only slightly.

The Big Question

The big question is "What makes software easy to use?" Microsoft and Visicorp are firmly committed to the mouse and the desktop-manager concept as the



Prototype of Visicorp's *Visi On* integrated applications environment. Note the multiple video windows and mouse. Since this photo was taken, Visicorp has changed to a two-button mouse.

answer. Microsoft will incorporate a mouse and window-management system into advanced versions of its Multitool series of packages (Multiplan is its first such package). Visicorp stole some of Apple's thunder when it previewed Lisa-like features on the IBM Personal Computer at Comdex last fall with a package called *Visi On* (see photo). *Visi On*, which is billed as an "integrated applications environment," has a two-button mouse and can support multiple tasks running in separate windows. Note that these software companies are putting great emphasis on a hardware device (the mouse) that will add between \$150 and \$250 to the cost of some of their products; this fact alone indicates the depth of these

companies' commitment to the future.

However, the real answer to the question posed in the previous paragraph is that nobody knows what will make software easy to use. Apple, Microsoft, and Visicorp each has its own option. Other companies, of course, have other solutions (for an excellent discussion of some different plans, see Phil Lemmons' *BYTE West Coast*, "Hard Choices for Software Houses," on page 242).

The air is already filled with claims and promises about the merits of each company's products, but nobody knows what makes software easy to use; the final answer will be in what the people buy. ■

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New Chips for Dynamic Memory Fans

I enjoyed Rob Belics's excellent article, "Practical Dynamic Memory System Design" (December 1982 BYTE, page 372). Your readers may like to know about two newer chips that have made dynamic memory much easier to use: the 4164 and the 6883.

The 64K- by 1-bit 4164 costs about the same per bit as the 16K- by 1-bit 4116 but requires only a single +5-V supply and uses less power and board space. The single power supply feature eliminates the need, in most systems, for an expensive three-voltage power supply and the chance that chips might be fried by application of supply voltages in the wrong order. The smaller memory cells make the 4164 more sensitive to alpha-radiation-induced random bit changes, but this happens infrequently enough that it is not much of a problem for most applications.

The Motorola 6883 synchronous address multiplexer makes interfacing dynamic memory to the 6809 microprocessor almost as easy as hooking up static memory. It handles all CAS and RAS timing, address multiplexing, and memory refresh. It can also interface the 6809 to Motorola's 6847 video display generator (as in the Radio Shack Color Computer) and provides all system timing so that dynamic memory refresh and display refresh are transparent.

Both the 4164 and the 6883 are well worth knowing about for anyone interested in dynamic-memory system design.

David Nye
209 West Lowe's Creek Rd.
Eau Claire, WI 54701

Turning on the 4116

I feel I must point out an important omission from Rob Belics's article "Practical Dynamic-Memory System Design" in regard to power supplies for the 4116 DRAM (dynamic random-access read/write memory) chip. Mr. Belics briefly describes these as "three separate power-supply voltages that must first be applied in a certain order." I searched the article carefully, and Mr. Belics never tells us in what order these supplies must be turned on and off.

In the April 1981 "Ask Byte" column (page 328), Steve Ciarcia states, "The most important thing to remember when designing any computer that uses 4116s is that the power-supply voltages must be turned on and off in sequence. To keep from blowing the 4116 on power-up, the -5-V supply must be turned on before the +5-V and +12-V supplies. On power-down, the -5 and +12 are removed. . . the sequence can be accomplished through the time constants of the power supply itself. . ."

Charles Reeves Jr., Physicist
Nuclear Division
Union Carbide
270 Park Ave.
New York, NY 10017

Multidos Update

Once again, the work of a software developer has outstripped the publishing process and an update is needed to my review "Multidos: A New TRS-80 Disk Operating System" (December 1982 BYTE, page 392).

The price of Multidos has increased from \$79.95 to \$99.95. There is also a new, \$39.95 version called ZDOS; although not as full-featured as Multidos, it provides double-density support and SUPERBASIC (write to Cosmopolitan Electronics, 5700 Plymouth Rd., Ann Arbor, MI 48105, for full details). The additional \$20 charge for Multidos buys you a disk sector and file editor or ZAP utility, a disk-drive timer utility, a tape-to-disk conversion utility, and a RAM (random-access read/write memory) test utility. The DOS part of Multidos version 1.6 now includes two-sided drive support, a PATCH command, a RESTOR command to recover a file deleted with the KILL command, a CAT (catalog) command that reads the directory of almost any Model I or III disk, and many additional options for the original commands.

Multidos is now claimed to support disk I/O (input/output) at 4.7 MHz, if you have a clock speedup that allows this.

SUPERBASIC, the disk BASIC that comes with Multidos, has added commands to remove REM statements; pack BASIC program lines together while preserving program logic; and save the current BASIC program in memory while working on another program, then return to

the original program (or append it to the new one).

Vernon Hester, the author of Multidos, has released one newsletter so far and promises to publish patches in 1983 that will enable some popular software to run under Multidos.

Let me close by saying that I have found Multidos to stand up very well to over a year's use; it is fast and reliable and provides a very flexible BASIC development environment.

Rowland Archer Jr.
5420 Loyal Place
Durham, NC 27713

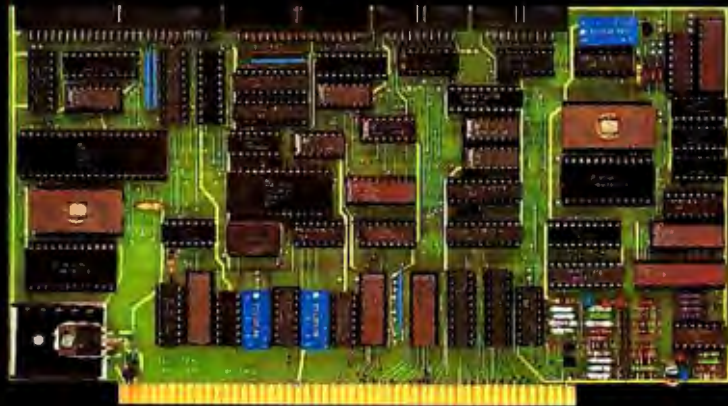
MDBS Takes Issue with User's Column

In the December 1982 BYTE "User's Column" (page 222), Jerry Pournelle notes that Micro Data Base Systems Inc. is working on enhancing the BDS Compiler. This new C compiler, called C', has been available for several months. Perhaps its most notable traits are its production of extremely compact object code and its relatively fast execution and compilation.

I would like to correct several misimpressions conveyed in Dr. Pournelle's column. First, Micro Data Base Systems Inc. is not a "bunch of Purdue University people." The company's management and staff of over 100 persons are not employees of Purdue University. While a number of our employees hold bachelors, masters, and doctorate degrees from Purdue, many others received training at other equally fine institutions.

A second error pertains to our database management product, MDBS. Dr. Pournelle states that "MDBS and the CODASYL database systems are hierarchical in structure." This is incorrect. Systems based on the CODASYL approach are not at all limited to hierarchical architectures. Indeed, the flexibility provided by CODASYL-network structures was a major advance over hierarchical systems. Furthermore, MDBS should not be confused with either CODASYL-network systems or hierarchical systems. MDBS is a post-relational system of the extended-network variety, which means that it overcomes many limitations of the old-time hierarchical, relational, and CODASYL-network approaches to database management.

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Letters

It should also be pointed out that, unlike MDBS, the many microcomputer file handlers that are very loosely referred to as relational databases have little in common with usual, long-established notions of what constitutes database management. These file handlers do not even begin to approach systems such as IBM's SQL/DS, the de facto standard for relational systems. The limitations of file management are not overcome merely by referring to files as databases.

With respect to MDBS documentation, it must be noted that "A Primer on Data Base Management Systems" by Dr. Clyde Holsapple, cited in the article, is not a component of the MDBS reference manual. It is a separate tutorial that is routinely and quite successfully used in introductory university courses on database management systems at the undergraduate level. We have distributed thousands of copies of the primer in the last few years, and the feedback has been overwhelmingly favorable.

Gary J. Koehler, Ph.D.
President and Chief Executive Officer
Micro Data Base Systems Inc.
POB 248
Lafayette, IN 47902

Video Displays and Elimination of Health Risks

The letter in the December 1982 BYTE from John C. Villforth of the U.S. Bureau of Radiological Health attempted to reassure VDT (video display terminal) users that these machines do not emit harmful levels of radiation. In reality, there are very good reasons for suspecting that the current generation of cathode-ray tube VDTs are hazardous and are causing cataracts and other diseases. Fortunately, however, VDTs can be built by several other methods that reduce or eliminate radiation emissions.

In cathode-ray tubes (CRTs), a high-speed beam of electrons is abruptly decelerated as it slams into the face of the tube. It is a basic fact of physics that this process produces x-rays and microwave and ultraviolet radiation. Mr. Villforth writes that the government has done studies showing that CRT x-ray emissions under "normal" conditions are not "significantly above the natural background radiation to which we are all exposed." Just exactly what does this mean? Why

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doesn't he tell us some actual measurements, in millirads per hour at a point 1 foot from the screen, so we can make up our own minds about just how dangerous they are?

Radiation emissions from CRTs may indeed be low, but it does not follow that they are not hazardous. With radiation, there is no threshold—all exposures, no matter how low, carry with them some additional risk of cancer and leukemia, genetic damage, and depressed function-

ing of the body's immunological system. Radiation to the eye in particular increases the likelihood of cataracts and eye damage. Furthermore, the x-rays, microwaves, and ultraviolet radiation may act together, in synergy, to do many times more damage than each by itself.

It is fundamentally unscientific to assert that measurements of radiation emitted from CRTs show that this radiation is safe. The only real way to tell is to analyze carefully controlled, long-term

epidemiological studies of the rates of cataracts and radiation-caused diseases in people using CRTs versus the rates of these diseases in people not using CRTs. These studies should be started immediately (because cataracts and cancer can take many years to become manifest), and they should be carried out by truly independent scientists. The federal cover-ups of the cancers among GIs and residents of Utah and Nevada caused by fallout from atomic-bomb tests show clearly that no federal agency—including the Bureau of Radiological Health—can be trusted to tell us the truth about radiation.

Fortunately, video display terminals can be built in a manner that eliminates radiation exposure. Liquid-crystal or light-emitting-diode displays emit no radiation. Another method is to have the operator look through glass at the image from a CRT reflected from a mirror. IBM already makes such terminals. Even the use of a lead-glass shield over the CRT screen should make a big difference.

Those of us who must use the ordinary computer CRTs can do several things to minimize the radiation risk. First, don't sit too close to the thing. (Radiation levels decrease with the square of the distance from the screen.) Second, turn the brightness (the voltage through which the electron beam is accelerated) down as low as you can without decreasing readability. Careful adjustment of room lighting to eliminate screen glare will enable the brightness to be turned down even lower, as does the highly visible amber screen, which is mandated by law in several European countries. And third, do investigate products such as lead-glass shields, which are claimed to have radiation shielding capabilities.

I'm not arguing for a risk-free society. I only point out that in this case we're taking a risk—one that may turn out to be quite severe—for no corresponding benefit. Radiation-free VDTs can easily be built to emit no radiation. But it's up to us, the computer users, to demand that such machines be built. No market, no product.

For those interested in further information, I strongly recommend the book *Radiation and Human Health* by John W. Gofman, M.D. and Ph.D., and one of the world's foremost authorities on the health dangers caused by ionizing radiation (Sierra Club Books, 1981). Another excellent book, which focuses in particular on microwaves, is *The Zapping of Ameri-*

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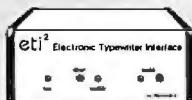
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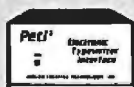
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Letters

ca by Paul Brodeur (W. W. Norton and Company, 1977).

Edward M. Gogol
407 South Dearborn, Suite 930
Chicago, IL 60605

Open Correspondence on JRT Pascal

At our local users group meeting of December 16, 1982, a show of hands was called on the subject of JRT Systems' \$29.95 Pascal offering.

Of the 12 people present who had ordered JRT Pascal, only 3 had actually received the product, yet 11 had already had their checks processed and returned. I myself have been waiting for more than four months. My check was processed over three months ago. I have called the factory twice; once I was put on hold for 15 minutes, the second time I was told that my product had been shipped three weeks prior and that I should wait another week. At the end of an additional two-week wait, I wrote the factory, and three weeks later wrote again. I received my third direct-mail offering for JRT Pascal two weeks ago, and again I wrote the company to ask that they ship my product immediately. Because so many other people share my experience with JRT Systems, I urge you to suspend the firm's advertising privileges until it can show proof that it has caught up with all back orders.

Scott Rainey
POB 6530
Portland, OR 97228

We are having delays in the shipping of JRT Pascal to our customers. I have received a number of letters from customers who are very concerned about this. Similar letters have been sent to the editors of the magazines in which JRT Systems advertises.

It has always been our policy to immediately cancel any order on request or make an immediate refund if payment has been processed and shipment not yet made.

As of today we have shipped 10,000 Pascals and have 7000 orders on backlog. About 6000 of those are less than six

weeks old. A six- to eight-week shipping delay is not unprecedented in the computer industry, but it is not acceptable to JRT Systems.

How did this backlog develop, and what am I doing to correct it? In May 1982 I cut the price of JRT Pascal from \$295 to \$29.95. I tested this formula by mass mailings of 100, then 400, then 1000, brochures. Sales response was excellent—10 to 15 percent—on the early mailings. I was able to rapidly expand the mass mailings and advertising leading to these approximate sales figures: May, 100; June, 350; July, 700; August, 1400; September, 2000; October, 4000; November, 3000; December, 5000.

In August, JRT Systems moved from my home to a small office on Irving Street in San Francisco. By October this office was severely crowded with six people, three phones, and two computers. In mid-December we leased 6000 square feet of space in Mill Valley. The shipping department has now moved into 1600 square feet of the new space. In the past two weeks, the shipping staff has grown from one to four full-time people. In this same period we completed installation of a sophisticated set of new shipping programs that automate, log, and validate every aspect of the shipping operation. Last week we exceeded 500 Pascal shipments per day. With our new system we can exceed 1000 per day.

We still have delays in obtaining copied disks rapidly enough, especially in 5¼-inch formats. Changes planned for the near future will eliminate this problem.

In short, the delay in shipping JRT Pascal is due to our staggering sales growth. We are moving as fast as possible to expand production capacity. [Letter is dated January 2, 1983].

J. R. Tyson, President
JRT Systems
550 Irving St.
San Francisco, CA 94122

As Mr. Tyson points out in his letter, shipping delays are not uncommon in the computer industry, as in all industries. Our readers should be aware of this situation when dealing with any firm. You have the right to demand a full refund if a product you have ordered is not shipped within thirty days of receipt of the order, or you may elect to wait for it to be delivered. The choice is yours. . . . P. C.

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Letters

Another Atari Character Editor

In his article "Character Editor for the Atari" (December 1982 BYTE, page 167), Tim Kilby says, "While several character editors are available commercially, none are specifically designed for use with ANTIC 4 and ANTIC 5 modes." That's not quite accurate.

I am the author of *The Next Step*, published by Sierra On-Line. It is an Atari graphics package centered around the idea of redefined character sets and has been on the market for about a year. Among other features, it contains explanations and example programs similar to those found in Mr. Kilby's article. *The Next Step* contains a powerful, easy-to-use character editor that fully supports ANTIC modes 4 and 5. As a matter of fact, it is the character editor that John Harris used for both the ANTIC mode 4 background and the player-missile graphics in his Atari version of *Frogger*.

As Tim Kilby says, redefined character sets are one of the most powerful features of the Atari computers. When teamed with custom display lists, as supported by *The Next Step*, impressive graphics are well within the reach of the BASIC programmer. Thank you for your help in spreading this knowledge.

Bob Stewart
The Logic Smiths
Pine Trail
Groton, MA 01450

Problems with FORTRAN-86

The problem with microcomputer FORTRAN compilers is more widespread than indicated by the letters from David Dunthorn and T. M. Putnam criticizing Microsoft's FORTRAN-80 and IBM Personal Computer FORTRAN, respectively (December 1982 BYTE, page 22). Version 1.0 of Intel's FORTRAN-86 (for Intel's 8086-based microprocessor development systems) incorrectly compiles data statements that use repeat factors, generates numerical error codes that are not documented in the Intel *FORTRAN-86 User's Guide*, frequently creates bad object code for operations involving 4-byte integers, and recently refused to compile an 8-line subroutine whose only executable statements were a type-conversion, an integer multiply, and RETURN.

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Intel had promised a July 1982 release date of a revised compiler, but as of mid-December 1982, I haven't seen so much as an updated bug list.

Meanwhile, the list price of this remarkable piece of software is a mere \$4300.

Jay Reynolds Freeman
POB AJ
Belmont, CA 94002

Disclaimers and the Law

I found the letters from David Dunthorn and T. M. Putnam regarding Microsoft's FORTRAN interesting. Unfortunately, both parties are mistaken in their belief that nothing can be done.

IBM's program license stating that the FORTRAN "is provided 'as is' without warranty of any kind . . . including . . . implied warranty of merchantability and fitness for particular purpose" may not be worth the paper it is printed on. If we can assume that the software is "goods" then it comes under Article 2 of the Uniform

Commercial Code (UCC).

Article 2 deals with the law of sales, warranties, disclaimers, remedies, etc. It has been substantially adopted by every American jurisdiction except Louisiana. While the specific question of whether software is "goods" has been not been answered, two different courts have ruled that it is "goods" when sold in a turnkey operation. (See *Triangel Underwriters Inc. v. Honeywell Inc.* (1978 E.D. NY) 457 F. Supp 765, 24 UCCRS 1088, affd in part and revd in part (1979, CA2 NY) 604 F2d 737, 26 UCCRS 1162, later app. *Triangel Underwriters Inc. v. Honeywell Inc.* (1981, CA2 NY) 651 F2d 132 and *W. R. Weaver Co. v. Burroughs Corp.* (1979, Tex Civ App 8th Dist) 580 SW2d 76, 26 UCCRS 64.)

Under the UCC, the implied warranties of merchantability and fitness for a particular purpose cannot be disclaimed after the sale. If the disclaimer first appears in the manual after it is bought, it is not worth the paper it is printed on (see *Zoss v. Royal Chevrolet*, (1972 Ind. Super) 11 UCCRS 527).

Furthermore, the states of Kansas,

Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Vermont, Washington, and West Virginia all limit a seller's or manufacturer's right to disclaim or limit the implied warranties.

Many warranties have limitation-of-damages provisions (e.g., "In no event shall the ACME Computer Company be liable for loss of profits, or benefits, indirect, special, consequential or other similar damages arising out of any breach of this warranty or otherwise.") These limitations are often upheld because the seller or manufacturer will repair the goods. However, in those cases where the seller or manufacturer refuses or cannot make the repair, a judge may rule that the original warranty "has failed in its essential purposes" and the full array of UCC remedies become available to the consumer. These remedies could include all actual, consequential, and incidental damages that the consumer suffered. Recovery could include such things as time spent trying to program around the bug, lost income because the program would not work, and the like.

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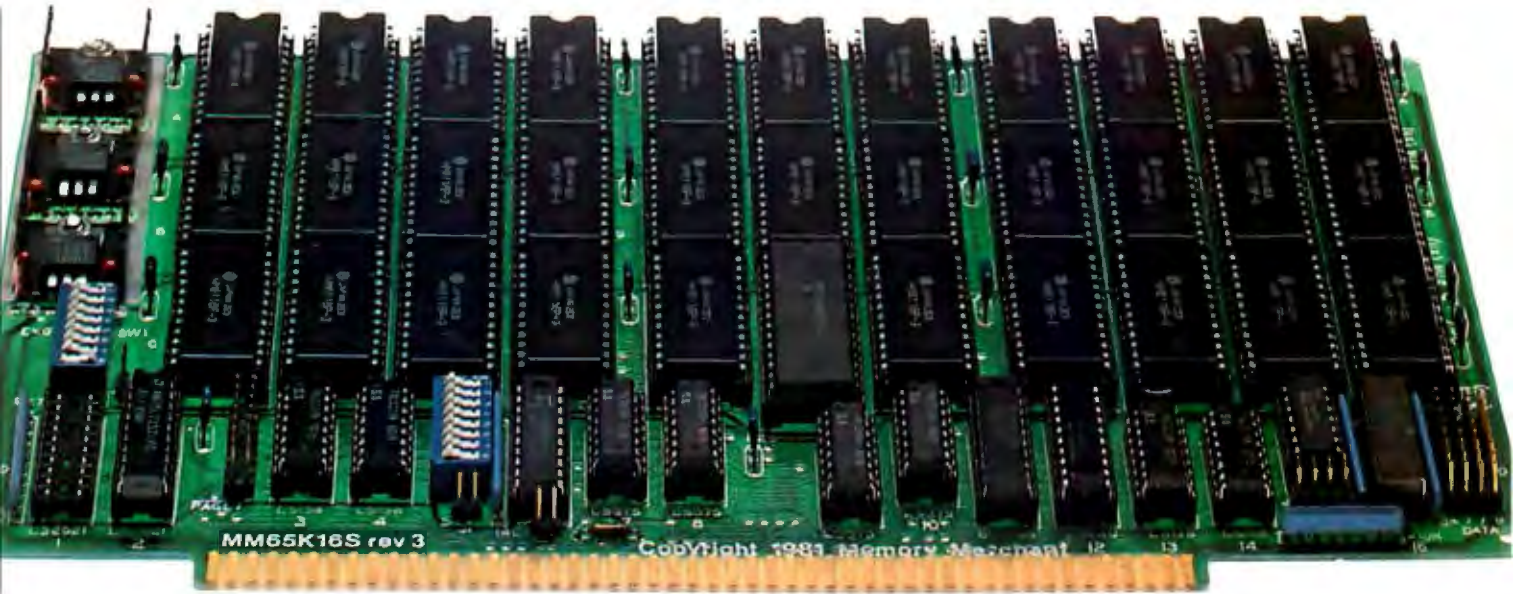
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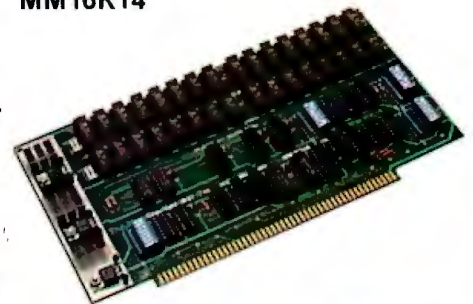
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among the parties. If Microsoft knew of the bug in its FORTRAN-80 package and refused to correct it or failed to put an adequate disclosure of it in its packaging, then punitive damages could also arise on the basis that it fraudulently and knowingly refused to repair a program with a bug (cf. *Hibschmann Pontiac Inc. v. Batchelor*, 266 Ind. 310, 362 NE2d 845 (1977)).

The fact that FORTRAN-80 went through three more releases with the same bug could indicate bad faith on the behalf of Microsoft and this by itself could allow punitive damages (see *Cantrell v. Amarillo Hardware Co.*, 266 Kan. 681, 602 P2d 1326 (1979)).

Finally, I am surprised that Microsoft would admit in a letter that it "has no intention of fixing the bug in FORTRAN-80 regarding FORMAT re-use." Such a letter will be deemed an admission against interest and would greatly ease any punitive damage claim against Microsoft.

As a final point, if Microsoft or IBM advertises its program as in full compliance with the ANSI (American National Standards Institute) Standard FORTRAN X3.9-1966 or any other ascertainable standard, then it has created an express warranty that the product will meet that standard. This express warranty cannot be disclaimed.

L. J. Kutten, Attorney at Law
201 South Central
POB 16185
St. Louis, MO 63105

Don't Blame Pascal

Jerry Pournelle's User's Column is stimulating, provoking, and sometimes misleading. He is appalled by the difficulties that Alex Pournelle has experienced in developing his introductory Pascal package (December 1982 BYTE, page 222). I sympathize with Alex, but from what Dr. Pournelle has written it appears that his problems have more to do with bad implementations of Pascal than with the language itself. It is unreasonable, for example, to blame Pascal for poor diagnostics, poor error recovery, collapsing compilers, and failure of nonstandard functions.

We all need strings, and it is unfortunate that they are not part of the standard language. Pascal implementors have added string handling in various ways,

none of which is completely satisfactory. Pournelle says that no Pascal compiler allows you to concatenate a single character to a string (page 226). This is not so, because Pascal/Z does this and other string operations in a fairly clean and consistent way.

The standard proposed, but not yet ratified, by the International Standards Organization for Pascal specifies two levels of compliance, level 0 and level 1. A level-1 compiler must support *conformant array parameters* (CAP) that permit the size of an array to be passed to a procedure or function. The ratification of the standard has been delayed by the United States representatives, who have refused to accept CAP in Pascal. I do not know of a microcomputer compiler that supports CAP, but some mainframe compilers do.

Pascal uses nested scoping, which may have been a great idea for ALGOL-60 but is somewhat passé today. Strict nested scoping does not support static variables in procedures. PL/I and C provide static variables, but, contrary to widespread belief, FORTRAN does not. (The FORTRAN standard does not mention stacks but is worded in such a way that stack allocation of variables is permitted.) Some versions of ALGOL-60 allow statically allocated *own* variables, but this seems to have been a kludge.

SIMULA-67 introduced *classes*, and many languages developed subsequently, including Ada, have a similar feature. A class is a collection of variables and procedures, some of which are private to the class and some are visible outside it. You can simulate packages in Pascal or C, but neither language supports them properly. As Lori Clarke et al. pointed out at the 1980 Ada Conference, if you have packages, "nesting is for the birds."

Wirth clearly recognized the weakness of Pascal's loop constructions, because his next language, Modula-2, allows loop exits. It is possible to code quite elegant loops in Pascal using loop variables. The method was introduced by L. V. Atkinson; here is a simple example:

```
VAR state : (searching, found, fail);
state := searching;
REPEAT
  IF end-of-list
    THEN state := fail
  ELSE IF item-matches
    THEN state := found
  ELSE get-next-item
UNTIL state <> searching;
```

```
CASE state OF
  found : . . .
  fail : . . .
END
```

The three-valued state variable allows us to distinguish normal and abnormal loop termination clearly and explicitly.

I have written this letter reluctantly because I find that debates about programming languages (and operating systems) are usually acrimonious and unhelpful. Most of these debates tend to be over such trivia as where the semicolons go and how many symbols you need to implement your favorite algorithm. We can compare languages meaningfully only if we agree beforehand on the environment in which they will run and the applications for which they will be used.

Peter Grogono
Metonymy Productions
4125 Beaconsfield Ave.
Montreal, Quebec H4A 2H4
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Software Boycott

Software piracy has been a concern to software vendors for some time. To protect their investment, vendors resort to copy protection and limiting the number of backup copies that can be made. Unfortunately, this often precludes the use of hard-disk storage and makes the system fragile. Businesses find it frustrating to have their systems down for a few weeks until the vendor ships a new disk. BYTE and other magazines have presented all sides of the pirating issue in the past.

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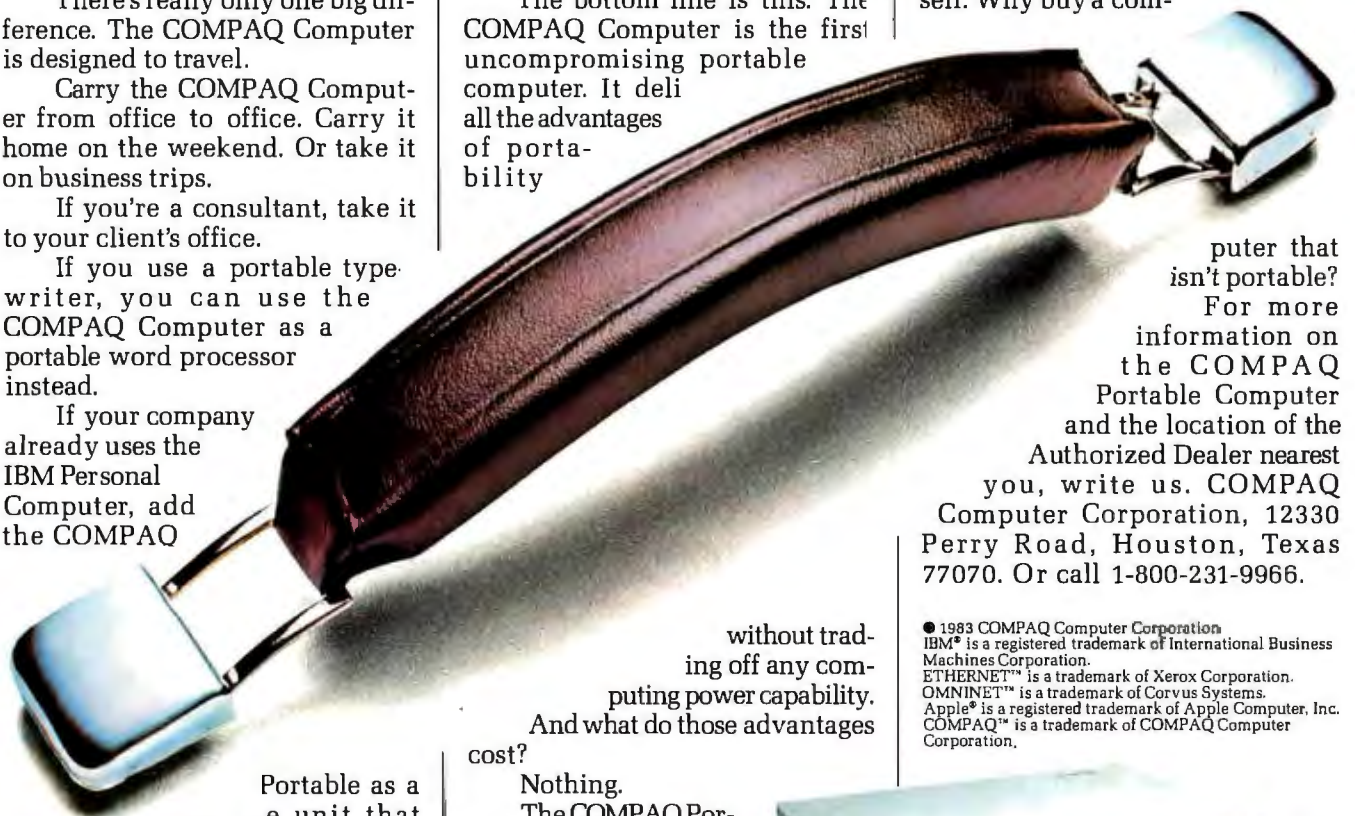
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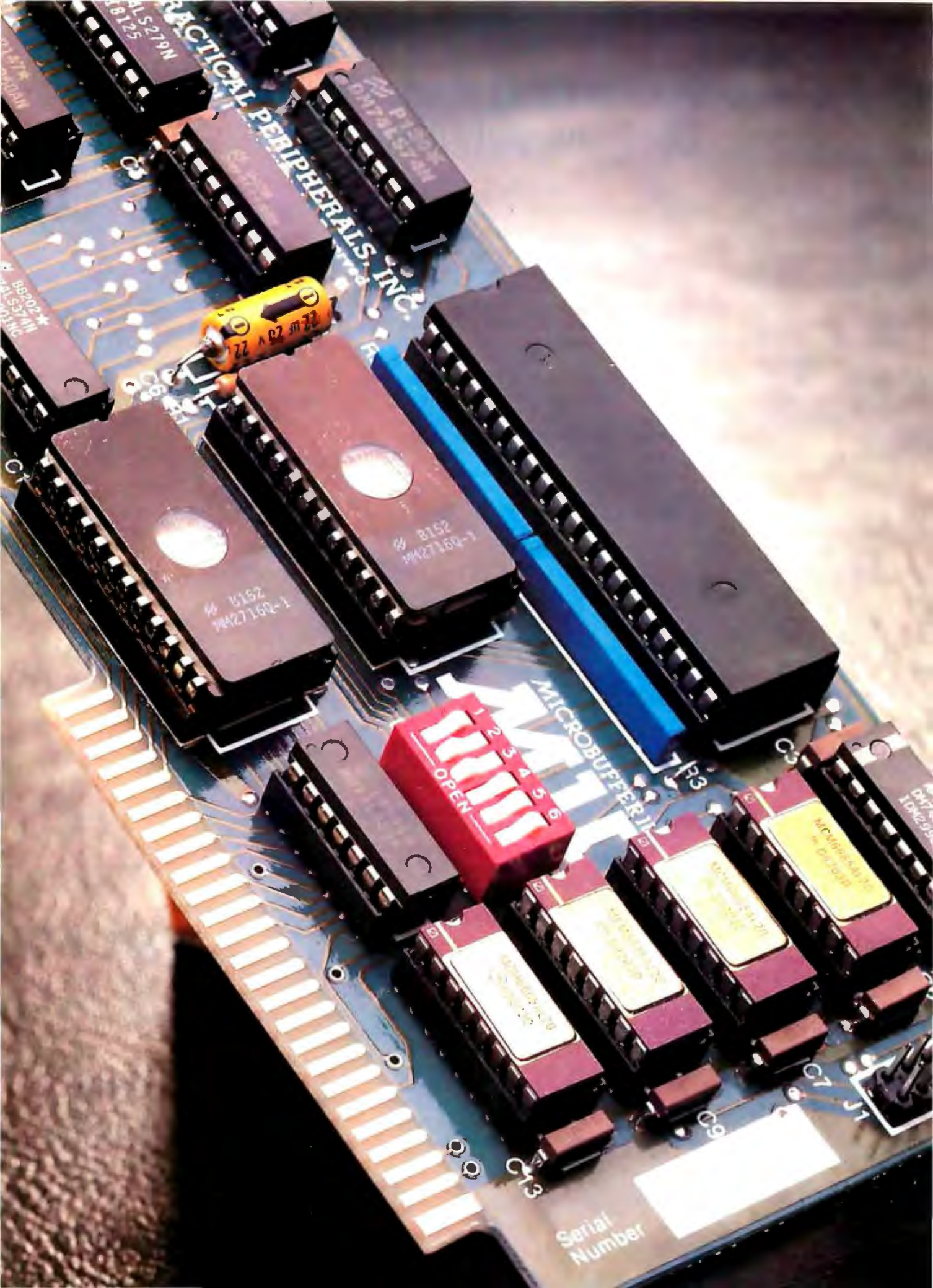


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Build an RS-232C Breakout Box

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Hundreds of exhibit-goers swirled around me as I elbowed wearily, yet warily, through the computer-convention crowd. Like Frodo Baggins approaching Mount Doom, I had to go to a place I feared to be: the BYTE booth. If I stayed anywhere near it, I was certain to be accosted by someone asking technical questions. (When your picture is plastered all over books sold at half a dozen booths, it's hard to remain incognito.)

Just as I started to take refuge behind the wall of 6000 boxed magazines in the BYTE booth, a voice behind me called out, "Steve, Steve! Help! I was going to send you an 'Ask BYTE' letter, but I need an answer right now on how to interface one of your projects to my computer."

I turned to respond as a man in his early thirties, carrying a briefcase and two shopping bags, hurriedly approached the counter. Panting a bit, he spoke with overtones of nervous anxiety combined with a note of triumph. I shrugged and responded, "Sure, I'll be glad to help if I can."

Most questions of this kind require minimal effort: at worst, digging out a few sheets of scratch paper and scribbling a schematic diagram or two. After all, most computers use similar parallel or serial interfaces.

"I have this computer. . . ." As

the man started to speak, he cleared about four feet of counter space with one elbow, leaned over to one of his shopping bags, and started pulling out pieces of equipment and cables. "Here, hold this . . . um . . . somewhere in here are the monitor, recorder, and this other junk . . . and, wait, here it is! I want to connect it to this here Microvox of yours. Can you do it for me? I've made some homebrew modifications to my computer, but that shouldn't keep it from working."

I've been told that, to be perceived as a good teacher, you have to be able to leave everything as an exercise for the student. Here I was, in the middle of a convention with 50,000 people, and this guy had dragged in his whole computer system. Mind you, I've spent hours talking shop with computer hobbyists in public places, and I've designed as much circuitry on the back of napkins as you see in this column each month. This, however, was a new twist.

His computer? It was an off-the-shelf budget model that I'd used before but hadn't tried with the Microvox speech synthesizer. It had a serial output, so I presumed it would work easily. As we shall see, that assumption was a mistake.

On the surface, it seemed a simple task. The unit had a four-wire serial interface that was described as conforming to the RS-232C specification established by the Electronic Indus-

tries Association. The connections in the interface were defined for transmit, receive, status, and ground lines. The Microvox can be connected in that way or through various other handshaking protocols. Inside the Microvox are jumper connections to reverse the functioning of the transmit and receive lines so that the Microvox can be set up as either kind of RS-232C device—data terminal equipment (DTE) or data circuit-terminating equipment (DCE). Given that there were only four wires, it should have been duck soup, right?

My first surprise came in finding that my querist's computer used a DIN (Deutsche Industrie-Norm) connector rather than the DB-25 connector typically used for RS-232C links. But by referring to his computer's instruction manual, we were able to attach the Microvox, set up as a DCE device, and hard-wire the computer's status input so it would see a "ready" condition all the time. The computer was set up as a DTE device, receiving data on pin 2 and transmitting on pin 3.

To our disappointment, when we executed the program to make the synthesizer talk, his computer transmitted nothing that could be received by the Microvox. I grumbled, "OK, maybe there's a typo in the Microvox manual." We reversed pins 2 and 3, setting the Microvox as a DTE device, and tried again. No luck. Still bending down over the hobbyist's machine, I looked over the top of my

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wire-rimmed glasses and asked as politely as I could, "Are you sure the serial output on this thing works?"

The subsequent discussion revealed that one of the modifications he had installed was a 20-mA (milliampere) current-loop output. But a serial printer attached to it had worked just prior to his bringing the computer to the show.

Because he had serial data coming out, we decided that it must be the Microvox that wasn't communicating. But how to test it at the show? Hmm. . . .

As I pondered that question, my gaze came to focus 20 feet across the aisle in another exhibit booth, on a computer system demonstrating a printer. As I looked closer, I saw an RS-232C cable connecting the computer and printer. Certain ideas came quickly into my mind. Gathering up the Microvox, my inquirer and I squeezed across the aisle and approached the booth's proprietor.

Fast footwork and a smooth tongue are necessities in such circumstances.

You have to put off saying the phrases "have a problem," "test," and "your computer" as long as possible. So, as I slipped the Microvox onto his serial printer cable, I distracted the exhibitor's attention by saying something like, "Hi, we have a booth over there, and we saw that you were demonstrating this neat printer, and we were wondering if we could try something on your system. . . . Can I put this here? . . . Do you mind if I just plug this in your computer . . . to test just one little thing?"

I had the cable connected before the potential horror of what I was proposing had time to sink in. In fact, the exhibitor was a bit amused as the Microvox started speaking the text that was intended for the printer.

A half hour later, after explaining the theory of text-to-speech algorithms to the curious exhibitor, we went back to the BYTE booth and the original problem. Finding that the Microvox worked, and while not directly suggesting that my shopping-bag computer hobbyist's RS-232C

output did not, I searched for a new strategy to make him happy.

Clearly, the problem was not simply one of making the right connections. I needed some way to take a better reading of what was happening. Even a mere bent paper clip and a light-emitting diode (LED) would have helped.

Again we went on the prowl for equipment. Three aisles away I found an exhibitor selling certain RS-232C diagnostic tools called breakout boxes who felt that he could trust me enough to lend me one of his less expensive models for a while. We took it back to the BYTE booth and set to work. We attached the breakout box to the serial output connector and watched for activity on the LED indicators. The transmit LED flickered as the data went to the Microvox, but I was still suspicious.

Back into the throng. Another aisle over I borrowed a DVM (digital voltmeter) and used it to check the voltage levels on the RS-232C output. Serial data appeared to be present, but it ranged from -0.7 to $+6.8$ V (volts) rather than from $+12$ to -12 V, as you typically find. The cheap (\$150) breakout box was responding to the $+6.8$ -V level, but it had no way of indicating negative voltage levels or open circuits.

Armed with this information, I checked some of the modifications that my comrade in debugging had made. Apparently the 20-mA current-loop circuit was at fault. It was optically isolated, as it should have been, but the optoisolators and other components were being powered directly from the RS-232C signals. The LEDs and protective shunting diodes were shorting out half the data! I disconnected the current loop, and two hours after the computer was first slipped out of its shopping bag, the Microvox spoke.


"Standard" RS-232C

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For instance, every time I buy a new piece of equipment, things seem to work this way: I spend five minutes reading the sales brochure, five minutes executing the financial transaction, and five hours trying to figure out how to make the new equipment communicate with my computer.

If you scan through product advertisements and equipment data sheets, frequently you see claims that products have "standard RS-232C interfaces." The people who perpetrate these lies have probably never connected two pieces of equipment together in their lives. What this phrase really means is that both ends of the communication line will probably be voltage-compatible and won't incinerate each other. Both will send and receive asynchronous or synchronous serial data following a specific timed sequence (bit rate) known by both ends. Beyond that, virtually nothing is reliably standard.

The only sure way to connect two serial devices is to examine the documentation for each and deter-

mine the proper connections of inputs and outputs, with lines crossing if need be. If the manuals are not available, then voltage-sensing and status-display devices must be used to examine individual lines. Depending on DTE or DCE convention, the same pin number may be either an input or output. And, generally speaking, in a

One of the most useful pieces of test equipment is the RS-232C breakout box.

fully implemented handshaking configuration, single-point signal monitoring is not enough. Frequently, multiple lines must be monitored to observe dynamic relationships.

I don't intend to spend too much time discussing RS-232C handshaking or interfacing. That subject has been covered in numerous other articles in BYTE, most recently by Dr. Ian Wit-

ten (reference 7). In my experience, simply knowing the conventions hasn't helped one bit. I always have to study the manuals for each interface and often have to verify voltage levels with a meter. When all the handshaking signals are used, it can be a prolonged task.

Ultimately, successful serial interconnection depends more on your ability to measure, cross-connect, and jumper-connect signal lines until some combination works. And sometimes you have to deal with a case wherein the lines might be connected properly but, as in the example above, operating at the wrong voltage levels.

The point of this month's article is to describe some of the hardware involved in testing the RS-232C connection. We'll look at various circuits that make voltage measurements, including two kinds of breakout boxes. Finally, to allow dynamic testing of the data communication on the transmit and receive lines, we will see how to build a terminal simulator, which

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	AA AB	101 102	Protective (Earth) Ground Signal Ground		
2 4 20 23	BA CA CD CH	103 105 108.2 111	Transmitted Data (TD) Request to Send (RTS) Data Terminal Ready (DTR) Data Signal Rate Selector (DTE source)	DTE	
24	DA		Transmitter Signal Element Timing (DTE source)		
14 19	SBA SCA	118 120	Secondary Transmitted Data Secondary Request to Send		
3 5 6 22 8	BE CE CC CE CF	104 106 107 125 109	Received Data (RD) Clear to Send (CTS) Data Set Ready (DSR) Ring Indicator (RI) Received Line Signal Detector (or Carrier Detect—CD)		DCE
21 23	CG CI	110 112	Signal Quality Detector Data Signal Rate Selector (DCE source)		
15	DB	114	Transmission Signal Element Timing (DCE source)		
17	DD	115	Receiver Signal Element Timing (DCE source)		
16 13 12	SBB SCB SCF	119 121 122	Secondary Received Data Secondary Clear to Send Secondary Received Line Signal Detector		

Table 1: RS-232C signals listed by function and source.

sends and receives ASCII (American National Standard Code for Information Interchange) characters at any standard data rate.

The RS-232C Breakout Box

One of the most useful pieces of test equipment is the RS-232C breakout box. This device is essentially a 25-line extension cable with apparatus attached that allows you to perform experiments on the serial link by inserting cross-connections, jumpers, and open circuits between the various signal lines. The most common use of the breakout box is to switch the Transmitted Data and Received Data lines (pins 2 and 3 in the commonly used connectors, abbreviated TD and RD). Another typical use is to make various combinations of connections between Request to Send (RTS, pin 4), Clear to Send (CTS, pin 5), Data Set Ready (DSR, pin 6), Carrier Detect (CD, pin 8—its official name is Received Line Signal Detector), and

Data Terminal Ready (DTR, pin 20). The more expensive units can also monitor voltage levels or decode serial data. Table 1 identifies the RS-232C signals by source.

A variety of commercial breakout boxes, ranging in price from \$100 to \$1000, are on the market. The more expensive products include such additional features as bilevel or trilevel signal monitoring, absolute voltage sensing, and signal-injection capabilities. Some of these features may or may not be important in your application.

When you are choosing a breakout box, be sure you get your money's worth. In some of the \$100 units, it appears that \$99 of the cost is for the case. The mechanical features are similar at all price levels, and only the addition of electronic bells and whistles adds to the cost.

In any breakout box, you find two 25-pin type-D subminiature (DB-25) connectors, two sets of 25 connection

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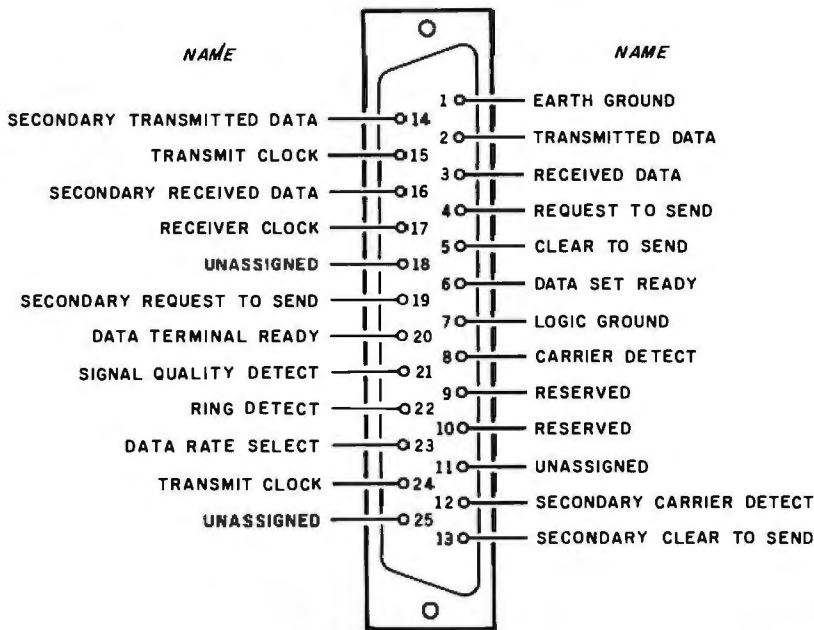


Figure 1: Pinout specifications of the RS-232C interface. The popular DB-25 connector is most often used for RS-232C connections, but it is not required by the EIA standard.

posts, and 24 or 25 switches. To begin testing, you connect the breakout box in series between the two pieces of equipment. The 25 lines on the first side go to 25 connection posts (often wire-wrap pins are used), and then 24 of the lines go into one side of three 8-pole DIP (dual-inline pin) switches. (Pin 1, the protective ground line, is directly routed to the output connector.) The 24 lines are directed through the DIP switches to another set of connection posts and then to the output connector. Figure 1 shows the pinout specification of the connectors.

To test the connection between two DTE-type RS-232C devices when no handshaking is involved, you merely insert the breakout box in the link; then, with all the switches closed except the two connected to pins 2 and 3, insert crossed jumpers between the connection posts to interchange the two signals. After you've made sure this works, you can permanently wire a cable to do the same job.

While most commercial breakout boxes connect and switch 24 of the 25 lines, most common RS-232C applications involving printers, low- and medium-speed modems, and video-

display terminals generally use only connector pins 1 through 8, plus pin 20. For these applications, we can construct a bare-bones breakout box, such as the one shown in the schematic diagram of figure 2 on page 38.

This simple construction will give you all the necessary features of a \$150 box for about \$15. Besides a signal-switching capability, this circuit incorporates passive voltage monitoring. Three components—a blocking diode, a constant-current diode, and an LED—indicate the presence of a potential of +4 V or greater on any signal line. The LED does not light for open circuits or negative voltages. Many low-priced RS-232C monitors use this type of circuit, and some cautions regarding its use are appropriate. Such an indicator draws its power from the signal itself (requiring about 4 mA), and in marginal situations it might kill the signal being measured.

For the RS-232C status signals, a line potential anywhere between +3 V and +15 V is logic 1, and a potential from -3 V to -15 V is a logic 0. If these signals are generated from low-power operational amplifiers (op amps) rather than RS-232C

drivers, there may not be enough oomph to communicate and light LEDs simultaneously. (Op amps are frequently used as a cost-cutting measure in budget equipment.) Finally, this cheap monitor senses only positive voltages (unless the circuit is reversed in polarity and duplicated everywhere) and gives no indication of negative voltages or ground potential. For example, you couldn't tell the difference between a broken cable lead and a logic-0 (inactive) status signal. Remember that RS-232C is a bipolar signal. As much happens (or doesn't) at negative potentials as at positive.

A Functional, Low-Cost Breakout Box

The previous point may have seemed minor, but it leads us to a discussion of better voltage sensors and use of active, rather than passive, monitoring techniques.

Figure 3 on page 38 is the schematic diagram of a much better indicator circuit for sensing RS-232C voltage levels. Using its own op amp to reduce signal loading, this bilevel monitor lights up in red for positive voltages and green for negative voltages. The feedback and gain-setting resistors are chosen so that the LEDs trigger at approximately +3 V and -3 V, respectively (internal current-limiting provides a relatively constant light level and protects the LEDs). Voltages between those values or open circuits light neither LED.

The indicator-circuit sections, one for every signal line, each use one section of an LM324 quad op amp. They present a virtually unnoticeable 100-kilohm load to the signal lines, can operate on any voltage with an absolute value between 4.5 V and 18 V, and can be powered easily from a battery of 6 AA cells for portability. I chose to use integrated two-color LEDs, but two regular LEDs (one red and one green) can be wired anode-to-cathode in parallel.

My idea of a reasonably useful breakout box is shown in figure 4. It combines the 24-switch-and-header portion of the commercial breakout boxes with the sensitive bilevel monitoring circuits just described.

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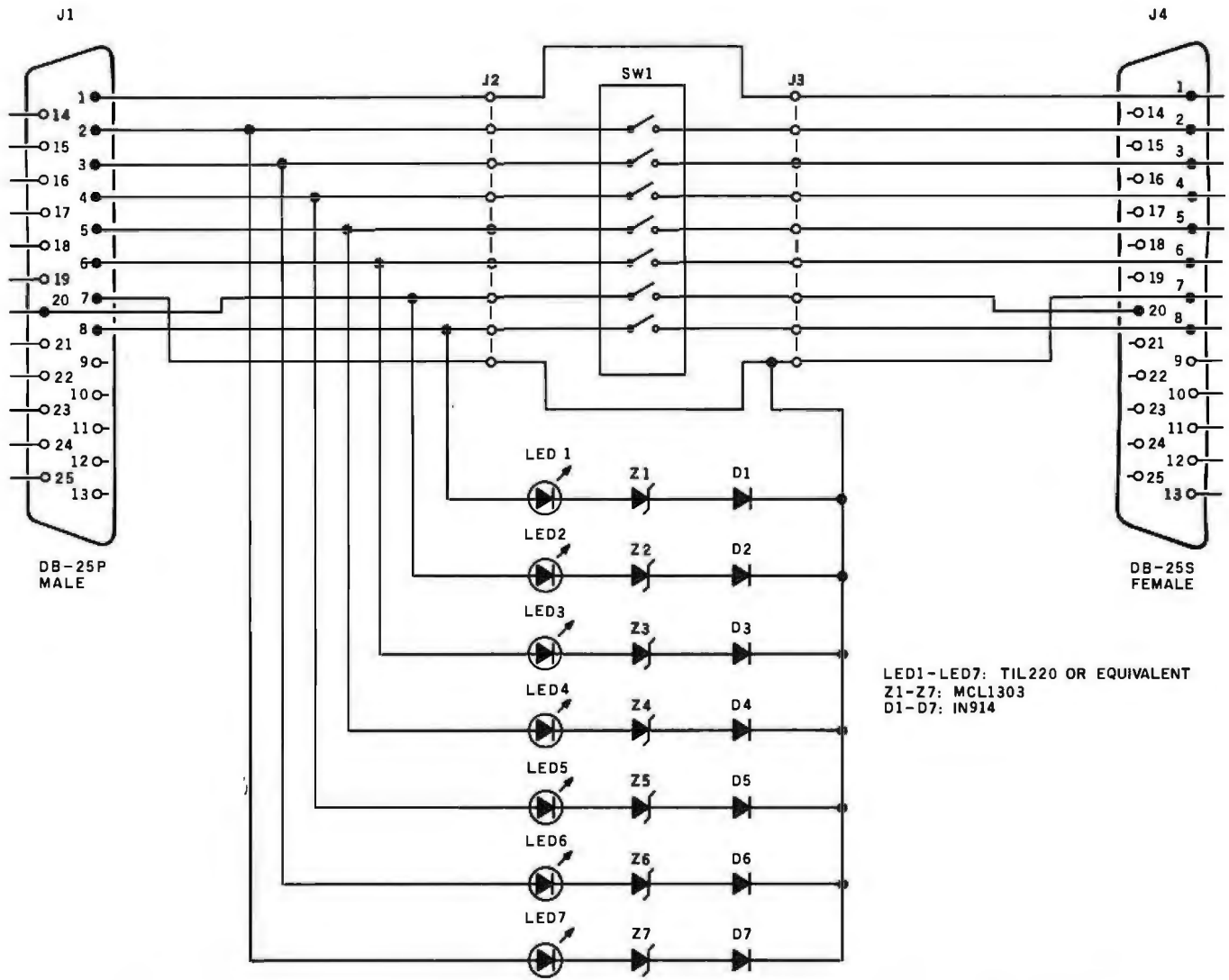


Figure 2: A simple homebrew breakout box for diagnosing serial RS-232C communication links. The 9 lines connected here are the ones most often used.

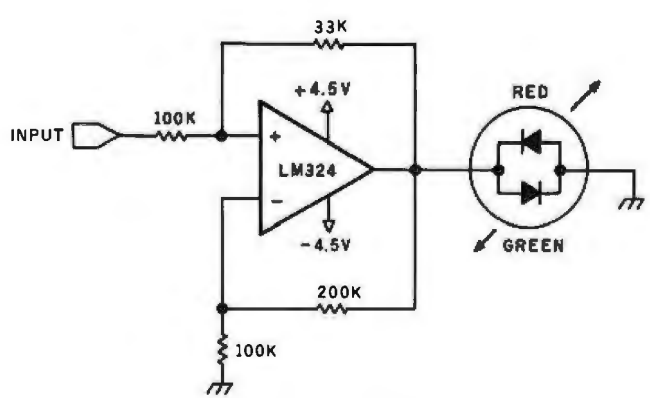


Figure 3: A line-state status indicator that incorporates an op amp to keep line loading to a minimum. The dual-LED component will glow red for positive voltages and green for negative.

Voltage indicators are hard-wired on the 11 most frequently used signal lines (2, 3, 4, 5, 6, 8, 15, 17, 20, 21, and 22), and the twelfth sensor can be connected to any line. A prototype of this circuit is shown in photo 1.

A Decade Voltage-Level Indicator

If you think back to my experience at the convention, you'll see that the problem was eventually detected as being voltage-related. It was undetectable with the cheap LED circuit, but it would have been caught by the circuit of figure 4. However, on some occasions even two levels are inadequate, and more precise measurements are necessary.

One extra indicator section was



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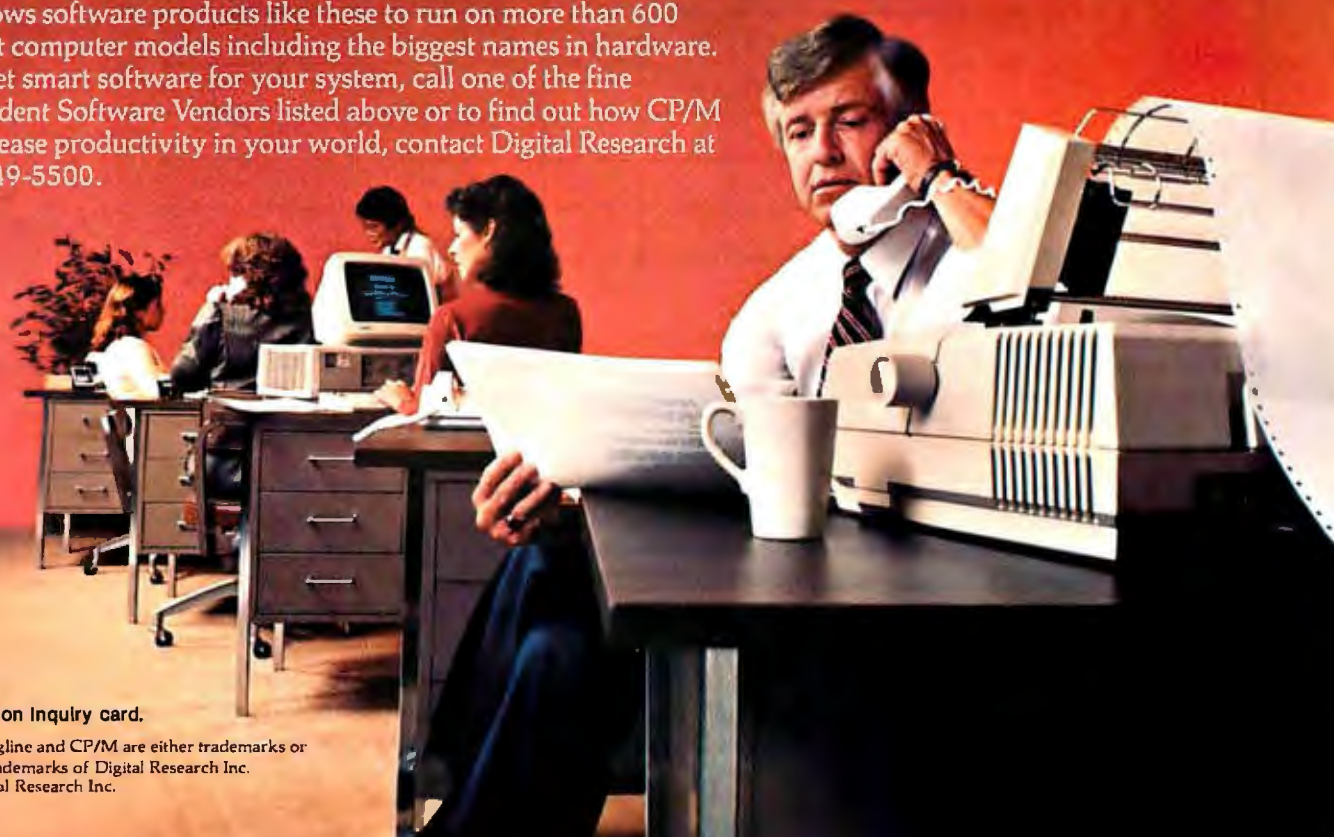
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(4a)

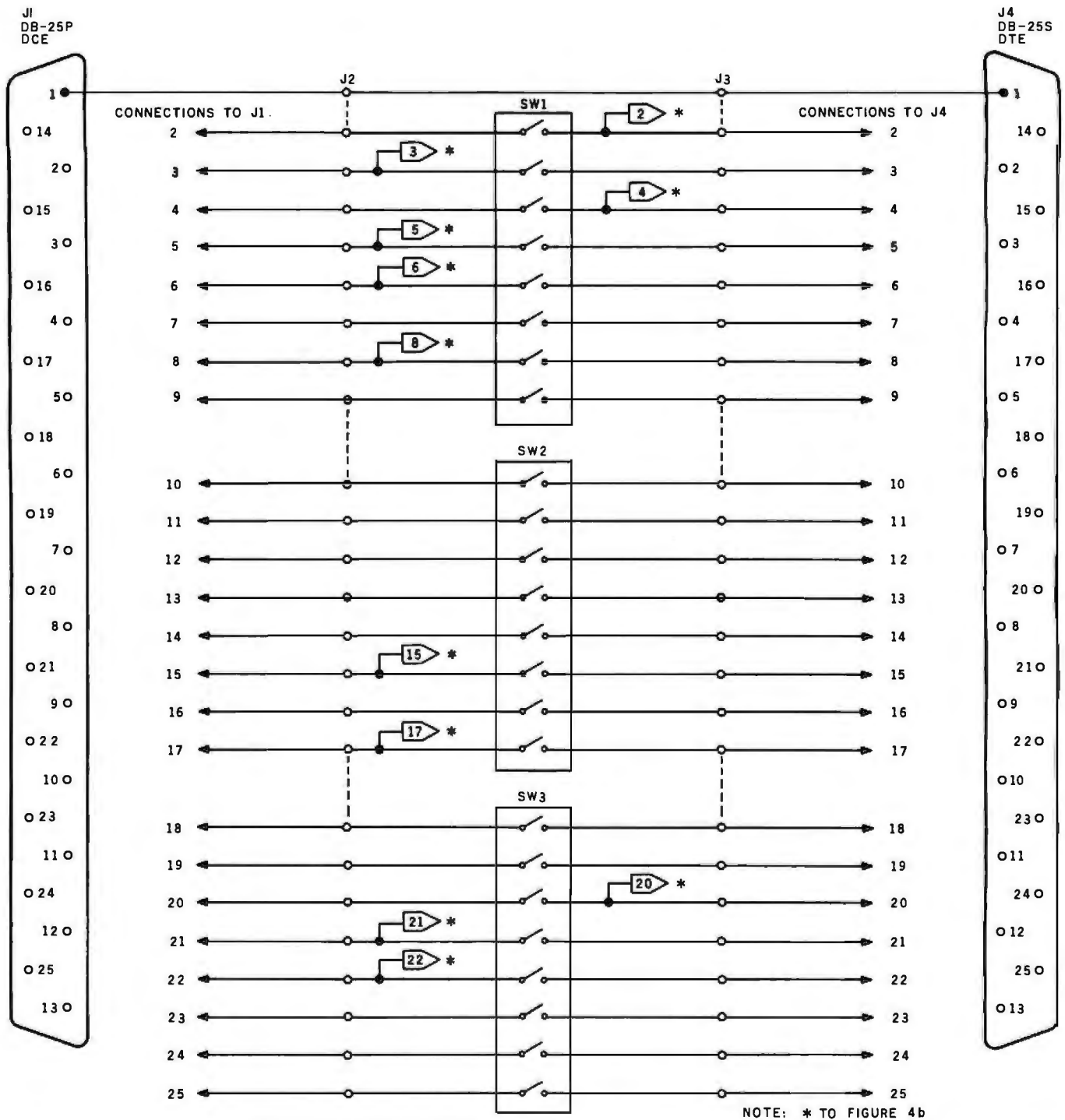


Figure 4: Schematic diagram (4a) of a breakout box that allows constant monitoring of the 11 most used lines, plus another line selectable by a jumper connection. The indicator circuit of figure 4b is reproduced 12 times; three LM324 packages, each containing 4 op-amp sections, are needed. The connections for each section are also shown in figure 4b.

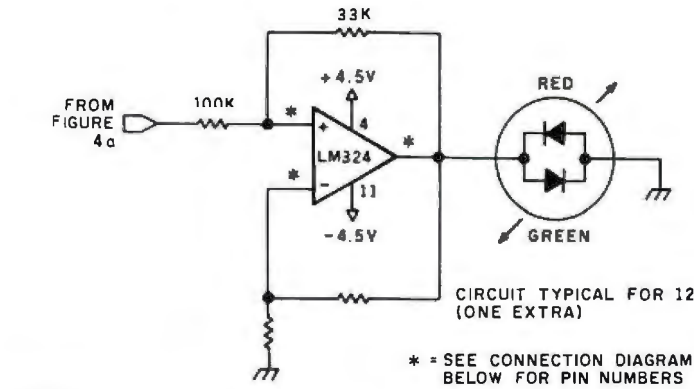
provided in the circuit of figure 4 so that it could be attached to any of the 25 input pins. If we expand this concept a bit further and replace this bipolar sensor with something having a little more resolution, we could take a better reading of voltage excursion. Granted, a DVM could be used, but such instruments are expensive and

are much more elaborate than required. Because of the RS-232C voltage range of -15 V to $+15\text{ V}$ (-3 V to $+3\text{ V}$ being no-man's-land), the resolution need be only about 3 volts at best.

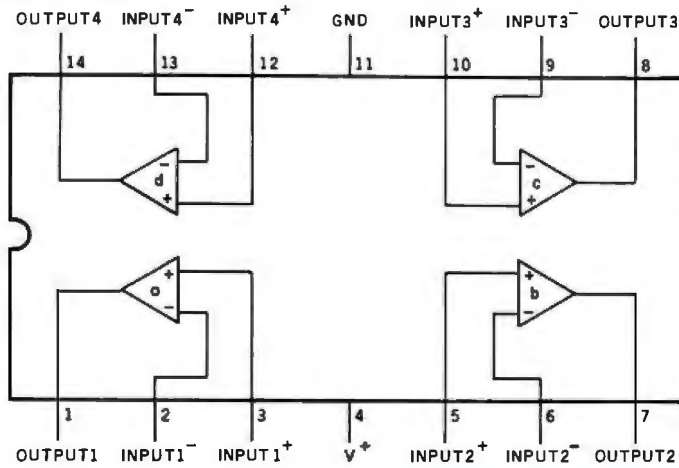
The circuit in figure 5 on page 44 is a single-digit decade voltmeter. Designed for installation in the

breakout box in place of the floating sensor, it has a higher resolution than the bilevel monitor, and it can be used in place of a DVM in less critical applications such as RS-232C level sensing. It uses an LM3914 LED dot/bar generator as a 10-step analog indicator. The 30-V ($\pm 15\text{ V}$) input range is divided into 10 incremental

(4b)



LM324 CONNECTION DIAGRAM



steps of 3 V. Different-color LEDs provide a quick visual indication of relative magnitude and polarity of the line states. A prototype of the circuit is shown in photo 2.

The decade-voltmeter circuit uses 2 or 3 integrated circuits. IC1a (an LM324 op amp section) scales the input voltage range from ± 15 V to ± 2.5 V (adjust potentiometer R1 to set the gain for 1/6). Another section, IC1b, shifts the resulting ± 2.5 V scaled signal to a 0-V to +5-V range at its output (adjust R2 for the proper shift magnitude). IC2, the LM3914 dot/bar generator, is configured to respond to a range of 0 V to +5 V.

When -15 V is applied to the circuit's input, LED1 lights; when +15 V is applied, LED10 lights. For an intermediate active voltage, such as +9 V, LED8 will light up. In the range of from -3 V to +3 V, which includes ground or open states, LED5 or LED6 will be lit. Using the same color convention as in figure 4, voltages greater than +3 V are shown on red LEDs, those less than -3 V are on green LEDs; in the inactive area between +3 V and -3 V, I used yellow. Any single input signal that swings between a red and green indicator is therefore at valid levels.

The decade-voltmeter circuit requires power at about +7.5 V (or greater) and -5 V (or less) for operation. Two 9-V battery cells (to provide ± 9 V) work very nicely. Or using a single +7.5-V source and the ICL7660 voltage inverter (IC3) allows the unit to be battery-operated (for some reason, the 7660 didn't seem to like inverting +9 V when I tried it).

Build a Terminal Simulator

The final thing to check when testing an RS-232C serial link is the existence of properly formatted data bits coming over the wire at the correct data rate. Voltage-level indicators make only quantitative measurements. It is necessary to take a *qualitative* measurement if the integrity of the transmission is in question. Most often the quality of the link can be ascertained with the transmission and reception of a single character.

One way of testing a suspect communication line is to drag around a

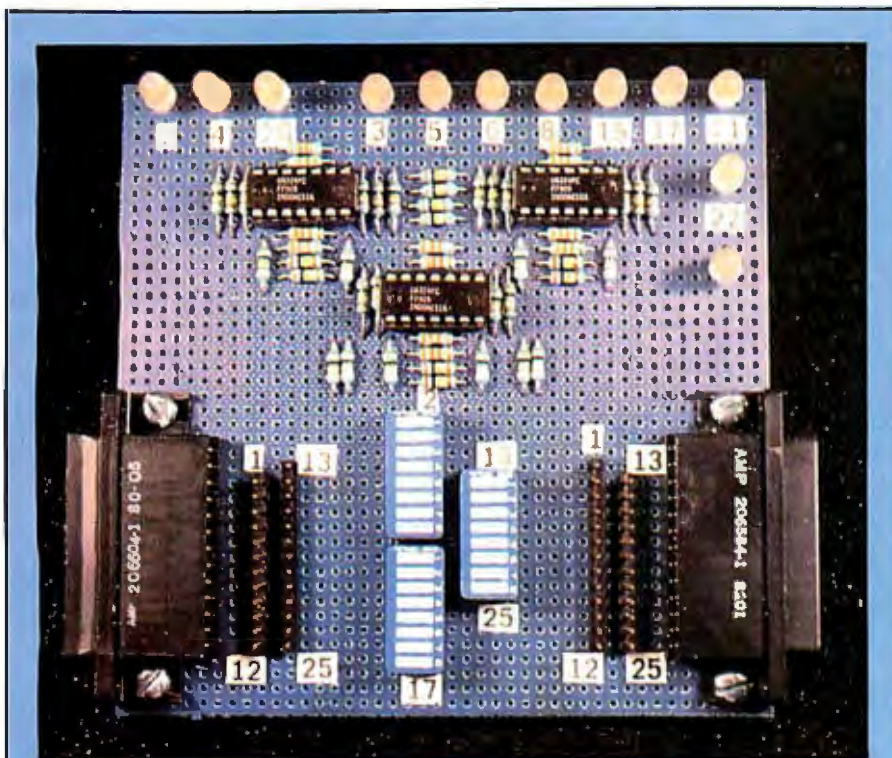
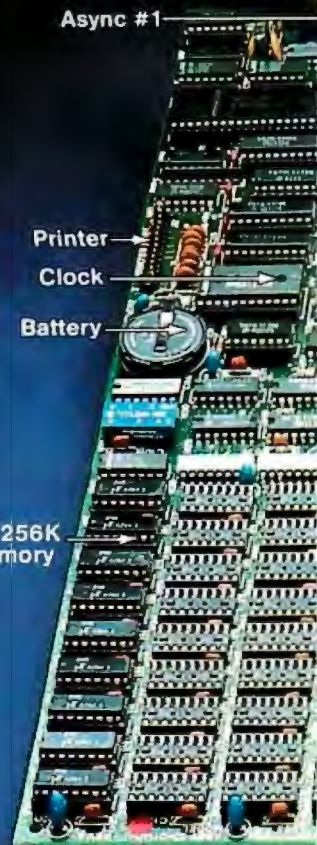


Photo 1: Breadboard prototype of the simple breakout box of figure 4.

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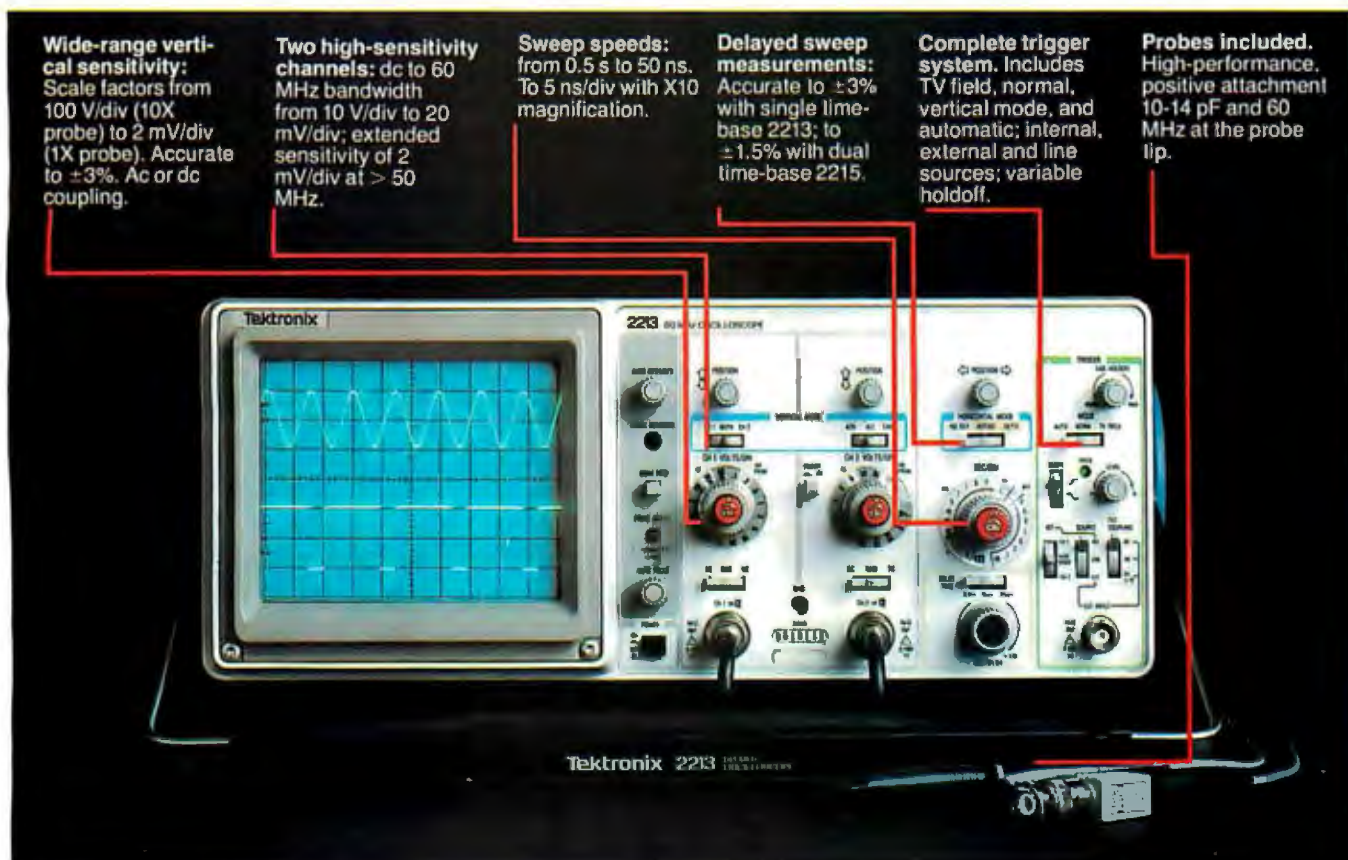
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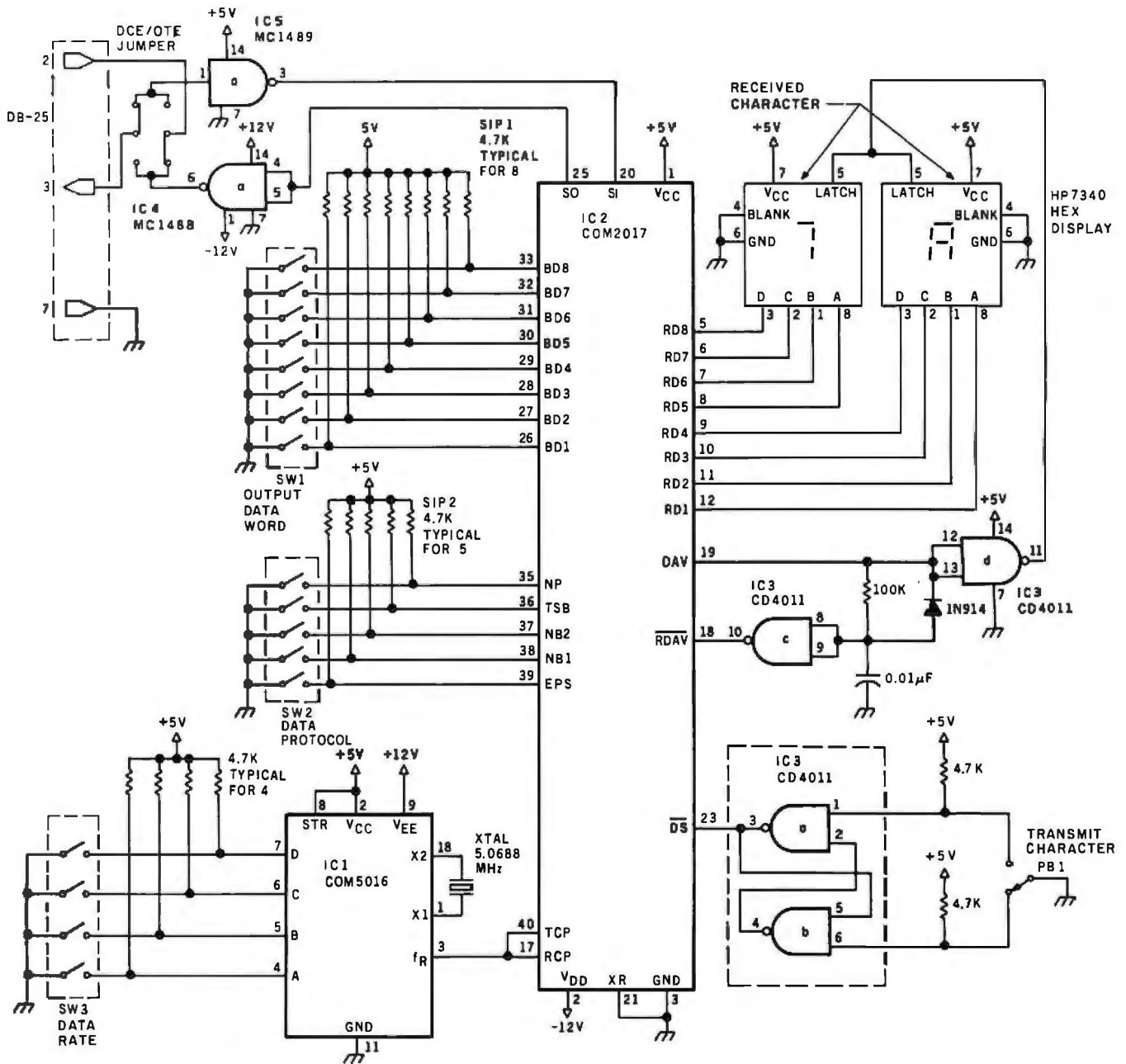


Figure 6: A terminal-simulator circuit used to test the functioning of an RS-232C communication link. This simple-minded device transmits a single, switch-selected ASCII character on demand or receives a single character for display in hexadecimal form.

ceiver/transmitter), IC2, to generate and accept data on the RS-232C line. (Because I have written elsewhere about the functioning of UARTs, I won't take the time now. See reference 2 for more information.) IC1 is a crystal-controlled data-rate generator. Depending on the settings of SW3, the clock rate of the UART will be set for one of the 16 data rates. Both the transmitter and receiver are set to the same rate.

The transmitter section is very sim-

ple. SW2 sets the status inputs to the UART for parity, word length, and stop bits. The character to be transmitted is set on SW1 (the most significant bit is BD8) in hexadecimal or binary format. It is transmitted each time pushbutton switch PB1 is pressed.

Data reception is just as easy. When a character has been received, the DAV (data available) output line of the UART goes high, and the received character can be read from the

output lines RD1 through RD8. The DAV signal is delayed, inverted and used to reset itself through the \overline{RDV} input. This same logic signal is used to latch the 8 data bits onto a 2-digit hexadecimal LED display. Each time a character is received, the display will be updated, although you won't be able to read a continuous data stream.

Of course, more sophisticated commercial terminal simulators exist that incorporate some processing power,

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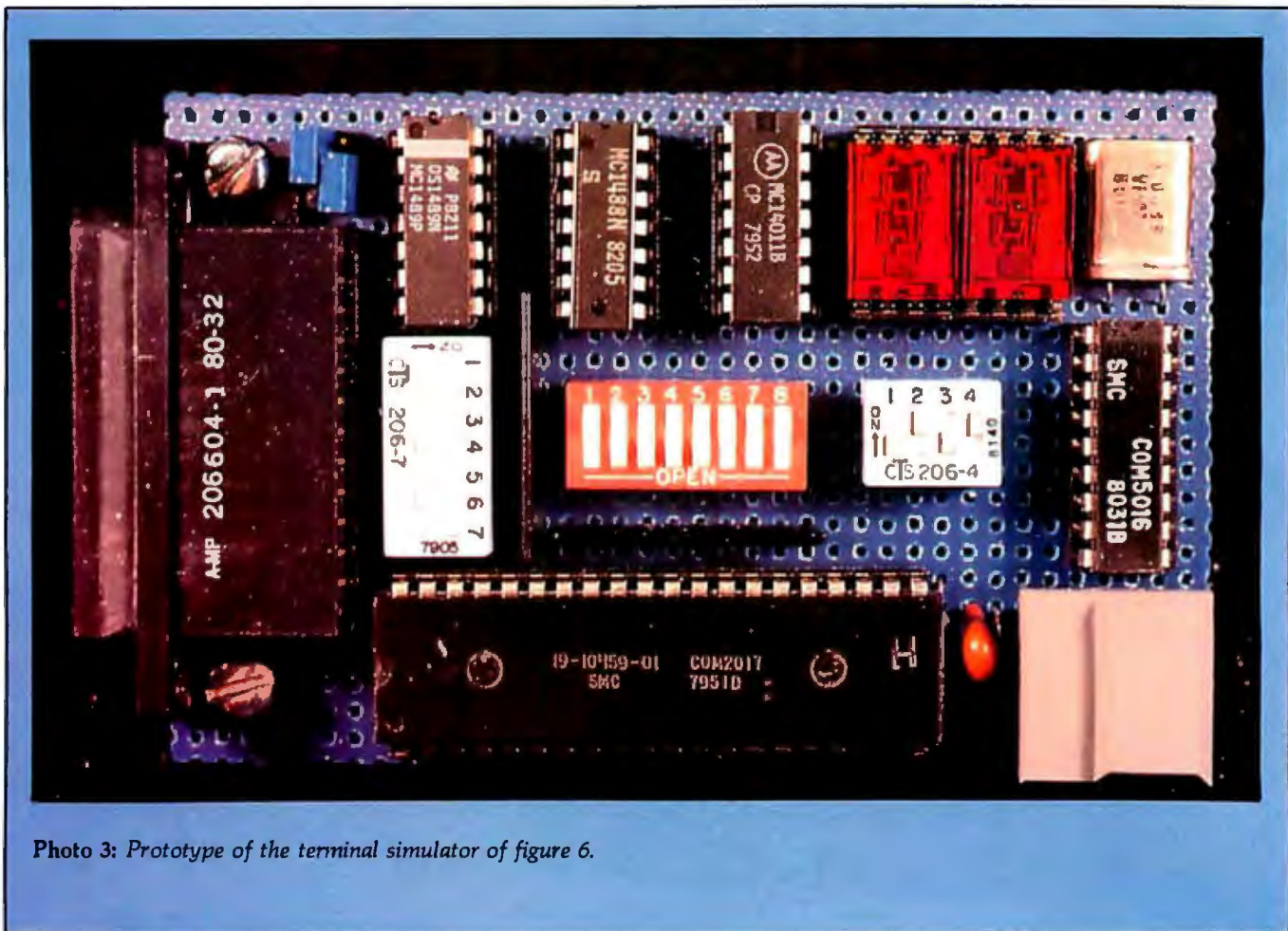


Photo 3: Prototype of the terminal simulator of figure 6.

but this one is simple enough to build yourself. Practically speaking, if I need more capability than this, I generally use a video terminal.

In Conclusion

This has been a rather long soliloquy on a rather oblique problem. I helped our shopping-bag computer hacker understand a little more about RS-232C, but a similar disaster might happen to him the next time he attempts to attach two serial devices.

As Dr. Witten has observed, most of the problems we find in using the RS-232C interface result from its being employed in ways never intended when it was invented.

For some of us, however, there's a light-emitting diode at the end of the tunnel. We can just whip out our little breakout boxes with all the pretty lights, decipher what's in or out, simulate all the handshaking signals, jumper everything to everything else, and make it communicate by brute force.

I'll probably still spend a few hours hooking up the Daisywriter 2000 I just got for my MPX-16. Nonetheless, maybe using some of the circuits I've presented will help cut down your frustration with RS-232C interconnections.

Next Month:

Build an RS-232C code-activated peripheral-device switch. ■

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5. Leibson, Steve. "The Input/Output Primer, Part 4: The BCD and Serial Interfaces." May 1982 BYTE, page 202.
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Editor's Note: Steve often refers to previous *Circuit Cellar* articles as reference material for each month's current article. Most of these past articles are available in reprint books from *BYTE Books*, McGraw-Hill Book Company, POB 400, Hightstown, NJ 08520.

Ciarcia's *Circuit Cellar*, Volume I, covers articles that appeared in *BYTE* from September 1977 through November 1978. Ciarcia's *Circuit Cellar*, Volume II, contains articles from December 1978 through June 1980. Ciarcia's *Circuit Cellar*, Volume III, contains the articles that were published from July 1980 through December 1981.

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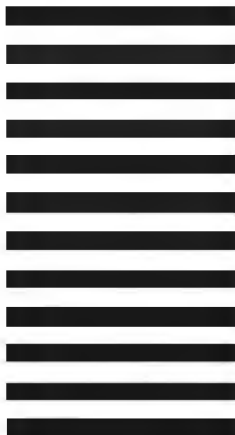
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The National Semiconductor NS16000 Microprocessor Family

The NS16000 family offers features formerly available only in much larger systems, but in a combination not available on any one system.

Glenn Leedy
National Semiconductor
Microprocessor Systems Division
2900 Semiconductor Drive
Santa Clara, CA 95051

The advent of extremely fast VLSI (very-large-scale integration) technology is quickly eradicating the gap between 8-bit small computer systems and 32-bit mini/mainframes. This decreasing gap means that many users now expect the performance and capacity of a large and costly mainframe to be combined with the flexibilities and economies of a microprocessor. The National Semiconductor Corporation has developed the NS16000 family of 16-/32-bit microprocessors to meet that expectation. (See table 1.)

The NS16000 is the only microprocessor with full 32-bit capability in

Virtual memory is the expansion of the computer's capability to include both physical or main memory and external or secondary memory.

the arithmetic logic unit (ALU) and internal data paths; the other major microprocessors with 32-bit capability, those in the MC68000 family, have 32-bit registers but a 16-bit arithmetic logic unit and data path.

The NS16000 fully supports demand-paged virtual memory addressing, totally implemented by memory-management hardware. Transparent to both programmer and user, who see just an extension of the microprocessor instruction set, the NS16000's memory-management unit (MMU), the NS16082, is capable of providing a uniform 16 megabytes of virtual

memory per user, eliminating the disadvantages of memory segmentation schemes.

Virtual memory allows you to combine a minimum of expensive primary storage (main memory) with lower-cost secondary memory. In this way, you can take full advantage of extremely large operating-system software and applications programs (now offered on large mainframes) without worrying about the hardware limitations of your system.

The "symmetrical" architecture of the NS16000 means that any data type can be used with any instruction (where appropriate), any addressing mode, and any operand source or destination. Because of this, you may be able to accomplish a given task with fewer instructions than you would with a microprocessor that has a less regular instruction set.

Additionally, the NS16000 has high-level language architecture, which means that it can execute high-level language instructions at speeds and code densities approaching as-

About the Author

Glenn Leedy is the marketing manager of external software products for the National Semiconductor NS16000 family. He has worked as a systems-software development engineer at IBM, Sycor, and Digital Equipment Corporation. At DEC he also served on the VAX software design team and as strategic market planner for low-end and fault-tolerant/high-availability systems.

(1a)

System

- A total 32-bit high-performance computer system with slaved 32-bit and 64-bit floating-point processing and 16-megabyte uniform virtual-memory management
- This family of chips will be offered at 6-MHz and 10-MHz processing rates during 1983, and 12-MHz and 14-MHz in 1984

Hardware

Central Processing Unit

- True 32-bit instruction (registers, arithmetic logic unit, and data paths)
- Symmetrical architecture
- High-level language support
- Modular programming support
- Powerful instruction set:
 - Over 100 instructions
 - Addressing modes optimized for high-level language references
 - General two-address capability
 - Expansion via slave processors
- 48-pin package

NS16082 Memory-Management Unit

- Full hardware support for 16-megabyte uniform demand-paged virtual memory
- Dynamic address translation
- 32-entry translation cache
- Automatic instruction "abort" and "retry"
- Program debugging support:
 - Program-flow traceback
 - Two breakpoint registers
 - Break-on-branch mode
- Security implemented through access-level checking and dual-system and user address-space mapping
- 48-pin package

NS16081 Floating-Point Unit

- Both 32-bit and 64-bit operation
- 8 general-purpose 32-bit registers
- Direct memory-to-memory operation
- High-speed instruction execution:

	32 bit	64 bit
Add	7.4 μ S	7.4 μ S
Multiply	4.8 μ S	6.2 μ S
Divide	8.9 μ S	11.8 μ S

- Conforms to IEEE FPU format
- 24-pin package

sembly language. [This is an ambitious claim that will be verified only after advanced compilers have been written for this microprocessor and benchmarked. . . . G. W.] Traditionally, high-level language programs have taken up to three times longer or more to execute than assembly-language programs and have required substantially larger memory space. Information from users of NS16000-based systems leads us to believe that code produced by NS16000-based compilers averages 40 percent longer than that produced by a human assembly-language programmer. We have also found that such code is considerably more compact and runs faster than that produced by compilers for the other major microprocessors.

Consistent with its high-level language capability, the NS16000 family supports modular programming techniques that allow you to divide complex programs into simpler, independent tasks and routines, each of which you can easily link for maximum efficiency. The NS16000 microprocessors even let you dynamically reconfigure and link together ROM-based software modules meant for any NS16000-based system. This can be done by using the NS16000 *link table* facility (to access both external software modules and global variables) along with the "external" addressing mode available to all NS16000 instructions.

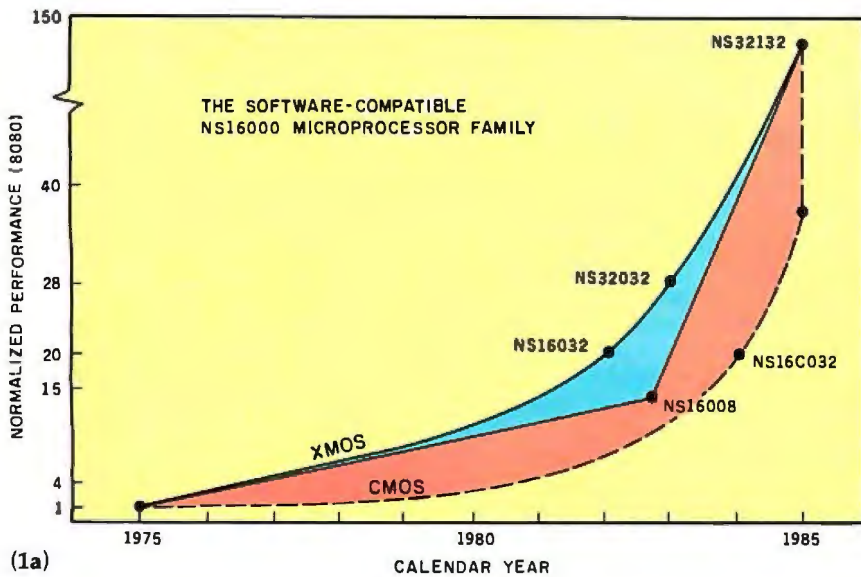
For more powerful performance in using high-level language programs,

(1b)

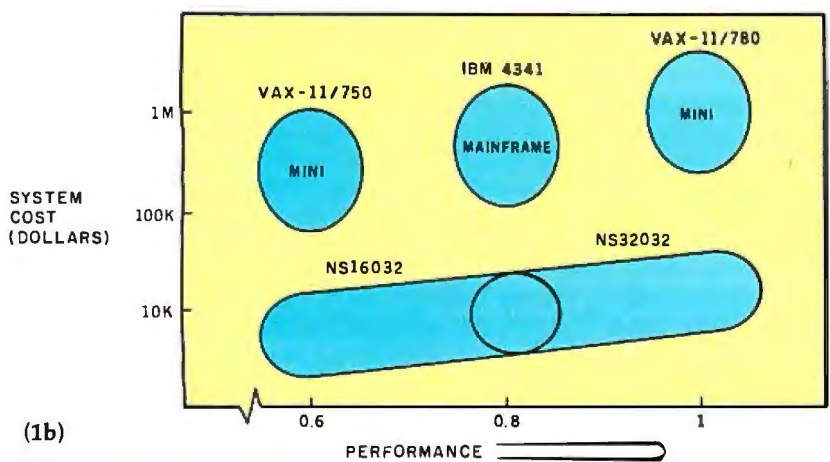
Microprocessor Characteristics

	NS16008	NS16032	NS16C032	NS32032	NS32132
registers	32 bit	32 bit	(low-power	32 bit	32 bit
arithmetic logic unit	32 bit	32 bit	CMOS	32 bit	32 bit
internal data path	32 bit	32 bit	version	32 bit	32 bit
external data path	8 bit	16 bit	of	32 bit	32 bit
real memory address	24 bit	24 bit	NS16032	24 bit	29 bit
virtual memory capabilities (with MMU support)	none	24 bit address (16 megabytes)	with same characteristics)	24 bit address (16 megabytes)	32 bit address (4 gigabytes)

Table 1: An overview of the NS16000 family hardware (table 1a) and various configurations of the microprocessor (table 1b).



(1a)



(1b)

Figure 1: The NS16000 family facts and performance. Figure 1a shows the performance of various members of the NS16000 family, while figure 1b compares the performance of the NS16032 and NS32032 with that of several minicomputers and mainframes.

the NS16000 features an instruction set with over 100 instructions, each of which is able to operate on up to five operand types. There are nine addressing modes, five of which enhance the use of high-level languages. In addition, all the code produced by the NS16000 instruction set is totally relocatable.

The NS16000 can execute operations (including all shift, logical, and arithmetic instructions) with both values in memory—known as a “two-address” capability. Combined with such features as multiple-way branching, a check instruction (to see if a value is within given limits), and

string instructions, it becomes easy to write compact programs in both high-level and assembly languages.

To carry out floating-point processing, memory management, or any other customized function for that matter, the NS16000 gives these operations to dedicated hardware. Such operations are made even faster by the use of special control and status lines that allow multiplexed inter-processor communication at speeds above normal processor-peripheral data-interchange rates. For example, the NS16081 floating-point unit (FPU) can carry out a divide operation in only 8.9 microseconds

(32-bit) and 11.8 microseconds (double-precision 64 bit) at 10 MHz, from 3 to 10 times faster than competitive units now on the market.

A comparison of the NS16000 family with popular minicomputers and mainframes now on the market shows how you can benefit from the high price/performance ratio of these microcomputers (see figure 1).

True Mainframe Performance

In order for a small microprocessor system to expand to the full capability of a mainframe, its architecture—the interface between the computer and its software—must optimize performance without compromising user protection. The system must accommodate the largest of user applications and yet remain cost-effective. Above all, it must be able to use the enormous software inventory now available on mainframes to avoid obsolescence and minimize cost. At National Semiconductor, we decided that the most effective way to achieve these design criteria was by implementing the following features: a highly symmetrical architecture, high-level language support, modular software support; a powerful instruction set, demand-paged virtual-memory support, and a memory-management unit.

Symmetrical Architecture

In the context of machine architecture, *symmetry* is the degree to which any data type can be used with any instruction, with any addressing mode, and with any operand source or destination. Symmetry is of paramount importance when implementing space- and time-efficient high-level languages.

High-Level Language Support

Programming in a high-level language (C, Pascal, PL/I, BASIC, FORTRAN, and COBOL, for example) is far more productive than programming in assembly language, which can be extremely tedious and time-consuming. A high-level language programmer often can produce the same number of debugged lines of code per day as an assembly language programmer; however, a line of high-

level language code usually performs a far more complex operation than a line of assembly-language code.

In the past, code generated by high-level languages required larger amounts of memory and took longer to execute. Depending on the compiler, computer, and applications, a compiled program might be well over three times longer and slower than the best assembly-language program. The basic reason: most contemporary architectures were not designed to support compilers.

The NS16000 family, with its symmetrical architecture, general-purpose registers, and other features, has eliminated these architectural deficiencies. Designed specifically to support high-level language compilers, the NS16000 family enables even relatively unsophisticated compilers to produce efficient code.

Because they can more efficiently translate high-level languages, compilers on the NS16000 can actually generate instruction-code densities approaching those of assembly language.

Another feature of the NS16000 is its *expanded addressing* capability. In addition to four standard addressing modes common to other microprocessors—register, immediate, absolute, and register relative—the new NS16000 has an additional five unique addressing modes oriented toward high-level languages: top-of-stack, memory, memory-relative, external, and scaled-index.

The *top-of-stack (TOS) mode* is useful for evaluating arithmetic expressions in a high-level language quickly and with a minimum number of instruction bytes. Any operand, or both operands, of an instruction may be referred to by the top-of-stack addressing mode. The operand is pushed onto the current stack, popped from it, or referenced without modifying the stack pointer. Most other microprocessors, which limit top-of-stack addressing to a small number of instructions, require several instructions to achieve the same result as one NS16000 family instruction.

The *memory mode* is similar to the standard register-relative mode,

Move instructions (5 instruction groups, 3 single instructions; total 18 instructions): These instructions move data among memory locations and registers. As with all instruction groups, the instructions that are part of an instruction group have three forms: byte (8 bits), word (16 bits), and double word (32 bits). Here, this means that many move instructions will work on 8-, 16-, or 32-bit quantities.

Integer arithmetic instructions (14 instruction groups; total 42 instructions): This group includes addition, subtraction, multiplication, division, remainder, and modulus operations.

Packed decimal instructions (2 instruction groups; total 6 instructions): The two operations are packed addition and packed subtraction. When used with 32-bit operands, this gives addition and subtraction instructions that work on 8-digit decimal numbers.

Integer comparison instructions (3 instruction groups; total 9 instructions): One instruction allows a comparison of a value with a 4-bit constant; normally, operands can be 8, 16, or 43 bits wide.

Logical and Boolean instructions (7 instruction groups; total 21 instructions): These instructions perform logical and, or, xor (exclusive or), and complement functions.

Shift instructions (3 instruction groups; total 9 instructions): This group includes a rotate instruction and both arithmetic and logical shift instructions.

Bit-manipulation instructions (7 instruction groups, total 21 instructions): This group includes various test, set, clear, and invert operations.

Bit-field instructions (4 instruction groups, 1 single instruction; total 13 instructions): This is a very useful group of instructions that allows you to interpret a series of bytes as a record of bits and manipulate arbitrarily placed subfields within this record.

Array instructions (2 instruction groups; total 6 instructions): One instruction checks a value to see if it is within an acceptable range of values; the other is used to help index into multidimensional arrays.

String instructions (3 instruction groups, 3 single instructions; total 12 instructions): This versatile set of instructions allows you to compare, skip over, or move strings. Various options allow the operations to take place starting at the end of the strings, working backward, and to continue until a match either occurs or doesn't occur.

Jump and linkage instructions (2 instruction groups, 16 single instructions; total 20 instructions): This set of instructions includes jumps, subroutine calls, case-like multiway branches, returns, jumps to external routines, and debugging-related instructions.

Microprocessor register instructions (5 instruction groups, 3 single instructions; total 18 instructions): These instructions manipulate the microprocessor's registers.

Miscellaneous instructions (3 single instructions): This group includes a wait, a no-operation, and a diagnostic instruction.

Floating-point instructions (4 instruction groups of 6 instructions each, 8 instruction groups of 3 instructions each, 4 single instructions; total 52 instructions): This group includes various floating-point arithmetic operations and instructions to convert to other forms. These instructions are available only if the NS16081 floating-point unit is connected.

Memory-management instructions (2 instruction groups, 4 single instructions; total 10 instructions): These instructions are available only if the NS16082 memory-management unit is connected.

Custom slave instructions (20 instruction types, most with more than one form): These open-ended instructions allow you to interact with an unspecified "slave" processor connected to the NS16000 family microprocessor. This scheme allows the NS16000 family to interact with performance-enhancing processors yet to be designed.

Table 2: An overview of the NS16000 family instruction set.

which allows memory to be accessed relative to one of four special-purpose registers. This mode simplifies many constructs needed by high-level language interpreters and compilers.

The *memory-relative mode* is used to manipulate fields in a record and allows pointers located in memory to be used directly without having to be loaded into registers, as with other microprocessors.

The *external mode*, unique to the NS16000, supports a modular soft-

ware concept (to be explained later), allowing modules to be relocated without traditional code modification in linkage editing.

The *scaled-index mode* is used to access elements in byte, word, double-word, or quadruple-word arrays. It computes the operand address from one of the general-purpose registers and a second addressing mode, which allows automatic indexing into tables of 1-, 2-, 4-, or 8-byte entries.

In general, high-level language programs reduce software obsolescence, one of the major problems facing the computer user, because these programs can be used on other systems with different architectures. In contrast, assembly languages are tailored to a specific computer instruction set and are rarely transportable.

Modular Software Support

Because the very complexity of large programs is one of the major factors contributing to software unreliability, decreasing the complexity increases reliability. Modular programming accomplishes this by dividing complex programming tasks into smaller and simpler subtasks, or modules, each of which performs a well-defined portion of the overall task.

You can develop each module independently of all other modules, without concern for inter-module addressing or *linking*. Using this approach, you can significantly reduce both software development costs and programming time. You can also increase program flexibility and simplify operating-system design.

Until the NS16000, microprocessors could not easily implement the concept of modular programming in ROM (read-only memory) because program code had to be modified to access specific data blocks and external procedures in a system. This significantly limited the use of programs written in ROM, which is unfortunate because if modules *could* be put into ROMs, you could build a very helpful library of ROM-based modules that could be used as needed in various applications.

Software modularity is an important issue because it is included in the structure of many high-level languages. For example, programs in Ada (a new Department of Defense high-level language) are composed of one or more subprograms, packages, or tasks, each of which can be compiled separately. In Pascal, program modules may refer to variables, functions, or procedures contained in another module by the use of extensions to the language.

Modular programs are more likely

to be correct and are easier to understand; hence, they are readily modified, maintained, and documented. And because inter-modular communication can be accomplished through well-defined interfaces, the inner operations of a module do not have to be known to another module.

An important part of modular programming, especially to the software designer, is the operating system. National Semiconductor realizes that one operating system, however successful, is not a sufficient software base for a new microprocessor. Because of this, the NS16000 will be supported by several choices in operating systems. The Pick operating system is a generic system already in use at nearly 20,000 facilities on a variety of computer systems. In the

One of the critical decisions made by designers of computer memory organizations concerns the "swapping" of data in and out of main memory.

future, the following operating systems will also be available for the NS16000 family: Xenix (Microsoft's extended, licensed version of Bell Laboratories' Unix); Oasis-16 (Phase One Systems); CP/M, Concurrent CP/M, and CP/NET (Digital Research Inc.); and the UCSD p-System (Softech Microsystem's version, modified to use the NS16000's larger address space). Through these operating systems, you will have available a variety of application programs and programming languages.

A Powerful Instruction Set

In addition to symmetrical architecture, modular software, and expanded addressing, high-level languages on the new National Semiconductor microprocessor family are supported by a sophisticated instruction set, which determines computing capability and programming effectiveness.

In the NS16000, there are over 100 instructions (see table 2), all chosen on the basis of their frequency of use, and each able to operate on up to five operand types. Because the set is symmetrical, instructions can be used (where appropriate) with any length operand, in any addressing mode, and with any general-purpose register.

Demand-Paged Virtual-Memory Support

While large-address-space programs and multitask/multiuser environments have always existed, microprocessors have had a hard time servicing them. Developed over a decade ago, the microprocessor was designed as a general-purpose device that was software programmable and therefore an alternative to a prohibitively expensive special-purpose chip. In addition, early microprocessors were rarely capable of exceeding a memory address of 16K bytes. Even today, many microprocessor systems are limited to 64K bytes of total memory or memory segments.

Basically, there are three aspects of memory organization: the entire memory structure, which is how the logical memory looks to the user and program; the mapping of logical memory to actual (physical) memory, called *address translation*; and finally, *virtual memory*, which is the expansion of the computer's capability to include both physical or main memory and external secondary memory such as disk-drive systems, with switching between the two being handled automatically.

The NS16000 uses a virtual memory organization. This organization solves two problems: the need for logical address spaces larger than physical memory, and the expense incurred by adding main memory. With virtual memory, the NS16000 stores only a minimum of logical-address information in physical memory, with the remainder located in low-cost disk memory until that information is needed to carry out a program instruction.

The architecture of this memory

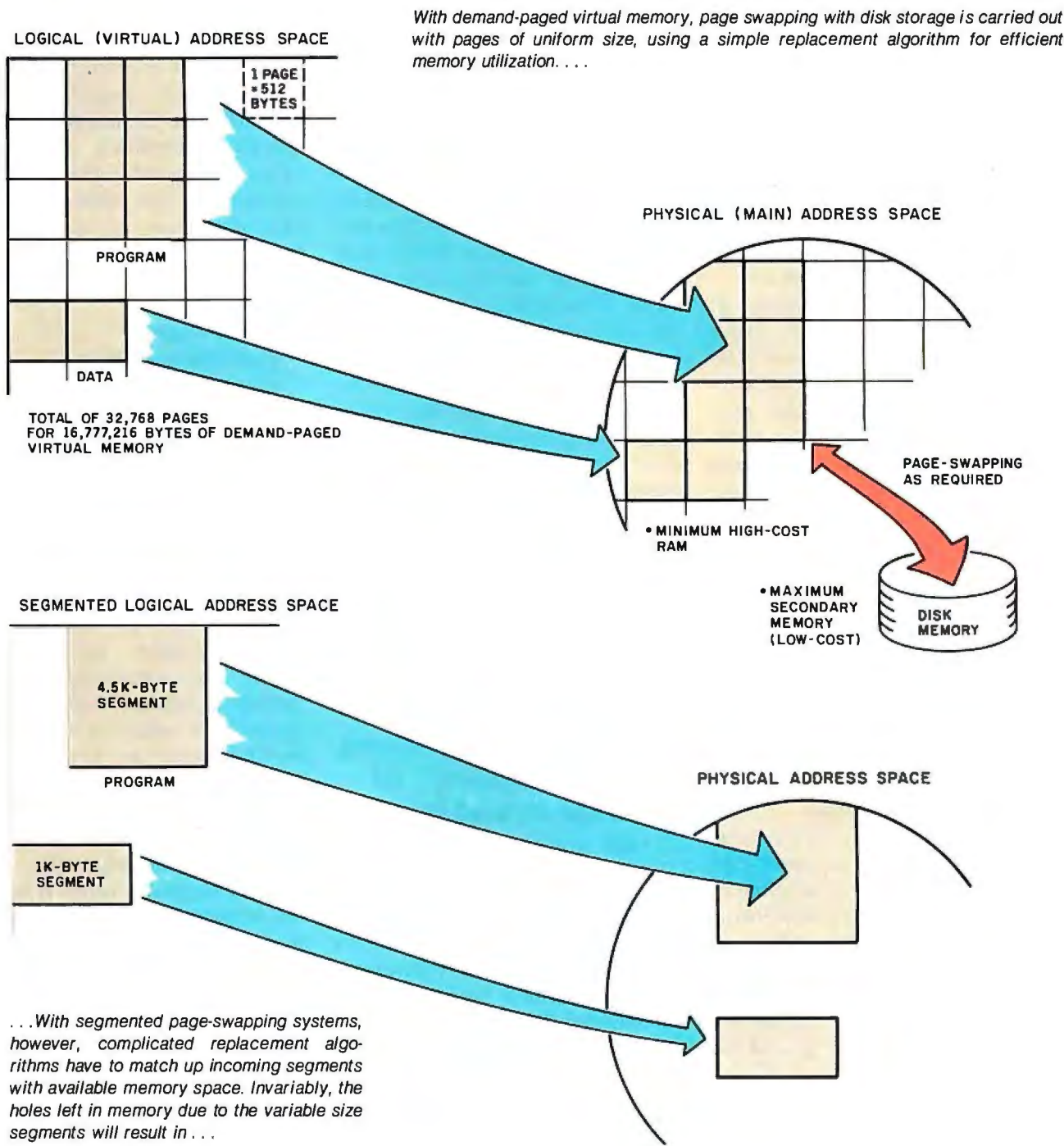


Figure 2: Fragmentation plagues segmented address space schemes.

organization is uniform rather than segmented. In a uniform address space, addresses start at location zero and proceed uniformly until the entire logical space is filled. A segmented address space consists of a collection of smaller uniform address spaces. (See figure 2 for some of the problems with segmented address space schemes.) One of the critical decisions made by designers of computer memory organizations concerns

the "swapping" of data in and out of main memory. This task must be accomplished quickly to carry out a program instruction, but additionally, the swap should contain as little unusable data as possible. The size of this swap is called a page, and in a uniform memory space, it can be any size the designer wants it to be. In a segmented memory system, the size of the swap is already determined by the size of the segment. The NS16000

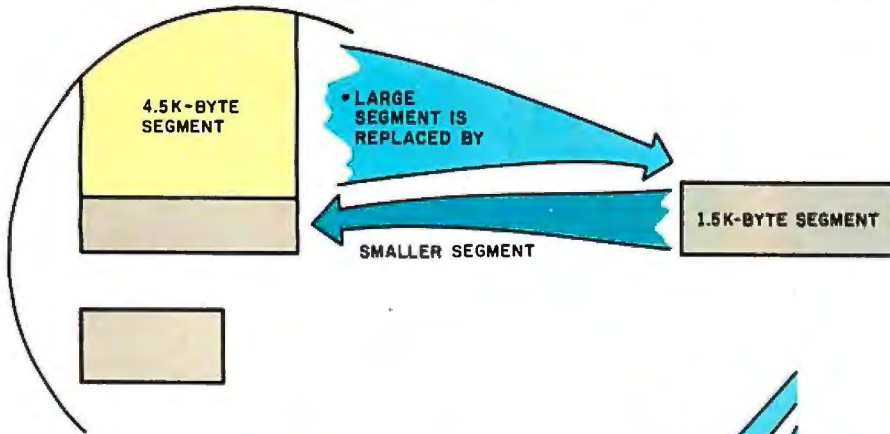
has the entire 16-megabyte virtual memory divided into 32,768 pages of 512 bytes each.

The NS16082 Memory-Management Unit

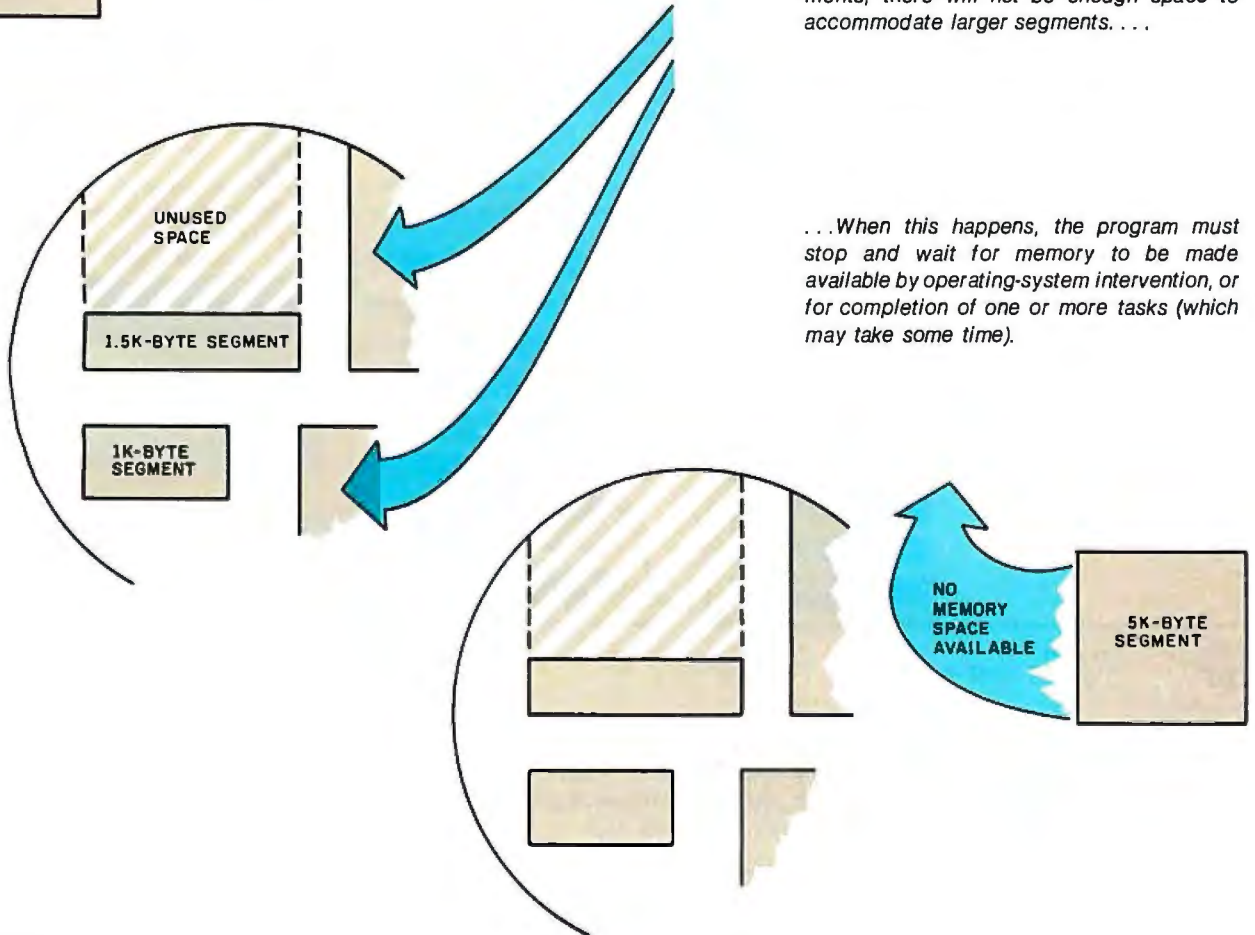
Successful management of the virtual-memory system is the function of the NS16082 memory-management unit. In addition to translating the logical (virtual) addresses generated by the NS16032/NS16C032/NS32032

SEGMENTED
PHYSICAL ADDRESS SPACE

...fragmentation. This occurs when—as page segments are swapped—larger segments begin to be replaced by smaller segments, creating unused free space. . . .



...Eventually, as memory begins to fill up and enough smaller segments replace large segments, there will not be enough space to accommodate larger segments. . . .



...When this happens, the program must stop and wait for memory to be made available by operating-system intervention, or for completion of one or more tasks (which may take some time).

Figure 2 continued

microprocessors into physical addresses, the memory-management unit can abort an instruction during execution by the microprocessor to load a nonmemory resident page and retry the same instruction immediately afterward. This feature is unique to the NS16000 system and is fully implemented in hardware.

Figures 3a and 3b give the logical and physical interconnections of the microprocessor and its memory-man-

agement and floating-point units. Important functions carried out by the memory-management unit are dynamic address translation using memory-page tables, on-chip cache for most recently used page-table entries, instruction abort and retry, and system debugging.

In *dynamic address translation*, the memory-management unit keeps track of the logical address requested by the microprocessor and its corre-

sponding values in physical memory at all times. To do this, it uses page tables containing pointers that indicate where to go in physical memory (see figure 4). Surprisingly, both page and pointer tables do not require large amounts of memory. An entire 16-megabyte virtual-memory map will use only one 1024-byte page table to point to 256 pointer tables of 512 bytes each for a total of 132,096 bytes devoted to mapping, or approximate-

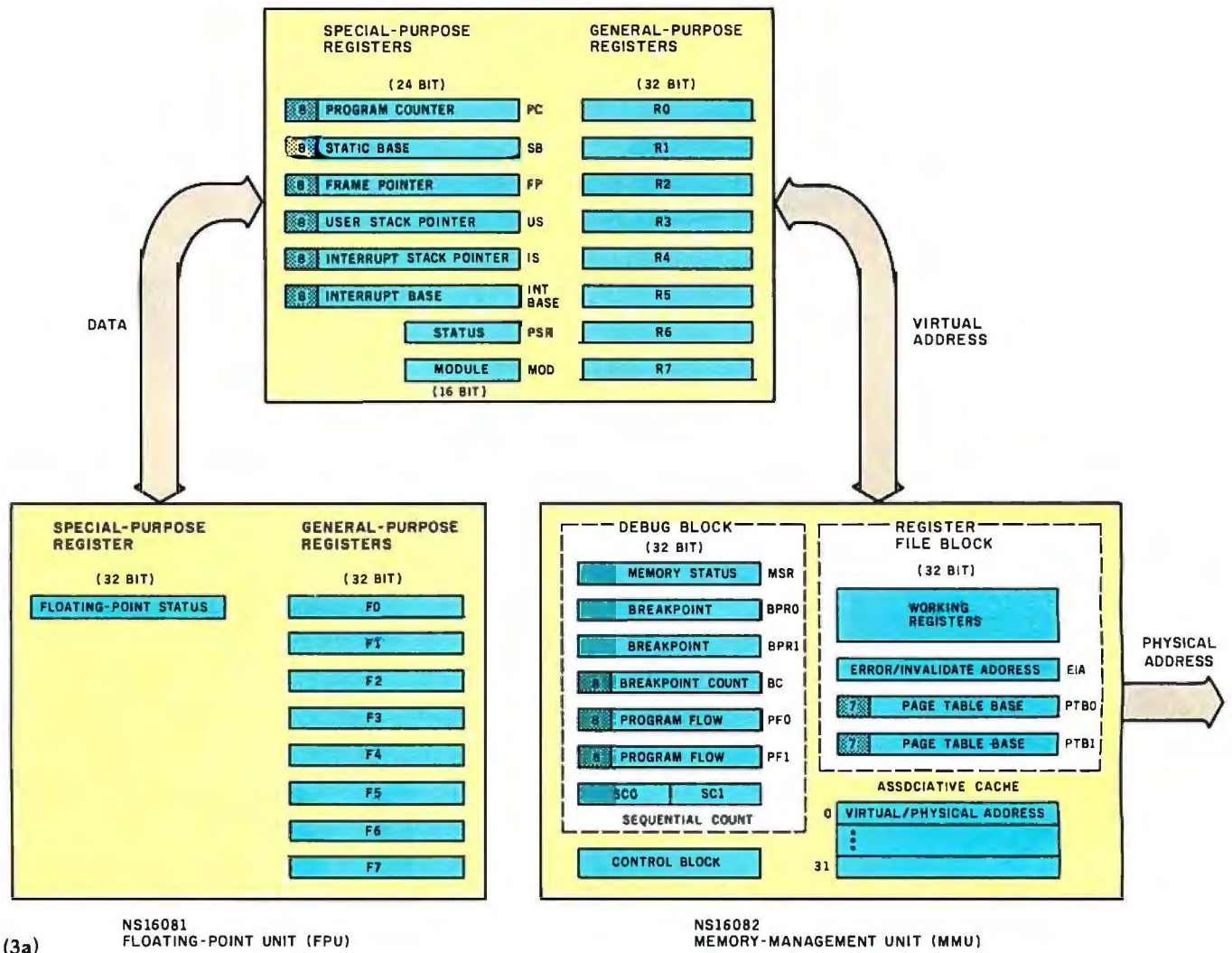


Figure 3: Component interconnection in the NS16000 family. Figure 3a shows the logical interconnection of the microprocessor and its memory-management and floating-point units, while figure 3b gives an overview of the physical interconnections.

ly 0.8 percent memory overhead. The memory-management unit NS16082 provides an entire 16-megabyte virtual address space for each user.

The address space itself is divided into fixed pages of 512 bytes each, which enables the NS16000 to transfer data into and out of memory quickly.

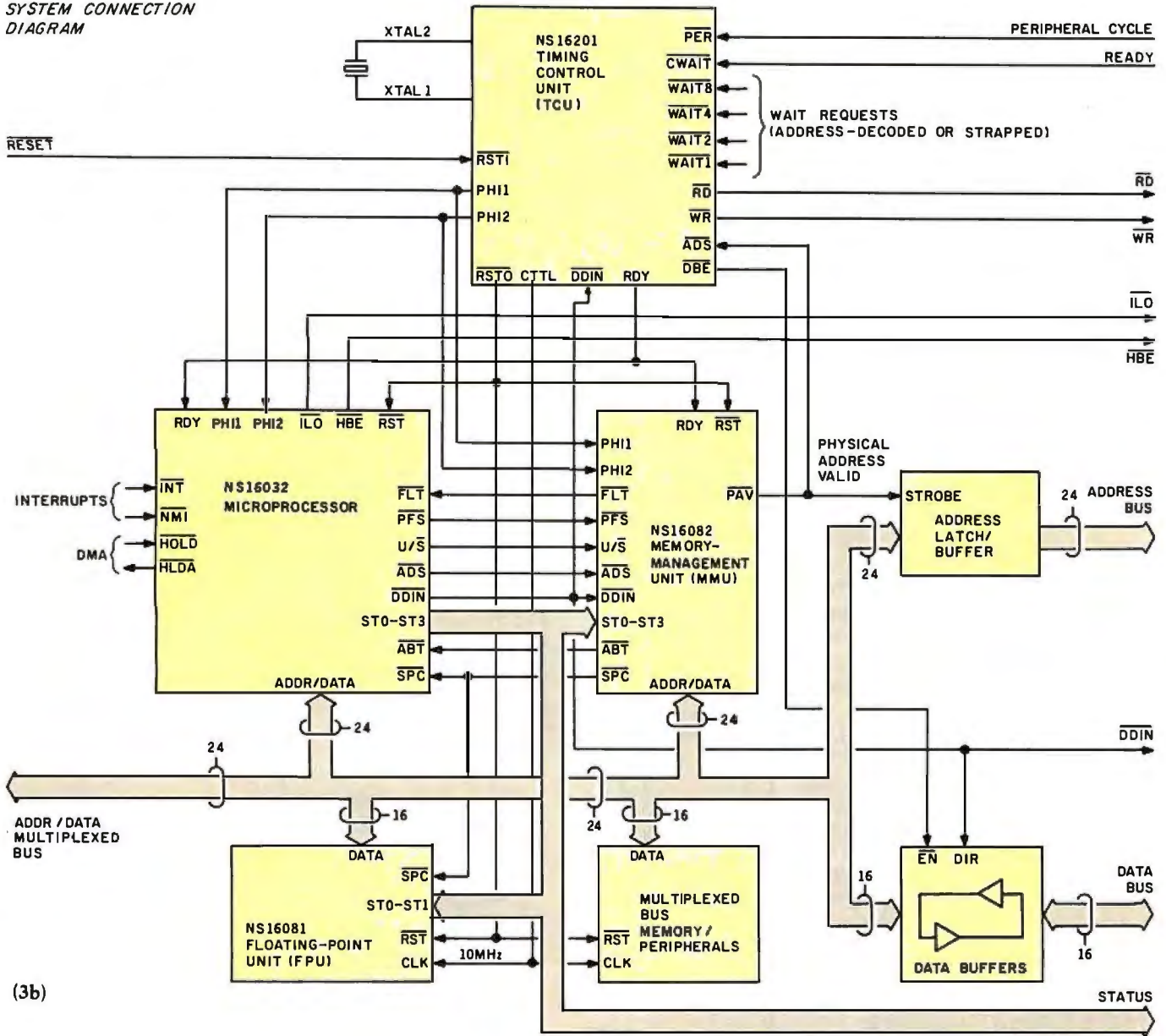
When the microprocessor passes a virtual address to the memory-management unit, the latter first attempts to match it with a special *associative cache* contained on the chip. This cache contains the 32 most recently accessed virtual addresses, as well as their translated physical addresses. If

the address requested by the microprocessor matches one of the 32 cache entries, the microprocessor is allowed access to the physical address immediately (see figure 5a). This virtual-to-physical address translation can occur in just one clock cycle, or 100 nanoseconds with a 10-MHz microprocessor clock. However, if the requested address is not present in the cache, the memory-management unit must fetch both page and pointer table entries from memory before address translation can be performed (see figure 5b). This can take up to 20 clock cycles, or 2 microseconds with a 10-MHz microprocessor clock.

The memory-management unit's associative cache, which operates transparently to the user, is an extraordinarily powerful tool in enhancing processing speeds. We have calculated that an address will be present in the cache about 97 percent of the time. This means that 97 percent of the data can be addressed with a typical virtual delay overhead of only one clock cycle.

The memory-management unit's *instruction abort and retry* features are perhaps its most significant. After fetching and decoding an instruction, the microprocessor sends the virtual addresses of the operand to the mem-

SYSTEM CONNECTION
DIAGRAM



(3b)

ory-management unit. If the memory-management unit decides that the information resides in main memory, it translates the virtual address to the physical address directly, allowing the microprocessor to operate directly on the memory.

However, if the data does not reside in one of the pages of main memory, the memory-management unit will initiate a *page fault* and send a signal to the microprocessor to abort its instruction. (A memory-access abort will also occur if the microprocessor tries to access a protected section of memory.) Once the instruction has been stopped, any

register that had been altered by the instruction will be returned to its original state.

A page fault is a hardware-generated trap that, in essence, tells the operating system to bring in the missing page containing the data from disk memory. (To signal whether a page or pointer-table entry is present in main memory or not, the page entry contains a "valid bit" for that purpose.)

Once a page fault is detected and an instruction aborted, the microprocessor then calls up the virtual-memory operating system routine, which locates the proper page con-

taining the data in peripheral memory and loads it into main memory (see figure 5c). If no room exists in main memory, it is swapped with a page that is determined to be the most expendable (or least likely to be recalled). If the operating system can do multitasking, it is free to do other tasks while pages are being loaded. When the operating system has completed its page swap, it executes a "return from trap" instruction and the aborted instruction resumes.

Debugging is handled by the memory-management unit with *breakpointing* and *flow-tracing* techniques. Breakpointing is a tool used to test if

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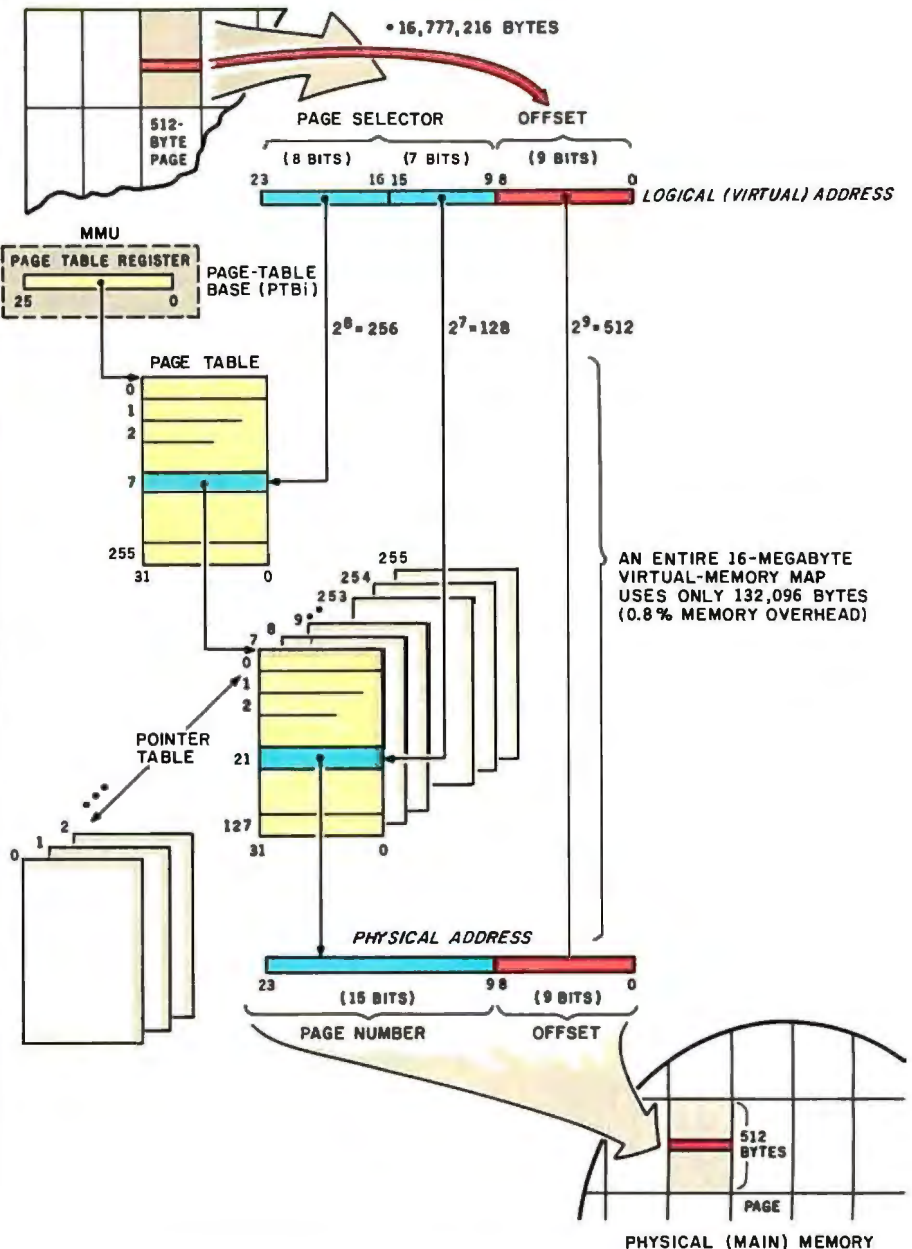


Figure 4: Dynamic address translation in the NS16000 family.

program execution is proceeding as planned. It can also be used to monitor data access. Often, a programming error may cause control to pass to a known location for some unknown reason. By using program flow tracing, the memory management unit follows the chronology of a program so that you can determine what went wrong. And because the memory-management unit's debugging facilities use hardware rather than software, they do not add to program execution time; therefore, these facilities can be used in a pro-

duction and a development environment.

The NS16081 Floating-Point Unit

To understand how a floating-point unit can enhance an application area, you must first realize the advantages a floating-point unit brings to a microprocessor. First, all floating-point units allow a microprocessor system the flexibility of handling a great numeric range (either large or small) beyond the normal range of a microprocessor's registers.

Several factors must be considered

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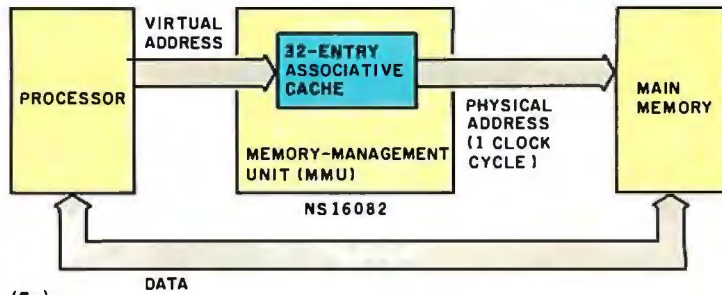
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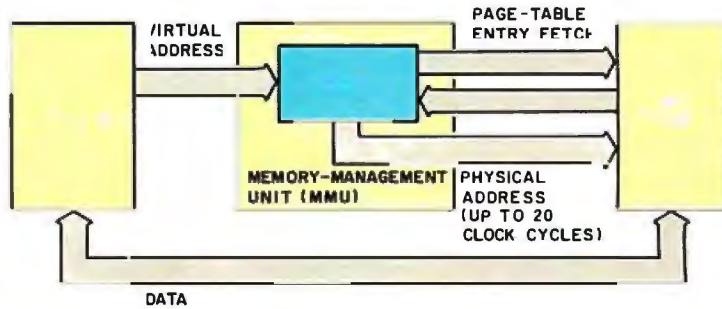
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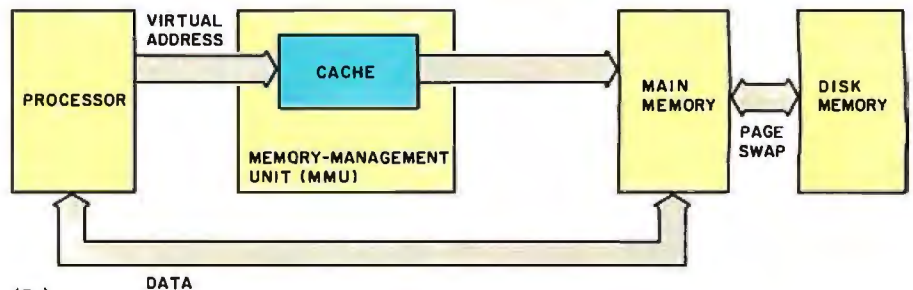
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(5a)



(5b)



(5c)

Figure 5: Memory access through the NS16082 memory-management unit. If the page-table entry (PTE) is in the cache memory of the memory-management unit and the program page is in memory (figure 5a), data addressing is completed in only one clock cycle (100 nanoseconds with a 10 MHz system clock). If the page is resident in main memory but the PTE is not in the cache memory, a page-table entry must be fetched from main memory (figure 5b), normally requiring up to 20 clock cycles (2 microseconds). If the page is resident in disk memory, it must first be swapped into main memory (figure 5c), after which it is treated as in figure 5b.

when designing a floating-point unit into a system. These include the method for handling a specific operation or instruction, the permissible length of actual data (operands), the amount of support that the floating-point unit expects from the rest of the system, and the interconnection schemes to enhance data communications to and from the chip.

The design of the NS16000 family fully supports 32-bit and 64-bit precision floating-point calculations through its NS16081 floating-point unit (FPU); the unaugmented microprocessor will handle 8-, 16-, and

32-bit fixed-point calculations. The NS16081 contains eight general-purpose onboard 32-bit registers, which you may use to provide either a single-precision (32-bit) or double-precision (64-bit) number (see figure 6).

While the eight general-purpose registers are reserved for actual data, a ninth 32-bit status register holds both control and error information. *Control* options include enabling microprocessor traps and floating-point error conditions and setting the operand rounding mode. *Error* conditions include traps for overflow, underflow, illegal division (division

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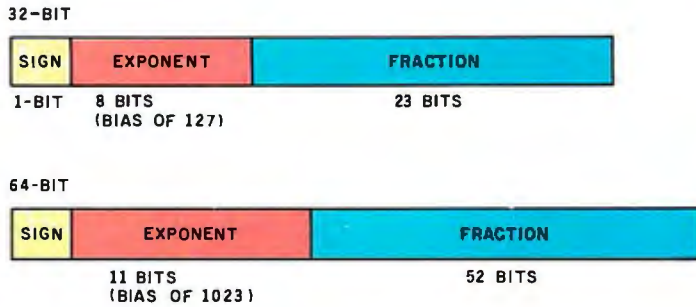
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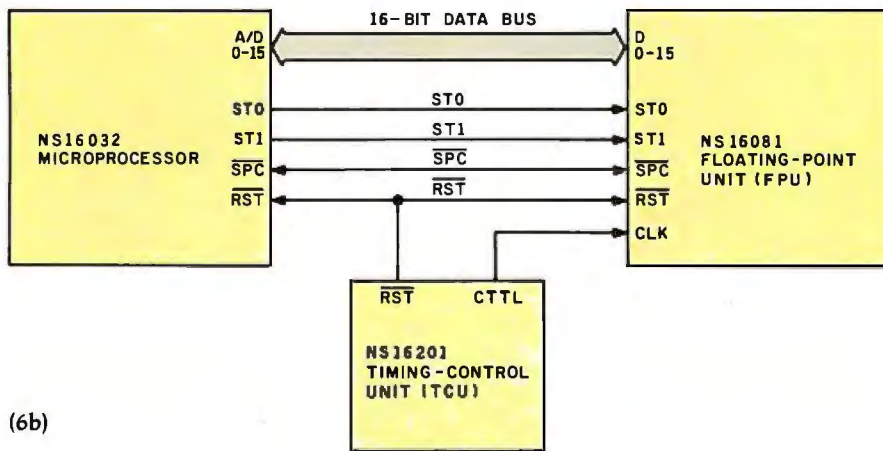
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(6a)

FPU SYSTEM IMPLEMENTATION



(6b)

Figure 6: Floating-point numbers in the NS16000 family. Figure 6a shows the NS16000 format for standard (32-bit) and long (64-bit) floating-point numbers. Figure 6b shows an overview of the physical interconnection between the microprocessor and the floating-point unit.

by zero), illegal instructions, inexact results, and undefined operand (for example, all-zero or all-one exponents). The programmer can individually enable or disable all the traps.

Unlike other microprocessor systems that support floating-point operations, the NS16000 architecture makes available to the floating-point unit all the system addressing modes, which aids efficient data handling. For example, in a scaled-index mode, an entry in a large array of floating-point data elements may be addressed by its logical index rather than by its physical address. This not only facilitates finding the data, but eliminates

wasting time with unnecessary programming schemes.

Used in conjunction with the NS16082 memory management unit to simplify large-memory management and data retrieval, the NS16081 floating-point unit becomes an even faster and more efficient data cruncher. For example, not only are a full 16 megabytes of virtual memory available for data storage, but all of the data-retrieval, dynamic-address, and memory-protection capabilities of the memory management unit become part of floating-point routines.

The instruction set of the NS16081 floating-point unit is compatible with

the proposed IEEE floating-point standard; its instruction set is summarized in table 2. The floating-point instructions use the same addressing modes as the other NS16000 instructions.

For greater speed, separate processors in the floating-point unit operate on each of the three principal segments of a number residing in either a 32-bit or 64-bit register—all under control of microcode. The first segment (containing 1 bit) is reserved for the sign, the second segment (8 or 11 bits) for the exponent, and the third segment (23 or 52 bits) for the fraction or mantissa.

Conclusions

The simplicity and efficiency of some of the concepts discussed here might lead you to believe that popular large computer systems would have integrated these features into their designs long ago. Not so. The IBM 360, 370, 43xx, and 30xx, for example, well known for their number-crunching abilities, do not possess symmetrical architectures, nor do they show much support of high-level languages and modular software. And—despite their high cost—these large systems currently offer no more than 16 megabytes of virtual memory. In these systems, sophisticated functions are carried out by slow, complex software, with lost time being made up by speedy (and costly) parallel-processing hardware techniques.

Digital Equipment Corporation's VAX minicomputer systems, on the other hand, do have a high degree of symmetrical architecture and support virtual memory. As a result, they offer a full 32-bit, 4-gigabyte virtual memory but at a cost some 20 to 30 times that expected for systems now being developed by manufacturers using National Semiconductor's new 16-/32-bit NS16000 family.

In short, the NS16000 family offers features formerly available only in much larger systems but in a combination not available on any one system. This family of microprocessors promises to be the foundation of a new generation of high-performance, low-cost computers. ■

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Design Philosophy Behind Motorola's MC68000

Part 1: A 16-bit processor with multiple 32-bit registers.

Thomas W. Starnes
Motorola Inc., Microprocessor Division
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In the mid 1970s at Motorola, a new idea was taking shape. As more and more demands were being made on the MC6800 family of microprocessors, the push was on toward developing greater programmability of a 16-bit microprocessor. A project to develop the MC68000, known as Motorola's Advanced Computer System on Silicon (MACSS), was started.

The project team began with the freedom to design this entirely new product to best fit the needs of the microprocessor marketplace. Developers at Motorola explored many possibilities and made many difficult decisions. The result can be seen in the MC68000, viewed by most industry experts as the most powerful, yet easy to program, microprocessor available. In this first of four articles, I will discuss many of the philosophies behind the design choices that were made on the MC68000.

Many criteria can qualify a processor as an 8-, 16-, or 32-bit device. A manufacturer might base its label on the width of the data bus, address bus, data sizes, internal data

paths, arithmetic and logic unit (ALU), and/or fundamental operation code (op code). Generally, the data-bus size has determined the processor size, though perhaps the best choice would be based on the size of the op code. I'll talk a bit about these features and then show how the MC68000 is both a 16- and 32-bit microprocessor.

Shaping a Design

Designers must make hundreds of decisions to shape the architecture of a new microprocessor. The needs of the users of the new product must be considered as the most important factors. After all, the users are the ones who really need a functional product, and if they are not happy with the features or performance, they will keep looking for a better alternative.

Unfortunately, it may be impossible to meet all of the needs of the users due to certain design limitations. The design must be inexpensive enough to produce in mass quantity. Also, current technology will permit only certain types and numbers of circuits to be manufactured on a silicon chip. These are the foremost factors that dictate the upper limits of the capabilities of a microprocessor.

In planning the new 16-bit MACSS, designers had to make a decision

concerning the general architecture first. What should it look like? A great deal of software written for the MC6800 family already existed. A processor that provides enhancements over an older processor, yet can run all of the programs for the older processor, has a real asset: it can capitalize on the existing software base. This may attract users by ensuring that they won't have to rewrite at least some of their programs.

Unfortunately, architectures, such as the early 8-bit microprocessors, were rather crude. Because they were designed to replace logic circuits, not enough thought was put into the software aspect of the parts. Their instruction set was oriented toward hardware. The designers did not consider carefully the future of these products, their expandability and compatibility. To try to design a microprocessor to be compatible with the older 8-bit parts was limiting.

Designers at Motorola decided that the new MACSS should be the fastest, most flexible processor available. They would design it for programmers, to make their job easier, by providing functions in a way that most programmers could best use them.

Early on, it appeared that to have a really powerful new generation of microprocessors, a totally new

About the Author

Thomas Starnes is an electrical engineer who has spent the last five years helping to plan the direction of the MC68000 family of processor products for Motorola.

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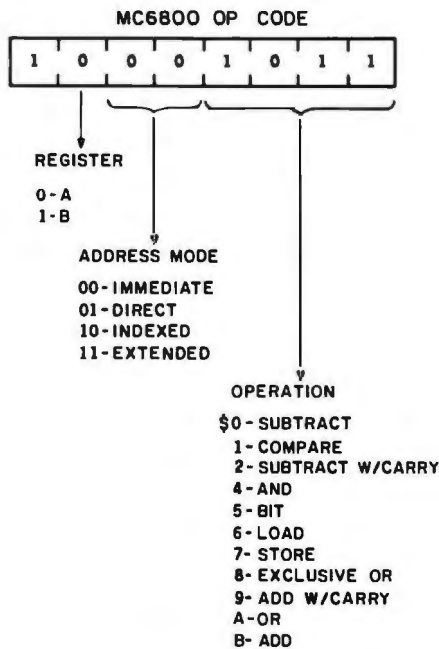


Figure 1: Op code organization for the MC6800. This processor is limited in its abilities because of its 8-bit size.

Expanded Capabilities

A properly designed 16-bit microprocessor has many advantages over the most sophisticated 8-bit microprocessor, especially to the programmer (see figures 1 and 2). The 8 bits of op code for the smaller processor provide only 256 different instruction variations. This may seem to be a lot at first glance, but consider the following.

If the microprocessor has two registers from which to move and manipulate data, those two registers require 1 bit for encoding the op code. If four different addressing modes are offered for accessing memory data, these require 2 more bits for encoding. This leaves the microprocessor with only 5 bits with which to encode the operation to be performed. Only 32 different operations can be performed.

Now admittedly this is plenty of operations for most applications, but realize that only two data registers and four memory-addressing modes are not very many to someone doing serious programming. Registers are there for fast data manipulation, and constantly swapping the contents of too few registers is not very fast. A more powerful microprocessor would have many registers, and they would all have to be accessible by the different operations.

Additionally, the more addressing modes you have for accessing memory data, the more efficiently you can get values in memory. Obviously, 8 bits of op code cannot give the microprocessor both the variety and the number of operations that a good 16-bit microprocessor can. With 64,000 different instructions possible in a 16-bit op code, you can perform far more complex operations.

This, then, is the real advantage of 16-bit over 8-bit microprocessors to the programmer. A 16-bit microprocessor will have twice the data-bus width of the 8-bit version. This wider bus allows twice as much information to go in and out of the processor in the same amount of time. This can, with proper internal design, almost double the rate at which operations take place over the rate of a similar 8-bit machine. Sixteen-bit micropro-

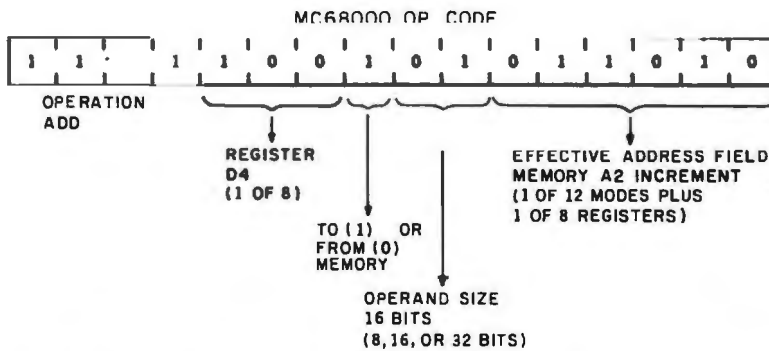


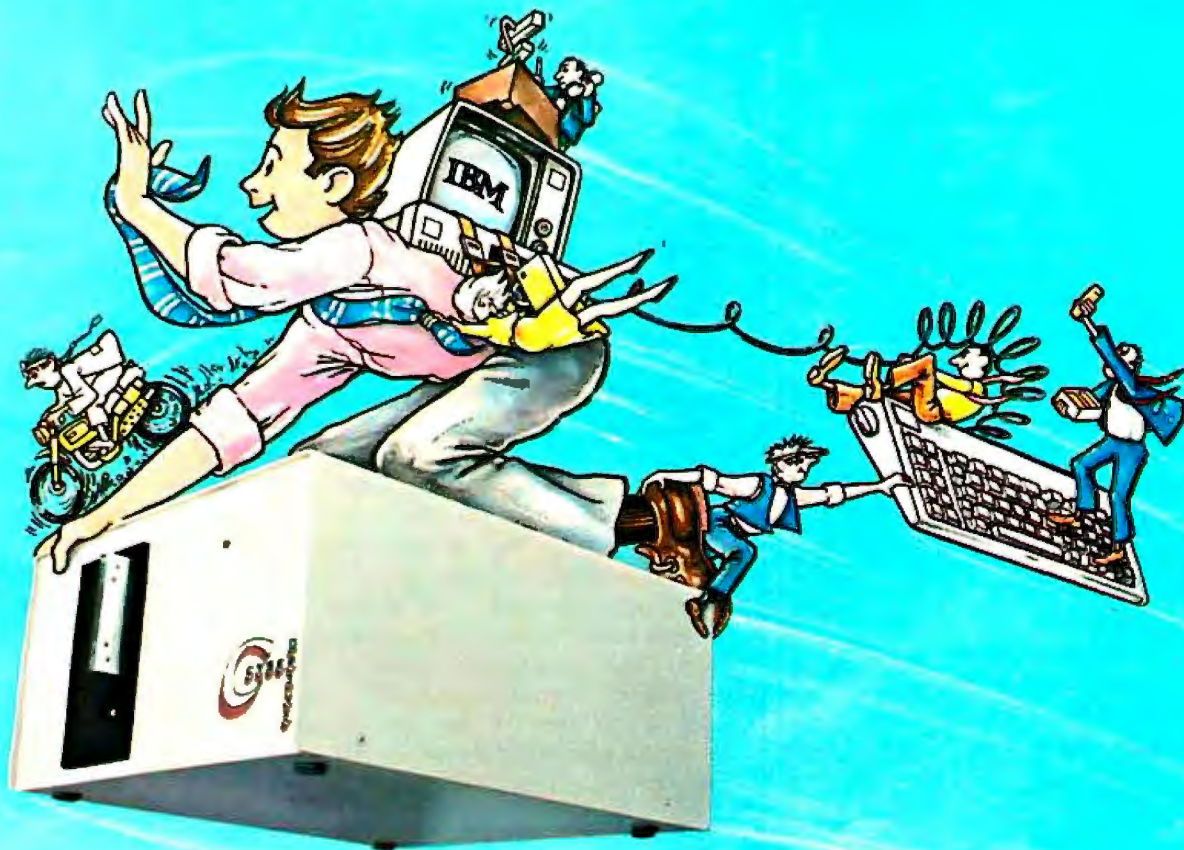
Figure 2: The MC68000 ADD instruction op code shows the power available with 16-bit operations. Multiple registers with variable operand sizes and a large address field give a programmer tremendous flexibility in programming.

architecture should be used and that earlier designs should be considered as examples rather than as models. This gave the MC68000 designers the freedom to introduce completely new concepts into microprocessors and to optimize the functionality of the new chip.

The planners decided there was one area in which ties to the 8-bit product family would be advantageous without exception. That area was in peripherals. Motorola decided that this new 16-bit microprocessor would directly interface to the 8-bit

collection of MC6800 peripherals. Because so many input/output (I/O) operations are 8-bit oriented, it seemed logical to retain this compatibility even though the 8-bit microprocessor interface would naturally be about half as fast as a comparable 16-bit. Compatibility with 8-bit MC6800 peripherals had the added benefit of immediately ensuring support of the new microprocessor with a complete family of peripheral chips, rather than requiring a wait of perhaps years for 16-bit versions to become available.

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MC68010

Motorola has recently developed an improved version of the MC68000: the MC68010. It is completely compatible with object codes of earlier versions of the 68000 and has added virtual memory support and improved loop instruction execution.

By using virtual memory techniques, the 68010 can appear to access up to 16 megabytes of memory when considerably less physical memory is available to a user. The physical memory can be accessed by the microprocessor while a much larger "virtual" memory is maintained as an image on a secondary storage device such as a floppy disk. When the microprocessor is instructed to access a location in the virtual memory that is not within the physical memory (referred to as a page fault), the access is suspended while the location and data are retrieved from the floppy disk and placed into physical memory. Then the suspended access is completed. The 68010 provides hardware support for virtual memory with the ability to suspend an instruction when a page fault is detected and then to complete the instruction after physical memory has been updated.

The MC68010 uses instruction continuation rather than instruction restart to support virtual memory. When a page fault occurs, the microprocessor stores its internal state on the supervisor stack. When the page fault has been repaired, the previous internal state is reloaded into the microprocessor, and it continues with the suspended instruction. Instruction continuation has the additional advantage of handling hardware support for virtual I/O devices.

As mentioned in the body of this article, the 68000 uses a prefetch queue to improve the speed of instruction execution. The 68010 goes one step further by making the prefetch queue more intelligent. Detection of a three-word looping instruction will put the microprocessor into a special mode. In this loop mode, the microprocessor will need only to make data transfers on the bus, because it latches up the queue and executes the instruction repeatedly out of the queue. Once the termination condition for the loop is reached, normal operation of the prefetch queue is resumed. This operation is invisible to the programmer and provides efficient execution of program loops.

processors should give the programmer far greater flexibility in coding and perform similar operations in less than half the time of an 8-bit microprocessor.

Memory Accessing

Users of the 8-bit microprocessors originally had difficulty imagining what kind of programs could fill up 64K bytes of memory. Many systems had no more than 8K bytes of ROM (read-only memory) and RAM (random-access read/write memory). But as time went on and the general software base grew, systems with up to 64K bytes of memory became more prevalent. Either code had to become more efficient or ways of fitting more than 64K bytes of memory in a system had to be developed. Sixteen-bit microprocessors could make code more efficient.

In planning MACSS, designers foresaw that the 16-bit, 64K-byte addressing range of popular 8-bit micro-

processors would be quickly outgrown by the newly proposed microprocessor. Each additional bit of address could double the addressing range of the processor.

Look at the techniques of expanding beyond a 16-bit addressing range and analyze the design trade-offs (see figure 3). You could extend the addressing range of early computers and minicomputers simply by appending some additional bits to the most significant of the 16 address bits. These additional bits were usually stored in an additional register, the page register. This method is called *paging*, because you work out of one page at a time. The page is set manually, and the lower 16-bits of address are included in the instruction stream or registers.

Paging has the advantage of being quite simple to implement in the processor. No real circuit change is needed over the straightforward 16-bit addressing, because all the

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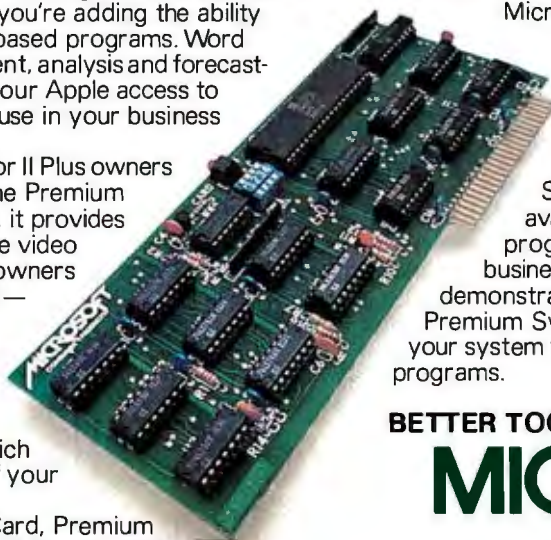
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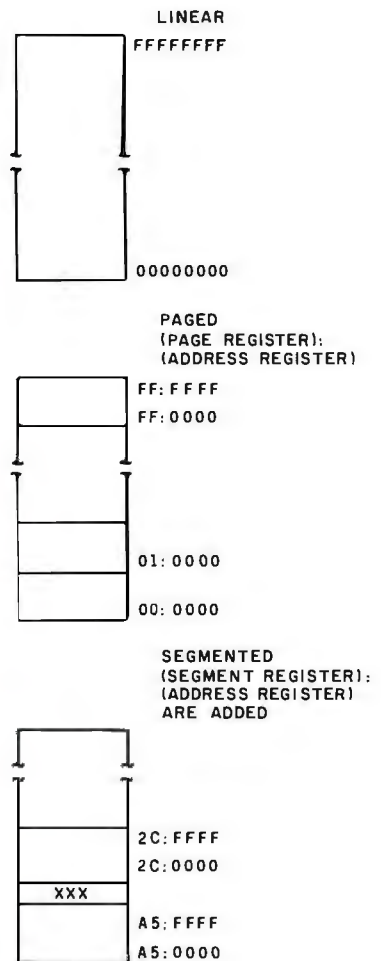


Figure 3: Three methods of addressing memory. The Linear method arranges a contiguous memory area. The Paged method organizes memory into blocks or pages of a prescribed length. The Segmented method gives each user or program a specific area in memory. Both the Paged and the Segmented method give the programmer access to only a small portion of memory.

expansion is done simply by appending bits to the core. It also has the advantage of having fairly dense code, because only 16 bits of address are carried around in the instructions.

However, there are many disadvantages to paging. The programmer is limited to accessing only the particular page of memory that happens to be set in the page register. To be assured that the right page is being used requires a check to see what is currently in the page register, possibly saving that page number, and loading the register with the desired page number. This takes time and requires both additional thought by the programmer and additional

Text continued on page 80

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code in the software. This additional code typically takes up the room saved by carrying around only 16 bits of address.

One way to get around the single-page limitation of paging is to provide many page registers. Other characteristics that determine which register will be active on a particular bus cycle include instruction fetch, data read/write, and stack access. While these additional registers give the programmer access to more than one page at a time, there is still only one page available for each type of access.

Some extensions to paging came out to compensate for some of the losses experienced in paging. *Segmentation*, for example, follows the same general principles of pagination. The key difference in segmentation is that the page number becomes a segment number and the segment number is essentially added to the core 16-bit address. This allows some relocation of the core address but still forces the programmer to check that the desired segment is

loaded, and limits the range of any segment to only 64K bytes of memory.

To a programmer, the simplest address technique is a direct addressing of any memory location. This would be without regard for whether the wanted data is near recently accessed data or whether it is miles away. The programmer wants a linear view of data, that is, the ability to specify a very simple, albeit long, address that will access any data.

Now, beyond the processor's memory-addressing method, memory management is sometimes used. With it more sophisticated systems dynamically relocate or control the various blocks of memory. This is done for protection purposes in larger systems. The advantage is that you can protect one user's work space from the devastating effects of another user's poor programs running amuck. To this end, a separate memory management unit (MMU), in conjunction with the operating system, performs some addition to or translation of an address. This technique may sound

similar to paging and segmenting memory, but this is done to serve a completely different purpose, and in a different way. The application program writer never sees this memory management and writes code as though the entire memory were available.

To expand the memory space on the MACSS, the best option, though not the easiest to implement on the chip, is a linear address space. This space is not broken up by paging, segmentation, or banking schemes. It is a very simple addressing technique, requiring the least effort by the programmer, while still allowing more advanced operations such as memory management.

A *linear address* is simply a straightforward 32-bit, for example, address. The address space is not broken up into blocks; and it is contiguous. Accessing such an address merely requires the expression of the 32-bits in the instruction or using a single address register. For convenience, if the upper 16 bits of the address are either all 0s

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or all 1s, then a shorter, 16-bit form of the address can be sign-extended to automatically provide the correct address. This is the way the MC68000 accesses memory and I/O.

How big an address space should a 16-bit microprocessor address? The natural address sizes greater than 16 bits are 24 and 32 bits, which are 3 and 4 bytes long, respectively. For a 16-bit microprocessor, the odd number of bytes becomes slightly unwieldy. Looking a little further into the future, it seemed that even the 16

megabytes of a 24-bit address might not meet the needs of large systems.

While 32 bits of address, reaching 4 gigabytes of memory, seems tremendous, once the need for more than 16 bits is established, 32 bits is the next most convenient size. It takes exactly two 16-bit bus transfers to move an address into the processor, and once the second transfer is needed, as it would be even for an 18-bit address, it is just as well to use the whole 16 bits brought in. Thus, engineers selected a virtual-memory address

space of 32 bits for the MC68000.

Now, from a practical packaging standpoint, 32 address signal lines are quite a few. The placement of integrated circuits (ICs) in dual inline packages (DIPs) with greater than 40 leads was rare before 1980. With only a few systems in the early '80s requiring more than 16 megabytes of memory, it seemed a reasonable trade-off to bring only the 24 least significant address bits to the outside world. That way fewer pins would be required, and MACSS could fit within a 64-pin DIP. Still, all 32 bits of address are maintained within the processor, and there are simple means of determining the upper 8 bits' values.

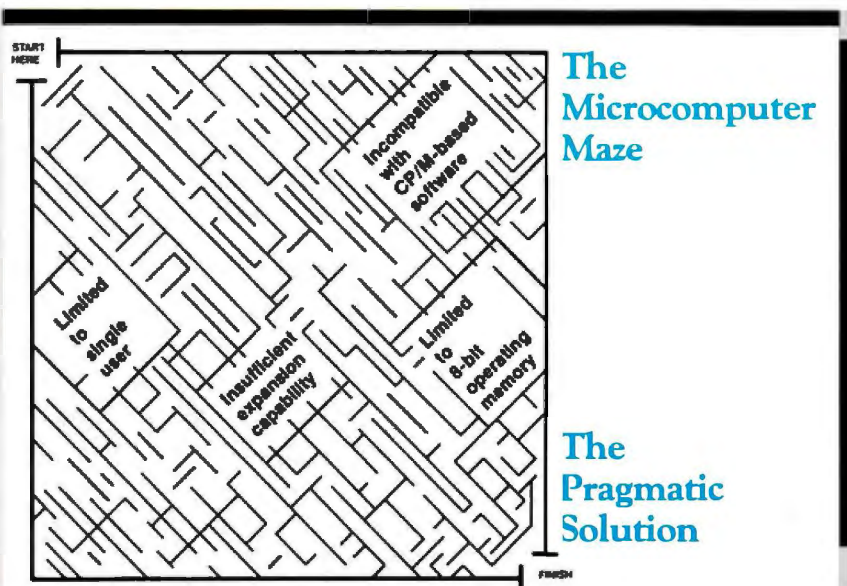
Multiple Registers

With the size of the memory address space determined, it was easier to settle on the register scheme of the new processor. The size and the number of registers had to be decided.

Designers originally envisioned onboard registers for a processor because operating on memory data requires a time-consuming transfer across the external bus. It just happens that in programming most data is operated on a number of times in succession before a result is obtained. Often many combinations with many different data pieces are used. The merging of these two observations leads to onboard or on-chip registers for fast manipulation of frequently used data.

It seems that from the day registers were brought into the processor, programmers have wanted more registers for their use. The goal, then, when designing processors, is to provide as many registers as possible for the programmer. In the MC6800, only two registers (A and B) were available for data manipulation, and one index register (X) to point to non-stack data. These few registers are being loaded and saved almost as often as the data within them is manipulated.

The loading and saving of registers is usually wasted time. The amount of time spent bringing data into on-chip registers for fast manipulation



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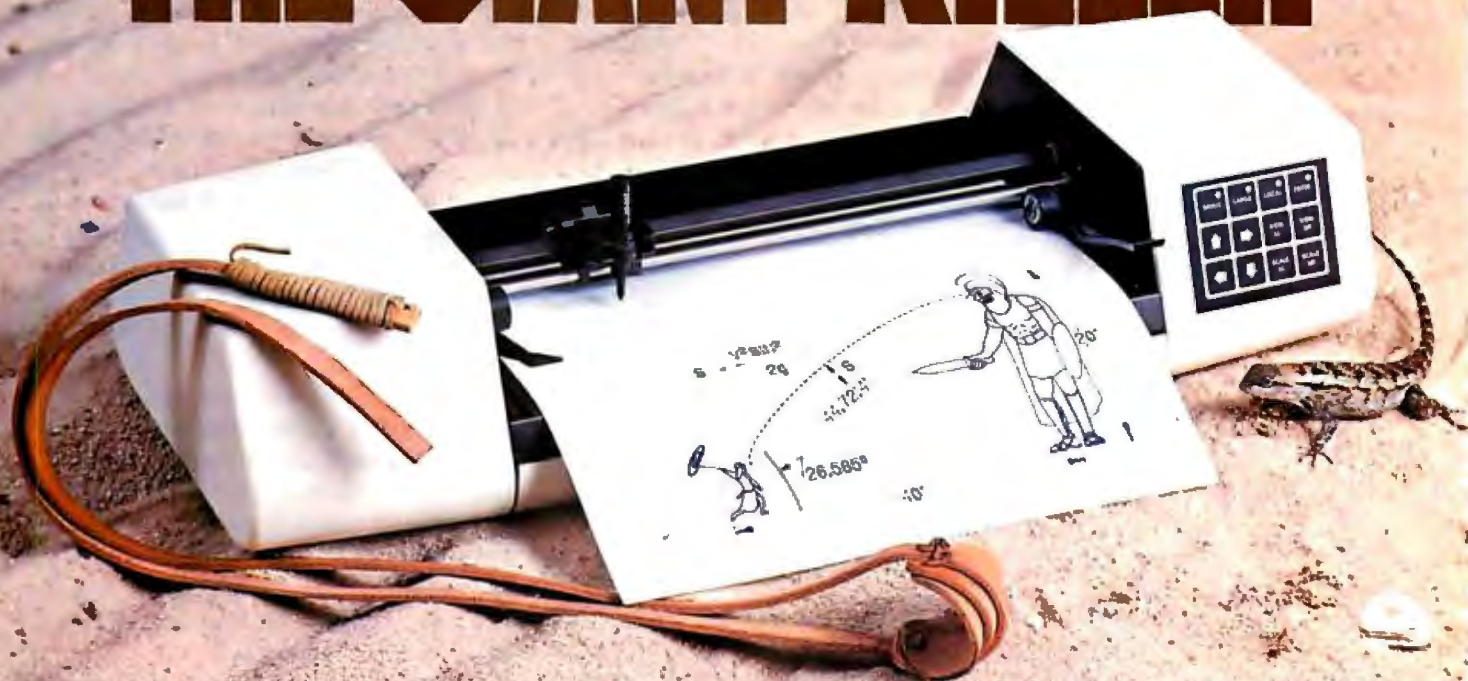
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depends upon the exact use of that data. However, the more registers available, the more likely it is that a register will not have to be saved just so that some other data can be operated on in that register.

The design of the internal execution of instructions through a microprocessor will determine many things about the suitability of the chip for programming. Instructions may operate either on what are called *dedicated registers* or on a *general register set*. Each of these methods has advantages and disadvantages.

In a microprocessor that uses dedicated registers, an instruction includes the address of the data to be worked on in specific registers. These registers are inherent in the instruction. The ADD instruction, for example, will add only from a memory location to, say, register A—not to register B, and not from register A to memory. If the value to be added to is not already in register A, it must first be placed there. Before it can be placed there, a number in A may have to be saved. All of this can be quite troublesome. This is not very

different from the situation in which there simply are not enough registers.

Contrast this with the example of a processor that uses true general-purpose registers. In a general-register machine, the ADD instruction may add data from memory to any of the internal registers. The instruction must contain information on which register it will operate on. This is determined when the instruction is assembled. If there were four registers in the processor, the ADD operation could be performed in register A, B, C, or D, as selected by the programmer.

Now if the value to be added to is in register C, the programmer simply designates C as the operand register. There is no need to shuffle registers and no need to save any register contents. The general-register machine, then, is easier to program and typically requires less time to execute an operation.

As it always happens, this ease of programming does not come free. You will see later that allowing a selection of registers requires bits in the op code for encoding and, therefore, more bits of the op code. Also, it is typically more difficult for the microprocessor designer to implement the circuitry that incorporates various registers because it takes time to determine which register is to be used and to activate that register. Streamlining internal operations so that this time is not detectable requires quite a bit of planning.

So while fewer registers or dedicated registers may be easier for the microprocessor designer to implement, they make programming the new chip more cumbersome and less flexible. But the extra time, effort, and expense of implementing general-register principles pays off by easing the programming of these devices.

Therefore, the MC68000 was designed with general-purpose registers. Any instruction may select any register for use as a source or destination operand or as a pointer in any allowable addressing mode. This tremendous flexibility gives programmers the ultimate in data and pointer placement.

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registers indicates they usually have one of two purposes: they may retain data for manipulation, or they may contain an address that points to a memory location. The use of a register for each of these purposes is quite different.

When data is moved into or out of a register or is manipulated within the register, all types of conditional information from the operation are important. Thus, you typically would like all condition codes to be properly set after a data operation. This way these condition codes may be used to branch or with other data operations.

On the other hand, an address might be placed in or taken from a register, or modified by incrementing or decrementing. Rarely is it important whether a carry comes out of the ALU or whether the result is negative (i.e., has a 1 in the most significant bit). In fact, a programmer would prefer manipulation of an address to have no effect on the condition codes.

Often in the middle of a complex data operation, you must bring in a new address or increment an address. To have this operation modify the condition codes most of the time will foul up the data operation in progress, and so is undesirable.

Therefore, two generic register types emerge: a data register (D0 through D7) and an address register (A0 through A7). The MC68000 has both types. In a data register, any operation will affect the condition codes of the microprocessor as is appropriate for the operation and the data used. However, in an address-register operation, condition codes will not be changed, but the codes from previous data operations will be retained. This way you can have address and index pointer changes made, without affecting the accuracy of the results, in the middle of a complex data operation that requires many instructions and transfers from memory.

What size and how many of each

type of register should be included in the microprocessor? The more registers there are, the better it is for the programmer. Unfortunately, the more register and control circuits in the chip, the more expensive it is. A good balance must be attained.

Two registers are too few, four are nice, but it is difficult to imagine even a complex routine requiring more than eight different memory pointers. The encoding of eight registers requires an even three bits. Because it seemed that eight was a good upper bound, the MC68000 has eight address registers and also eight data registers.

With 16 registers available, divided half and half for data and address, almost any sizable routine will never require the temporary storing of a value in a register just so that the register can be used for something else. And, within the routine, manipulations of memory pointers in address registers will not interfere with an ongoing data calculation,

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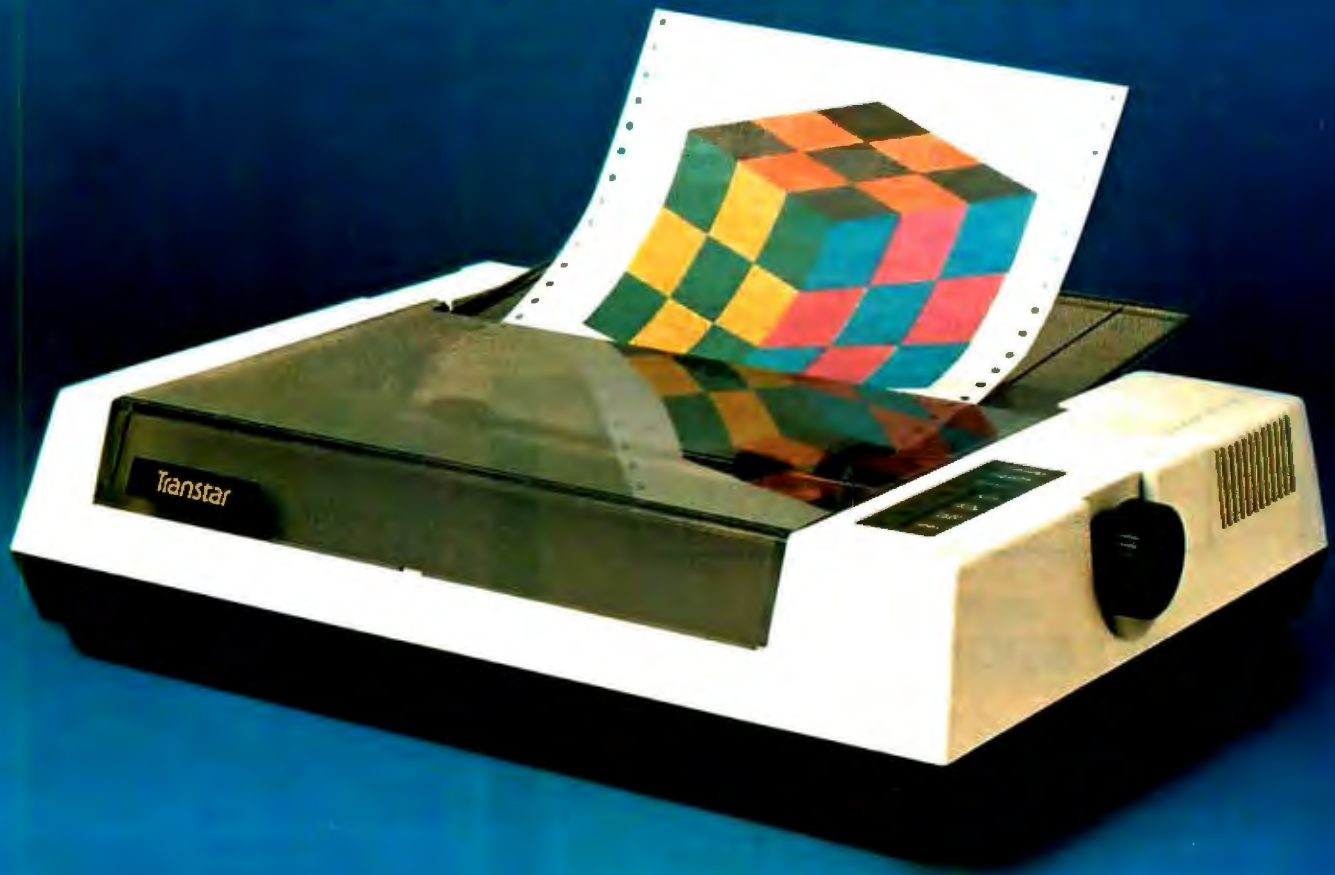


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because of the distinction of how the condition codes work for the different register types. It is easy to see how the MC68000 is easier to program.

Earlier I explained that MACSS would handle all of its addresses as 32-bit quantities. Anyone who has ever programmed 8-bit microprocessors, which have 8-bit accumulators and 16-bit index registers, has seen the difficulty with the two different sizes. Once programmers figure out how to put the 16-bit value in both 8-bit accumulators, things get tougher when they try to get arithmetic carries from the lower half to

the upper half of the value.

A little of this experience led the MC68000 designers to decide that using data that is the same size as the address register could make some software design significantly easier. In order to handle a linear 32-bit virtual-address space, the MC68000 needed to have 32-bit address registers. How would 32-bit data registers fit into a 16-bit microprocessor?

You would expect a 16-bit microprocessor to process 8- and 16-bit data, but does it make sense for it to also process 32-bit data? Obviously, the addresses will have to be handled

in that size. Designers recognized that in 8-bit microprocessors the ability to handle 16-bit data came in quite handy for more advanced applications. The 8-bit processors soon had to be upgraded to handle 16-bit operands, and users of 16-bit mini-computers needed 32-bit operations.

Once a few 32-bit operations become necessary in a microprocessor, you need a whole array of operations. If a multiplication operation generates a 32-bit result, in order to do anything with that result, other 32-bit operations are needed. For consistency, again, Motorola decided that the data registers would be 32 bits wide and operations on all 32 bits could take place with a single instruction.

Three Arithmetic Units

The exact manner of processing data and addresses through the MC68000 came about later, with careful analysis of the internal architecture and the need for address and data in the sequence of instructions. The chip ended up with three separate arithmetic units, which could work in parallel. I'll describe their purpose to give some insight into how the machine works.

The MC68000 has a 16-bit-wide ALU that essentially performs all data calculations and provides single-pass evaluation of the 16-bit data, for which the MC68000 is primarily designed. There are also two other internal arithmetic units. Both are 16 bits wide and are generally used in conjunction with each other to perform the various address calculations associated with operand effective addresses. This makes sense because all addresses are 32 bits wide. An effective address (EA) is the calculated result based on a selected addressing mode of the processor. In the MC6800, for instance, if an "index-register-plus-offset" address mode were used, the EA would be the result of adding the contents of X with the given offset. Because EA evaluation takes time and can be a significant portion of the instruction, it is important to perform this quickly.

At one time, then, one 32-bit address and one 16-bit data calcula-

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tion can take place within the MC68000. This speeds instruction execution time considerably by processing addresses and data in parallel. The MC68000 also operates on 32-bit data. This is usually done by taking two passes of 16-bit data, one for the lower word and one for the upper word. This is reflected in the execution time of many 16- and 32-bit instructions.

Prefetch Queue

Another way designers made the MACSS faster was to include what is called a *prefetch queue*. This prefetch queue is more intelligent than other microprocessor queues; its control varies according to the instruction stream contents.

The prefetch queue is a very effective means of increasing microprocessor performance; it attempts to have as much instruction information as possible available before a particular instruction begins execution. The microprocessor uses an otherwise idle data bus to prefetch from the instruction stream. This keeps the bus active more of the time, increasing performance because processing of instructions is often limited by the time it takes to get all the relevant information into the processor.

The part of memory from which instructions are fetched, the program space, contains op codes and addressing information. The prefetch queue can contain enough information to execute one instruction, decode the next instruction, and fetch the following instruction from memory—all at the same time.

Exactly what is in the queue is very dependent upon the exact instruction sequences. The queue is intelligent enough to stay fairly full without being too wasteful.

For instance, when a conditional branching instruction is detected, the prefetch is ready to either branch or not by the time a decision is made. The queue tries to fetch both the op code following the branch instruction and the op code at the calculated branch location. Then, when the condition codes are compared and a decision is made whether to branch,

the processor can begin immediate decoding of either instruction. The other unnecessary op code is ignored.

You can use the prefetch queue in many other special ways as well. One example is in speeding up the repetitious Move Multiple Registers instruction, where it is used to accelerate successive data transfers. The prefetch queue allows many frequently used instructions to execute in exactly the time it takes to fetch the op code (actually, the time to prefetch the next op code).

Microcoding

One other significant implementation feature from the MACSS project emerged from the choice between a *random logic design* versus a *microcoded design*. Both techniques have advantages and disadvantages. Earlier microprocessors were largely of random logic design. Advanced techniques of very large scale integration (VLSI) and the increasing complexity of the chips have made

microcoding more attractive.

Random logic design of a microprocessor or other logic device is the building of the device from discrete components—gates, buffers, and transistors. This limits the components to those that are essential. There are no unused gates, duplicated circuits, or clever uses of otherwise unused components. The design is usually packed as tightly as possible and is quite fast.

The difficulty is that, as the design becomes more and more complex, as VLSI has, the planning and layout of the components and signal traces become exponentially more difficult and often impossibly so. This means that it takes exorbitant amounts of time to design the circuits.

Another problem with the use of random logic in very complex circuits occurs in modeling and testing. Before such circuits are finally placed in silicon, they must be modeled and simulated on computers because of the great difficulty in running down



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bugs once the chip is in silicon compared to debugging a wire-wrap board. The entire circuit must be modeled all at once to ensure that one combination of signals affects only the expected section of the device.

Similarly, once the circuit is in silicon, the pass/fail testing of the components in a random logic chip is quite difficult. You typically have only a few lines to send sequences of patterns through for testing. Because a particular section of the circuit may be exercised only by a very few given inputs, a normal test may not detect a stuck gate or other error caused by some strange combination of inputs.

On the other hand, in much the same way that microprocessors made designing systems with medium-scale integration/large-scale integration (MSI/LSI) easier, microprogramming has come to ease the complications in the design of microprocessors. Microprogramming is to a microprocessor what a microprocessor is to a logic design of a system. A microprocessor has central components that can be

considered black boxes with inputs and outputs. For each given operation (instruction, interrupt condition, etc.), the microprocessor can route certain information to these black boxes as inputs, and the outputs can be routed to other components. The control of this routing is performed by a microcontroller or microsequencer.

Similar to a microprocessor, the microsequencer directs the flow of data through the various components (ALU, registers, condition flags, shifters, buses, etc.) according to microprogrammed instructions. Each instruction has its own microroutine, or sequence of microwords, which routes the associated data to the proper component in the proper order. Conditions and branches may redirect the microroutines.

Microcoding a complex circuit simplifies design mostly because it makes the circuit modular. It takes a controller, a block of microprogram, and the components through which data is to flow. Each of these elements

may be modeled, built, and tested with individual inputs and outputs. Microcoding is a big step toward simplifying the design process because it breaks up the design into manageable blocks, thereby easing the testing of the finished product.

Another advantage of microcoding is that it allows tremendous flexibility in the exact operation of the circuit. Its microwords allow more combinations of the inputs through the components than most random logic would allow. Microcoding's programmability makes it especially attractive to silicon designers because random logic in silicon is not easily changed.

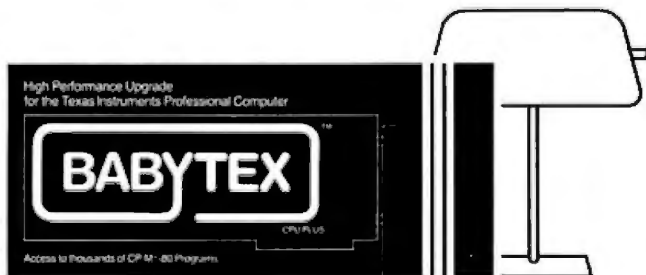
Last-Minute Changes Possible

You can change the microROM of the microcoded device right up to the minute before the masks for the device are processed. To change a small facet of an operation may mean altering a few bits in the microROM, but this changes only whether or not there is a gate on the bit's transistor—a simple alteration. Similarly, after the silicon is cast, should a change be necessary, it will likely be just a microcode change, which would be much easier than random logic modification in silicon.

The disadvantage of a microcoded circuit lies primarily in its generality. Because it is made up of modules and is programmed, the microcoded circuit is more wasteful of transistors and therefore makes a larger circuit. This may add up to 20 percent more board space or chip area than a tight random logic design. But microcoding has advantages that make up for this disadvantage, making it the design choice for modern VLSI circuits.

There are two types of microprogramming, horizontal and vertical (see figure 4). *Horizontal microcoding* is the more direct form. It is unencoded, so that, for instance, 1 bit in each microword would enable each register. For 16 registers, then, 16 bits of microcode must be dedicated. Horizontal microwords tend to be quite long, and because the size of the microcode directly affects chip size, they can quickly increase chip cost.

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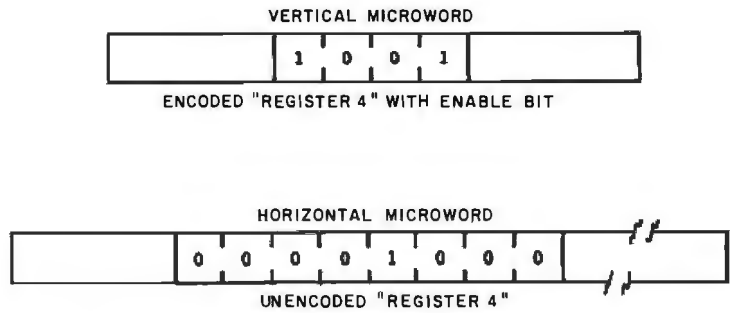


Figure 4: Comparison of horizontal and vertical microcode patterns.

A denser but slower form of microcoding is *vertical microcoding*. Here, control functions are encoded, so that only 4 bits of microcode are required to select one of 16 registers. While it needs a much shorter microword, vertical microprogramming is potentially slower than horizontal microprogramming. Vertical microprogramming will take at least one level of logic gates to decode the encoded signals. This level of gates may just throw the total gate propagation delay over the threshold of the clock pickets, forcing an additional clock cycle into the instruction.

In the MACSS project, the MC68000 was selected to be microcoded. In retrospect this was a very wise decision. The first silicon prototype worked well enough so that the major circuits in the device could be tested, and subsequent "fixes" were often just microcode corrections. The instruction set was not firm until just before the masks went to wafer fabrication, allowing some late decisions to be made to improve the performance of the chip.

A combination of horizontal and vertical microcoding was used on the MC68000 to gain the optimum advantages of both. Essentially, a microcode and a nanocode were developed. The microcode is a series of pointers into assorted microsub-routines in the nanocode. The nanocode performs the actual routing and selecting of registers and functions, and directs results. This combination is quite efficient because a great deal of code can share many common routines and yet retain the

individuality required of different instructions.

Decoding of an instruction's op code generates starting addresses in the microcode for the type of operation and the addressing mode. Completion of an instruction enables interrupts to be accepted or allows access to the prefetch queue for the next op code. The prefetch queue actually keeps bus use at 85 to 95 percent, i.e., the bus is idle only 5 to 15 percent of the time!

Conclusion

Let's look back now at the MC68000 and see what parts of it might qualify it as a 16-bit device. The internal data ALU is 16 bits. It processes 32-bit addresses, though only 24 bits are brought off chip. The op code that tells the processor what operation to perform is 16 bits wide. The data bus is 16 bits wide. The microprocessor will operate on either 8, 16, or 32 bits of data automatically. There are 16 general-purpose 32-bit-wide registers in the chip.

The MC68000 is generally considered a 16-bit microprocessor, though it uses 32-bit addresses and contains 32-bit registers. It also can operate on 32 bits of data as easily as 8 and 16. Many users of the MC68000 consider it a 32-bit just as much as a 16-bit processor. Whatever you consider it there is no doubt that the MC68000 is indeed a powerful microprocessor. In coming articles, I will discuss in more detail exactly what operations are available in the MC68000 and will illustrate examples of MC68000 code. ■

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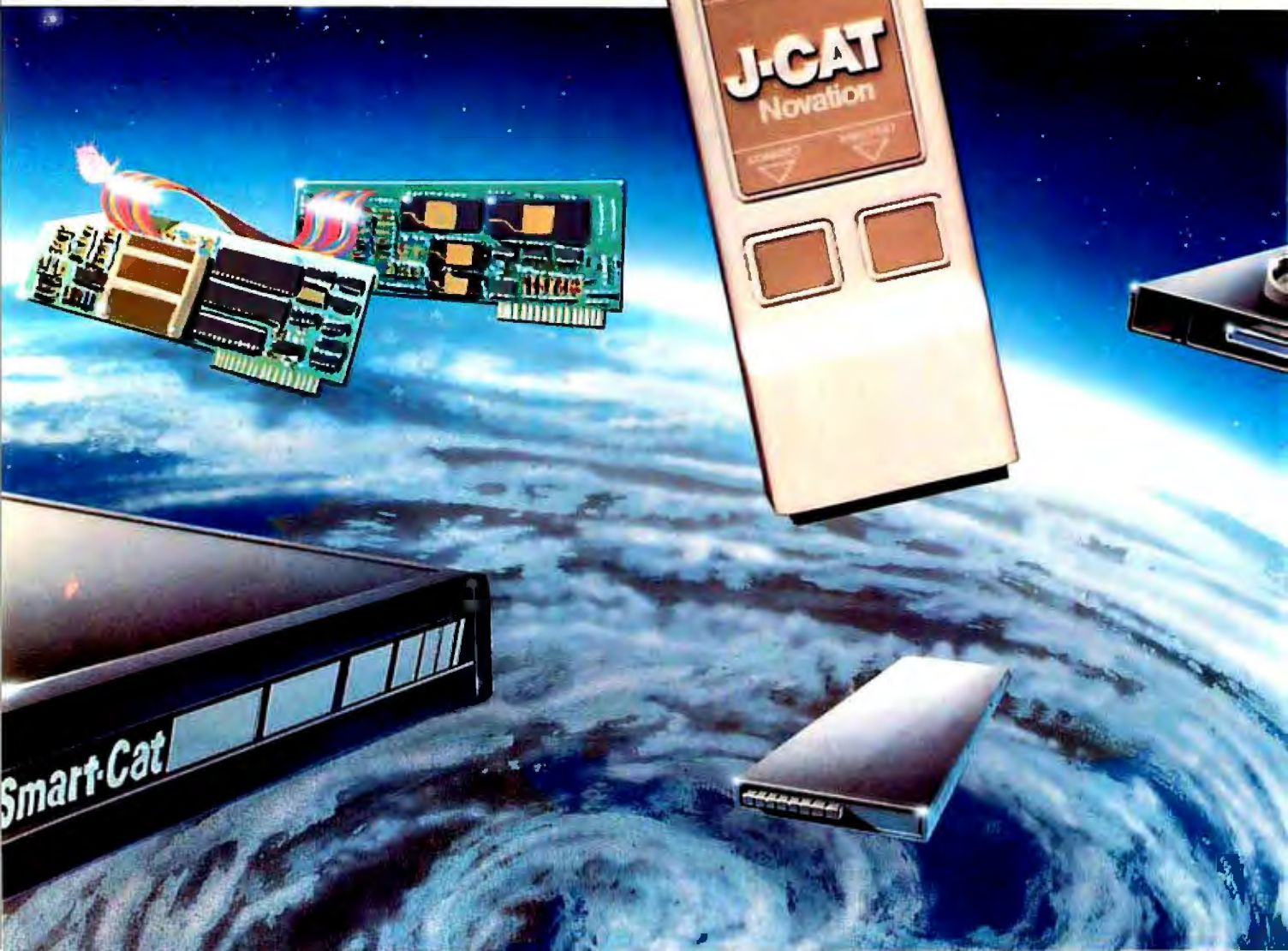
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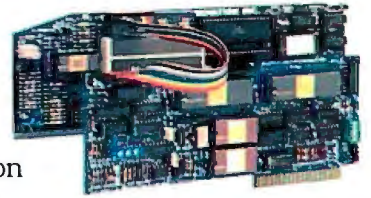
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The CRT 9007 VPAC (video processor and controller) is a powerful new "next-generation" CRT (cathode-ray tube) controller that features advanced memory-addressing techniques and flexible video-timing parameters.

To better understand the virtues of the VPAC, we should first review the function of the basic CRT controller. Characters are "painted" by the scan of a modulated electron beam across the screen phosphors. All CRT displays demand continual readdressing of a video memory to refresh the screen before the characters fade. This screen addressing must be synchronized to the raster scan (via the horizontal and vertical sync pulses) to ensure that the characters are in the same screen position every *frame* or refresh period. In the most elementary sense, a CRT controller is nothing more than a memory-address generator to refresh and synchronize the video screen.

If a CRT controller is to gain acceptance, users must be able to program its screen parameters and format (i.e., the number of characters per row, the

number of rows, the character cell size, sync pulse widths, and so on). Moreover, the controller should offer other characteristics desirable in a display system. These include cursor generation, retrace blank generation, and interlace capability.

The first-generation LSI (large-scale integration) controllers all fit this description. Some of them differ architecturally in the techniques of addressing data and so on, but they all provide much the same function. The first-generation CRT controllers revolutionized the terminal marketplace by reducing the chip count of earlier CRT terminals built with SSI (small-scale integration) and MSI (medium-scale integration) techniques by some 50 to 60 chips. As a result, they substantially reduced both cost and board space and made relatively inexpensive multifeature terminals possible. The CRT controllers also removed much of the black magic associated with CRT display design, bringing the design of CRT displays within the reach of most engineers.

Although the first-generation CRT controller chips were very successful in reducing hardware costs by reducing component counts, they did nothing to improve the actual terminal performance. Over the last few years, however, the terminal market-

place has changed. Computer manufacturers, wanting to enhance their powerful new mini- and microcomputers with powerful new displays, were forced to surround the first-generation CRT controllers with the discrete circuitry needed to provide smooth scrolling and more transparent memory-contention schemes. In addition, they overburdened CRT processors with the software required to provide editing features.

A New Generation

When Standard Microsystems Corporation began on a next-generation CRT controller to replace the first generation CRT 5037 (introduced in 1977), the company decided that a true next-generation CRT controller should not only simplify hardware design decisions but carry out software tasks previously relegated to the system's processor. The designers also felt that the CRT controller should not dictate the hardware architecture of the CRT terminal. The controller should be versatile enough to give the terminal designer maximum freedom in specifying components.

The result was the CRT 9007 VPAC and a family of ancillary circuits. Four LSI circuits resulted from this project: the CRT 9007 VPAC, the CRT 9006 SRB (single-row buffer),

About the Authors

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Auxiliary ICs

CRT 9006 single-row buffer: contains RAM, an address counter, and data latches. Two versions are available: CRT 9006-135 (up to 135-column display) and CRT 9006-83 (up to 83-column display). Both versions can be cascaded for longer data rows.

CRT 9212 double-row buffer: essentially two single-row buffers in one package. One buffer fills with character data while the other provides screen refresh. It has separate clocks for reading and writing the buffers to allow for different input and output data rates.

CRT 9021B video attributes controller: controls video attributes (blink, blank, reverse video, underline, and intensity along with double height/double width and programmable cursor) and graphic attributes (wide and thin modes). Contains 28.5-MHz video shift register.

Table 1: The three auxiliary ICs developed by Standard Microsystems Inc. to support the CRT 9007 VPAC.

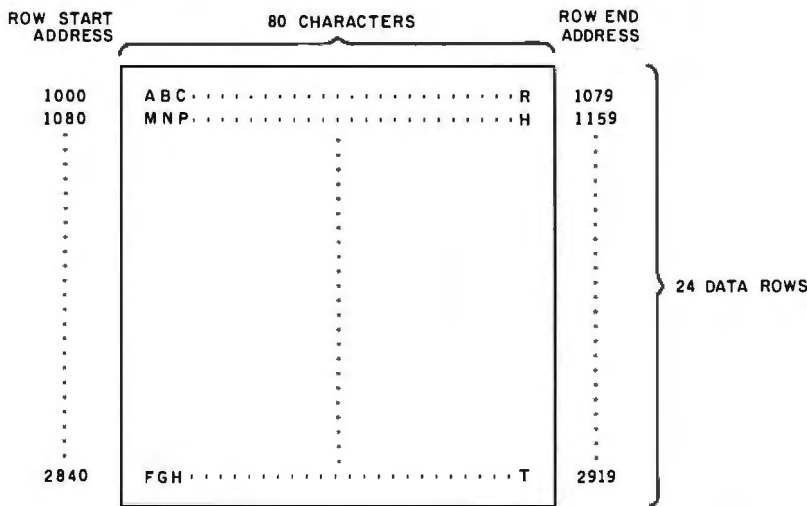


Figure 1: A typical (80 by 24) display employs sequential memory addressing for its 1920 bytes of video memory.

the CRT 9212 DRB (double-row buffer), and the CRT 9021B VAC (video attributes controller). See table 1.

VPAC Design

The CRT 9007 contains 30 registers, 12 of which contain the *vital screen parameters*, the data that determines the screen format. The remaining registers provide for cursor control, light-pen operation, and the software features that are unique to the VPAC.

Traditionally, video memory is addressed sequentially. In sequential addressing, the characters on the display screen are located in suc-

cessive memory locations. As each character is read out for display refresh, an internal video-address counter is incremented by one, to point to the next character to be accessed. For example, an 80-character by 24 data-row display will require 1920 sequentially located bytes that represent all character locations on the screen (see figure 1).

Intelligent terminals must provide on-screen data manipulation through editing functions. Typically, such designs also include display features such as double-height and double-width characters, bidirectional variable-speed smooth scrolling, and

multiple-width screens (83 and 135 columns).

With sequential memory addressing, inserting and deleting single characters within a row are relatively trivial examples of data manipulation. However, when whole lines are inserted or deleted, large blocks of data must be moved rapidly to avoid screen flashing, "garbage" displays, or undesirable blanking of the entire screen. A single-line insertion in an 80-column display requires that every succeeding memory byte be moved forward by 80 address locations. On a 24-row display, this can involve moving up to 2K bytes of data. The microprocessor manipulating this data must also be able to service the various interrupts coming from data-communication ports, the keyboard, and possibly even a magnetic-storage medium.

Nonsequential Memory Addressing

To take some of the burden off the microprocessor, the VPAC provides not only sequential memory addressing but two modes of *row-table* oriented nonsequential memory addressing to assume the duties of moving data from the host processor.

The row table, a list of starting addresses for the rows, resides in memory for addressing by the VPAC. Row-table addressing links each data row by pointers, eliminating the need to locate the rows in sequential memory addresses. Instead of manipulating entire data rows, only the pointers need be moved. Two formats for the row-table organization are provided—*contiguous* and *linked list*. In the contiguous format, a start address register in the VPAC points to the first entry of the row table (see figure 2). In the linked-list format, the start address register points to the beginning of the linked list. The first 2 bytes of each data row point to the starting address of the following data row, as shown in figure 3.

To insert a data row using a row table, the VPAC modifies the row table by entering the starting address of the new data into the table. To delete a data row, the VPAC deletes the existing entry in the row table.

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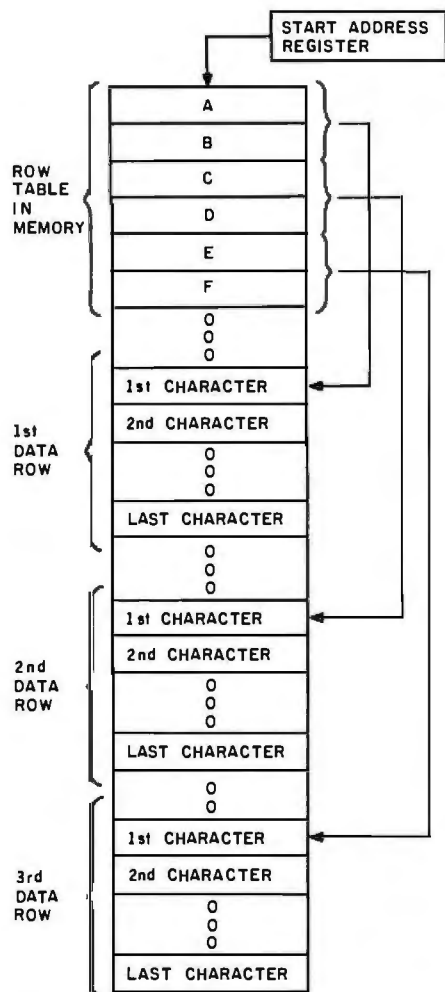


Figure 2: Contiguous row-table format. Each data row (screen line) is stored contiguously within memory. The start address register points to the first row table.

Additional Features

Another addressing feature of the VPAC is the provision of *sequential break* and *auxiliary address* registers.

When a break is encountered in the sequential addressing mode, the VPAC begins addressing the memory locations indicated by a starting address stored in one of two auxiliary address registers. This enables you to scroll a portion of the screen while keeping the rest fixed. The position of the sequential breaks is defined in sequential break registers 1 and 2 and programmed with the data-row number that starts the particular break.

You can combine a row-driven screen for the top portion of the display with a sequential screen for the bottom portion of the screen (i.e., split screen) by specifying a row-driven format in the table start

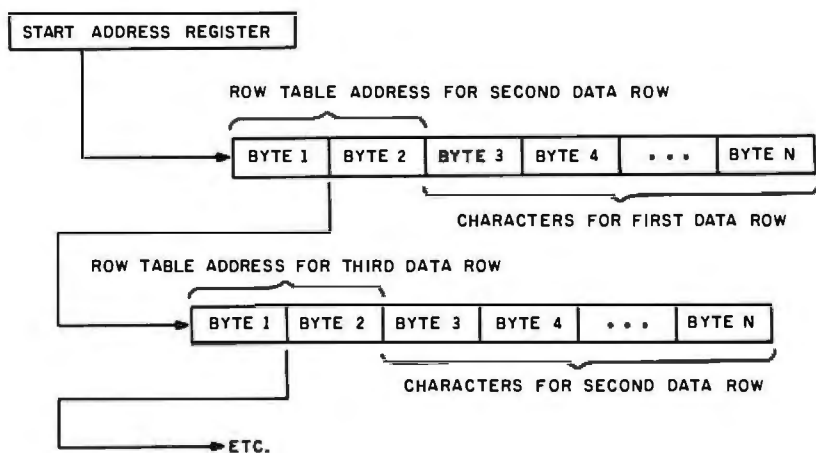


Figure 3: Linked-list row-table format. The start address register points to the address for the second data row. The first 2 bytes of that data row point to the address of the next data row, and so on.

register and then using sequential break register 1. If sequential break register 1 is programmed within the displayable screen parameters, the row address for that data row will be overridden and the remainder of the screen will be addressed sequentially, starting at the address specified in auxiliary address register 1.

Combining a row-driven screen with a sequential screen could be useful in some communications applications. A high-priority message to the terminal could be stored sequentially. As more of the message came in, sequential break register 1 would be decremented to allow the message to overlay the row-driven screen one data row at a time. By programming sequential break register 1 outside the display range, the original row-driven screen is restored.

Display Formatting

To allow the terminal designer maximum freedom, nine registers are used to store the horizontal and vertical timing parameters that are output to the monitor.

Horizontal timing is determined by four registers (R0-R3). Both R0 and R1 are 8-bit registers that contain, respectively, the number of character time periods per horizontal period (i.e., 1 scan line) and the number of displayable characters per horizontal period (i.e., the active display time). R2 is a 6-bit register that can be pro-

grammed for the time between the beginning of horizontal sync and the end of horizontal blanking. R3 is a 7-bit register that defines the horizontal sync width. When you program these registers, sync widths can be generated narrow enough for so-called *sync monitors* or wide enough for *drive monitors*. The sync pulse can be extended well into the active video portion of the horizontal time or kept within the blank time.

Vertical timing capabilities are as broad as the horizontal, with five registers used to store the vertical timing parameters: R4 defines the vertical sync pulse width, R5 the delay between the leading edge of vertical sync and the end of the vertical blank, R7 the number of data rows per frame, R8 the number of scan lines per data row, and R9 (an 11-bit register) the number of scan lines per frame. An 11-bit register enables the designer to program the VPAC for as many as 2048 scan lines per frame so that it can be used in systems ranging from low-cost terminals to high-resolution word-processing and graphics applications.

Some Hardware Configurations

An intelligent terminal must allow both the CRT controller and the host processor contention-free access to the video memory. Unless the CRT controller has continuous memory access, the display will flicker. The

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MEMORY ADDRESS (TYPICAL)	MEMORY DATA (8 BITS)
0D00	ATTRIBUTE 0
0D01	CHARACTER 0
0D02	ATTRIBUTE 1
0D03	CHARACTER 1
⋮	⋮
⋮	⋮
2N	ATTRIBUTE N
2N+1	CHARACTER N

Figure 4: The Attribute Assemble mode lets the programmer create a pseudo 16-bit word that describes both the character and its attributes (see text).

processor cannot, however, be denied access to memory.

The simplest and most common terminal configurations may be referred to as *repetitive memory addressing*. In the repetitive addressing configurations, the microprocessor and the VPAC share memory. The VPAC will repeat the sequence of video addresses for every scan line of every data row. To allow the processor access to the memory, you can use one of several schemes. In one approach, *retrace intervention*, the processor is given memory access during the blanked portion of the display and the VPAC has priority during active video.

The retrace-intervention approach, although simple, does reduce microprocessor throughput by denying the host processor access to memory during active video. An alternate—and more expensive—variety of repetitive memory addressing uses double-speed memory. In double-speed memory addressing, both the processor and the VPAC are allowed video-memory access during alternating time slots within one character time.

Single-Row Buffer Operation

By using the VPAC's DMA mechanism and SMC's CRT 9006 single-row buffer, efficient sharing of the video memory results in systems that have high throughput. In this system, data is loaded into the single-row buffer during the first scan line of

every data row. The CRT 9006 also allows this data to be simultaneously sent to the character generator and the CRT 9021B. During all subsequent scan lines, the display is driven by the row buffer, which frees up the video memory. In a display with 12 scan lines per data row, the processor will have uncontested access for 11 scan lines, or 92 percent of real time.

In a single-row buffer arrangement, the processor must be idle for one entire scan line, which could be for 50 to 60 microseconds. This delay means that the processor's ability to respond swiftly to real-time events is compromised. A second DMA device within the system, if needed, might create restrictive timing conflicts. The processor itself might not be able to tolerate a DMA cycle of 50 to 60 microseconds.

Double-Row Buffer Operation

The use of the VPAC with the CRT 9212 double-row buffer lets the user overcome such restrictions by evenly distributing the DMA requests for each data row throughout all scan lines within the data row. With a double-row buffer, while one buffer is fully loaded and supplying data to the character generator for the data row currently being painted, the other buffer is being loaded with the data for the next data row. In the double-row buffer mode, the user can program the number of DMA cycles for each burst and the delay between each DMA burst. In this way, the processor and other DMA devices can perform their tasks more quickly.

Attribute Assemble

In addition to the 7 or 8 bits used to provide character or graphic data, 8 bits may be used to provide attributes such as color, reverse-video, blink, blank, underline, and intensity. This will typically result in 16 bits per character. There are, however, many reasons to keep the video memory 8 bits wide while still providing all the advantages of wide-memory terminals. First, an 8-bit processor might be all that you need to meet the CRT system's design goal. Second, the most inexpensive memory devices, dynamic RAMs (random-access

read/write memories), are all 1 bit wide. An 8-bit-wide video memory requires 8 devices; a device must be added for each bit increase in memory-data width.

The Attribute Assemble mode lets the user maintain an 8-bit-wide video memory but "assemble" a 16-bit-wide word for the CRT display. By arranging an 8-bit-wide memory as shown in figure 4, the user can sacrifice time to gain memory-bit width. In other words, for 80 characters per data row, instead of accessing 80 locations of 16 bits each, the VPAC accesses 160 locations of 8 bits each. The VPAC "assembles" the first 8 bits in an internal attribute latch during the first access and outputs these 8 bits while accessing the second 8 bits. At this time the VPAC causes a 16-bit word to be loaded into two double-row buffers every other video-memory fetch.

Double-Height Double-Width Display

The VPAC will enable double-height/double-width characters to be displayed on a row-by-row basis as a function of the two most significant bits of the particular row-table entry. When a particular scan line is to be painted in double height or double width, the VPAC activates the CURS output during the retrace interval (CBLANK). (See figure 5.) This allows logic external to the VPAC to divide the character and dot clocks to produce the desired visual effect. Proper phasing of the divided character clock with respect to CBLANK is necessary so as not to cut the first visible character on the data row in half. The CRT 9021B video attributes controller will automatically perform the division and phasing of the character and dot clock as required to display the double-height or double-width data rows with no additional hardware.

Smooth Scrolling

When a page is filled in a typical CRT system, the entire display jumps up one row, making room for more data to be entered on the bottom row. When *jump* scrolling takes place on a frequent basis, the display is hard to



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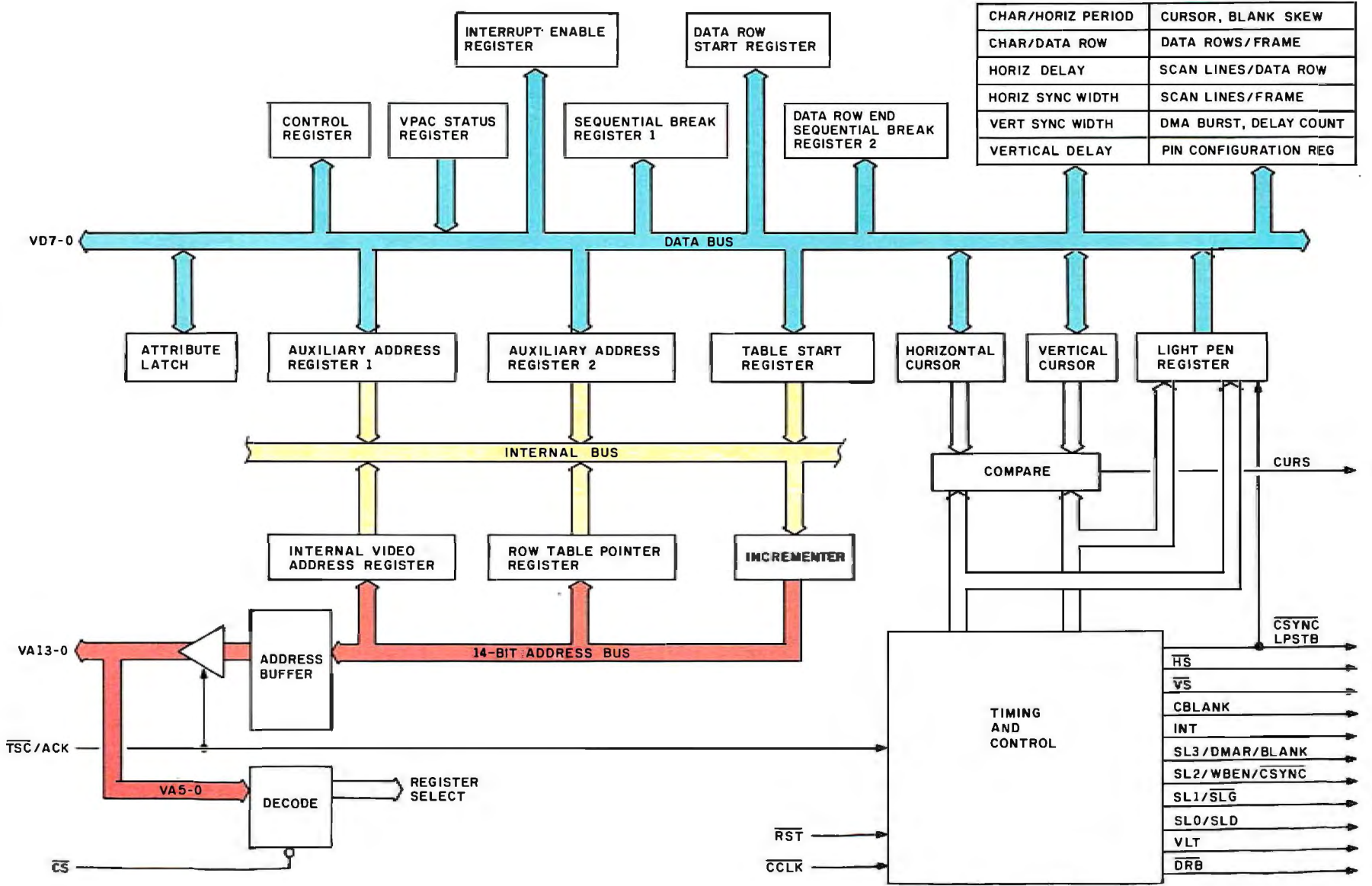
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Figure 5: A block diagram of the CRT 9007 VPAC.



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read. If the increments occur one scan line, rather than one data row, per frame time, the scroll is smoother and easier to read. The CRT 9007 VPAC provides smooth scrolling at variable rates. Furthermore, bidirectional smooth scrolling may take place over any selected portion of the display rather than the whole display.

Smooth scrolling adds some interesting requirements to system design. You can no longer assume that a particular scan line (usually the first or last one within a data row) has an absence of dots as defined by the character generator. Smooth scrolling can define any scan line as the first one in a data row. In any given frame, fractions of full data rows will be displayed when the display is in the process of scrolling. Thus the data row that is defined to start a smooth scroll interval and the data row one less than the data row defined to end a smooth scroll interval can show fractional data rows. The first and last data row for a partial-page smooth-scrolling operation is defined in the *data row start* and *data row end* registers respectively. Because a constant number of scan lines is painted on each frame, as one data row loses scan lines, another must appear to take up the extra scan lines. Because of this, it is necessary to maintain an extra data row within the row table. Once the display is scrolled, a portion of the extra data row must enter the display at the appropriate place. If 24 data rows are defined, then for an unscrolled display 24 data-row boundary (\overline{DRB}) signals are generated, all equally spaced in time as defined by the number of scan lines per data row. In this case, the data-row boundary signals will coincide with scan line count 0. Once the display is scrolled, an extra \overline{DRB} will appear, and some \overline{DRBs} will not be equally spaced.

A smooth scrolling operation involves a data-row insertion at the point defined by the data-row end register when it goes from an unscrolled frame (no offset) to a scrolled frame. In each successive frame, the offset is updated. If the software updates the offset by 1 scan line each

frame, the display will scroll smoothly at the rate of 1 scan line per frame. Under software control, it is possible to update the offset register by any number of scan lines to produce a variable-speed smooth scroll. When the offset register is again loaded with 0, it means that the smooth scroll of a single data row has concluded.

A smooth scroll-down operation is accomplished by reversing the process. The offset register is decremented and a data row is inserted at the data-row start position when going from an unscrolled to a scrolled display section. A data row can be deleted in a similar fashion.

Conclusion

The use of LSI circuitry in the CRT 9007 video processor and controller has two major consequences for manufacturers of video terminals. First, because so many functions are integral to the chip, the component count can be substantially reduced—to less than 20 chips in some applications. As the chip count decreases, the costs of design and manufacturing decrease. Second, some of the features of the VPAC, such as Standard Microsystems' scheme of nonsequential memory addressing, were not previously available on a cost-effective basis. The primary benefit of nonsequential memory addressing is data-row insertion/deletion without moving large blocks of data. Therefore the terminal processor is not overworked and the video display is free from flickering and blanking. The other major feature is bidirectional smooth scrolling.

For the end user, these improvements mean the next generation of smart terminals will contain even more features at a reduced cost—a trend to be encouraged. ■

For Further Information

For those who want more information on the VPAC and its support chips, Standard Microsystems Corporation has published a data sheet, two technical notes, and two application notes covering the VPAC's programming and use. For copies, contact SMC at 35 Marcus Blvd., Hauppauge, NY 11788.

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New Japanese Microcomputers

A Report from the Japan Data Show and Electronics Show

Phil Lemmons
West Coast Editor

The Japanese will make mistakes in the process, but sooner or later they will make some excellent personal computers. That is the lesson of the Japan Data Show '82, held October 19 through 22 at the Tokyo International Trade Center Exhibition Site on Harumi Island. The Japan Electronics Show, held at the same site during the following week, confirmed this impression and also revealed more about the intentions of the Japanese consumer-electronics companies. In short, most of the major Japanese electronics manufacturers are now or soon will be offering every type of microcomputer from hand-held units to extremely powerful desktop systems. Most of the Japanese companies have chosen the Intel 8088 and 8086 microprocessor chips for their top-of-the-line personal computers. In addition, the consumer-electronics companies are beginning to produce home computers of a type not yet seen in the United States: sleek, consumer-oriented machines that will enter the home as part of an advanced video-entertainment system.

In this article I'll describe the most

impressive machines I saw in Tokyo. I'll also touch on some interesting new developments such as an infrared modem, both infrared and fiber-optic local networks, and the continuing spread in Japan of high-resolution video graphics and dot-matrix and inkjet printers.

The Japanese offer broad product lines aimed at all segments of the world market.

Japanese 16-bit Microcomputers

At least twenty 16-bit microcomputers were on view at the Japanese electronics shows. I will report on the machines of greatest interest to personal computer owners and shoppers. (The order of the following presentation is random.)

National Mybrain 3000: This is the personal computer that you would expect from Matsushita, whose brand names in the United States include Panasonic, National, and Quasar. As photo 1 shows, the Mybrain 3000

comes in four separate units: detached keyboard with eight programmable function keys, a numeric pad, cursor keys, editing keys, and palm rest; a system unit; a video monitor for high-resolution color graphics; and disk drives.

The Mybrain 3000 has an 8088 central processor, a minimum of 96K bytes of user RAM (random-access, read/write memory), and 32K bytes of additional video RAM, plus a 16K-byte ROM (read-only memory). Video RAM can be increased to 128K bytes. Video graphics have a resolution of up to 640 by 400 dots. The available floppy-disk drives include 3-inch, 5¼-inch (160K-byte), and 8-inch (1.2-megabyte) drives, all in separate vertical units. An RS-232C serial input/output (I/O) port is standard, and an IEEE-488 port, a light-pen, joysticks, and a graphics tablet are available.

National is offering both MS-DOS (from Microsoft) and CP/M-86 (from Digital Research) as operating systems, along with many of the languages available with these operating systems in the United States. Applications software can be expected to ap-

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Photo 1: National Mybrain 3000.



Photo 4: NEC PC-9800.



Photo 2: Mitsubishi Multi16.



Photo 3: Toshiba Pasopia 16.

pear by the time the Mybrain 3000 reaches the United States, probably in mid-1983.

With two 5¼-inch disk drives, a video monitor, an 80-column dot-matrix printer, an operating system, and BASIC, the system lists for 783,500 yen (about \$3000 at the exchange rate of 265 yen per dollar, which I will use throughout). With one 5¼-inch floppy-disk drive and no printer, the cost in Japan is about \$2000. Of course, shipping the machines to the United States and marketing them here should add to the cost.

Mitsubishi Multi16: Since the Multi16 has already been introduced in the United States, I'll be brief. The Multi16 looks like an "all-in-one" microcomputer (all the components in one box), but the combined monitor/disk-drive unit is detachable from the system unit/keyboard combination (see photo 2). The Multi16 has an 8088 processor and an optional 8087 coprocessor, standard memory of 128K bytes expandable to 576K, 640- by 400-dot video resolution, one or two 300K-byte 5¼-inch floppy-disk drives, an RS-232C port with optional GP-IB, a general-purpose parallel bus, and the CP/M-86 operating system. Several different disk drives and several different printers are also available.



Photo 5: NEC N5200. It is marketed as the Advanced Personal Computer in the U.S.



Photo 6: Hitachi BASIC Master 16000.

Microsoft BASIC, Multiplan, and Supercalc-86 are among the available software, as well as a Japanese word processor with the intriguing name Multiword-J. Could this be related to Microsoft's rumored Multiword?

Toshiba Pasopia 16: The Toshiba personal computer, sold in the United States as the T100, is called the Pasopia in Japan, and the Pasopia 16 is its big brother. (In the United States, the Pasopia 16 will be called the T300.) A variety of video monitors is available with resolution ranging from 320 by 200 to 640 by 500 dots. The monitor rests on its own pedestal or on the top of the compact system unit, which contains two thin-line 5¼-inch disk drives holding a total of 640K bytes. Photo 3 shows the Pasopia 16 with an optional 80-column dot-matrix printer resting on the system unit. Eight-inch floppy disks are also optional. The slender detached keyboard has a cursor diamond, numeric pad, editing keys, and programmable-function keys. The processor is an 8088; an 8087 math coprocessor is optional. Standard memory is 4K bytes of ROM and 192K bytes of RAM expandable to 512K. Users can also add video RAM of 128K or 256K bytes. Standard equipment includes one RS-232C port and one parallel printer port.

MS-DOS is the only operating system available for the Pasopia 16. Toshiba offers T-BASIC 16 and other Microsoft languages.

In addition to the Pasopia 16, Toshiba showed the Tosbac UX-300, based on the Toshiba 88000 processor, which has segment registers and seems to be very much like an 8086. The UX-300 runs Unix and has a vertically oriented video monitor resting on a pedestal, 512K bytes of RAM, two RS-232C ports, and an 8-inch disk drive holding 1 megabyte and resting horizontally in the separate system unit. With a 10-megabyte hard disk, the UX-300 costs about \$9300.

NEC PC-9800 and Advanced Personal Computer: One of the surprises at the Japan Data Show was the NEC (Nippon Electric Company) PC-9800 (see photo 4), a personal computer based on the Intel 8086—the true 16-bit version. The PC-9800 surprised people because NEC introduced its 8086-based Advanced Personal Computer (APC) in the United States in mid-1982. In Japan, the APC machine sells under the name N5200 (see photo 5). How many American companies make two 16-bit microcomputers based on the same processor?

In Japan, the APC (N5200), with 128K bytes of RAM, two 8-inch floppy disks holding 1 megabyte



Photo 7: Hitachi PT-1 Personal Terminal.



Photo 8: Sanyo MBC-55.

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each, a high-resolution monochrome monitor (640 by 475), a serial port, and a printer port, has a list price equivalent to about \$2800. The same system lists in the United States for \$3900.

With its separate keyboard (cursor keys, programmable keys, numeric pad, and editing keys), system unit, monitor, and disk drives, the PC-9800 looks more like a home machine than the APC does. The standard memory is 128K bytes expandable to 640K. However, the PC-9800 also has a 96K-byte ROM containing NBASIC-86, and you can get another 96K bytes of video RAM. NEC offers monitors for the PC-9800 with resolution as high as 640 by 400 dots and also an assortment of disk drives. Both MS-DOS and CP/M-86 are available. With two 8-inch drives storing a megabyte each, the keyboard, and the system unit containing 128K bytes of RAM, the PC-9800 costs the equivalent of about \$2600 in Japan. When the PC-9800 reaches the United States (and the NEC spokesmen would not say whether or when that will happen), the list price will probably be about the same as that of the APC.

When I pressed the hosts in the NEC booth about the differences between the APC and the PC-9800, they would say only that the PC-9800 lacks the software power-down that the APC has. There's also the BASIC in ROM, of course, and the PC-9800 system unit is clearly too small to hold the boards that go in the APC's large card cage. (I was not allowed to look inside the PC-9800 or any other machines at the Japanese shows.) The last obvious difference is that the APC has 22 programmable-function keys to the PC-9800's ten.

Both the APC and the PC-9800 are impressive machines. NEC deserves praise for basing both of its top personal computers on the 8086 rather than imitating IBM and choosing the less powerful 8088.

Hitachi BASIC Master 16000 and PT-1 Personal Terminal: Like NEC, Hitachi is offering two 16-bit personal computers, the BASIC Master 16000 (photo 6) and the PT-1 Personal Terminal (photo 7). The BASIC Master

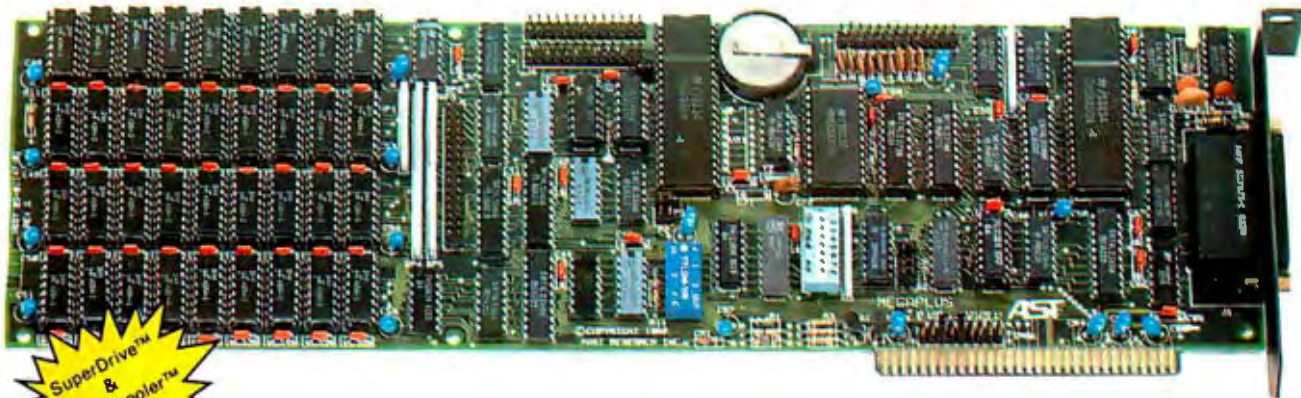
16000 has an 8088 processor, runs MS-DOS, and has 320K bytes of RAM as standard equipment. Video resolution is 640 by 400. The system unit, unlike most of the other modular Japanese microcomputers, is taller than it is deep. Two 5¼-inch floppy disks hold 320K bytes. The Hitachi booth had no brochures about the BASIC Master 16000, and information about it was limited, but the price quoted was 490,000 yen, or about \$1850. I was unable to determine for certain whether that included the video monitor and two disk drives, but it seems hard to believe that it could.

The PT-1 also uses the MS-DOS operating system. Video resolution is 720 by 520, and each of the 8-inch floppy disks holds a megabyte of data. The Hitachi exhibits of office automation equipment showed the PT-1 communicating with larger Hitachi systems.

Both the PT-1 and the BASIC Master 16000 have detached keyboards. Besides the numeric keypad, cursor keys, and editing keys, the PT-1 has 24 programmable-function keys. The BASIC Master 16000 has 10 programmable-function keys besides editing and cursor keys and a numeric pad.

Sanyo MBC-55: Sanyo's top-of-the line personal computer is the 8088-based MBC-55. The compact system unit contains two thin-line 5¼-inch floppy disks holding 160K bytes each. Although a Sanyo representative in the booth at the Electronics Show said the disk format used is not the same as the IBM PC's, he also said that the hardware bus is compatible. Buyers should, therefore, be able to use boards made for the IBM PC in the Sanyo MBC-55 when it reaches the United States.

The MBC-55 runs CP/M-86, Concurrent CP/M-86, and MS-DOS. Standard memory is 64K bytes expandable to 256K. A 4K-byte "boot" ROM (which contains instructions for reading the operating system from a floppy disk) is standard. An 8087 coprocessor is optional. The MBC-55 will go on sale in the United States in June or July 1983. Although the exact price in the United States has not been



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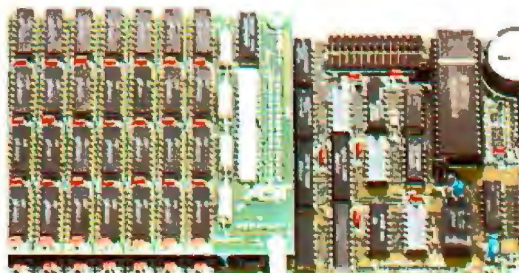
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Photo 9: Sord M-343.

decided, the Sanyo booth attendant said that the MBC-55 with 64K bytes and one floppy will cost about \$1000. That does not include the video monitor.

As photo 8 shows, the MBC-55 is very compact and seems aimed at the home market. Sanyo did not exhibit the machine at the Data Show, saving it for the more consumer-oriented Electronics Show. Sanyo showed a great deal of video-recording equipment, and the MBC-55 looks as if it might be part of the same family of products. The MBC-55's system unit is only $4\frac{1}{2}$ inches (11 cm) thick, just deep enough to accept boards made for the IBM PC. To keep the keyboard as small as possible, Sanyo chose to supply only four programmable-function keys. The numeric keypad, as on the IBM PC, doubles as a cursor-control pad. Although no Sanyo spokesman said so, I would not be surprised to see the MBC-55 sold as part of a home-video system and used to control video storage systems and to mix computer graphics with video images. (See the section on the Sharp X1 microcomputer later in this article.) The marketing approach would be to say, "Since you're buying a new color television, why

not let us throw in an IBM-compatible personal computer?"

Sord M-343: Sord, one of Japan's few new companies, makes several interesting microcomputers. (See the comments on the M5 home computer and the M23P portable later in this article.) As photo 9 shows, the M-343's color graphics are impressive. The M-343 is the Sord flagship and is powerful indeed. The pro-

The M-343's color graphics are impressive.

cessors include an 8086, and 8087, and a Z80A. The M-343's large, all-in-one unit can hold up to 1176K bytes of RAM. The video resolution is 640 by 400. There are four serial I/O ports, and the M-343 can serve as the hub of a network of Sord M23 Z80A-based computers. Standard floppy-disk storage is 1.2 megabytes. The keyboard has 20 programmable-function keys, cursor-control keys, a numeric keypad, editing keys, and another 12 keys that I believe are dedicated to communications and system operations. Finally, the M-343

is the only major Japanese 16-bit microcomputer that has three vacant S-100 bus slots.

Sord offers five different operating systems: the Realtime Disk Operating System, the Realtime Multi-job Disk Operating System, MS-DOS, CP/M-86, and the UCSD p-system. Sord has developed an applications system (PIPS) that integrates database, spreadsheet, and graphics functions. Sord achieved this software integration sooner than its American competitors.

Anritsu Packet II Hy Personal Computer: What happened to the 68000 processor chip? The only new 68000-based personal computer that I saw in Japan is the Anritsu Packet II. This powerful machine is an all-in-one computer with two $5\frac{1}{4}$ -inch floppy disks (150K bytes each) horizontally mounted to the right of the video monitor. The keyboard has cursor keys, editing keys, 10 programmable keys, 12 keys dedicated to BASIC commands, and a numeric keypad. A printer is built in and sends 40-column paper scrolling out above the monitor. Standard equipment includes 256K bytes of RAM. You can add memory in 128K and 256K increments. You can also add various kinds of ports and an analog-to-digital (A/D) converter. One of the best features of the Packet II is the way it accommodates added features. The back has six horizontal metal plates that come off and allow you to slide a board in just as you slide a drawer into a chest. Each board has a metal plate on its back that closes the opening in the back of the machine. Each I/O board has appropriate sockets in its back. Anritsu intends the Packet II for technical users, and the software supports engineering graphics.

AI Electronics AI-M16: Another hefty and powerful Japanese microcomputer is the AI-M16 from AI Electronics. Based on the 8086, the M16 also has an 8089 I/O processor and an optional 8087 math coprocessor. The keyboard is detached, but everything else comes in one big package with disk drives mounted vertically to the right of the monitor. Standard equipment includes a calendar clock.

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Sage	3,200
Sanya 1000 w/software	1,540
Seattle Gazelle	4,920
Televideo TS-802	2,600
Televideo TS-802H	4,450
Televideo TS-806	5,200
Televideo TS-1602G	3,479
Televideo TS-1602GH	5,409
Vector 4	CALL
Victor	CALL
Zenith ZF-100-21	2,525
Zenith ZF-110-22	3,099
Zenith ZF-120-22	3,176

PRINTERS

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C. Itoh, F-10, daisy	1,300
Daisywriter 2000 48K	1,150
Diablo 620, daisy 25 cps	990
Diablo 630, daisy	2,050
IDS Prism 132 all opts.	1,430
NEC 3510	CALL
NEC 7710 R/O	2,325
NEC/Sellum 1, 16K, trc.	2,595
Okidata 92L	510
Qume 9/45 full panel	1,799
Qume 9/55 full panel	2,180
Qume 11/35	1,280
Smith Corona TP-1, daisy	545
Tally 160L w/tractor	790
Texas Instr. TI 810	1,240
Texas Instr. TI 810LQ	1,944

OTHER PERIPHERALS

Amdek Color II monitor	694
Amdek Color Ila (III)	768
Ventel 212 + modem	765
Corvus 10 meg. H.D.	2,995
Houston Instr. DMP-29	1,779
Houston Instr. DMP-40	775
Houston Instr. DMP-41	2,209
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Qume QVT102 terminal	537

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Apple Basic Compiler	256	Spellguard (ISA) 8"	112
IBM Wordstar	240	Supercalc - 8"	237
Hayes Micromoden 100	279	Supercalc - Apple	177

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Standard RAM is 256K bytes expandable to 1 megabyte. The public bus is an IEEE-796 bus. There are two serial ports and provision for a lightpen. A 16K-byte boot ROM and an 8K-byte character-generator ROM are standard, and a 128K-byte kanji (Japanese-character) ROM is optional. Mass storage can be on 8-inch floppy disks or 5¼-inch Winchester hard disks.

The M16 comes with a wide choice of operating systems: Genix, CP/M-86, Concurrent CP/M-86, MP/M-86, MS-DOS, or the UCSD p-System. Languages mentioned include LISP, PL/I, and C.

Seiko 9500 and 8600: The 16-bit Seiko microcomputer shown in Tokyo was the 9500 Super Personal Computer. All the components come in one large package with disk drives mounted horizontally beside the monitor. What makes the 9500 super? It has an 8086 processor, an 8087 math coprocessor, and two 8088s: one to manage I/O and the other to control communications. Standard RAM is 256K bytes, maximum is 512K. The operating system is RMX/86 (from Intel?). The color video is dazzling, with 512 by 480 resolution. But the large package would be awkward in most settings.

While I was in Japan, Seiko introduced the 8600, based on the 8086 microprocessor, intended for the American market, and decidedly smaller and better looking than the 9500.

Slick Consumer Computers

Sharp X1: One eight-bit computer made a big impression at the Electronics Show, the Sharp X1. The X1 has two primary components, the CZ-800D and the CZ-800C. Shown in photo 10, the X1 is a Z80A-based machine but certainly not another Z80A desktop system. Sharp offers the CZ-800D 14-inch color television monitor for 113,000 yen, or about \$425. The CZ-800D has one button that other color televisions don't; it turns the television into a color monitor. For another 155,000 yen (about \$585) you can have the CZ-800C, consisting of an integrated computer and keyboard unit. The computer is

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Photo 10: Sharp X1. The symbol of the Tokyo Data Show is superimposed on the television broadcast.



Photo 11: Aval AVC-777J2.

based on a Z80A and has 64K bytes of RAM, 4K bytes of video RAM, and 6K bytes of character RAM. The 80C48 and 80C49 processors supplement the Z80A. You can add another 48K bytes of video RAM as an option.

The computer unit includes a built-in cassette-tape recorder for data

storage. Also standard in the computer unit are a Centronics-type printer interface, an interface for two joysticks, a clock with battery backup, and sound-synthesis output capacity ranging over eight octaves. When the system is being used as a computer, it can display 25 lines of 80 characters on the monitor. Four addi-

tional I/O ports are optional, as is a unit containing two very thin, 5¼-inch floppy disks.

An optional digital Telopper (the CZ-8DT) lets you connect the computer to a video camera, video-tape recorder, or videodisc. The keyboard has five separate blocks: character keys, number keys, function keys, television-monitor-control keys, and tape-operation keys. A color BASIC interpreter is standard equipment and includes a function that assigns a priority to each character and color in order to achieve the appearance of perspective. You can enlarge, reduce, or move graphics displays under program control. You can change each color variable instantly. You can paint and hatch graphic "phrases" (areas that can be manipulated as units) in eight basic colors and neutral colors to achieve the effect of "tile-painting." You can mix five different character styles in the same display. The calendar clock works with a programmable timer and can turn on the television for a broadcast while you are away.

The Sharp X1 lets you superimpose your computer graphics on video images. You can, in other words, display television signals and computer graphics simultaneously. An RGB (red-green-blue) mix circuit makes the superimpositions possible. Sharp has named the concept *visual integration* and calls the X1 the world's first personal computer/television monitor system. Suggested applications include video editing, art, and games. The most obvious use would be putting titles on home videotapes.

Sony SMC-70: The SMC-70 is another Z80A-based microcomputer and seems destined for integration in a video system too. Sony revealed at the electronics show that the SMC-70's add-on 8086 unit will run MS-DOS. Sony has sold the SMC-70 in the United States only as a business system and has not sold the system in Japan at all. The system differs from the Sharp X1 in several important respects: the SMC-70 has two 3½-inch disk drives as standard equipment, can be upgraded by adding an 8086 microprocessor, has a numeric keypad only as an optional

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separate unit (strange for an office computer), and costs much more than the X1. Even though the SMC-70 can control videodiscs, Sony's true consumer computer has yet to appear.

Japanese Portables

I expected to find a lot of new Japanese portable computers at the Tokyo shows but found only four portables of interest, two of them from Aval, one from Sord, and one from Epson.

Aval AVC-777J2: This portable all-in-one computer (see photo 11) running CP/M 2.2 might be thought of as Japan's answer to the Otrona Attache. A Z80A system with 64K bytes of user RAM and 16K bytes of video RAM, The AVC-777J2 has a 5-inch monochrome video monitor, two double-sided thin-line 5¼-inch drives storing 600K bytes each, a built-in 5-inch thermal printer, one parallel port, two RS-232C serial ports, a connector for an 8-inch floppy-disk system, a connector for the system bus, and video output for a larger monitor. The keyboard is detachable and fits into the carrying case along with everything else. The price in Japan is 880,000 yen, or about \$3320. The weight is 12.5 kilograms, or about 27.5 pounds.

Aval AVC-666: This is billed as a CP/M 2.2 development system, but I find it even more appealing as a portable. It doesn't have a printer or a monitor and has the two 5¼-inch drives mounted horizontally. In many other respects, the AVC-666 is just like the 777J2. The AVC-666 is only as wide as the two 5¼-inch floppy disks, brings a video signal out for connection to a monitor, and weighs much less than the 777J2. It costs the equivalent of about \$2500, with an optional 12-inch monochrome monitor costing another \$152. With one monitor at home and the other in the office, the AVC-666 would serve as an adequate portable by today's standards.

Sord M23P: I consider the Sord M23P (see photo 12) a true portable and a good value. The M23P has a Z80A processor, 128K bytes of RAM, and an 8-line by 80-character liquid-crystal display (LCD). That is enough

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phic Systems	High Resolution	80 character	HX-12	RGB

80 character display

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Photo 12: Sord M23P.



Photo 13: National JR-200 Personal Computer.

of a display to permit work on the road; you can edit text without too much strain on human memory. At home, of course, you'll want the optional 12-inch green monitor or 14-inch color monitor (both 25 lines by 80 characters). The integral keyboard has a numeric pad, four cursor keys, seven programmable-function keys, plus the standard keyboard. Two double-sided Sony microfloppies (running at 600 revolution per minute) provide a total of 580K bytes of high-speed mass storage. With the LCD, the carrying case, and the rechargeable battery pack (the yellow box in photo 12), the M23P weighs 9 kilograms or 19.8 pounds. The M23P runs Sord's PIPS integrated spreadsheet-database-graphics software package and will cost about \$2200 in the United States. The combination of size, price, and performance should make the M23P a real competitor among the portables.

Epson HC-20: This true portable is sold in the United States as the HX-20. It has a tiny display, micro-cassette mass storage, and limited computing power compared to the M23P. The HX-20 costs only about \$800. It is the ideal size for portability (the whole computer is no bigger than full keyboard size) but does have performance limitations. It will be interesting to see how the long-term competition based on size, price, and performance treats the HX-20 and the M23P.

New Home Computers

National JR-200 Personal Computer: The computer shown in photo 13 is one of the three low-cost home computers now produced by Matsushita; the others are the National JR-100 and the Tomy 16-bit Graphics Computer. The JR-200 has a 6802 processor, 16K bytes of ROM, and 32K bytes of RAM. The rubber keyboard has a wonderful touch, a diamond configuration for the cursor keys, plus a full standard keyboard



Photo 14: Sord M5

with shift, insert, and delete keys. It can be used with a variety of monitors, including a television set or an RGB monitor. The JR-2000, which has a list price of about \$300 in Japan, can use tape recorders or disk drives for mass storage, drive a speaker, and handle input from joysticks.

JR-100: The JR-100 has a 6802 pro-

cessor, 8K bytes of ROM, 16K bytes of RAM, a more limited keyboard, and a list price of about \$210. (The Tomy machine was not exhibited at the Electronics Show, but later I saw it for sale in the Akihabara district in Tokyo. The Tomy processor is a TMS9995.)

Sord M5: This computer (photo 14) has a Z80A processor, an 8K-byte ROM containing a monitor, 4K bytes of system RAM, and 16K bytes of graphics RAM. You can get software for the M5 in audio cassettes or ROM cartridges. Cartridges include BASIC, household accounting, bank-loan management, and simple word processing. Most of the ROM packs are 16K bytes. The keyboard is typewriterlike, two joysticks are optional, an audio cassette provides mass storage, and both an AC power unit and a DC power pack are available. The M5 features RF (radio-frequency) output so that you can use a television as a display. Most interesting of all is an animation program that lets you use 32 types of special figures called sprites. The basic M5 costs about \$187 in Japan.

Sanyo PHC-25: The Sanyo PHC-25 is an advanced home computer with a list price of about \$264. The complete computer is slightly larger than a standard keyboard but has four cursor-control keys and four programmable-function keys. A 24K-byte BASIC is in ROM, and there are 22K bytes of RAM. As you

would expect, the PHC-25 uses a television as a video monitor and a cassette recorder for mass storage. The Sanyo PHC-20 is less expensive and less powerful than the PHC-25.

New Hand-Held Computers

Sanyo PHC-8000: This hand-held computer has an NSC-800 CMOS microprocessor, 24K bytes of ROM, and 4K bytes of RAM. To the right of the one-line LCD are five programmable-function keys and the break key. Four cursor-control keys and a home key are in a diamond configuration—a first, I think, for hand-held computers. The QWERTY keyboard is too small for touch-typing, as the description “hand-held” implies. The list price is 69,800 yen or about \$263. An optional I/O unit, the PHC-8010, costs almost twice that amount and permits connection to a video monitor and a microcassette recorder as well as adding 14K bytes of ROM and 22K bytes of RAM. A tiny printer is available, as is an acoustic coupler. Computer, I/O unit, microcassette recorder, acoustic coupler, and

printer all fit in a custom attaché case.

Toshiba Pasopia Mini: The computer in photo 15 has an 8-bit CMOS microprocessor, 4K bytes of RAM, and 20K bytes of ROM, which contain a 16K-byte BASIC. The one-line LCD is above the keyboard. Four cursor-control keys are above the numeric keypad. The base price is about \$210. Another 12K bytes of RAM costs \$113. An I/O expansion unit permits connection of a printer and a cassette recorder and costs another \$170.

NEC PC-2001 Hand-Held Computer: This is the hand-held computer that I liked best. It has an 8-bit CMOS uPD7907 microprocessor running at 4 MHz, 36K bytes of ROM, and 16K bytes of RAM. It also has an RS-232C serial port (up to 2400 bits per second) at the left end, a 2-line by 40-character LCD, four cursor-control keys, two editing keys, five programmable-function keys, a numeric pad, and a typewriterlike keyboard that is, of course, too small for touch-typing. The list price is 59,000 yen, or about \$225.

Company Lines

The trend among electronics companies in Japan is to produce complete lines of microcomputers, everything from hand-held to very powerful desktop systems. Consider NEC, for example. It makes the PC-2001 hand-held computer, the PC-6000 home computer, the PC-8000 Z80-based personal computer, the PC-8800 (an improved Z80-based personal computer), the PC-9800 (an 8086-based personal computer), and the N5200 (or Advanced Personal Computer, another 8086-based personal computer). Toshiba makes the Pasopia Mini hand-held computer, the Pasopia Z80-based personal computer, the T200 8-bit desktop computer with two 5¼-inch floppy disks, the T250 8-bit desktop computer with two built-in 8-inch floppy disks, and the Pasopia 16, an 8088-based personal computer. Both NEC and Toshiba spokesmen said that they will produce keyboard-sized computers similar to the Epson HC-20 before the end of 1983. More powerful portables are likely to appear also.

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Photo 15: Toshiba Pasopia Mini.



Photo 16: These Radicom infrared transceivers are mounted on top of Hitachi BASIC Master 16000 computers. The tapes running from each transceiver to mirrors in the ceiling indicate the path taken by the infrared beams.

What American manufacturer is producing a comparable line of microcomputers? Only Hewlett-Packard. True, Hewlett-Packard makes no home computer like the PC-6000, but HP is making portables, a variety of 8-bit systems, at least two 16-bit systems—one based on the 8086, the other on the 68000—and the incredible new model 9000, which represents the state of the art in microcomputing (a 32-bit system with 128K-byte RAM chips and very fast operation). To some degree, Hewlett-Packard's emphasis on technical users may suggest that the company is not competing for as broad a market as NEC, but Hewlett-Packard cannot be accused of fearing to compete.

The Japanese seem determined to keep making new microcomputers until each segment of the world market says, "That's the computer I've been waiting for." Let's hope that more of the major American electronics manufacturers will broaden their product lines and compete more vigorously.

High-Resolution Displays and Printers

The Japan exhibitions demonstrated once again that the Japanese are pushing ahead in the development of relatively inexpensive high-resolution video monitors, inexpensive high-resolution dot-matrix printers, and color displays and printers. As has often been noted, the Japanese

katakana and kanji character sets force the Japanese to use high-resolution displays and very fine dot-matrix printers. The Japanese had to develop low-cost versions of such displays and printers if the microcomputer market was to expand in Japan as rapidly as elsewhere, and they have now done so. Many companies showed dot-matrix printers that produced characters that could be described fairly as "letter quality." Fujitsu and Matsushita both demonstrated impressive thermal color-transfer printers.

Disappointments

One disappointment—and probably the reason that so few portable computers were introduced—concerned the development of flat-screen displays. The plasma displays and LCD televisions were on view at the shows, but price, product life, or both have prevented their use in affordable portable computers. The Sony flat-screen cathode-ray tube (CRT) was not exhibited. The Victor company showed a very high resolution 5-inch CRT monitor.

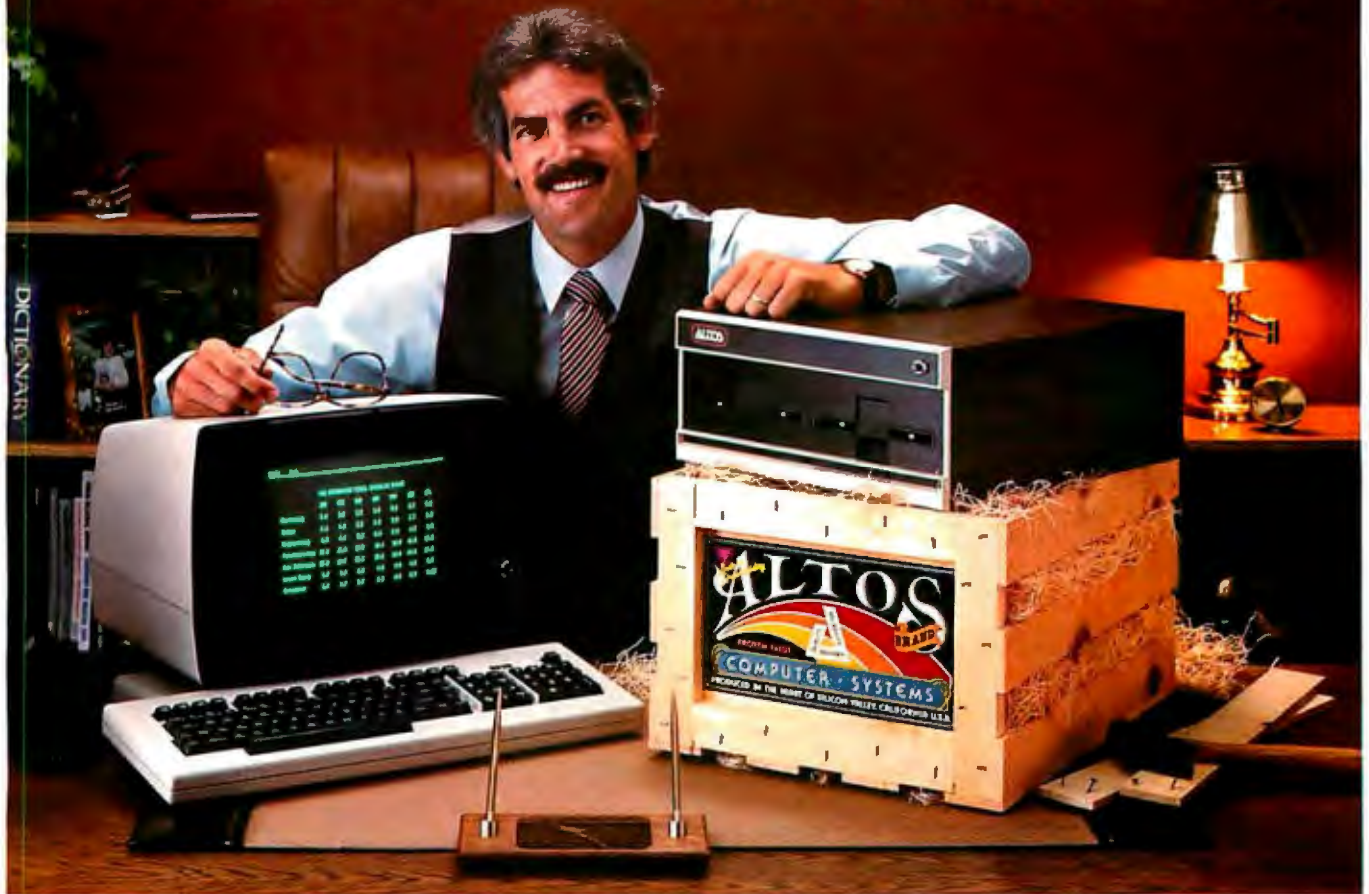
Nor was there an abundance of low-cost 5¼-inch Winchester disks. While Matsushita showed an optical storage system, the most interesting such exhibit was from Drexler, an American company (see "Optical-Memory Media" by Edward Rothchild, March 1983 BYTE, page 86).

Optical and Infrared Communications

NEC showed a fiber-optic-based microcomputer network called Netbranch 4800. NEC had four microcomputers connected by NEC optical branch modules at the Electronics Show. The network provides communication at 10 million bps and can extend over 3 kilometers. The Branch 4800 module connects the local network to a larger network.

Is the world ready for an infrared-based local network? Hitachi and a small company called Yagi showed an infrared-based network connecting two Hitachi BASIC Master 16000s. As you can see from photo 16, the usual cables are replaced by infrared transceivers—which look like

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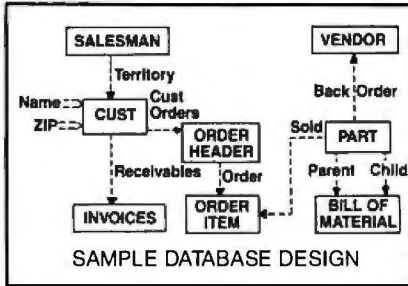
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lamps—located atop each BASIC Master 16000. The transceivers, called Radicom, communicate with one another via mirrors on the ceiling. That's right, it's all done with mirrors. As the network gets bigger, you need more mirrors, but you don't need any cables. Would cigarette smoke impair communications? If so, throw the smokers out. The Radicom network at the show was described as a prototype.

Yagi also showed a working infrared-based modem called the Beacom. As you might expect, it looks like a lamp. Described as a free-space optical communication system, Beacom can link two points that cannot be linked by cable, can relay television broadcasts, can perform high-speed data communications, and is said to be free from interference from sunlight and artificial light. Different models communicate at from 1 to 3 million bps and at ranges of from 300 to 1600 meters. Of course, you need interfaces between the computers and the light transmitter/receivers.

In the communications products just described, in the clever and attractive Sharp X1 microcomputer, and in printers and displays, the Japanese have brought something new to the world of microcomputing. More innovations would be welcome, including those innovations that substantially lower the price of equipment already available elsewhere. ■

Exploring the Asian World of Microcomputers

During my travels in Asia, I attended the Korea Electronics Show in Seoul, the Taiwan Electronics Show in Taipei, the Hong Kong Consumer Electronics Show in Kowloon, and China Comm 1982 in Beijing, People's Republic of China, as well as the Japanese shows described in the accompanying article.

A delightful surprise was the discovery of the Akihabara neighborhood in Tokyo, an electronics bazaar that surpasses anything I have ever seen or imagined. I'll discuss this wondrous neighborhood as well as encounters with microcomputers at the other shows in a second article in the May issue of BYTE. . . . P.L.L.



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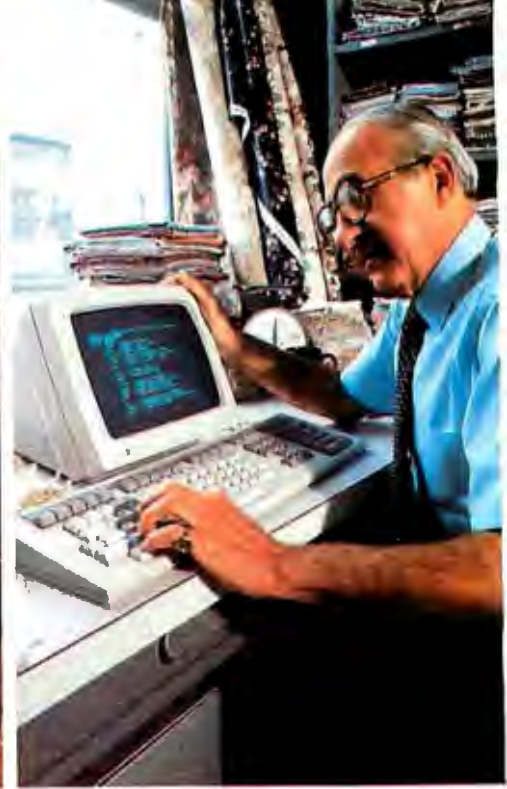
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Intel's 80186

A 16-Bit Computer on a Chip

The 80186 is the first integrated circuit that attacks the cost problem in 16-bit microcomputers.

Tony Zingale
Product Marketing Engineer
Intel Corporation
3065 Bowers Ave.
Santa Clara, CA 95051

Two factors are slowing the rush to 16-bit microcomputers. The 16-bit systems cost more than their 8-bit ancestors, and they have less software available to them than 8-bit systems. Fortunately, time is solving the problem of software availability for 16-bit machines, and very-large-scale integration (VLSI) will soon reduce the cost of 16-bit systems.

The 80186 or iAPX 186 (advanced processor) from Intel is the first integrated circuit that addresses the cost problem in 16-bit microcomputers. The phrase "computer on a chip" is often used to describe microprocessors, but they are really central processing units (CPUs) only. The 80186, on the other hand, incorporates in a single chip all the functions of a CPU board except memory.

The 80186 combines an enhanced 8-MHz 8086-2 CPU with a clock generator, two independent high-speed DMA (direct memory access) channels, and a programmable interrupt controller. It includes three program-

mable 16-bit timer/counters, programmable memory-select and peripheral-select logic, a programmable wait-state generator, and a local bus controller, all on one 68-pin chip (see figure 1). One 80186 chip will replace as many as 20 other chips, reducing the size, weight, power-supply requirements (a single 5-volt supply is all it needs), and the cost of the system while increasing performance (see table 1).

Up until now, the difference in the cost of integrated circuits for 8-bit and 16-bit systems has been significant. A little computation confirms that fact. Building an 8086-based computer system requires the CPU chip (\$19.15 in quantities of 10,000) and additional integrated circuits that cost \$52.35. Building an 8-bit 8085-based system requires a CPU chip that costs only \$2.65 and other chips costing \$27.10, for a total of

\$29.75. The integrated circuits for an 8086-based system, then, cost \$41.75 more than similar parts for an 8085-based system.

The 80186 chip narrows that price differential considerably. While the chip itself costs \$30.00, the additional integrated circuits to complete the system cost only \$5.90. Consequently the integrated circuits for the 80186 cost only \$6.15 more than those for the 8085 system (see table 2).

Equally important to the end user, the 80186 uses the same instruction set as the 8086 and 8088 and is compatible with the large and growing body of software and peripherals available for those systems. The 80186 adds 10 instructions that enable programmers to make more efficient use of the code, and Intel is revising its development software tools to include support for the new instructions.

About the Author

Tony Zingale, product marketing engineer for Intel's 80186 and 80188 microprocessors, has extensive experience in the use of microprocessor technology in a wide variety of applications.

	8085	8086	80186	80286
Performance in MIPS	.07	0.3	0.7	1.5
Cost/performance ratio in IPS/\$	700	1500	10,000	7500

Table 1: Performance comparisons of four microprocessors. MIPS means million instructions per second; IPS/\$ means instructions per second per dollar.

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• enumeration types (no I/O)	• records and selected components
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control structures	
• labels • goto • exit	
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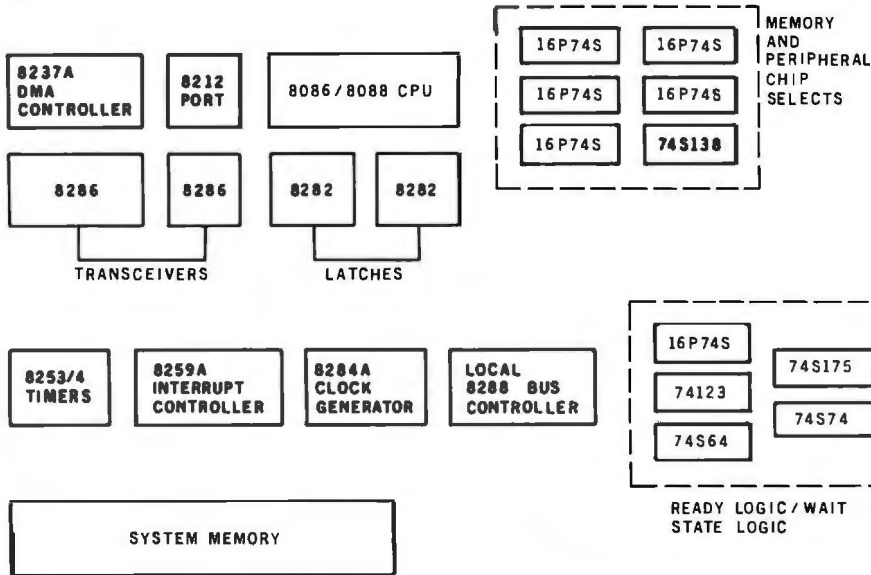
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(1a)



(1b)

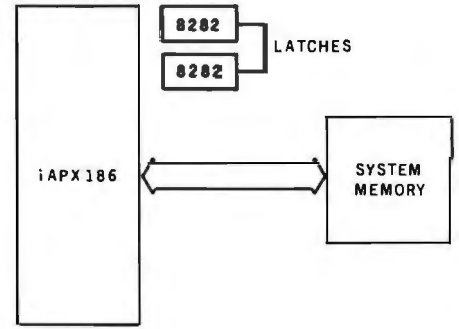


Figure 1: (1a) Chips necessary to make an 8086-based microcomputer system. (1b) Chips necessary to make an 80186-based microcomputer system.

The Intel 8086 family is growing. The 80186 expands on the basic workhorse 8086, and the 80286 (see the text box on page 144) adds multi-user capabilities. The 8088 has the same 16-bit internal architecture as the 8086, but it uses an external 8-bit bus. The same is true for the 80188 or iAPX 188 highly integrated 8-bit microprocessor. (Unless otherwise noted, all references to the 8086 and 80186 apply to the 8088 and 80188.) For detailed information about the architecture of the 8086, see *The 8086 Book* by Russell Rector and George Alexy (Osborne/McGraw Hill, 1980) and *The 8086 Primer* by Stephen P. Morse (Hayden, 1980).

System designers who are familiar with the 8086 will recognize the identical architectural scheme in the 80186. In some cases, hardware has been used to support functions formerly handled in microcode. Though the programmer's instructions are the same, the user will notice the enhanced performance of the 80186 (see table 3).

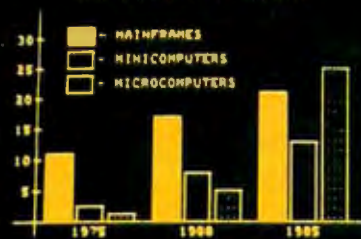
The instruction set, including the new instructions, is divided into those for data transfer, arithmetic operations, string manipulation, logicals/shifts/rotates, processor control, procedure entry and exit, and program-transfer operations. There are 101 instructions in the 80186 set (see table 4).

The registers within the 80186 are identical to those in the 8086, with the addition of the 16-bit relocation register, which locates the 256-byte peripheral control block in the 80186's 1-megabyte memory or 64K I/O (input/output) space. The control-block registers define the func-

10K Piece Kit	
80186	\$30.00
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8086 CPU (5 MHz)	\$19.15
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timers (8253)	3.40
2 latches (8282)	5.90
2 transceivers (8286)	5.90
chip-selects (6 memory/7 peripherals)	3.50
wait-state generator	3.50
local bus controller (8288)	7.95
clock generator (8284A)	3.15
total	\$71.50
8-bit CPU Board	
8085 CPU (3 MHz)	\$ 2.65
interrupt controller (8259A)	3.75
DMA controller (8237 + 8212 port)	8.80
timers (8253)	3.40
latch (8282)	2.95
transceiver (8286)	2.95
chip-selects (3 memory/3 peripherals)	1.75
wait-state generator	3.50
total	\$29.75
Note: An 8088-based 8-bit board price following a similar set of options comes to a total of \$58.65.	
Table 2: Price comparisons of chips necessary to make 8- and 16-bit systems based on Intel microprocessors.	

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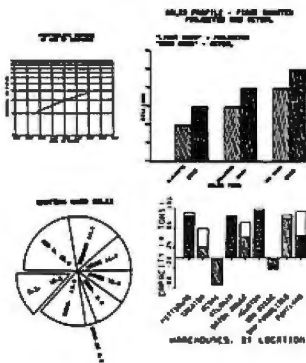
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Relative 80186 Execution Times
8086 time divided by 80186 time (8-MHz clock rate)

Instruction	8086 (5 MHz)	8086-2 (8 MHz)	8086-1 (10 MHz)
Move Contents of Register to Memory	2.0 to 2.9	1.2 to 1.8	1.0 to 1.4
Add Contents of Memory to Register	2.0 to 2.9	1.2 to 1.8	1.0 to 1.4
Multiply 16-bit Register	>5.4	>3.4	>2.7
Divide 16-bit Register	>6.1	>3.8	>3.0
Multiple (4-bits) Shift/Rotate Memory	3.1 to 3.7	1.95 to 2.3	1.6 to 1.8
Conditional Jump	1.9	1.2	1.0
Block Move (100 bytes)	3.4	2.1	1.7

Table 3: Comparison of execution speeds of 8086 microprocessors to those of the 80186.

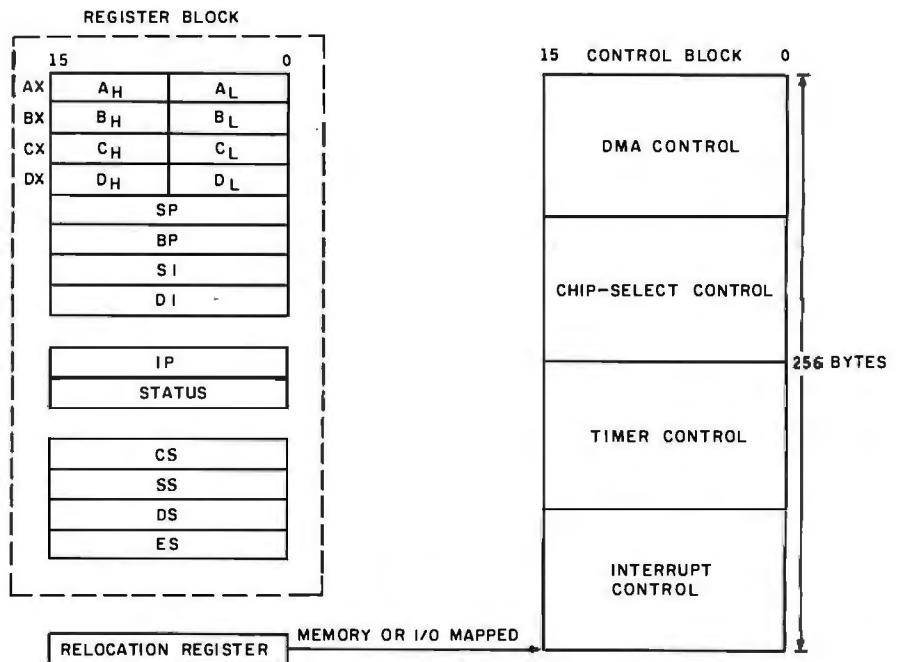


Figure 2: The 80186 register file. Each of the four segment registers—CS, SS, DS and ES—defines a 64K-byte area of memory. There are four general-purpose registers: AX, BX, CX, and DX. The pointer and index registers are stack pointer (SP), base pointer (BP), source index (SI), and destination index (DI). IP is the instruction pointer.

tions of the on-chip timers, DMA support, interrupt controllers, and chip-select logic (see figure 2).

Enhanced CPU

Several enhancements have been made to the 80186's CPU to reduce the number of instructions it needs to carry out a task and to increase the overall processing speed. The multiplier portion has been augmented with additional parallel hardware to

provide a fivefold to sixfold improvement in executing multiplication and division instructions over the standard 5-MHz 8086.

Using its own dedicated hardware adder, the bus-interface unit (BIU) calculates the effective addresses of operands and instructions in parallel with the execution unit (EU). Formerly, this task was done in microcode using the adder that resides in the arithmetic and logic unit (ALU).



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Data-Transfer Instructions	
GENERAL PURPOSE	
MOV	Move byte or word
PUSH	Push word onto stack
POP	Pop word off stack
PUSH(X)	Push user-specified value
PUSHA	Push all registers on stack
POPA	Pop all registers from stack
XCHG	Exchange byte or word
XLAT	Translate byte
INPUT/OUTPUT	
IN	Input byte or word
OUT	Output byte or word
ADDRESS OBJECT	
LEA	Load effective address
LDS	Load pointer using DS
LES	Load pointer using ES
FLAG TRANSFER	
LAHF	Load AH register from flags
SAHF	Store AH register in flags
PUSHF	Push flags onto stack
POPF	Pop flags off stack

String Instructions	
MOVS	Move byte or word string
INS	Input bytes or word string
OUTS	Output bytes or word string
CMPS	Compare byte or word string
SCAS	Scan byte or word string
LODS	Load byte or word string
STOS	Store byte or word string
REP	Repeat
REPE/PREZ	Repeat while equal/zero
REPNE/REPNZ	Repeat while not equal/not zero

Arithmetic Instructions	
ADDITION	
ADD	Add byte or word
ADC	Add byte or word with carry
INC	Increment byte or word by 1
AAA	ASCII adjust for addition
DAA	Decimal adjust for addition
SUBTRACTION	
SUB	Subtract byte or word
SBB	Subtract byte or word with borrow
DEC	Decrement byte or word by 1
NEG	Negate byte or word
CMP	Compare byte or word
AAS	ASCII adjust for subtraction
DAS	Decimal adjust for subtraction
MULTIPLICATION	
MUL	Multiply byte or word unsigned
IMUL	Integer multiply byte or word
AAM	ASCII adjust for multiply
DIVISION	
DIV	Divide byte or word unsigned
IDIV	Integer divide byte or word
AAD	ASCII adjust for division
CBW	Convert byte to word
CWD	Convert word to doubleword

Processor Control Instructions	
FLAG OPERATIONS	
STC	Set carry flag
CLC	Clear carry flag
CMC	Complement carry flag
STD	Set direction flag
CLD	Clear direction flag
STI	Set interrupt enable flag
CLI	Clear interrupt enable flag
EXTERNAL SYNCHRONIZATION	
HLT	Halt until interrupt or reset
WAIT	Wait for TEST pin active
ESC	Escape to extension processor
LOCK	Lock bus during next instruction
NO OPERATION	
NOP	No operation

Table 4: The 80186 instruction set. The 80186 instructions not found in the 8086 instruction set are highlighted. Table 4 continues on page 139.

Shift/Rotate/Logical Instructions	
LOGICALS	
NOT	
AND	
OR	'Inclusive or' byte or word
XOR	'Exclusive or' byte or word
TEST	'Test' byte or word
SHIFTS	
SHL/SAL	Shift logical/arithmetic left byte or word
SHR	Shift logical right byte or word
SAR	Shift arithmetic right byte or word
ROTATES	
ROL	Rotate left byte or word
ROR	Rotate right byte or word
RCL	Rotate through carry left byte or word
RCR	Rotate through carry right byte or word
High-Level Instructions	
ENTER	Format stack for procedure entry
LEAVE	Restore stack for procedure text
BOUND	Detect values outside prescribed range

Additional hardware offers the programmer streamlined string-manipulation operations. Previously, the Repeat Prefix to Move instruction on the 8086 caused a delay for each byte that was moved because a microcoded subroutine had to be executed to decrement the CX register and check the status flags for "end of move." The extra hardware on the 80186 eliminates this overhead by performing these operations in parallel. As a result, string-move operations occur at nearly bus bandwidth (2 megabytes per second).

Bit-manipulation instructions such as Shift and Rotate have also been enhanced by means of additional hardware. Now both operate at a rate of 1 bit per clock.

Superset of Instructions

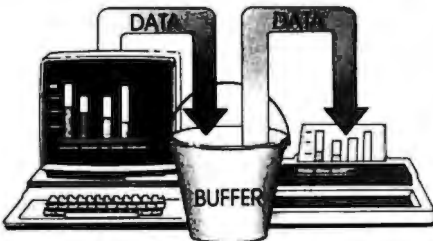
The 80186 adds additional instructions to those of the 8086. The Block I/O Move instruction is similar to the existing 8086 string instructions but allows the source or destination to be in the I/O space rather than in memory. If Block I/O Move is used with the repeat prefix, the number of words or bytes specified by the CX register is moved. The result is a very high transfer rate (4 megabytes per

Program-Transfer Instructions			
CONDITIONAL TRANSFERS		UNCONDITIONAL TRANSFERS	
JAJNBE	Jump if above not below nor equal	CALL	Call procedure
JAJNB	Jump if above or equal not below	RET	Return from procedure
JB/JNAE	Jump if below not above nor equal	JMP	Jump
JBE/JNA	Jump if below or equal not above		
JC	Jump if carry	ITERATION CONTROLS	
JE/JZ	Jump if equal/zero		
JG/JNLE	Jump if greater/not less nor equal	LOOP	Loop
JGE/JNL	Jump if greater or equal/not less	LOOPE/LOOPZ	Loop if equal/zero
		LOOPNE/LOOPNZ	Loop if not equal/not zero
JLE/JNG	Jump if less or equal/not greater	JCXZ	Jump if register CX = 0
JNC	Jump if not carry	INTERRUPTS	
JNE/JNZ	Jump if not equal/not zero		
JNO	Jump if not overflow		
JNP/JPO	Jump if not parity/parity odd	INT	Interrupt
JNS	Jump if not sign	INTO	Interrupt if overflow
JO	Jump if overflow	IRET	Interrupt return
JP/JPE	Jump if parity/parity even		
JS	Jump if sign		



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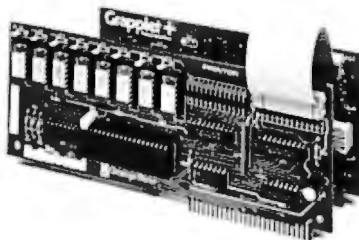
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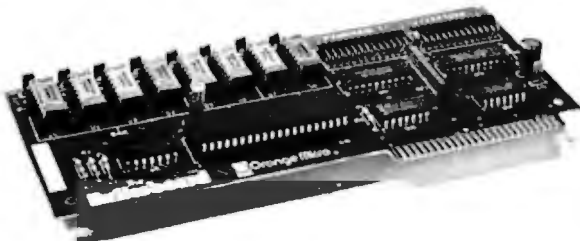
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- Automatic memory configuration
- Automatic self test
- Includes interface docking cable.

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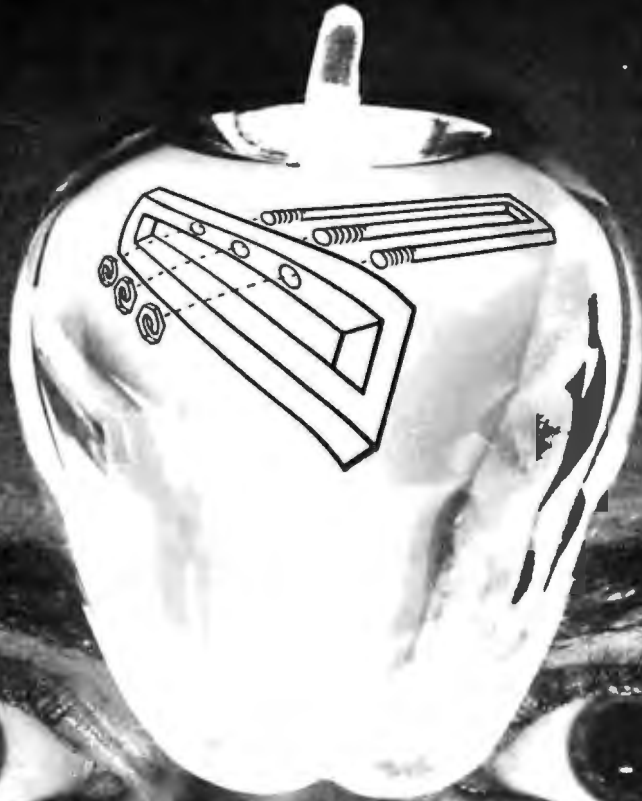


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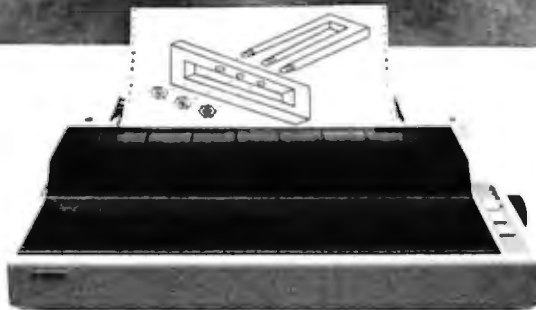
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second) because no op codes are fetched during the operation.

To support block-structured, high-level-language programs, Enter Procedure and Leave Procedure instructions are included. The Enter instruction performs the calling sequence for a high-level language, flushes the register set, and sets up the segment pointer registers as well as performs the other necessary "housekeeping" tasks. The Leave instruction, on the other hand, restores the 80186 to its state prior to entering the procedure. Normally, such operations would be done using assembly-language subroutines. In that case, the operations are performed with microcode for increased throughput.

Instead of using an internal register to temporarily store constants during a routine, the new Push Immediate instruction lets the user put a signed 8- or 16-bit value directly on top of the stack.

Numeric calculations are faster with "immediate" instructions, too. The two Multiply Fast instructions

(one for signed 16-bit, the other for extended 8-bit values) work with immediate values. These instructions take one operand from the immediate field of the instruction itself and the other from either a memory or a register. In both cases, the values are "latched" by the new streamlined multiplier array for fast processing. These new instructions are very handy and were specifically designed for array index calculations in high-level languages.

Array handling is further enhanced by a Bound instruction that checks to see that the bounds of an array index value have not been exceeded. The index to be checked is kept in a register, and the upper and lower bounds are stored in a two-word block that is pointed to by the instruction's effective operand address. If the index is out of bounds, a "trap" is generated that vectors instruction execution to a known memory location.

Immediate Shift and Rotate instructions speed bit manipulations. In addition to the 3-bit field for deter-

mining left or right movement, an additional byte specifies the number of bits to be shifted or rotated; this eliminates the need to use a loop to perform that same function.

Finally, the contents of the AX, BX, CX, SP, BP, SI, and DI registers can be pushed onto the stack with a single Push All instruction. Similarly, they can be popped off with the Pop All instruction. Again, this instruction eliminates the use of slow assembly-language subroutines when you're servicing interrupts and subroutine calls. Another enhancement in the 80186 is its ability to generate an error interrupt when the 80186 attempts to execute an illegal instruction op code.


Interrupt Controller

The on-chip interrupt controller can handle eight prioritized, vectored interrupt sources. Internal interrupt sources are the counter/timer unit and the two DMA channels, which can be selectively disabled via bits in

Text continued on page 148

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The 80286

Today's microcomputer systems are capable of serving many users and simultaneously running a variety of programs. These multiuser, multitasking systems require high-performance processing, a large memory space, efficient addressing, and an effective means to protect system software from inadvertent user mishandling. In addition, each user's programs and data must be protected so that another user's program cannot "write" over them. Isolating both system software and user software requires effective hardware-supported protection.

Multiuser and multitasking systems are not new concepts; minicomputers have offered both of these features for years. But the demand for such microcomputer systems is a relatively recent development. To date, no microprocessor exists that has built-in memory management and protection or the ability to efficiently address a gigabyte (2³⁰) of virtual memory. In that regard alone, the 80286 or iAPX 286 sets a precedent. The capabilities of the 80286 along with its high performance make for a rare combination indeed.

Moreover, the 80286 lets users take advantage of a large base of existing software. Underlying several new instructions aimed at streamlining high-level-language coding and operating system execution (see table 1) is the familiar instruction set of Intel's popular iAPX 86/88 (8086/8088) family. The 80286 is compatible with the software that exists for these other processors. As a result, users can now achieve an immediate increase in a system's performance simply by making design changes in the new 80286 hardware and using the existing software or the growing base of third-party software written for the 8086. Later, programs may be moved to run in a memory management and protection environment. Further system enhancements or completely new products can be produced with no hardware changes.

Many logic elements, and therefore many active devices such as transistors, are required to handle all the functions that the 80286 includes. The 8086 microprocessor contains approximately 29,000 transistors; the 80286, in comparison, contains 130,000.

Organized in Four Pipelined, Functional Units

In most microprocessors, a complete sequence of instruction fetching, decoding, and execution must take place before the next instruction can be fetched. In the 80286, these operations are carried out in parallel, resulting in an overall increase in performance without the use of faster memory chips, which would be needed if performance were enhanced simply by speeding up the clock rate.

Pipelined architecture permits the CPU to detect invalid op codes well in advance of their execution, another advantage. The 80286, for example, has time to perform the memory-protection functions without degrading the processing performance or restricting memory access.

Pipelining in the 80286 is separated into four logical units: bus, address, instruction, and execution.

The bus unit provides a demultiplexed bus interface between the processor, system memory, and external I/O subsystems. It monitors bus-cycle requests from other processors or the chip's own address unit, and when there is a pause, the bus unit's "prefetcher" grabs the next instruction and places it in a "code queue." Here, instructions are available for immediate access by the chip's instruction unit.

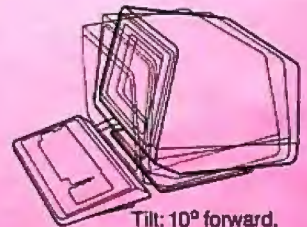
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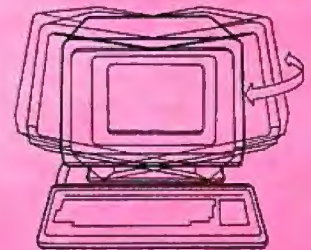
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Text box continued:

The instruction unit receives data at a rate of 1 byte per clock cycle, decodes and formats complete instructions, and places them in its "instruction queue" to await action by the execution unit.

The execution unit contains the CPU registers, the arithmetic and logic unit (ALU), and the microcode firmware for the CPU in read-only memory (ROM). Instructions are executed under the control of the ROM's internal micro-instruction sequence. When it nears completion of the sequence, the ROM signals the execution unit to take the next instruction out of the instruction queue. This treadmill-like process keeps the execution unit operating very efficiently.

Finally, the address unit performs the memory-management and protection function by translating virtual addresses to physical addresses and checking protection rights, all simultaneously. This unit maintains its own explicit cache containing all address mapping and protection information (base address, boundary limit, and the access rights) for the virtual-memory segments currently selected by the executing task. By storing this information in its own on-chip cache, the address unit does not need to retrieve it from memory-based address-translation tables. Therefore it can perform all functions in a single clock cycle.

By operating in parallel, these units enable the 80286 to manage virtual memory and protect the memory without degrading system throughput.

Memory and User Protection Via Tight Access Control

The 80286's memory-management and protection mechanism is an integral part of the architecture. It is physically integrated on the same silicon die as the rest of the CPU, so the protection of system and user code and data does not require extensive system software or add-on memory-management units (MMU). Such an approach has many advantages. It is more reliable, easier to implement, and faster. It also reduces software overhead.

The 80286 protects users from one another and the system software from its users. Each user has up to one gigabyte of virtual address space that may be split between shared and private use. Common data, files, and library routines are typically stored in shared space. Each user's private space is accessible only to him.

Each user's large virtual address space contains his "view" of the operating system. Because all users share the operating system, it is usually stored in the shared address space. Putting the operating system within the direct-address space of each user means that access to operating system routines is simpler and faster. Within each user's virtual-memory space are up to four hierarchical protection levels, so that even within his own space a user's application-program tasks can be guarded from improper access to the operating system.

The 80286's hardware supports this four-level protection hierarchy. Should a task attempt to access an address without right of access, the CPU will prevent it and then signal that a fault has occurred. In addition to providing more protection than usual, this architecture is more flexible and efficient than the typical two-level schemes minicomputers and other microprocessors use. It offers the user more flexibility, configurability, and reliability for the system software. These features are especially important for reprogrammable business and office systems applications, which will typically have many concurrent users.

Software Compatibility

Like the 80186, the 80286's instruction set is a superset of the 8086/8088 set, and its software is compatible with them. This provides a real upgrade path from the 8086 and 8088 to the 80286, and users can take advantage of the wealth of existing 8086/8088 software to get a jump on the development process. Current 8086 users will be able to enhance system performance immediately simply by changing the CPU subsystem hardware for the 80286. They can also modify their software to take advantage of the 80286's new instructions for further performance enhancements.

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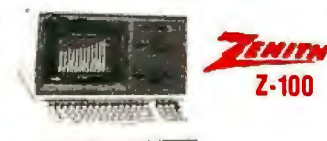
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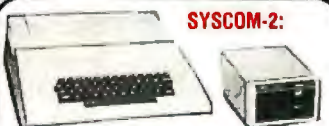
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the interrupt control register. The controller resolves simultaneous requests based on predefined priorities. The higher-priority interrupt will cause servicing to cease on a lower one. Interrupt control can be expanded externally by cascading 8259A programmable interrupt control chips or 80130s to the 80186 via dual-function interrupt pins provided for that configuration. Five external interrupt input pins—four plus non-maskable interrupt (NMI) input—can be programmed to respond to either levels or edges.

Chip-Select and Ready Functions

All CPU subsystems must interface with an array of memory and peripheral chips. In other typical microcomputer systems, external random logic or VLSI components must be used to translate microprocessor output states into appropriate memory or peripheral chip-select signals. Because the 80186 has built-in chip-select generation circuitry, in many cases no additional external logic is needed to interface with memory I/O subsystems.

Users can program in a selection of wait states (0 to 3 states) to accommodate memory or peripheral chips with a variety of access-time characteristics. Where the 80186's internal wait-state selections are not sufficiently long, external wait-state generators can be ORed to the internal "read" circuitry.

Memory can be divided into three separate sections—upper, middle, and lower. The upper- and lower-memory sections are selected by a single select line. The middle-memory section is selected by four select lines, so it can be further divided into four equally sized subsections. Memory-block sizes may be programmed for 2K, 4K, 8K, 16K, 64K, or 128K bytes. The upper and lower sections can be programmed for those sizes as well as for 1K and 256K bytes. Thus if sixteen 64K by 1-bit chips are used in the upper segment, that select line would be programmed for 128K bytes.

Peripherals are selected by as many as 7 signal lines. Each line is active for

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a 128-byte memory segment (the peripheral block). As many as 7 of these segments can be grouped contiguously, and the entire 996-byte set of blocks may be located on any 1K-byte boundary. Two control registers, the base address register (PACS) and the mode register (MPCS), govern the function of the peripheral select lines.

Users can select 5 or 7 lines. The 5-line mode is convenient for 8-bit peripherals because the remaining 2 lines can be used as latches for the A₁ and A₂ address lines. That way, the 80186 can treat the address lines as if they were 16-bit peripherals located on even-address boundaries. Then no external logic or compensatory software routines are necessary.

Direct Memory Access Support

When blocks of data are to be moved from one memory location to another, or from memory to an I/O device, or even from one I/O device to another, it is inefficient for the CPU to handle this data 1 byte or word at a time. DMA makes these kinds of transfers much more efficient by limiting the CPU's involvement. The 80186 supports two such DMA channels, each capable of transferring data at a rate of 2 megabytes per second.

Each DMA channel maintains two 20-bit source and destination hardware pointers that can be incremented or decremented after each data transfer. Each transfer typically consumes only two bus cycles, one to fetch the data and the other to store it in its new location.

Each channel is associated with a control register that specifies word or byte transfers and states whether an interrupt must be generated upon completion. The control register also specifies automatic incrementing (or decrementing) of source or destination registers, the channel priority, and the starting and stopping of the transfer itself.

Programmable Counter/Timers

Many microcomputer applications depend on timing or counting external events, generating nonrepetitive waveforms, and combinations of



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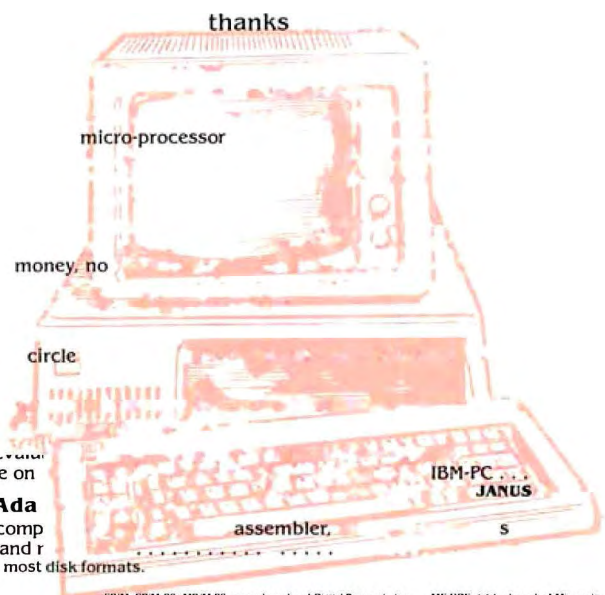
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counting and timing. To meet these needs, CPU subsystems commonly have one or more timer/counters implemented with external circuitry. The 80186's three timer/counters eliminate the need for the external circuits.

Two of the 80186's 16-bit timer/counters are designed to interface to external circuits, and the third is for internal operations. All three have several programmable options that are selected by a set of three 16-bit control registers. In addition, each timer has its own maximum-count register (timers 0 and 1 have two).

Each timer/counter can be programmed to halt or continue when it reaches the specified maximum count. Users can program the counter to issue an interrupt upon reaching maximum count and then either continue or reset and then continue. The various functions are programmed via the mode-control register.

On-Chip System Clock

An on-chip system clock is implemented by a crystal oscillator and divide-by-two logic. By connecting a 16-MHz crystal to the external pins, an 8-MHz system clock signal is pro-

duced. This signal is used internally to control the synchronous execution of instructions and operations. One of the 80186 pins provides an external clock signal and can be used to synchronize external circuits to the internal clock.

Interface with Support Chips

The 80186 interfaces with Intel's full line of peripheral control components. Like the 8086, the 80186 communicates with and controls those components via the system bus. The 80186 emits the same local bus handshake signals as the 8086.

Memory control, data communication, and display control components as well as VLSI controllers are available for the graphics display, disk drive, and keyboard interface. Controllers for the serial and parallel, asynchronous and synchronous data-communications protocols are also available.


Systems integrators can choose from several operating systems, among them iRMX-86, CP/M-86, and MS-DOS. Compatible operating system software for the above is available from Intel for the 8086, 8088, and 80186.

Many applications programs have been written for 8086- and 8088-based systems. The list is growing significantly as a result of IBM's introduction of the 8088-based Personal Computer.

For users who already have developed software for their 8086- or 8088-based machines, the 80186 offers an additional advantage: programs written for the 8086 and 8088 will run on the 80186 without modification. The 10 new instructions can replace longer subroutines, making programs more compact.

Conclusion


The 80186 replaces as many as 20 chips in an 8/16-bit microcomputer at about half the cost of the 8086/8088 kit of parts. It also has twice the capability of the standard 8086/8088 running at the standard 5-MHz clock rate. The 80186 will pave the way for the next generation of microcomputers to be both less expensive and more powerful. ■





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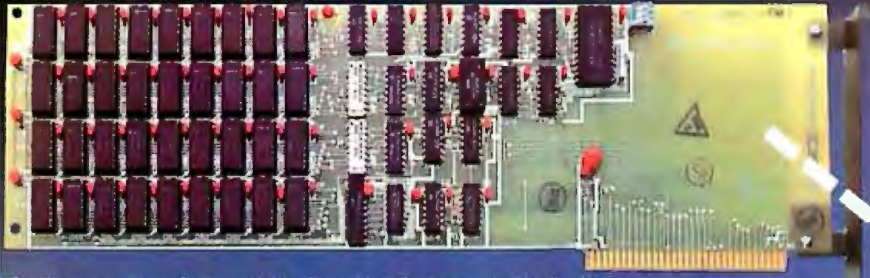
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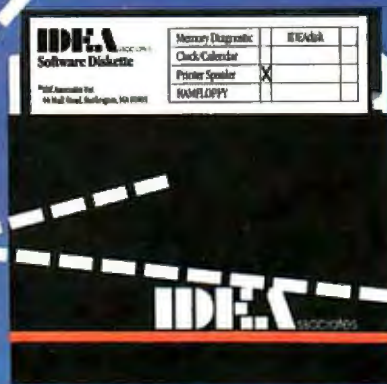
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Registers

The 8087, due to its special status as a coprocessor, combines with the

About the Author

Bob Simington is a curriculum developer for Intel's customer training department. He is responsible for the development of all microprocessor training curricula. His most recent assignment was to develop a course based on 16-bit personal computers.

architecture of the host processor to produce a processor that contains all the capabilities of an 8086 or 8088 plus a register stack of eight 80-bit registers, as shown in figure 1. The NDP also brings the ability to execute a set of 68 new floating-point-arithmetic instructions in addition to the extensive instruction set of the host alone. These 80-bit registers hold all the operands for the floating-point operations in a format called Tem-

porary Real, which is capable of representing any whole number up to 2^{64} exactly. This 80-bit format is accurate enough to guarantee 18-decimal-digit accuracy.

You can think of the eight registers of the 8087 as a standard register set or use them as a classical stack. This arrangement allows you a great amount of flexibility in using these storage areas. You can use the registers as a stack, for example, to

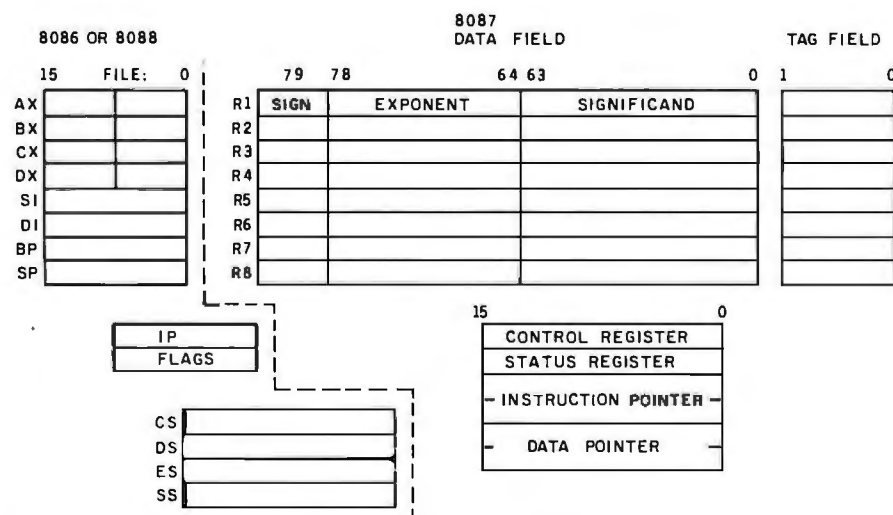


Figure 1: The NDP register set of eight 80-bit registers.

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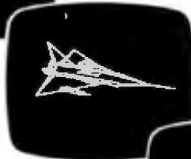
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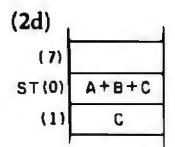
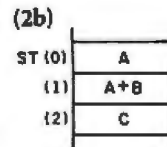
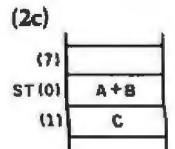
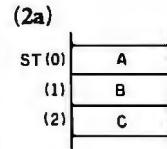


Figure 2: The effects of instructions on the register stack.

pass operands to a floating-point subroutine that expects to find its parameters in the 8087 register stack. The instruction set of the 8087 exploits this capability by allowing assembly-language instructions that use the stack top as one of the operands implicitly.

You can also treat these registers as a standard register set; the instruction set supports this use of the registers by allowing both operands to be specified explicitly for an operation. Look at the example in figure 2.

Your NPX stack contains the values A, B, and C, as shown in figure 2a. You can cause the value in the stack top to be added to the value in the next stack element (ST(1)), as shown in figure 2b, and then have the stack popped, so that the sum is the new stack top, as shown in figure 2c, with the one instruction FADD. This is the classical stack operation where none of the operands are specified. The same instruction could have been specified explicitly with the instruction FADDP ST(1),ST.

As another example, you could add the value that is in ST(1) to the value in the stack top and retain both values, as shown in figure 2d, with the instruction FADD ST,ST(1). All registers are addressed with respect to the current stack top. The Status Word of the 8087 contains a field that identifies the current stack-top status at all times.

Status Word

The Status Word, as its name implies, reflects the status of the NDP at

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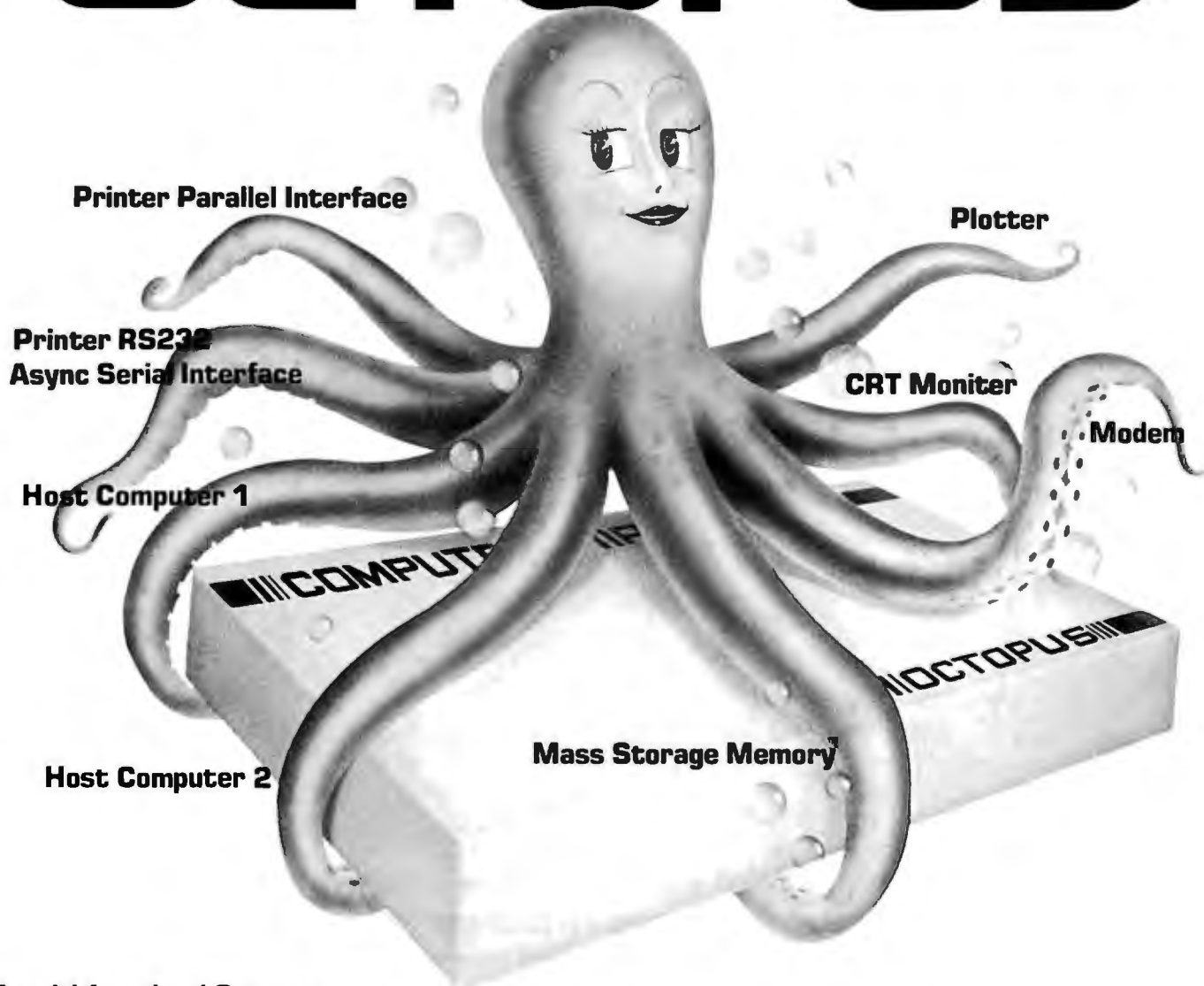
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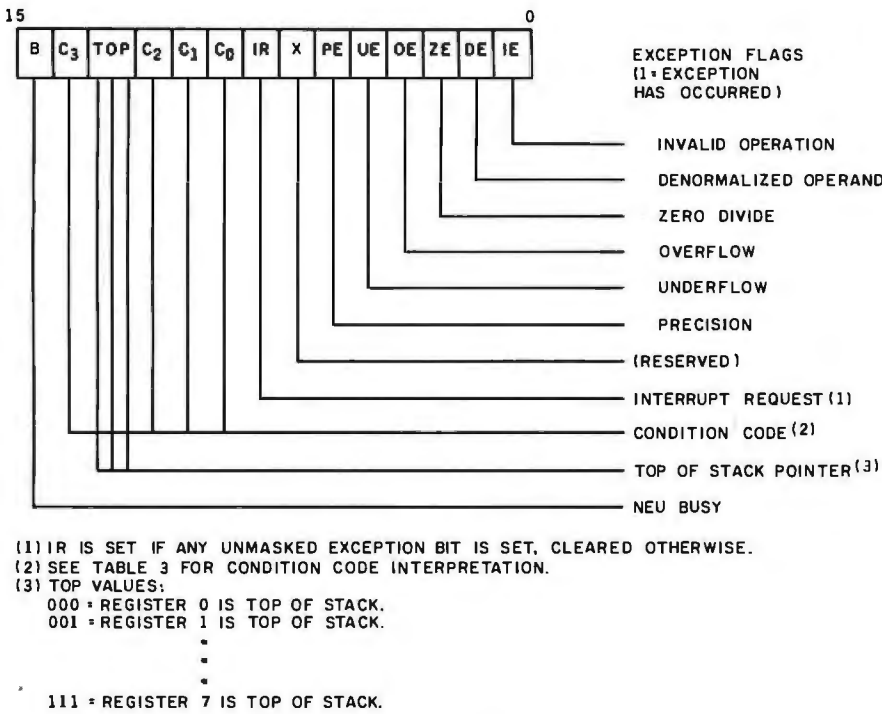


Figure 3: The various fields of the Status Word.

all times. The various fields of the Status Word are shown in figure 3.

The Busy bit indicates whether the 8087 is in the process of performing an operation at any given time. The 4 condition bits (C3 through C0) denote the result of a previous operation, and the host processor can examine them to determine if a branch should take place in the program.

This is accomplished by storing the 8087's Status Word in memory and then causing the host processor to fetch and examine the condition codes.

Three of the bits of the Status Word, ST2 through ST0, specify which register is the current top of the stack. Notice that if the ST field contains 000, for example, and a value is

pushed onto the NDP's stack, the ST field would decrement to 111. By the same token, if the ST field contains 000 and a value is popped from the stack, the ST field would increment to 001.

As it turns out, you really don't need to know which register is the current stack top, but this gives you some idea of what the bits mean. You *do* need to know the relative position of your various data elements on the stack, however, and keeping track of them is one of the jobs of the programmer.

All the remaining bits in the Status Word apply to exceptions (errors) and the way to handle them. Bits 0 through 5 signify whether the NDP detects an exception condition. Table 1 indicates the significance of these exceptions. Bit 7 is set to indicate whether the 8087 requests the host central processing unit to execute an interrupt-service routine in response to one of the exception conditions. It is possible for an exception condition to take place without an interrupt request if the programmer masks a particular exception (or group of exceptions). Generally, however, the NDP uses a collection of built-in default routines to handle most exceptions.

If you really want to avoid the messy error-condition-handling business, you can leave those problems to the nice people who wrote the

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- Attempt to pop an operand from a register
- Operand is a NAN (not a number)
- Operands cause operation to be indeterminate (% , $\sqrt{\quad}$ - number)

Denormalized Operand

- Attempt to use an operand that is not normalized

Zerodivide

- Attempt to divide by 0

Overflow

- Result too large for destination format

Underflow

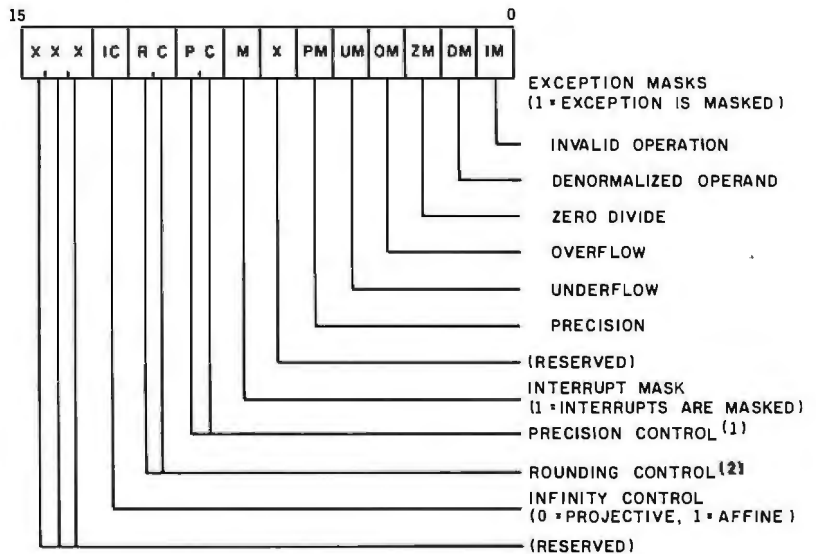
- Result too small for destination format

Precision

- Result not exactly representable in destination format
- 8087 rounds result

Note: Exception bits are "sticky" and can be cleared only by the FCLEX (clear exceptions) instruction.

Table 1: The significance of the exceptions.



(1) PRECISION CONTROL

- 00 = 24 BITS
- 01 = RESERVED
- 10 = 53 BITS
- 11 = 64 BITS

(2) ROUNDING CONTROL

- 00 = ROUND TO NEAREST OR EVEN
- 01 = ROUND DOWN (TOWARD -∞)
- 10 = ROUND UP (TOWARD +∞)
- 11 = CHOP (TRUNCATE TOWARD ZERO)

Figure 4: The Control Word.

IEEE standard that specifies the NDP default routines. (See the text box on pages 174-175.) In other words, you can take responsibility for handling an exception condition or you can let the chip do it. To inform the NDP which exceptions it will handle and which ones you will handle, you use the Control Word.

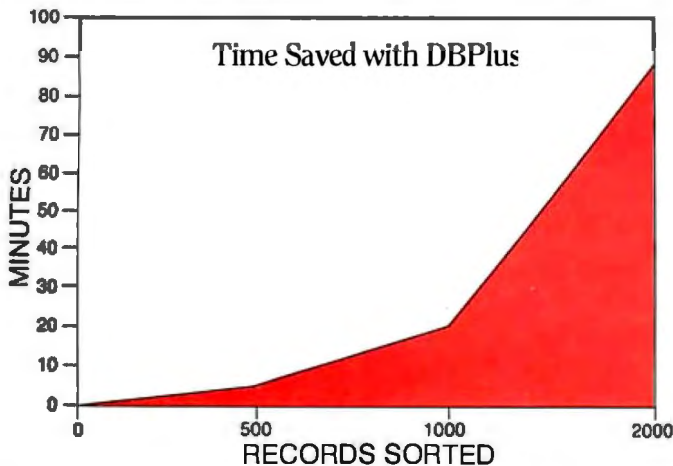
Tag Word

Before we move to the Control Word, let's look at one other thing,

How would the NDP know if we had tried to pop something from an empty register so that it could set the invalid operation flag? For that matter, how would it know if one of the operands was not a number? Well, the NDP stores a Tag Word that contains a 2-bit field for each of the eight registers, and which keeps track of the contents of each register and marks the contents as being Valid, Zero, Special (not a number, infinity, etc.), or Empty.

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Control Word

The Control Word is shown in figure 4. The least significant portion of the Control Word coincides with the least significant portion of the Status Word in that you set or clear these bits to mask or unmask (respectively) the exception conditions and to disable or enable the ability of the 8087 to interrupt the host processor. The Control Word also has bits that allow you to set the precision of the NDP to various levels. You should realize that there is no advantage to lowering the precision of the NDP in terms of execution speed. This capability exists only to allow the 8087 to more accurately emulate previous floating-point products that might be replaced by the 8087.

The next 2 bits in the Control Word set the rounding convention that the NPX uses. You can set the NPX to round up, round down, round to the nearest or even number, or to round toward zero.

Lastly, a bit in the Control Word selects the model of infinity for the NPX. Just think, philosophers argue whether infinity even exists and you get to define it in one of two different ways!

Simply put, the first method, known as the Affine closure mode, considers that there are numbers that are positively infinite and numbers that are negatively infinite. While this may seem reasonable, it can cause unexpected problems in calculations. For example, if we divide a number by the number X, and X is very, very small and positive, the result could be positive infinity. If X is very, very small but negative, the result could be negative infinity. In other words, you have two very different results.

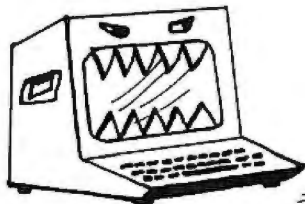
The Projective closure mode uses only one infinity. Although it is very large, it has no sign. This mode is the easiest to use and therefore is recommended.

Exception Pointers

If an exception does take place, and you have unmasked that particular exception flag, it would be nice to know a few things before you jump in and try to recover from your error. You would probably like to know

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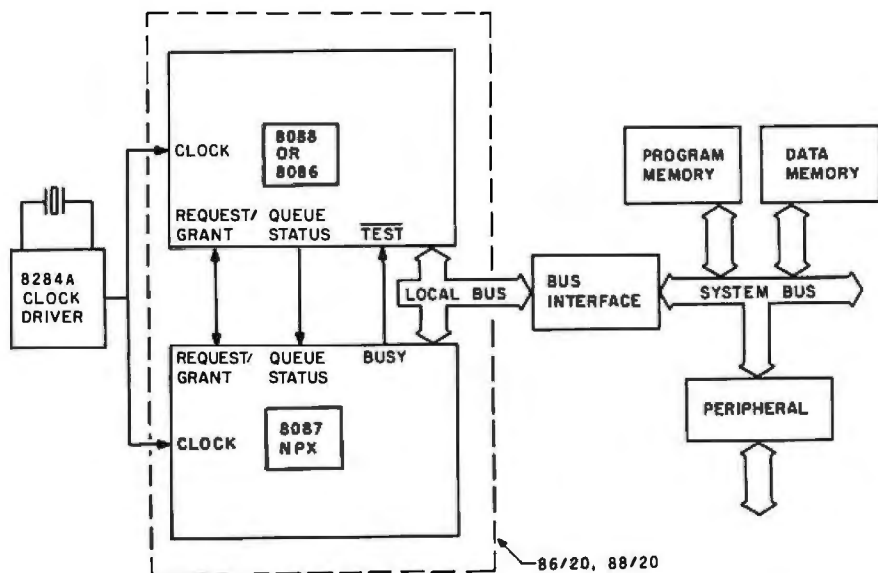


Figure 5: The interface and communication lines.

which instruction or op code caused your problem. It would also be nice if you could determine this instruction's address so that you might resume at that point when you have eliminated the cause of the problem. Also, if the instruction operated on data in memory, you might want to know where this data came from. The 8087 contains all this information in three registers that are collectively called the Exception Pointers. The operational details of these registers are beyond the scope of this article, but can be found in Intel technical documents.

Synchronization

The 8087 works in close harmony with its host. In order for this to take place, there must be some communication and synchronization between the two devices. The interface and communication lines are shown in figure 5.

When you add an 8087 to a host microprocessor, the host retains the responsibility of fetching the instructions from system memory. As the host fetches these instructions, the 8087 also captures them and puts them in a queue—just as the host processor does. The answer to how the 8087 knows whether to emulate the 6-byte queue of the 8086 or the 4-byte queue of the 8088 is quite simple.

Whenever the processor is reset,

the host processor goes to absolute address 0FFFF0 hexadecimal to begin fetching instructions. The 8088 always fetches a byte from this location because the 8088's data bus is a byte wide. The 8086, however, can fetch its instructions one word at a time. So when it goes to address 0FFFF0 to fetch its first instruction, it

**In order for the
8087 to work in close
harmony with its host,
there must be some
synchronization
between
the two devices.**

fetches a word instead of a byte. To accomplish this, the 8086 issues a signal called Byte High Enable (BHE/). The 8087 simply looks to see if its host generates a BHE/ signal when it performs its first op-code fetch after a reset. The presence or absence of the signal determines if it is connected to an 8088 or an 8086, and it then emulates the correct queue.

All 8087 instructions have a unique 5-bit prefix called the Escape prefix (11011). When the host fetches an op code with this prefix, it is placed in the queue as any other instruction would be. The 8087 captures the same op code as it is fetched by the host

and places the op code in its own queue. As this op code moves through the queue of the host processor, its movement must be emulated by the NPX queue as well. The mechanism that is set up to do this is the first of the three types of synchronization signals that are shared by the host and the NPX. The host has two lines called the Queue Status lines (QS0 and QS1). They allow an external device such as a coprocessor to emulate its queue. When this floating-point instruction finally makes its way through the queue, the host determines that it is an instruction for the NPX rather than for itself.

Once the host has determined that the instruction is an NPX instruction, it looks at the instruction to see if the NPX will need to access memory in the execution of the instruction either to fetch (read) an operand from memory or to store (write) an operand to memory. If it sees that this is the case, the host will calculate the address of the operand and perform a *dummy read*. By performing this dummy-read operation, the host can supply the NPX with the address of the memory operand. The host generates the address and even issues the strobe signals, but it ignores the data that is read from the addressed location.

The NPX, on the other hand, captures the address that the host generates. Then, depending on whether the NPX needs the data that is read or whether it needs the address so that it can write a result in memory after it finishes its instruction, the NPX captures the data or ignores it. Even if the data were required by the NPX to execute the instruction at hand, the dummy read will result in only one byte or one word of data. Typically, the NPX will be working with data types that are 4, 8, or even 10 bytes in length. This means that the 8087 will have to perform additional memory-read cycles in order to access the remainder of its operand. Because the 8087 shares the host processor's buses, it must have a way of informing the host that it wishes to use them.

The mechanism to do this is the

Text continued on page 170

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same used by any potential bus master to borrow bus cycles from the host. This line is the Request/Grant line (RQ/GT), and it is the method that the host uses to implement the HOLD and HLDA (hold and hold acknowledge) functions. When the NPX wants to use the buses, it toggles the RQ/GT line low. The host latches this request and, when it is done with the buses, three-states its buses and signifies to the requesting device that it can have them by toggling the same line low itself.

The NPX takes over the buses at this point and generates all the signals (address and control) to access the operand. It signifies when it is finished by once again toggling the RQ/GT line low. In the case where the NPX needs the address generated during the dummy read to store a result, it simply executes its instruction, saving the address until it has completed the execution and then re-

quests the bus so that it can perform the memory-write cycles required to put the result in the proper memory location.

In some cases, the host can continue to fetch and execute instructions (with the NPX emulating its queue) while the 8087 is busily crunching numbers. There may be a situation, however, when this cannot take place. For example, we have two instructions in a program, the first of which causes the NPX to operate on a variable and to store the result in memory. If the second instruction causes the host to use this result, we must not allow the host to execute the second instruction and to access the variable until the 8087 has written the proper value in the variable location.

To accomplish this, we precede the instruction intended for the host with a WAIT instruction. The WAIT instruction causes the host to look at its TEST pin. The TEST pin, as you can

see in figure 5, ties to the BUSY line of the NPX. Whenever the NPX is busy, the BUSY line is high and the TEST pin on the host is high. When the host executes the WAIT instruction, it cannot go on to the next instruction until its TEST pin goes low.

Another case where you would not want the host to go off blindly is when you have more than one floating-point instruction back to back. In this situation, the host would like to be more than obliging by performing all the dummy reads in the world just so that it can get to an instruction that it can execute. The problem is that the 8087 queue has to be in sync with the host, and if the host just gobbles its way through a series of floating-point instructions, ignoring them as it is designed to, the devices will never be able to regain sync. You can solve this problem simply by adding a WAIT instruction in front of all floating-point instructions.

Listing 1: An application of the 8087 using an Intellec Series III Microcomputer Development System and Intel's 8087 software emulator.

```

SERIES-III 8086/8087/8088 MACRO ASSEMBLER V1.0 ASSEMBLY OF MODULE PYTHAGORUS
OBJECT MODULE PLACED IN :F1:EUCLID.OBJ
NO INVOCATION LINE CONTROLS

LOC  OBJ                LINE    SOURCE
      . 1 +1             $SYMBOLS DEBUG
      2
      3                 NAME PYTHAGORUS
      4
      5                 EXTRN   INIT87:FAR
      6
      7                 TRIANGLE STRUC
0000  8                 BASE    DD      ?      ; The DD memory allocation allows
0004  9                 ALT     DD      ?      ; enough space for the variables
0008 10                 HYP     DD      ?      ; to be defined in the SHORT REAL
000C 11                 AREA    DD      ?      ; format.
      12                TRIANGLE ENDS
      13
      14                DATA   SEGMENT PUBLIC 'DATA'
      15
0000 16                RIGHT   TRIANGLE <>      ;We will assume that these
0004  ??????????
0008  ??????????
000C  ??????????

      17                                     ;variables are initialized by
      18                                     ;another program.
0010 3E03             CONTROL_87    DW      033EH
      19
      20
      21                 ; This is the default control word which masks all exception except
      22                 ; INVALID OP, leaves the INTERRUPTS UNMASKED, ROUNDS TO NEAREST OR EVEN,
      23                 ; and sets the INFINITY CONTROL to PROJECTIVE.
      24
      25
      26                DATA   ENDS
      27
      28
      29                STACK   SEGMENT STACK 'STACK'
      30
0000 (100             DW      100 DUP(?)
      31             )
      )

```


Application

The following application of the 8087 uses an Intellec Series III Microcomputer Development System and Intel's 8087 software emulator (see listing 1). The program takes the base and altitude of a right triangle, which are stored in memory as two fields of a structure called TRIANGLE, and uses this data to calculate the area of the triangle and the length of its hypotenuse. Notice that I define the fields of the structure as double words (DD). This allows me to define the variables in the Short Real format. I will discuss the program using both the listing and a chart in figure 6 that tracks the status of the NPX's stack as references. When I refer to the chart, I use lower-case letters in parentheses.

The procedure INIT87, which I reference on line 42, is in the 8087 emulator and prepares the environment. The FLDCW instruction on line

46 causes the Control Word, which is stored in memory at a location symbolically called CONTROL-87, to be loaded into the 8087. The function of the Control Word is explained beginning with line 21.

Notice that all the floating-point instructions are preceded by a hexadecimal 9B op code. This is the WAIT op code that is inserted automatically by the assembler. The first thing that I must do is set up the stack so that I can perform my calculations. The instructions on lines 50 through 53 perform this. FLD1 puts the number 1.0 on the top of my stack (figure 6a). FADD ST,ST(0) causes the value at ST(0), which is my stack top, to be added to the stack top.

The result of this instruction is to multiply the stack top by 2 (figure 6b). The FLD instructions cause the 8087 to load the contents of the specified memory locations, which are considered to be in the Real for-

mat, on the stack (figure 6c). In the process of loading these values, they are transformed into the Temporary Real format. Notice that because the host processor calculates all the operand addresses, I can use any of the addressing modes of the host. The 8086 and 8088 processors are capable of 24 powerful addressing modes. In this case, I am accessing a field of a structure.

Next, I calculate the area of the triangle. The instructions that do this are on lines 57 through 60. The FLD ST(1) instruction causes the contents of the current ST(1) register to be duplicated on the top of my stack (figure 6d), and the FMUL ST,ST(1) instruction puts the BASE X ALT in the stack top (figure 6e). FDIV ST,ST(3) divides the stack top by the 2.0 that I have saved on the stack (figure 6f), and the FSTP causes the result, which is equal to the area of the triangle, to be popped into the ap-

Listing 1 continued:

```

00C8          32      T_O_S LABEL WORD
              33
----         34      STACK ENDS
              35
              36 +1  $EJECT
----         37      CODE SEGMENT PUBLIC 'CODE'
              38          ASSUME CS:CODE,DS:DATA,SS:STACK
              39
              40          ; INITIALIZE 8087
              41
0000 9A0000---- E    42      INIT: CALL INIT87          ; This routine is in a library.
              43                          ; It sets up the environment
              44                          ; for the 8087.
              45
0005 9BD92E1000 R    46          FLDCW CONTROL_87      ; Load control word from memory.
              47
              48          ; SET UP 8086 REGS AND CONSTANT STACK IN 8087
              49
000A 9BD9E8          50      SETUP: FLD1          ; PUT 1.0 IN STACK TOP (ST)
000D 9BDCC0          51          FADD ST,ST(0)      ; ST=ST X 2
0010 9BD9060000 R    52          FLD RIGHT.BASE      ; ST <-- BASE
0015 9BD9060400 R    53          FLD RIGHT.ALT      ; ST <-- ALT
              54
              55          ; CALCULATE AREA=(BASE X ALT)/2 AND STORE IN MEMORY
              56
001A 9BD9C1          57      CALC: FLD ST(1)          ; Duplicate BASE in ST
001D 9BD8C9          58          FMUL ST,ST(1)      ; ST <-- BASE X ALT
0020 9BD8F3          59          FDIV ST,ST(3)      ; ST <-- ST/2
0023 9BD91E0C00 R    60          FSTP RIGHT.AREA      ; Store ST in AREA and discard
              61
              62          ; CALCULATE HYPOTENUSE = ((BASE**2)+(ALT**2))** 1/2
              63
0028 9BDCC8          64          FMUL ST,ST(0)      ; Square ALT
002B 9BD9C9          65          FXCH ST(1)          ; Exchange ALT**2 and BASE
002E 9BDCC8          66          FMUL ST,ST(0)      ; Square BASE
0031 9BDEC1          67          FADD ST,ST(0)      ; ST <-- BASE**2 + ALT**2
0034 9BD9FA          68          FSQRT          ; ST <-- ST** 1/2
0037 9BD91E0800 R    69          FSTP RIGHT.HYP      ; Store ST in HYP and discard
              70
003C F4             71      HALT: HLT
              72
              73
              74
----         75      CODE ENDS
              76          END INIT,DS:DATA,SS:STACK:T_O_S

```

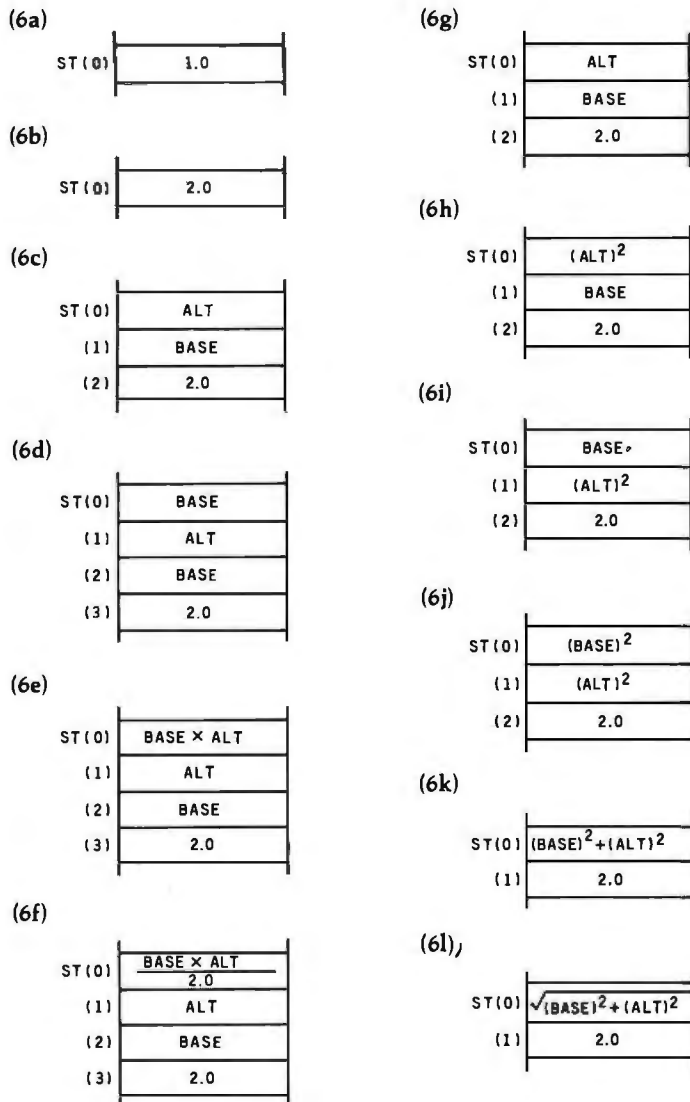


Figure 6: The status of the NPX stack during operation of the program in listing 1.

appropriate memory location in the Short Real format (figure 6g).

My next task is to calculate the length of the hypotenuse of the triangle. The instructions to do this are on lines 64 through 69. First, I multiply the element on the top of the stack by itself (figure 6h). Next, I exchange this element with the element below it (figure 6i), and once again I square the stack top by multiplying it by itself (figure 6j). All that remains is to add the stack top to the register below it, pop the old stack top (figure 6k), and find the square root of the stack top (figure 6l). The value in the stack top now equals the length of the hypotenuse. I next pop this value into the appropriate location in memory and I am finished.

This concludes the example. I have just performed calculations that involve transcendental functions and that use operands that are very accurate with no concern for either the complexity of the algorithm or the accuracy of the result. If I had attempted to perform the same calculation in software, I would have had to write some very complicated algorithms and the code necessary to trap any errors that may have occurred. Instead, I let the 8087 and the standard to which it complies worry about such things. It puts the world of accurate, high-level mathematics in the realm of every assembly-language programmer. ■

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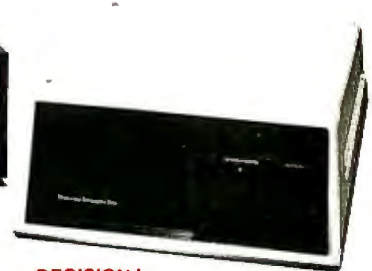


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In an attempt to standardize both the data types and algorithms used in floating-point arithmetic problems, the IEEE formed a committee in 1979 to produce a standard to which all floating-point arithmetic processors and software would comply. This standard not only established standard data formats, but also set rules for rounding and precision control and required that all machines (and software packages) complying with the standard be capable of performing the same algorithms with the same predictable results. The concept of exception handling was expanded and standardized so that all machines (and software) that complied with the standard would monitor their own activity and be capable of signifying when the result of their calculations was suspected of being in error. The 8087 implements this standard fully.

Data Formats

One of the most important aspects of the IEEE standard was the definition and standardization of the seven data formats that would be used in floating-point calculations. These formats belong to three basic types: Integer, Decimal, and Real.

The Integer type should be familiar because it is a standard data type used quite generally. The Integer formats are capable of representing signed whole numbers. The most significant bit denotes the sign (where a 0 indicates a positive number and a 1 indicates a negative number that is represented in standard two's-complement notation). The three Integer formats differ in length. The shortest format, Word Integer, is 16 bits in length and identical to the Integer format used by the host processor in its own instruction set (IMUL, IDIV). The Short Integer is 32 bits in length. Most 8086 assemblers allow you to allocate space for this type of variable using the Define Doubleword (DD) operator. Appropriately, the longest format is the Long Integer, which is 64 bits in length. Most assemblers allow you to allocate space for this type of variable with the Define Quadword (DQ) operator.

The Packed Decimal format, 80 bits long, is similar to the Integer format in that the most significant bit is a sign bit.

The similarity ends there, however, because the data is stored in Packed Decimal format where the 18 least significant nybbles (bits 0 through 72) each represent a decimal digit. This means that each group of 4 bits must be equal to a value between 0 (0000) and 9 (1001). If this looks like a lot of data, remember that this processor is capable of delivering results that use all 18 nybbles of this format with no round-off error! You can use the Define Ten-byte (DT) operator to allocate space for this variable.

Up until now I have described only data formats that represent whole numbers. While it would be nice if everything always worked out neat and clean without any fractions, in the real world we have to deal with all types of numbers. The next data type, Real, was created to handle these types of numbers.

The Real data type contains three formats. They are very similar to the scientific notation that represents large decimal numbers. A number represented in scientific notation has three components—sign, mantissa, and exponent. In scientific notation, I would represent the decimal number $-547,390$ as -5.4739×10^5 . In other words, I denote the sign of the number in the normal manner. Then I display its value or mantissa as a value between 0 and 10. I do this by moving the decimal point to either the right or the left. Whenever I move the decimal point to the left to normalize the number (make it equal to a value between 0 and 10), the exponent increases. When I move the decimal point to the right to normalize the number, the exponent decreases. For example, 0.0075 becomes 7.5×10^{-3} . The Real formats also have a sign, mantissa or significand, and an exponent, but they are binary values that are calculated a little differently.

As an example, I'll convert the decimal number 66 to the Short Real format. The Short Real format uses the 23 least significant bits to denote the mantissa of the number, the next 8 most significant bits to denote the exponent, and the most significant bit to denote the sign of the number. The first thing I must do is to convert the

number to binary: decimal 66 = binary 1000010. Because this is a whole number, I have no fractional part to worry about. Now I must normalize the number by moving the decimal point over so that the value has a "1" in the most significant digit. As in scientific notation, I increase the exponent whenever I move the decimal point to the left and decrease the exponent whenever I move the decimal point to the right. In this case, because I move the decimal point to the left, the exponent is positive: $1000010 = 1.000010 \text{ E } 110$.

Now I am just about to finish the conversion, but you must know two things. In the Short and Long Real formats I save a bit by dropping the leading "1" bit of the significand. This allows me to denote 24 or 53 digits in the space required for 23 or 52 in the Short or Long formats, respectively. For some reason, this is not done in the Temporary Real format. The second thing is that the standard format requires that a bias be added to the exponent so that negative exponents appear as positive values. The bias is different for each format and is shown in figure 7. The bias for the Short format is 7F hexadecimal (01111111). This means that the exponent becomes $110 + 01111111 = 10000101$. Putting it all together, I get

sign	biased exponent
0	10000101
	significand
	000010000000000000000000

or

0100 0010 1000 0100 0000 0000 0000 0000

With a number with a fractional part, the conversion looks like that shown in table 2. Table 3 is useful in understanding the power of the various data types.

Guaranteed Accuracy

The key to the 8087's ability to produce results with such a high degree of accuracy lies in the fact that the 8087 performs all its calculations in the Temporary Real data format. Regardless of the format in which an operand is stored in memory, any piece of data

that is loaded into the 8087 is transformed into this highly accurate, 80-bit-long format. The benefit derived by using this format for all internal calculations can be best illustrated by the following analogy.

I have a calculator with a range of 3 decimal digits and I want to use it to solve the equation $F = A \times B / C$. I got a calculator with 3-digit accuracy because I determined that A, B, and C would never be greater than 3 digits in length. If $A=100$, $B=10$, and $C=10$, you can see that I will have trouble

solving this problem using my calculator because $A \times B$ is outside of its range. Even though the final result may be well within the range of my calculator, I may have trouble with the intermediate results.

Although changing the order of operations may help in this particular situation, it should be obvious that this solution will not resolve the problem in all cases, for instance, if $A=100$, $B=10$, and $C=0.1$. In this case, I would have a problem if I were to calculate A/C .

Now, if I got a new calculator that had a range of 4 or 5 digits, even though I expected all my results to be 3 digits or less, I could solve my problem. Regardless of the order in which I did my calculations, the intermediate results would probably not overflow the range of the new calculator.

This is precisely how the 8087 can guarantee such accurate results. By using the Temporary Real format for all its calculations, it avoids errors that may appear in the calculation of its intermediate results. The Temporary Real format, as you can see from table 3, has a range so large that we would probably never overflow it in our calculations. Also, because it uses 64 bits for the mantissa, it can provide results that are accurate to 18 significant digits with no round-off errors.

Ease of Use

Another way in which the 8087 can guarantee accurate and standard results is by providing default exception handlers that ensure results even though an error may have occurred during one of the intermediate calculations. For example, if for some reason during the operation of one of my calculations I somehow manage to attempt to divide a number by 0, the 8087, rather than aborting the operation, executes a default response to the zerodivide exception and replaces the quotient with the most reasonable value—infinity. In this manner, the 8087 provides standard results.

```

-178.125D = -10110010.001B
10110010.001 = 1.0110010001 E 111
111 + 01111111 = 10000110
sign    biased exponent    significand
1       10000110          011001000100000000000000
1100  0011 0011 0010 0010 0000 0000 0000

```

Table 2: The conversion of a number with a fractional part.

Data Type	Bits	Significant Digits	Approximate Range
Word Integer	16	4-5	-32768 < x < 32767
Short Integer	32	9	-2E9 < x < 2E9
Long Integer	64	18	-9E18 < x < 9E18
Packed Decimal	80	18	-99...9 < x < 99...9 (18 digits)
Short Real	32	6-7	0, 1.2E-38 < x < 3.4E38
Long Real	64	15-16	0, 2.3E-308 < x < 1.7E308
Temporary Real	80	19-20	0, 3.4E-4932 < x < 1.1E4932

Table 3: The various data types.

DATA FORMATS	RANGE	PRECISION	MOST SIGNIFICANT BYTE									
			7	07	07	07	07	07	07	07	07	07
BYTE INTEGER	10^2	8 BITS	₇ ₀ TWO'S COMPLEMENT									
WORD INTEGER	10^4	16 BITS	₁₅ ₀ TWO'S COMPLEMENT									
SHORT INTEGER	10^9	32 BITS	₃₁ ₀ TWO'S COMPLEMENT									
LONG INTEGER	10^{18}	64 BITS	₆₃ ₀ TWO'S COMPLEMENT									
PACKED BCD	10^{18}	18 DIGITS	S ₁₇ D ₁₆ ₁ D ₀									
SHORT REAL	$10^{\pm 38}$	24 BITS	S ₇ E ₀ ₁ F ₂₃ F ₀ IMPLICIT									
LONG REAL	$10^{\pm 308}$	53 BITS	S ₁₀ E ₀ ₁ F ₅₂ F ₀ IMPLICIT									
TEMPORARY REAL	$10^{\pm 4932}$	64 BITS	S ₁₄ E ₀ ₀ F ₆₃									
INTEGER: I			REAL: (-1) ^S (2 ^{E-BIAS}) _(F₀·F₁...)									
PACKED BCD: (-1) ^S (D ₁₇ ...D ₀)			BIAS = 127 FOR SHORT REAL 1023 FOR LONG REAL 16383 FOR TEMPORARY REAL									

Figure 7: The seven data formats contained in the three basic types.

Super Graphics Hardware from NEC

The NEC 7220 GDC is a new item of sophisticated graphics hardware for microcomputers.

Graphics capability is rapidly becoming a common feature of personal computers, partially because of consumer demand. The latest item of sophisticated graphics hardware for personal computers is the NEC (Nippon Electric Company) 7220 GDC (graphics-display controller), already found in the NEC Advanced Personal Computer, Epson's QX-10, and the Corvus Concept.

Before explaining what this controller does, I'll make a distinction between video displays and graphics. A video controller generally deals with displaying alphanumeric information such as ASCII (American National Standard Code for Information Interchange) characters. Primarily, it converts ASCII data into a dot pattern that a video monitor displays. You can read a good basic discussion of this subject in *The TV Typewriter Cookbook* by Don Lancaster (Howard W. Sams, 1976).

By contrast, a graphics-display controller converts graphics-image

About the Author

Steve Levine is currently programming computer-graphics simulations and voice I/O for the U.S. Navy. He is employed by Information Network Systems in Warminster, Pennsylvania. Steve is also one of the cochairmen of The Personal Computer Arts Group, which is responsible for five annual Symposia on Small Computers in the Arts held in Philadelphia. He is also involved in the research of a new digital music synthesizer.

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data into pixel (picture-element) data, and then stores them into or fetches them from display memory. The pixel data represents some arbitrary number of different shades or colors (including white or black) for each element of the picture. A graphics controller shares the display memory with a host computer. This arrangement permits both the host and the controller to read from or write to the display memory. In many cases, this arrangement uses a dual-port memory or interlaced DMA (direct memory access). Thus, data written into display memory can be manipulated by the GDC while the processor is off doing something else.

The most time-consuming part of getting a computer to draw a shape is calculating the next display-memory address to access. In fact, you must repeat this part of the process to change any dot on the screen. If you use the host processor to perform the calculations, the display often exhibits flicker and jerkiness because of the calculation time required. Despite this drawback, however, most small-computer manufacturers leave graphics control to the microprocessor, trading quality for lower cost. Pres-

ently, special graphics computers use external hardware dedicated to vector generation, as well as shape functions (such as rectangles, squares, and circles) prestored in ROM (read-only memory). With these systems cost is usually secondary, as performance is of most importance to the user.

Parts of the 7220 GDC

The 7220 GDC has several parts. The *microprocessor-interface module* serves as an 8-bit bidirectional interface to the host processor. Data transfers into and out of the device are done by monitoring status-register bit flags, which reflect the state of a FIFO (first-in/first-out) buffer. These transfers do not interfere with internal ongoing operations, and the FIFO buffer can store up to nine 16-bit words. The *command processor* decodes commands, interprets the contents of the FIFO buffer, and passes parameters to the proper blocks within the GDC.

The *DMA control* gives you an easy interface to Intel's 8257 and 8237 DMA controller devices. You can also interface other DMA controllers. Display data can be directly loaded into or out of the GDC display memory over the host microprocessor's bus. Sixteen bytes of internal *parameter RAM* (random-access read/write memory) hold the display parameters used by the GDC when drawing. The programmable *video-sync generator*

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takes its time reference from the master clock and provides synchronization signals for interlaced video raster. It also accepts external slave synchronization when used in conjunction with multiple 7220s. The *memory-timing generator* provides two clock-cycle refresh signals and four clock-cycle read/modify/write signals for the display memory.

The *zoom and pan controller* module allows you to program a zoom factor (or magnification factor) in integers between 1 and 16. Pan (or side-to-side) control is effected by programming different display-

window starting addresses. The *drawing controller* calculates the pixel addresses for lines, figures, and characters. You set the drawing parameters and a starting point, and the controller proceeds to draw the desired figure, without assistance, from that point on. The *display-memory controller* handles all memory multiplexing, modification, refresh counting (for dynamic memories), and partitions the video-field time between different types of cycles. Finally, the *light-pen de-glitcher* looks for two rising edges occurring at the same point in two suc-

cessive video fields. When this occurs, its signals change a status bit to show that the address contained in the light-pen register is valid.

Display Modes

You can select three basic display modes with the 7220: graphics, character, or mixed.

The graphics mode lets you use bit-mapped graphics at the pixel level. This mode allows a display to be up to 4096 pixels square (allowing 1 bit per pixel for intensity information) or 1024 pixels square (allowing 4 bits for color or intensity-level information). Other combinations can be set up as well—the circuit used in this article produces a 512- by 240-pixel window, 1 bit deep, on a 1024-pixel-square, 1-bit-deep world.

Character mode allows up to 8K bytes of display memory for character codes and attributes.

The mixed character and graphics mode allows 64K bytes of display memory.

Displaying Memory

A basic read/modify/write cycle takes place in less than 800 nanoseconds (ns). This interval is the minimum for writing totally new pixels into memory, one at a time. The GDC provides the memory control, refresh, and handshake with DMA controllers. The benefits are obvious. The hardware designer does not have to design circuitry to produce refresh signals, because the 7220 generates them. Additionally, because the 7220 controls the data-modification and video-display functions, you get a clean display without visi-burps. You control several display parameters, including the horizontal width, vertical size, and the world size (total amount of display memory). You can also select zoom factors and interlaced or noninterlaced synchronization.

To display a complete frame of video information, an image must be kept in display memory. Because memory organization is a linear-address space, an image of a single horizontal line is actually stored as a number of widely separated dots. If you divide the number of dots per

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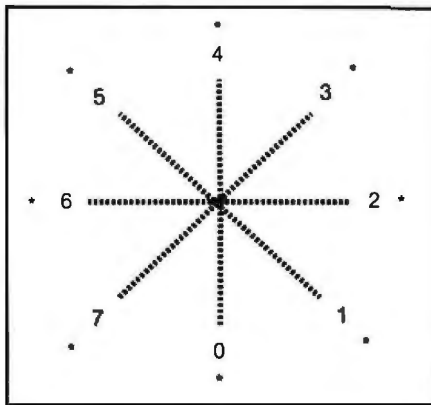
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(a) Pitch (P)
 $P = (XMAX + 1) / 16$

(b) Line-Base Address (LBA)
 $LBA = P \cdot Y$

(c) Execute Address (EAD)
 $EAD = LBA + INT(X/16)$

(d) DAD (dot address)
 $DAD = \text{remainder (from EAD calculation)} \cdot 16$



A0	Read	Write
0	S/R	Parameters into FIFO
1	FIFO	Command into FIFO

Figure 1: Four equations to locate an individual dot address.

Figure 2: A direction map for controlling pixel-drawing direction.

Figure 3: GDC addressing.

Data Ready	FIFO Full	FIFO Empty	DWG in Progress	DMA Execute	V-sync Active	H-blank Active	L-pen Detect
B7	B6	B5	B4	B3	B2	B1	B0

Figure 4: The status register.

line by 16 you get a value called pitch, or the number of 16-bit memory words per line. To move the cursor down one dot on the screen, you add the pitch to the 18-bit value in the word address and use a 4-bit dot address to access the individual pixel within that word. To move the cursor forward or backward on a line, all you need are simple increments and decrements. You obtain diagonal movement with some combination of these two methods.

When a new pixel is to be written into display memory, its position within a 16-bit word is loaded into the mask register. Then you specify the absolute cursor position, the modification pattern, and the type of modification (replacement, complement, set, or reset). The GDC automatically changes only the bit you want to update. The host processor continues to do other things while the display processor performs this legwork. You will notice the real power of this approach when you try to create complex shapes made up of many fundamental shapes and scale, and then move or redraw them.

Pixel Addressing

There can be up to 2^{22} pixels organized as 2^{18} sixteen-bit words, and you need a two-part address to select an individual pixel. First, the

EAD (execute address) selects a particular 16-bit word out of the 256K bytes; then the DAD (dot address) selects which bit or pixel from the 16 to operate on.

Consider an x - y vector-list scheme where we would like to find the individual dot address (see figure 1). You simply derive the P or pitch from equation a, find the line-base address (LBA) using equation b, and get the EAD from equation c. Next you obtain the dot address from equation d, and you now point to the exact pixel in the x,y matrix. We structure the memory as a power of 2 in order to avoid real arithmetic for these calculations. We send these numbers to the GDC (in binary) to set the cursor position.

An important parameter in deriving consecutive pixel addresses is the DIR, which controls pixel-drawing direction. This is best illustrated by the direction map in figure 2. Drawing direction is divided into eight movements about the center. By specifying a direction, you get a resulting dot movement according to the figure.

Talking to the 7220

The GDC appears as two consecutive addresses to the host, which selects between the two by using address bit 0 (see figure 3). The first ad-

dress is status register on read and parameter into FIFO buffer on write. The second address serves as read/write FIFO buffer, with write pertaining only to command into FIFO buffer. In order to get commands and data into the FIFO buffer, you handshake with a FIFO ready bit in the status register. You first send a command byte followed by several parameter bytes that make up the command. After initial loading, an internal command processor decodes the commands, sets the appropriate registers to the passed values, and starts the specified process.

A simple software or hardware handshake is necessary when loading data into the GDC FIFO buffer. The status register has FIFO FULL, EMPTY as well as other flags of interest to the programmer (see figure 4).

Summary of Commands

The FIFO buffer holds both commands and parameters. By writing data to the second, or command, address, you apply a special tag to the data that identifies it as a command when it is put into the FIFO buffer. This tag helps the command processor to tell the difference between parameters and commands. When the command processor receives a new command byte, it terminates previous commands. Commands for the GDC are shown in table 1.

Figure Drawing

The digital differential analyzer (DDA) forms the workhorse section of the figure-drawing logic. It per-

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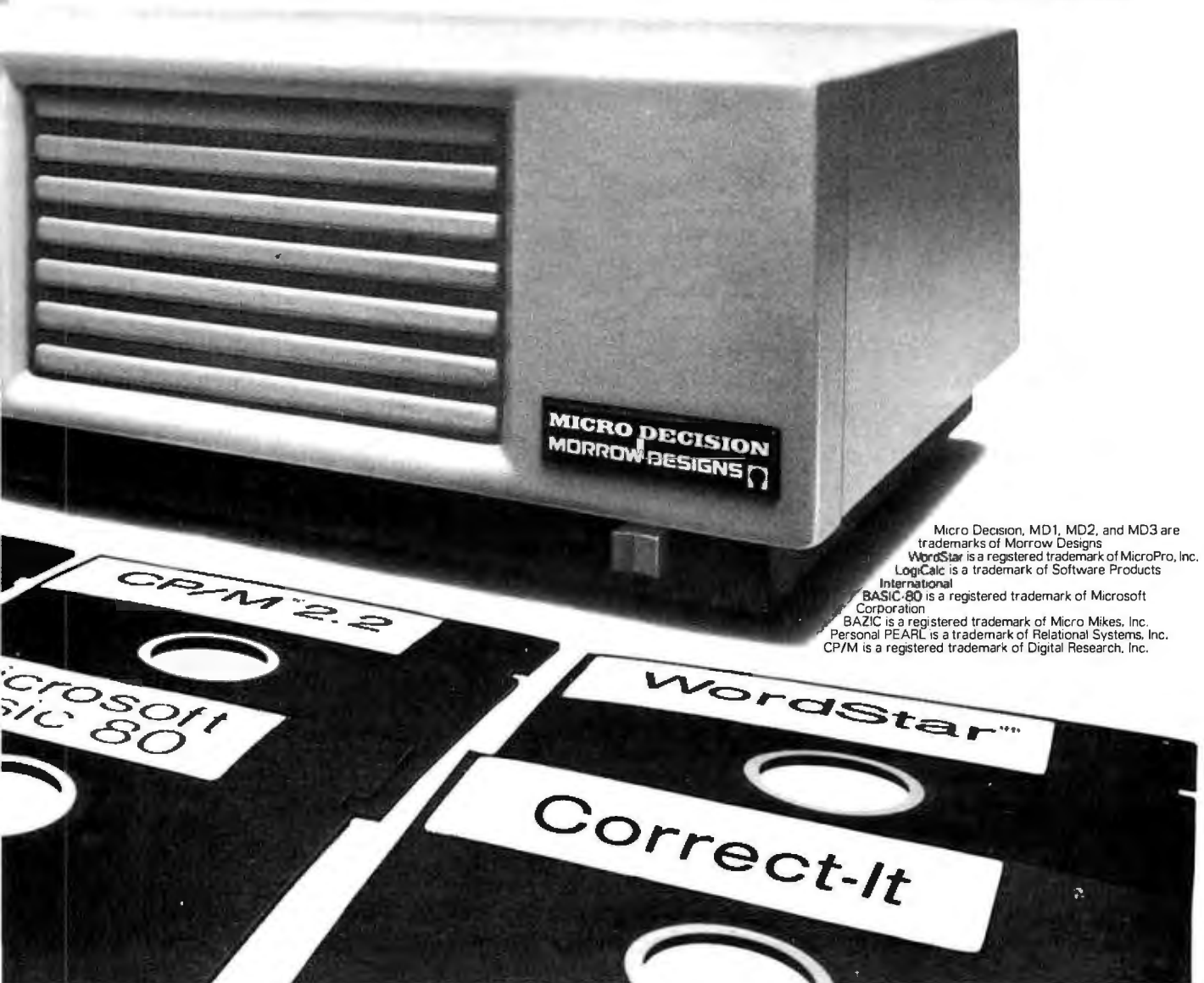
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Video Control		
A	RESET:	Set 7220 to idle, set video-display format
B	SYNC:	Set video-display format
C	VSYNC:	Master or slave video-sync mode
D	CCHAR:	Cursor and character row heights
Display Control		
A	START:	Begin scanning
B	ZOOM:	Specify zoom factors
C	CURS:	Specify cursor position in display memory
D	PRAM:	Set display area's start and length. Also set 8 bytes for the graphics character
E	PITCH:	Display-memory X-dimension width
Drawing Control		
A	WDAT:	Write data into display memory
B	MASK:	Specify mask-register contents
C	FIGS:	Figure specify of drawing parameters
D	FIGD:	Draw the above specified figure
E	GCHRD:	Graphics character draw
Data Read		
A	RDAT:	Read data from display memory
B	CURD:	Read cursor position
C	LPRD:	Light-pen address read
DMA Control		
A	DMAR:	Request a DMA read transfer
B	DMAW:	Request a DMA write transfer

Table 1: The GDC command summary.

16-bit integer used as a slope term. These four parameters are derived from equations that represent initial and ending vectors of a line, arc, or rectangle. In addition to specifying values for these four parameters, you must load the EAD of the beginning pixel, the DAD, and the DIR values before you issue the FIGD (figure draw) command.

With a minimum of instructions, you can make the GDC draw fundamental shapes. The DDA, which is on-chip hardware, does the time-consuming calculation to produce the next pixel address for the shape. This circuit and the memory-modification hardware (read/modify/write) combine to produce a rapid update of new pixels.

When you want to begin figure drawing, you load a figure type, drawing direction, drawing parameters, cursor starting address, and the pattern into the FIFO buffer. Then you issue a FIGD command. A FIGS (figure specify) command alerts the GDC to the necessary drawing parameters, which are either computed by the host processor or stored in a table (see figure 5).

A Line-Drawing Example

The GDC drawing technique uses independent and dependent axes. The host processor determines which axis is independent and which is dependent for the particular drawing direction or octant of that vector. To draw a line from XY Start to XY End, you first move the cursor to XY Start with the CURS command, then calculate the Deltas ($\Delta X = X_{End} - X_{Start}$, $\Delta Y = Y_{End} - Y_{Start}$, and find the direction by locating the quadrant and the octant (see table 2). If $ABS \Delta X = ABS \Delta Y$, the vector is on octant boundary within that quadrant and you choose the higher-numbered odd octant.

You then determine the independent and dependent axes with the following equation:

$$\begin{aligned} &\text{If } \Delta X > \Delta Y \\ &\quad \text{Then } I = X, D = Y \\ &\text{If } \Delta X \leq \Delta Y \\ &\quad \text{Then } I = Y, D = X \end{aligned}$$

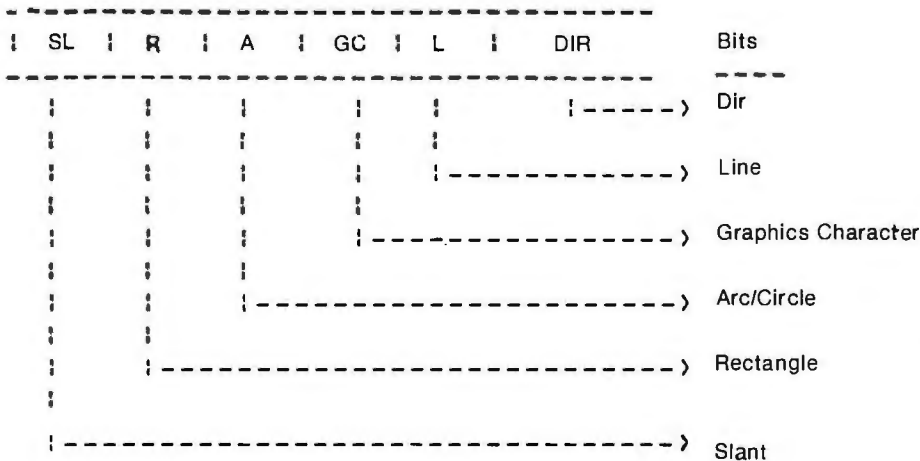


Figure 5: The layout of the FIGS (figure specify) command.

forms the necessary adds, shifts, and counts that allow you to draw a 100-pixel figure in only 80 microseconds (μs), using differential equations to specify the delta x, y information. (See *Principles of Interactive Computer Graphics* by William M. Newman and Robert F. Sproul [McGraw-Hill, 1979, pp. 22-28].)

To perform the differential opera-

tions on vectors, you specify values for the DDA parameters. The four DDA parameters for vector operations are DC (dot count), an unsigned integer from 0 to 16,383 calculated by the host to be the total number of pixels to move; D1, the same type of number, but used for slope-encoding terms; D, a 16-bit integer, also used as a slope term; and D2, another



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Delta_X sign	Delta_Y sign	Quadrant
+	-	1
-	-	2
-	+	3
+	+	4

Octant		Octant
ABS Delta_X	>	ABS Delta_Y
If Quadrant	Then	Octant
1		2
2		5
3		6
4		1

Octant		Octant
ABS Delta_X	<	ABS Delta_Y
If Quadrant	Then	Octant
1		3
2		4
3		7
4		0

Table 2: Information for locating the quadrant and octant for line drawing.

Now you compute the line-drawing DDA parameters:

$$DC = ABS(\Delta_I)$$

$$D = [2 * ABS(\Delta_D)] - ABS(\Delta_I)$$

$$D2 = 2 * [ABS(\Delta_D) - ABS(\Delta_I)]$$

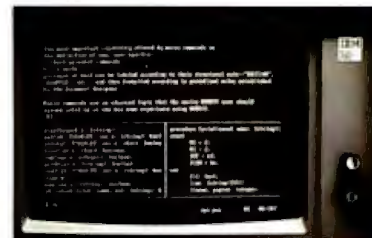
$$D1 = 2 * ABS(\Delta_D)$$

You can make these operations fairly efficient by using a table for octant and axis determination.

Once these parameters are calculated, you load them into the GDC FIFO buffer with a FIGS command. Then you load a pattern into parameter RAM with a PRAM command. The pattern corresponds to the type of line—broken, dashed, or solid. A WDAT (write data) command with bit modifier and a FIGD command complete the figure-drawing process (see photos 1 through 4).

Drawing a circle of arbitrary radius at a specified point on the display requires that you prepare most of the parameters discussed above with the

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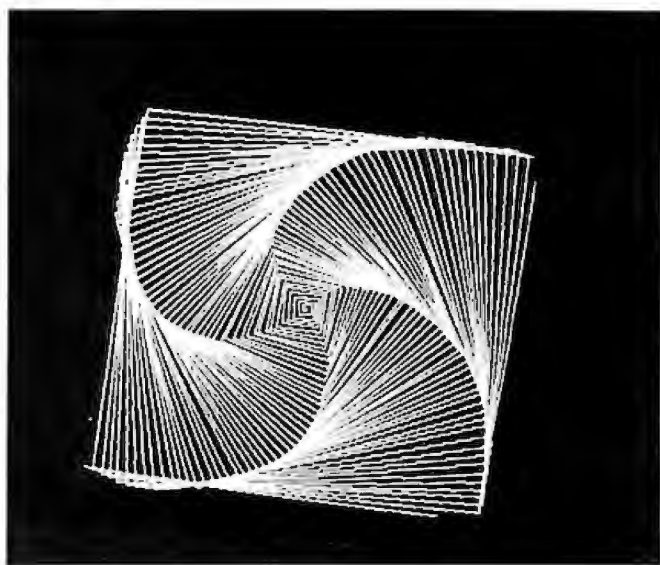
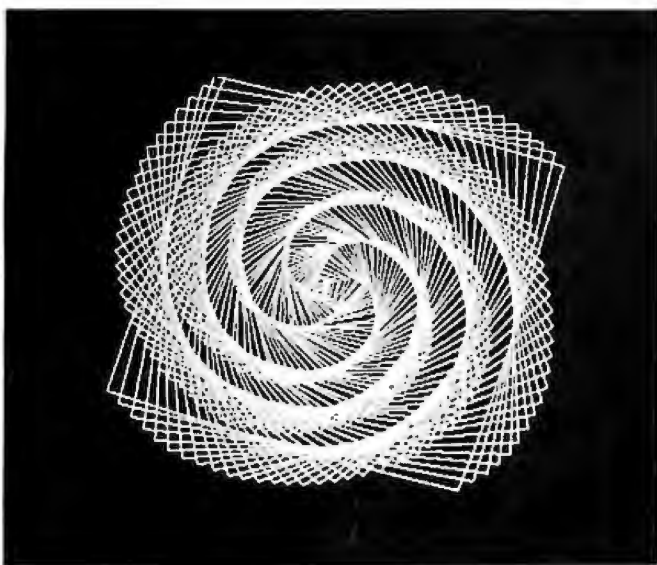
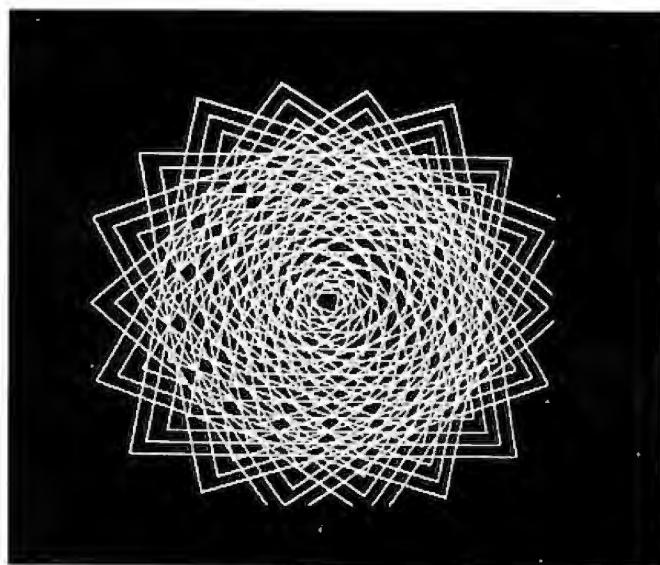
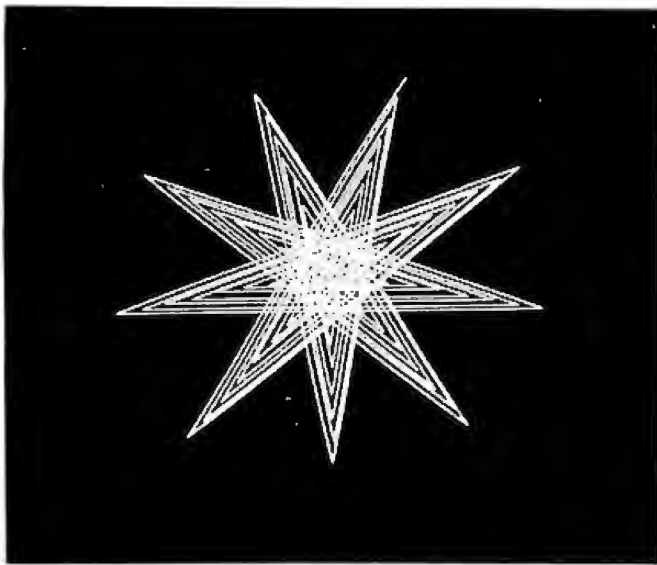
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Photos 1-4: Examples of the GDC figure-drawing process.

exception of the DDA drawing parameters. The following information draws a circle as eight arcs, with two per quadrant:

- DC = Radius * Sin (Theta)
- D = Radius - 1
- D2 = 2 * (Radius - 1)
- D1 = -1
- DM = Radius * Sin (Phi)

The starting points might be

- radius, 0
- 0, radius
- radius, 0
- 0, -radius

Rectangle drawing is similar, but simpler:

- DC = 3 (fixed for circles or arcs)
- D = (Total number of pixels in initially specified direction) - 1
- D2 = (Total number of pixels in perpendicular direction) - 1
- D1 = -1
- DM = Same as D

Applications

The 7220 GDC is not a simple device. While many of you have probably written a BIOS (basic input/output system) or CRTC (cathode-ray tube controller) handler, developing a decent assembly-language driver for this chip is non-trivial. The driver I am currently using was written by Frank Caparello

under the auspices of Roger Amidon and others, the developers of the new Epson QX-10. The S-100 board I used to draw the demonstration screens was also developed by them. The Epson QX-10 uses a 7220 as a display chip but has operating-system calls to do all the fancy stuff.

The GDC design manual that NEC provides is very well written and offers you a basic tutorial on computer graphics. It includes numerous examples of parameter derivation as well as hardware-interface information. I highly recommend it.

I believe the 7220 GDC will be a standard for microcomputer displays for the next few years. If the price falls, you may even find it in arcade games and low-end terminals. ■

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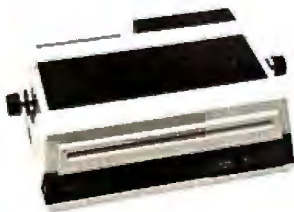


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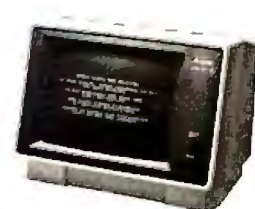
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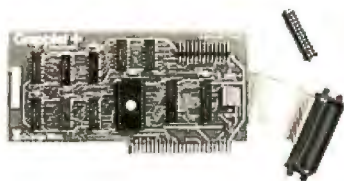


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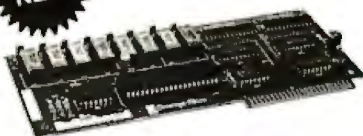


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Part 1 of this series presented an overview of NAPLPS. In part 2 I described the basic features of NAPLPS with an emphasis on the actual coding. In this part I will concentrate on the more advanced features of NAPLPS, specifically, Incremental Lines, Macros, Dynamically Redefinable Characters, and Fields. This article will present merely an overview of these advanced features. In order to

get a complete description of them, you should obtain a copy of the actual NAPLPS document from the Computer and Business Equipment Manufacturers Association (CBEMA), whose address is listed at the end of this article.

Incremental Lines

As we saw in part 2, line drawings and objects can be encoded by specifying the endpoints of each line using a terminal-independent coordinate system. In general, it takes about 3 bytes to encode each line in a drawing. For objects with only a few sides or a regular shape (i.e., rectangle, arc, etc.), this efficient approach makes it easy to encode lines. But if an object has an irregular shape, the normal encoding method becomes very inefficient.

NAPLPS supports a method of *chain-encoding* irregular edges of shapes. An assumption is made that the irregular edge is composed of a large number of small line segments. Each segment can be encoded using just 2 bits of information—a substantial reduction over the 3 bytes needed using the normal method.

The method for chain-encoding line segments with 2 bits is shown in table 1. The first step is to establish a pair of relative coordinates (symbolized as dx , dy) that determines the length of the line segments. Multiple 2-bit values are then specified that indicate directions in which to draw the line segments. As shown in table 1, a line segment can be drawn horizontally, vertically, or diagonally.

If a horizontal segment is specified, it is drawn in the direction initially set by the value dx . If dx is positive, the horizontal segment will be drawn to the right; if dx is negative, the segment will be drawn to the left.

If you are following closely, you may be asking how we could get lines drawn to the left if we initially specify dx as positive. As shown in table 2, an Escape sequence is provided to reverse the direction of the drawing. Any time a 2-bit value is 00, the next 2 bits are interpreted as an instruction to change direction. The sequence 00 01 indicates that the horizontal direction should be reversed, the sequence 00 10 changes the vertical direction, and the sequence 00 11 reverses both directions.

About the Author

Jim Fleming is a member of the ANSI X3L2 Committee on Character Sets and Coding. He is an independent consultant specializing in interactive computing systems.

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Two-Bit Incremental Line Instructions

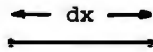
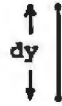

Symbolic Code	Two-Bit Encoding	Result
-	00	Change dx or dy values (see table 2)
X	01	
Y	10	
D	11	

Table 1: With the Incremental-Line features of NAPLPS, some line segments can be specified with just 2 bits of information. The values dx and dy signify relative coordinates. If dx is negative, the line will be drawn to the left; if dy is negative, the line will be drawn downward. Other lines can be drawn by using the 4-bit direction changing codes shown in table 2.

Incremental Line Escape Sequences

Symbolic Code	Four-Bit Encoding	Result
- -	00 00	If pen is down, then lift it up. If pen is up, then put it down.
- X	00 01	dx = -dx
- Y	00 10	dy = -dy
- D	00 11	dx = -dx, dy = -dy

Table 2: Four-bit codes are used to change the direction of the drawing and control the pen position.

If you are still with me, you may ask what happens when 00 is followed by 00. That sequence indicates that the state of the pen should be reversed. If the pen is currently down, it will be lowered.

The 2-bit values are encoded in a series of bytes, 6 bits per byte (from left to right in table 3). The pen is

assumed to be down at the beginning of a command. The last byte can be padded with a pen reversal if the number of line segments is not even.

Figure 1 shows a chain-encoded outline of the state of Indiana that is composed of 217 short line segments. These 217 segments require 87 bytes of coding in NAPLPS. If I had encoded this drawing using the normal



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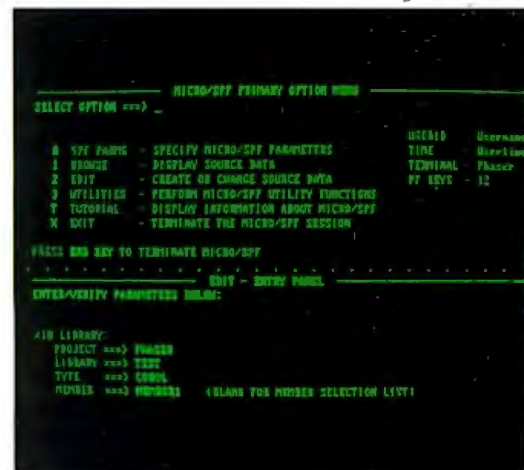
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Figure 1: An example of an incremental-line drawing. The size can be changed simply by changing the values of the relative coordinates dx and dy . This drawing was done on a Diablo 630.

method, 651 (217×3) bytes would have been needed. (Although these calculations ignore the fact that the northeast corner of the state could be efficiently drawn with normal straight lines, a large amount of memory would be required nonetheless.)

A symbolic representation of part of the chain encoding for figure 1 appears in table 3. It is the coding for part of the southwestern border of Indiana. The corresponding binary and octal values of the encoding are also included. The two outlines were produced from the same encoded data.

The scaling effect achieved in figure 1 was accomplished by changing the size of the dx and dy values. As shown in figure 2, the Incremental-Line op code (3A hexadecimal or 3/10 using a 16 by 16 column/row representation) and a relative coordinate pair (dx , dy) precede the encoded data. This (dx , dy) value can be changed to create some interesting effects. For example, it can be scaled so that the resulting drawing is larger or smaller, even though the *same* en-

coded data is used. Also, the values of dx and/or dy can be negative, resulting in mirror-image drawings from the same encoded data. The values of dx and dy can be very different, resulting in a stretching effect in one of the dimensions.

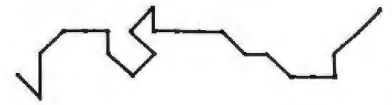
Besides chain-encoded outlined drawings, NAPLPS also supports chain-encoded filled polygons. These solid figures are subject to the same attributes of objects such as rectangles and arcs. These attributes can be used to draw the state of Indiana with a textured interior to help distinguish it from other objects on the screen or page.

Incremental encoding is a powerful technique for compactly representing irregular objects. The efficiency obtained by incremental encoding pays off in data-transmission time and disk storage. Another feature of NAPLPS that improves coding efficiency is the Macro capability.

Macros

Macros provide a means of storing an arbitrary string of NAPLPS codes

Sample of Incremental Line Encoding



Symbolic Code	Binary Code	Octal Code
- Y D	X1 00 10 11	113
- Y Y	X1 00 10 10	112
Y D X	X1 10 11 01	155
X - Y	X1 01 00 10	122
Y D -	X1 10 11 00	154
Y D -	X1 10 11 00	154
X D -	X1 01 11 00	134
X D -	X1 01 11 00	134
Y Y X	X1 10 10 01	151
X X D	X1 01 01 11	127
X D X	X1 01 11 01	135
X - Y	X1 01 00 10	122
Y D D	X1 10 11 11	157

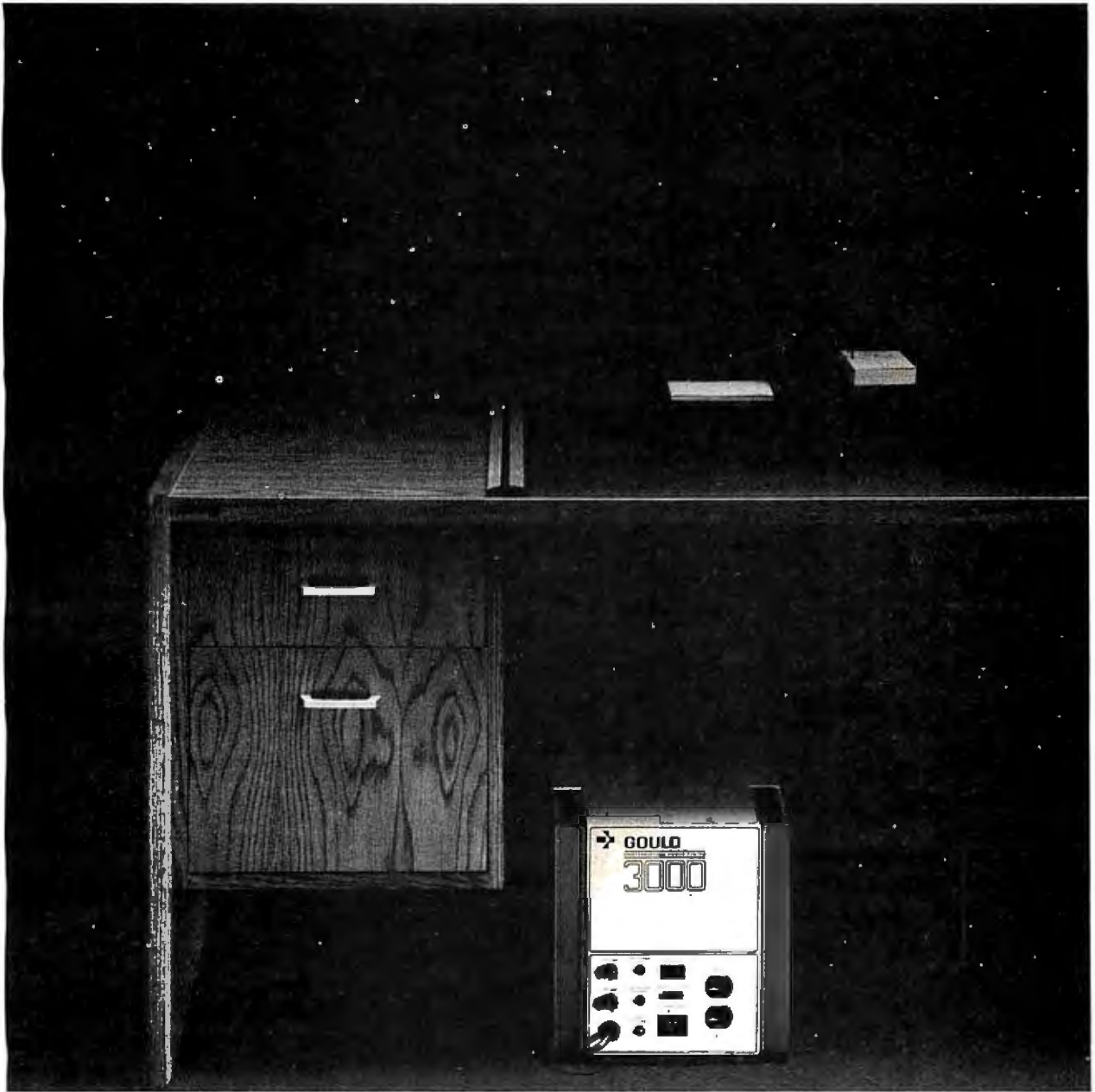
Table 3: An example of incremental-line coding. This is part of the coding used to produce the drawing of Indiana in figure 1.

under one of 96 names. The string can be recalled using the 1-byte name associated with the string.

Macros are useful when a common string of NAPLPS codes is used for a particular application. For example, in a home-banking application the words Balance, Amount, and Payment will appear many times during a session. NAPLPS lets us store these words as macros and recall them by transmitting just 1 byte.

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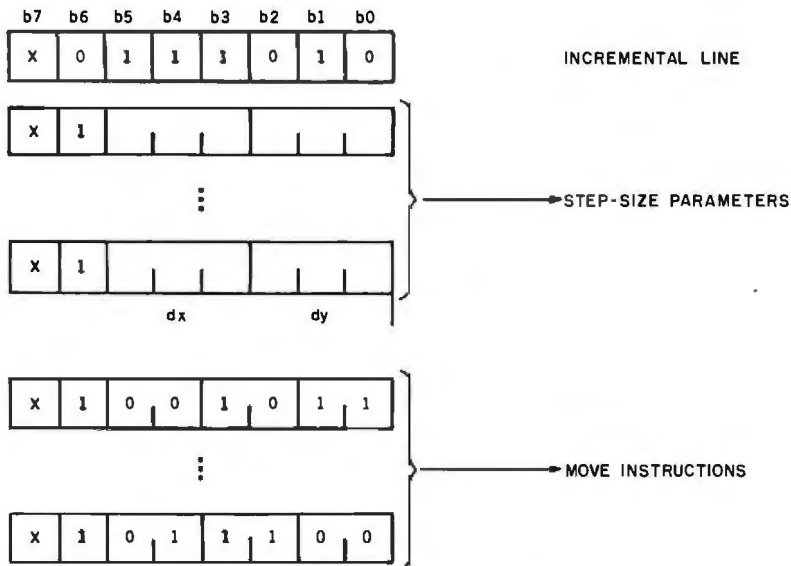


Figure 2: Structure of the Incremental-Line instructions. The first byte indicates that a series of Incremental-Line instructions will follow. The next series of bytes indicates the size of the relative coordinates dx and dy to whatever resolution is desired. The last series of bytes is composed of the actual 2- and 4-bit drawing instructions.

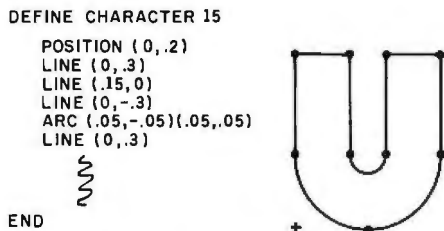


Figure 3: Using the Dynamically Redefinable Character Set (DRCS) capability of NAPLPS, we can define our own characters.

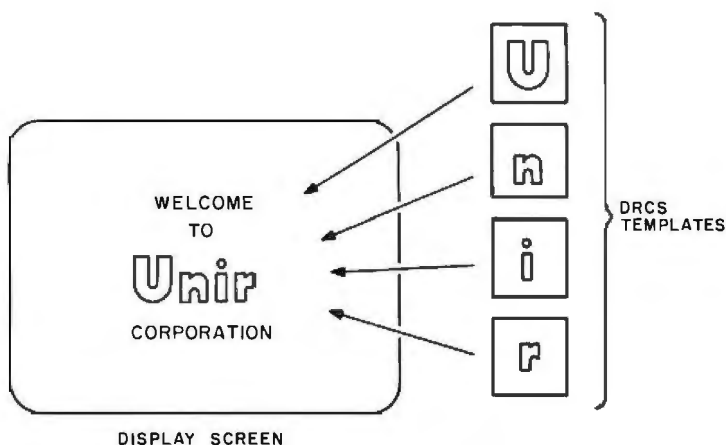


Figure 4: Once a DRCS set has been defined, its characters can be mapped just like text characters onto the display screen.

formation can be stored as one macro. In addition, other text and graphics can be intermixed with macros.

In applications like adventure games, each time a new room is entered, a macro can be defined with the picture of the room. If the room is reentered later in the game, the long graphics-and-text description does not have to be retransmitted. The host computer simply has to refer to the macro name and the entire room is drawn.

If the host computer is really smart, it can send down macros for all the rooms that are near the current room you are in. This can be done while you are deciding your next move. The screen will not be changed as these macros are defined. When you finally move to a new room, the host refers to the proper macro that was previously defined, and the user sees an almost instant response.

Macros can also be applied in conjunction with the Incremental-Line op code described earlier. Nothing prevents you from storing just the encoded data as a macro. If this is done, an Incremental-Line op code (3/10) can be sent followed by a (dx, dy) coordinate value followed by the macro reference. In the previous example (Indiana), the 87 bytes of encoded data would be retrieved and processed as if they had been sent after the (dx, dy) value. Thus, the size of the shape could be changed almost instantaneously.

Part 1 of this series includes an example of macro definition and reference. A NAPLPS code segment for that example is shown in listing 1. As you may recall, a macro (Macro 26) was defined that cleared the screen to blue and put the string "READY:" on the screen in white. Whenever Macro 26 is later referenced, the screen will be cleared and "READY:" will appear.

The amount of storage allocated to macros has been left open as a terminal- and application-dependent parameter. With 96 macro names and the ability to store long variable-length strings, the macro storage required could exceed the internal memory capacity of most personal

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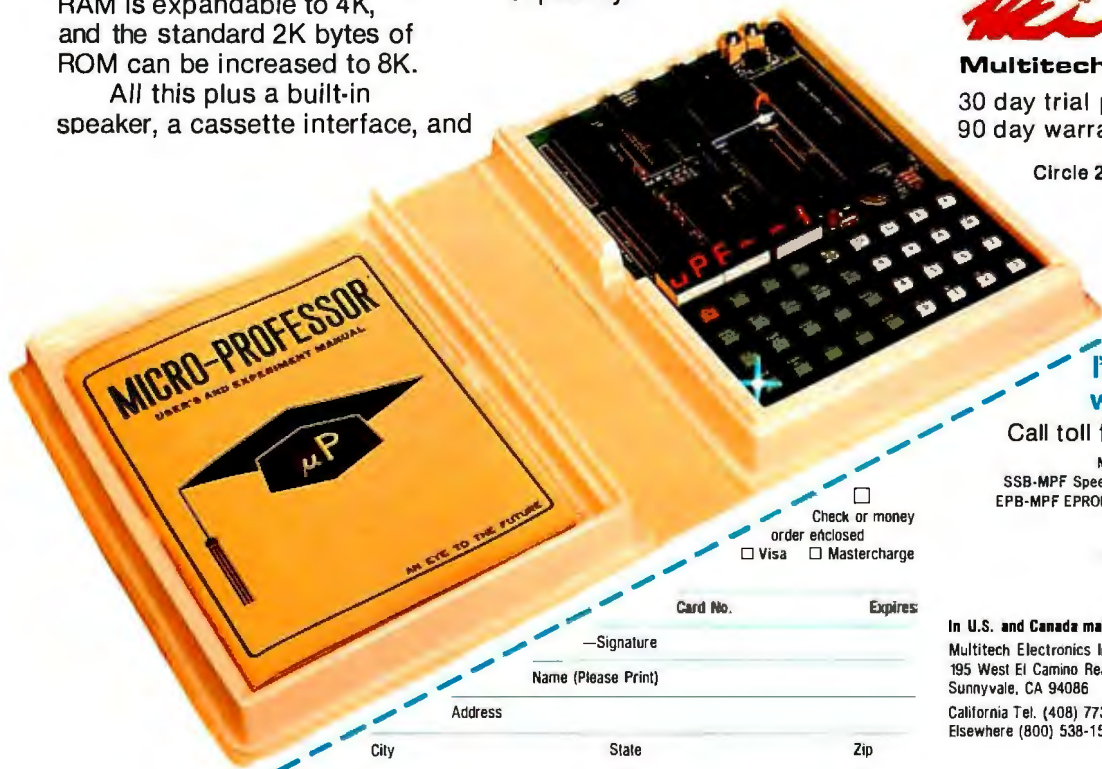
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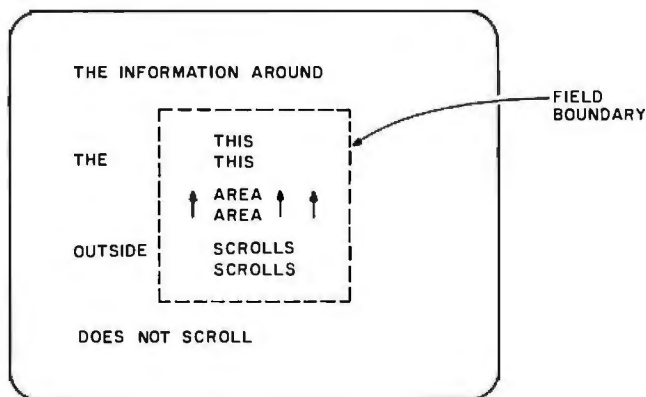


Figure 5: In NAPLPS, some fields of the display screen can be scrolled; others remain stationary.

window is completely mapped to the viewport, which is mapped to the character field on the screen. Figure 4 illustrates this mapping. Because the character field can cover an area from one pixel (picture element) to the entire screen, a scaling effect is achieved.

The DRCS capability is another method for reducing the transmission time of data sent from the host. In applications that require many special symbols, the symbols can be defined, given a name, and referenced with only 1 byte—even for a symbol that may require hundreds of bytes of definition. By replacing the hundreds of bytes with a single one, the transmission is compressed to the point that the users think they are connected to the host by a high-speed link.

Two popular methods of handling DRCS in terminals are available. The first method cuts the template as soon as the DRCS is defined. When the DRCS is requested, the previously cut template is retrieved and handled like any other character-definition template. The templates are usually stored on 8 by 8 or 16 by 16 grids internally in the terminal.

The second method for handling DRCS is to store the graphics commands themselves. No template is cut. When a DRCS is requested, the template is cut in a size appropriate for the current character field. The template may be 32 by 32, or even 256 by 256 for full-screen DRCS.

Once this template is cut, it is mapped to the display screen using the spray-paint concept.

The primary difference between these two methods appears in the areas of speed and resolution. The first method is good when DRCS characters must be displayed very fast and with minimum resolution. If the DRCS is scaled to a much larger size, however, a crude image results from the pre-cut template. The crude image results from the fact that some of the information may be lost when the cutting is performed, especially if the template is very small.

The second method preserves all the information by maintaining the DRCS definition in its original form. If a large DRCS is requested (i.e., the character field is large), all the original information can be used to draw the character. The disadvantage of this method is that the original definition has to be decoded each time the DRCS is requested. This can be quite time consuming for a DRCS that contains several hundred bytes of definition.

These two methods are not the only ways of handling DRCS. As with most features of NAPLPS, no restriction is placed on the method of implementation. The cleverness of the implementation will determine how much of the original information is transferred to the user. The appropriate time, space, and cost trade-offs have to be made in choosing implementation strategies. These decisions,

of course, will help differentiate various companies' products. It would be an extremely boring world if NAPLPS were so restrictive that every terminal looked and performed *exactly* the same.

Fields

The last advanced feature to be discussed here is Fields. Fields are logical rectangular areas defined on the unit screen by the Field command (3/8). These areas are not visible to the user. Only one active field exists although, as will be seen, multiple fields can be defined as long as they do not overlap. Fields are used in a variety of ways in NAPLPS.

A common use of the Field capability is for setting margins. The Field command is used to establish the current active field, which is normally the entire screen. Each time a text character is placed on the screen, an internal cursor position is updated. If the boundaries of the field are exceeded, the cursor is moved to the other edge of the field in a manner compatible with most data terminals. If the cursor moves beyond the top or bottom of the field, a feature called partial screen scrolling comes into play. If scrolling is enabled, only the information inside the field is scrolled. The information around the field is not changed. Figure 5 attempts to show this concept.

Fields are also used to establish an area for high-resolution image display. The Incremental-Point command (3/9) can be used to specify the color information for each point inside a given field. In applications like real-estate listings, these features can be used to combine a photographic-like picture of a house with textual information concerning the same. Figure 6 illustrates a result that can be obtained.

But the most important use of the Field capability is for user input in systems such as videotex. As described in part 1, users are given one or more blank "sheets of paper" on their screen. The Field command is used to define where these sheets are placed.

When these so-called unprotected fields are placed on the screen, the

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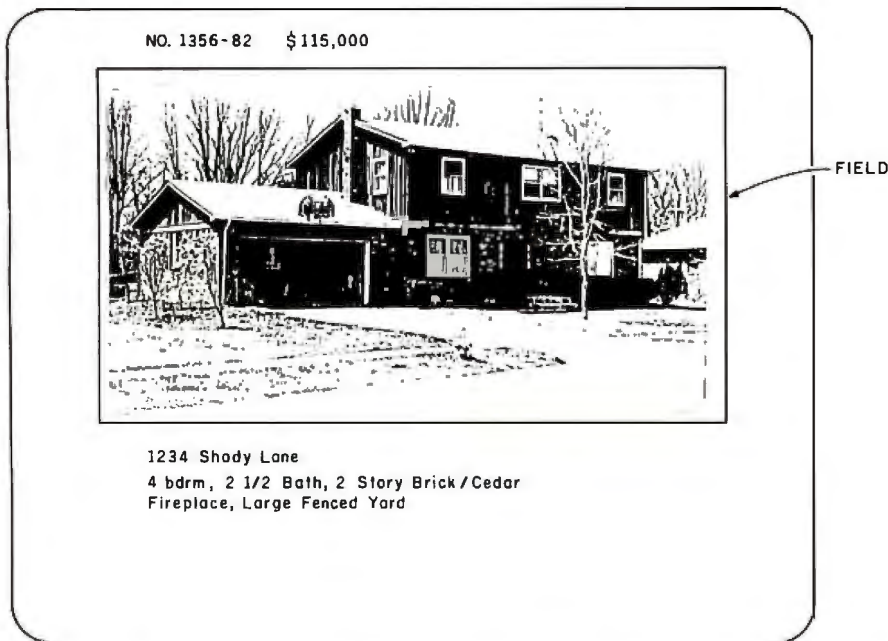


Figure 6: The Incremental-Point command can be used to specify the color information for each point inside a field. In an application such as real-estate listings, a photographic-quality picture of a house can be included with textual information.

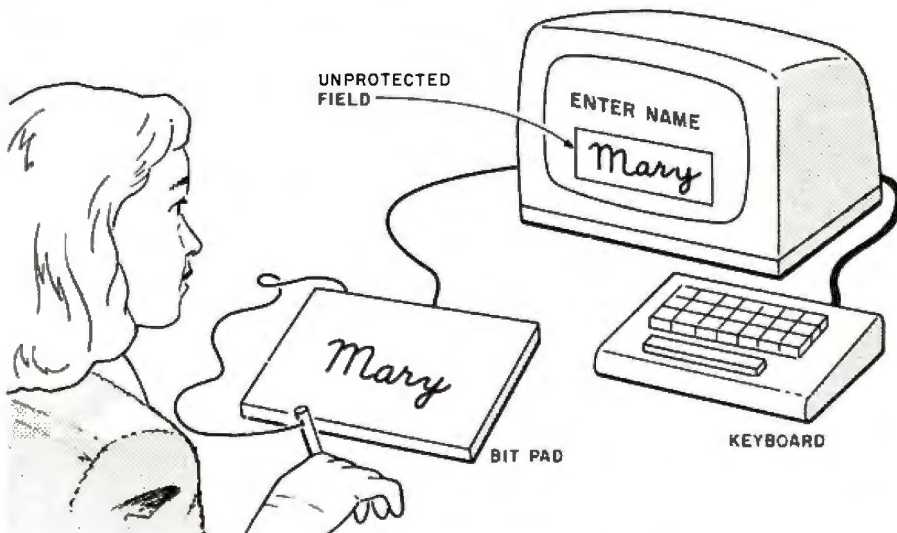


Figure 7: Input from a bit pad can be translated into a series of Incremental-Line instructions and placed into an unprotected (user) field.

user is allowed to enter information. The user can also edit the information with any local capabilities provided by the terminal. Once the information is entered, the user sends the contents of the field to the host.

Any legal NAPLPS stream can be placed in a field. In the example shown in figure 7, a person has used a bit pad to put a signature in the field. When the field is eventually sent to the host, the contents of the field would be an Incremental-Line command followed by a stream of data for the signature.

If, on the other hand, the user had typed information into the field, the information would be sent to the host as characters from the Primary Character Set.

The information that is sent to the host is identified with the location and dimensions of the field. If multiple fields are set up, the host is sent data only from the fields that are modified by the user.

The Field capability provided in NAPLPS is extremely versatile. In comparing this capability with the fields commonly found on data-processing terminals, you should note two items. First, the fields described here are true two-dimensional areas on the screen. This is quite different from the typical one-and-one-half-dimensional fields found on most terminals. Figure 8 illustrates this difference.

The other item of note is that NAPLPS places no restrictions on the user in regard to what type of information can be placed into a field. The

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1 1/2 DIMENSIONAL FIELDS

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2 DIMENSIONAL FIELDS

Figure 8: An example of the one-and-one-half-dimensional fields found in most terminal systems and the true two-dimensional fields possible with NAPLPS.

NAPLPS has many other powerful features. It is impossible to cover all the features in the context of this series of articles. As I have indicated in the past, anyone who wants more information about NAPLPS, or who is interested in doing serious work with NAPLPS, should obtain a copy of the specification. Copies are available for \$18 from

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options available to the user for entering information into fields become merely terminal-dependent features. Terminal manufacturers are thus able to provide unique input and editing facilities to distinguish their products.

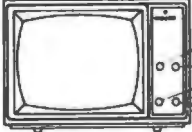

No facilities are available in NAPLPS to specify the type of data that can be entered into a field. Many data-processing terminals now forbid

you to enter, for example, alphabetic information into a numeric field. In contrast, the spirit of NAPLPS is to allow free-form user input.

Someday host computers may become smart enough to know that "100," "One hundred," and "1 hundred" all mean the same thing. NAPLPS will be ready to accommodate this capability when it becomes available.

Next Month

NAPLPS offers us a powerful new communications medium, one that should have a significant impact on the amount and the *type* of information we can exchange among ourselves. Next month, I will describe some of the advanced color capabilities and speculate on the ways in which NAPLPS will affect the personal-computer user. ■

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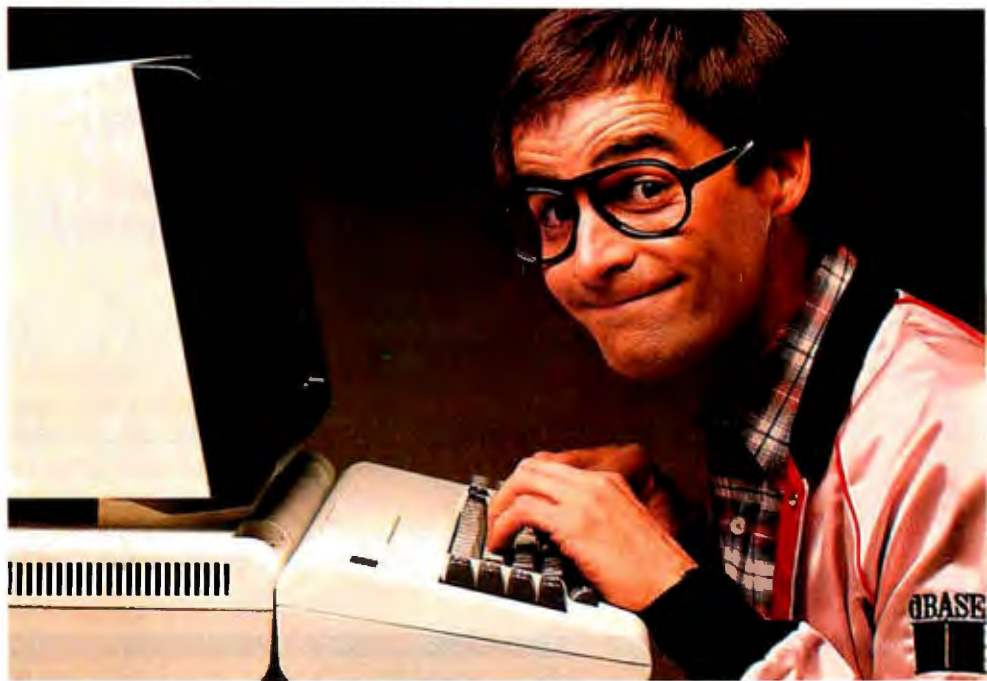
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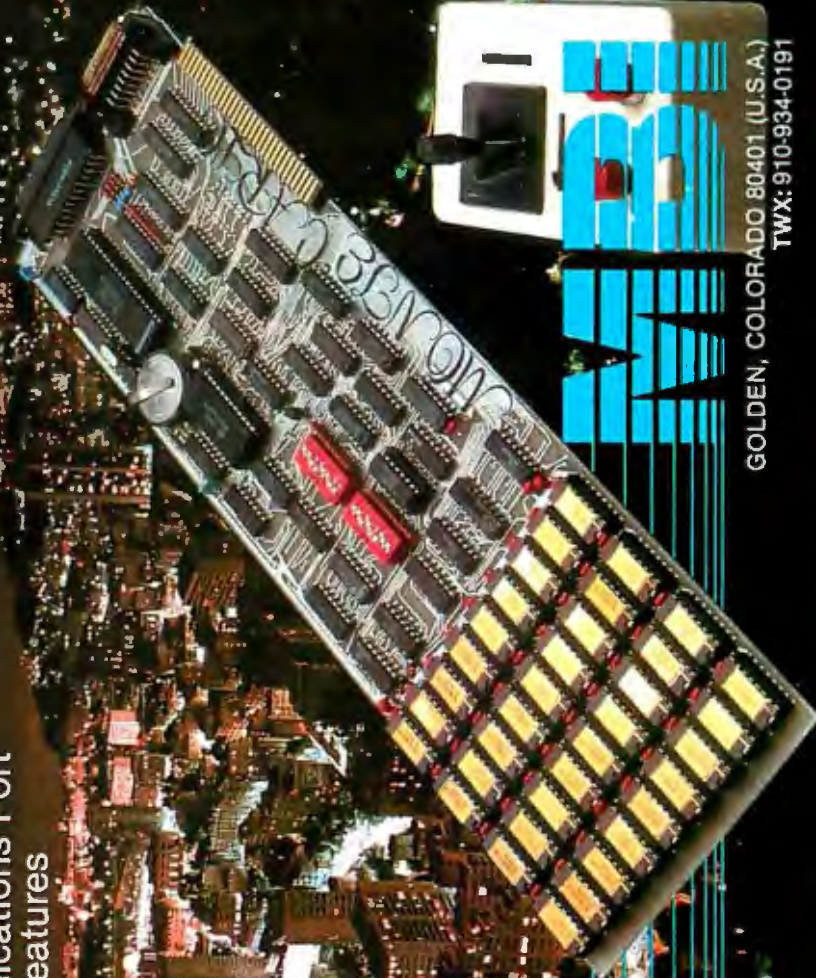
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Virtual Memory for Microcomputers

Four New Memory-Management Chips Pave the Way

Stephen Schmitt
2890 Sandhill Rd.
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Not too long ago, a microcomputer system with 32K bytes of memory was considered a luxury. Because memory was very expensive, you took great pains to squeeze, pack, and cram programs into the small amount of memory that you could afford. Today, however, you can buy 256K bytes for less than \$500. And new 16- and 32-bit microcomputers feature directly addressable storage spaces that are 100 to 10,000 times larger than those found in 8-bit architectures. Like the pauper who just became rich, how do you handle this vast wealth?

Another drastic change in the microcomputer world deals with software. Multitasking operating systems, high-level languages, and flexible business software have become popular. The problem is now more complex: How do we take advantage of both the increased hardware power and the new complex software?

Virtual-memory techniques offer

About the Author

Stephen Schmitt has worked for Hewlett-Packard and also taught at Michigan Technological University. He is now doing a review of a version of the Ada programming language for microcomputers.

one answer. Virtual memory is an automatic system for controlling very big memories. But special hardware functions are essential for building such a system. And now, single-chip memory-management units (MMUs) have been developed to provide these capabilities for microcomputers.

In the first part of this article, I will introduce some of the basic concepts

Virtual memory is a powerful concept. It allows you to consider main memory to be very large—much larger than its actual physical size.

of virtual memory. Next, I'll compare and evaluate four MMU chips that have recently become available: Intel's iAPX 286, Motorola's MC68451, and Zilog's Z8010 and Z8015. [This survey does not include the National Semiconductor NS16082 MMU for the NS16032 microprocessor. Because of its fairly recent introduction, the part was not evaluated for the review. The

NS16082 is another interesting MMU that merits analysis.] Finally, I will discuss some implications and applications of virtual memory in microcomputer systems.

Program Folding

Almost every computer system has several types of memory devices that differ in speed and storage capacity. A fundamental tenet of computer technology states that memory price is directly related to its speed. Storage hierarchies thus usually represent an effective compromise between a large, slow, inexpensive memory and a small, expensive one with high access speed. Familiar examples of this are systems with relatively small amounts of fast RAM (random-access read/write memory) and larger, slower, and cheaper disk-storage devices.

Although the cost benefit of such a configuration is substantial, the efficient management of this structure presents a challenge. The movement of data between these two hierarchy levels should be minimal; otherwise, the access time for the slow memory will predominate over the speed of the fast memory. In a typical two-level system, main memory (MM) is

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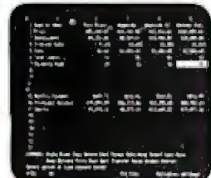


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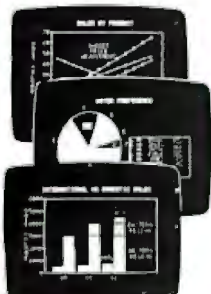


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1000 to 5000 times faster than the magnetic disks used for secondary storage. Thus, disk accesses should be as infrequent as possible if we are to take advantage of the high speed of the main memory.

Another problem is that the relatively small size of the main memory in most systems limits program size. An excessively large program must be broken into parts; each piece is loaded into main memory prior to its processing turn and returned to disk after execution. This technique is called *folding* or *overlaying*, and the task of folding programs is usually a job for the programmer. The problem is that the mechanics of defining separate program parts and adding code to control data transfer between main and secondary memory are usually cumbersome tasks. Also, the additional folding code clouds program logic. Compilers and linkers can simplify the task, but you must still design the overlay framework.

Despite these difficulties, however, folding operations are common. In fact, the word processor I'm using to write this article applies the concept twice. First, the program is too big to fit completely into memory and is divided into three overlays. Second, only a portion of my large text file resides in memory at a given time—the rest is stored on disk.

As you can imagine, manual folding consumes considerable time and effort (as much as 25 to 40 percent of programming costs). But there is a way we can take advantage of the benefits of large, sophisticated programs without spending a tremendous amount of time manually folding them to fit into small memory spaces.

Virtual Memory: Definition

Computer facilities that automatically fold programs and data between two or more memory levels are called virtual-memory systems. Virtual memory is a powerful concept. With it, you can consider main memory to be very large, much larger than its actual physical size. Intermediate files, overlays, and many file-access procedures are no longer necessary. Pro-

gram logic is simpler and is focused on problem solutions, not critical resource management.

The objective of virtual memory is straightforward: to permit programs with very large address spaces to run at MM speeds. In virtual systems, main memory serves as a window (or group of windows) onto the entire address space held in secondary memory. If the window is big enough, and if it accurately reflects the active part of total memory, the technique works extremely well.

The reason for this is that programs tend to access small portions of memory over fairly long periods of computer time. This is called *clustering* or *locality of reference*. Code loops and manipulations of a data structure are examples of clusters or programs with good locality. A virtual system must detect and maintain in main memory only the *working set* of a program,

Address space in a typical virtual system ranges from 16 megabytes to 64 gigabytes, enough to handle very ambitious programming projects.

that is, those locations with high activity. As activity gradually shifts to other memory regions, these areas of secondary storage are automatically accessed and brought into main memory. As you might imagine, a high rate of secondary-storage access will severely degrade performance. This is known as *thrashing*.

Benefits

Let's examine the benefits of virtual-memory management. Foremost, it removes the limit on program size imposed by main-memory size. Address space in a typical virtual system ranges from 16 megabytes to 64 gigabytes—large enough, I dare say, to handle even the most ambitious programming project! And virtual systems offer other advantages:

- Main memory is allocated automatically according to the demands made

by a program. The user does not have to estimate memory allocation prior to execution.

- Manual folding is eliminated and replaced, in part, by high-speed hardware. Thus, programming costs tend to be lower.

- Programs execute correctly regardless of actual main-memory size. But note that the execution speed may be affected if the fast store is too small to meet average memory requirements.

- Relocation and task switching are enhanced indirectly.

- Multiprogramming environments have greater flexibility. The problem of deciding the optimal placement of programs in a fixed-size memory is reduced. More programs can execute concurrently because only the active portion of each occupies main memory. While this may induce less efficient use of the total addressable space, more effective use of the main memory is achieved.

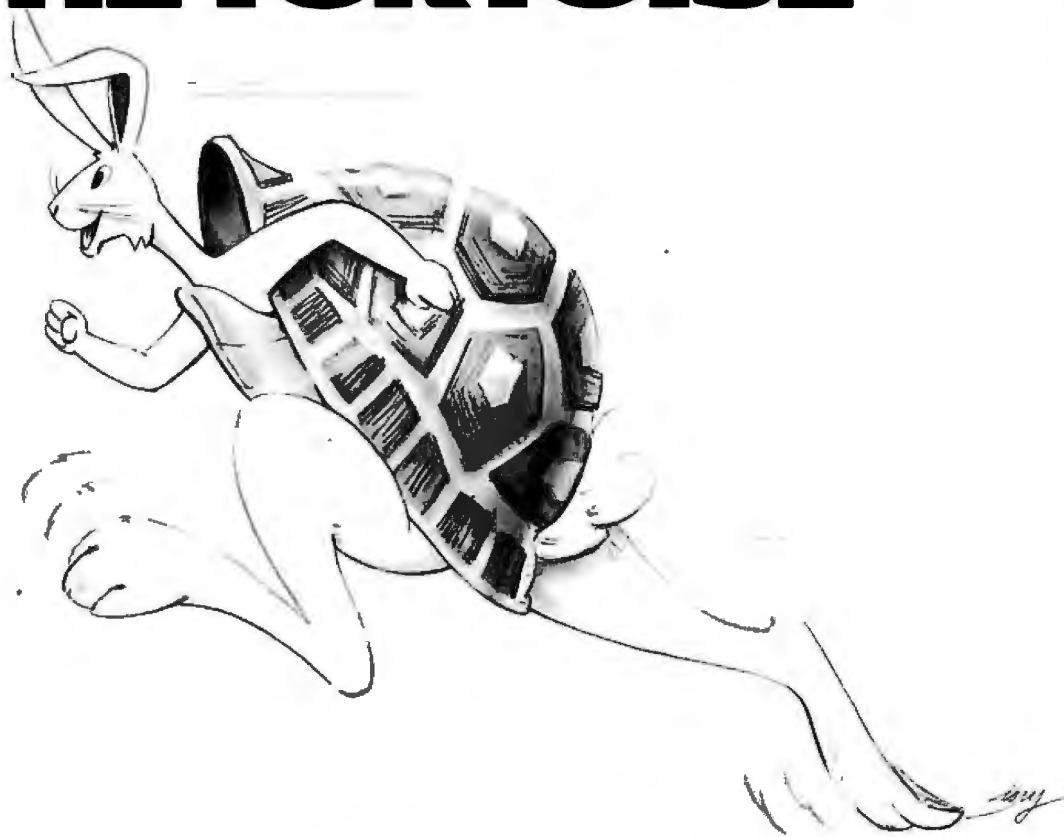
Having outlined the motivation for virtual storage, we are ready to explore basic components of system design. The memory-control process must be transparent to normal operation and relatively efficient. On face value, you might doubt if reasonable performance is possible, but research into virtual-memory behavior clearly demonstrates the concept's potential (see reference 2). I hope to show that some practical systems can also have a remarkably simple design.

Virtual-Memory Design: Basic Concepts

Virtual storage systems require a mixture of specialized hardware- and software-control policies. I will focus on architectural features that influence virtual-memory operation. An understanding of intended applications should aid our analysis of MMU products later.

A computer's *address space* (AS) is the legal range of addresses that can be generated by its instruction set. The maximum size of this is determined by the number of bits in the processor's address register. A *logical address* is a memory specification used by the central processor. *Physical addresses*, on the other hand,

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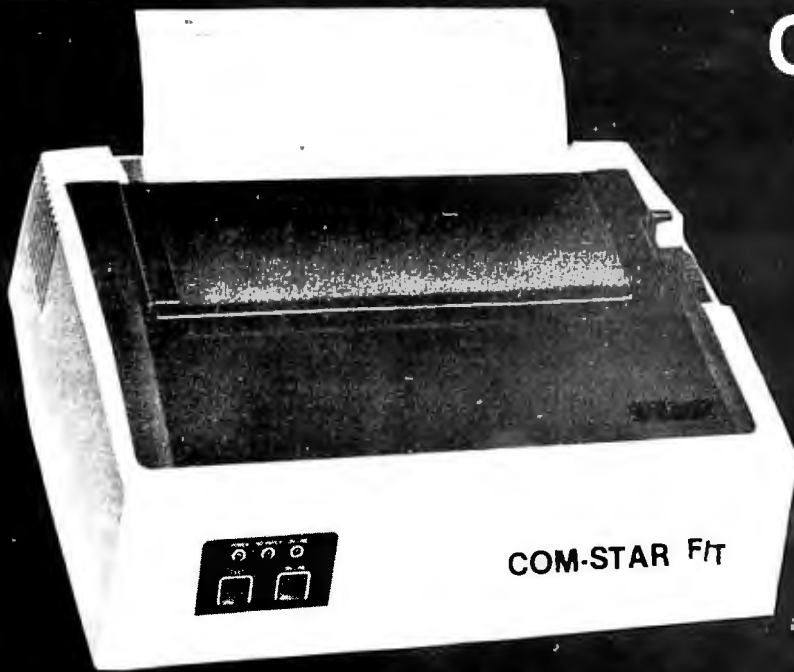


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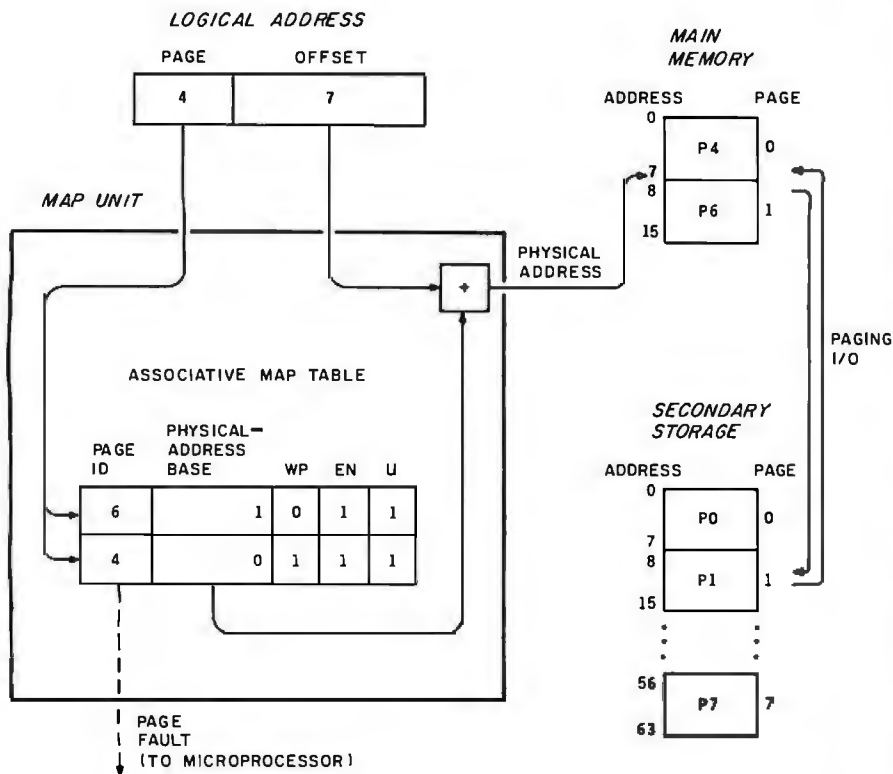


Figure 1: The associative mapping scheme for virtual-memory systems. The central processing unit specifies a memory location with a two-part logical address that includes a page field and an offset field. The page field provides the value used for searching the map table. All cells in the table are searched in parallel. If a match is found, the selected cell's physical-address-base field is added to the offset field. A page fault occurs when there is no match. In this simple diagram, the second cell matches and translates the logical address. The attribute fields in the above map table are WP (write-protected), EN (valid main-memory page; EN = 0 only when main memory is not full), and U (used; recent page access has occurred).

describe actual locations in the main memory. In most systems, logical and physical addresses are one and the same (as, for example, in 8-bit microcomputers). With a virtual system, however, the size of the AS can be significantly larger than main memory. The AS may be thought of as occupying a contiguous area in secondary storage; and logical addresses no longer correspond exactly to actual physical RAM locations.

In a virtual system, main memory contains changing portions of AS. At various times, an instruction may address a part of the AS that is not contained in main memory. This is known as a *page fault*. A virtual-memory system must be able to detect a page fault and move the desired part of the AS into main memory. Then, when that part is subsequently addressed by an instruc-

tion, the system must be able to translate that part's logical address into its present physical address in main memory. This is known as the *mapping process*. Both these processes, page-fault detection and mapping, are fundamental to every instruction step. They must therefore be performed by high-speed hardware.

A page fault stops execution of the current activity that the central processor is performing (e.g., fetching an instruction or processing operand data) until the absent memory is brought into MM. A page fault is similar to an interrupt except that it may occur partway through instruction processing. Thus, special processing logic is needed to handle partially executed instructions (consider the problems associated with restarting a MOVE BLOCK instruction).

In a virtual system, memory can be



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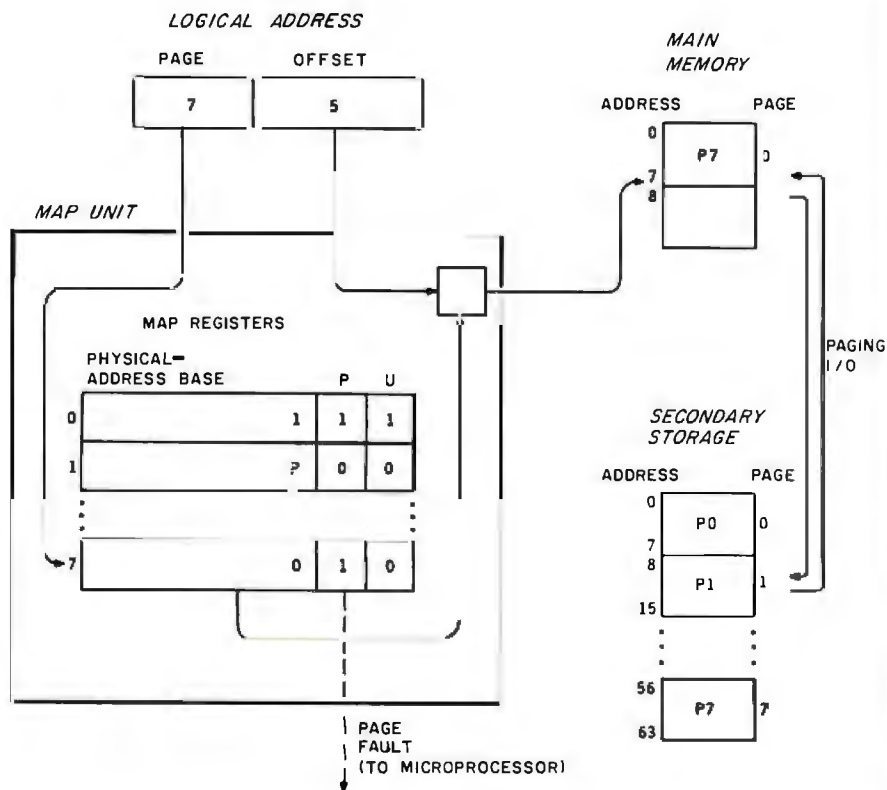


Figure 2: The mapping-by-address (or mapping-by-register, MBR) scheme for virtual-memory systems. This is similar to associative mapping except that each map cell is a register that refers to a page in secondary storage. In this simple example, the page field in the logical address refers to register 7, which in turn refers to page 0 in main memory. If register 1 had been accessed instead, a page fault would have occurred ($P = 0$). Page 1 would then be placed into main memory, probably in the space now occupied by page 7, because page 7 has not been accessed recently ($U = 0$).

divided into either *pages* or *segments*. A paged policy divides memory (both AS and MM) into equal-size blocks. The rationale for pages relates to the clustering principle. Memory activity occurs in scattered parts or clusters of the AS. By organizing storage into pages, you can "break out" the busy sections and place them in main memory. Paging, like disk blocking, also implies a smaller number of data transfers between disk and main memory.

Segments are merely pages of variable size. Segments can closely model program units because code modules and data structures vary in size (as do clusters). Trade-offs exist between page and segment organizations. I'll discuss these later. For now, you can ignore the distinction and call both pages.

Several mapping schemes exist for virtual systems. Figures 1 through 3 illustrate three common techniques.

In the examples, logical-address fields are composed of two parts: a page field and an offset field. The logical page number is translated into a physical location by the map unit. Adding the offset field to this location forms the complete physical address. A simplistic memory model will be used to show the basic operations of each technique.

Associative mapping is shown in figure 1. The logical-address page field is compared, in parallel, to all page entries in the map table. If an entry matches, its corresponding physical-page address is combined with the offset value to form the complete physical address. A page-fault condition is raised when no match occurs. The problem with associative maps is that they are expensive. High-speed register memory with integrated comparative logic is needed; translation has to be fast and transparent. The associated map has to be as large as



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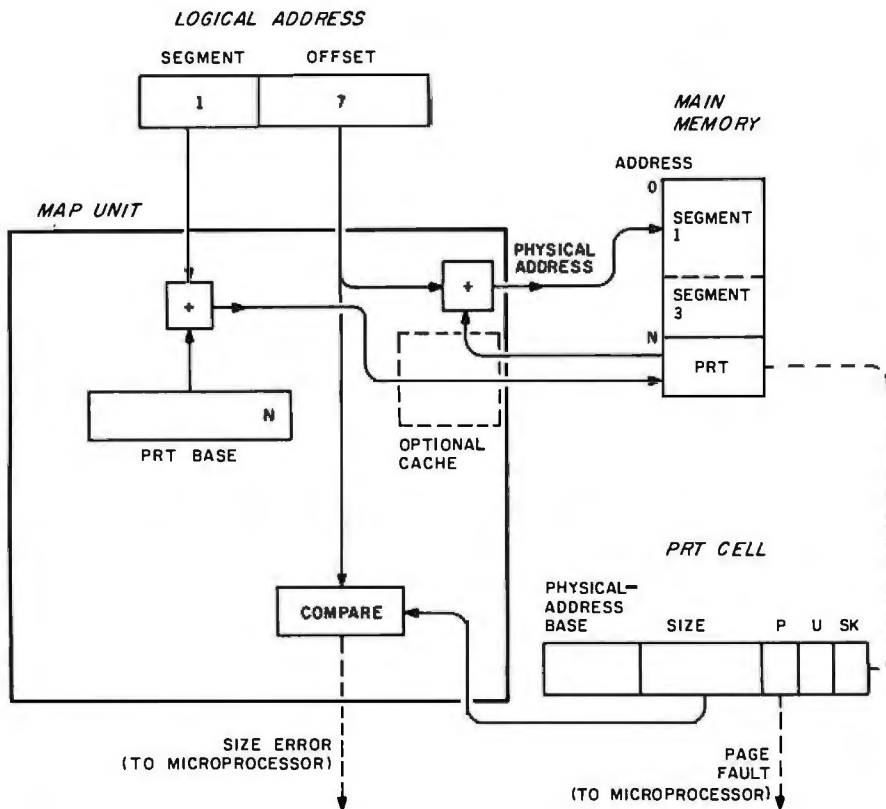


Figure 3: The segment map table scheme for segmented virtual-memory systems. In this mapping scheme, information on each segment of a program in secondary storage is kept in a program reference table (PRT) in main memory. The location of the PRT is stored in a PRT Base register. In this simple example, the segment field in the logical address is added to the contents of the PRT Base register (N). This refers to a map cell at location $N + 1$. In this map cell is a physical-address base that is added to the offset to obtain the desired address in main memory. Note that bounds-checking can easily be done by comparing the offset with the size field. Also, note that things can be speeded up by placing the most active map cells in a small associative cache memory. The attribute field SK indicates a stack segment (i.e., the offset orientation is reversed).

the number of MM page frames. If you change the size of main memory, you have to change the map size accordingly. Associative mapping works best for systems with a large number of AS pages and a moderate-sized, fixed main store.

Figure 2 illustrates *mapping by address* or mapping by register (MBR). In this technique, the logical-address page field refers to an array of high-speed registers. These registers hold status and physical-address information. Mapping by address is analogous to indirect memory addressing except that the registers permit very high processing speeds. Page faults are detected when the addressed register's "present" bit is clear. The problem is that every page in the AS requires a corresponding map register. Fortunately, the economy of conventional registers offsets the mapping array size. Note that the mapping hardware is unaffected by changes in MM size. For relatively small address spaces, mapping by address is quite attractive.

The last technique I'll present applies to segmented systems. Figure 3 design is based on the Burroughs Corporation B5500 mainframe. This approach gives you more flexibility, but is slightly more complex and necessitates additional hardware (for the

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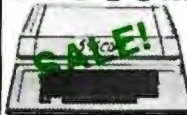
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segment-size field and the *program reference table* or PRT). A segment field replaces the logical-address page field. You can have any number of system segments; MM and AS sizes do not constrain the choice. Translation is similar to mapping by address. The program reference table contains the size and location for each segment. It resides in main memory for two reasons: (1) to allow a large number of segments, and (2) to avoid the high cost of registers that would be wide enough to hold extra mapping data. The table acts like mapping registers, with the segment field—not the page field—providing the index address. At first glance, it looks as if the scheme is twice as slow as the others because every reference needs two memory accesses (one for the PRT and one for the actual data). But this problem can be handled by putting a small buffer-register set in the MMU. Keeping copies of the most active PRT entries in this high-speed buffer greatly increases mapping speed.

Besides translating addresses, mapping units also provide other functions. They hold information to aid memory management and data protection. Table 1 is a list of information found in various mapping systems. Each virtual system uses a subset of these items, determined by the particular mapping scheme used and the memory-control functions.

Up to now, attention has centered on the hardware aspects of virtual systems. Now, let's consider the memory-management and software requirements for virtual systems.

Paging Policies

As mentioned previously, a minimal amount of secondary-storage access is central to a virtual system's viability. Figure 4 shows a graph of disk activity versus main-memory size allocated to a program. From the graph, we see that given enough main memory, disk access approaches zero. However, a primary aim of virtual memory is to provide a huge address space while minimizing expensive main memory. To satisfy both conditions, you must operate at a point just below the "knee" of the

Field	Abbreviation	Description	Field Size (bits)	Memory Structure (Segment vs Page)
Present	P	Indicates if page is present in main memory	1	Both
Used	U	Indicates if page has been recently accessed	1	Both
Dirty	D	Indicates if page has been modified	1	Fixed-page
Type		Various page properties	1-4	
	RP	Read-protected		Both
	WP	Write-protected		Both
	EX	Executable code		Both
	SH	Shared		Segment
	SK	Stack memory		Segment
	OW	Overflow warning		Both
Size	SZ	Size of segment	16-32	Segment
Priority or mode	PR	Indicates task priority or system context to permit access	1-8	Both
Virtual time	LREF	Time of last access to page	12-32	Both
Task ID	TID	Identifies task(s) that owns the segment	8-16	Segment
Fix	F	Indicates that page is not to be replaced	1	Both
I/O access	IO	Protect or hold page for input/output	1	Both
Enable	EN	Indicates valid pages for access (when main memory is not full)	1	Both

Table 1: A summary of the control and status information-used by virtual-memory mapping units. Most mapping schemes use a subset of these different attribute fields.

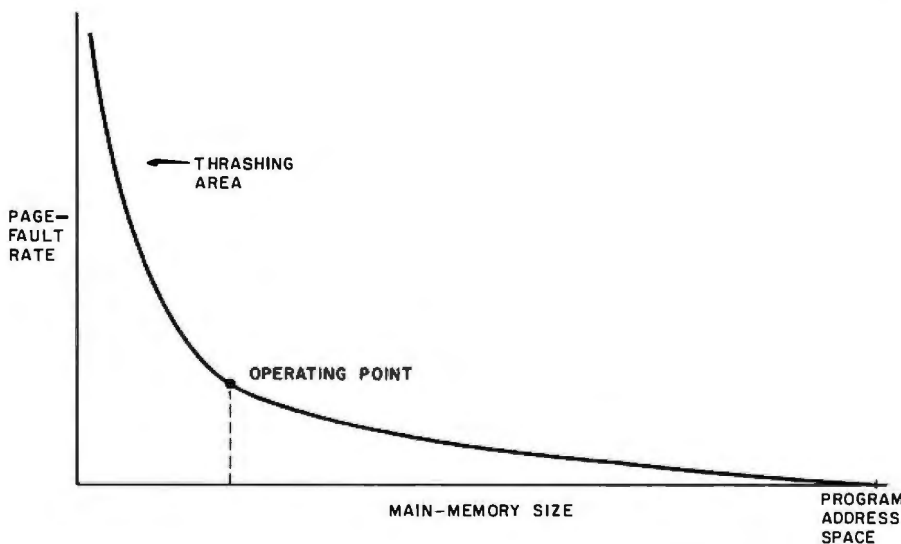


Figure 4: A graph showing how the page-fault rate (i.e., the rate of accesses to pages not present in main memory) is related to the size of main memory. The operating point is the memory size sufficient to hold a program's most frequently accessed routines—its working set. Adding memory past this point has little effect on the page-fault rate. Of course, as the needs of a program change, the operating point will shift.

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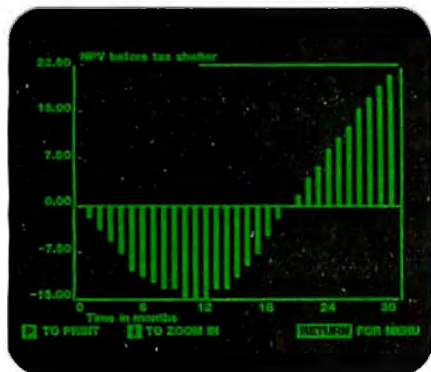
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curve (labeled operating point). The locality principle states that the amount of MM needed at any given time is but a small portion of AS. Hence, if you keep the active cluster or working set in memory, thrashing and main-memory needs are minimized.

Sounds simple, doesn't it? Alas, a few minor problems "gum up" matters. For openers, measuring a system's working set is a dynamic process. The size and contents of a working set change rapidly. Keeping track of working sets involves considerable time, resources, and problems. Just how is this working set determined? At what times do we change the working set to reflect locality movement? What happens when several programs are running or there is program I/O? All these problems are handled by a *paging policy*.

Basically, a paging policy does three things:

- Fetching—decides when to transfer pages from secondary storage to main memory
- Placement—determines which MM page frame should hold the fetched page
- Replacement—when main memory is full, chooses which MM page frame should be replaced by the fetched page

In regard to fetching, research has found that demand paging is generally best. When a page fault takes place, you fetch the desired page from secondary storage. The placement decision is resolved automatically by mapping hardware. The last issue, however, choosing which page to replace, is the hard part. The replacement policy affects how well we address the other concerns mentioned above.

Page-replacement techniques, which determine the set of main-memory pages, are all approximation algorithms. This is so because you can't calculate the best page to remove without some future knowledge of which page will be required. The optimal algorithm (OPT), or Belady's algorithm, replaces the ac-

tive page that is next referenced the furthest into the future. Even though totally impractical, it is a benchmark for comparing other techniques.

Page-Replacement Algorithms

Virtual-system performance is very much dependent on the page-replacement technique that is used. Because the process selects departing pages, it indirectly determines the pages remaining in main memory. If the algorithm closely models a system's actual working-set memory demand, few page swaps will result. Algorithms usually base removal choices on prior reference activity, because the locality principle implies that past behavior approximates future needs (at least over short time periods).

Here I will discuss four specific page-replacement algorithms: Least recently used (LRU), Clock, Generalized working set (WS), and WS-Clock.

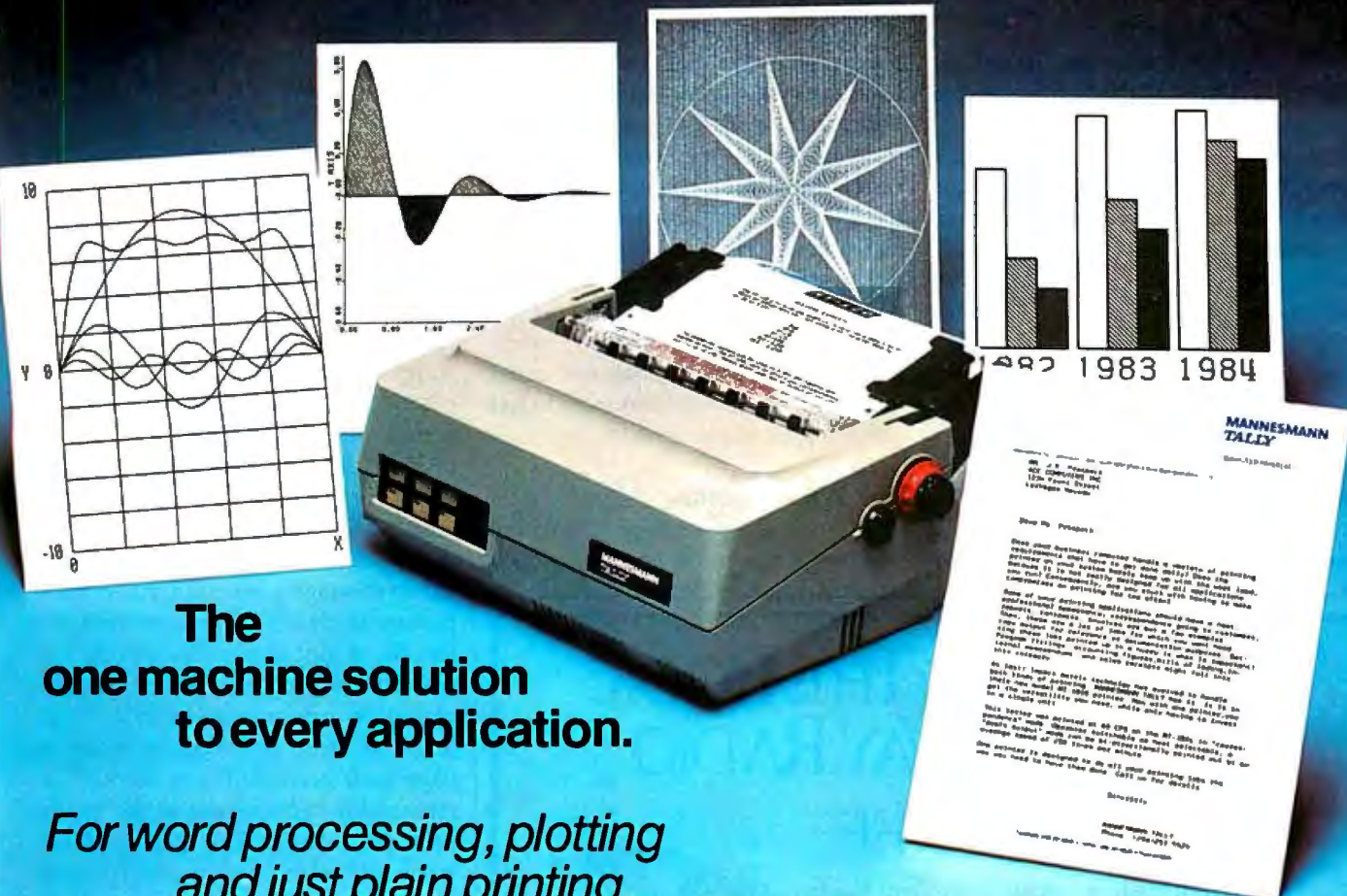
The LRU Algorithm

This page-replacement policy is conceptually related to the optimal algorithm. Instead of selecting the page with the furthest time until next access, you pick the page whose last reference occurred longest ago. If not used for a long time, the probability that the page will soon be referenced is small. When a page fault happens, you scan the map cell for each page and replace the page having the smallest (oldest) virtual time.

To implement LRU, the memory-management hardware must support two features: a virtual time register in the map unit and the ability to update the page access time during address translation. The time register should be wide enough to ensure sufficient resolution. In addition, the necessity of associating a time stamp with every memory reference dictates high-speed logic and added map complexity.

The LRU algorithm works well. Its performance is much better than that of an arbitrary replacement policy or many other paging policies. But because LRU is a *global policy*, it can exhibit anomalies in multitasking systems. For example, global LRU tends to save pages of the task last executed

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and favors jobs with smaller locality; low-priority tasks and large programs may experience reduced throughput.

Computer systems using LRU include the CDC Star-100 and the Multics drum-to-disk control. Micro-computer MMU parts lack the hardware mechanisms needed for a "pure" LRU policy.

The Clock Algorithm

This algorithm is a variation of the LRU algorithm. Main-memory pages are logically ordered in a circular list. You can envision each page as a unit marking of a clock face. A pointer or hand always points to the last page replaced. On a page fault, you advance the pointer clockwise to the succeeding page. Then you check and clear that page's *used* bit. If the bit was set (i.e., the page was used recently), scanning continues; otherwise, the frame is not recently used and replaceable. If the replaceable page has been changed (or *dirty*), you must schedule it for transfer back to secondary memory. Scanning stops

when a clean, not recently used page is found, and the pointer is left at the chosen page. A replaceable page is not processed if accessed before the disk transfer.

Studies indicate that the Clock algorithm closely simulates LRU replacement, and the hardware needed is inexpensive. As implied above, only 2 flag bits per cell are required (changed and used). Software complexity and overhead are small. Calculations are trivial and the average number of scans per page fault is a fraction of total map size. Many successful mainframe systems, including the IBM 370 and Multics, use Clock algorithms. However, you should note that deficiencies of LRU apply equally to Clock. The technique offers a simple mechanism and good efficiency; but, as you shall see, other paging algorithms exhibit even better performance characteristics.

The WS Algorithm

This page-replacement algorithm represents the most practical policy

according to empirical studies. WS is so named because it approximates the working-set locality model. In WS, any page referenced within a specified time (designated as Θ) is regarded as a member of the working set. Real working sets of course have variable durations, but if the WS time-control value (Θ) is properly chosen, a real working-set model can be closely approximated.

I will briefly highlight WS operation (see reference 1 for details). The WS policy defines a working set (W) to be those pages of the AS that have been referenced within the previous Θ time units. In order to determine when a page (p) in main memory is no longer in W , and thus is replaceable, we need two things: (1) a procedure to calculate a time value (L) equal to the owning task's current execution time (ET) minus the last reference time for every AS page, $LREF(p)$, and (2) a scan mechanism to check for values of L greater than or equal to Θ . Calculating L can be done with page-frame counter registers. When the page is accessed, its counter register is cleared. Then, at fixed intervals, a global broadcast pulse increments all the counters. The scan operation can run at various times (e.g., at fixed intervals or when a page fault occurs). Pages marked as replaceable become part of the available pool (AP). The page-replacement algorithm merely selects some page from the AP and replaces it. If the AP is empty, the system must suspend a task to free pages.

Although WS accurately models dynamic-memory demands, the computational overhead and extra hardware support it requires diminish the algorithm's viability. Space for the $LREF(p)$ field can effectively double page-table size. Moreover, the counter mechanism is relatively expensive. Scanning requires inspection of each map cell at regular intervals, and AP maintenance adds more control functions. On the plus side, the local scope of WS enforces more consistent multitasking management. And pure WS simulations perform better than other policies. Research systems have implemented practical WS schemes and observed substantial

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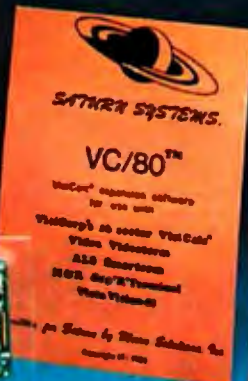
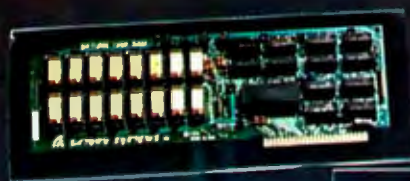
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improvements over Clock techniques. The parameter Θ allows you to "tune" a virtual system for different applications. Also, investigations have found that use of the constant value Θ deviates less than 10 percent from an optimal WS.

WS is technically appealing, but design difficulties detract from its advantages. Like LRU, classical WS is impractical for microcomputer application. But the next technique surveyed approaches WS performance and is feasible for microcomputers.

The WS-Clock Algorithm

WS-Clock combines the best properties of Clock and WS. Additionally, the new strengths offset some problems of the separate procedures:

- the extra scanning required by WS is replaced by a simple Clock mechanism
- WS-Clock is a local policy
- LREF(p) registers are needed only for main-memory pages, not for

every AS page

- the available pool (AP) is eliminated

This algorithm organizes page frames in a circular list like Clock. The clock pointer identifies the page replaced during the last scan. When a page fault occurs, the scan advances clockwise to the next page. The used bit is checked and cleared. If the bit was set, you reset the page's LREF(p) to the owning task's accumulated execution time (ET). Otherwise, if the used bit is clear and if $L = ET - LREF(p) > \Theta$, you remove the page from W. If dirty, a replaceable page is scheduled for disk transfer and not replaced. Scanning halts when you encounter a clean, replaceable page.

WS-Clock approximates WS replacement, and W for the two policies becomes equivalent when the task executes for Θ units of time. Performance differences appear negligible and can be ignored. Thus, WS-Clock approaches WS behavior with a significantly simpler mechanism. The

average number of frames examined per page fault compares favorably with WS. And to implement WS-Clock, you need minimal map hardware: a used bit, a dirty bit, an LREF field, and a task ID descriptor.

Multitasking and Load Control

In a multitasking system, virtual-memory management must coincide with general resource-sharing policies. The problem is that in a dynamic multiprocessing environment, wide variations in programming level and memory demand occur. Every active task consumes a portion of total memory (in both MM and AS). At some point, adding another task will push MM demand past the ideal operating point in figure 4 and trigger the onset of thrashing. Left unchecked, throughput diminishes rapidly. Accordingly, you must either prevent the "overcommitment" of memory or recognize the condition and make corrective adjustments. This is done by a load-control policy.

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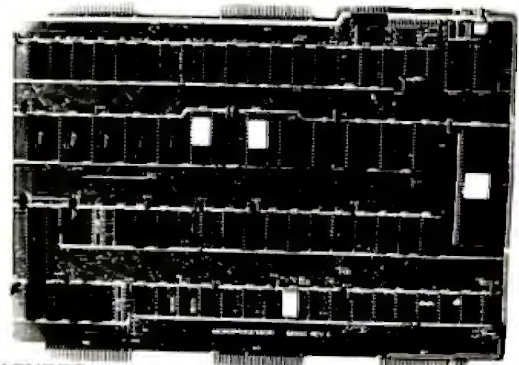
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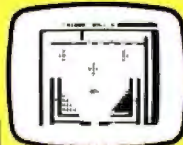
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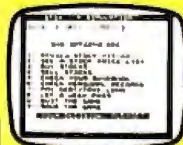
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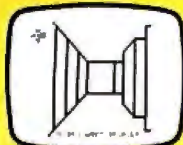
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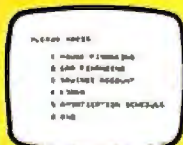
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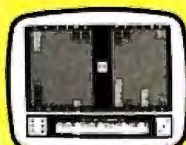
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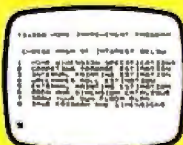
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Function or Characteristic	Memory Structure	
	Segments	Fixed Pages
Flexibility	+ Can model pages, has more design options, promotes protection, data sharing, and so on	- Lessens "tuning" options, trade-off exists between efficient I/O blocking and memory waste
Hardware requirements	- Cost and complexity fairly high	+ Lower cost, simpler hardware
VS(1) systems	+ Better security	+ Simpler design
VS(n) systems	+ Segments are mandatory for VS(n) designs	0 Not applicable
Mapping unit		
Map-register size	- More space needed for size fields	+ Minimal
Table size	+ Fewer frames needed if segments are large	0 Larger pages result in memory waste
Memory management overhead	- Extra logic needed to close "holes" and to manage extra attributes	+ Placement simple
Allocation policy	+ Make segments the desired size	0 More complex, but no main-memory waste
Protection	+ Superior—facilitated by extra attribute fields	- Pages do not correspond to program "objects"
Sharing	+ Direct support	- Much harder
I/O efficiency	0 Depends on segment size	+ Facilitated by relating page size to disk block size
Memory usage		
Internal fragmentation	+ None	- Some main memory wasted
External fragmentation	0 Can reclaim with "garbage collection"	+ None
Page-fault rate	+ Lower rate	0 Depends on page size

Table 2: A comparison of the relative strengths and weaknesses of segmented and fixed-page memory organizations. The +/− column indicates approximate merit: (+) good; (−) poor; (0) okay or does not apply.

Load control is sensitive to page-replacement strategy. Local strategies estimate each task's independent memory needs and allocate sufficient main storage to hold the locality set. Global page-replacement strategies discriminate in favor of the most recent task's memory set and can lead to thrashing.

System Design: Issues and Options

Virtual memory reflects a composite of hardware, resource management, and programming processes. We now turn our attention to alternatives that can affect overall micro-computer system design.

VS(1)

A fundamental system decision is whether you treat the large virtual

address space as a shared resource divided among the several active jobs or whether each process is provided a separate AS. The first class, termed VS(1), extends the idea of a conventional operating system where supervisor, system resources, and user tasks occupy one large address space. Software compatibility with non-virtual systems is a major benefit of this system. System complexity is minimized and a single mapping table can define AS structure.

VS(n)

VS(n) systems give each executing task a unique AS. To support this feature, every job has its own mapping table. Typically, a mapping-table origin register (MTOR) points to the mapping table of a running task. When switching tasks, you change

the MTOR and reload the mapping hardware. A VS(n) system gives you, in effect, several virtual machines, each using the same physical resources, running concurrently. VS(n) systems also give you improved system integrity and data protection.

Page Size

An important design consideration is block memory structure. If you select a fixed-page structure, you must determine the number and size of page frames. Secondary storage transfers data in fixed-size units. Hence, for efficient paging memory frames should be an integer multiple of a disk block. Big pages reduce disk overhead and map hardware. On the other side of the coin, however, a large number of small pages lowers page-fault rates and increases the number of locality sets. Some compromise is in order. My research indicates that 1K- to 4K-byte pages are considered optimal.

A segmented address space reflects programming features such as scope rules, data encapsulation, modularity, and so on. Pages, being constant in size, usually waste some memory, a condition termed *internal fragmentation* (e.g., a 5K-byte program takes two pages in a system with 4K-byte pages—3K bytes are unused). Although segments avoid this problem, they are prey to a form of waste called *external fragmentation*. Because variable-size units are allocated, program termination leaves holes of unused space. You must close up these areas periodically to provide sufficient space for large segments. Consequently, the procedures to reclaim these holes add to operating overhead. In general, segmented schemes offer more flexible designs while page organizations make for easier memory management. Table 2 summarizes trade-offs between page and segment organizations.

Many other topics related to virtual memory have not been covered: operating-system interaction, I/O considerations, page locking for non-swappable memory, disk-access properties, and more—the subject is rather deep. However, the topics

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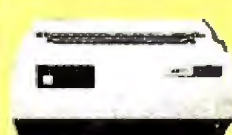

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to extend the address space of limited-address machines (e.g., the HP-1000 or DEC PDP-11 minicomputers).

A Survey of MMU Chips

The main thing we'll look for when examining these MMU products is how well they implement virtual-memory concepts. We'll review four products: Zilog's Z8010 and Z8015, the Motorola MC68451, and Intel's iAPX 286 processor/MMU. The Zilog chips are to be used primarily with the Z8003 16-bit microprocessor for virtual storage. The MC68451 MMU is designed to work with the soon-to-be-released MC68010 processor. Finally, the iAPX 286 represents a combination of both an 8086-compatible processor and an integral memory-management unit.

The Z8010, MC68451, and iAPX 286 feature segmented-memory architectures. The Z8015, however, is designed specifically for a fixed-page virtual-memory system. All four units support a 16-megabyte physical-address space. Logical-address spaces range from 8 megabytes for the Zilog chips to a whopping 1 gigabyte in the iAPX 286. Tables 3 and 4 compare the basic properties of these chips on a point-by-point basis. As the tables show, there's quite a bit of diversity. For each MMU, I'll point out its unique characteristics, operation, and programming details. Later I'll describe some applications for virtual memory.

The Zilog Z8010

The Z8010 was one of the first single-chip MMU devices on the market. As a consequence, it has a few flaws that have been corrected on newer products. In fact, virtual memory appears to have been an afterthought for this chip because you will need extra hardware to handle the Z8000 microprocessor's page-fault procedure. Still, the product does have good protection features, and it directly supports a supervisor mode for operating-system functions. Another virtue is its fast translation time.

The Z8000 architecture defines logical addresses for 128 segments,

Text continued on page 234

FUNCTIONAL CHARACTERISTICS	MEMORY-MANAGEMENT UNITS			
	Intel iAPX 286	Motorola MC68451	Zilog Z8010	Zilog Z8015/PMMU
Address-translation delay (10 MHz)	0-1.5 μ s	100 ns	60 ns	70 ns
Supports multiple MMUs?	No	Yes	Yes	Yes
No. of MMUs needed to map address space	1	1	2	Depends on MM size
No. of unique address spaces possible (no. of users)	Unlimited	256	8	8
VS(n) support?	Yes	Partial	No	No
Priority levels	4	0	0	0
User/supervisor modes available?	No, uses priority levels	Yes	Yes	Yes
Data sharing?	Yes	Yes	Limited	No
MMU control method	Special instructions	I/O program	I/O program	I/O program
Fault restart data	None	Limited	Moderate	Extensive
Control and status attribute names (dash indicates not supported)				
Present	P	—	CPU	—
Used	A	U	Ref	Ref
Dirty	—	M	Chg	Chg
Write-protected	W	WP	RD	RD
Read-protected	R	—	—	—
Executable code	E	—	Exc	Exc
Shared	—	AST	—	—
Stacked memory	ED	—	DIRW	DIRW
I/O access	—	—	—	DMAI
Overflow warning	—	—	DIRW	DIRW
Virtual time	LREF	—	—	—
Task ID	(Yes)	(Yes)	(Yes)	(Yes)
Fix	F	—	—	—
Enable	—	E	—	Valid

Table 3: A comparison of the functional characteristics of the four surveyed memory-management units.

covered should give you the perspective to analyze the capabilities of the new memory-management units for microcomputer virtual-memory systems.

Memory Management

The need for a memory-management unit (MMU) derives from two concerns: efficient control of large memories and support for multiprocessing environments. We can summarize the major goals of memory management as follows:

- **Memory allocation**—Allocation policies determine what portions of memory are committed to particular tasks. Address translation allows you to treat physically separate blocks as logically contiguous. Dynamic allocation, which adds memory during execution, is a valuable feature. A

virtual system's large address space makes allocation less of a concern.

- **Program relocation**—Relocation hardware permits a program to load anywhere in physical memory without changing the logical addresses. Systems that swap tasks to disk may need to relocate a program when it's reloaded.

- **Protection**—This prevents inadvertent or unauthorized destruction of data. Also, one task cannot interfere with another's operation.

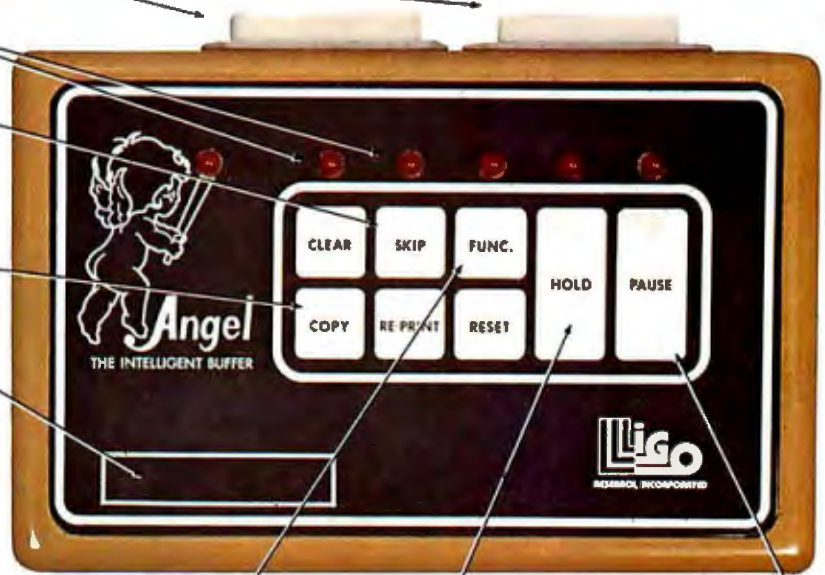
- **Data sharing**—Controlled access to common data or code.

- **Multitasking**—Several tasks can logically occupy main memory during a given time frame.

Virtual memory is just one of several approaches to memory management. Another approach is *dynamic mapping*, a technique used

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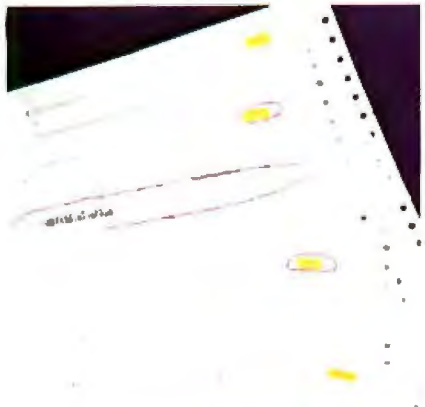
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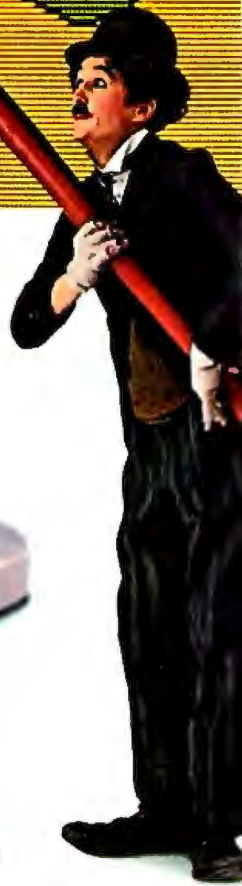
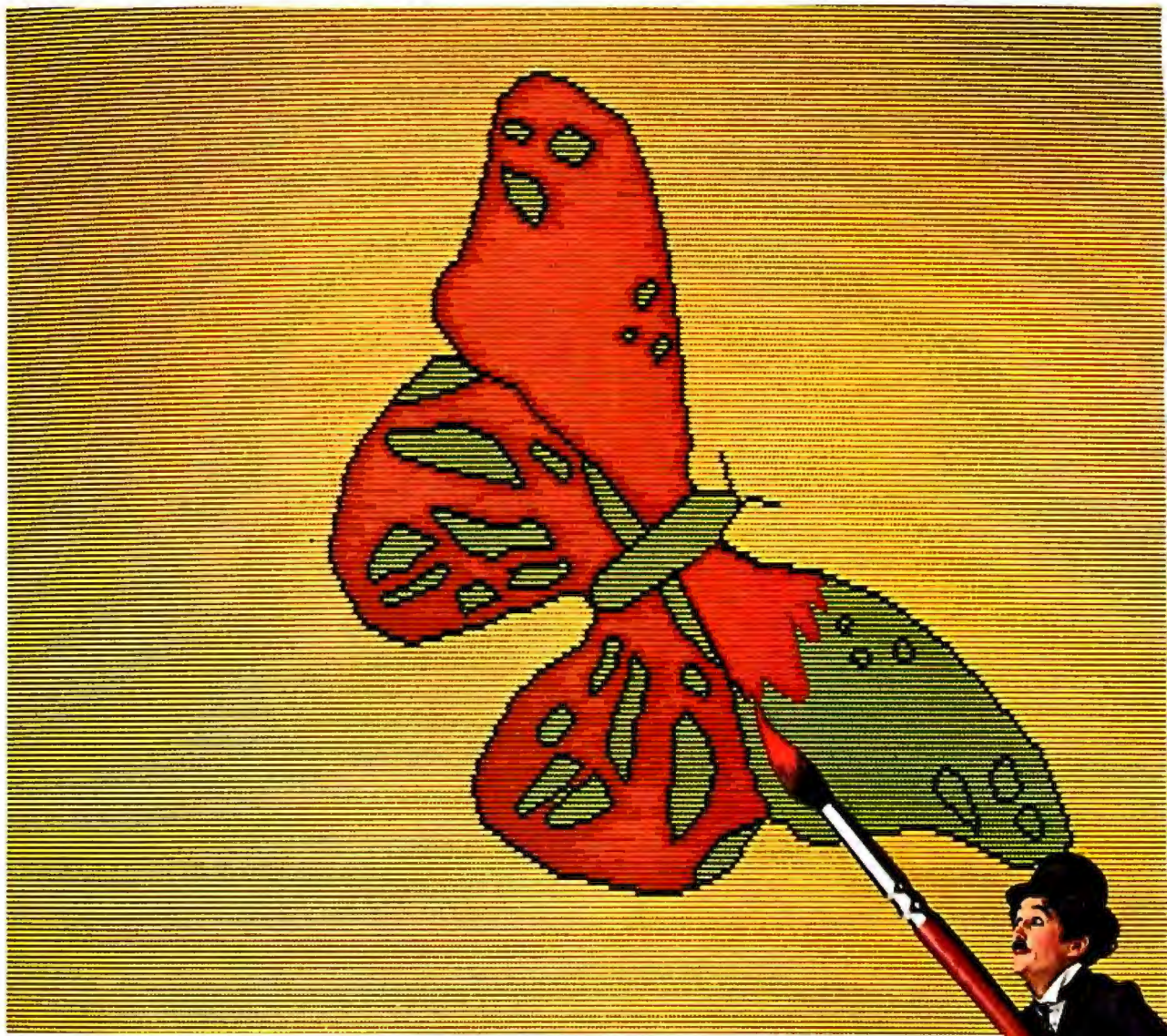
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PHYSICAL CHARACTERISTICS	MEMORY-MANAGEMENT UNITS			
	Intel iAPX 286	Motorola MC68451	Zilog Z8010	Zilog Z8015/PMMU
No. of pins	68	64	48	48
Integrated processor?	Yes (8086)	No	No	No
Dimensions (mm)	24 by 24	22 by 81	15 by 51	15 by 51
IC process	HMOS	HMOS	NMOS	NMOS
Power (W)	3	1	1.5	1.5
Compatible processors				
Model	Integral	MC68010	Z8001/3	Z8003/4
Clock rates (MHz)	8, 10	4, 6, 8, 10	4, 6, 10	4, 6, 10
Cost per unit (10 MHz)	\$237	\$111	\$383	\$137
Logical addresses				
Virtual size	1 gigabyte	16 megabytes	8 megabytes	8 megabytes
Address width (bits)	32	24	23	23
Memory structure				
Segment or page?	Segment	Segment	Segment	Page
Size field (bits)	16 limit	16 mask	8 limit	NA
Size range	1 byte – 64K bytes	256 bytes – 16 megabytes	256 bytes – 64K bytes	2K bytes
Resolution	1 byte	Power of 2	256 blocks	Adjustable
Page boundary	1 byte	256 bytes	256 bytes	2K bytes
Map organization (mapping scheme)	Segment map table	Associative lookup	Mapped by address	Associative lookup
Maximum no. of pages or segments per MMU	16,384	32	64	64
Map cell width (bits)	64	72	32	32
Physical-address base field width (bits)	24	16	16	13
Attribute field (bits)	8	8	8	7
No. of high-speed registers	4	32	64	64
MMU address-generation unit	24-bit adder	16-bit logical	16-bit adder	13-bit concatenation
Global control-register set	1 byte (7 bits)	4 bytes	3 bytes	3 bytes
Global status-register set	0 (status pushed on stack for faults)	18 bytes	6 bytes	9 bytes

Table 4: A comparison of the physical characteristics of the four surveyed memory-management units. All four have the same physical-memory limit: 16 megabytes.

and the Z8010 has 64 map registers. If you use the mapping-by-address technique, you will need two MMUs to map AS. The user/supervisor flag can be used as an extra addressing bit to increase memory size to the full 16 megabytes. With this type of organization, four MMU chips are necessary (i.e., 128 segments in two separate address spaces).

You can assign four protection attributes: read-only, data/code, system reserved, and I/O enable. If you do sophisticated I/O processing, you'll appreciate the I/O flag. Another feature, the direction and warning (DIRW) attribute, indicates the orientation for a stack segment. When set, offsets can be negative. DIRW also provides a warning if you are accessing the last 256 bytes of the segment. The warning allows the sys-

tem to dynamically extend segments during execution, making allocation procedures easier to implement.

Programming the MMU is accomplished through 22 special I/O instructions. By placing the MMU into command mode, you can manipulate map cells and global status registers in a manner similar to programming DMA or peripheral controllers. Z8000 instructions permit you to send a block of commands and data to speed up the process.

Provisions for virtual memory are marginal at best. Only three attribute flags aid paging policies: present, accessed, and changed. Up to eight separate users are possible, but this requires additional MMUs and external hardware. The Z8010's limited number of segments has two major drawbacks. First, it discourages small

segment size. The segment-size resolution may not reflect program modularity (studies indicate that median module size is about 50 words). More important, the number of pages it can handle may be insufficient for working-set purposes. Although you can share data, utility is minimal. Many of the benefits of a segmented design are not fully realized.

The Clock page-replacement policy would probably work well with the Z8010. Without an LREF field and strong multiuser support, WS-Clock is likely to be inefficient. Poor sharing and task switching make a VS(n) design impractical. Time required for MMU programming and the page-fault recovery procedure is partially offset by translation speed. I can't see the Z8010 finding much use outside of systems with few users or nonvirtual environments.

The Zilog Z8015

The Z8015 is most notable for its paged-memory strategy. Although markedly different in mapping and logical block structure, most of its features borrow heavily from the Z8010 design. Protection, programming, and multiprocessing components are virtually identical. This MMU's main selling point is the simplified allocation and storage mechanism inherent in a paged system. Also, several mistakes found in the Z8010 are corrected in the Z8015.

The Z8015 employs an associative lookup mapping scheme. Each Z8015 MMU chip can map 64 pages, each 2K bytes in length. Thus, each unit directly maps 128K bytes. Up to 64 units can be grouped together, giving you a total of 4096 page frames (8 megabytes)—ample room for system expansion.

If you don't like 2K-byte pages, simple wiring alterations allow different size options. Page attributes are the same as a Z8010's except that I/O enable is omitted—too bad, it's a handy feature. Translation time is about 15 percent slower.

As with the Z8010, you should stick to the Clock replacement algorithm and a VS(1) design. The MMU supplies all the information necessary

to recover from a page fault; extra hardware is not required. The increased number of page frames is noteworthy: you can achieve a higher degree of multitasking, and it is easier to expand storage. But with the Z8015's fixed-page policy, you sacrifice some degree of flexibility. Adequate support for virtual memory and system security yield the components of a virtual microcomputer. On top of all this, you can use the Z8015 to implement dynamic mapping for the Z8004, the 16-bit-address version of the Z8000 processor.

triguing methods to build the functions that constitute a virtual-memory scheme.

Like the Z8015, the MC68451 relies on associative mapping. Address translation takes place in two stages consisting of an address range and user-space comparison. A clever technique accomplishes both lookup and segment bounds-checking in one fell

several logical-address page values can map to a single cell entry.

Each map cell contains a user-space number and associated mask. A valid memory reference must match the active processor user number. The masking function allows a range of user numbers (or just one) to use the same segment; sharing among users becomes almost a trivial task.

One worrisome point is the map-table size. You get merely 32 map cells per MMU, and physical limitations restrict you to a total of eight MMU devices (or 256 cells). You need more than that. Also, the MMU design is complex; it has too many internal registers and multiple MMU coordination is complicated. You have your work cut out for you programming this hardware.

Status registers contain used and changed bits to aid virtual paging routines. But there's no provision for an LREF attribute. Curiously, some bits cause an interrupt to be generated whenever reference is made to the segment. The purpose of this feature eludes me—maybe it's for debugging.

Motorola's excellent MC68451 furnishes the horsepower to construct a serious virtual computer system.

The Motorola MC68451

Motorola has come up with an excellent memory-control product. The MC68451 furnishes the horsepower to construct a serious virtual computer system. In combination with the MC68000, which I think is the best 16-bit microprocessor around, the MC68451 is quite impressive. Before getting too worked up, however, I should mention that I do have a few reservations about the device. Despite this, the MMU uses some in-

swoop. Normally, logical page numbers and each map cell's page number are compared bit-wise for a match. Instead, the MC68451 employs a mask field that selects which address bits to check against a map cell's page number. The mask effectively turns some of these bits into "don't cares." The end result is that

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Protection and data typing are practically nonexistent. You can only write-inhibit segments. Any distinction between code and data or user and supervisor happens at the processor level—this makes security less effective.

The MC68451's multiuser facilities and fast context switching make WS-Clock a possible paging strategy. But you must build an extra data structure to hold reference times to support this approach. Though the MC68451 is short on facilities to fully protect data resources, you are compensated by more features for virtual memory. Also, its architecture delivers functions conducive to VS(n) designs.

The Intel iAPX 286

The Intel iAPX 286 constitutes a complete virtual-memory processor that I believe supplies the best features available in the microcomputer world today. What I consider most amazing is the fact that the memory-control unit is practically identical to a Burroughs B5500 mainframe system—a highly touted segmented architecture. Benefits are numerous and problems sparse. To summarize, I'll list the principal advantages:

- it has an integrated processor/MMU design using the 8086 microprocessor, one of the most popular 16-bit processors, making it compatible with existing software
- it has a gigantic (1-gigabyte) address space
- memory segments can be sized with a resolution of 1 byte, making it ideal for program modules
- it features advanced data-protection measures: four priority levels and several data attributes
- it can completely support WS-Clock and VS(n) designs

The iAPX 286's local data table (LDT) register points to a map table residing in MM. There's also a global equivalent of this (GDT) for shared segments. You can define up to 16,384 active segments per user. The number of users is almost boundless. Four fast internal processor registers hold the most recently accessed seg-

ment descriptors (called a cache). If you reference a map cell held in one of these registers, there's no translation-time penalty.

Because the iAPX 286, like the 8086, uses segment registers, your program must load these registers prior to memory access. Only branching instructions allow you to specify a full 32-bit virtual address. Segment-register management has two negative aspects: segment-control code clutters a program and net translation time grows. Compilers normally solve the first problem. The time problem is more of a nuisance.

The iAPX 286 features excellent virtual-memory support. Map cells have 16 undefined bits that you can use for several purposes. For instance, 12 to 14 bits would be sufficient for an LREF field. You could also allocate a fix bit to lock special pages into MM (e.g., a supervisor kernel program or an LDT table). Used and segment present bits are supplied, but a changed bit is noticeably absent.

The Intel product represents a superb tool for building virtual memory. Drawbacks are minor: small cache size, the need for segment-register management, and no changed bit. And the device is easy to program. Instead of an I/O program to operate a separate MMU, you do simple loads and stores of memory. The iAPX 286's integrated approach, its numerous features, and its regular design comprise an impressive computing engine.

Evaluation

Which MMU should you choose? The answer depends on various factors. Above all else, the companion microprocessor sways this decision. Get a system with a processor you like—it influences your software and operating-system selections. Performance requirements and intended applications are important. Is the multitasking level a factor? Do you want the flexibility of segmentation or the simplicity of paging? What software policies or peripheral components fit your needs? Table 5 compares the MMU products. The evaluation offers a yardstick for

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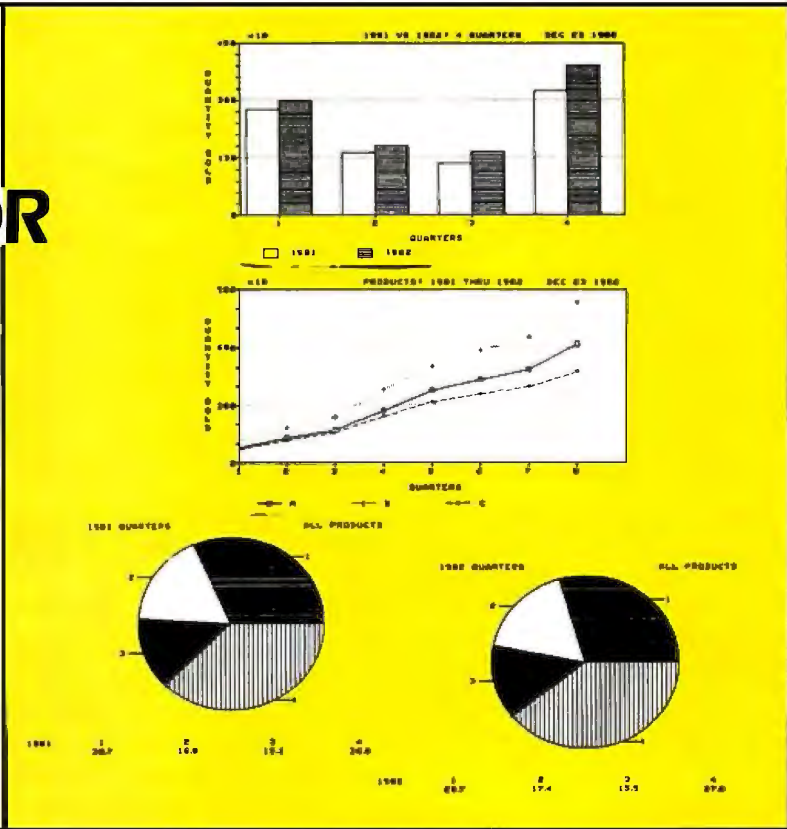
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OVERALL RATINGS	MEMORY-MANAGEMENT UNITS			
	Intel iAPX 286	Motorola MC68451	Zilog Z8010	Zilog Z8015/PMMU
Virtual-memory features	Excellent	Good	Poor	Average
Support for the Clock page-replacement algorithm	Excellent	Excellent	Good	Excellent
Support for the WS-Clock algorithm	Excellent	Good	Poor	Poor
VS(n) architecture	Excellent	Good	Poor	NA
Device features and performance				
Translation speed	Excellent	Poor	Good	Average
Address space	Excellent	Good	Poor	Average
Block resolution	Excellent	Good	Average	NA
Mapping strategy	Good	Excellent	Average	Excellent
Companion processor				
Popularity	Excellent	Good	Average	Average
Architectural design	Average	Excellent	Good	Good
Multiuser capability	Excellent	Excellent	Average	Average
Design flexibility	Good	Good	Average	Poor
Expansion potential	NA	Good	Average	Good
Protection features	Excellent	Average	Good	Good
Ease of programming	Excellent	Average	Good	Good
Hardware requirements	Excellent	Good	Poor	Good
Complexity (board level)	Excellent	Good	Poor	Average
Page-fault overhead	Good	Excellent	Poor	Poor

Table 5: An overall comparison of the four memory-management units surveyed in this article. This evaluation highlights the differences between each MMU and gives you an idea of the application possibilities.

analyzing potential applications. You can draw your own conclusions on how well each device addresses virtual-memory concepts.

New Horizons

Virtual memory opens up a whole new world for microcomputer systems. The expanded address space accommodates traditional large-scale software applications: database-management systems, sophisticated operating systems, and complex high-level-language translators. Moreover, some unique applications of virtual memory exist for microcomputer systems.

Virtual storage streamlines database operations. For example, you don't have to use complex file-access techniques to locate data. A 1-giga-byte address space defines an enormous amount of information. Applications can be much bigger and retrieval time much faster.

A VS(n) design has very exciting implications for microcomputers. You may have observed the trend among microcomputer vendors to offer a choice of several of the leading operating systems with their hardware. With a VS(n) organization, several different operating systems

could run in the separate logical-address spaces concurrently. Think of it, CP/M for one user, Xenix for another, Oasis-16 over there. The IBM 370/VM (virtual machine) applies this approach with good success.

Virtual microcomputers give you many other unique software avenues. Consider the memory needs of a 1K-by 1K-byte color graphics system. With various shades and colors, you will quickly consume 1 megabyte of memory. And how about the trend toward integrated business environments? Word processing, report generation, spreadsheet analysis, electronic filing, etc., collectively take a sizable amount of storage.

When will virtual microcomputers be available? They are right now. Altos Computer Systems, Integrated Business Computers (IBC), and Plexus all feature virtual systems designed around the Motorola MC68000 processor. IBM has been looking at the iAPX 286 with some interest, and its future microcomputer systems should prove interesting. The trend is just beginning.

Conclusion

Virtual memory will play a vital role in the evolution of microproces-

sor-based computer systems. The memory-management units I've reviewed here lay the foundation by supplying the essential hardware components.

Some people claim that virtual memory fails to provide good performance. I disagree. A carefully designed unit, properly tuned (e.g., with the proper Θ parameter for the WS-Clock algorithm), should actually improve a system's operation. MMUs, sophisticated microprocessors, and simple management policies collectively supply the elements that make virtual systems viable and inevitable. A wider range of advanced applications becomes feasible.

Which MMU is the best is not totally clear. Obviously, the iAPX 286 offers some outstanding features. However, your intended applications and software considerations should figure prominently when you make your determination.

A big memory space presents a new software frontier. With these new MMU devices, it will soon be possible to have the processing power of a mainframe in the size of a desktop. ■

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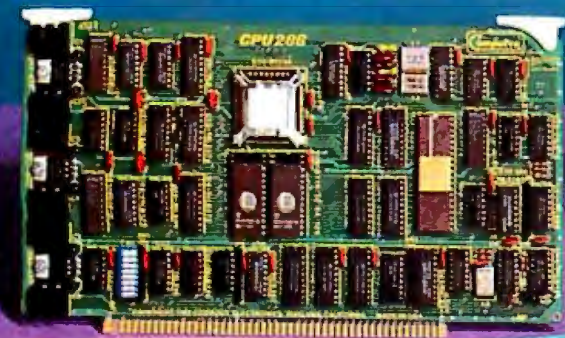
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Hard Choices for Software Houses

Phil Lemmons
West Coast Editor

The memory-addressing range of the 16-bit microprocessors presents a grand vista to programmers, but an empty one, like the Grand Canyon. The addressing range of these processors extends from 1 to 16 megabytes and up—far enough to hold an applications programmer's grandest dreams: to increase speed of execution, to integrate functions previously done by separate applications programs, to make software easier to use, to design whole new software architectures that revolutionize the way people use computers.

But the actual memory in most of today's 16-bit microcomputers is usually 64K bytes, or sometimes 128K bytes. The present contrast between addressing range and actual memory places software houses in a dilemma. Not to use more than 64K bytes of memory is to waste the greatest asset that the 16-bit microprocessors offer. But if software houses do decide to use more than 64K bytes, how much memory should they require? Answering this question is not a simple matter of surveying the installed base of 16-bit systems to determine the average amount of memory owned. Software houses can

use additional memory to make software more attractive. If the software is attractive enough, people will order the amount of memory necessary to run it at acceptable speed. In other words, software can not only exploit memory but also sell it.

Nevertheless, there is a limit to the amount of memory that most microcomputer users can afford to buy. Software houses must somehow divine that limit to determine how much memory they will have to work with. Whether the amount of memory is 128K bytes, 192K, 256K, or even 512K, software houses will still have to set priorities for its use. How much memory should they devote to increasing speed, how much to integrating functions, and how much to increasing ease of use? Has the time yet come for software that revolutionizes the "user interface" at affordable prices?

Increasing the speed of execution is the easiest and most obvious way to use additional memory, and it is also an important way. In systems with 64K bytes of memory—the most that an 8-bit processor can address—complex programs had to be divided into modules kept on disk. As the user called for specific functions,

the program would go to the disk and bring the necessary module of code into RAM (random-access read/write memory), overwriting another module. Users of the program had to wait for these modules, called "overlays," to be read in. In most cases, 128K bytes of RAM is enough to hold an entire applications program at one time and to eliminate the delays caused by overlays. In addition to eliminating overlays, memory in excess of 64K bytes will also provide room for more of the user's data. Text-editing programs will therefore be able to edit more text more quickly, databases to sort more data more quickly, and so on.

Depending on their priorities, software designers may continue to use overlays, choosing to integrate functions rather than increase speed. Using virtual memory is another strategy for integrating more functions than system memory can hold at one time. In this case, the operating system rather than the applications program swaps modules of software from disk to semiconductor memory and back again. While techniques exist to minimize the delays caused by the use of virtual memory (see "Virtual Memory for an Object-Oriented



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Language" by Ted Kaehler, August 1981 BYTE, page 378), some delays are inevitable.

Integrating functions can make programs so big as to cause delays in managing memory, yet integration can also eliminate delays of another kind. By integrating a number of functions that formerly had to exist in separate programs, software can spare users the inconvenience of exiting one program and loading another and of transferring data from one program to another.

Integrating functions can also make software easier to use. The more the combined functions have the same user interface, the more the user will find the integrated program easier to work with than a set of equally powerful programs that call for different function keys, control codes, and overall methods to perform similar functions.

In an 8-bit program running in 64K bytes of memory, the use of menus, mnemonics, and online textual help is the highest degree of friendliness

available. But 16-bit processors can address enough memory to transform the user interface into something never seen in the 8-bit world. Graphics-based guidance and selection by pointing let the user perform a function without learning special terminology. Moving a pointer or cursor onto the symbol of a function is easier than remembering and typing the name of the function or the number or letter that represents the function.

Be-All and End-All

To illustrate the sort of hard decisions software houses face, let's consider a hypothetical integrated software package called Be-All and End-All. The entire package will fit in system memory at one time, leaving at least 64K bytes free for data. Overlays and virtual memory are unnecessary, and there are no delays for disk accesses except as needed for the user's data.

Be-All and End-All includes a word processor (which incorporates a

mailing-list program, a spelling checker, a thesaurus, and other writers' aids to spot clichés and other flaws of style); a financial spreadsheet, which has all the functions included in Visicalc, Multiplan, or Supercalc; a graphics program that can take figures marked in the spreadsheet or the databases and generate bar graphs, pie charts, and line graphs; a fully relational database manager that has all the functions of dBASE II; a communications package that permits asynchronous file transfers and conversations with other computers; and a datebook that keeps track of appointments, deadlines, and expenses and generates reminders automatically and reports on demand.

The user interface of Be-All and End-All is organized on the same principles throughout. It permits the user to see, point, and do. All the programs it incorporates can run simultaneously, and the user can view the different processes through adjustable windows on each. "Cut-and-paste" procedures make data transfer between programs as easy and quick as moving a block of text in a simple word processor. Be-All and End-All may integrate more functions than any one person is ever likely to need, but no matter; it will someday be available for only \$500.

Suppose you are the programmer and you receive one added specification for Be-All and End-All: it must run at an acceptable speed in 128K bytes of memory. "Impossible!" you say. "Well, get as much of it in as possible," your boss says. "Take all the time you need, as long as it isn't more than six months." What do you include? What do you leave out? What if you could argue for having 192K bytes of memory—would things be any better? What about 256K? Half a megabyte? What if you are told that Be-All and End-All's speed must be sensational rather than acceptable? How many more possible improvements must you then leave out?

Bright people at software houses across the land have been facing similar questions and coming up with different answers. Not surprisingly,

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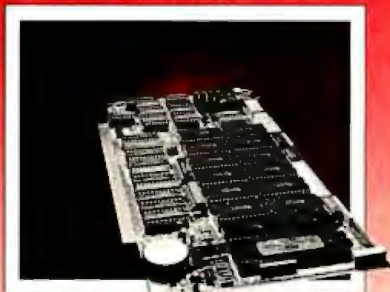
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few of these software houses have targeted their software for the same amount of memory, and even those who agree about the amount of memory available disagree on how to use it.

To date, the software houses that have placed the greatest emphasis on enhancing the user interface have been understandably slower in bringing their products to market. They seem to be centering their new user interfaces on the object/verb "desktop manager" approach developed at Xerox PARC (Palo Alto Research Center). The screen becomes a metaphor for a desktop, and users select first what they want to work on (the object) and then the action that is to be performed on the object (the verb). (For a fuller description of a desktop manager, see "The Smalltalk Environment" by Larry Tesler, August 1981 *BYTE*, page 90, and "The Lisa Computer System" by Gregg Williams, February 1982 *BYTE*, page 33). To select both object and verb, you usually point at them with a mouse or a similar device.

Software houses are responding to the issues of integration and ease of use in several different ways. Three general approaches prevail: the all-in-one approach, which combines all major applications in a single program; the separate-but-compatible approach, which provides fully functional independent programs with some mechanism for data interchange among them; and the desktop-manager approach described above, which gives the user access to all applications, entirely hiding from him the problem of data interchange.

The products described in the pages that follow are among the most important ones under development now.

All-in-One

Context Management's MBA: If the question is "Which integrated program currently incorporates the most functions?" the answer can only be MBA. Written in Pascal for easy portability to different processors, MBA is a full-featured spreadsheet, a business graphics program that lets you choose one of nine different

kinds of graphs for a set of data, a database that permits sorting data on as many as eight keys, a word processor that takes advantage of function keys to implement its 13 commands, and a communications program that takes data from big computers and automatically loads it into an MBA spreadsheet. The database is relational and lets you add, delete, and rearrange fields at any time. Moreover, you can query the database by typing an example of the sort of thing you want to search for. It can also support databases as large as 16 megabytes, if disk capacity permits.

Although the early version of MBA ran rather slowly on the IBM Personal Computer, it was faster than loading and unloading several different programs to get a job done. The more recent version of MBA shown at last November's Comdex in Las Vegas ran much faster on the IBM PC and faster still on the new Hewlett-Packard Series 200 Model 16, a 68000-based system.

Aside from integrating the user interface for its constituent programs, MBA is not especially innovative. Most commands are invoked by typing a mnemonic preceded by the "/" that Visicalc uses. The program provides online help. MBA organizes data as "folders" containing up to 28 files each—somewhat like the desktop-manager file concept. MBA uses virtual memory to permit documents to refer to data in other documents. When it's in the spreadsheet "context," MBA will divide the display into as many as four windows, any of which may be text, data, a model, or graphics. MBA automatically redraws graphics after changes in data.

Jim Peterson, director of development at Context Management, says that integrating functions was the highest priority in creating MBA partly because integration itself is the main issue in achieving both ease of use and speed. "You have to look at overall speed including telecommunications and the time required to complete an overall task such as producing a report," he notes. Peterson adds that Context has made MBA run faster by reducing the number of

overlays and keeping some memory free for user workspace.

Peterson distinguishes MBA from Lotus Development's 1-2-3 (see below) by saying that "having graphics and numbers and text all on the screen at the same time is important. 1-2-3 doesn't do that. MBA uses more function keys and works in a window while other things are on the screen. The time required to go into and out of a word processor is another drawback for 1-2-3." As for Visicorp's forthcoming Visi On, Peterson expects that its use of a desktop manager will significantly slow execution speeds. He also observes that, while mice are useful when you are just looking at data, you still have to use the keyboard when you're entering data. Mice are expensive, too, he adds.

Lotus Development's 1-2-3: Gregg Williams has already fully described this program (see December 1982 BYTE, page 182), so I will cover it only briefly here. Lotus Development's 1-2-3 runs in 128K bytes and runs fast because it is written entirely in assembly language. The program incorporates three general functions: spreadsheet, graphics, and database management, but the database is quite limited. Lotus plans to add a word processor later. For the most part, the user interface of 1-2-3 is a good implementation of the command-line-plus-online-help strategy familiar from the 8-bit world, but highlighting and selection by cursor do simplify some aspects of the program. The program has some delays

while it goes to disk for help text, which also takes up a lot of disk space. As a result, you can't run 1-2-3 on single-sided drives in the IBM PC. For the present, 1-2-3 is best classified as an enhanced spreadsheet.

Separate but Compatible

Micropro's Star Series: Micropro International Corp. introduced Infostar, a relational database manager, at Comdex. Infostar is now available only for 8-bit systems. Seymour Rubinstein, Micropro's president, is proud of the company's achievement in producing a series of compatible programs that let users program applications without knowing a programming language. Users must understand what they want to do but need to know nothing about the grammar, syntax, or command structures that overwhelm many computer users.

The user interface of all the Micropro application programs seems to be based on the enormously successful Wordstar word processor. All versions of Wordstar to date use the same control-code-based user interface Wordstar first introduced some years ago. The most common control codes are shown in on-screen help menus that can be suppressed once the user learns the codes. Like other programs that require the user to enter control codes to execute commands, Wordstar is difficult to learn. Once learned, however, it is powerful. Micropro's strategy for integrating software seems to be to make data movable between applica-

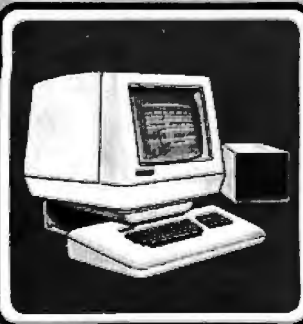
tions but to keep each application program independent. This seems to result in a powerful set of programs. Curiously, the 16-bit version of Wordstar uses as many overlays as the 8-bit version regardless of how much memory is present in the 16-bit machine.

The current 16-bit version of Wordstar runs in 64K bytes, but Seymour Rubinstein believes that 256K bytes of RAM will become standard because "the standard memory size [of a system] has always been determined by the size of the standard memory chip." Most recently, the standard chip has been 64K bits (8 chips make 64K bytes of memory). Next year the standard chip will be 256K bits. "Memory has two big applications," Rubinstein says. "Graphics and networking."

Rubinstein also anticipates continual improvements in the user interface. To the extent that these improvements use graphics, they will demand memory. Rubinstein adds, "There will be breakthroughs in input beyond the keyboard." Whether Micropro is preparing such a breakthrough remains mysterious, but Rubinstein does point out that Micropro owns a Xerox Star, the first commercial computer system with a mouse-driven desktop manager. Furthermore, rumors abound that Micropro will make major announcements at the National Computer Conference in May. When the 16-bit version of Infostar becomes available, however, using the Micropro programs under Concurrent CP/M-86

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might result in the highest degree of integration of the Micropro product line.

Sorcim's Superware: Sorcim's Supercalc is an excellent electronic spreadsheet that provides good textual online help on demand. Sorcim has recently expanded its product line (called Superware) by introducing Superwriter, a word processor; Superdata-File Manager, a database management system; Superchart, a business graphics program; and Superdata Interchange, a program that permits data interchange among the Sorcim programs. Superdata In-

terchange converts Superware files into either a common BASIC file format or a Superware format. Supercalc can manipulate data stored by Superdata, Superwriter can include Supercalc data in a text file, and Superchart can generate graphics from Supercalc data.

Each of the Superware programs uses conditional overlays. If memory is scarce, overlays are read in from disk when needed; if memory is abundant, overlays reside in memory rather than on disk. This approach takes advantage of the additional memory that 16-bit machines may

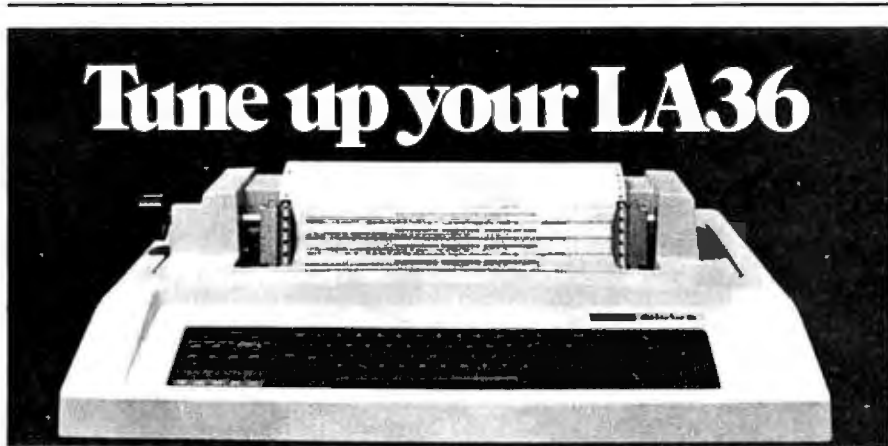
have but does not require it.

Each Sorcim application program is powerful. Superwriter, for example, incorporates an excellent spelling checker and a mailing-list feature for producing form letters. Superdata File Manager can sort on 16 fields at once and can manage files of up to 32,000 records each and 1023 bytes per record. In addition, Superdata permits the linking of files to form larger files and the creation of new file formats from old ones. All the Superware programs have user interfaces much like Supercalc's. The Superware series will run under Concurrent CP/M-86, which means that you can have multiple Superware programs running simultaneously and switch at will among them.

Richard Frank of Sorcim sees three main problems in achieving the next step toward greater ease of use and integration: creating an underlying data structure, providing sufficiently powerful applications programs, and writing good drivers for I/O (input/output). He says that Sorcim is now at work in all three of these areas, and he argues that neither CP/M-86 nor Unix will support the solution of all three problems.

Because Visi On works atop MS-DOS and CP/M-86, Frank believes that the new Visicorp software cannot properly address the problem of the underlying data structure; it deals only with the I/O process. Sorcim will be developing its future software for machines running MS-DOS but will create its own data structure. It will be interesting to see how much of Sorcim's "data structure" resembles traditional operating systems.

If the I/O drivers are done well, Frank says, they will handle keyboards, mice, touch panels, and other types of I/O devices. Frank believes that the design of the software should not require a mouse. "The hardware people are trying to make the machines' 'footprints' [the amount of desk space an object occupies] smaller," Frank observes, "while software people are trying to make footprints bigger by requiring space for a mouse to roam." He notes that people have enough trouble just managing the keyboard, and adding a mouse

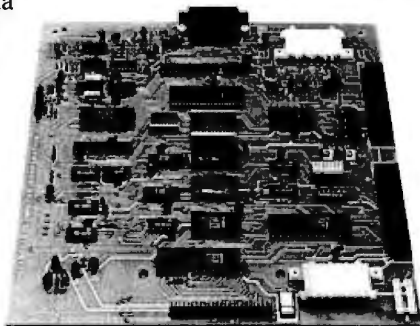


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with its own buttons won't make matters easier.

As for concurrency, Frank argues—as does Microsoft's Bill Gates—that simultaneously running more than one application program on a single microprocessor is neither necessary nor desirable. What he believes users really need is *interruptability*—the ability to switch quickly from one application to the next. Frank also discounts the usefulness of splitting the screen among four applications. There is no need, he says, to run a spreadsheet while running a word processor; the real need is to run one after the other in rapid succession. That is the end toward which Sorcim is working.

Concurrency for Separate-but-Compatible Programs

Digital Research: Digital Research's Concurrent CP/M-86 provides a mechanism that can help integrate separate application programs. Under Concurrent CP/M-86, you can run several independent application programs (or other kinds of software) at one time. Instead of having windows on each application, Concurrent CP/M-86 permits easy switching from one "virtual terminal" to another. Each virtual terminal is the whole-screen display of one of the application programs that is running. You can get information from one program while running another by switching briefly from one virtual terminal to the next. More direct integration of data from one program into another depends on their data structures. By choosing application programs from a single vendor who has created a common data structure and a common user interface for all the programs, you should be able to achieve a high degree of integration under Concurrent CP/M-86.

Digital Research has often expressed a commitment to making computers accessible to more people, and president Gary Kildall suggests visual aids as one means to that end. There is a lot of speculation about Digital Research's plans for making computers easy to use, but the company has not announced any plans that extend beyond creating tools to

increase the productivity of programmers working for independent software vendors.

Desktop Managers

Microsoft's Multi-Tools Series: Microsoft chairman Bill Gates says, "You can do a lot in 192K." While he offers few details about the company's forthcoming Multi-Tools series of integrated applications programs, Gates notes that Charles Simonyi, formerly of Xerox PARC, is Microsoft's manager of end-user software. Simonyi and Larry Tesler, who was instrumental in the development of Apple's Lisa applications software, spent some time together at Xerox PARC disputing the number of buttons that a mouse should have. Tesler said one, and Lisa has a one-button mouse. Look for Microsoft to use a two-button mouse.

The Multi-Tools series will be available in two versions: one will run on all machines, and one will run on advanced hardware. The Multiplan that runs now on the IBM Per-

sonal Computer probably shows what the run-on-anything series will be like. Even without a mouse, the program lets users select functions by cursor movement. For those who prefer words to formulas, Multiplan's ability to let users refer to cells by English labels rather than alphanumeric coordinates (i.e., "Sales*Unit-price" instead of "C15*C16") is an important convenience.

The advanced-hardware version of the Multi-Tools series requires a non-keyboard input device (such as a mouse), high-resolution graphics, and a 16-bit processor. This version will provide a desktop manager and windows on more than one application at a time. Each application will have a separate window and its own verbs (as opposed to all applications sharing the same window and verbs).

Gates remarks that software shown to date has "ignored the metaphor of how you see data. In a spreadsheet, remembering formulas in cells is a problem. Popping graphs out of windows is also unsatisfactory. You need

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a more substantial metaphor." His comments suggest that Microsoft conceives of the window on each application not just as a means of gaining access to data but also as a way to provide user aids uniquely suited to the particular application. The idea is to integrate the user interface as much as possible for different applications without sacrificing coherence or intuitive appeal.

Gates also argues that true concurrency is not really desirable. Instead of needing to run more than one application program on the same microprocessor at the same time, Gates says, users need to be able to switch rapidly from one application to the next. "You need interruptability," Gates says, "but not simultaneity." The argument is that timesharing a single microprocessor is less efficient than having the microprocessor run only one application program at a time and switch from one to the next quickly as the user requests. [In many cases, users would have trouble perceiving any difference between interruptability and simultaneity (concurrency).] Nevertheless, Microsoft's MS-DOS will support true concurrency in a future release.

Visi On from Visicorp: When Dave Clough, project manager at Visicorp, was asked how much memory a system would need to resolve the conflict between ease of use and added functionality, he said, "That conflict will never go away." Clough also said that when forced to choose between ease of use and additional functions, Visicorp would choose ease of use.

The prototype of Visi On shown at Comdex was a desktop manager that appeared to integrate substantial functionality and great ease of use. While the Visi On desktop manager lacks the Lisa's pictorial detail, it still allows the user to choose from items shown on the desktop by using a mouse to point at one item. The mouse used with Visi On has two buttons.

Visi On's windows let the user view different applications in progress simultaneously. Nine verbs will be common to all applications under Visi On, and other verbs are specific to each application.

The word processor shown with Visi On, presumably a relative of Visi Word, resembles Multiplan in that it enables the user to select a function by pointing at an item in a list. Visicorp has a whole new series of applications, not yet shown or described, that will run under Visi On.

Visi On will permit users to install applications modules as needed. If you need a database and a word processor but not a spreadsheet, you can buy only what you want. If your needs change, you can install an additional module yourself.

Visi On, described as an "operating environment," occupies an interesting territory between conventional operating systems and application programs. It runs on top of either CP/M-86 or MS-DOS and provides concurrency independently of the underlying operating system. Because Visicorp will make technical details about Visi On available to applications programmers, software written outside Visicorp should be available to run in the Visi On environment. Visi On will be portable to different machines, and different application programs can be written to be portable under Visi On.

Apple Computer's Lisa: It's easy to see that a company like Apple Computer Inc., which produces both its new Lisa computer and the Large-scale Integrated Software Architecture to run on it, has an advantage over software houses in producing new-generation software. (For full descriptions of Apple's Lisa and its software, see the February 1982 BYTE.) Apple can change the software and the hardware to suit each other. Knowing that Lisa will have a megabyte of memory has enabled Apple to succeed in a remarkably ambitious project. For combined integration of function and ease of use, Lisa is the leader by far. Lisa's drawback is its high price—not high in relation to function or value, but in absolute terms. While a toolkit will permit programmers to write application programs that run on the Lisa, the Lisa's software cannot be transferred to MS-DOS and CP/M-86 systems. Apple has plans to implement fuller database functions on the Lisa but ad-

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mits that the present database manager is somewhat limited. For ease of use, however, Lisa's database manager is unrivaled.

Summing Up

Most of today's software falls far short of our hypothetical Be-All and End-All package. Such a large and friendly software package is likely to remain hypothetical for some time. But inexpensive memory and 16-bit processors may make many of today's hypotheses real surprisingly soon. For those who have spent years struggling to coordinate unrelated application programs in the past, any of the approaches to integrating software represents real progress and welcome relief.

As for deciding what software to buy now, the choice is difficult. The revolutionary graphics-based software has great appeal as long as it doesn't sacrifice one of the specific functions that you happen to need, decrease the operating speed of the program beyond your tolerance, or

increase the price of a system beyond your means. When specific products meet your needs, you will buy one of the new software packages whether it has been announced today or not.

If none of the revolutionary products meets your specific requirements in function, speed, and cost, you must choose between the separate-but-compatible approach to application software (as in Sorcim's Superware) and the all-in-one approach (as in Context Management's MBA). In making this choice, the most important factor will probably be whether the all-in-one program offers all the features and all the power that you happen to need. If you do buy separate application programs, the best course is probably to buy from one software house and hope for increased integration in subsequent releases. If an all-in-one program has almost but not quite everything you need, you might ask its publisher whether future versions will include what you need.

Advances in hardware technology

may hasten the triumph of the revolutionary software by reducing the price of very fast mass storage and thus reducing the penalty paid for using overlays and virtual memory. But no revolution is perfect or final or above criticism. A small skeptical voice inside me keeps raising three questions:

- Should all software be written so that it's easy for a novice to learn, or so that it is most useful and productive in the long term?
- Will the metaphor of the desktop remain a good one? It seems appropriate for the transition from paper work to computer work, but once we grow accustomed to working with computers, why should we want our computers to emulate desks?
- Can the mouse compete with the efficiency of programmed function keys in all fundamental operations like deleting characters? To delete characters with the Delete key, you just put the cursor on the characters to be deleted and press the key. Auto repeat makes swift deletion of more words and sentences easy: you just hold the Delete key and watch the cursor swallow the characters to its right. To delete characters with the mouse-driven systems that I have seen, you put the mouse's pointer on the character you want, press a button on the mouse to select the character, and press a button on the mouse to choose the verb Delete. That seems to add a step. Selecting larger blocks of text may require you to press more buttons (or the same button more times) on the mouse.

To date, ingenious software designers have debated these and the other issues of integrated and friendly software. All their conclusions remain as hypothetical as Be-All and End-All. Only the marketplace can say which hypotheses are true. The decision of the marketplace is uncertain because the people who will constitute most of the market have never touched a computer. Technology will determine how these people will first touch computers, but from then on they as new users will decide everything on non-technical grounds. ■

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50 and 100 Years Ago in **BYTE**

Edited by Rich Malloy

As staff members of one of the world's oldest microcomputer magazines, we sometimes enjoy looking back at the interesting articles we've published in the past. For example, here are some items that appeared in our pages 50 and 100 years ago this month.

BYTE

APRIL, 1933: The International Business Machines Company of Elmira, New York, announced last month that, although it will continue to manufacture typewriters and adding machines, most of its resources will be devoted to the development and sale of fire alarm systems.

"We figure that the most important device in a business office is the fire alarm," said Thomas Watson, the president of the company. "After all, if there's a fire, who cares whether you have a typewriter or not. In fact, in future years, when you think of International Business Machines, the first thing that'll come to your mind will be fire alarms."

In a related item, film star Charlie Chaplin turned down a request by International Business Machines to appear in its promotional literature. "It's a great company," said the mustachioed comic, "but frankly the idea of having me promote business machines is one of the most ridiculous things I've ever heard."

* * *

Things continue to heat up in the adding-machine market. Following the introduction last year of the mini-adding machine, rumors have reached us that the Japanese are ready to market a "micro-adding machine." This new invention, said to employ VLSS (very large-scale smallness) technology, has an incredibly light weight of only 47 pounds. To combat the threat of this new small machine, American adding-machine manufacturers are said to be at work incorporating deluxe features into their new models. One rumor has it that work is almost complete on a machine that can multiply.

* * *

The Acme Calculating Company of Piscataway, New Jersey, has just announced a machine which it calls a "Disk Storage Device." The machine consists of a disk-drive mechanism called a "turntable" and a series of interchangeable data disks, or "records." The disk is read by placing it on a rotating platform located on top of the disk drive. A pin, called a stylus, is inserted into one of dozens of grooves etched on the disk. Under proper conditions, a voice-like sound can be heard. This voice can be used to encode all types of data and can even be used to portray music-like sounds.

The Acme Calculating Company will market the Disk Storage Device as part of an "Office System," which will include a typewriter, an adding machine, a typist, and someone to crank up the turntable. Also included will be software by Al Jolson and Rudy Vallee and His Connecticut Yankees.



APRIL, 1883: Professor Eaton Zweiback of Slippery Rock University recently announced the discovery of a new number system called the "Binary System." This system uses only two numerals, 0 and 1, as opposed to the decimal system which uses ten. Professor Zweiback claims that the binary system will have absolutely no practical value and will be used mostly as a mathematical novelty.

* * *

Harvard anthropologists have discovered the remains of an ancient Arabian city just 75 miles north of where ancient Babylon once stood. Little is known about the inhabitants of this city except for the fact that for some unknown reason they wrote the numeral zero with a slash through it. The anthropologists are completely puzzled as to why these people used such a strange symbol.

* * *

Agricultural experts have abandoned efforts to develop farm land in the valley south of San Francisco, California. The experts claim that is difficult to grow crops in the soil because there is too much silicon. There is so much silicon present that some residents of the valley have started gathering it together and melting it into "chips," which they then plan to dump somewhere near Boston, Massachusetts.

* * *

Missionaries near Peking have discovered a very small abacus, which the Chinese call "Mei Kro." This extremely small device, about the size of a postage stamp, is said to be extremely fast for computations. One of its drawbacks, however, is that the operator must use a pair of tweezers to manipulate the beads.

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The Enhanced VIC-20

Part 3: Interfacing an MX-80 Printer

Joel Swank
12550 SW Colony #3
Beaverton, OR 97005

To do any serious programming with the Commodore VIC-20, you need a printer. Commodore markets two that plug directly into the VIC serial port: the VIC-1515 and the VIC-1525 graphics printers. Both form characters with a 6 by 7 dot matrix and operate at 30 characters per second.

For most uses these printers are satisfactory. But if you look closely at a VIC character on the screen, you can see that it is composed of an 8 by 8 matrix of dots. Neither Commodore printer can print true VIC characters or graphics. And because the VIC has only a serial printer port that uses a DIN (Deutsche Industrie Norm) connector, you can't interface printers that have standard Centronics-style parallel ports with the VIC.

This article will show you how to select an alternative printer for use with the VIC and how to interface it with the computer to get true VIC characters and graphics.

Selecting a Printer

The first consideration is which printer to buy. A large number of low-cost dot-matrix printers offering a wide range of features and capabilities are now available. Two features in particular are necessary to adapt the printer to the VIC. First, the printer must have graphics capability so that the VIC character patterns can be formed in memory and then sent to the printer. Second, the printer

must have 8 or more wires in its print head if it is to print the VIC's 8 by 8 characters efficiently.

Many printers use a 7-wire print head and normally print a character that is only 7 dots high. These printers can print only 7 dots vertically on each pass of the print head across the paper. Because the VIC character is 8 dots high, the print head would have to make two complete passes to print the entire VIC character, slowing the effective printing speed by one-half. Making two passes can also distort the VIC character because horizontal alignment is not always perfect on some printers.

The Epson MX-80 is one of the more popular printers. It has a 9-wire print head, and with the Grafrax option, it can do graphics. The MX-80 also offers italics, several print sizes, and proportionally spaced characters. To give you an idea of some of its features, I have included a summary of its escape sequences and control codes in table 1. These are the commands that the computer uses to tell the printer the desired print format. The MX-80 meets the requirements for use with the VIC and is moderately priced.

Interfacing the Printer

The next consideration is how to connect the printer to the VIC. The most obvious way is through the user I/O (input/output) port, which is the opening at the left rear of the VIC case. The logic assignments of each pin on this port are given in table 2 (see figure 1 on page 288 for user port I/O connections). Some of the pins are already assigned to other uses, but a full 8-bit parallel I/O port that is capable of driving a printer does exist. This is actually the B port of a 6522 VIA (versatile interface

Editor's Note: *The VIC-20 is one of the new breed of low-cost computers that offer a surprising amount of computing power for the money. But its low cost also means that it lacks some of the features we've come to take for granted. In this series of articles, author Joel Swank will "enhance" the VIC-20 and in so doing increase the utility of this very interesting computer. . . S. J. W.*

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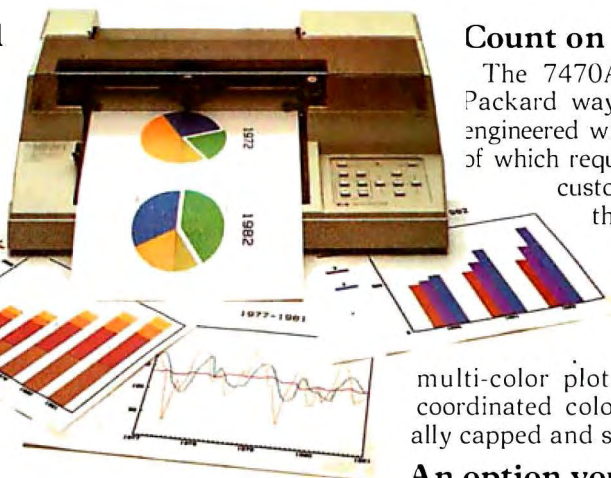
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VIC to Epson Connections

VIC Via Pin #	VIC User Port	Signal	Epson 36-Pin Connector
	A	GND	19
CB1	B	Acknowledge	10
PB0	C	D0	2
PB1	D	D1	3
PB2	E	D2	4
PB3	F	D3	5
PB4	H	D4	6
PB5	J	D5	7
PB6	K	D6	8
PB7	L	D7	9
CB2	M	Data Strobe	1

Table 3: VIC-20 to Epson MX-80 connections. This illustrates the output pins from the VIC versatile interface adapter (VIA) chip, the connections from the VIC user port, the signals involved, and the corresponding pins on the MX-80.

6522 VIA. Table 3 shows the physical connections you need to connect the MX-80 to the VIC via the user port. Eleven wires must go from the VIC to the printer; one to ground it, 8 for the 8 bits of data, and 2 for handshaking. Handshaking lines are used to keep the printer and the VIC synchronized. The VIC uses the DATA STROBE line to tell the printer when a character is ready. The printer uses the ACKNOWLEDGE line to tell the VIC when it has accepted the character. The 6522 VIA, when used in the handshake output mode, takes care of these signals.

The least expensive way to connect the VIC and the MX-80 is with a ribbon cable. To do so, keep the length of the wire as short as possible. I have used an 8-foot cable with no problems. The VIC end of the cable must be a 24-pin card-edge connector that has contacts on 0.156-inch centers. The MX-80 end must be a 36-pin Centronics-style male printer connector. I have a standard printer cable with a male connector on each end. To use this cable, I wired a short ribbon cable from the VIC connector to a female 36-pin connector. My VIC can now be connected to the standard printer cable. These connectors are available at many electronics stores and from mail-order companies.

The interface as shown in table 3 does not take full advantage of all of the features of the MX-80. Seven other signals on its connector are not used. These provide, among other things, an out-of-paper signal and a busy

adapter) chip, a very powerful I/O device that is used on many computers that have the 6502 microprocessor. The VIC programmer's reference manual gives a complete description of it starting on page 229.

Most printers, including the MX-80, come equipped with an "industry-standard parallel interface." This interface is not actually a standard, but all versions are similar, and all of those I've seen can be driven with a

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POKE 780,2	Select graphic LPI (no space between lines).
POKE 780, (anything else)	Select 6 LPI.
POKE 781,1	Select double horizontal density. Uses 960 graphics mode. Slows printer 1/16 ASCII mode. Good for work to be photocopied.
POKE 781, (anything else)	Select single density. Uses 480 mode graphics. Slows printer 1/4 over ASCII mode.
SYS(7188)	OPEN printer for ASCII output. All printer escape sequences and control codes are under user control. Some standard VIC characters are also Epson control codes.
SYS(7202)	CLOSE the printer and restore the output vector. If in graphics mode the end of the last line must be sent to the printer.

Table 4: VICEPS program commands. The SYS commands open and close the VIC user port for output to the printer. The POKE commands select various printer options.

signal. You don't need to use these signals to get the MX-80 to work. Because the VIC has no more user I/O pins available, the extra signals are ignored.

Software Interface

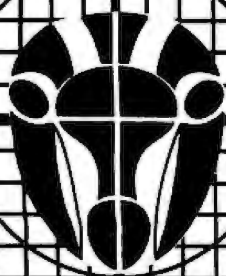
Listing 1 is the VICEPS program, which allows the VIC to communicate with the MX-80. Written in 6502 assembly language, it occupies about 400 bytes of memory. It is accessed with a BASIC SYS command. To use the program, you must first enter the command SYS (7168) to start the OPEN routine (see line 36). This routine initializes the VIA and the printer and inserts the address of the printer output routine into the VIC's display vector as well. The display vector is the pointer to the VIC's program to display a character on the screen. All screen output comes through this vector. It was provided by the designers of the VIC for just such an application as this. After the initialization routine has been started, all characters that are displayed on the screen will also be sent to the printer.

Before entering the SYS command you can also give some information to the OPEN routine. This information is passed via the SYS register area at memory locations 780 and 781. Table 4 lists a summary of the VICEPS program options. Location 780 is used to select the vertical print density—how much space is left between lines of print. Entering 1 into location 780 produces a vertical density of 8 lines per inch (LPI). This leaves one blank row of dots between lines. Entering a 2 into location 780 results in graphic density. This leaves no space between lines so that graphic characters will connect, as they do on the VIC screen. Entering any other number into location 780 produces the default print density of 6 LPI, which makes for the most readable program listings and text.

Text continued on page 280

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Listing 1: The VICEPS program is a software interface between the VIC-20 and the MX-80. It controls output to the printer.

```

LINE#  LOC   CODE   LINE
0001  0000      ; VICEPS ; VIC-20 INTERFACE TO THE EPSON MX-80 PRINTER
0002  0000      ;          VIA THE VIC PARALLEL USER PORT
0003  0000      ;          THE EPSON MUST HAVE GRAFTRAX
0004  0000      ; ZERO PAGE LOACTIONS
0005  0000      RUSMOD =#C7          ;REVERSE MODE FLAG
0006  0000      QUOTMO =#D4          ;QUOTE MODE FLAG
0007  0000      VICPAT =#FB          ;TEMPORARY ZERO PAGE POINTER
0008  0000      ; VIC PIA LOCATIONS
0009  0000      IORB1 =#9110         ;I/O REG B
0010  0000      DORB1 =#9112         ;DATA DIRECTION REG B
0011  0000      PCR1 =#911C         ;PERIPHERAL CONTROL REG
0012  0000      IFR1 =#911D         ;INTERUPT FLAG REG
0013  0000      IER1 =#911E         ;INTERUPT ENABLE REG
0014  0000      ; TV CONTROLLER LOCATIONS
0015  0000      TVCTL5 =#9005      ;CHARACTER SET/SCREEN BUFFER PORT
0016  0000      ; VIC SUBROUTINES
0017  0000      VICOUT =#F27A      ;ROUTINE TO SEND CHAR TO SCREEN
0018  0000      ; VIC RAM
0019  0000      SYSA =#30C         ;A REG STORAGE FOR SYS COMMAND
0020  0000      SYSX =#30D         ;X REG STORAGE FOR SYS COMMAND
0021  0000      DISVEC =#32E      ;VECTOR TO SCREEN DISPLAY ROUTINE
0022  0000      ; EQUATES
0023  0000      CR =#0D           ;RETURN CHAR
0024  0000      INSDel =#14          ;INSERT-DELETE CHARACTER
0025  0000      ESC =#1B          ;ESCAPE CHARACTER
0026  0000      LF =#A           ;LINE FEED CHARACTER
0027  0000      LINLIM =60          ;MAX CHARACTERS PER LINE
0028  0000      LPIGRF =8           ;PRINTER GRAFIC DENSITY CODE
0029  0000      LPI8 =9           ;8 LINES PER INCH CODE
0030  0000      LPI6 =12          ;6 LINES PER INCH CODE
0031  0000      * =#1C00
0032  1C00      ;**
0033  1C00      ;*** OPENS ; ENTRY POINT TO TURN ON ROUTINE TO
0034  1C00      ;**          ECHO CHARACTERS TO THE PRINTER IN
0035  1C00      ;          IN FULL VIC GRAPHICS
0036  1C00  20 26 1D  OPENS JSR INITOT          ;INIT THE PIA FOR OUTPUT
0037  1C03  A9 30          LDA #<GRFOUT        ;MOVE OUTPUT ROUTINE ADDRESS
0038  1C05  8D 26 03          STA DISVEC
0039  1C08  A9 1C          LDA #>GRFOUT
0040  1C0A  8D 27 03          STA DISVEC+1
0041  1C0D  20 6A 1D          JSR INITPR          ;INITIALIZE THE PRINTER
0042  1C10  20 40 1D          JSR INILIN         ;INITIALIZE FOR FIRST LINE
0043  1C13  60          RTS
0044  1C14      ;**
0045  1C14      ;*** OPENA ; ENTRY TO TURN ON ROUTINE TO ECHO
0046  1C14      ;**          CHARACTERS TO PRINTER IN ASCII
0047  1C14  20 26 1D  OPENA JSR INITOT          ;INIT PIA FOR OUTPUT
0048  1C17  A9 16          LDA #<ASCOUT        ;MOVE ADDRESS OF ASCII DISPLAY
0049  1C19  8D 26 03          STA DISVEC         ;ROUTINE TO DISPLAY VECTOR

```

Listing 1 continued on page 270

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Listing 1 continued:

```

0050 1C1C A9 1D LDA #>ASCOUT
0051 1C1E 8D 27 03 STA DISVEC+1
0052 1C21 60 RTS

0053 1C22 ;**
0054 1C22 ;*** CLOSE ; ENTRY TO TURN OFF EITHER ECHO ROUTINE
0055 1C22 ;**

0056 1C22 A9 7A CLOSE LDA #<VICOUT ;RESTORE VECTOR TO SCREEN
0057 1C24 8D 26 03 STA DISVEC ;DISPLAY ROUTINE
0058 1C27 A9 F2 LDA #>VICOUT
0059 1C29 8D 27 03 STA DISVEC+1
0060 1C2C 20 A9 1C JSR FILLIN ;FINISH CURRENT LINE
0061 1C2F 60 RTS

0062 1C30 ;*** GRFOUT ; ROUTINE TO GENERATE VIC GRAPHICS
0063 1C30 ; ON THE PRINTER

0064 1C30 8D 9D 1D GRFOUT STA ASAVE ;SAVE CHARACTER
0065 1C33 48 PHA
0066 1C34 8A TXA ;SAVE ALL REGS
0067 1C35 48 PHA ;ON STACK
0068 1C36 98 TYA
0069 1C37 48 PHA
0070 1C38 AD 9D 1D LDA ASAVE ;GET CHAR BACK
0071 1C3B 20 7A F2 JSR VICOUT ;SEND TO VICS SCREEN

0072 1C3E ; NOW CONVERT THE ASCII CHARACTER INTO A VIC
0073 1C3E ;POKE CODE, KEY ON OR TO END LINE,
0074 1C3E AA TAX ;HI BIT ON?
0075 1C3F 10 1C BPL BITOFF ;NO
0076 1C41 29 7F AND #$7F ;YES, TURN IT OFF
0077 1C43 C9 7F CMP #$7F ;CONVERT $7F TO $5E
0078 1C45 D0 02 BNE NOT7F
0079 1C47 A9 5E LDA #$5E
0080 1C49 C9 20 NOT7F CMP #$20 ;CONTROL CHAR?
0081 1C4B 80 0C SCS NOTCTL ;NO
0082 1C4D C9 0D CMP #CR ;RETURN?
0083 1C4F F0 4B BEQ FINLIN ;YES
0084 1C51 A2 D4 LDX #QUOTMO ;IN QUOTE MODE?
0085 1C53 F0 4D BEQ GRFBAK ;NO, THEN IGNORE IT
0086 1C55 09 C0 ORA #$C0 ;ON 2 HI BITS
0087 1C57 D0 26 BNE SAUPOK ;TO MAKE POKE CODE
0088 1C59 09 40 NOTCTL ORA #$40 ;TURN ON BIT 6
0089 1C5B D0 1C BNE CKRUS ;AND GO CHECK REVERSE

0090 1C5D C9 0D BITOFF CMP #CR ;RETURN CHAR?
0091 1C5F F0 38 BEQ FINLIN ;YES, END OF LINE
0092 1C61 C9 20 CMP #$20 ;CONTROL CHARACTER?
0093 1C63 80 0A BCS NOCTL ;NOPE
0094 1C65 C9 14 CMP #INSDLE ;YES, IS IT DELETE?
0095 1C67 F0 39 BEQ GRFBAK ;YES, IGNORE IT
0096 1C69 A6 D4 LDX QUOTMO ;NO, IS QUOTE MODE ON?
0097 1C6B D0 10 SNE HIBIT ;YES, THEN PRINT IT
0098 1C6D F0 33 BEQ GRFBAK ;NO, IGNORE IT
0099 1C6F C9 60 NOCTL CMP #$60 ;OVER $60?
0100 1C71 90 04 BCC LOWER ;NO
0101 1C73 29 DF AND #$DF ;YES, OFF BIT 5
0102 1C75 D0 02 BNE CKRUS
0103 1C77 29 3F LOWER AND #$3F ;TURN OFF BITS 6 & 7
0104 1C79 A6 C7 CKRUS LDX RUSMOD ;REVERSE MODE ON?
0105 1C7B F0 02 BEQ SAUPOK ;NO
0106 1C7D 09 80 HIBIT ORA #$80 ;ON BIT 7 TO REVERSE CHARACTER
0107 1C7F 8D 9D 1D SAUPOK STA ASAVE ;SAVE POKE CODE

0108 1C82 ; CHECK FOR FULL LINE
0109 1C82 AD 9E 1D LDA LCOUNT ;CHECK CHARACTER COUNT
0110 1C85 C9 3C CMP #LINLIM ;AT LIMIT?
0111 1C87 D0 08 BNE NOTFUL ;NO, SKIP
0112 1C89 A9 0A LDA #LF ;SEND LINE FEED TO PRINTER
0113 1C8B 20 19 1D JSR FUTCHR

```

Listing 1 continued on page 274

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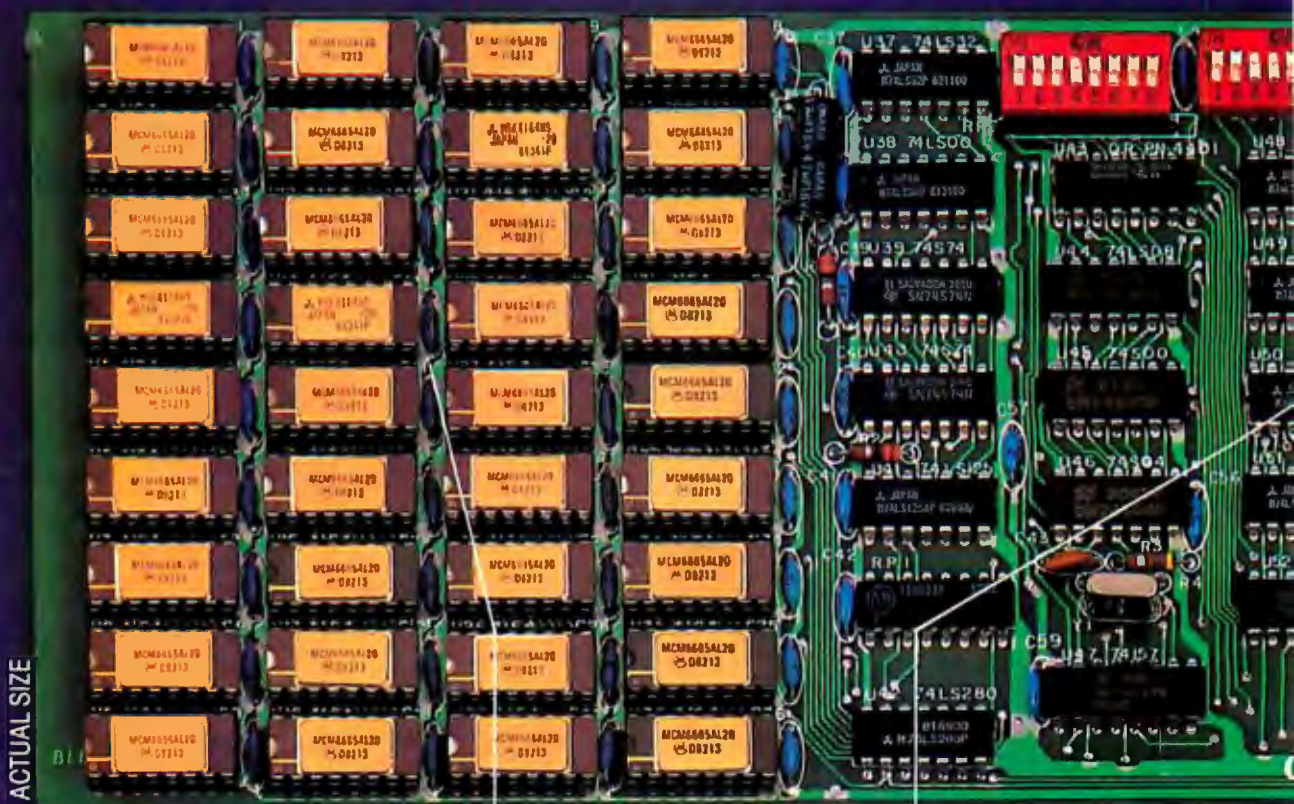
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Listing 1 continued:

```

0114 1C8E 20 40 1D      JSR INILIN      ;SETUP FOR NEW LINE
0115 1C91 AD 90 1D      NOTFUL LDA ASAVE  ;RETRIEVE POKE CODE
0116 1C94 20 EF 1C      JSR SEND       ;SEND CHAR TO PRINTER
0117 1C97 EE 9E 1D      INC LCOUNT    ;COUNT IT
0118 1C9A D0 0E        BNE GRFBK      ;SKIP TO END

0119 1C9C              ;FINISH LINE
0120 1C9C 20 A9 1C      FINLIN JSR FILLIN  ;FILL LINE WITH BLANKS
0121 1C9F 20 40 1D      JSR INILIN     ;INITIALIZE NEW LINE

0122 1CA2 68          GRFBK  PLA       ;RESTORE ALL REGS
0123 1CA3 A8          TAY
0124 1CA4 68          PLA
0125 1CA5 AA          TAX
0126 1CA6 68          PLA
0127 1CA7 18          CLC
0128 1CA8 60          RTS           ;END RETURN

0129 1CA9              ;*** FILLIN : FILL REMAINDER OF LINE WITH BLANKS
0130 1CA9 AE 9E 1D      FILLIN LDX LCOUNT ;GET CHAR COUNT
0131 1CAC E0 3C        CPX #LINLIM   ;AT LIMIT?
0132 1CAE B0 0A        BCS NXTLIN    ;YES, QUIT
0133 1CB0 A9 20        LDA #32       ;NO, SEND A BLANK
0134 1CB2 20 BF 1C      JSR SEND
0135 1CB5 EE 9E 1D      INC LCOUNT   ;COUNT IT
0136 1CB8 D0 EF        BNE FILLIN    ;REPEAT
0137 1CBA A9 0A        NXTLIN LDA #LF   ;SEND LINE FEED TO PRINTER
0138 1CBC 4C 19 1D      JMP PUTCHR

0139 1CBF              ;*** SEND : ROUTINE TO USE VIC POKE CODE TO FIND
0140 1CBF              ; THE CHARACTER PATTERN, CONVERT IT TO
0141 1CEF              ; THE PRINTERS FORMAT AND SEND TO PRINTER

0142 1CBF              ; FIRST CALC THE ADDRESS OF THE CHARACTER
0143 1CBF 85 FB        SEND  STA VICPAT  ;SAVE POKE CODE
0144 1CC1 A9 00        LDA #0        ;IN PATTERN POINTER
0145 1CC3 85 FC        STA VICPAT+1
0146 1CC5 A0 02        LDY #2        ;LOOP TO MULTIPLY THE POKE CODE
0147 1CC7 18          MULTS CLC           ;BY 8 TO GET OFFSET INTO CURRENT
0148 1CC8 26 FB        ROL VICPAT   ;CHARACTER SET
0149 1CCA 26 FC        ROL VICPAT+1
0150 1CCC 88          DEY
0151 1CCD 10 F8        BPL MULTS     ;THREE TIMES THRU
0152 1CCF A2 80        LDX #80
0153 1CD1 AD 05 90     LDA TVCTL5    ;USE DATA FROM TV CHIP TO
0154 1CD4 29 0C        AND #8        ;DETERMINE LOCATION OF
0155 1CD6 F0 02        BEQ NOALT    ;OF CURRENT CHARACTER SET
0156 1CD8 A2 10        LDX #10
0157 1CDA 8A          NOALT TXA         ;ADD IN HI NYBBLE
0158 1CDB 18          CLC           ;OF CHARACTER SET ADDRESS
0159 1CDC 65 FC        ADC VICPAT+1
0160 1CDE 85 FC        STA VICPAT+1
0161 1CE0 AD 05 90     LDA TVCTL5    ;CALC SECOND NYBBLE VALUE
0162 1CE3 29 03        AND #3
0163 1CE5 18          CLC
0164 1CE6 0A          ASL A
0165 1CE7 0A          ASL A
0166 1CE8 65 FC        ADC VICPAT+1  ;AND ADD IT IN
0167 1CEA 85 FC        STA VICPAT+1

0168 1CEC              ; CONVERT VIC PATTERN TO PRINTER PATTERN
0169 1CEC A0 07        LDY #7
0170 1CEE B1 FB        BYTLUP LDA (VICPAT),Y ;GET A VIC PATTERN ROW
0171 1CF0 A2 00        LDX #0
0172 1CF2 0A          BITLUP ASL A     ;SHIFT EACH BIT INTO A
0173 1CF3 7E 95 1D      ROR PRTPAT,X  ;COLUMN OF THE PRINTER PATTERN
0174 1CF6 E8          INX
0175 1CF7 E0 08        CPX #8        ;GOT ALL 8?
0176 1CF9 90 F7        BCC BITLUP   ;NO, DO ANOTHER
0177 1CFB 88          DEY         ;YES BUMP Y TO NEXT ROW OF VIC PATTERN
0178 1CFC 10 F0        BPL BYTLUP   ;DO ALL 8

0179 1CFE              ; SEND CONVERTED PATTERN TO PRINTER:

```


DATA STORAGE FROM 1 TO

33.2

MEGA-BYTES



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Listing 1 continued:

```

0180 1CFE A2 00          LDX #0
0181 1D00 BD 95 1D    OUTLUP LDA PRTPAT,X      ;GET A DOT COLUMN
0182 1D03 20 19 1D          JSR PUTCHR        ;SEND TO PRINTER
0183 1D06 AC 9F 1D          LDY DOTFLG       ;DOUBLE DOT MODE?
0184 1D09 C0 01          CPY #1
0185 1D0B D0 03          BNE NOZDOT       ;NO, SKIP
0186 1D0D 20 19 1D          JSR PUTCHR        ;YES, SEND IT AGAIN
0187 1D10 E8          NOZDOT INX
0188 1D11 E0 08          CPX #8           ;DONE ALL?
0189 1D13 90 EB          BCC OUTLUP       ;NO, REPEAT
0190 1D15 60          RTS

0191 1D16          ;*** ASCOUT ; ROUTINE TO SEND ASCII CHARACTER TO PRINTER

0192 1D16 20 7A F2    ASCOUT JSR UICOUT      ;SEND TO SCREEN

0193 1D19          ; SEND BYTE TO PRINTER
0194 1D19 48          PUTCHR PHA        ;SAVE CHARACTER
0195 1D1A A9 10          LDA ##10         ;TEST INTERRUPT BIT
0196 1D1C 2C 1D 91    WAITO BIT IFR1    ;IN FLAG REG
0197 1D1F F0 FE          BEQ WAITO        ;WAIT UNTIL IT TURNS ON
0198 1D21 68          PLA
0199 1D22 8D 10 91          STA IORB1        ;THEN SEND CHARACTER
0200 1D25 60          RTS

0201 1D26          ;*** INITOT ; INITIALIZE PIA FOR OUTPUT

0202 1D26 AD 1C 91    INITOT LDA PCR1        ;GET PCR
0203 1D29 29 0F          AND ##0F         ;CLEAR B: PORT BITS
0204 1D2B 09 A0          ORA ##A0         ;SET IT TO AUTO PULSE MODE
0205 1D2D 8D 1C 91          STA PCR1        ;AND STORE IN PCR
0206 1D30 A9 10          LDA ##10         ;DISABLE INTERRUPT
0207 1D32 8D 1E 91          STA IER1
0208 1D35 A9 FF          LDA ##FF         ;SET ALL BITS TO OUTPUT
0209 1D37 8D 12 91          STA DDRE1
0210 1D3A A9 00          LDA #0           ;START WITH A NULL
0211 1D3C 8D 10 91          STA IORB1
0212 1D3F 60          RTS

0213 1D40          ;*** INILIN ; PREPARE FOR SENDING A LINE

0214 1D40 A9 00          INILIN LDA #0           ;CLEAR L COUNT
0215 1D42 8D 9E 1D          STA LCOUNT
0216 1D45 A9 1B          LDA #ESC         ;START ESCAPE SEQ
0217 1D47 20 19 1D          JSR PUTCHR
0218 1D4A AC 9F 1D          LDA DOTFLG       ;DOUBLE DOT MODE REQUESTED?
0219 1D4D C9 01          CMP #1
0220 1D4F D0 08          BNE ONEDOT       ;NOPE
0221 1D51 A9 4C          LDA #'L'         ;YES, 960 MODE
0222 1D53 A0 C0          LDY #<960        ;LOAD 960 INTO X AND Y
0223 1D55 A2 03          LDX #>960
0224 1D57 D0 06          BNE PUTREG       ;GO SEND
0225 1D59 A9 4B          ONEDOT LDA #'K'         ;480 MODE
0226 1D5B A0 E0          LDY #<480        ;480 INTO X & Y
0227 1D5D A2 01          LDX #>480
0228 1D5F 20 19 1D          JSR PUTCHR       ;SEND CODE
0229 1D62 98          TYA
0230 1D63 20 19 1D          JSR PUTCHR       ;AND THEN COUNT
0231 1D66 8A          TXA
0232 1D67 4C 19 1D          JMP PUTCHR

0233 1D6A          ;*** INITPR ; STARTUP INITIALIZATION FOR PRINTER

0234 1D6A A2 00          INITPR LDX #0
0235 1D6C BD 92 1D          IPRLUP LDA PRTAB,X      ;GET A BYTE
0236 1D6F F0 06          BEQ IPDUN        ;QUIT IF 0
0237 1D71 20 19 1D          JSR PUTCHR       ;SEND IT
0238 1D74 E8          INX
0239 1D75 D0 F5          BNE IPRLUP
0240 1D77 AE 0C 03          IPDUN LDX SYSA        ;GET A REG
0241 1D7A A9 09          LDA #LPIB        ;GET 8 LPI CODE
0242 1D7C E0 01          CPX #1           ;1=8LPI
0243 1D7E F0 08          BEQ FUTDEN       ;YES, 8LPI
0244 1D80 A9 08          LDA #LPIGRF      ;LOAD GRAPHIC DENSITY CODE
0245 1D82 E0 02          CPX #2           ;2=GRAPHIC DENSITY

```

Listing 1 continued on page 278

WESTICO — The Software Express Service that really delivers:

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STATPAK — Statistics software library in Microsoft BASIC. Performs probability calculations, one independent variable statistics, discrete distribution functions, continuous distribution functions, regression analysis, means testing, survey data/contingency tables, non-parametric statistics and analysis of variance. Includes plotting and file management modules. \$500/\$40.

PRIORITIES — Easy to learn system for efficient time management. Schedules and prioritizes daily and recurring tasks and appointments for individuals or entire staff. Tasks not accomplished on schedule automatically appear on the next day's agenda, which can be updated and printed at any time. Saves valuable time because necessary data such as names and phone numbers are included on the agenda. \$195/\$35.

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PROPERTY MANAGEMENT — Manages real estate accounting from single family homes to office complexes. Reports include operating statements, G/L accounts, A/P accounts, late rents, tenant/vendor lists, etc. \$695/\$35.

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Listing 1 continued:

```

0246 1D84 F0 02          BEQ PUTDEN          ;YES
0247 1D86 A9 0C          LDA #LPI6          ;ELSE DEFAULT TO 6 LPI
0248 1D88 20 19 1D      PUTDEN JSR PUTCHR
0249 1D8B AD 0D 03      LDA SYSX          ;SAVE DOT MODE FLAG
0250 1D8E 8D 9F 1D      STA DOTFLG
0251 1D91 60            RTS

0252 1D92              ; PRINTER PARM TABLES

0253 1D92 1B          PRTAB .BYT ESC,'A',0
0254 1D93 41
0255 1D94 00

0256 1D95              ; DATA AREAS

0257 1D95          PRTPAT **+=8          ;PRINTER PATTERN AREA
0258 1D9D          ASAVE **+=1          ;CHARACTER TEMPORARY
0259 1D9E          LCOUNT **+=1        ;CHARACTER IN LINE COUNTER
0260 1D9F          DOTFLG **+=1        ;DOT MODE FLAG

0261 1DA0          LAST .END
0262 1DA0          ERRORS= 0000

```

SYMBOL CROSS REF FOR VIC TO EPSON MK-80 INTERFACE PAGE 05

SYMBOL DEFINED REFERENCES

A	0000	0172	0165	0164			
ASAVE	0258	0115	0107	0070	0064		
ASCOUT	0192	0050	0048				
BITLUP	0172	0176					
BITOFF	0090	0075					
BYTLUP	0170	0178					
CKRUS	0104	0102	0089				
CLOSE	0056						
CR	0023	0090	0082				
DDRB1	0010	0209					
DISVEC	0021	0059	0057	0051	0049	0040	0038
DOTFLG	0260	0250	0218	0183			
ESC	0025	0253	0216				
FILLIN	0130	0136	0120	0060			
FINLIN	0120	0091	0083				
GRFBK	0122	0118	0098	0095	0085		
GRFOUT	0064	0039	0037				
HIBIT	0106	0097					
IER1	0013	0207					
IFR1	0012	0196					
INILIN	0214	0121	0114	0042			
INITOT	0202	0047	0036				
INITPR	0234	0041					
INDEL	0024	0094					
IORB1	0009	0211	0199				
IPDUN	0240	0236					
IPRLUP	0235	0239					
LAST	0261						
LCOUNT	0259	0215	0135	0130	0117	0109	
LF	0026	0137	0112				
LINLIM	0027	0131	0110				
LOWER	0103	0100					
LPI6	0030	0247					
LPI8	0029	0241					
LPIGRF	0028	0244					
MULT8	0147	0151					
NOALT	0157	0155					
NOCTL	0099	0093					
NOT7F	0080	0078					
NOTCTL	0088	0081					
NOTFUL	0115	0111					
NOZDOT	0187	0185					
NXTLIN	0137	0132					
ONEDOT	0225	0220					
OPENA	0047						
OPENG	0036						
OUTLUP	0181	0189					
PCR1	0011	0205	0202				
PRTAB	0253	0235					

Listing 1 continued on page 280

Expand your possibilities with Concurrent CP/M.™

If you have to wait impatiently for your personal computer to finish a job before moving on to another task, you need Concurrent CP/M. This new software technology from Digital Research increases the productivity of your IBM PC by allowing you to do more with it.

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The image shows a person from behind, sitting at a desk with four computer monitors. Each monitor displays a different application:

- Top Left Monitor:** An email interface.

TO: Frank Belliker
FROM: Davis North
RE: Staff Meeting

Frank,

This memo is to remind you of our staff meeting, which will be held this Friday at 10:00 a.m. in the boardroom. The major objective of this meeting will be to review the sales figures for the past fiscal year, and to present what level of business we can realistically expect to achieve next year.

I think we all recognize how important this meeting will be. The marketing manager will be in attendance to help us develop key accounts for our sales team. Hopefully, by the end of the meeting we will have a well defined strategy to help us meet our objectives.

Davis North

Executive@ Symbolics Printer@ IBM 10:27:28 Wed
- Top Right Monitor:** A calendar application.

Friday

9:00 - 9:30 Study project status

10:00 - 12:00 Staff Meeting
Note: Marketing Manager will attend

12:00 - 1:30 Lunch with Dave

2:00 - 3:00 Interview J.L. for Marketing Rep Position

4:00 - 5:00 Review Daily Mail

7:00 - Bill and Davey coming for Marketing Rep Dinner

Executive@ Symbolics Printer@ CALIBRE 10:30:00 Wed
- Bottom Left Monitor:** A ledger application.

January Journal For David Robley

Number	Amount	Date	Amount	Description
1000	100	10/1/82	11.00	Gas bill
1001	270	10/2/82	30.00	Cash
1002	107	10/4/82	42.30	Electric bill
1003	105	10/5/82	121.00	Car repair
1004	103	10/9/82	51.20	Food
1005	342	10/11/82	7.25	Trip
1006	109	10/13/82	75.42	Phone bill
1007	142	10/15/82	46.21	Books
1008	139	10/18/82	200.00	House repair
1009	104	10/19/82	32.20	Money
1010	117	10/22/82	25.20	Cable TV
1011	108	10/24/82	8.00	UES
1012	102	10/25/82	342.00	Airplane ticket
1013	132	10/27/82	62.00	Rent car
1014	200	10/29/82	42.00	Theater tickets

Executive@ Symbolics Printer@ IBM 10:28:07 Wed
- Bottom Right Monitor:** A bar chart application.

Projected units shipped in 1983

Month	Units Shipped
J	1000
F	1500
M	2000
A	2500
M	3000
J	3500
J	4000
A	4500
S	5000
O	5500
N	6000
D	6500

Executive@ Symbolics Printer@ IBM 10:30:00 Wed

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Listing 1 continued:

```

PRTPAT 0257 0181 0173
PUTCHR 0194 0248 0237 0232 0230 0228 0217 0186 0182 0138 0113
PUTDEN 0248 0246 0243
PUTREG 0228 0224
QUOTMO 0006 0096 0084
RUSMOD 0005 0104
SAVPOK 0107 0105 0087
SEND 0143 0134 0116
SYSR 0019 0240
SYSX 0020 0249
TVCTL5 0015 0161 0153
VICOUT 0017 0192 0071 0058 0056
VICPAT 0007 0170 0167 0166 0160 0159 0149 0148 0145 0143
WAITO 0196 0197
X 0000 0235 0181 0173
Y 0000 0170
  
```

Text continued from page 266:

Location 781 passes the horizontal density to the OPEN routine. The MX-80 offers two horizontal densities in graphic mode: 480 dots per line (DPL) and 960 DPL. Entering a 1 into location 781 produces the 960 DPL mode, and entering anything else in 781 produces the 480 DPL mode. In both modes 60 VIC characters are printed on a line. In 960 DPL mode, each dot of a VIC character is printed twice, resulting in a very black, dense printout. In 480 DPL mode each dot is printed only once, resulting in lighter print.

Printing in graphics mode slows the speed of the MX-80 considerably. It cannot print bidirectionally in

graphics mode, thus halving the normal printer speed. It takes two passes to print a line in 480 DPL mode, slowing printer speed to one-fourth the normal rate. In 960 DPL mode the printing speed is reduced by one-half and it takes four passes to print each line, resulting in one-sixteenth of normal printing speed.

Once the OPEN routine has been executed, any character that is displayed on the screen will also go to the printer. Characters that are entered directly into the screen buffer with a POKE command will not be printed. When you have finished printing, you can turn off the printer by entering the command SYS (7202) to execute the CLOSE routine, which restores the display vector. No

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Data transfer rate is 5 megabits per second and average seek time 120 milliseconds.

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16 Mbyte	\$2375
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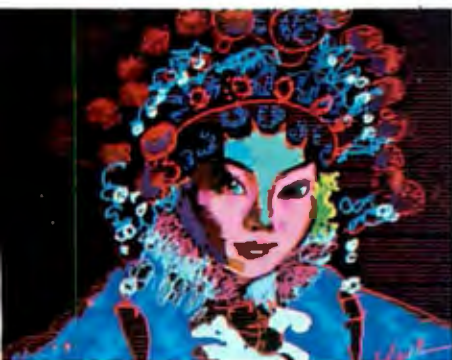


Image achieved by DGS' CAT 1600 Series color video graphic workstation. Picture courtesy of Digital Graphic Systems, Inc. See story below.

GRAPHICS: NOW MAX-IMIZED

CANOGA PARK—March 30, 1983—The decreasing costs and increasing density of memory made possible the present boom in digital graphics. Graphic systems designers are now able to take another major step with the introduction of MAX-M, a one megabyte memory board for \$1983. As large size system memory and multi-megabyte Virtual Disk, MAX-M opens up major new low cost implementations.



Wayne Maw, Director of R&D for RGB Dynamics, Salt Lake City, Utah, reports, "My application is dependent on speed. With the Macrotech dynamic board, I have the needed speed." The RGB system is a Z80-based, high resolution color directory system for shopping malls, due for April release.

Empirical Research Group of Kent, Washington, creates a state-of-the-art high resolution color video graphics system by integrating their fast 68000 computer, Macrotech system memory, and the color video image processor from Digital Graphic Systems, Inc., Palo Alto, California. Radcliffe Goddard of Digital Graphics states, "High speed image processing requires large system memory to provide instantaneous display frame paging."

The demand for MAX-M by the graphics industry was nearly instantaneous following the initial Macrotech announcement. ■

MAX—256K to 1M S-100 Memory

CANOGA PARK—March 30, 1983—Mike Pelkey, Macrotech International president, today released details of the revolutionary MAX line of S-100 memory boards. Pelkey stated: "IEEE-696 now has a new standard for dynamic memory. The MAX product line offers 256K to 1M, at a price that ranges down to less than \$0.00023 per bit." Pelkey continued, "The MI product line now includes our ultra fast (70 ns) 128K static memory, with battery backup capability, plus the 150 ns dynamic memories—in every 128K step from 256K through 1M (1024K) bytes, and add-on kits to permit field upgrade of sizes."

The extreme density of the MAX family is made possible through the use of proprietary PALs (programmable array logic). Also stated as available for add-on to any size MAX is

Macrotech's popular M³ memory mapping architecture. M³ permits the 16-bit address space of an 8-bit processor to be dynamically mapped in 4K pages into as much as 16 megabytes of physical memory.

Parity error detection and 8/16 bit data transfer capabilities are provided as standard on the MAX series memory board. ■

Software for M³ Available

BURBANK—March 30, 1983—"M³ bank switching for 8-bit processors is much more useful with the new creative systems programs," states Dan West of Westcom Systems Inc. MP/M II* disk intensive applications are greatly improved with the new Virtual Disk routines now available through Macrotech OEM's and dealers for their M³ memory boards.



Westcom Systems, as the software consulting firm for Macrotech, has also provided subroutine listings to easily incorporate M³ mapping into the new CP/M 3.0* (CP/M Plus*) Biosmodule. The advantages of CP/M 3.0* with disk buffering, hashed directories, and user program expansion go hand in hand with Macrotech's flexible "bank switched" memory capabilities.

All Macrotech software and manuals are available through Dan West's CompuServe account #70250,102. Leave comments/questions as E-Mail

These new techniques can combine the above features with custom needs of the future, such as printer buffering, multi-page display and memory-intensive graphics displays.

The software listings are included in the Macrotech memory board manuals and are optionally available on 8" diskettes. ■

PRICE INDEX

	SIZE	P/N	PRIC
Static Memory	128K	128-ST	\$1232
Dynamic Memory	256K	MAX-256	\$1108
24-bit	384K	MAX-384	1292
	768K	MAX-768	1815
	896K	MAX-896	1899
	1M	MAX-1M	1983

256K/768K	MKT-2/1	876
256K/896K	MKT-2/8	967
256K/1M	MKT-2/M	1060
384K/512K	MKT-3/5	600
384K/768K	MKT-3/7	784
384K/896K	MKT-3/8	876
384K/1M	MKT-3/M	968
512K/768K	MKT-5/7	284
512K/896K	MKT-5/8	376
512K/1M	MKT-5/M	468
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more characters will be printed until the OPEN routine is executed again.

A second OPEN routine, called by the command SYS (7188), is provided to allow the VIC to communicate with the MX-80 directly in ASCII (American National Standard Code for Information Interchange) instead of VIC character patterns. This enables the VIC to take complete control of all of the MX-80's features. If you want complete control, remember to initialize the printer as necessary for your application. Notice that some of the VIC control characters for color change and cursor movement are also command codes to the printer (see table 1). If you aren't careful, you could get some strange results.

Listing 2 is the CHARACTER SET program that prints the entire VIC character set in the various modes. A sample of its output follows the program listing. The entire listing was printed with an MX-80 by the VIC.

The main routine in the VICEPS program is a subroutine called GRFOUT (see line 64). It is executed each time a character is sent to the VIC screen. It must convert the ASCII code into a VIC screen POKE code so that it can find the VIC character pattern in memory. A routine in the VIC KERNAL ROM at location E756 hexadecimal converts ASCII to VIC screen codes. Unfortunately, this routine is part of the display routine and cannot be called externally. GRFOUT is based on the logic in this routine. After converting ASCII to screen code, GRFOUT calls the subroutine SEND to convert the screen code to a graphic image and send it to the printer. SEND finds the character pattern the same way that the VIC TV controller chip finds the pattern; as a result, any character that can be displayed on the screen can be printed. If you've designed your own characters for the VIC, this routine will find them and print them.

After the appropriate character pattern is found, it must be converted into printer format. The VIC stores its character patterns in memory as rows of dots. Each of the 8 bytes of the pattern represents one row of dots of the character. The printer requires that the character be sent a column at a time. Row patterns must be converted into column patterns. Next, each column must be sent to the printer, which requires sending 8 bytes in the 480 DPL mode and sending 16 bytes in the 960 DPL mode.

VICEPS should be fairly easy to convert for use with another printer whose print head has 8 or more wires. Any changes required will be in the subroutines INILIN and INITPR (see lines 214 and 234). These routines send to the printer the commands to set the LPI and initialize the graphics mode. These commands will be different for another printer.

Some printers may represent a column of dots differently from the MX-80. The MX-80 uses the high-order bit of the byte to represent the top dot in the column and the low-order bit to represent the bottom dot. Other printers might do the reverse, which would make all characters come out upside-down. You can correct the situation by reversing the direction of the Y register-loop index in the pattern-conversion routine in the subroutine SEND. It currently starts Y at 7 and decrements through

Text continued on page 286

Okidata **MICROLINE 92**

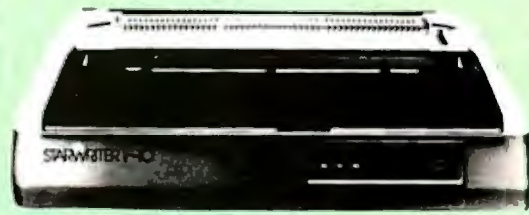


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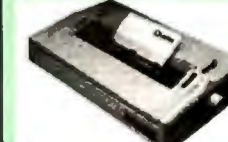
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Listing 2 continued:

```
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!#$%&'()*+,-./0123456789:;<=>?@ABCDEFGHIJKLMNopqrstuvwxyz[\_`~
!#$%&'()*+,-./0123456789:;<=>?@ABCDEFGHIJKLMNopqrstuvwxyz[\_`~
```

480 MODE AT 8 LPI

```
"QJ0LE4←←R-SUN"
!#$%&'()*+,-./0123456789:;<=>?@ABCDEFGHIJKLMNopqrstuvwxyz[\_`~
!#$%&'()*+,-./0123456789:;<=>?@ABCDEFGHIJKLMNopqrstuvwxyz[\_`~
!#$%&'()*+,-./0123456789:;<=>?@ABCDEFGHIJKLMNopqrstuvwxyz[\_`~
!#$%&'()*+,-./0123456789:;<=>?@ABCDEFGHIJKLMNopqrstuvwxyz[\_`~
!#$%&'()*+,-./0123456789:;<=>?@ABCDEFGHIJKLMNopqrstuvwxyz[\_`~
```

960 MODE AT 8 LPI

```
"QJ0LE4←←R-SUN"
!#$%&'()*+,-./0123456789:;<=>?@ABCDEFGHIJKLMNopqrstuvwxyz[\_`~
!#$%&'()*+,-./0123456789:;<=>?@ABCDEFGHIJKLMNopqrstuvwxyz[\_`~
!#$%&'()*+,-./0123456789:;<=>?@ABCDEFGHIJKLMNopqrstuvwxyz[\_`~
!#$%&'()*+,-./0123456789:;<=>?@ABCDEFGHIJKLMNopqrstuvwxyz[\_`~
!#$%&'()*+,-./0123456789:;<=>?@ABCDEFGHIJKLMNopqrstuvwxyz[\_`~
!#$%&'()*+,-./0123456789:;<=>?@ABCDEFGHIJKLMNopqrstuvwxyz[\_`~
```

480 MODE AT GRAPHIC DENSITY

```
"QJ0LE4←←R-SUN"
!#$%&'()*+,-./0123456789:;<=>?@ABCDEFGHIJKLMNopqrstuvwxyz[\_`~
!#$%&'()*+,-./0123456789:;<=>?@ABCDEFGHIJKLMNopqrstuvwxyz[\_`~
!#$%&'()*+,-./0123456789:;<=>?@ABCDEFGHIJKLMNopqrstuvwxyz[\_`~
!#$%&'()*+,-./0123456789:;<=>?@ABCDEFGHIJKLMNopqrstuvwxyz[\_`~
!#$%&'()*+,-./0123456789:;<=>?@ABCDEFGHIJKLMNopqrstuvwxyz[\_`~
```

960 MODE AT GRAPHIC DENSITY

```
"QJ0LE4←←R-SUN"
!#$%&'()*+,-./0123456789:;<=>?@ABCDEFGHIJKLMNopqrstuvwxyz[\_`~
!#$%&'()*+,-./0123456789:;<=>?@ABCDEFGHIJKLMNopqrstuvwxyz[\_`~
!#$%&'()*+,-./0123456789:;<=>?@ABCDEFGHIJKLMNopqrstuvwxyz[\_`~
!#$%&'()*+,-./0123456789:;<=>?@ABCDEFGHIJKLMNopqrstuvwxyz[\_`~
!#$%&'()*+,-./0123456789:;<=>?@ABCDEFGHIJKLMNopqrstuvwxyz[\_`~
```

Text continued from page 282:

0. To invert the characters, you could change it to start at 0 and increment through 7. Listing 3 is an example of how you could rewrite this section of VICEPS for such a printer. Notice that this routine requires slightly more memory than its counterpart in VICEPS.

It is possible to print full VIC graphics with a 7-wire printer. To do this, the program would have to store an entire line of character patterns in memory, then send them in two lines to the printer. The top half of each character would be printed on the first line, then the paper would be advanced half the height of a character,

then the bottom half of each character would be printed. If the alignment were perfect, the characters would look as if they had been printed with an 8-wire printer. Printing this way would require an extra 480 bytes of memory to store all the patterns.

If you have a 7-wire printer you'd like to use with the VIC, you might consider another solution. It's possible to achieve acceptable results by printing only the top 7 dots of the VIC character and eliminating the bottom row altogether. The VIC capital letters and numbers don't use the bottom row of dots, anyway. Graphic characters

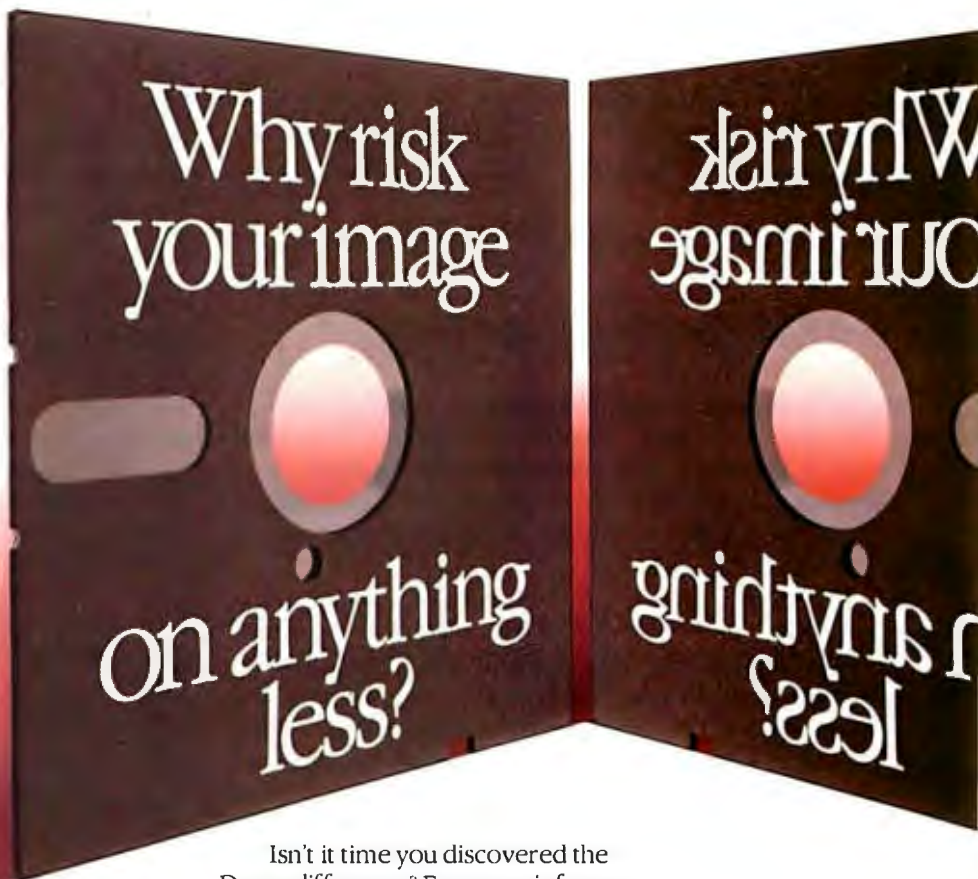
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Listing 3: An alternate version of the SEND subroutine for the VICEPS program. This enables you to use the program with other printers that use the reverse of the MX-80's representation of dots in a column.

```

0168 1CEC          :   CONVERT VIC PATTERN TO PRINTER PATTERN
0169 1CEC      A0 00      LDY #0
0170 1CEE      B1 FB      BYTLUP LDA (VICPAT),Y :GET A VIC PATTERN ROW
0171 1CF0      A2 00      LDX #0
0172 1CF2      0A          BITLUP ASL A :SHIFT EACH BIT INTO A
0173 1CF3      7E 97 1D    ROR PRTPAT,X :COLUMN OF THE PRINTER PATTERN
0174 1CF6      E8          INX
0175 1CF7      E0 08      CPX #8 :GOT ALL 8?
0176 1CF9      90 F7      BCC BITLUP :NO, DO ANOTHER
0177 1CFB      C8          INY :YES BUMP Y TO NEXT ROW OF VIC PATTERN
0178 1CFD      C0 08      CPY #8 :DONE THEM ALL?
0179 1CFE      90 EE      BCC BYTLUP :NO, CONTINUE

```

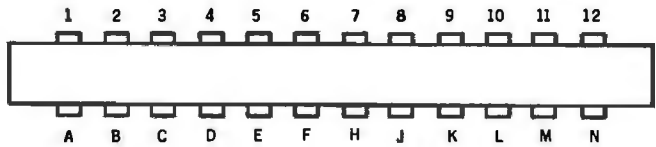


Figure 1: VIC-20 user port I/O connections.

would be incomplete but recognizable. The descenders on lowercase and special characters would be lost. This method might be acceptable for many applications. I have implemented both of the above solutions using my Base 2 7-wire printer. This method could also be used on the VIC-1515 printer.

VICEPS as shown in listing 1 resides in VIC memory at location 1C00 hexadecimal. It uses the top two pages of BASIC memory, the area normally used by BASIC for string storage. To keep BASIC from using this area and destroying VICEPS, you must move the end of BASIC memory down by using a POKE command to enter a 28 into locations 52 and 56. On an expanded VIC with more than 8K bytes of memory, 1C00 would not be a very

good place to locate VICEPS because it would be right in the middle of BASIC memory. Assembling VICEPS at a higher address would be better.

Conclusion

By interfacing a full-featured printer to the VIC-20, you can make lighter work of developing programs. And by breaking the VIC out of the benevolent grasp of Commodore-manufactured peripherals, you can further unleash the power of this talented computer. ■

The VICEPS program has been incorporated into a full-featured printer driver program for the Epson and other printers. The program supports VIC graphics and all Epson functions via standard BASIC OPEN, CLOSE, and PRINT# statements (no SYS calls). It also has a special mode that formats BASIC program statements for readability. It will communicate to the printer via either the parallel method described above or via an RS-232C interface at up to 9600 bits per second with handshaking. For more information contact United Microware Industries Inc., 3503C Temple Ave., Pomona, CA 91768.

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----------------------	----------------------	----------------------

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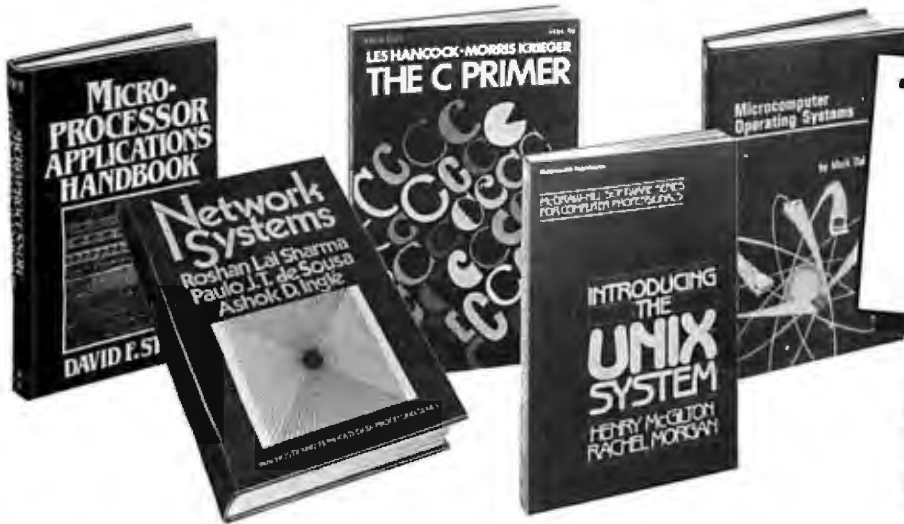
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Two Ways to Use CP/M-80 on the IBM PC

Xedex's Baby Blue and Byad's DS1

Phil Lemmons
West Coast Editor



Photo 1: The Baby Blue CPU Plus from Xedex converts your CP/M-80 files into PC-DOS format and attaches a header to the file to identify it. You don't have to keep track of two different file formats.



Photo 2: The DS1 from Byad uses a technically more elegant approach to integrating the Z80B system into the IBM PC. When the Z80B is in control, the 8088 uses its system memory for disk and print buffering.

People who own a lot of CP/M-80 software but want to buy an IBM Personal Computer have several choices about how to keep running their old software with the PC. One such option is to purchase an 8-bit processor board. Both Xedex and Byad make fine Z80B boards for the IBM Personal Computer. Each has a printed-circuit board with 64K bytes of RAM (random-access read/write memory) as well as the Z80B microprocessor. What distinguishes these boards is the software sold with each and the way they integrate with the IBM PC. Choosing between the boards is largely a matter of determining your software needs.

Xedex and Byad provide utility programs for converting some 5¼-inch CP/M-80 disk file formats to the format used by each of the new boards. Both companies found the problem of conversion much more complex than initially thought. (See the text box, "Reading CP/M-80 Disk Formats with the IBM PC," on page 298.) If you need to convert a lot of disk files (whether data or programs) for use with Xedex's Baby Blue or Byad's DS1, be sure that software is available from Xedex or Byad to handle conversion of your old disk format. If neither company has software to read your old disk format, you may still be able to send your old data to the IBM PC on a serial communications line. Both companies supply the necessary software for receiving data on the IBM PC as part of the standard DS1 package.

Xedex's Baby Blue CPU Plus

Xedex's software for the Baby Blue includes programs called Header, Bind, and Convert. Header must be added to the beginning of each CP/M-80 program in order for the program to run on Baby Blue under PC-DOS, IBM PC's operating system. (You don't actually get CP/M-80 with Baby Blue; it emulates CP/M.) Bind attaches Header to the beginning of CP/M-80 files. Convert takes CP/M-80 programs in any of four different disk formats—NEC PC-8001, IMS 5000, DEC VT-180, Heath/Zenith (48 tracks per inch)—converts them to PC-DOS format, and then attaches Header to the beginning of the

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At a Glance

Name

Baby Blue CPU Plus

Type

Z80B card for running CP/M-80 programs on the IBM Personal Computer

Manufacturer

Xedex Corporation
Box 222, Route 59
Suffern, NY 10901
(914) 368-0353

Price

\$600

Hardware

A printed-circuit board with a Z80B microprocessor and 64K bytes of dynamic RAM with parity

Software

Header, a prefix for CP/M-80 programs that enables them to run under PC-DOS in the IBM Personal Computer; Bind, a program that attaches Header to the beginning of CP/M-80 files; Convert, a program that converts four 5¼-inch CP/M-80 disk formats—NEC PC-8001, IMS 5000, DEC VT-18, Heath/Zenith (48 tracks per inch)—and the CP/M-86 format for the IBM Personal Computer into IBM PC-DOS disk format

Documentation

Forty-page typeset manual with index

Audience

Any IBM PC owner who needs to run CP/M-80 software

DOS finds the Xedex Header on a file, the operating system sends the program to Baby Blue's Z80B for execution. While the Z80B executes the CP/M-80 program, the Header sends CP/M-system calls to the IBM PC's 8088 microprocessor. Then the 8088 manages input/output for the CP/M program. Software with the Baby Blue also includes a program for moving files through the PC's serial port.

Baby Blue is easy to install and use, performs as advertised, and has a superb user's guide. One of Baby Blue's beauties is that after converting your 8-bit programs to PC-DOS format, you no longer have to worry about managing two different file formats on one computer. You don't have to keep track of which disks are CP/M-80 disks and which are PC-DOS disks. Most important of all, any CP/M-80 program or PC-DOS program can access and process any of your data files, because they are all in PC-DOS format. Well, perhaps not any program. The Baby Blue user's guide says (pages 21 and 22), "We have never promised anyone perfect compatibility with CP/M-80. . . . What's of interest to us and to the majority of users is compatibility with plain-vanilla, no-tricks, maximally portable, hardware-independent CP/M-80 programs." The only software that the Baby Blue definitely won't run is CBASIC. The Baby Blue console interface emulates the Televideo 950 terminal to support screen handling (cursor placement, etc.) of CP/M-80 programs.

Baby Blue is easy to install because the procedure is straightforward and the user's guide is written and illustrated well. Photographs orient the user at different stages of installation. The instructions for resetting the IBM and Baby Blue switches to configure both the PC and the Z80B board for different amounts of memory leave nothing to chance. Side-by-side illustrations of the correct positions of all eight switches for the PC and Baby

converted file. In other words, Convert does the same work as Bind but also converts the file to PC-DOS format. After the Header is added, whether by Bind or by Convert, the user can invoke the CP/M-80 program just as if it were a program written for the IBM PC. When PC-

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Blue cover every possibility in 32K-byte increments all the way from 128K bytes (including Baby Blue's own 64K bytes) to 544K bytes. Steve Walton, the author of the Baby Blue user's guide, could do the microcomputer world a great service by teaching courses in how to write clear and pertinent documentation.

If you already own 8-bit versions of your favorite applications programs, you will probably want to convert them and run them on Baby Blue. It is worth noting, however, that Xedex sells versions of Wordstar and Mailmerge for Baby Blue. In fact, Xedex has done a better job of adapting Wordstar to run on Baby Blue than Micropro has done of converting Wordstar to run on the IBM PC's 8088. Xedex's version of Wordstar makes better use of the IBM PC's function keys by both using more keys and making better choices of which control codes are sent by the keys. Xedex sells Baby Blue, Wordstar, and Mailmerge as a package for a total of \$980. In effect, you get the 8-bit versions of both Mailmerge and Wordstar for \$380. Xedex also offers Personal Pearl and the Baby Blue for \$650.

Note that Baby Blue's software does not include the CP/M-80 operating system and its utilities. You do not receive a license to CP/M-80 when you buy Baby Blue. Header and Bind just enable Baby Blue to execute machine-language command (.COM) files that will execute under CP/M-80. The usual procedure when selling one machine and buying another is to write the publisher of each program and pay a small fee to transfer your license from the old processor to the new one. Presumably you should do that before using Header and Bind to make your old CP/M-80 programs run on Baby Blue.

Byad's DS1

When you buy Byad's DS1, you buy both a Z80B board and a license to CP/M-80, including all its utilities. Obviously this implies complete compatibility with CP/M-80 (although some versions of CP/M-80 may differ in disk formats and hardware-specific features). Byad now sells CP/M-80 version 2.2 with DS1 but will also offer CP/M-Plus, the greatly enhanced new version of the venerable 8-bit operating system. For those IBM PC owners who have chosen CP/M-86 or Concurrent CP/M-86, the Byad DS1 (or its cousin, the DS2, which has its own RS-232C serial port that can also drive RS-422A lines) is the logical choice as a CP/M-80 card. The DS1 and DS2 use the same disk format on the IBM PC as CP/M-86.

The DS1's software includes programs called Transfer, Filex, and Setup as well as the usual CP/M-80 utilities (STAT, PIP, ED, etc.). Transfer enables you to capture data coming through the IBM PC's serial port. Filex lets you read certain 5¼-inch disk formats (including NEC PC-8001, Televideo, Cromemco, Heath/Zenith, Intertec Superbrain, and others) into the DS1 format. Setup is necessary for configuring the system after installing the DS1 board. Among other things, Setup lets you enhance CP/M by setting aside some of the PC's memory to serve as disk buffers, a print buffer, a serial-in buffer, and a

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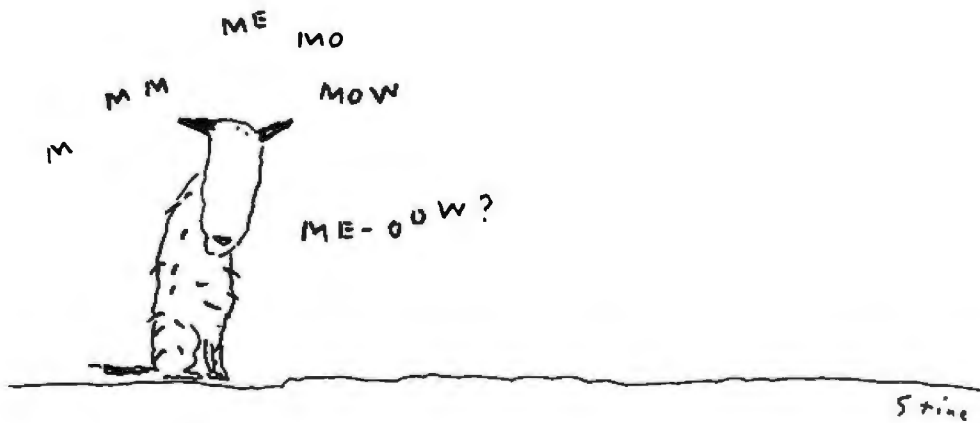
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MicroPro
The Microcomputer Software Company

At a Glance

Name

DS1

Type

Z80B card and CP/M-80 operating system for the IBM Personal Computer

Manufacturer

Byad Inc.
5345 North Kedzie Ave.
Chicago, IL 60625
(312) 539-4922

Price

\$660

Hardware

A printed-circuit board with a Z80B microprocessor and 64K bytes of dynamic RAM with parity

Software

CP/M-80 and all its utilities; Setup configures the DS1 for different hardware and terminal emulation; Format formats disks; Filex converts files from certain CP/M-80 5¼-inch disk formats (including NEC PC-8001, Televideo, Cromemco, Heath/Zenith, and Intertec Superbrain) to Byad format; and Transfer enables the DS1 to receive files from another CP/M-80 computer

Documentation

Preliminary at time of review

Audience

Any IBM PC owner who needs to run CP/M-80 software

serial-out buffer. You can also choose to have the DS1 emulate one of three different terminals: the DEC VT-52, the Lear Siegler ADM 31, or the Heath H-19.

Installation of the DS1, following the **instructions** in the *preliminary* version of the manual, was somewhat awkward. The manual was about average; the only serious lack that I noted was instructions for setting the PC's switches to accommodate different amounts of memory. The blame for the awkwardness of installation, however, goes more to the procedure itself than to the manual. You must remove any other memory expansion boards from the IBM PC while installing the DS1. You must then set the PC system board switches for either 48K or 64K bytes of RAM. After putting in the DS1 board, you close up the system to see whether it will still run PC-DOS. Having done this, you remove the PC-DOS disk and boot the Byad CP/M-80 system and run some CP/M utilities (such as STAT, the disk status command) to confirm that CP/M works. No problem. But then you have to configure the system to use any memory not on the PC's system board or the Byad board.

Configuration takes two steps: first, edit the Byad file called SETUP.CMD; second, run SETUP.CMD. It sounds easy, but you have to use the CP/M editor ED to edit SETUP.CMD. ED is a primitive editor, and most people who use CP/M-80 use another editor. I had to reread the old Digital Research instructions for using ED in order to install the DS1.

Having relearned ED, I was all set to reconfigure the system for my expansion memory, which required entering the correct segment addresses. The DS1 instructions gave only four possibilities, so I was off to the IBM PC manuals. Having decided at last on the segment addresses, I went on editing SETUP.CMD in order to configure some of the DS1's buffers. I wanted to try using 64K bytes of RAM as a print buffer, but because I hadn't yet put back my own 256K-byte memory board or reset the system board switches, Setup informed me there was not enough memory for the desired buffer. I should have realized that. But I still faced a problem: I couldn't configure the system for my hardware until my own memory board was installed and the switches were adjusted, but the instructions told me that I also couldn't use the configuration procedure until after removing my memory board—sort of a "catch-22" installation procedure. The solution was to go through the setup procedure for one set of parameters, reinstall my memory board, and then repeat the configuration procedure. At length, after re-reading the Byad preliminary documentation and reexamining the ED documentation, I succeeded in installing the DS1. Of course, although the setup procedure is awkward and time-consuming, installation is usually a one-time event, and the DS1 documentation was preliminary.

To use CP/M-80 with the Byad board, you just boot the IBM PC with the Byad system disk in drive A. After doing so, I had no difficulty in running a variety of CP/M-80 applications programs on the DS1. Performance seemed excellent.

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[Late notes: Scott Bartky of Byad informs me that the installation procedure has been simplified since I used the system. The instructions now require using ED to edit only a single line of text and show exactly what the user must type to edit that one line. In addition, the instructions list the segment address that must be entered for any amount of memory that may be in the machine.]

At Comdex in November, Byad and Digital Research announced an agreement under which Byad will produce a new Z80B card to be called the CP/M Card. The new card will be equipped with 256K bytes of RAM, a Z80B, and a serial port. Digital Research acquired all rights to the CP/M Card, including the marketing rights. The availability of the CP/M Card with CP/M-86 for the IBM PC will enable CP/M users to run 8- and 16-bit software without worrying about maintaining two different disk file formats. Using the CP/M Card along with Concurrent CP/M-86 will make possible running a CP/M-80 program as one task while the 16-bit operating system is in control. Byad itself will also be bringing out a Z80B board with up to 256K bytes of memory and is making its boards compatible with PC-DOS, no longer requiring the user to keep separate disks for PC-DOS and CP/M-80.

Conclusion

If you just want to run your old 8-bit machine-language programs on your IBM PC, then Xedex's Baby Blue CPU Plus probably suits your needs. If you want to continue doing work with the CP/M-80 utilities or to keep revising your old 8-bit assembly-language programs, then the Byad DS1 is the better choice (though you can use CP/M development tools, languages, linkers, etc., with Baby Blue). Another major factor in deciding on one of these two boards is your choice of 16-bit operating systems for the IBM PC. If you are using PC-DOS (Microsoft's MS-DOS) exclusively, you will want Baby Blue CPU Plus. If you are using Digital Research's CP/M-86 or Concurrent CP/M-86, you will want the DS1. ■

Reading CP/M-80 Disk Formats with the IBM PC

W. Scott Bartky
Byad Inc.
5345 North Kedzie Ave.
Chicago, IL 60625

In designing a Z80B board to let users run CP/M-80 on the IBM Personal Computer, we encountered several obstacles that made it difficult to read CP/M-formatted 5¼-inch soft-sectored disks on that machine. Although the disks were supposedly physically compatible with the PC, a combination of three factors determined whether or not a successful read operation could take place.

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One factor was a problem in the disk-controller hardware. The IBM PC uses a disk-controller chip manufactured by Nippon Electric Company, the NEC 765 or 765a. Either chip has a built-in reset tied to the detection of the disk's index hole. If you try to read a disk that has been formatted with the first sector too close to the index hole, the chip doesn't have enough time to reset itself and read the disk.

The solution is simple: cover the disk's index hole. Most popular soft-sectored formats identify each sector by the sector's header block. The controller does not need to use the index hole for locating a given sector. Fortunately, the 765 does not require the index hole to either read or write data. In fact, the index hole is important only when formatting the disk.

To use this solution, you should start all disk records at the same point on each track so that track-to-track seeks can take place quickly and efficiently. Once the disk is formatted, the hole can be covered, and the controller will still be able to read and write data. The only possible complication is that the operating system may never wait the maximum time needed to read a disk if your machine uses the index hole for this purpose. The IBM PC uses an independent time-out schema, and the covering of the hole won't produce a change in performance.

With the hardware problem solved, we soon found another obstacle to reading disks formatted on other systems. Some systems format their disks in ways that violate common rules of good engineering practice. For example, Intertec's implementation of ten 512-byte sectors per track exceeds the sensible track-length specification by some 70 bytes. This design reduces the size of the interrecord gap, the

space between the first and last sectors on a track.

When we find a format in which this interrecord gap is too small, we use either of two possible solutions. One is to set up a formatting function on the IBM PC to format disks for the nonstandard machine. Then we take the disk formatted by the IBM PC, use it with the other machine and transfer all the files to that disk. A second solution is to slow the speed of the nonstandard machine's drive slightly (about 1 percent) to produce a longer interrecord gap when it formats a disk. Neither solution may work all of the time because multiple writing and reading may cause "creeping" of the records, and the gap will shorten once more.

The third problem affects even well-designed disks such as Cromemco's. IBM uses a phase-locked loop (PLL) in its data separator. Unlike the simpler one-shot multivibrator designs, used in some older systems, that synchronize to the data stream in two pulses, the PLL requires several clock pulses to lock in. (Although it requires the additional pulses, the PLL is a better design than its simpler counterpart because it is less susceptible to noise and rapid fluctuations.) If you attempt to read disks from an older system and are unsuccessful, it is highly probable that your problem is in the data separator design. There is no permanent cure for this incompatibility without altering the IBM card—a complicated operation. All you can do is try again or transfer the data through some other means.

As a result of our efforts to overcome these obstacles, the Byad DS1 is now successfully reading and writing a large number of nonstandard formats on the IBM PC.

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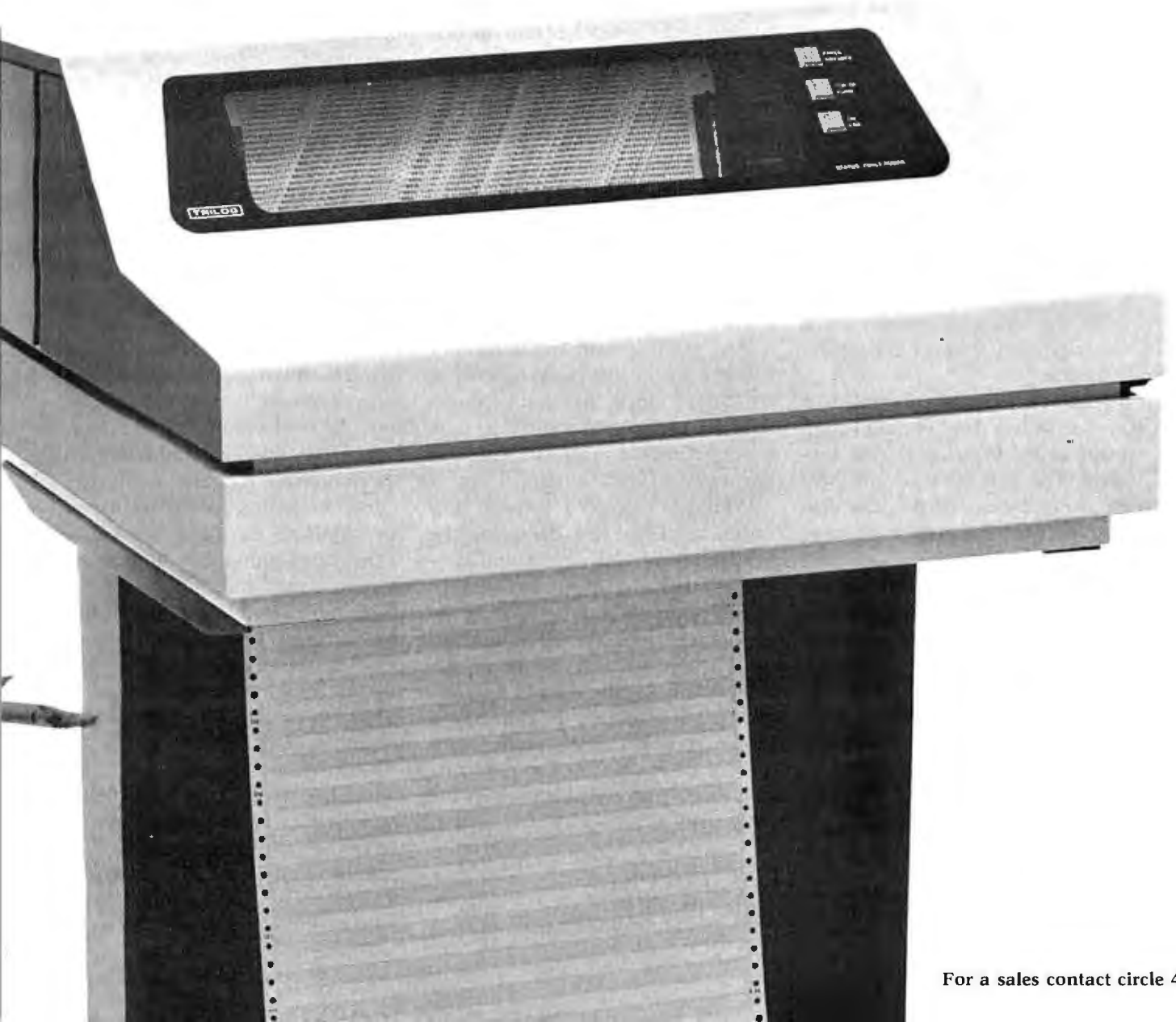
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Building a Hard-Disk Interface for an S-100 Bus System

Part 2: The Hardware

Andrew C. Cruce and Scott A. Alexander
ASC Associates Inc.
209 Spring Valley Dr.
Lexington Park, MD 20653

In last month's article we described Winchester disk-drive technology and generally how drives of this type are integrated into microcomputer systems. This month we will be more specific and describe how a particular set of hardware can be assembled to provide Winchester disk capability for an S-100-bus microcomputer. After reading this article, you should understand the concepts involved in the design, fabrication, and integration of the hardware needed for a 10-megabyte S-100-based Winchester disk system.

The block diagram presented in figure 1 shows the various components of the Winchester disk subsystem. The functions of the host computer adapter (HCA), the disk controller, and the disk drive were described in last month's article. The only remaining component in the diagram is the power supply, which provides the disk drive and controller with power.

About the Authors

Andrew Cruce has a Ph.D. in Aeronautical Engineering and has recently received an S.M. degree in management as a Sloan Fellow at MIT. Scott Alexander has an M.S. in Electrical Engineering. Both have extensive design and implementation experience with small computers and are full partners in the firm of ASC Associates, which markets the hardware described in this series of articles.

This diagram suggests an approach to designing the disk system. The first step is to establish the data path; that is, you must determine how the HCA, the disk controller, and the disk drive are connected. Before you can do this you need to settle on the particular disk and controller to be used in the system as well as the functions that are to be included in the HCA. Once you complete this process, you'll have enough information available to specify power requirements for the system and to identify power supplies that could be used in the system. Finally, when the data interface is complete and you've chosen a power supply, you can consider how to package the system.

We'll now proceed through this design sequence, first discussing the availability of disk drives and controller cards and which ones we ultimately adopted. Next we'll cover the requirements for the HCA and go into the detailed logic design of this component. Finally, we will examine some of the options in choosing a power supply for the system and show the steps required to construct an attractive and reliable package for the system.

Disk Selection

The first decision we made in selecting a disk was on its size and stor-

age capacity. As we stated last month, we chose the 5¼-inch disks because they offered what we consider to be more than sufficient storage capacity for most applications at a reasonable price. When we started this project, a number of manufacturers, including Seagate Technology, Shugart, Memorex, and Miniscribe, offered 5¼-inch Winchester drives. We needed a drive with a disk-to-controller interface equivalent to that of the ST-506 disk drive manufactured by Seagate Technology. This interface has become the de facto standard in the industry and provides the freedom to select from a number of potential controllers that are compatible with this interface.

In considering the storage capacities available on the 5¼-inch-drive systems, we found that 10-megabyte systems were becoming available at prices only marginally higher than the smaller 5-megabyte systems. Based on the attractive cost per bit of storage capacity of the 10-megabyte drives, we opted for the higher-capacity disk systems.

With these criteria in mind, and taking into account the price/performance ratios of the available units, we chose the 10-megabyte disk drive manufactured by the Miniscribe Corporation. Our initial choice could change because we made it at a time

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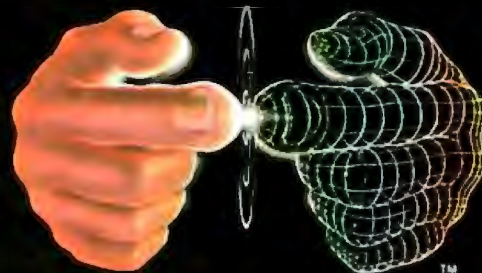
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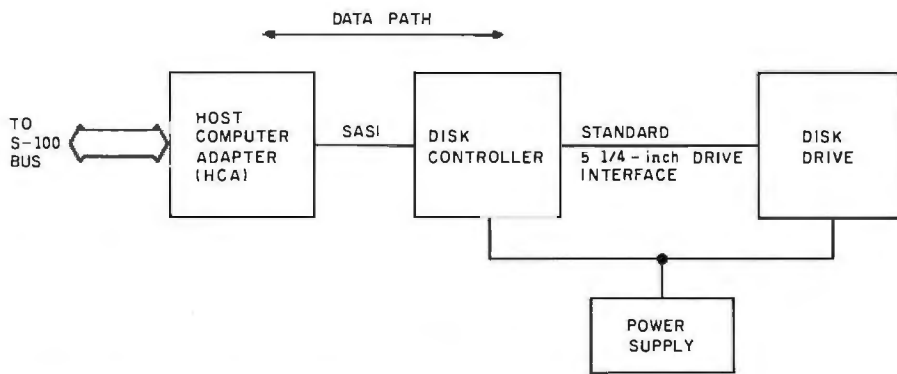


Figure 1: Winchester disk-drive subsystem block diagram.

when many disk-drive manufacturers had not yet commenced delivery of .10-megabyte hardware. However, now that the Seagate Technology interface has become the industry standard, virtually any new 5¼-inch drive currently being manufactured could be immediately plugged into whatever controller we selected. This also means that, for the purposes of this article, you could substitute any other 5¼-inch Winchester disk drive as long as it uses the Seagate Technology standard interface.

Controller Selection

Our decision on which controller to use in the system was somewhat more complicated. The first and most important requirement was that the controller be compatible with the Seagate Technology ST-506 interface (so as to be compatible also with any of the disk drives we were considering).

The second requirement was that the controller implement the Shugart Associates Systems Interface (SASI) to the HCA so that we could interface not only to S-100 systems, but also to a variety of other microcomputers such as the Apple, the Osborne, and the TRS-80. This criterion eliminated some of the available controllers, including those made by Morrow, which interfaced directly with the S-100 bus. A few of these devices would also have been eliminated because any system they are used in must conform to the IEEE standard for the S-100 bus. The problem here is that many of the older S-100 systems do not conform completely to this standard (for example, a number of

systems do not implement the extended 24-bit addressing of the IEEE S-100-bus specification) and thus would not operate properly with the "S-100-compatible" controllers.

Working within these constraints, we considered the cost, performance, size, and power consumption characteristics of a number of commercially available Winchester disk-drive controller boards. At the time we made the selection, the Xebec S1410 controller appeared to offer the best performance per dollar expended. Again, for purposes of this article, the choice of the particular controller board does not largely influence the rest of the design. If you have a controller board that uses the SASI to connect to the HCA and a Seagate-Technology-compatible interface to connect to the Winchester drive, then the hardware and software designs covered in this series should work with little or no modification.

After we verified that the controller and disk were indeed compatible, all we needed to complete this interface was to fabricate a 34-conductor and a 20-conductor ribbon cable to connect the disk and the controller. The next step was to decide on the requirements for the HCA and to design the hardware accordingly.

HCA Interface Requirements

Several preliminary choices had to be made before we designed the host computer adapter for the Winchester disk system. The first was whether the disk subsystem should have DMA (direct memory access) capability. The alternative was to design the HCA to allow the host computer to

perform data transfers between the disk and computer memory. Based on our assessment of most microprocessor system requirements, we considered that the additional speed gained by providing DMA capability in the HCA was not worth the additional complexity and expense that this capability would require. Thus we initially decided that the HCA would not perform DMA data transfers from the disk to memory.

The second decision concerning the design of the HCA was whether or not this device should contain a PROM (programmable read-only memory) chip and a new system-bootstrap program. Assuming that the system to which the Winchester disk is to be connected is operable, it should already have a bootstrap program. However, this program is designed to work with the original disk peripherals. It is possible to interface a Winchester disk with such a system and then use a separate "Winchester Boot" program to bring the Winchester disk BIOS (basic input/output system) routines into the system. However, this means that a hardware bootstrap will always go to the original disk system and that the Winchester Boot program must always be run to bring the Winchester drive into the system. We considered this to be a fairly cumbersome procedure and decided that we should provide the capability for a new bootstrap for the system that would bring up the Winchester disk and all the previously existing peripherals in the system.

Host Computer Adapter Design

Based on these requirements, the design of the HCA can be divided into three essential elements: a connection to the SASI on the disk controller board, a PROM subsystem on the HCA board to store a new bootstrap program, and an interface to the S-100 bus that provides all the signals required to support the first two elements. The combination of these elements results in the initial top-level HCA block diagram presented in figure 2.

The SASI interface on the disk controller is a 2-byte parallel interface.

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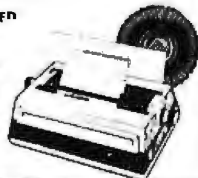
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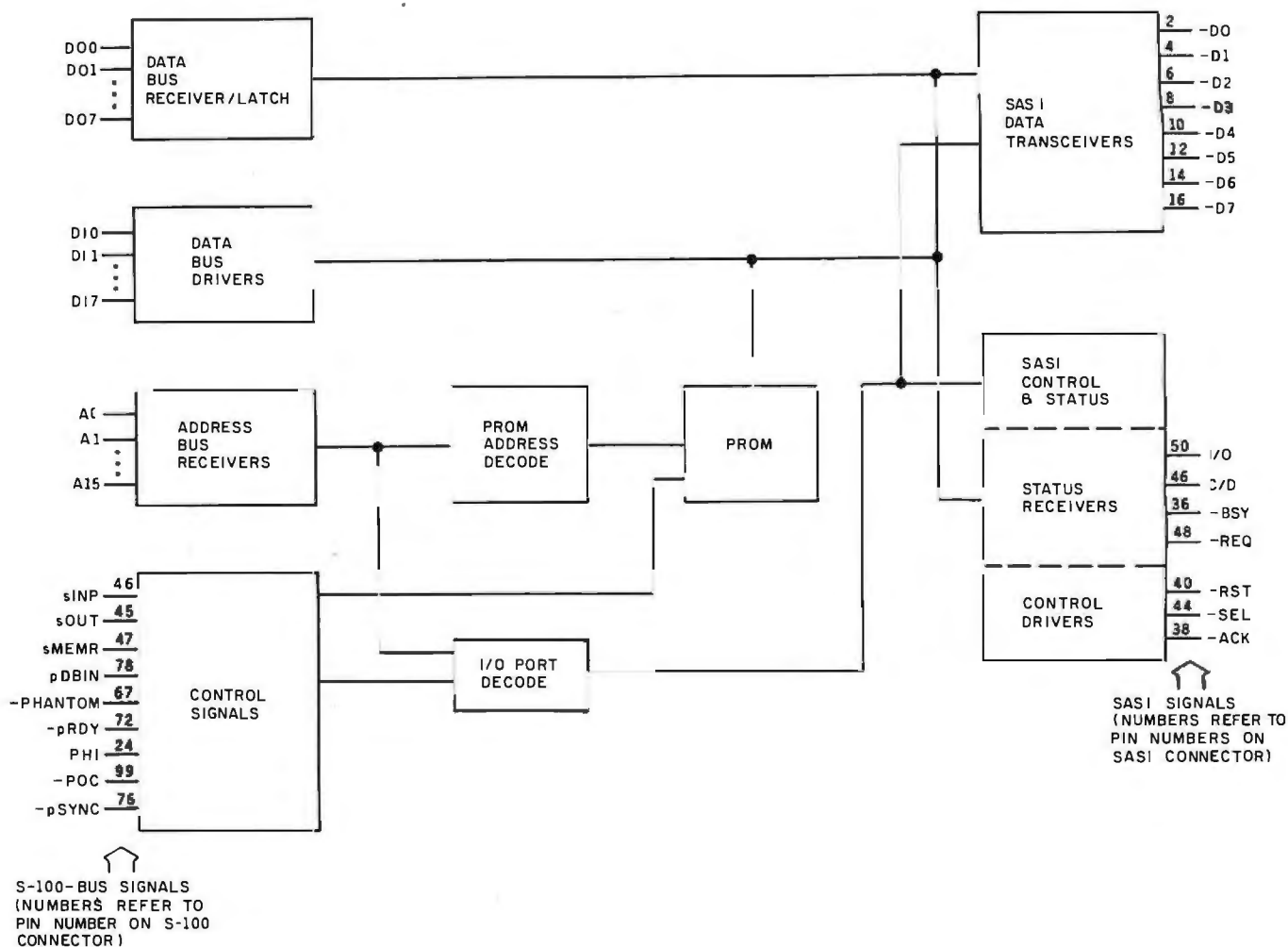


Figure 2: Block diagram of the host computer adapter (HCA) for the Winchester disk drive.

The first byte contains 8 bits of data being sent to or received by the controller. The second byte consists of control and status signals that are used by the host processor to determine the status of and provide control to the disk controller board. The controller board receives these signals on a standard 50-conductor ribbon cable. The signal names, descriptions, and pin numbers are presented in table 1. The portion of the HCA that communicates with the disk controller must send these signals to the controller, preferably via a 50-conductor cable.

The PROM portion of the HCA board is relatively simple in concept. Basically, it provides 2K bytes of nonvolatile memory to store a bootstrap loader. However, in considering the actual design, a number of questions arise. The first is whether to provide a wait state for access to the

PROM. Depending on the speed of the processor being used, it may be necessary to make the processor wait during memory-access operations to allow the PROM time to access the requested data. Another question is whether to provide compatibility with memory systems that support phantom memory. In these systems the bootstrap PROM can be located in memory locations that overlay normal RAM (random-access read/write memory). During the bootstrap operation, the PROM system must assert a PHANTOM signal, which causes the RAM in the computer not to respond as long as the signal is asserted. Thus the PROM is accessed during the bootstrap, and then after the bootstrap is finished the PROM is disabled and conventional RAM memory replaces the PROM in memory. As we will show, neither of these two options is particularly difficult to

implement, so we decided to design both a wait-state enable and phantom-memory support into the HCA. Again, figure 2 shows basically how these two capabilities fit into the system.

With the SASI interface and the PROM memory established, it is now possible to determine what signals from the S-100 bus must be used to communicate with these two elements. Accessing the PROM is like accessing normal memory. All that is required is some address-decode logic and some combinational logic using the S-100 bus signals sMEMR and pDBIN to gate the PROM data onto the S-100 bus. Several other signals are needed to support the memory wait state and the phantom-memory capability. These are the -pRDY signal going back to the processor (which keeps the processor in a wait state), the -PHANTOM signal back

Signal Name	Pin Number	Description
I/O	50	Input/Output: open collector output from controller to HCA. Low level indicates a controller-to-HCA data transfer. This signal is qualified by -REQ.
C/D	46	Command/Data: open collector output from controller to HCA indicating command or data on the data bus. Low level means command bytes. This signal is qualified by -REQ.
-BSY	36	Busy: open collector output from controller to HCA indicating a controller is ready to receive data or command information from the HCA. High level means controller is ready for data.
-MSG	42	Message: open collector output from controller to HCA indicating that the current command is complete. (This signal is not used in our design.)
-REQ	48	Request: open collector output from controller to HCA to initiate controller-host handshaking sequence.
-ACK	38	Acknowledge: host-generated signal that is asserted active low in response to controller -REQ when the host is ready to receive or transmit data. In order to complete the handshake, the host adapter must send -ACK in response to each -REQ from the controller.
-RES	40	Reset: host-generated signal, active low, that resets the controllers. This signal must remain low for at least 100 nanoseconds.
-SEL	44	Select: host-generated signal, active low to initiate a command transaction to a controller.
-DB0	2	Data Bus 0 through 7: tristate input/output bus to send data/command information from the host to the controller or for the host to receive data from the controller.
-DB1	4	
-DB2	6	
-DB3	8	
-DB4	10	
-DB5	12	
-DB6	14	
-DB7	16	

Table 1: Signals and pin locations for the Shugart Associates Systems Interface (SASI) between the disk controller and the host computer adapter (HCA).

to RAM (causing it not to respond), one phase of the system clock (PHI), and the Power On Clear signal (-POC or -RESET).

In addition to supporting the PROM, it is also necessary to provide for data communication between the S-100 bus and the SASI ports on the HCA. There are two ways of doing this. One is to make the SASI ports appear as memory to the processor and use memory-mapped I/O to communicate with these ports. However, this uses up memory space, and a better approach is to use the I/O ports that are accessed by the 8080 IN and OUT instructions. This again

calls for some address-decode logic to determine which port is selected and some combinational logic on the S-100-bus signals sINP and sOUT. These signals indicate whether data is to be written to or read from the particular port selected; figure 2 shows generally how they are used in the HCA design. They are standard S-100 signals, and a detailed description of their use and required characteristics can be found in any complete description of the S-100 bus.

In the logic design process, the block diagram shown in figure 2 is expanded to include the digital logic necessary to perform the functions in-



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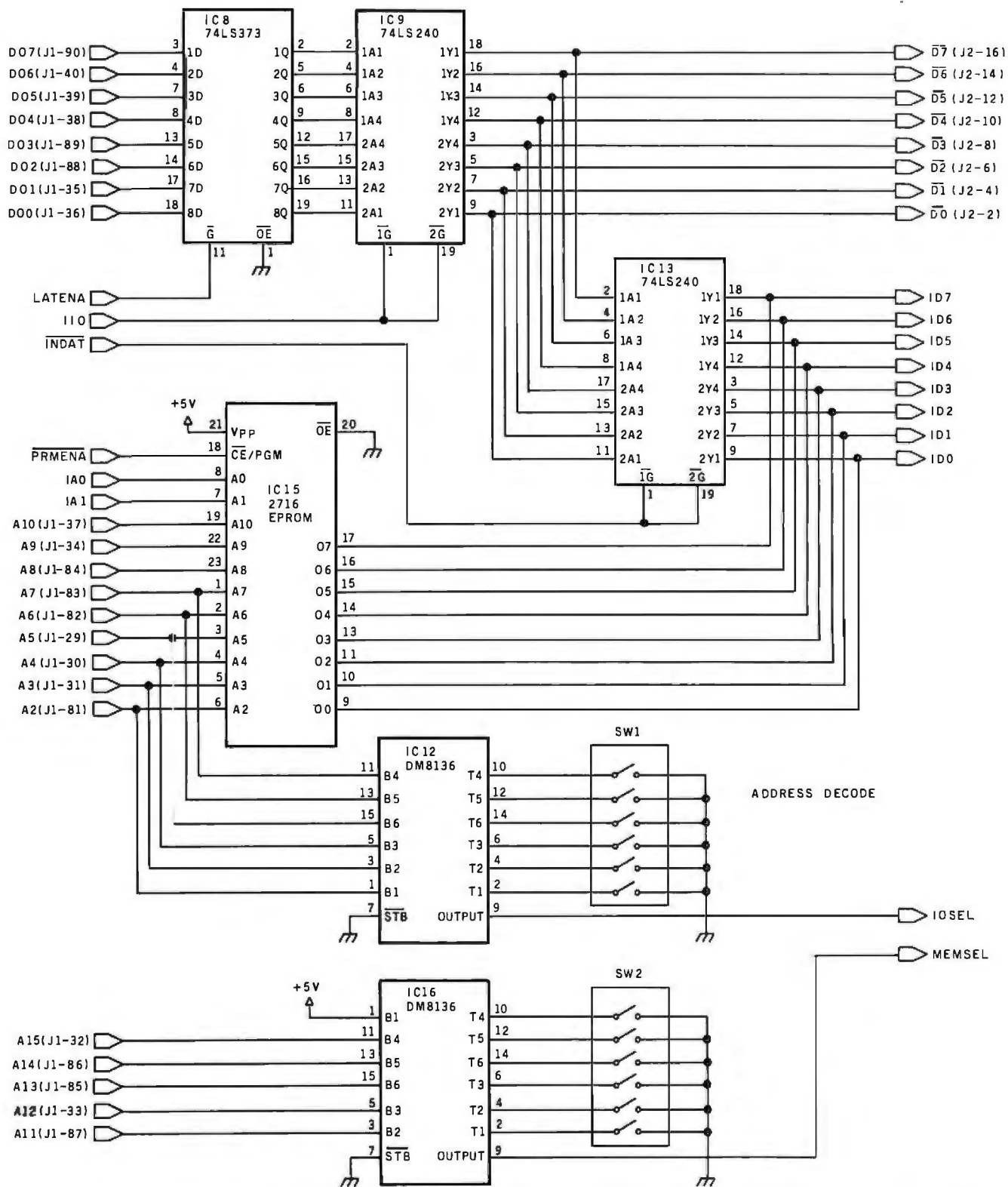
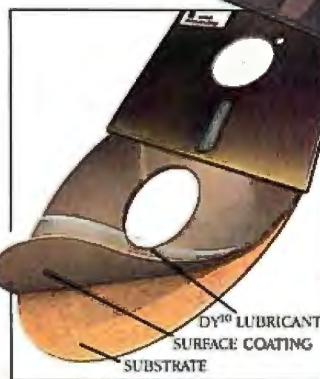
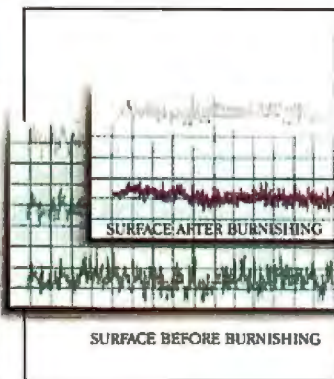


Figure 3: Diagram of the address-decode logic of the HCA.

Number	Type	+5 V	GND	Number	Type	+5 V	GND
IC1	74LS10	14	7	IC10	74LS74	14	7
IC2	74LS139	16	8	IC11	74LS74	14	7
IC3	74LS244	20	10	IC12	DM8136	16	8
IC4	74LS00	14	7	IC13	74LS240	20	10
IC5	74LS04	14	7	IC14	74LS04	14	7
IC6	7438	14	7	IC15	2716	24	12
IC7	74LS240	20	10	IC16	DM8136	16	8
IC8	74LS373	20	10	IC17	74LS244	20	10
IC9	74LS240	20	10	IC18	74LS00	14	7

Power table applies to figures 4 and 5, as well.

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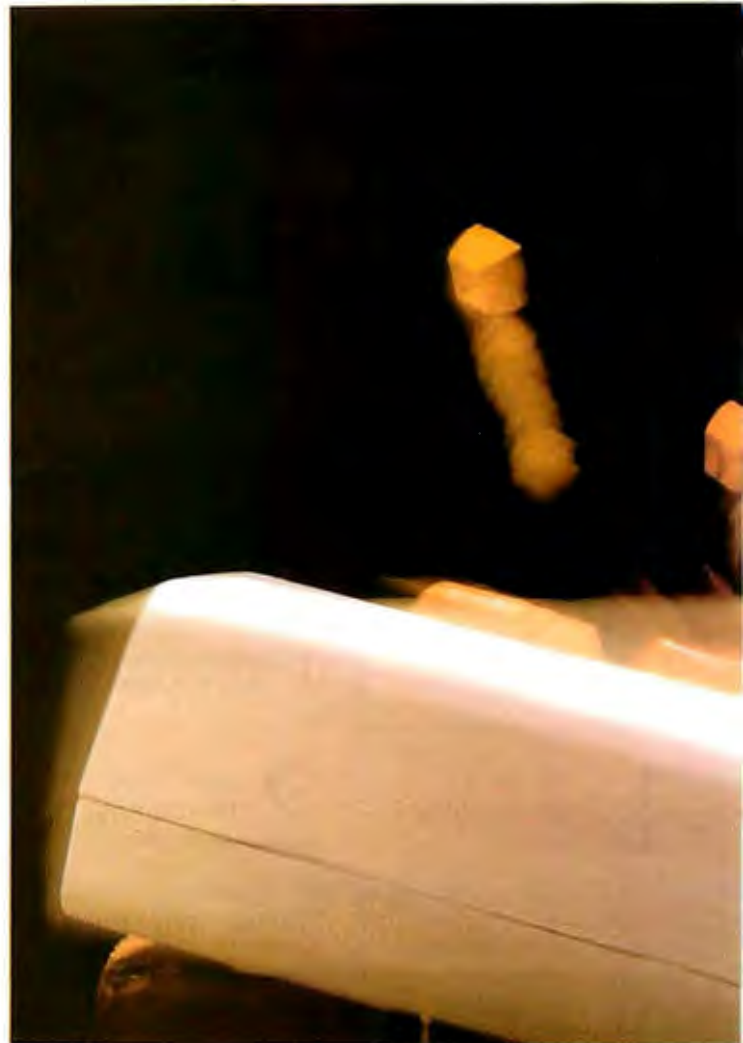
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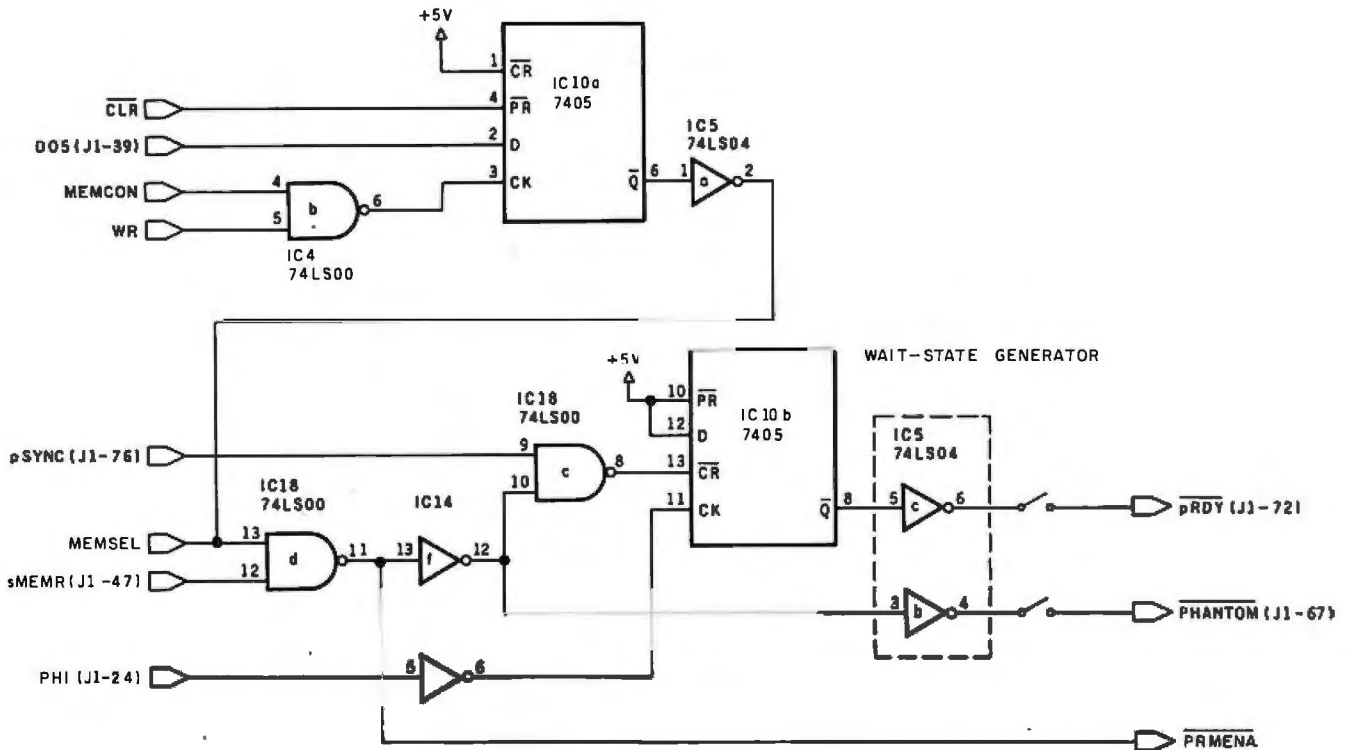


Figure 4: Diagram showing how the PHANTOM signal and the memory wait state are generated in the HCA.

Port Number	Action	Function
0	READ	reads SASI data onto S-100 data lines
	WRITE	writes S-100 data to SASI data port
1	READ	returns four status bits on S-100 data lines
	WRITE	generates SASI SELECT signal
2	READ	no action
	WRITE	with data bit 5 set turns PROM on
3	READ	no action
	WRITE	generates SASI RESET signal

Table 2: I/O port read/write functions of the host computer adapter (HCA), relaying information between the S-100 bus and the disk controller.

indicated in the diagram. Figures 3 through 5 show the result of this expansion. Figure 3 shows the address-decode logic and the S-100/SASI data bus buffering. Figure 4 shows how the PHANTOM signal and the memory wait state are generated, and figure 5 shows the port-decode logic and the remainder of the system.

The memory and port-address logic are set up so that the address of the PROM and the I/O ports are selectable using a set of switches on the HCA board. For the PROM, the upper five address bits are compared with a switch setting on the board and used to generate the MEMSEL

signal, which is used by the logic in figure 4 to generate -PRMENA to enable the PROM. Similarly, bits 2 through 7 of the address are compared with switch settings on the HCA to determine if an I/O port on the HCA has been selected. If a match is found, IOSEL is asserted and bits 0 and 1 are used to determine which of four possible I/O ports has actually been selected. At this point there are eight possible operations because each possible I/O port may be either read or written depending on the status of the sINP and sOUT signals on the S-100 bus. Table 2 shows the results of each of these possibili-

ties. If ports 0 or 1 (of the block of four selected I/O ports) are read, signals are generated that cause either SASI status or SASI data to be placed on the S-100 data bus. Reading ports 2 or 3 does not cause anything to happen. A write to port 1 generates a select signal at the SASI, and a write to port 0 writes 8 bits of data from the S-100 bus to the SASI data port. A write to port 3 generates a -RST signal at the SASI. Finally, a write to port 2 with data bit 5 set or reset enables or disables the PROM on the HCA.

Figure 4 shows how the wait-state and the phantom-memory options are handled. When the memory is selected, the output of the flip-flop U10 is set low and remains low until the next transition of the PHI clock signal raises it. This sequence generates the -pRDY signal, which is qualified by a switch setting. If the switch setting allows this signal to get to the S-100 bus, the result is a single wait state each time the PROM is selected. This allows use of PROM memory that would be too slow to respond to the high-speed Z80 processor boards on some S-100 systems. The upper portion of the figure also

shows the combinational logic used to generate the PHANTOM signal.

The PHANTOM signal is generated whenever the PROM is selected, depending on the state of flip-flop (U10). This flip-flop enables generation of the PHANTOM signal on receipt of the Power On Clear (-POC) signal and disables generation of PHANTOM when the host writes to port 2 of the four selected output ports with data bit 5 set. This whole operation is qualified by the switch on the board that either allows or disables PROM operation. For systems that support phantom memory, the intended mode of operation is to have the Power On Clear signal (which is the hardware boot signal) enable the PROM and the generation of the PHANTOM signal. The bootstrap in the PROM would then run and load a loader program into RAM. The loader program would then load the CP/M operating system, and (as a final instruction before transferring control to the operating system) the loader program would write data to

port 2 with data bit 5 reset to select the PROM from memory.

Figure 5 shows how this all comes together to perform the required HCA functions. For a PROM access, the upper five bits of the address, qualified as shown in figure 4, form the -PRMENA signal that enables the PROM. The lower eleven bits of the address are sent directly to the PROM to select the byte of data from the PROM that is to be read. This data is then placed on the S-100 data bus using the tristate bus driver (U17).

The way data and control information are transferred to and from the SASI depends on the particular portion of the SASI being addressed. The -RST and -SEL signals are generated by writing to ports 3 and 0, respectively. The -ACK signal is automatically generated if -REQ is asserted any time data is read from or written to the SASI. The control information from the disk controller to the host computer is read by sending an IN instruction to port 1. This places four bits of control information on the

S-100 data bus. The data portion of the SASI is addressed by reads and writes to port 0. A data write to port 0 latches the data off the S-100 bus (U8) and passes this data through the data bus driver (U9) to the SASI if it is enabled by the SASI I/O control line. Data is received from the SASI data bus by U13. When the HCA is driving the data bus, the latched data from the S-100 bus will be turned around through U9 and U13 and will be available if a read is directed to port 0. This state exists whenever a controller is not active on the SASI bus and is useful for verifying the HCA data paths.

The next step in the design process is to take the logic diagrams shown in figures 3 through 5 and reduce them to a printed-circuit card that can be inserted in a standard S-100 bus 100-pin socket. Because the S-100 bus is fixed, the only choice in this operation is to decide how the HCA card will be physically connected to the disk controller card. For our controller card, this is done using a

Text continued on page 319



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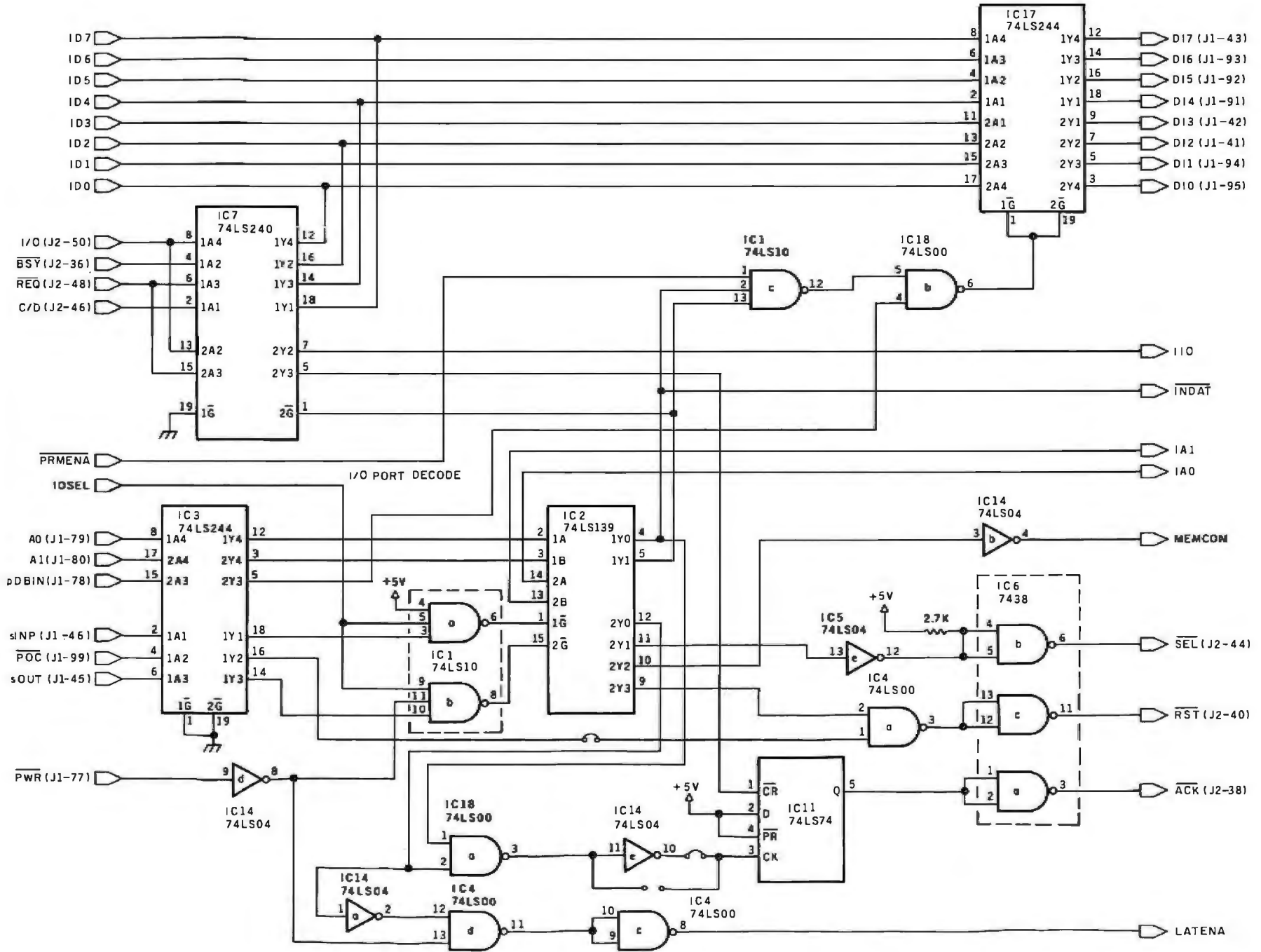
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Figure 5: Diagram of the port-decode and HCA-interface logic.



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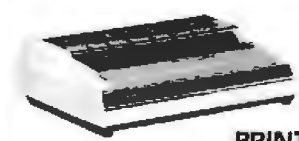
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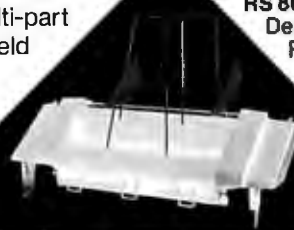
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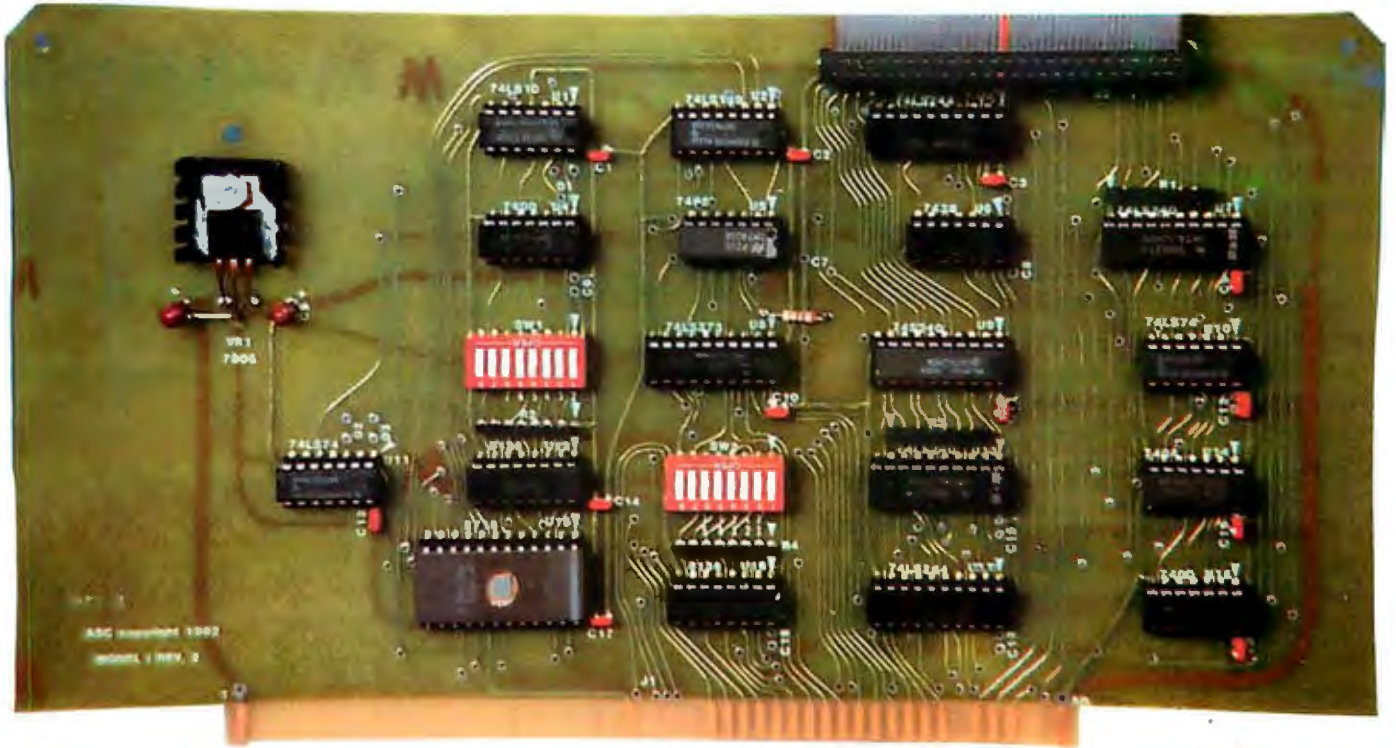


Photo 1: The host computer adapter (HCA) printed-circuit card.

50-conductor ribbon cable, which is the SASI standard. Photo 1 shows the printed-circuit card that results. For anyone interested in building only one of these devices, the HCA could also be implemented on a wire-wrap card instead of a printed-circuit card.

Power-Supply Characteristics

The HCA board obtains its power

from the S-100 bus so the only elements of the Winchester disk subsystem that require external power are the disk drive and the controller card. Both these devices require +5 and +12 volts (V) DC. Adding up the power requirements for both devices at both voltages results in total power requirements of about 1.5 amps at +12 V and about 3.0 amps at +5 V.

Several options were available for providing this power. These included designing and constructing a power supply, buying a commercially available linear supply, or finding a commercially available switching supply. Fortunately we were able to find a commercially available switching supply that provided 2.0 amps at +12 V and 3.0 amps at +5 V. This exactly fit our power requirements. Because it was a switching supply it was small enough physically that we could include it in a small enclosure with the disk drive and controller card, and the supply was relatively efficient so that power dissipation and cooling problems in the disk enclosure would be minimized.

System Packaging

Choosing the power supply completed the overall design of the Winchester disk subsystem. The only remaining step was to devise a way to package the system. This was particularly important due to the characteristics of the Winchester disk drive. Photo 2 shows the Miniscribe disk as it is delivered from the manufacturer. From this view it is apparent that the disk drive, as is true of all Winchester disk drives, is intended to be mounted

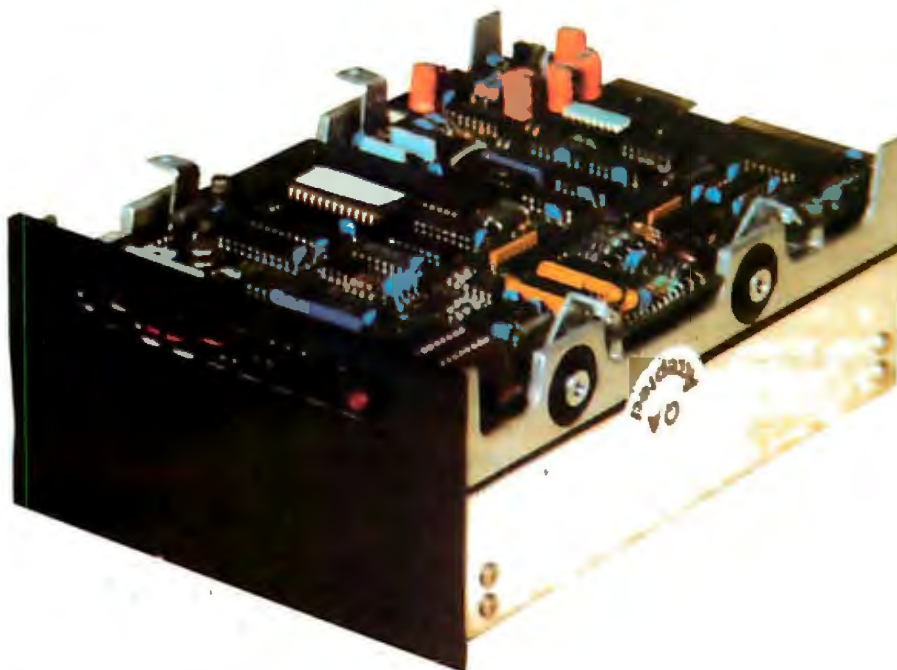


Photo 2: The Miniscribe 5 1/4-inch Winchester disk assembly.

in some type of enclosure. In fact it is even more important to install this disk in an enclosure than the photo would indicate. The disk is meant to be installed using the isolation points shown in the photo to isolate the disk mechanically from the rest of the system. These isolation points absorb high-frequency shocks occurring during handling that could result in damage to the very sensitive read/write head of the drive. Thus it is imperative to install the disk in an enclosure as soon as possible and to exercise extreme care in handling the disk prior to its installation.

The controller card and the power supply we chose had dimensions that made it feasible to mount both these elements in the same enclosure as the disk drive. Photo 3 shows all these elements before assembly. We chose to mount this equipment in a box 7 inches wide, 12 inches deep, and 7¼ inches tall. In our opinion, a box this size approached the median between having a small, compact system and still providing enough free space in the enclosure for adequate ventilation.

The enclosure selected had a removable top, and photo 4 shows how these various components were mounted in the box. The disk drive was bolted to channels attached to the box. The controller card was attached to the bottom of the box using angle brackets, and the power supply was bolted directly to the bottom of the box. We constructed a cable harness to route electrical power from the power switch to the power supply and on to the disk drive and controller. Also we fabricated three ribbon cables. One of these was used to connect the HCA to the controller board and the other two were used to connect the controller board to the disk drive. Photo 4 shows the installation with all the cables in place. As the photo shows, the installation is still rather compact but has sufficient room for ventilation.

One of the last but, from a reliability standpoint, one of the most important design considerations was to allow sufficient ventilation of the assembled product to prevent excessive heat buildup. Photo 5 shows

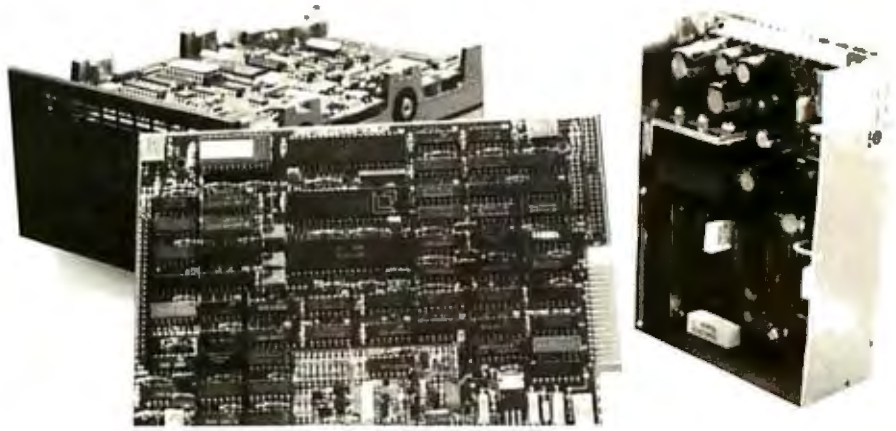


Photo 3: The Winchester disk-drive subsystem components before assembly.

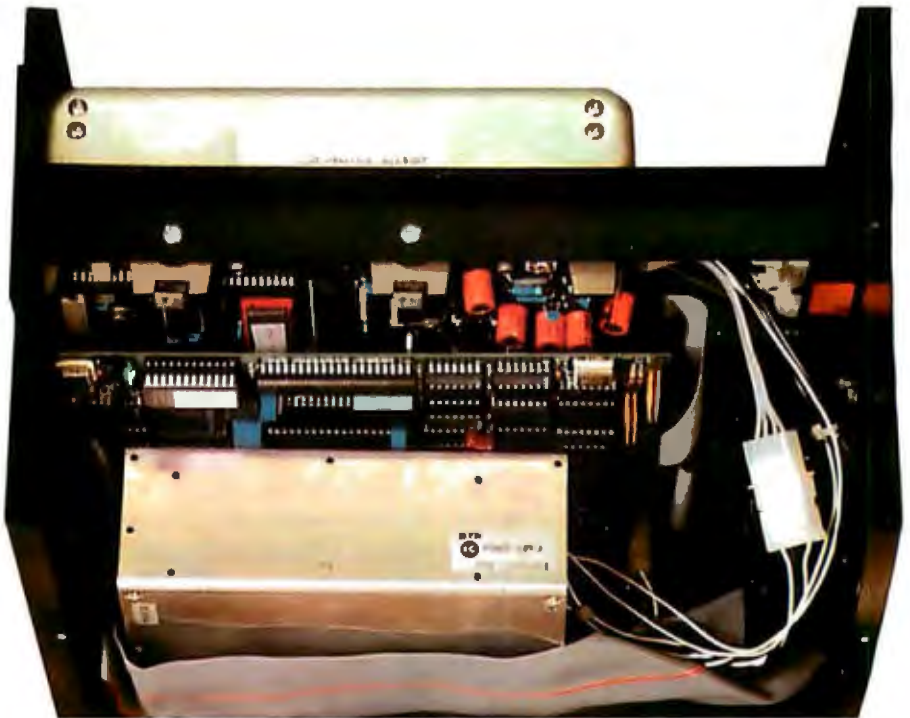


Photo 4: The completed disk-drive assembly.

both the front and back of the assembled enclosure. We punched ventilation holes on the front of the enclosure and on the rear we included a ventilation fan to force air through the system. We then measured the exhaust temperature of the air at the fan and measured the temperature inside the box during operation to assure ourselves that there were no hot spots in the box. The fact that we found no hot spots was not surprising because all the equipment in the enclosure is designed to be convectively cooled, and the fan we chose had a volume flow rate that replaced the air in the enclosure about 40 times every minute. The end result of the entire

design operation was the set of hardware shown in photo 6, a forced-air enclosure containing the disk drive, controller, and power supply; an HCA card that plugs into an S-100 backplane; and a 50-conductor ribbon cable to connect these two elements.

Summary

In this article we have described the design and construction of the hardware necessary to interface a Winchester technology disk drive with an S-100 computer system. You should now have a detailed understanding of what is required to perform this type of integration, and with sufficient

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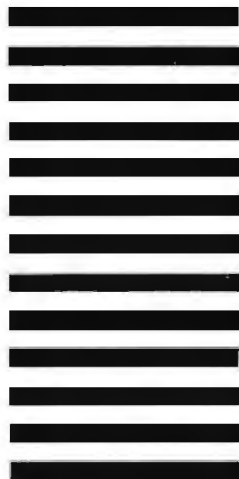
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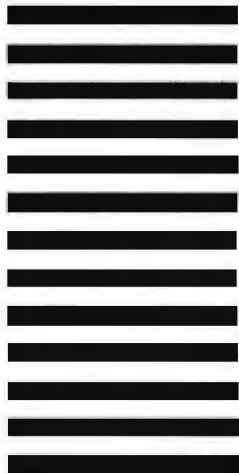
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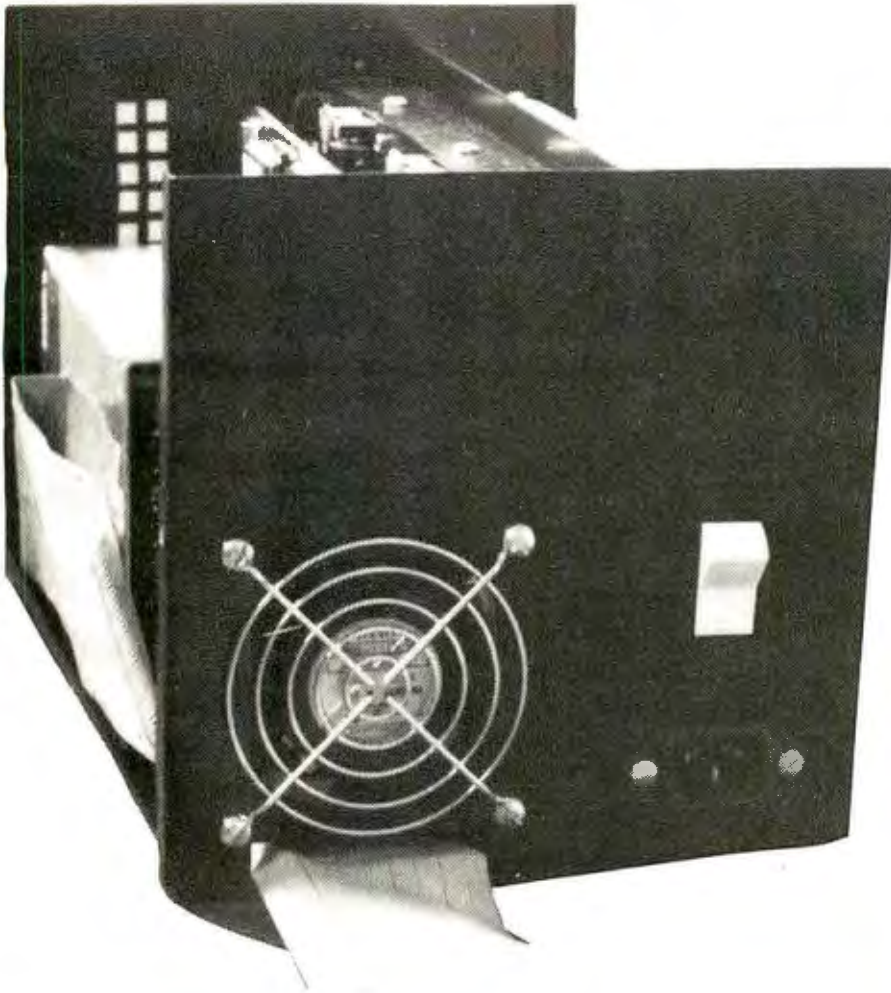


Photo 5: Ventilation details of the disk-drive assembly.

perseverance you should be able to design and construct one of these systems. Next month we will finish this series by describing the various software components that must be developed to interface the hardware with the system. Specifically, we will cover how to write a BIOS that combines the BIOS for the existing peripherals on the system with a set of BIOS routines to handle the hard disk. We will also discuss how to write a relocatable bootstrap loader for the HCA PROM and discuss some of the methodology involved in testing and debugging the various hardware interfaces in the system. ■

The Winchester disk-drive subsystem described in this series of articles is available as a completely assembled unit from ASC Associates of Lexington Park, Maryland. In addition to the S-100 version discussed, versions are also available for TRS-80 and Apple computers. The disk-drive systems for these computers use the same drive and controller hardware as the S-100 version but use a different host computer adapter and interface software. Until a nationwide dealer distribution network is established, these systems will be available by mail order for \$1995. To order or obtain further information, write to ASC Associates Inc., POB 615, Lexington Park, MD 20653, or phone (301) 863-6784.

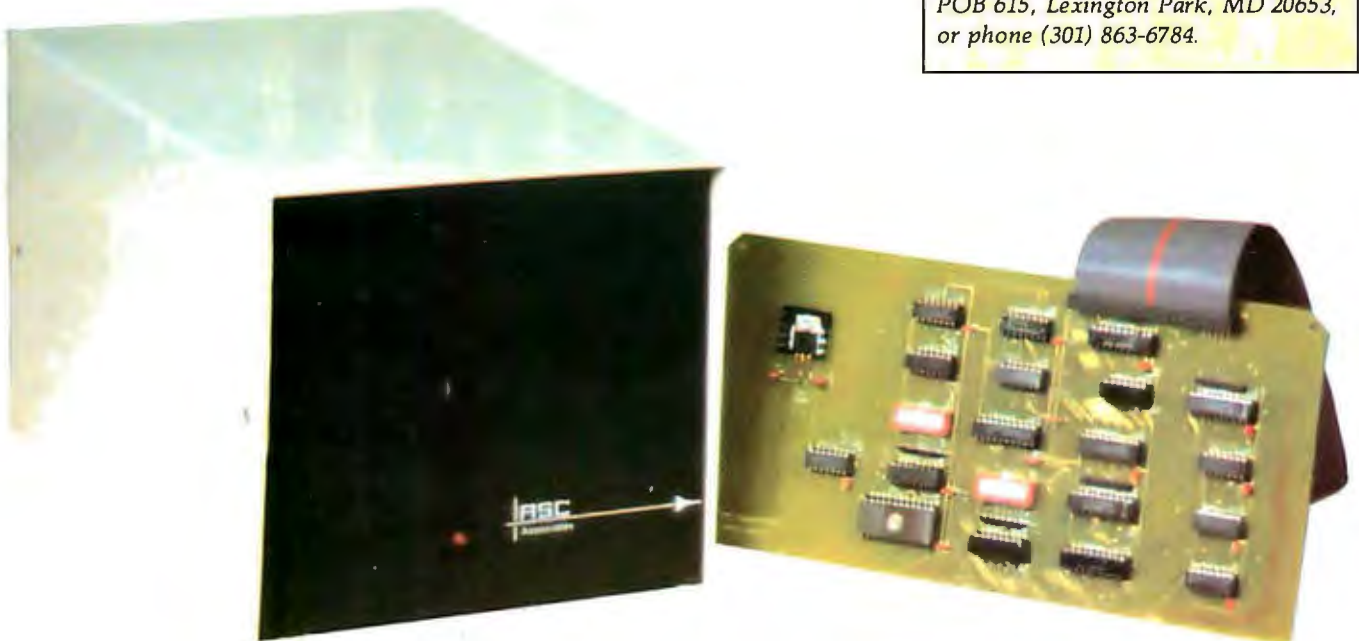
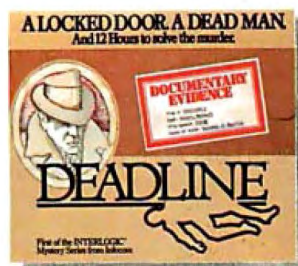


Photo 6: The completed disk subsystem showing the drive assembly and the HCA printed-circuit card.



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Terminal Solutions, Manual Madness, BASIC Bits, and Info Helpers

Terminal concerns for Wordstar users, BASIC comments, and a bunch of useful utilities are reviewed at Chaos Manor.

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My Televideo (TVI) 950 terminal holds an ambiguous position here at Chaos Manor. I rather like it in some ways. However, I haven't got around to writing a program that will make use of all its reprogrammable keys, and it has all these extra (and nonreprogrammable) "feature" keys that seemed so useful when I bought it, but which turn out to be worse than useless now that I have it. For example, not one text-editor program I know of can make use of the arrow keys. Worse, there's Back Tab.

I find I'm not alone in my distaste for the Back Tab key on the Televideo 950 terminal. It does nothing useful at all. I and many others keep hitting it instead of the Control key. For those not familiar with TVI terminals, Back Tab is just below Control and outboard of Shift, optimally placed for being hit when it shouldn't be. It produces the sequence Escape I, which, depending on what you're doing at the time, can range from annoying to disastrous.

Thus, sometimes I think I'll keep the 950, and other times I'm tempted to sell it.

My friend and sometime associate Tony Pietsch has found a way for his WRITE text editor to distinguish between an Escape sequence done by a human operator and one sent by a programmable key. I'm not sure how he does it. One way would be to use a timing test: Escape followed by some character is interpreted one way if the character comes almost immediately, as it will if it's part of a sequence sent by the terminal, and another way if there's an appreciable lag between the Escape and the following character.

However Tony does it, his installation of WRITE on the TVI converts the Back Tab key to something harmless. That's certainly one possible solution, and somewhat less drastic than what I was tempted to do, which involved removing the key entirely. Of course, it works only when using the text editor, although I suppose I could use the same sort of trick in my

CBIOS (customized basic input/output system) to intercept Back Tab's Escape I and turn it into, say, a null . . .

Good News for Wordstar/TVI Addicts

Wordstar users now have available a very elegant way to get around Back Tab, while making use of all those lovely extra feature keys that made the TVI 950 so attractive when I thought of buying it, and which turned out to be so useless once I brought it home. Wordtech Systems TV2000 Conversion will turn the TVI 950 into an excellent Wordstar terminal.

The Wordtech system consists of a new PROM (programmable read-only memory) that replaces the one that comes with the 950, a new set of key tops, and a label strip. It's easy enough to install, although getting the old PROM out and putting the new one in does involve opening up the terminal, and you'll want to be

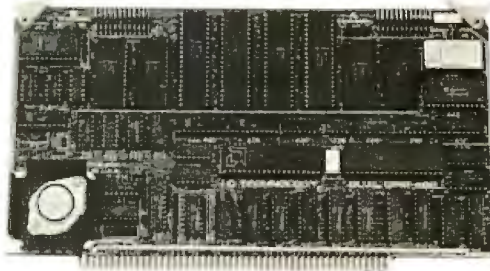
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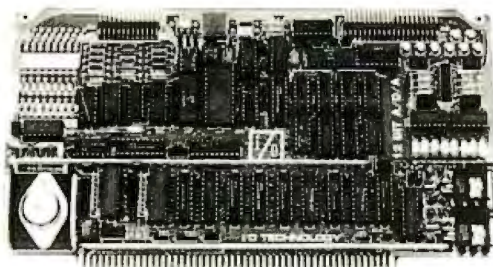


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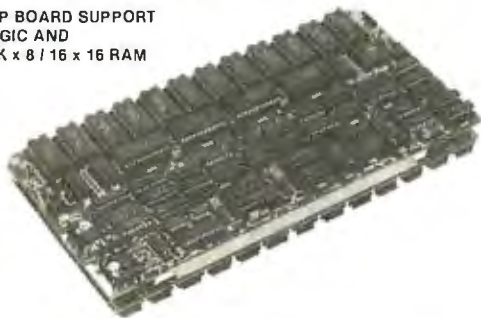
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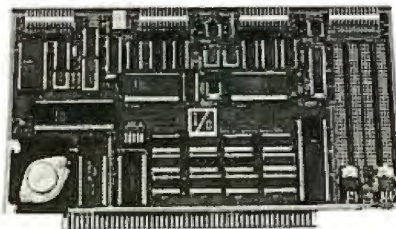


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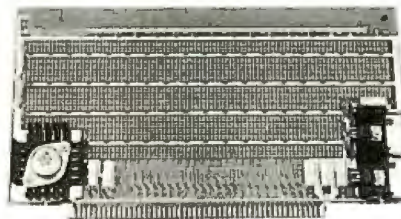
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careful in handling the chips. Once that's done, you pull off the old key tops and put in the new according to a chart provided by Wordtech.

The Wordtech changes will be invisible, and your TVI terminal won't seem to be changed until you enable it through an Escape sequence. Once that's done, all the new key tops will apply. Back Tab, for example, becomes Block Menu or Control-K. All the other keys become useful also. The Wordtech rearrangement of the keyboard is not the one I would have designed, but then I'm not a Wordstar user, and thus might easily be

mistaken. One thing's for sure, the Wordtech arrangement is about a zillion times more convenient than the way the TVI keyboard comes.

You can go back to regular TVI mode any time with a different Escape sequence. The key tops have the old function names as well as the new.

The Wordtech scheme is an excellent one, and I recommend it for all Wordstar users who have the TVI 950 terminal.

I've been talking to the people at Wordtech, and they claim they can make me a new PROM for the TVI

that will optimize it for WRITE and Wordmaster, which are the editors I use. I think I'll love that.

Status Line Removal

Several letters inform me that there's a simple way to get rid of the TVI 950's status line: just go Escape g Escape f Space Space Space Carriage Return. (The case is important: that is, use lowercase g and f.)

This certainly works, although I wasn't able to figure it out from the manual. I thank those who told me about it.

Manual Trades, Part One

There's good news and bad news on the document front. The good news comes from Paul Brest of Pro/Tem Software who says, "In a review of Cardfile several months ago, you quite justly criticized the documentation. The review persuaded me to rewrite the manual from scratch." He enclosed a copy of the new manual.

Cardfile is marketed by Digital Marketing, an organization whose distinctive logo shows up in a lot of places. In its own words, "Cardfile automatically stores, retrieves, and displays the sort of information typically kept in index card files—summaries of books and articles, notes, recipes, menus, catalogs of phonograph records, etc." It does this in a complex way that's made reasonably transparent to the user. In my previous review I said I was favorably impressed by the program, but quite unhappy with the manual.

That's fixed now. The new manual is very good. It tells what the program does and how to make it do that. There are plenty of examples, and it's clearly written. My only complaint is relatively trivial: unlike the previous manual, this one is not punched for storage in a 3-ring binder, and it's a little too thick for my punch, while too thin to have its name on the spine so it can be shelved by itself.

Manual Trades, Part Two

I really do like Digital Research and much of what it publishes, honest I do. That doesn't stop me from trying

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to change its documentation habits, which aren't very good.

Example. The other day I decided to put random-access files into my Minimum Data Base (MDB), which is written in CBASIC and CB-80. CBASIC pseudocompiles to an intermediate code that is then interpreted a line at a time; CB-80 compiles to true 8080 machine code. They aren't the same language, but they don't differ by much. If you're careful, programs will compile in both. CBASIC will run under CP/M 1.4; CB-80 needs 2.2 or later. MDB is a little do-all program that I use for Christmas cards, menus, and all kinds of odd jobs.

I haven't done much CB-80 file-management programming for a while, so I thought I'd read the manual as a refresher. After all, the CBASIC manual had taught me enough about random-access files to allow me to write the accounting program I use, and what I had in mind for the MDB wasn't anywhere near that complicated. Because I was going

to work primarily in CB-80, I took out that manual and turned to the index.

No entry for "random access." None for "sequential" either.

I began to splutter. "Now wait a minute!" I yelled, causing my assistant, two of the boys, and the dog to come running in to see what was wrong. There *had* to be random-access files in CB-80. I *know* there are, because the POST program that takes my journals and posts them into ledgers, although written originally in CBASIC, compiles and runs fine under CB-80; and each of those ledger pages is a random-access file.

Nothing for it but to scan the table of contents, which I did. Nothing on file types at all. Best to read the whole chapter, then. In the opening paragraphs on "File Description" there is a brief discussion of "fixed" and "stream" files. It is terse to the point of uselessness.

The remaining 13 pages on files are much the same: if you can understand what's said there, you already know

at least that much about the subject. If you don't know what's going on, you won't learn it from that stupid manual. Perhaps that's an overstatement, but not by much.

The old CBASIC manual, published before Digital Research bought out Gordon Eubanks and his Compiler Systems company, had more than 20 pages on files, including an excellent section called "Programming with Files" that explicitly discussed the differences between "sequential" and "random-access" files, and explained precisely how "random access" worked. Example:

Randomly accessed records must use the fixed [record length] organization. CBASIC locates each record on a randomly accessed file by taking the relative record number specified in the program, subtracting one from the number, and multiplying it by the length of a record. The result is the byte displacement of the record measured from the beginning of the file. If the records were of varying length, the displacement could not be calculated in this manner.

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And so forth. That's informative. The result was that way back when I began playing with small computers, I was able to create a pretty sophisticated accounting program, because the CBASIC manual told me something about the language, and said it in comprehensible terms.

None of that is in the CB-80 manual. Now true: the CB-80 manual calls itself a "Reference Manual," meaning, I suppose, that it's the user's responsibility to get his or her own primer. This is not, in my judgment, a sane marketing strategy. Whatever the relative merits of CB-80 and Pascal—and I am prepared to defend CB-80 as a real candidate for the beginner's microcomputer language of the future—there's no contest if you can't learn one of the languages.

Adding insult to it all, at the bottom of every page is the silly phrase, "All Information Presented Here is Proprietary to Digital Research." The constant repetition of this meaningless pomposity would be irritating enough if the information were more comprehensible, but given what you actually get it's doubly so.

I'd strongly advise Digital Research to generate a good beginner's manual for CB-80. The language, with features like true local variables, parameter passing, functions that can serve as true "procedures" and can be called by name, etc., is far too good to be restricted to experts. Flash: there have been reforms at Digital. More next month.

Free BASIC and PBASIC

My October 1982 column generated a lot of mail, some angry and some thoughtful, by quoting computer expert Edsger Dijkstra:

It is practically impossible to teach good programming to students that have had a prior exposure to BASIC; as potential programmers they are mentally mutilated beyond hope of regeneration.

Now I don't believe that; not only can people whose first computer experience was BASIC programming

learn to write good code in other languages, but some good programs are written in BASIC itself. By a "good" program, I mean one that does something useful, is easily used, and can be updated and maintained; and I contend that Minimum Data Base and my Accounting Package both meet those criteria. (I don't say there aren't *better* programs; only that for me these are *good enough*.)

However, Dijkstra, whose paper "GOTO Seen Harmful" was one of the primary works that began the structured-code movement, has a valid point. BASIC, especially its early versions, encouraged "spaghetti" code, and many older BASIC programs expire in an impenetrable fog of GOTO statements. No one, including the original programmer, has any idea of what's going on, or why, and it's very easy to write that sort of horror in BASIC.

Several possible solutions to this problem are available. One is to give up BASIC; an idea that has many advocates among my readers. Unfortunately, there's no agreement on what to put in its place. Pascal, Logo, various assemblers, FORTRAN and RATFOR, C, PL/I, FORTH, and LISP all have their (very vocal) advocates. Moreover, a lot of people out there have BASIC and don't want it to go to waste.

Another possibility is to change BASICs. CBASIC was a start. Its compiled successor CB-80 is a more obvious candidate; indeed, CB-80 has nearly all the structured features of Pascal. However, CB-80 is expensive, and, as I noted above, the introductory manuals leave something to be desired; while CBASIC is slow. For files programming these versions have another disadvantage: not only are they slower than Microsoft's MBASIC, but their files take up considerably more disk space. That used to be more important than it is now in these days of megabyte floppies, but it can still be significant if you have a machine with limited disk capacity such as an Osborne.

Furthermore, there are a lot of advantages to using an *interpreted* language like Microsoft MBASIC. Interpreted languages make programming

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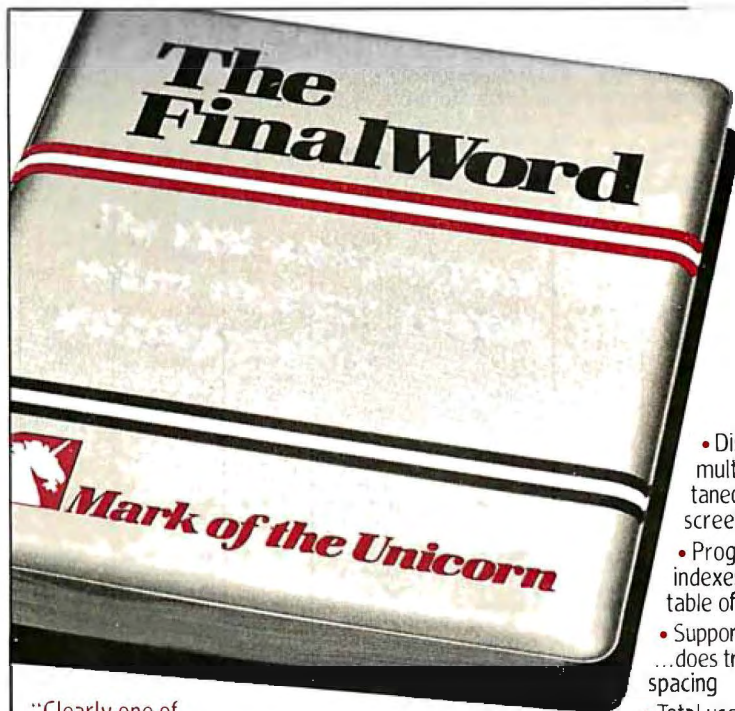


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simpler; you can check out your code a little at a time and trace the program operation. It's especially nice if you can then compile it to increase program operation speed, as you can with Microsoft's BASCOM. A lot of people have MBASIC; perhaps there's a way to structure programs while still using it?

Which brings us to the third possibility, given in Richard Mateosian's excellent book *Inside Basic Games*. Far from just a book on games (although it is that, and quite good, too), this book is a darned good lesson in programming technique.

Early in the book, Mateosian introduces what he calls "Free BASIC." This isn't really a language; it is what my mad friend used to call a *meta-language description* of a program. Free BASIC uses an exact syntax and includes most of the constructs required for structured programming: IF. . THEN. . ELSE, DO. . WHILE, DO. . UNTIL, and CASE. The programs Mateosian uses as illustrations are all "top-down" structured, and in

his discussions of how to program he emphasizes the techniques of top-down programming, introducing concepts such as "stubs" (dummy subroutines for checking program logic). If all BASIC programs were first written in Free BASIC before translation to regular BASIC, there would be a great deal less criticism of the BASIC language.

Alas, though, there is no such thing as Free BASIC; that is, unlike RATOR, for which there is an actual preprocessor that translates top-down structured code into standard FORTRAN, there is no Free BASIC program; the "language" exists only in concept, and once you've written your program in Free BASIC you must hand-translate it into actual code. I agree with Mateosian that using Free BASIC is an excellent idea and to be recommended; but I am also certain that, like many good ideas, it's not likely to be adopted. That shouldn't stop beginning programmers from reading his book, though.

Another possibility is PBASIC. This is an actual preprocessor that takes structured code and turns it into Microsoft MBASIC.

PBASIC allows unlimited comments, "pretty printing" with indentation to increase readability, alphabetic labels for subroutines, code without line numbers, local variables and parameter passing, and the like. It also makes "chaining" programs easier: that is, programs can call other programs as subroutines. Finally, PBASIC has simplified methods for creating and maintaining a library of subroutines and including them in new programs as needed.

Bruce Tonkin, PBASIC's creator, is convinced that PBASIC is much better than both CBASIC and CB-80. He may well be right about CBASIC. PBASIC is a compiler rather than an interpreter, of course, and thus has some inherent problems; but it compiles into interpretive MBASIC, which is usually easier to debug.

I don't think I agree about CB-80,

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which has excellent structured features. No matter. Anyone who has Microsoft BASIC Version 5.2 or later should get PBASIC, whether or not they intend to get CB-80 or CBASIC. PBASIC isn't perfect, but it's more than worth its price to anyone who intends writing Microsoft BASIC programs.

PBASIC comes with a very good library of callable subroutines, such as "CALLPROG" that will actually chain to another program, a set of alphabetic and numeric conversions, uppercase and lowercase converters, and so forth.

There are a couple of problems. First, PBASIC doesn't have all the structured concepts of Free BASIC. It's another dialect. Because it's a pre-processor, it can't get inside Microsoft MBASIC and make fundamental changes; the result is that there are some costs. For example, there aren't any *real* local variables; PBASIC keeps track of variables internal to subroutines and procedures and doesn't allow their names to be used outside the subroutine, but it can't do more than that. They're still global variables, and you can have problems with nested subroutines if you're not careful.

Finally, the documentation isn't all that clear. You'd want to be pretty familiar with BASIC before tackling the PBASIC manual. It does have a good index, and there are examples; it's not *that* formidable.

PBASIC is mostly compatible with BASCOM, the Microsoft BASIC compiler. You can write PBASIC programs with any text editor that uses Carriage Return-Linefeed pairs as newline characters and doesn't set the eighth bit. (Wordstar in nondocument mode is fine; so is Wordmaster. WRITE and Electric Pencil will require a simple conversion program; a suitable converter is available along with a lot of other useful stuff on CP/M Utility Disk One from Workman and Associates.)

If you do much programming in Microsoft BASIC, I recommend that you get PBASIC. If you're just learning, I recommend that you get Mateosian's *Inside Basic Games* and read about Free BASIC, then get PBASIC.

PBASIC is available in standard 8-inch CP/M format directly from the author; it can also be obtained in Osborne, Otrona, KayComp II, and (possibly) other formats from Workman and Associates. Osborne users, with their limited disk space, should find PBASIC especially valuable, because Microsoft MBASIC packs random-access disk files into about 60 percent of the space required by CBASIC. Do understand that PBASIC is not a stand-alone language; you must have Microsoft BASIC 5.2 or later to make any use of it.

Active Trace

Another extremely useful program for Microsoft BASIC users is Active Trace, by an outfit known as The Data Works. Active Trace is distributed by Digital Marketing.

Three major programs are included in Active Trace: VREF, which makes an alphabetized cross-reference table of variables in an MBASIC program; GOREF, which makes a map of every line called by GOTO or GOSUB; and SCOPE, which runs with the program much like TRON (the built-in trace utility within MBASIC), but which outputs not only line numbers but variable values as the program runs.

These programs were written in Microsoft BASIC, but the source code is not provided. They have been compiled with Microsoft's BASCOM, and both the linked (.COM) versions and the BRUN versions (which require that you have Microsoft's BRUN run-time package, not provided with Active Trace) are included on the disk.

The documentation is good, if a bit disorganized. It contains examples, a tutorial, and a rambling essay on structured programming and program philosophy. I had no problems understanding it, but some of the students here required help. They didn't need *much* help, but the documents would be improved by testing with high school or undergraduate beginning programmers. I've got a class of Boy Scouts working on the Computer Merit Badge meeting here in a couple of weeks, and I'll try to note down

Text continued on page 338

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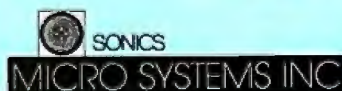
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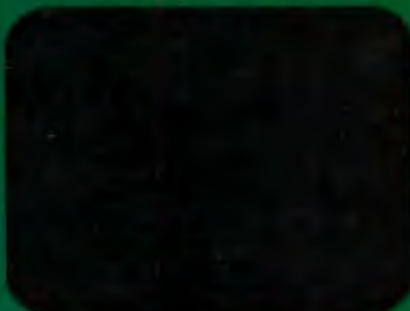
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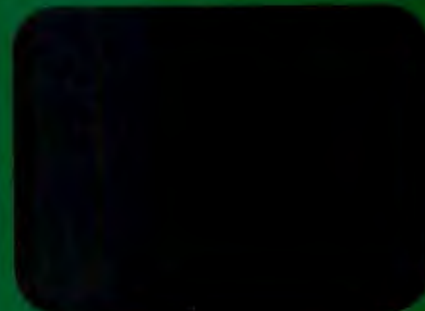
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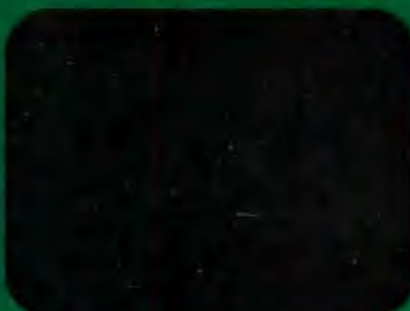
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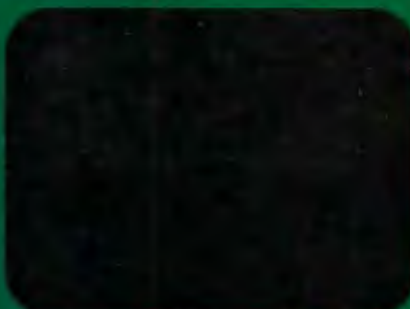
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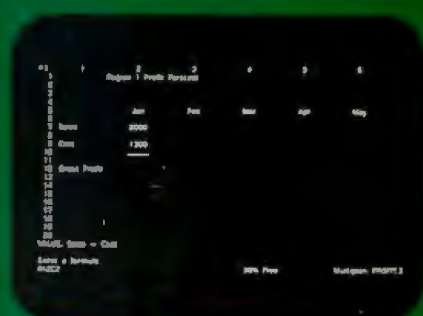
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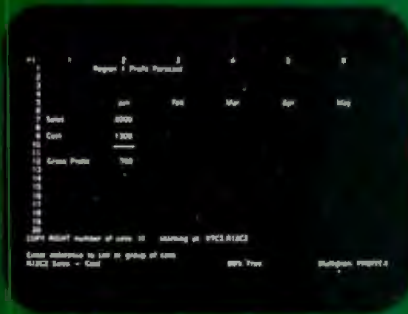
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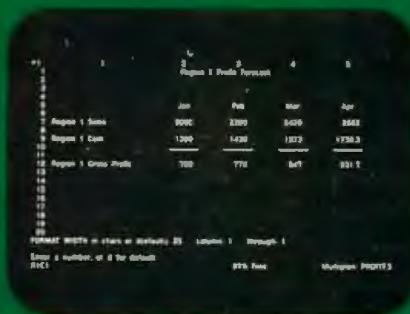
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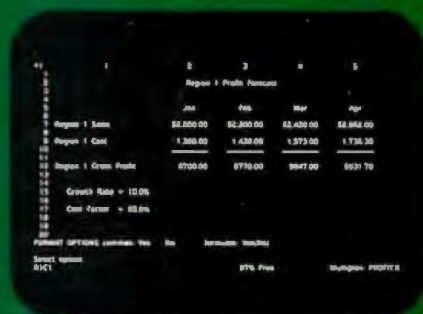
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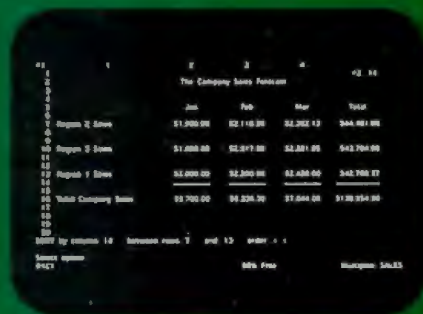
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their questions to feed back to The Data Works. However, I don't want to overstress the document problem; this was better than most I see.

Anyone doing much programming in Microsoft BASIC should appreciate Active Trace a *lot*.

Osborne Expands

Two weeks ago I packed up my Osborne and sent it off to Osborne in Hayward. It was returned today. Along with it came new system disks in double density.

What should I say? It works, and instead of 92K bytes on each disk there's now 184K bytes for data storage; not quite as much as my first computer's single-density 8-inch disks with their 242K bytes, but enough for most purposes.

A manual update explains what double density is, and it tells you that you've not only bought double density, but also the ability to read disks created by a variety of machines: Osborne 1 single density, Xerox 820 single density, Cromemco single den-

sity, and the IBM PC double density providing that it used CP/M-86 (all in 5¼-inch disks, of course). They don't mention it, but the new Osborne will also read disks created by Compupro.

There's no universal standard in 5¼-inch disks, but Osborne is doing his best to get around that. I applaud his efforts.

The manual is quite good; although comprehensible at the elementary level, it is quite complete. Everything works beautifully, and I can't imagine anyone who has an Osborne will want to be without the double-density conversion.

The New Math

Actually, not new math, but a new way to do math: the 8087. The 8087 "math chip" can do 16-bit mathematical operations like lightning; matrix-operation programs that took 10 to 20 minutes to run with the 8088 can now run in less than a minute.

There aren't many implementations of the 8087, and not much software for it; but I expect both those

situations to change.

I have two boards that can make use of the 8087. One comes from Compupro and is an 8086/87 board for the S-100 bus. I don't have that running yet because I'd have to disable the 8085, and I need that dual processor.

The other 8087 comes from Jim Hudson of Hudson and Associates. Hudson sells a small "piggyback" board that plugs into my Compupro CPU-816 dual processor CPU (central processing unit) board, fitting in where the 8088 chip normally goes; the 8088 is then put into Hudson's board. (One wants to take due care not to allow static charges while messing with chips; like all complex chips, the 8087 is sensitive to static. Ground yourself and don't work on a carpet; having high humidity in the room helps, too. In my case we keep tropical fish, which humidifies things nicely . . .)

The 8087, alas, runs only at 5 MHz, meaning that if you're going to use it you have to slow the processor down somewhat; but if you have many math operations to do, the result is *well* worthwhile: on my benchmark matrix-multiplication program, using Pascal/MT+86 with the 8087 "reals" linked in, the 20 by 20 case ran at 7.8 seconds. For a 50 by 50, it ran in 1:41.2; both these times are faster than the Sage II using UCSD Pascal.

As I write this, I have seen only two software sources that support the 8087: Pascal/MT+86 from Digital Research and the C86 C compiler from Computer Innovations. I know nothing of the C compiler, but I use Pascal/MT+ routinely now. We're just getting CPM-86 running; when I do, I'll use MT+86 with the Speed Programming Package even more. Its only rival is the Sage II (which continues to operate beautifully).

I've only started using the Hudson 8087 board, and as I write this I hear from Bill Godbout that Compupro is going to be marketing Hudson's board (with a few Compupro modifications); but since Hudson's system works nicely now, and Godbout's people have a prodigious reputation for improving anything they get their



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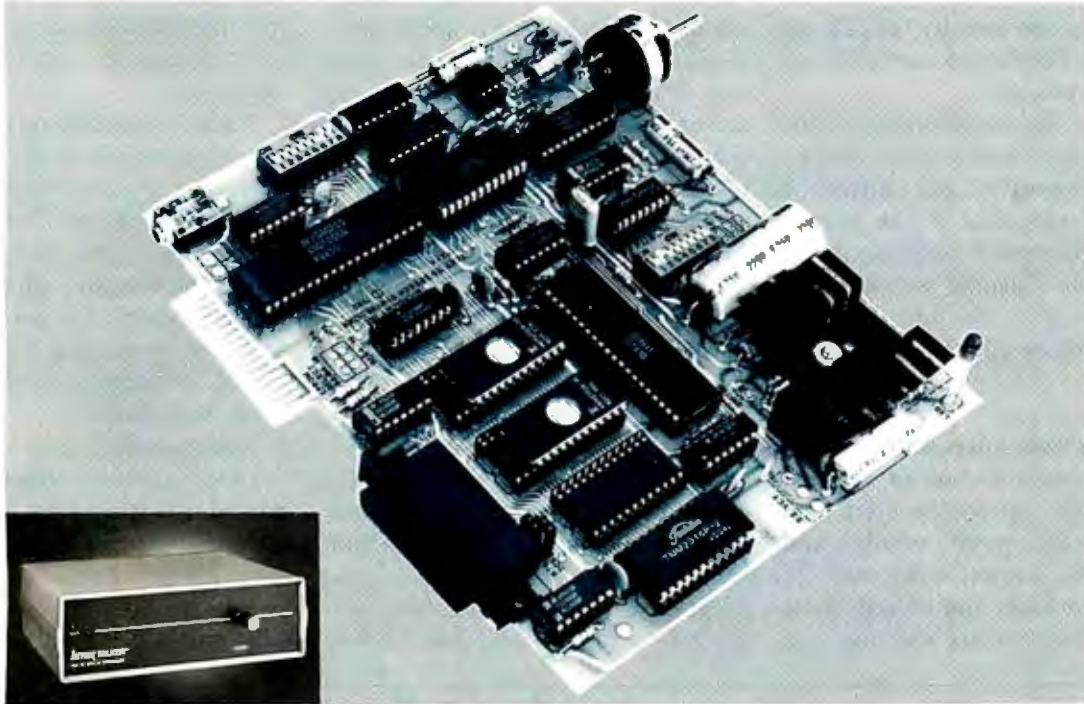
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hands on, I have no difficulty in predicting that the Compupro edition will work very well.

If you have a need for fast number-crunching—and that includes financial stuff as well as scientific—the 8087 may be what you need. I don't want to be too dogmatic about that: the Sage II is also awfully fast. I'll try to get some benchmark comparisons for another column.

Note that the development of the 8087 is another instance of my motto, "Iron is expensive, but silicon is cheap"; meaning that if you have a good versatile system with capability for expansion, people will develop upgrades for you. The great thing is to be able to use all this new stuff.

Mathemagic

One thing computers are supposed to do is compute, but in my experience most microcomputers end up processing more words—and playing more games—than they do number-crunching; and indeed, most microcomputer owners also own one

or more sophisticated calculators, which they use in preference to their computers when they want to do math.

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Mathemagic advertises that it "transforms your microcomputer into the ultimate calculator," and while it might not go so far as *that*, still it's no bad thing. Mathemagic is a menu-driven way to put your head back in shape if you had nauseating math teaching. It's not as versatile as spreadsheet programs like Sorcim's Supercalc, but it will handle longer and more complex formulas, and it's fairly easy to use. I can think of applications in which Mathemagic would be much more useful than Supercalc (although I'd rather have Supercalc myself).

Whatever you do, though, *don't* buy Mathemagic from the publisher; go to a reputable dealer, one you trust, and get a demonstration of the program in comparison to its competition. Make up your mind *before*

you put out any money. If this sounds like harsh advice, it's merited: International Software Marketing, which publishes Mathemagic, has reached new levels in "user-threatening" licensing agreements.

Not only does this company explicitly say it's going to prosecute you for any violation of its terms, but it doesn't assume *any* responsibilities whatsoever.


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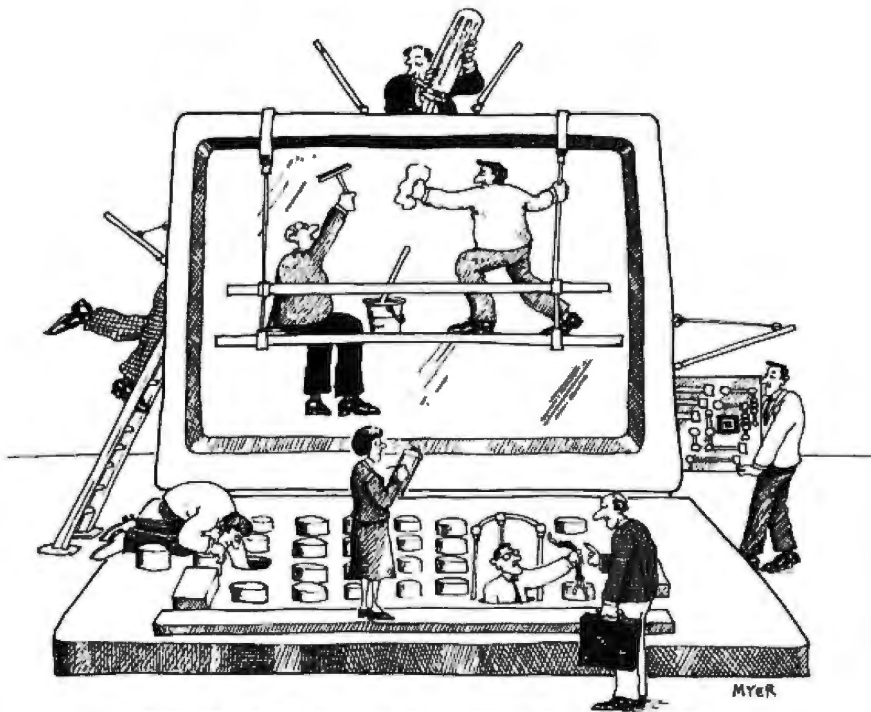
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dealer) assume the entire cost of all necessary servicing, repair, or correction." Later it says, "ISM does not warrant that the functions contained in the program will meet your requirements or that the operation of the program will be uninterrupted or error free."

Translation: if it don't work, tough luck, baby. We may fix it, but you get to pay.

So. As I said, get a demonstration from a dealer you trust.

Footnote

I don't use Wordstar to *create* text, but it's awfully handy to have around. It's not so much Wordstar itself as the tons of support programs like Footnote that make it useful. I have no doubt that when WRITE becomes more generally available, comparable programs will be developed for that, too, but meanwhile most of the really nifty word-mashing utilities need Wordstar.

Footnote comes from Pro/Tem and is marketed by the ubiquitous Digital Marketing. Like all Digital Marketing products, it's way above average, with very complete documentation and well-tested programs. The marketing agreement is rational, too.

As you'd suspect, Footnote handles footnotes in Wordstar text files. It does what everyone wants it to, putting the notes at the bottom of the page or, alternatively, into a separate file that can be appended to the end of a document. The format is standard thesis style, suitable for term papers, dissertations, or submissions to academic journals.

Footnote is easy to use. You don't need to remember the numbers; all notes get the symbol @ when created, ↑R indicates the beginning of a block of notes, @ delimits each note within the block, and .pa ends the block. Notes can be put in anywhere you please, near the place referenced or before or after it; it makes no difference, as long as ↑R precedes the block and .pa ends it.

The program then goes through and numbers the notes, both in the text and within blocks of notes; after that it extracts the notes, reformats the text, and moves everything

around so that it will print out properly. (Naturally you must give the program your text-printout format: margins, line width, line spacing and lines per page, etc.)

It does it all painlessly and simply.

Some programs are so well done that there's not much to say about them. Footnote is one of those; it's hard to think of improvements.

My copy of Footnote came bundled with a program called "Pair," which matches the underline and boldface characters for Wordstar so that you don't end up with page after page of unwanted underlined material. WRITE doesn't require that kind of checkup, but Wordstar users ought to appreciate it.

If you do scholarly writing and you use Wordstar, you'll want Footnote.

Wedged . . .

Everywhere you look there's a new spreadsheet program for sale. Spreadsheets are programs that let you enter a matrix of numbers and formulas, and recalculate the whole matrix if you change the value of any one entry. The first of these was called Visicalc, which was a really great idea, and one of the most useful programs ever developed for microcomputers.

Visicalc is one of the great success stories of the computer world, and I truly wish I'd thought of it. (I did, actually, as a sort of "I wish I had a program that would . . .", but I didn't do anything about the wish, so that counts as not thinking of it.)

Visicalc was designed for the Apple, and I'm told it was responsible for a lot of Apple sales. Naturally there was a rush to get versions running for the CP/M 8080/Z80 family of machines. One of the earliest, and best, Visicalc "workalikes" was Sorcim's Supercalc, which I've mentioned here often enough, and which I recommend.

Predictably, there's a rash of others. It's very hard to compare them feature by feature, and in general they all do the same thing anyway, so how do you tell them apart (other than by price)? One possible marketing strategy is to make distinctive product packages.

Text continued on page 346

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While Basic is easily learned, for just a little extra effort invested, Pascal pays much bigger dividends. Many universities use only Pascal to teach programming; *it's the more modern language, incorporating advanced programming techniques*. Example: by dividing programs into modules, JRT Pascal makes very complex programs—of nearly any size—a breeze to manage.

Pascal code is *self-documenting*; program sections are identified by meaningful names, not line numbers. And error messages are verbal, not number codes. JRT offers more (and more powerful) *data types: 12*—to Basic's 2 or 3. Use regular or hex numbers; JRT gives you the choice.

Total it all up, and the result is a language that's very easy to use.

2 POWER

For power—the ability to write better, clearer programs, faster—Pascal is the run-away winner. The CASE statement is just one good example:

Basic	JRT Pascal
IF X = 5 OR X = 10 THEN\ X = 73\ GOTO 99	CASE X OF 5,10 : X = 73; Z-4 : WRITE (X); ELSE : WRITE ('X NOT VALID'); END ;
IF X = Z - 4 THEN\ PRINT X\ GOTO 99	
PRINT "X NOT VALID" 99 REM	

JRT simplifies programming by accomplishing complicated operations (for Basic) with one command:

Basic	JRT Pascal
IF A\$ = "V" OR A\$ = "W" OR A\$ = "X" OR A\$ = "Y" OR A\$ = "Z" THEN...	IF A IN ['V'..'Z'] THEN...

Convinced?

Here's the real shocker!

Features	Basic	JRT Pascal
Structured programs	No	Yes
Separate compiled modules	"Chaining"	Structured procedures with auto-loading & purging
Arithmetic precision	Usually 6 or 7 digits	14 digits
Indexed files	No	Yes
Maximum string size	255 characters	64,000 characters
Loop statements	1	3
Data types	Usually 2 or 3	12
CASE statement	No	Yes
Introduced	1965	1980
Price	???	\$29.95!

3 FLEXIBILITY

JRT Pascal's wide variety of data types reduces programming restrictions; *the language works for you, not against you*. And Pascal data types are not all fixed in size. Add *JRT's 3 looping statements* (Basic has one), and you get programming better tailored to your specific needs. That's flexibility.

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Basic generally limits text strings to 255 bytes; *JRT strings go up to 64K*. You process entire documents, not just single lines.

Flexibility—it could be JRT's middle name.

4 EFFICIENCY

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*CP/M is a Digital Research TM. A 56K CP/M system is required.

The Wedge, by Access Software Inc. of Palo Alto and marketed by Systems Plus Inc., does just that. It comes in a handsome cardboard 8-inch disk box rather than in a loose-leaf binder or something similar as most do. All the documents have slick, glossy covers. I find the name unfortunate, but the package is attractive enough.

I haven't had time to do a lot with The Wedge, but it seems to work all right, and it was easy enough to install. There's a set of 8-inch flash cards, that is, slick paper sheets, each of which has a tutorial lesson on getting the spreadsheet running, setting up spreadsheets, saving them, printing them, etc. As far as the program itself goes, I didn't notice any special features not present on other spreadsheets, and the documents don't seem to claim any. It will handle numbers up to 999,999,999.99 (just shy of a billion), and as small as 0.001, and that's a greater range than many such programs have, although not outstandingly so.

The Wedge's competitive edge, then, must be the documents; and if Access Software had stayed with the style of its typeset tutorials, there'd have been a real contest, and I'd have had a lot more work to do. Alas, it was not to be. I suspect the manuals, 20 pages in the Installation Guide and 80 pages with index in the Applications Manual, are well written and fairly complete; but I could confirm my suspicions only at the risk of my already failing eyesight, and I'm just not willing to do that.

The outside pages, including the Table of Contents, are typeset and readable; but the body of both documents is two-column printout, probably from a Diablo. It is not right justified. It was printed with either a bad ribbon or a misaligned print head (or most likely both), then photoreduced. In a strong light I can read them, though not easily, and as I said, I think they're well written. However, I'm never going to find out, and everyone else here declines to do so, so I guess we just won't have a test

of The Wedge against Supercalc.

I can't imagine why, having spent what Access Software did on the rest of the package, it didn't get a good dark typescript to work from; after all, amateur science-fiction magazines ("fanzines") manage it. This company didn't, though, and thus wedged itself out of my being able to give it a fair evaluation. Those with much patience and stronger eyesight than mine might find this product interesting.

Superfile

I swear it: something has got to be done about silly licensing agreements before we all become a complete nation of scofflaw computer users.

Let's look at the good part first.

Authors have problems: we have to keep track of characters. For short stories that's not so difficult, but with epic-sized books like *Lucifer's Hammer* or our new *Footfall* things can get messy. We may think we're done with a character in chapter one—say the aged uncle of the waitress in the restaurant where the main characters meet—and then later discover he's just ideal for a walk-on in chapter nine; except that we don't remember precisely where he appeared, or what we named him, and we sure don't want to stop and look it up.

Consequently, for some time I've had in my "Do It" book a note to make up a table of characters for *Footfall*, our novel in progress. I haven't got around to it, though, mostly due to sloth. I expected to do it in my own Minimum Data Base that allows search by keywords and is easy to set up; easy or not, however, it involves work. I'd have to have a paper copy of the book to read while entering the names and data, or else have two machines going side by side, one displaying text, the other taking data entries.

Then, suddenly, there was Superfile, which appeared out of the blue courtesy of UPS. (Turns out Alex had spoken with the company while I was in Italy.)

Superfile has some very nice features. It requires no fixed length for fields, you can mix entry lengths, and you use your own text editor to create

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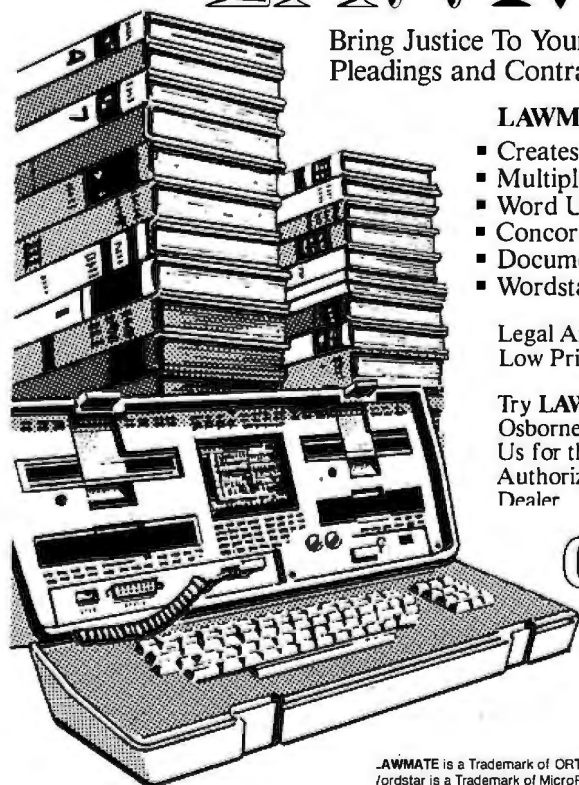
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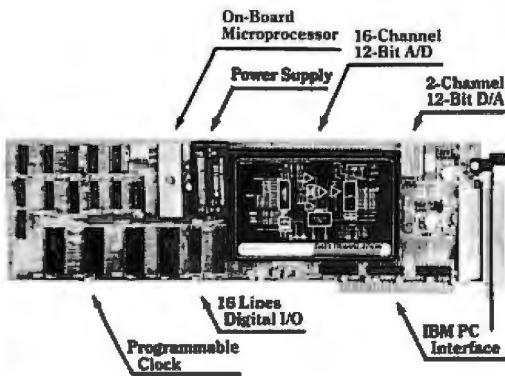
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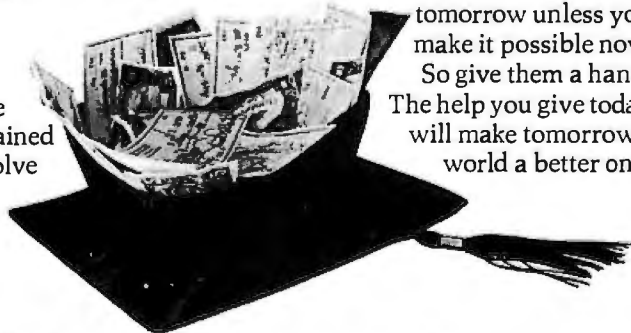
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index files. When it's all done, it makes a "dictionary" of keywords used, and you can search using up to 64 keywords combined with AND, OR, and NOT.

The search algorithm used has some problems: although it upper-cases both keyword and search entry (there is an override if you really want to differentiate between upper-case and lowercase), it doesn't use an "include" comparison; the result is that BYTES won't be found if you search for BYTE. I think this is unfortunate, but you can live with it.

There are problems with the Sort feature, too. Superfile thinks all numbers are strings; at least that's my guess as to what's going on. What's certain is that "numbers used for sorting must all be the same length and format. If you use numbers 1 through 999, for example, all one- and two-digit numbers must have leading zero's (0) as 'pads,' like this: 001, 002 . . ."

Problems always exist with any "free-form" data-retrieval system; because the data is not in any fixed format, it's hard for a Sort routine to find the "field" on which you want to sort. The advantage, of course, is that you don't have to enter data in fixed format and in response to prompts.

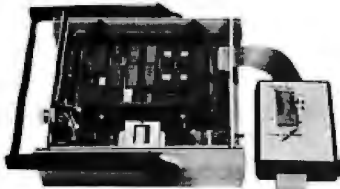
My intention with Superfile is to go through and, using my normal text editor, "mark up" a copy of *Footfall*. Superfile thinks that *C begins a data entry, *K begins the keyword field for that entry, / separates keywords, and *E ends the entry. Thus, I should be able to create a characters database right from the marked copy of the text. This isn't an *indexing* program, so it won't know what page it found the entry on, but that isn't fatal; the great thing is that it ought to pull all that stuff out. If I make the character name the first entry after the *C, according to the documents Superfile will be able to sort the newly created database, giving me an alphabetic list of my characters along with whatever comments I decide to include between the character name and the *K; plus a bunch of keywords, such as the names of people they're associated with, so that I can find them again.

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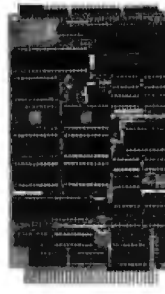
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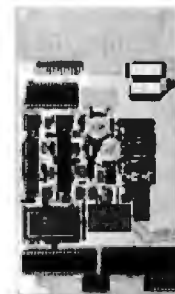


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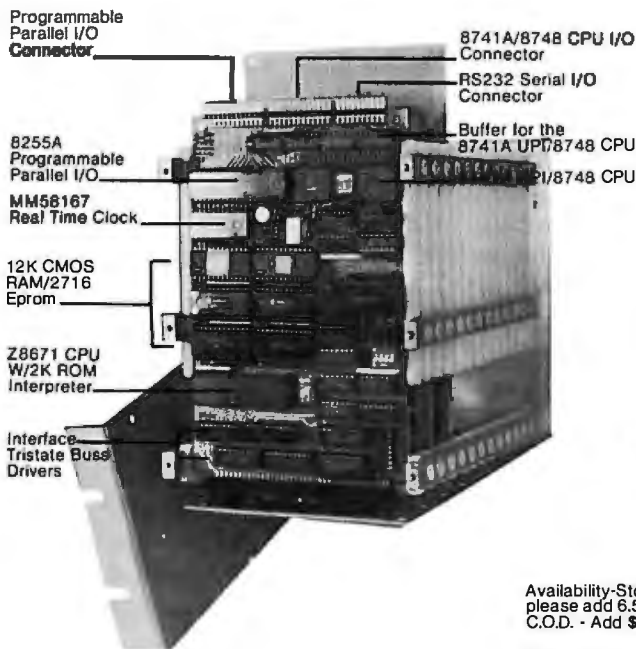
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Superfile runs only on a Z80 (I tried it with the 8085/8088 Compupro dual-processor system, and it won't run on that), but I have Zeke II running fine, so that's no difficulty.

There is a problem. The program documents give no examples at all. They write instructions in what's very nearly baby talk, but they don't show what's going on. Let me give an example.

There's a Superfile utility that will open a file, copy it to a new file, and on the way through change any characters to any others. This kind of utility is called a filter, and it's very useful for doing such things as changing the print-format commands so that text files created by one editor can be printed by another.

Superfile is all menu driven. To run this utility, you specify the "change characters" option in the utilities program. I now give you Superfile's instructions exactly as they appear in the book:

```
Enter the present characters first, then
the replacement characters
present      >
```

```
change to   >
```

```
At this point you simply list the
characters that you want changed,
and then what you want them
changed to.
```

That's it. No more instructions. One problem: how does it know when you're finished listing characters you want changed, and ready to accept the ones you want them changed to? On trying it, I find that you simply list what you want it to look for, end the list with a Carriage Return, and begin a new list; the program lines them up for you, old above new, so it's relatively easy to do; but it sure would have been a lot simpler to figure out if they'd given an example.

Please. Any of you out there writing programs and contemplating sales: Do not assume that your deathless prose is so sparkingly clear that you can dispense with examples. Paper isn't that expensive.

Incidentally, the Superfile utility will let you enter characters by ASCII

(American National Standard Code for Information Interchange) number, so that you can change all the Control-Qs to Control-As or any such. Alas, there doesn't seem to be a way to create or remove eighth-bit-set characters (which appear as reverse video on my system) as created by Wordstar. For reasons I don't understand, Superfile will accept numbers greater than 128 (the ASCII representation of a character with the eighth bit set), but what it does with them is simply not predictable.

Still in all, let's try it. I'll go do that now.

* * *

The asterisks indicate passage of time. They also indicate mild gnashing of teeth. Superfile has its good

Superfile has its good points, but there are some infuriating aspects to it as well.

points, but there are some infuriating aspects to it as well.

First, like many programs nowadays, Superfile wants your text editor to mark the ends of lines with not only Carriage Return, but Linefeed. This is annoying. To save space on files, WRITE (like Electric Pencil before it) marks paragraph ends with a Carriage Return. (It doesn't mark line ends at all, but of course when you're using something like Superfile you'll make each line a separate paragraph; no problem.) Thus, I have to run my stuff through a filter before Superfile will deal with it—and Superfile's "change characters" utility will *not* deal with that problem, because it won't substitute two characters for one. Grrr.

Second, Superfile doesn't extract stuff from your old document; what it does is make a mess of pointers to where in your document each entry can be found. Then it renames it. Thus, I started with a chapter called DISCOVERY.TXT and went through marking it up: whenever I found a

character, I put a *C at the beginning of a line, then the character name, then notes that were often just pulled from the text itself; then *K and a bunch of keywords, then *E to show that entry was done. It wasn't onerous. I didn't bother to eliminate the text between entries.

To be safe, I saved that as DISCHAR.TXT, put it into the B drive, and invoked Superfile. After some frustration with the instructions—they *will* not give examples and just assume that all is very clear—we succeeded in "creating a database" called FOOTCHARS (meaning characters in *Footfall*, the title of the novel).

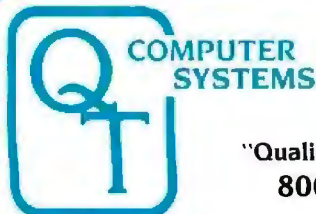
Examining the disk shows there are new files: FOOTCHARS.NDX and FOOTCHARS.DIC, as well as a file called DISCHAR.D00, which is nothing more than DISCHAR.TXT with a new extension name. Four entries were crammed in among one whole lot of useless text. No extraction had been done at all. I'd obviously had the wrong idea about what Superfile does—yet I'd spent some time reading the documents.

Close rereading discloses that if I want to add anything to my "database," it will append the new files on to the old one; it still won't extract.

This means that my scheme of marking up existing stuff and extracting it into a Superfile isn't going to work; I'll have to eliminate the extraneous matter. It will be simple enough to write a small filter program that does that, and while it's at that job it can put Carriage Return-Linefeed pairs wherever it sees a Carriage Return; whether that's easier than using my Minimum Data Base (which *will* find included strings and thus would find BYTES if you searched for BYTE) is another matter.

Thus, after a couple of hours' work I was able to figure out what Superfile is and does. Understand, it's not all that hard to *use* the program, because it's all menu driven and the documents are pretty good at walking you through a lot of it; but I, at least, had my problems figuring out what it was going to do until it did it.

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like. You begin each entry with a *C. If you want to make mailing labels, you can make the first entry a name, last name first for sorting. This still isn't clear to me because there's no entry for "mailing labels" in the index, and the various references to making labels didn't tell me much; I presume that if I read the whole document I'd find out.

You can put anything you like, in any format you like, in the entry. This free format severely limits the ways Superfile can sort your data; the simplest is by the first words after the *C. There appear to be ways to do "numeric" sorting as an alternative, but that isn't clear, and the sort algorithm insists that the numbers be padded with leading 0s.

Lines in the entries must be separated by Carriage Return-Line-feed pairs; anything else will prohibit you from displaying any filed data, making the whole exercise futile. Superfile will *not* add Linefeeds, although it does have some limited filter capabilities.

At the end of the data part of the entry you put a *K, followed by keywords. Keywords must be separated by the "/" character; since there can be spaces in keywords (i.e., Superfile can use keyword *phrases*), this is reasonable, but of course that means that spaces are significant characters; BYTE NOW and BYTE NOW are different. Furthermore, Superfile looks for the *exact* keyword, and there is no provision for searching for *inclusions*.

Superfile takes the whole text file you've just created, renames it, and makes up an index; it also makes a sorted dictionary of keywords. This is done automatically and painlessly and is one of the best features of the program. The text file you've created becomes your "database." You can mark up existing files and add them to the database; however, extraneous matter not part of any entry will remain in the database, taking up space and presumably adding to the access-time requirements. I don't know what happens if you try to sort a database containing extraneous matter.

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confident that you'll like it that it will let you have it for a 30-day trial; if at the end of the time you don't want it, you can return all the materials plus a certificate swearing that you've kept no copies, and FYI will refund your money.

Superfile seems to work, and I expect it's easy enough to learn. The cascade menu system is nearly fool-proof—I deliberately tried to crash the system by typing Control-C at various places and I couldn't do it—and the various prompts and error messages make sense, or at least do so with increasing experience. There are some annoying aspects, but on the whole this is a pretty good program. It's a lot faster than dBASE II, but of course it's also a lot less versatile.

I'd recommend it, especially with that money-back guarantee and trial period—except that FYI has devised another user-threatening agreement. This thing is in tiny print; I need a strong light and the glass from my transistorized *Oxford English Dictionary* to read it, and even then I have trouble.

The agreement is in legalese. It begins with the word *Whereas*, goes on to *witnesseth*, and ends with a signature block so damned small that I couldn't get my real name in there if I were foolish enough to sign the silly thing. If you're planning to sign as J. Doe you can just about do it, and maybe that's no bad plan unless your name really is J. Doe.

I don't know what FYI warrants; the print's too small to read. I see in the last line it disclaims any responsibility for letting you assume this product was useful or merchantable or fit for any particular purpose.

In another place there's a provision to be sure the lawyers are paid no

matter what else happens. I wonder why that doesn't surprise me?

In theory you can't get Superfile without signing this thing, which is actually in the form of an application; the last line says "Upon receipt of two (2) properly completed and signed copies of this Agreement, along with the appropriate Order Form(s) and Fee payment, FYI or its authorized Dealer will return one copy of this Agreement to End User [I think that means customer] along with the appropriate FYI product materials."

Now that I look at it, I've apparently locked myself out of ever being able to be an authorized user: that is, I sure haven't signed this stupid agreement; but one of its provisions is that any use of FYI products without having signed this is unlawful and subjects me to all kinds of horrible penalties, liability for which I acknowledge by signing the agreement . . .

If you can put up with a company that lets its lawyers run wild like that, and you're willing to sign a licensing agreement that you can't read and hasn't room for a signature anyway, you might like Superfile, although I suggest you examine Cardfile first to see if it would do; Superfile has a number of features Cardfile lacks, but it costs a lot more, too.

I may yet use it, if I get around to writing the filter programs it would need before it could solve my problems. ■

Jerry Pournelle welcomes readers' comments and opinions. Send a self-addressed stamped envelope to Jerry Pournelle, c/o BYTE Publications Inc., POB 372, Hancock, NH 03449. Please put your address on the letter as well as on the envelope. Due to the high volume of letters, Jerry cannot guarantee a personal reply.

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Text box continued on page 356

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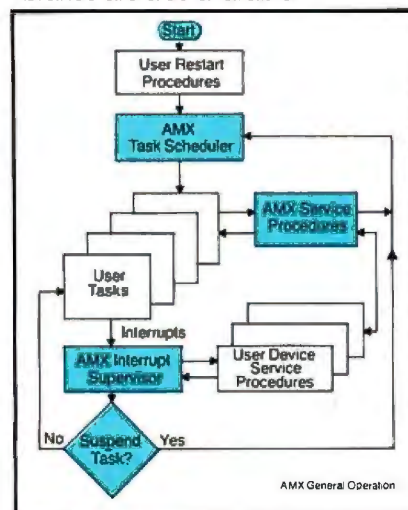
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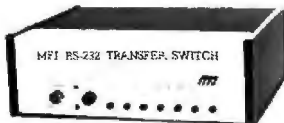
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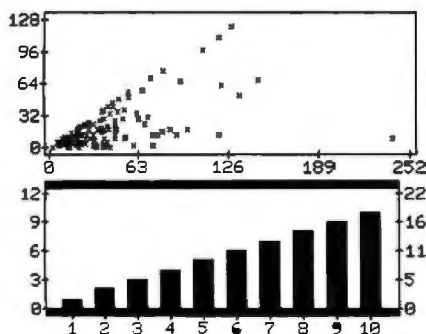
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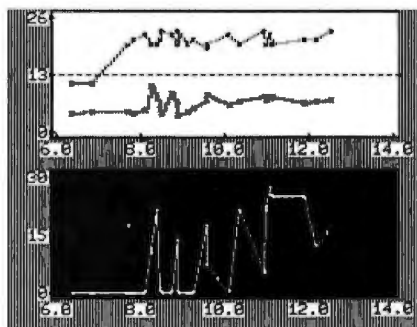
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This month I will continue development of the 64K-byte memory board (see part 1 in the March 1983 BYTE, page 310) by describing the construction procedure I followed (skipping the errors I made). You should follow the "test-as-you-go" procedure to reduce the bug hunt to a small portion of the board at a time.

You can build this memory board if you can solder cleanly and wire-wrap consistently. As I mentioned last month, careful construction of the circuit will result in a dependable, versatile memory that you can fill with software and enjoy for years. If you rush the job or buy untested parts, you could have a stimulating puzzle to tinker with or worse. Wiring problems (errors, poor wrapping, loose metal floating around, cold solder joints) have been known to

blow the lids off ceramic integrated-circuit (IC) packages. Building this memory card should not be attempted as a first project.

The parts are all widely available, except for the crystal. The circuit

**For a happy ending,
don't rush the job
and don't buy untested
parts.**

seems to work with any clock from 4 to 15 MHz, but wait states are necessary below 14 MHz when using a 4-MHz Z80 microprocessor. The crystal is not critical, but I advise you to stay between 13 and 14.5 MHz, especially if you can't measure the frequency it runs at. Crystals love to run at impossible harmonics. The prototype board seemed to have trouble holding data until I forced its 10.17-MHz crystal to stop oscillating at 20.34 MHz.

Incidentally, if you can't get a 74S65, use a 7422 and a 7403 with all their outputs tied together. You may substitute regular TTL (transistor-transistor logic) for the S-type

Schottky TTL (labeled 74SXX), but you may get a wait state in some opcode fetches. If you buy a spare set of ICs, a wiring disaster can't cost too much time (table 4 is a parts list). The heat sinks I used were made from 3/4-inch aluminum angle stock: a 1-inch length for the -5-volt (V) regulator, and a 3-inch length for both positive regulators. (The -5-V regulator barely gets warm; the others get hot, but not dangerously so.)

Mark locations and edge-pin numbers before installing anything. Use the layout in figure 6 to minimize bus-line length. Leave one row of holes between the memory ICs and two or three holes between rows of TTL: this leaves space for later additions.

Build the power supply first. Wire the regulators so that you can change them for debugging or for future 5-V-only memory devices. The supply fits in a 1- by 5-inch strip at the end of the board, out of the way. Test the supplies with a pair of number 47 pilot lights and a voltmeter. Two bulbs in series, across +12 V and ground, glow white, and in parallel each 5-V regulator can light both

All caption numbers are continued in sequence from part 1, March 1983 BYTE, page 310.

About the Author

Cameron Spitzer designs I/O channels for Four-Phase Systems, a Motorola subsidiary.

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Circle 341 on inquiry card.

Item	Designation	Quantity	Description	You May Substitute
1	Board	1	Vector 8801-1 bare S-100 plugboard	10- by 5-inch perforated board
2	RAMS	32	MK 4116-3 16K-bit dynamic RAM	(See table 1, March BYTE, page 311)
3	XTAL	1	14.5-MHz quartz crystal	4 to 14.5 MHz (see text)
4	7805	1	5-V, 1-A positive voltage regulator (TO-220)	LM340T-5.0
5	7905	1	5-V, 1-A negative voltage regulator	LM320T-5.0, 79M05, 79L05
6	7812	1	12-V, 1-A positive voltage regulator	LM340T-12
7		2	22- μ F, 25-V electrolytic capacitor	4.7 μ F tantalum
8		1	47- μ F, 25-V electrolytic capacitor	22 μ F tantalum
9	Caps	40	0.1- μ F, 15-V ceramic capacitor	
10		1	150-pF ceramic capacitor	
11		2	33-pF ceramic capacitor	
12	Diodes	5	1N4001 50-V, 1-A silicon diode	1N4002, etc. Do not use 1N914
13	U9,U12	2	74S00 quad NAND gate	74LS00
14	U2	1	74LS00	7400
15	U15	1	74S04 hex inverter	*
16	U1	1	74S10 triple NAND gate	*
17	U36	1	74LS30 NAND gate	Any 74LSxx (see text)
18	U21	1	74S65 AND-OR-INVERT	7465, 7403, and 7422 (see text)
19	U3,U10	2	74S74 dual D-type flip-flop	74LS74
20	U13,U27	2	74LS74 dual D-type flip-flop	7474A
21	U20	1	74LS139 dual 1-to-4 decoder	*
22	U33	1	74LS151 1 of 8 multiplexers	4151
23	U4	1	74S175 4-bit D-type flip-flop with clear	*
24	U26	1	74LS240 octal line receiver	*
25	U19,U24	2	74LS373 octal D-type latch	25LS373 (74LS240, U19 only)
26	U17,U18,U25	3	74LS374 octal edge-triggered flip-flop	25LS374
27	U6,U11	2	74LS393 dual 4-bit counter	4x 74LS293, etc. Binary only
28	RP1	1	1 k Ω \times 13 14-pin resistor DIP	
29	RP2	1	4.7 k Ω \times 13 14-pin resistor DIP	
30		1	2 k Ω	
31		3	470 Ω	
32		14	33 Ω	} 1/4-watt 5-percent resistors
33		1	1 k Ω	
34		6	20-pin	
35		37	16-pin	
36		17	14-pin	
37		75	loose wire-wrap pins	
38			#30 wire-wrap wire	
39			#18 bell wire	
40			#18 inner-diameter Teflon sleeving	
41			solder	
42		2	4-inch length of 3/4-inch aluminum angle stock cut into 1- and 3-inch pieces (for heat sink)	

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	spare ICs	20
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* Indicates "do not substitute"

Table 4: Parts necessary to build the 4116-type memory.

bulbs yellow. Do not proceed until the power supplies are just right. You may bolt both positive regulators to the same heat sink, but be sure to isolate the case of the 7905, because it is at -5 V.

Next, mount the memory sockets, as shown in figure 6, by soldering AWG18 wire to all pins 16 (ground) in a grid. I formed the wire into a zigzag and slid bits of Teflon tubing down it. Then I could solder in a whole row at one time. Each pin 16 is connected to the next, horizontally and vertically, to form a low-impedance ground plane. Repeat the grid process on pins 1 and 8 separately. Use a buzzer or ohmmeter to

check for shorts between the three grids. Use sunlight to look for bad (rough, dull) solder joints. Remove bad solder, don't just reheat it.

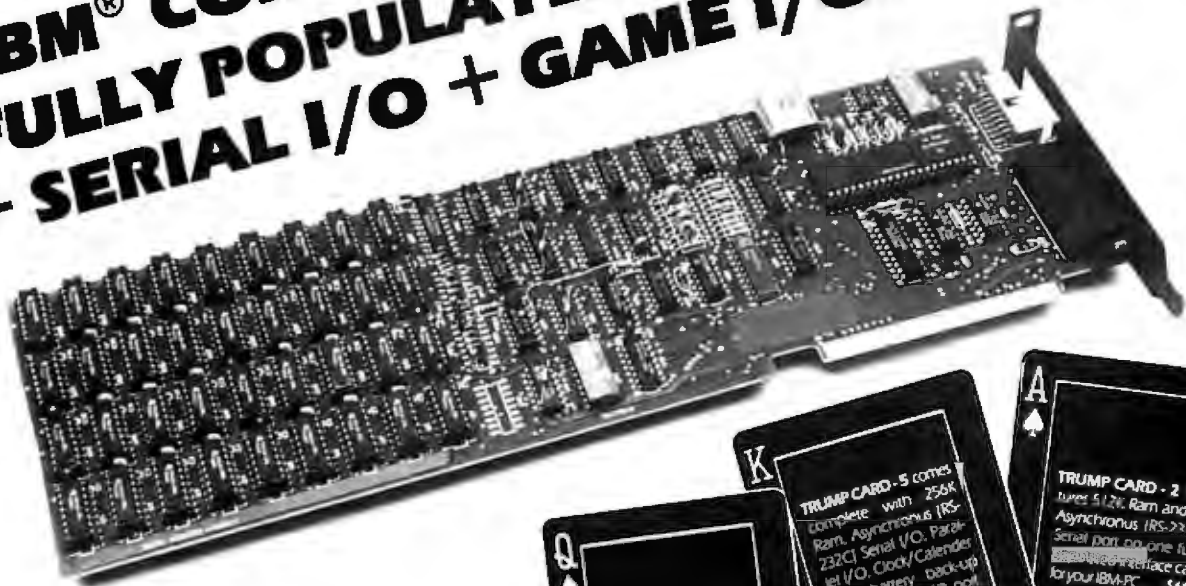
The TTL-supply wiring is less critical. I supplied power to the TTL sockets by wiring a few wrap posts up with AWG18 copper wire, then connecting these to the sockets with AWG30 wire-wrap wire. The +5-V supply is wired as an address line, using a grid pattern. Again, check for shorts.

Copy the schematic diagram twice. Wire the address and data lines among the memory devices as shown in figure 4 (see part 1 in March 1983 BYTE, page 320). Notice how the ar-

ray works: almost all corresponding pins are just tied in parallel (i.e., all the pins 15 are hooked together). The exceptions are $\overline{RAS0}$ through $\overline{RAS3}$, and the data pins 2, 4, and 14. Each \overline{RAS} line runs across a bank of eight devices. Each data line (16 of them, in all) ties four pins together vertically. Do not tie together any pins with different numbers. On the first schematic copy, color each line you complete. Wire the TTL and resistors point to point, minimizing each line length (neat bundles of wire-wrap wire will just cause noise trouble). Do not connect the circuit to its regulators yet.

The clock is wired by soldering the

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Listing 2: *These loops exercise parts of the board for observation by oscilloscope. (See also photo 4a.) Remember to disable the chain not being tested.*

```

0000 21 06 00    LD HL,l      ; Reading test.
0003 11 80 7F    LD DE,RAM    ; Row=0s, col=1s
0006 1A         ! LD A,(DE)    ; Observe
0007 E9         JP (HL)

0006 12         LD (DE),A    ; Write test (same loop)
                        END

7F7D 21 80 7F    LD HL,7F80
7F80 E9         JP (HL)    ; Observe an op-code fetch
                        END ; Used for photo 4a

```

listing 1, on page 372). Run the test overnight. When you see no errors, celebrate and continue with the next section.

Alas, a swarm of potential bugs could plague your new card. Using the divide-and-conquer method, you can sort them into *bus* and *on-card* categories and chase them all down.

First, eliminate the most obvious bus problems. Dig out the schematics of your other cards to see if any of them are using pin 67 for anything but PHANTOM. If one is, remove the jumper at J2. Check the processor-board schematic to find out how it derives the status signals. The most common processor board will be a Z80 driving a few gates (probably 74LS02). For this board, connect by jumper pins 1 and 2 on J3, as well as pins 5 and 6. If your system is an 8080A, using an 8228 to derive sMEMR, place the read-status jumper on pins 2 and 3 of J3. If your system is an 8080 with no 8228 or a Z80 inside a spiderweb of gates and one-shots (monostable multivibrators), try moving the other jumper also.

In the worst case, you may have to figure out what the status lines from your particular processor really do and use them to set the three request flags via some special circuit. (I will be glad to help readers who send all the details of their problems, along with a self-addressed, stamped envelope.) Most non-8080 processors have a lot of trouble generating pSYNC, so you might look there first. Some processors generate the S-100 clocks with one-shots, also suspects.

If you have the Z80 version and the card doesn't work, the bug is probably on the card. I debugged the prototype with only a computer, a 5-MHz oscilloscope, and a logic probe. Starting with a valid schematic means you can probably find your manufacturing problem with just a probe.

As you can see in figure 3 (March BYTE, page 318), all activity on the card propagates down two chains: *refresh* and *memory*. The chains share the cycle generator, its clock, power, and the memory devices themselves. Because the refresh chain runs (when all is well) by itself, it's easiest to check first. If your probe can't detect a 25-nanosecond (ns) pulse, hook up a Schottky one-shot on a breadboard for these tests. Check the refresh chain with no other cards plugged into the S-100 bus.

Check to see if the clock is running. If it's not, try a 74LS04 in the socket. The clock ripples through the timer and sets the refresh-request flag (IC13, pin 5). Check whether the flag is stuck and whether the pulse gets to IC4, pin 4 (ANY REQ). IC4 should cycle, clearing the flag again. This logic is self-clearing for any initial state, so any stuck flag reveals a defect. IC4 will cycle every 10 microseconds (μ s). Refresh cycles make pulses on IC3, pins 2 through 6, that reach IC20 (address selector) and IC19. IC11 counts, producing long square waves (down to 1 kHz). If any of this isn't happening, the break in the chain pinpoints the trouble.

Because the TTL is static logic, you can run it very slowly. (I first ran the

board at 1 Hz to check the gross logic design.) CK5 will still be 20 ns to 40 ns long, however. You can therefore root out a total failure using LEDs (light-emitting diodes). Some devices (the "untested" or "hobby-grade" ones), though, fail only their AC timing tests, and they'll seem to work at low speeds.

The memory-cycle chain is more complex, but its shared parts have been tested already. The easiest part to check is the read-buffer latch (IC24) and its interface. Unplug the memories. Stick a 470-ohm resistor in each of eight memory sockets between pin 14 and either pin 16 (logic 0) or pin 9 (logic 1), and try to read the test pattern formed by using your monitor. If you can't read the proper pattern, lift pin 11 of IC12 and try again. This test checks the path through J1, MADDR, TALK, and the output latch. If lifting pin 11 of IC12 makes it work, you have trouble around the CAS gate.

To check the write logic, probe memory pin 3 as you write with your monitor. There should be one pulse per write. (Be sure J1 is properly connected by jumper for this test.) The chain from MWRT to pin 3 is simple. The write-request flag must be free to change state.

If you have an oscilloscope, it's easy to follow pulses through both chains. You can check the signal at various points by lifting one of the request-flag pins and exercising the board with a tight software loop as you observe the other chain (see listing 2). Remember that extra activity is as bad as no activity. CAS should stay high during refresh cycles. WR (write) should stay high during reads. CK5 should never be low for more than 50 ns; it may be hard to see, but it can trigger a 74LS74 clock.

Before giving up, have a friend double-check the board for you. Some people can check the same error a dozen times and never see it. Perhaps the information in listing 1 and photos 4a and 4b on page 370 can be used to some advantage.

Think Big

In part 1 of this article, I mentioned

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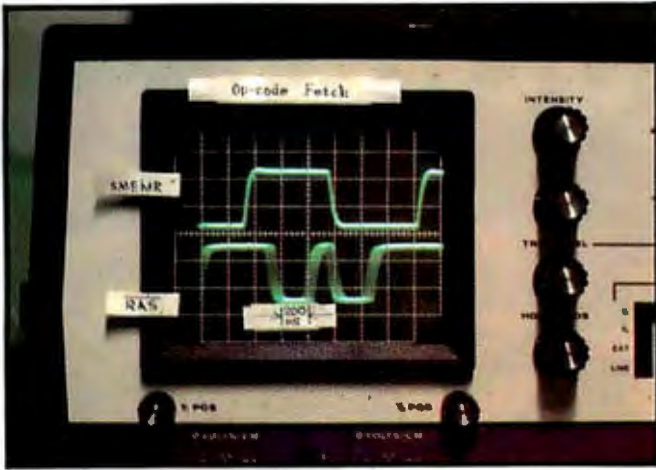


Photo 4a: The Z80 clock runs at 3.58 MHz, and the memory clock at 14.5 MHz. An op-code fetch (a short Read with M1 high) sets two request flags. The first \overline{RAS} pulse is the actual op code being fetched, and the one on its heels is a "hidden refresh." The time elapsed for each vertical line on the scope face is 200 ns. The horizontal smear on \overline{RAS} is the 69-ns latency time of the cycle generator.

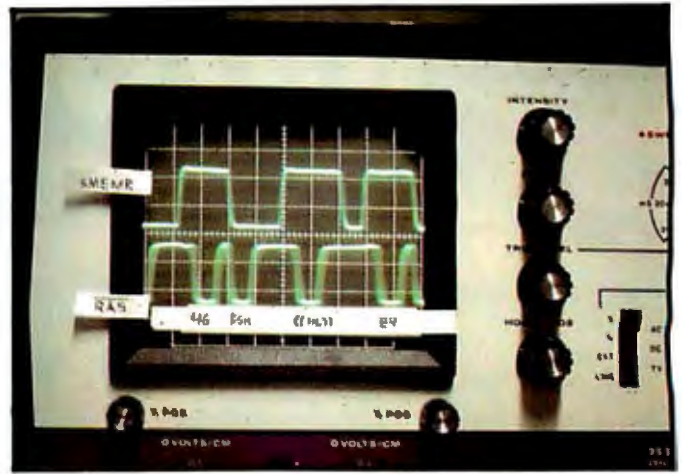


Photo 4b: This is a "scope loop," like those in listing 2. The first sMEMR (high-going pulse) fetches an indirect-read instruction (B-(HL)). The next sMEMR carries out the instruction. Because HL points to the instructions location, we have two kinds of read from the same location. The single \overline{RAS} in the middle is the data read. Finally, an E9 hexadecimal (jump to (HL)) is fetched, restarting the loop.

that this card may be expanded to cover a larger address space and to support write protection and overlaid-page selection (sometimes called *paging* or *multiuser*). I have described in detail a 64K-byte memory, but for simplicity's sake the schematic (see figure 4 in part 1 in the March 1983 BYTE, page 320) doesn't show any upgrade options. The fancy addressing additions will fit on the card if you pack the circuit as tightly as I did, but each user's requirements will be different.

On the other hand, the upgrade to denser memory devices is easy. The 4164 is a 64K-by 1-bit dynamic memory device whose pins are almost the same as the 4116's. There is one more address pin (9), and there's only a +5-V supply. Here's how to use the 4164s:

1. Get the board working with 4116s first!
2. Remove the 4116s, the 7812, and the 7905 and its diodes. Replace the 7812 with another 7805. Mount a 1k-ohm resistor between pin 8 and pin 1 of any memory device.
3. Remove any capacitors from pin 9 of the memory grid that used to be the +5-V supply. Connect the pin-9 grid to the two dangling resistors marked by a star on figure 4). Make sure the +5

voltage is no longer present on any pin 9.

4. Move the two wires now on S-100-bus pins 32 and 86 to pins 16 and 17, respectively. Each 8K-byte jumper now represents one 32K-byte block (for a total of 256K bytes).
5. Install the 4164s. Run your toughest memory test. The early version of the 4164 sometimes suffered a high error rate due to internal radioactivity, but this problem has been solved.

As for the other upgrades, you can easily change the 2-bit bank-select latch (IC2) into an output port and control it via software. Be sure to install only two jumpers on J1, or the same 16K-byte block will appear all over your address space.

To build a PC board that will provide write protection for 8K-byte blocks, change the input of the write-request flag (IC13, pin 12) from MADDR to the output of another multiplexer, controlled by a port instead of jumper straps. The port will then control the write enable to each 8K-byte block. It should be cleared by a power-up reset.

Large-Scale Integration

The 4116 contains more than

20,000 transistors. Why, then, can't we find an equally complex IC to replace all that TTL? The manufacturers offer some dynamic RAM (random-access read/write memory) controllers and other support parts now (error-correction devices, line drivers, etc.), but most are still unavailable on the hobby market. The older ones, Motorola 3242 and Intel 8202, provide only a 7-bit address path with no latches in it. These parts do not support the 4164, which is now the preferred device for new designs. Some new parts, now in volume production, are National's DP8409, TI's TMS4500A, Intel's 8203 and 8207, and AMD's Am2964B. These devices support the 4164.

During the time this article was in production, my associates at Video Concepts of Maryland (4401 East-West Highway, Suite 408, Chevy Chase, MD 20014) have developed my hobby project into a commercial-quality printed-circuit board. They have added addressing accessories that support most of the de facto standard operating systems used in S-100 machines. The card easily accommodates 4116s, 4164s, or the newly available 41256s (you guessed it: 256K bits in one 16-pin package!), and it uses the Am2964B to save about half the small TTL devices shown in this article. ■

Listing 1: Use this program to convince yourself the card is really working. The program writes a test pattern, waits 5 seconds (to test refresh), checks the pattern, and inverts the pattern. After two passes, the main loop has tested each cell with a 0 and a 1. The program calls monitor routines for I/O, as described in the equates at the top. You will have to fill in the addresses for your monitor. It prompts for the limits of memory in order to test and for a character in order to flag continuous or once-through operations.

A counter is maintained for each 4116. The low byte counts errors, and the high byte records the error pattern. The counter dump forms a map of the board (front view), so that you can see a bad device easily. A dump of all 0s says all is well.

The column buffer register isn't exercised by the test. To check it, use your monitor to write at 1000 hexadecimal. Check that the byte you wrote doesn't appear at addresses 1080, 1100, 1200, . . . , 3000 hexadecimal. An open or stuck bit would cause the same byte to appear at two locations.

```

;
;           CONFIDENCE           by Ram Spitzer
;                               and Phil Perucci
;
; This program will count errors in an expanse of RAM.
; It requires external I/O routines for 16 bit numbers, and for ASCII.
; A single pass will count ALL errors, and once there are no hard
; errors, the continuous mode will accumulate soft errors.
;
; Stuck RAM address lines will appear as large chunks of errors.
; The column address buffer register, and address lines A7-A15 are not
; tested.
;
; Fill in the locations of your monitor routines:
;
F2E4      SP16IN EQU    0F2E4H   Type a space, then get a number into HL.
F317      OUT16 EQU    0F317H   Type out value in HL.
F355      ASCOUT EQU   0F355H   Type A out as ASCII.
F361      ASCII EQU   0F361H   Get an ASCII character into A.
F015      CRLF EQU    0F015H   Type carriage return, line feed.
F081      YERMON EQU   0F081H   Graceful monitor re-entry point.
;
0093      TIX EQU     93H      Data retention time constant (about 5 sec.)
;
; The test resides in 1K of known good RAM, beginning at SAFE.
;
0000      SAFE EQU    0000
;
0000      ORG      SAFE
;
0000 00   TIMES DB    0        Single or running test.
0001      ERRS DS    64        Bit error count, (32 words)
;                               low byte counts errors, High byte records
;                               error bit pattern. (ERRS) refers to Bank 0,
;                               bit 0. (ERRS+63) refers to Bank 3, bit 7.
;
0041 00 00 WASTE DW    0
0043 00 00 STRMUD DW    0      Start of MUD, (Memory Under Debug.)
0045 00 00 ENDMUD DW    0
;
03FD      STAK EQU   SAFE+3FDH
;
0047 31 FD 03 BEGIN LD    SP,STAK
004A 3E 40   LD    A,"a"
004C CD 6E 00 CALL  ASCO      Prompt for lower test limit.
004F CD E4 F2 CALL  SP16IN
0052 22 43 00 LD    (STRMUD),HL   Save lower limit.
0055 3E 38   LD    A,";"
0057 CD 6E 00 CALL  ASCO      Prompt for end of supposed RAM.
005A CD E4 F2 CALL  SP16IN
005D 22 45 00 LD    (ENDMUD),HL   Upper limit.
0060 3E 58   LD    A,"X"
0062 CD 6E 00 CALL  ASCO
0065 CD 61 F3 CALL  ASCII
0068 32 00 00 LD    (TIMES),A   Continuous test?
;
006B C3 78 00 JP    GENTP
;
006E C3 55 F3 ASCO  JP    ASCOUT   Eases relocation for you.
;
007A      ORG      78H
;
; Loop to write a test pattern:
;
007B ED 5B 43 00 GENTP LD    DE,(STRMUD)
007C 0E 00   LD    C,00H      Positive mask. (Neg. = FFH)
007E 78     ONETP LD    A,E
007F A9     XOR    C
0080 12     LD    (DE),A   The positive test pattern is simply
;                               the low byte of the address.
;
0081 CD CD 00 CALL  CPDEHL
0084 2B 03   JR    Z,TPISIN

```

Listing 1 continued on page 376

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Listing 1 continued:

```

0086 13          INC    DE
0087 18 F5      JR     ONETP
;
; Setup the test.
;
0089 AF          TPISIN XOR    A          Zero.
008A 06 40      LD     B,64
008C 11 01 00   LD     DE,ERRS
008F 12          CLRERR LD     (DE),A      Initialize error counters.
0090 13          INC    DE
0091 10 FC      DJNZ  CLRERR
0093 06 02      LD     B,2          Loop count for single test,
;
0095 00 00 00 00 00 PAD1  DW    0,0,0,0,0,0,0,0
;
; Main loop.
;
00A5 CD 6A 01   TEST  CALL  LAPSE
00A8 CD DB 00   CALL  BYTES  Check pattern
00AB CD 04 01   CALL  COMPL  Flip it
00AF CD 28 01   CALL  DUMP   Dump error count.
00B1 3A 00 00   LD     A,(TIMES)
00B4 FE 31      CP     '1'  Once?
00B6 20 ED      JR     NZ,TEST
00B8 10 EB      DJNZ  TEST
00BA C3 81 F0   JP     YCRMDN Done.
;
00BD          PAD2  DS    16
;
; Compare DE, HL
;
00CD A7          CPDEHL OR    A          Clr carry.
00CE E5          PUSH  HL
00CF ED 52      SBC  HL,DE
00D1 E1          POP   HL
00D2 C9          RET          Zero if =, Minus if DE>HL.
;
00D4          PAD3  DS    8
;
; Verify expected pattern
;
00DB ED 5B 43 00 BYTES LD     DE,(STRMUD)
00DF 2A 45 00   LD     HL,(ENDMUD)
00E2 1A          ONETST LD     A,(DE)
00E3 AB          XOR    E
00E4 A9          XOR    C
00E5 28 06      JR     Z,OKBYTE
00E7 CD 91 01   CALL  BYFAIL  Count the erroneous RAMs.
00EA 7B          LD     A,E
00EB A9          XOR    C          Recompute the expected pattern.
00EC 12          LD     (DE),A      Remind the flaky RAM.
;                                     This way, soft errs count just once.
00ED CD CD 00   OKBYTE CALL  CPDEHL
00F0 C8          RET     Z
00F1 13          INC    DE
00F2 18 FE      JR     ONETST
;
00F4          PAD4  DS    16
;
; Complement mask and test Pattern
; After two passes, main loop has tried 0's and 1's
; in each bit of MUD.
;
0104 79          COMPL LD     A,C
0105 2F          CPL          Mask
0106 4F          LD     C,A
0107 ED 5B 43 00 LD     DE,(STRMUD)
0108 2A 45 00   LD     HL,(ENDMUD)
010E 1A          ONEFLP LD     A,(DE)
010F 2F          CPL          RAM contents
0110 12          LD     (DE),A
0111 CD CD 00   CALL  CPDEHL
0114 C8          RET     Z
0115 13          INC    DE
0116 18 F6      JR     ONEFLP
;
0118          PAD5  DS    16
;
; Dump out the 32 error counters
;
0128 C5          DUMP  PUSH  BC
0129 E5          PUSH  HL
012A DD 21 3F 00 LD     IX,ERRS+62  Dump in descending order.
012E 06 04      LD     B,4          4 Banks.
0130 CD 15 F0   DBANK CALL  CRLF
0133 C5          PUSH  BC
0134 06 08      LD     B,8          8 Bits.

```

Listing 1 continued on page 378

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Listing 1 continued:

```

0136 3E 20          DBIT      LD      A,' '
0138 CD 6E 00      CALL    ASCO
013B DD 66 01      LD      H,(IX+1)
013E DD 6E 00      LD      L,(IX+0)
0141 CD 17 F3      CALL    OUT16
0144 DD 2B         DEC     IX
0146 DD 2B         DEC     IX
0149 10 EC         DJNZ   DBIT
014A C1           POP    BC
014B 10 E3         DJNZ   DBANK
014D E1           POP    HL
014E C1           POP    BC
014F C3 15 F0      JP     CRLF
                                Blank line upon completion.

0152          PAD6 DS      24
;
; Delay (to test data retention while no MCYRQ's)
;
; LAPSE PUSH BC
016A C5          LD      B,TIX Time is roughly proportional to TIX cubed.
016B 06 93          LD      B,TIX
016D C5          L1     PUSH BC
016E C5          L2     PUSH BC (For TIX=FFH, at 4MHz Z-80 clock,
016F 10 FE          L3     DJNZ L3 LAPSE takes about 20 seconds.)
0171 C1          POP    BC
0172 10 FA          DJNZ L2
0174 C1          POP    BC
0175 10 F6          DJNZ L1
0177 C1          POP    BC
0178 C9          RET

0179          PAD7 DS      24
;
; Bad data was read, so count each 4116 in error.
; Entry: (DE) => bad byte
; (A) => set bits flag error positions.
;
; Exit: All appropriate error counters have been bumped.
; No regs A-L altered
; (IX) => counter of highest bad bit.
;
0191 E5          BYFAIL PUSH HL

```

Listing 1 continued on page 380

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Listing 1 continued:

```

0192 D5          PUSH    DE
0193 C5          PUSH    BC
0194 F5          PUSH    AF
0195 DD 21 01 00 LD      IX,ERRS      Point to base of error counters.
0199 7A          LD      A,D
019A CB 0F      RRC     A
019C CB 0F      RRC     A
019E E6 30      AND    00110000B
01A0 5F          LD      E,A          E => which bank has failure in it, (Bits 5,4)
01A1 16 00      LD      D,0
01A3 DD 19      ADD    IX,DE          Point to 8 counters.
01A5 F1          POP    AF              Restore bad bits to A.
01A6 F5          PUSH   AF
01A7 06 08      LD      B,8          Load 8 times.
01A9 CB 0F      BITCHK RRC    A
01AB 4F          LD      C,A
01AC E6 80      AND    10000000B
01AE 79          LD      A,C
01AF 2A 03      JR     Z,OKBIT
;
01B1 DD 34 00      INC    (IX+0)          Here he is!
;                               Count the little jerk.
;
01B4 DD 23          OKBIT  INC    IX
01B6 DD 71 00      LD      (IX+0),C      Store the error pattern.
01B9 DD 23          INC    IX              Ready next counter.
01BA 10 EC      DJNZ  BITCHK
01BD F1          POP    AF
01BE C1          POP    BC
01BF D1          POP    DE
01C0 E1          POP    HL
01C1 C9          RET
;
; Special thanks to Litton Amecom's Electronic Warfare Product
; Development Department, for the after-hours use of their Zenith Z-89
; microcomputer, on which this program was assembled. Also the Real-
; Time Software Department for the use of their line printer, and
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; I am proud to have been associated with this organization.
;
END      BEGIN

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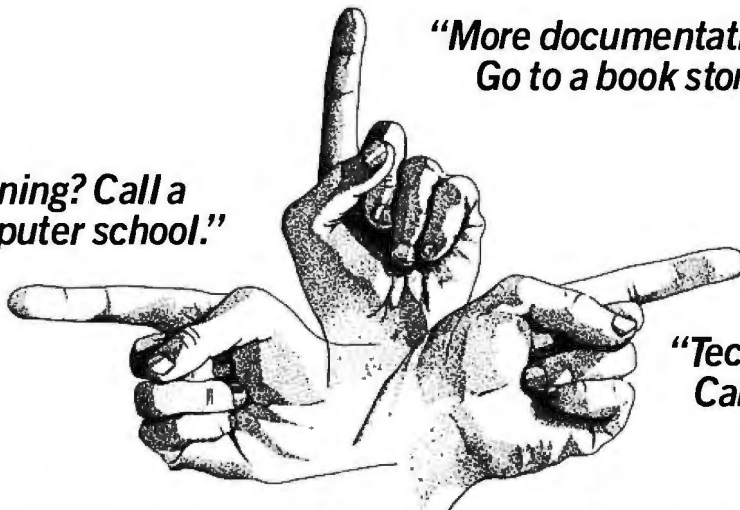
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Modula-2

A Worthy Successor to Pascal

Niklaus Wirth, creator of Pascal, now brings us a general-purpose systems-implementation language based on modules.

Joel McCormack
Richard Gleaves
Volition Systems
POB 1236
Del Mar, CA 92014

In 1969, no appropriate programming language existed to clearly display the problem-solving techniques known as *structured programming*. Niklaus Wirth wanted to teach the principles of structured programming unencumbered by the irregularities and deficiencies of existing languages. To accomplish his task, he designed a new and elegant language: Pascal. Then, after nine years of researching Pascal's prob-

lems, Wirth created a language to replace it; that language is Modula-2.

Despite its lack of support from either the government or the computer industry, Pascal's remarkable ability to clearly express algorithms and data structures soon vaulted it out of academia and into the commercial world. In 1977, Welsh, Sneeringer, and Hoare (see reference 3) stated that "Pascal is at the present time the best language in the public domain for purposes of system programming and software implementation." Pascal's popularity soared phenomenally through the 1970s, and today it is one of the most popular microcomputer languages.

And yet, Brian Kernighan, a proponent of the C language, describes Pascal in its pure form as "suitable only for small, self-contained programs that have only trivial interactions with their environment and that make no use of any software written by anyone else" (see reference 1). In his blunt but accurate analysis of Pascal, Kernighan identifies eight major areas where Pascal lacks capabili-

ties necessary for serious programming. He concludes that "Pascal is a toy language, suitable for teaching but not for real programming."

How can Pascal be the best system-programming language available while being completely unsuitable for anything but teaching?

Extended Pascal

In his famous Turing Award lecture (see *Communications of the ACM*, February 1981; reprinted in September 1981 *BYTE*, page 414), Tony Hoare offered advice on language design that helps to resolve these two points of view: "You include only those features which you know to be needed for every single application of the language and which you know to be appropriate for every single hardware configuration on which the language is implemented. . . . That is the great strength of Pascal, that there are so few unnecessary features and almost no need for subsets. That is why the language is strong enough to support specialized extensions. . . ."

Editor's Note: Portions of this article were presented at the Mini-Micro '82 Computer Conference and Exhibition, September 14-16, Anaheim, California.

About the Authors

Joel McCormack is a software and hardware engineer at Volition Systems. As a UCSD graduate student, he coauthored the UCSD Pascal Z80 interpreter. McCormack is coauthor of Volition's Modula-2 compiler.

Richard Gleaves is a software engineer and technical writer at Volition Systems. Formerly a member of the UCSD Pascal project, Gleaves is coauthor of the original Apple Pascal interpreter and Softech Microsystem UCSD Pascal compiler.

Computer manufacturers, software houses, and universities have repeatedly shied away from computer languages nominally designed for "real programming." Recognizing the truth in both Kernighan's and Hoare's comments, they have instead chosen (or created) extended versions of Pascal. These computer users have no desire to sacrifice Pascal's unique abilities to:

- clearly describe data structures and algorithms
- detect programming errors as syntax errors (rather than quietly rearrange the meaning of the program)
- protect against improper mixing of different types
- prohibit assigning illegal values to variables

While C and FORTH proponents often dismiss these advantages as trivial, the worldwide proliferation of Pascal dialects testifies to the number of programmers who disagree.

Oregon Software and Digital Equipment Corporation have extended Pascal for real-time work; the University of California, San Diego, and Microsoft included features oriented to programming operating systems; Texas Instruments, Hewlett-Packard, Burroughs, National Semiconductor, and IBM have all added capabilities beyond the basic language. Even Tony Addyman, the driving force behind the ISO (International Organization for Standardization) Pascal Standard, admits to using a "kludged version of Pascal" in his hardware laboratory. How much do these various Pascals have in common? How well designed are their extensions?

The answers, sadly enough, are "not much" and "not very."

For example, UCSD Pascal (and derivative systems such as Apple Pascal and Pascal/M) includes predefined procedures for manipulating character arrays. Called Scan, MoveLeft, MoveRight and FillChar, these procedures blithely accept arguments of incorrect types, perform no checking of array bounds, and, unless used with the utmost care, can "wear out their welcome

with random precision." Microsoft Pascal has a similar but different set of procedures called ScanEq, ScanNe, MoveL, MoveR, and FillC.

Critical analysis of existing extensions drives home two points: (1) most programmers (though they may be very good programmers) are poor language designers; and (2) any given deficiency of Pascal has been "solved" in at least a dozen different ways.

Standard Extended Pascal

The alarming growth in extended Pascal dialects naturally led to the idea of defining a standard set of Pascal extensions. The first such effort was organized (with Wirth's approval) in January 1978 by Dr. Jorgen Steensgard-Madsen. Nine major implementers of Pascal (all but one from universities) attempted to reach agreement on a small number of extensions. This effort resulted only in the OTHERWISE clause for the CASE statement and some suggestions on the ISO Pascal standardization effort regarding conformant array parameters (see reference 2).

A second group—this time mostly commercial implementers—was assembled by Ken Bowles in July 1978, but this effort fared no better than the first. Though many language extenders were in attendance, few were experienced language designers. Group members tended to be loyal to extensions already implemented in their own compilers, so in the limited amount of time allotted for the conference only a small number of extensions—all trivial—was approved. A large number of items was passed on to the Steensgard-Madsen group, which at the time still appeared to be a viable committee. The remaining hodgepodge of conflicting proposals was tossed together under the label "experimental." (This meeting is documented in "Proceedings of the UCSD Workshop on Systems Programming Extensions to the Pascal Language," Institute for Information Systems, UCSD, 1979.)

Today, a third attempt is being made to standardize Pascal language extensions, this time under the auspices of the American National Standards Institute (ANSI). Con-

sidering the outcome of the first two groups (in which one of the authors participated) and the slow and tortuous path taken just to define an ISO Pascal standard, we have doubts that the ANSI effort will prove any more effective than its predecessors. The time for agreement on Pascal extensions quietly passed years ago; even if ANSI could issue a standard tomorrow, the prospects are bleak for conformance by major Pascal vendors. Popular systems such as Apple Pascal and UCSD Pascal fail to conform to even the base language standard. With their large (and growing) user base, such vendors may find it difficult to offer a new set of standardized extensions while maintaining compatibility with their plethora of existing proprietary extensions.

Meanwhile, Modula

Niklaus Wirth's direct involvement in the Pascal extension efforts was conspicuously small. Indeed, years of debate might have been avoided had he stepped in with his own extension proposals. However, Wirth's comments reflect a motivation by ideals rather than by politics: "If a language proves to be only marginally suitable for some application that was obviously not envisaged by its originator, we should muster the courage to build a new, truly adequate tool, instead of just grafting a fix onto the existing one" (see page 83 of reference 4).

After designing Pascal, Wirth chose to investigate the programming problems posed by multiprocessing and I/O devices. He designed the special-purpose language Modula to gain firsthand experience with programming small real-time control systems:

The primary benefit of the use of a suitable high-level language lies in the possibility of defining abstract machines in a precise manner that is reasonably independent of characteristics of particular hardware. Assembly code is still used virtually exclusively in those applications whose predominant purpose is not to design a new system based on abstract specifica-

tions, but to operate an existing machine with all its particular devices. . . . A major aim of the research on Modula is to conquer that stronghold of assembly coding, or at least to attack it vigorously [reference 4, page 3].

Modula consisted of a minimal subset of Pascal, to which was added the module structure, an improved syntax, and facilities for multiprocessing and low-level machine access. Unlike Pascal, Modula was not intended as a general-purpose language: among other things, it lacked Pascal's files, sets, and pointers. Modula's most significant feature was the module structure. While programming was awkward without Pascal's data-structuring facilities, modules proved an invaluable asset—as far a step beyond Pascal's block structure as the block structure had been beyond the FORTRAN subroutine call.

Though Modula is still in use today at some universities, Wirth discontinued his own research with the language after spending a sabbatical year at the Xerox Palo Alto Research Center (PARC). Modula had served its purpose as a programming tool designed for a specific task.

Finally, Modula-2

At Xerox PARC, Wirth had the opportunity to use the Alto personal computer and the Mesa programming language. Upon returning to Switzerland, he embarked on a project to design a similar but simpler computer system—including both hardware and software. Wirth states:

This system (later to be called Lilith) was to be programmed in a single high-level language, which therefore had to satisfy requirements of high-level system design as well as those of programming of parts that closely interact with the given hardware. Modula-2 emerged from careful design deliberations as a language that includes all aspects of Pascal and extends them with the important module concept and . . . multiprocessing [see page 3 of reference 5].

Modula-2 is a general-purpose systems-implementation language that includes the best elements of its predecessors. Modula-2's statement structures and data types are a superset of Pascal's; the systematic syntax, module concept, machine access, and multiprocessing are improved versions of those features found in Modula-1. In addition, the design of Modula-2 systematically addresses Pascal's problems (see "Solving Pascal's Problems" on page 389).

Modules

The key difference between Modula-2 and Pascal is in the way they are extended. Pascal extensions are built into the language, so Pascal programmers cannot change them or add new extensions. Modula-2 is extensible—it allows Modula-2 programmers to create their own extensions. The key to this ability is the module structure.

A module is a collection of declarations that work together to perform a given task. A simple example of a

Listing 1: The module RandomNumbers serves as a wall around the random function and its seed variable. The export statement allows the random function to be called outside of the module, but the seed variable remains hidden inside the module and can be accessed only by the random function. The outer block of the module is automatically executed when the program begins; it assigns an initial value to Seed by assigning it the value of the identifier SystemTime. SystemTime is declared outside of the module but can be accessed inside because it has been imported.

Note how the module contains all the details concerning the operation of the random-number generator; only the identifier Random is visible outside the module. It is their ability to collect together and hide all the unnecessary details of a mechanism that makes modules such powerful constructs for organizing large programs.

```
MODULE MainProgram;
  VAR i: INTEGER;
  ...

MODULE RandomNumbers;
  IMPORT SystemTime;
  EXPORT Random;

  VAR Seed: INTEGER;

  PROCEDURE Random(): INTEGER;
  CONST Modulus = 7415;
        Inc     = 25543;
  BEGIN
    Seed := (Seed + Inc) MOD Modulus;
    RETURN Seed;
  END Random;

  BEGIN
    Seed := SystemTime;
  END RandomNumbers;
  ...

  BEGIN
    i := Random();
    ...

  END MainProgram.
```

Listing 2: This program uses three separately compiled modules: the library module *SimpleFiles*; the definition module, which exports the type *FILE* and file operations; and the implementation module.

```

DEFINITION MODULE SimpleFiles;

  EXPORT QUALIFIED
    FILE, Open, Close, Read, Write, Error;

  TYPE FILE;      (* Opaque type... structure unknown outside *)

  PROCEDURE Open (VAR f: FILE; name: ARRAY OF CHAR);
  PROCEDURE Close (VAR f: FILE);
  PROCEDURE Read (f: FILE; VAR ch: CHAR);
  PROCEDURE Write (f: FILE; ch: CHAR);

  PROCEDURE Error (f: FILE): BOOLEAN; (* TRUE if I/O error *)

END SimpleFiles.

IMPLEMENTATION MODULE SimpleFiles;

FROM SYSTEM IMPORT ADDRESS, ADR;

CONST FileNameLength = 20;

TYPE blockrange = [0..511];

TYPE FILE = POINTER TO RECORD      (* Details hidden inside *)
  FileName: ARRAY [0 .. FileNameLength-1] OF CHAR;
  CASE diskfile: BOOLEAN OF
    TRUE: diskblock: CARDINAL;
        byteinblock: blockrange;
        buffer: ARRAY blockrange OF CHAR;
    | FALSE: IOUnit: CARDINAL;
  END (* case *)
END (* FILE *);

PROCEDURE Open (VAR f: FILE; name: ARRAY OF CHAR);
  (* body of Open *)
END Open;
...
PROCEDURE DiskIO (unit: CARDINAL; buf: ADDRESS);
  (* low-level procedure hidden in module *)
END DiskIO;

BEGIN
  ...
END SimpleFiles.

MODULE MyProgram;

  FROM SimpleFiles IMPORT
    FILE, Open, Close, Read, Error;

  VAR f1, f2: FILE;
      ch: CHAR;

BEGIN
  Open(f1, "myfile.data");
  ...
  Read(f1, ch)
  IF Error(f1) THEN HALT END;
  ...
  Close(f1);
END MyProgram.

```

module is a random-number generator consisting of a random function and its seed variable (see listing 1). A module forms a wall around its objects; except for explicitly *imported* and *exported* identifiers, the module's contents are isolated from the surrounding program. In the random-number generator, the procedure `Random()` can be called from outside the module because it is exported; the variable `Seed`, however, remains hidden inside the module and is accessible only by the random function.

It is their ability to encapsulate related declarations that makes modules such a powerful concept—they are the software equivalent of a “black box.” Modules partition large programs into logically related pieces with well-defined interfaces (i.e., the imported and exported identifiers); as a result, Modula-2 programs are easier to read, easier to understand, and less prone to erroneous side effects than Pascal's block-structured programs. (Anyone who has ever read a large Pascal program knows how they are structured: an army of procedures interconnected by pages of global declarations.)

The ability of modules to divide programs into semi-independent parts provides the foundation for separate compilation in Modula-2. Library modules are divided into two separately compiled parts: a *definition module* and its corresponding *implementation module*. The definition module contains declarations made available to other modules (called *client modules*). The implementation module contains the actual code and data that implement the operations defined by the definition module.

Listing 2 shows three separately compiled modules. The library module *SimpleFiles* provides a simple file I/O system, the definition module exports the type *FILE* and file operations, while the implementation module contains the code implementing the file system.

The type *FILE* is called an *opaque* type—its record fields are fully accessible within the implementation

module, but only the type name is visible outside the module. Opaque types are a form of the programming concept known as *abstract data types*. Abstract data types are objects whose only operations are defined by a set of procedures. Pascal's FILE type is an example of an abstract type; however, Pascal does not allow programmer-defined abstract types.

This example introduces the concept of *qualified export*. When an export list includes the symbol QUALIFIED, client modules must prefix all references to the exported identifiers with the name of their module; for instance, the identifier Open would have to be referenced as SimpleFiles.Open. Qualified export allows library modules to avoid clashes with identifiers already declared in client modules. Client modules in turn can "unqualify" identifiers by preceding their import lists with the symbol FROM and the library module name.

The module MyProgram imports SimpleFiles to perform its file I/O. MyProgram is an executable program; however, it can also be called by other modules as a subprogram. (Subprogram calls are performed with the procedure Call exported by the library module Program.) Programs and subprograms share information by importing the same library module.

Separate Compilation

The separate compilation facilities in most programming languages are more aptly termed "independent compilation" facilities; no type checking is performed between separately compiled parts. This has traditionally been a great source of problems, especially when parts of a large software system are developed by different people. In fact, data-processing professionals invented a special term to describe this sometimes harrowing task: they call it "system integration."

Modula-2 is specifically designed to maintain type checking across module boundaries. The compiled form of a definition module contains type information that is accessed when compiling both the corresponding implementation module and all

Solving Pascal's Problems

In a paper entitled "Why Pascal Is Not My Favorite Programming Language," the noted C language proponent Brian Kernighan identifies eight major problems with Pascal. R.T. Summer and R.E. Gleaves have shown how Modula-2 addresses each of these problems ("Modula-2—A Solution to Pascal's Problems," ACM SIGPLAN Notices, September 1982):

Pascal arrays are fixed in size, making string handling difficult and general-purpose math libraries impossible.

Modula-2 includes "open" array parameters, which accept arrays of varying length. Also, character strings are assignable to array variables of different lengths.

Pascal's lack of "own" variables forces programmers to use global variables, which have a larger scope than they ought to.

The module structure offers a superior method for hiding variables from most of a program.

Pascal's lack of separate compilation hinders the development of large programs and makes the use of libraries impossible.

Modula-2 offers separately compiled library modules and subprogram modules. Library modules are collections of procedures and data that are accessible by other modules. Subprogram modules are separately compiled modules that can be called by other modules. Unlike many languages, Modula-2 offers full type checking across separately compiled modules.

Pascal's required declaration order prevents related declarations from be-

ing grouped together.

Modula-2 allows constants, types, variables, procedures, and modules to be declared in any order. Modules provide an even better way to group related declarations.

Pascal's Boolean expressions are not conditionally evaluated, resulting in convoluted expressions and extraneous state variables.

Modula-2 explicitly defines the evaluation order of logical expressions as conditional "short-circuit" evaluation, allowing statements like "WHILE (p < > NIL) AND (p!.data < 0) DO. . .".

Pascal's CASE statement is hampered by its lack of an OTHERWISE clause.

Modula-2 CASE statements have an optional ELSE part for catching unspecified case values. Also, subranges can be used in case constant lists, eliminating the need to explicitly declare all case constant values.

Pascal's I/O facilities are extremely limited; they cannot deal with real-world files or program arguments.

The Modula-2 language includes no I/O facilities. I/O is provided by standard library modules, but these can be supplemented (or replaced) by defining different I/O modules.

Pascal's strict enforcement of type checking prohibits low-level programming.

Modula-2's low-level programming facilities provide machine-level operations: type conversion, pointer arithmetic, bit manipulation, and direct access to memory. Unlike many languages, Modula-2 provides controlled low-level access, preventing erroneous high-level programs from merely becoming low-level programs.

client modules. The separation of definition and implementation enables you to change implementation modules without forcing recompilation of all client modules. Because the definition module remains unchanged, type consistency is preserved. This saves a lot of unnecessary system-generating (sysgen) time when maintaining large software systems.

Changing both definition and implementation, however, invalidates all client modules because the inter-

face between the module and its clients has now changed. Executing an out-of-date client module might crash the system.

Wirth solved this problem in Modula-2 by maintaining a system-wide module-version control scheme. When a definition module is compiled, the compiler assigns a unique value to the module. This value is known as a *module key*. When the corresponding implementation module is compiled, it inherits the module key of its definition. When a

client module imports the library module, a copy of the imported module's key is recorded in the resulting code file.

When a program is executed, the program loader checks that the module keys recorded in the program match those found in the compiled code of the imported implementation modules. As implementation modules receive their keys from the corresponding definition module, implementations can be optimized, modified, or entirely replaced without affecting any client modules. But if a definition module (and, subsequently, its implementation) is recompiled—perhaps to change a parameter list or add a variable to the module's interface—a new module key is assigned. Attempts to execute client modules compiled with the old library module result in a version error, indicating that the client module must be recompiled.

The implications for multiperson project management are revolutionary: system integration no longer needs to be plagued by mismatches between the agreed-upon interfaces and the actual code.

If a software system is sufficiently well understood to be fully defined beforehand, the system's definition modules can be distributed in compiled form to the programming team members, who can then write and modify implementation modules without forcing everybody else on the project to recompile when a change is made. Individual team members cannot alter a module interface, as the compiler enforces conformance between the procedure headings declared in the definition module and the corresponding headings in the team member's implementation module.

If team members are granted access to the source text of definition modules (to make small changes to the specification), several versions of the "same" definition module may proliferate; however, the version-control system prevents the execution of mismatched modules, allowing system testing to proceed only after all modules adhere to the same set of interfaces.

Libraries

Pascal requires an underlying operating system for its I/O and storage management. Modula-1 requires a small run-time system for scheduling processes. Modula-2 requires neither: because such operations are programmed as library modules, the language itself requires virtually no support above the hardware level.

A Modula-2 library typically contains modules for the following operations:

- Console I/O and keyboard polling
- Format conversion between text and binary representations
- File I/O operations—read, write, and seek
- File directory operations—create, delete, and rename
- Storage management—new and dispose
- Program execution
- Process scheduling
- Mathematical functions
- Dynamic string manipulation

It is no coincidence that these operations are normally the domain of an operating system; however, there is a crucial difference between module libraries and operating systems. Operating systems are traditionally written by elite bands of systems programmers who, in their attempts to deliver monolithic systems suitable for all applications, often create systems with so much overhead that they are unusable. Modula-2 lets you select the system facilities you need without having to pay for those you don't need. The module library constitutes a flexible and extensible operating system.

The library contains not only the usual system facilities, but also every library module and program module in the system. Any library module in the system can be imported by any other module; any program module in the system can be called as a subprogram by any other module. This encourages a building-block approach to the development of software systems: high-level library modules are built from collections of

low-level modules; large programs are built from collections of smaller programs.

Modula-2's library concept offers the potential for writing portable software systems that can be moved with little or no change across different operating systems. A set of standard definition modules can provide client modules with an operating environment that is independent of any operating system. Moving software to a new operating system merely requires a set of implementation modules that use the host system's facilities to implement the standard definition modules. (This approach is equally suited for using large systems to develop software targeted for small stand-alone systems.)

Modula-2 also has a remarkable ability to incorporate existing software into the Modula-2 environment. Programs written in other languages can be called as subprograms, thus becoming part of a Modula-2 program. Specially defined modules can access non-Modula library routines, host-operating-system calls, and even machine instructions. Yet, because all these facilities are accessed via definition modules, they are uniformly referenced as Modula-2 library modules.

As Wirth so succinctly states, library modules are "an essential part of a Modula-2 implementation" (see reference 5).

Run-Time Binding

The modular nature of Modula-2-based systems requires a different environment from that of most software development systems. In particular, the compiler, program loader, and library form an integrated system, with module binding performed automatically at run time. Adding a module to the library (or updating an existing module) requires only that the module be compiled; the compiler writes the code file to the library, so when the module (or one of its clients) is executed, the loader can find it by searching the library.

Run-time module binding eliminates linking and the resulting problems associated with large linked object files containing multiple copies

of the same module code. Instead, a single copy of a module-code file can be shared by a number of programs. Because run-time binding is slower than executing prelinked object files, facilities are also provided for optionally linking collections of modules together to form a single object file. This yields faster program loading at the expense of extra effort to update any of the modules in the program.

Procedure Variables

The module structure encourages the development of reusable software components. (The philosophy of software components is simple: it is easier to use an existing program than it is to write one from scratch!) A common problem with software components is that they are often difficult to tailor to the needs of client modules. For instance, one client may want a library module to perform its own error handling, while another client of the same module may want to substitute different error-handling routines.

Modula-2 addresses this problem by introducing the concept of *procedure variables*, a generalization of Pascal's procedure parameters. Procedure variables are variables that are assigned procedures as values. Calling a procedure variable invokes the procedure assigned to it.

Procedure variables allow client modules to "plug" their own procedures into a library module. For instance, a client can plug an error-handling procedure into a library module; when the library module detects an error condition, it calls an internal procedure variable, in turn invoking the client's own error-handling procedure.

Another use of procedure variables is the definition of automatic initialization and termination sections for library modules. This enables a library module to start up and shut down its own resources independently of any client modules.

For example, a network-handler module might define an initialization procedure that performs the hardware operations necessary to hook itself up to a network; similarly, it would define a termination procedure

to unhook the network connection. The network-handler module passes these procedures to the program loader, indicating that they are to be called when the module is first loaded into memory and when it is about to be released. Client modules are unaware of these actions; all they know is that the module gives them access to an open network connection.

Listing 3 shows how procedure

variables can be used to implement error handling and initialization/termination sections in a network-handler module.

Machine Access

Because low-level system facilities are written as library modules, Modula-2 provides facilities for machine-level programming. Such facilities are by nature machine-dependent, so they may vary across

Listing 3: *In this example of procedure variables, the library module Network manages a network connection. Initialization and termination procedures are established by calling the procedure SetEnvelope imported from the loader (a module named Program). The initialization procedure is called when Network is first loaded; the termination procedure is called when it is about to be released from memory.*

The procedure SetHandler allows error handlers to be attached to open network nodes. (The type PROC is a predefined type denoting a parameterless procedure.) The client module NetWriter declares its own error-handling procedure and attaches it to the node variable by calling SetHandler. Note that Netwriter does not require error-checking code after every network operation, because the network module will automatically call NetWriter's error-handling procedure if a network error occurs.

```

DEFINITION MODULE Network;

  EXPORT QUALIFIED
    NODE, Open, Close, Send, Receive, SetHandler;

  TYPE NODE;

  PROCEDURE Open    (VAR n: NODE; device: CARDINAL);
  PROCEDURE Close  (VAR n: NODE);
  PROCEDURE Send    (n: NODE; ch: CHAR);
  PROCEDURE Receive (n: NODE; VAR ch: CHAR);

  PROCEDURE SetHandler (VAR n: NODE; handler: PROC);

END Network.

IMPLEMENTATION MODULE Network;

  FROM Program IMPORT SetEnvelope;

  ...

  TYPE NODE = POINTER TO RECORD
    HandleProc: PROC; (* error handler procedure *)
    AccessMode: NetAccess;
    Buffer: ARRAY bufrange OF CHAR;
    ...
  END;

  PROCEDURE Send (n: NODE; ch: CHAR);
  BEGIN
    ...
    IF LostConnection THEN n^.HandleProc() END;
  END Send;

  ...

```

Listing 3 continued on page 392

Listing 3 continued:

```
PROCEDURE SetHandler (VAR n: NODE; handler: PROC);
BEGIN
  n^.HandleProc := handler;
END SetHandler;

PROCEDURE Startup;
BEGIN
  (* open network connection *)
END Startup;

PROCEDURE Shutdown;
BEGIN
  (* disconnect from network *)
END Shutdown;

BEGIN
  SetEnvelope(Startup, Shutdown);
END Network.
```

```
MODULE NetWriter;

  IMPORT Terminal;

  FROM Network IMPORT
    NODE, Open, Close, Send, SetHandler;

  PROCEDURE handler;
  BEGIN
    Terminal.WriteString("Network error!");
    HALT;
  END handler;

  VAR n1: NODE;
      ch: CHAR;

  CONST Copier = 121;

BEGIN
  Open(n1, Copier);
  SetHandler(n1, handler);
  ...
  Send(n1, ch)
  ...
  Close(n1);
END NetWriter.
```

Modula-2 implementations and should be avoided in programs designed for portability. Machine-level programming is usually isolated in a small number of modules to separate machine-specific from portable software.

The predefined type BITSET is defined as a set that fits in one machine word. Bitsets allow efficient bitwise manipulation of word quantities.

The predefined module SYSTEM exports the system-dependent identifiers WORD, ADDRESS, SIZE, TSIZE, and ADR. When the type WORD is used as a parameter type, it is compatible with any object occupying one word. When WORD is used as the base type of an unbounded array parameter (ARRAY OF WORD), the parameter is compatible with variables of any size or type, including records and sets. The type WORD

allows for writing general-purpose routines that operate on variables of any type.

The type ADDRESS is compatible with the type CARDINAL (unsigned integer) and all pointer types. Arithmetic operators can be applied to variables of type ADDRESS, allowing pointer and address arithmetic. This is important for writing storage managers, especially since Modula-2 translates the standard procedures NEW and DISPOSE into calls to the low-level procedures ALLOCATE and DEALLOCATE. These procedures are usually imported from a standard storage-management module, but they can also be defined in other ways to allow different styles of storage management.

The functions SIZE(x) and TSIZE(t) return the size of variables and types. The function ADR(x) returns the memory address of variables.

Variables can be declared to reside at fixed memory addresses. This is useful for accessing memory-mapped device registers.

Type checking can be circumvented by using a type identifier as a *type-transfer function*, which converts the type of its parameter argument to the type of the function identifier. Type conversion is restricted to objects that occupy the same number of words.

Code procedures enable Modula-2 programs to directly access facilities provided by the underlying hardware or host operating system. A code procedure consists of a procedure heading followed by the reserved word CODE and a series of machine instructions; these instructions are substituted inline for each procedure call. The use of code procedures is generally restricted to low-level modules.

Listing 4 shows Modula-2's machine-level programming facilities in action.

Multiprocessing

Most modern systems-programming languages include multiprocessing facilities as part of the language. For instance, Modula-1 offers processes and semaphores, Ada includes tasks and rendezvous, and

Concurrent Pascal contains monitors. Modula-2 forgoes these higher-level multiprocessing models in favor of the simpler and lower-level *coroutine* concept.

Coroutines are procedures that execute independently but not concurrently. In a group of coroutines, only one coroutine executes at a time—the rest are inactive. Coroutines communicate by calling each other; in a coroutine call, the calling coroutine becomes inactive, and the called coroutine resumes execution.

Coroutine facilities exported by the module SYSTEM include the procedures NEWPROCESS, TRANSFER, and IOTRANSFER, and the type PROCESS.

The procedure NEWPROCESS (Procedure, Adr, Size, Coroutine) creates a new coroutine. The parameter Procedure specifies the procedure to be executed by the coroutine. The parameters Adr and Size specify an area of memory for the coroutine to execute in. The newly created coroutine is returned in the parameter Coroutine, which is a variable of type PROCESS.

Coroutine calls are performed with the procedure TRANSFER (with process variables Old and New). TRANSFER suspends the current coroutine, assigns it to the process variable Old, and then resumes execution of the coroutine previously assigned to the process variable New.

The procedure IOTRANSFER (with process variables Old and New, and integer value IntVect) allows coroutines to be used as interrupt handlers. IOTRANSFER initiates a coroutine call from Old to New; however, when the peripheral device specified by IntVect causes an interrupt, control is automatically transferred back to the interrupt-handling coroutine. Listing 5 shows how coroutines work as interrupt handlers.

Coroutines are appropriate for many common multiprocessing applications; however, when higher-level forms of process scheduling are needed (e.g., semaphores or message passing), they can be constructed in terms of coroutines and stored in library modules. Modula-2 thus has

Listing 4: This program demonstrates Modula-2's machine-level programming facilities. The module MyStorage provides a very simple storage allocator: starting at memory address 0, it assigns successive memory words to dynamically allocated variables. Note that ALLOCATE accepts arguments of any pointer type and that any calls to NEW in this program are handled by the storage module.

The variable Console is declared to reside at hexadecimal memory address FFE8. The variable Sneaky uses a type-transfer function to gain bitwise access to a 32-bit real number. The code procedure LoadByte provides direct access to the Apple Pascal p-code instruction LDB: it loads a byte from memory onto the P-machine evaluation stack. The procedure PrintHex accepts variables of any type as arguments. Inside PrintHex, the parameter is viewed as an array of words in the range 0 to HIGH(mem). HIGH is a standard function that returns the upper index of array parameters.

```

MODULE LowLevel;

  FROM InOut IMPORT WriteHex;

  MODULE MyStorage;
    EXPORT ALLOCATE;

    VAR HeapTop: ADDRESS;

    PROCEDURE ALLOCATE (VAR ptr : ADDRESS; size: CARDINAL);
    BEGIN
      ptr := HeapTop;
      HeapTop := HeapTop + size;
    END ALLOCATE;

  BEGIN
    HeapTop := 0;
  END MyStorage;

  VAR Console [OFFE8H]: BITSET;

  PROCEDURE LoadByte (base: ADDRESS; offset: CARDINAL): CARDINAL;
  CODE
    190; (* LDB p-code: gets base & offset off stack *)
  END LoadByte;

  PROCEDURE PrintHex (mem: ARRAY OF WORD);
  VAR i: CARDINAL;
  BEGIN
    FOR i := 0 TO HIGH(mem) DO WriteHex(mem[i], 0) END;
  END PrintHex;

  VAR ch: CHAR;
      r: RECORD
          x,y,z: REAL;
        END;
      a: ARRAY [0..50] OF CARDINAL;

  TYPE SetReal = SET OF [0 .. 31];

  VAR Sneaky: SetReal;

  BEGIN
    Sneaky := SetReal (1.0E-13);
    a[0] := LoadByte(3FFFH, 3);
    PrintHex(ch);
    PrintHex(r);
    PrintHex(c);
  END LowLevel.

```

Listing 5: This program, which illustrates coroutines and interrupts, writes a continuous stream of "hos" to the screen, but an occasional "hi" pops up among the "hos."

The main program creates the coroutines Hi and Ho, then transfers to Hi (suspending itself permanently). The first thing Hi does is execute IOTRANSFER, transferring control to Ho. Ho runs in a loop, continually writing "ho" out to the screen; however, when an interrupt occurs through interrupt vector 4, control is automatically transferred back to Hi. Hi writes out "hi," transfers back to Ho, and waits for the next interrupt. In this example, interrupt vector 4 might be triggered by typing a key on the keyboard. Interrupt-vector assignment varies on different systems.

```

MODULE HiHo;

  FROM SYSTEM IMPORT
    WORD, ADR, SIZE, PROCESS, NEWPROCESS, TRANSFER;

  FROM Terminal IMPORT WriteString, Writeln;

  CONST maxHiHo = 17;

  VAR i: CARDINAL;
      Hi, Ho, Main: PROCESS;
      A, B: ARRAY [1..200] OF WORD;

  PROCEDURE WriteHi;
  BEGIN
    LOOP IOTRANSFER(Hi, Ho, 4); (* intpt. vector = 4 *)
      WriteString("hi");
    END;
  END WriteHi;

  PROCEDURE WriteHo;
  BEGIN
    LOOP WriteString("ho");
      INC(i);
      IF i > maxHiHo THEN
        Writeln; i := 0;
      END;
    END;
  END WriteHo;

  BEGIN i := 0;
    NEWPROCESS(WriteHi, ADR(A), SIZE(A), Hi);
    NEWPROCESS(WriteHo, ADR(B), SIZE(B), Ho);
    TRANSFER(Main, Hi);
  END HiHo.

```

the advantage of being able to provide most any kind of process scheduling (including none at all).

Miscellaneous Improvements

Modula-2 is more than just Pascal extended with modules, machine access, and multiprocessing. It also introduces the following changes to Pascal that simplify programming and improve program readability and efficiency, as shown in listing 6:

- Each structured statement has an explicit terminating symbol: UNTIL for the REPEAT statement, and END

for the rest. This eliminates the need for Pascal's compound statement (i.e., BEGIN . . . END).

- Everywhere Pascal allows constants, Modula-2 allows constant expressions; for instance, TYPE a = ARRAY [0..n-1] OF CHAR.

- CASE statements can have subranges in their case constant lists (eliminating the need to specify each constant value); also, CASE statements have an (optional) ELSE part.

- Variant records use the same syntax as CASE statements.

- Functions can return any type, including records and arrays.

- Procedures can declare unbounded ("open") array parameters, which accept arrays of varying length.

- The symbols # and & are defined as synonyms for the often-used symbols < > and AND.

- The AND and OR Boolean operators skip the second operand if the expression value can be determined from the first operand. Conditional-expression evaluation simplifies the programming of many situations.

- The LOOP/EXIT statement allows for clear and efficient expression of loop-and-a-half constructs.

- The FOR statement has an optional BY part for specifying step values other than 1.

All characters in a Modula-2 identifier are significant, not just the first eight, allowing you to use long identifiers without having to worry about accidental aliasing. The capitalized reserved words stand out in larger programs, improving readability. Modula-2 enforces case sensitivity of identifiers to prevent identifier aliasing (e.g., MYIDENT being the same as myIdent).

Conclusion

Pascal is ill-suited for implementing systems software, yet its basic structure is sound enough that many have chosen to extend the language rather than abandon it. This has resulted in an irremediable Tower-of-Babel syndrome from which the only escape is a new and better language.

Other languages vie for this honor, notably C and Ada, but none can be demonstrated to be superior to extended Pascal. C has proven itself as a practical language, but it suffers from unreadability, lack of type checking, and inadequate separate compilation facilities. Ada is a jungle of intertwined features; one suspects it was designed as a challenge to compiler writers, not as a tool for software engineers.

With Modula-2, Niklaus Wirth has created the language that will replace Pascal. Modula-2 can express everything from device drivers and system software to libraries and ap-

Listing 6: Modula-2 is more efficient and more readable than Pascal. The example shows a piece of Pascal code and its Modula-2 equivalent. The Modula-2 code is two lines shorter and has one less variable reference and two fewer statements. Modula-2's conditional-expression evaluation eliminates the need for the second Pascal "if" statement. The standard procedure INC shortens the expression (and produces more efficient object code) by eliminating the second reference to the variable accountbalance.

(* PASCAL *)

```

if p <> NIL then
  if p^.update then
    begin
      p^.accountbalance := p^.accountbalance + receipts * 2;
      p^.update := false;
    end;
  end;

```

(* MODULA-2 *)

```

IF (p # NIL) & p^.update THEN
  INC(p^.accountbalance, receipts * 2);
  p^.update := FALSE;
END;

```

plication programs. Modula-2's module concept and improved syntax make it more readable than Pascal. Modula-2 is as simple as Pascal and is small enough to allow efficient program development on 8-bit microcomputers. Modula-2 has enough in common with Pascal that Pascal programmers are able to write Modula-2 programs in a matter of hours.

In short, Modula-2 contributes to the design of software systems what Pascal has contributed to the design of programs. It is indeed a worthy successor to Pascal. ■

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5. Wirth, N. *Programming in Modula-2*. New York: Springer-Verlag, 1982.

Where to Get Modula-2

The following organizations distribute Modula-2:

Institut für Informatik
ETH
CH-8092 Zurich
Switzerland

ETH Zurich is the university where Modula-2 was conceived. ETH distributes Modula-2 compilers for the PDP-11, 68000, 6809, and Lilith. Lilith is a high-speed personal computer with superior graphics, a mouse, and a bit-slice processor designed to execute M-code.

Modula Research Institute
950 North University
Provo, Utah 84604

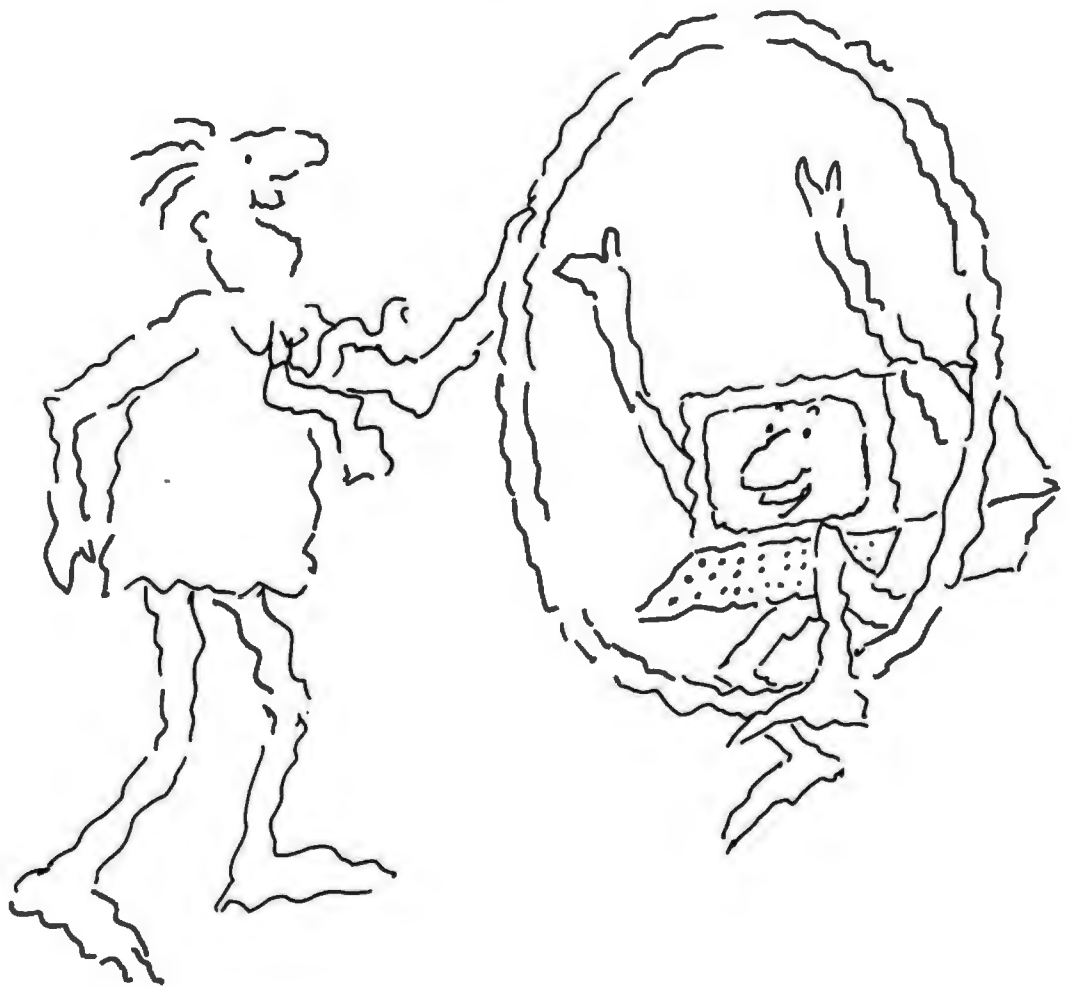
MRI is a nonprofit research organization that builds Lilith computers and sells them to large organizations for about \$15,000 apiece. Liliths include Modula-2 software developed at ETH.

Volition Systems
POB 1236
Del Mar, CA 92014

Volition Systems released the first commercial implementation of Modula-2. Volition's current Modula-2 system runs under the UCSD Pascal system; it is available for the Apple II, Apple III, Sage II, Scenic One, NCR ALP-2, TI 9900, and 8080/Z80-based systems. Modula-2 compilers for other processors and operating systems will be available in the near future.

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To explain: since 1-2-3's information management, spreadsheet and graphing functions reside in memory simultaneously, you can go from retrieval to spreadsheet calculation to

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The spreadsheet function.

If 1-2-3 were just a spreadsheet, you'd want it because it has the largest workspace on the market (2048 rows by 256 columns). To give you a quick idea of 1-2-3's spreadsheet capabilities: VisiCalc's spreadsheet for the IBM PC offers 15 arithmetic, logical and relational operators, 28 functions and 32 spreadsheet-related commands. 1-2-3 has 15 operators, 41 functions and 66 commands. And if you include data base and graphing commands, it actually has 110!

In addition, 1-2-3 is up to 50 times as fast as established spreadsheets. With all the features you've ever seen on spreadsheets. 1-2-3 also gives you the capability to develop customized applications (with 26 macro keys) and lets you perform repetitive tasks automatically with one keystroke. If 1-2-3 were just a spreadsheet, it would be a very powerful tool. But it's much, much more.

The information management function.

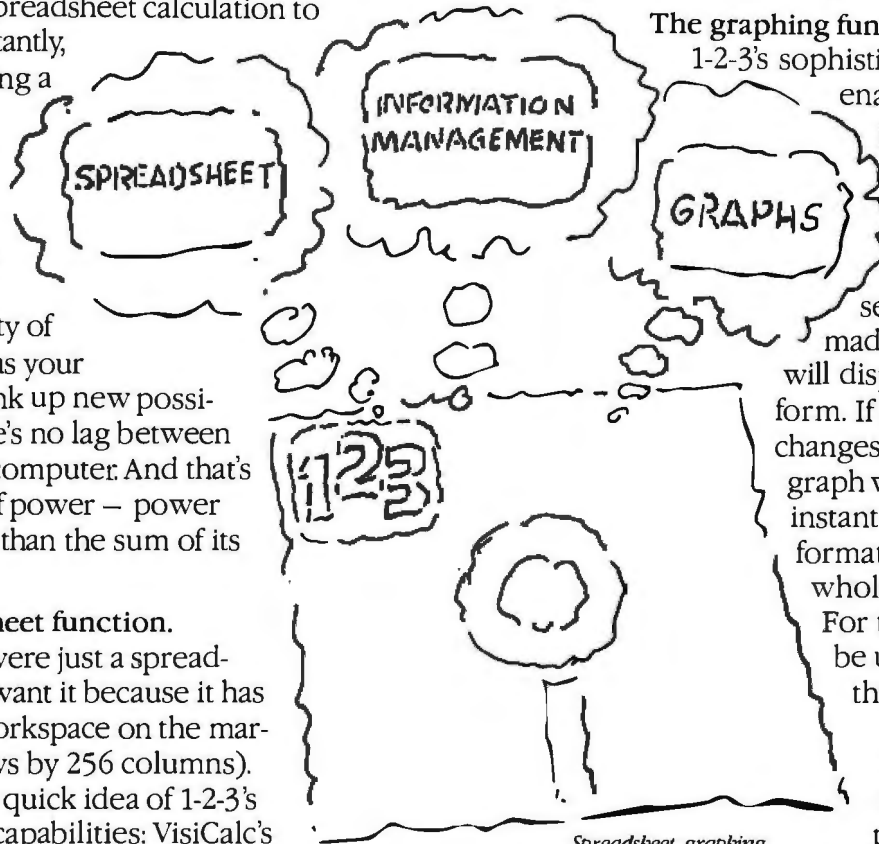
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The Design of an Advanced Logic Simulator

Macrocircuits and time-saving features make this new version easy to use.

Robert M. McDermott
33 Dora Circle
Bridgeport, CT 06604

In a previous article ("Simulation of Simple Digital Logic through a Computer-aided Design System," January 1983 BYTE, page 396), I described the design of a primitive logic simulator to replace hardware breadboarding in learning to design basic digital circuits. I also outlined enhancements that could give the program functions comparable to professional-level simulators available on large mainframe computers. After finding how easy it was to write a logic simulator for Radio Shack's TRS-80, I endeavored to write a professional-level program. This article includes the program and describes in detail the operation of the enhancements. While the description is oriented toward the logic simulator, the basic concepts employed could be used in other ap-

plications as well, particularly the processing of macroinstructions and the use of selective trace for event-driven phenomena.

Background

As described in the previous article, a logic simulator accepts the description of a proposed design in

and the process is repeated. This operation implies that every logic element produces the same delay. This fixed delay allows for the modeling of sequential devices because feedback loops work properly.

The propagation of signals among the various logic elements is controlled by a description of the logic network, consisting of a list of each element's logic type and the nodes to which the element's input and output are connected. The appearance of one node as the output of one element and the input to another element implies that the output and input are electrically connected. Node numbers serve as an index to an array that contains the logic values (old and new) for each signal.

The primitive version of this program was a direct implementation of this concept that merely filled the appropriate arrays directly from the input provided and proceeded to simulate the design in a single-step manner. The logic primitives supported were the standard logic operators: AND, NAND, OR, NOR, and XOR. This basic approach, while simple to implement, left much to be

A macrocircuit is a black box with specified input and output signals.

terms of logic-element interconnections and external stimuli. It applies the external stimulus to the simulated logic network and displays the resultant output.

The simulator operates by keeping track of the states of all connection nodes. An *old* (before stimulus) state is used as the input to each simulated logic device, and results are stored as *new* state; once all devices have been stimulated using the old values as inputs, the new values replace the old

About the Author

Robert M. McDermott is the manager of CAD (computer-aided design) software engineering at International Telephone and Telegraph's Large-Scale Integration Technology Center. The recipient of both BEE and MS degrees, he also teaches computer science at Bridgeport Engineering Institute.

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desired in terms of ease of use, error checking, and models of commonly used higher-level logic elements (flip-flops, counters, etc.).

A more professional system is shown in listing 1 (see page 428) and diagramed in figures 1 and 2; it supports named nodes rather than numbers, a "macro" capability for repetitiously used blocks of circuitry, an expanded library of logic primitives (see figures 3 and 4), procedures for rapid simulation, and a flexible output-display feature.

Named Nodes

Most nodes in a proposed design have functional names associated with them (e.g., Clock, Reset, etc.). For ease of use and a more meaningful input description, a well-designed program must support the use of named nodes. It is much easier to debug a design described by lines such as

```
AND DATA LOAD DATA-IN
```

rather than

```
AND 3 7 33
```

The advanced version of this program uses a free-field input format. Spaces are used as string delimiters when a line is read and parsed into distinct names by the subroutine at line 10000. A table look-up assigns unique numbers to each signal name. The subroutine at line 11500 looks up each name, while the routine at line 11600 adds to the list names not already there. Note that unused entries have the name "0," and this is the only reserved signal name; any other combination of symbols can be used as a valid signal name (e.g., LOAD— could be used to signify a load-not signal). Additionally, some devices subsequently described contain numeric parameters, such as an N-bit shift register, and these numbers are distinguished from signal names by using # (the number sign) as the first character in the name.

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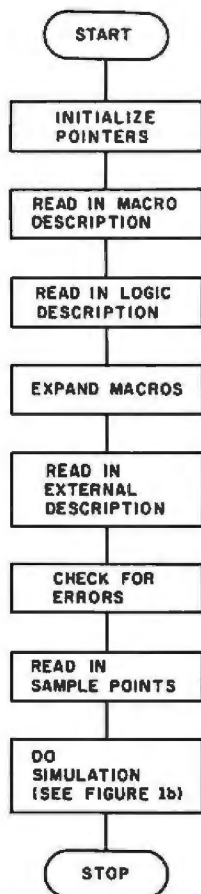
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(1a)



(1b)

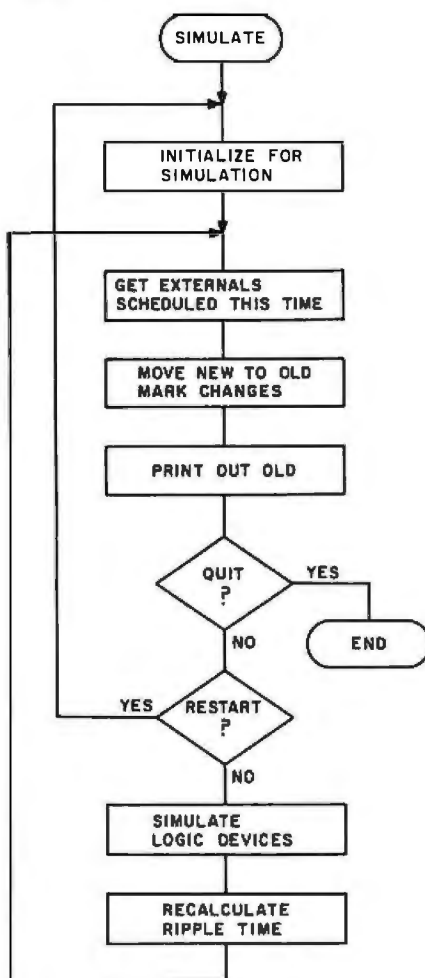


Figure 1: Flowchart of the fundamental procedures used in the simulator. Figure 1a shows the arrangement of the functional blocks; figure 1b describes in more detail the actual simulation process.

capability should be included to allow predefined blocks of circuitry—macrocircuits—to be installed simply. A macrocircuit is a black box with specified input and output signals; the description of the macrocircuit includes the logic devices required to generate the output from the inputs, using internal

A macrocircuit is similar to a function call in BASIC or a subroutine call in FORTRAN or Pascal.

signals as required. Handling a single-level macrocircuit involves the replication of a block of logic devices, with the appropriate translation of the signal names used within the macrocircuit to those used within the circuit.

A macrocircuit is similar to a FUNCTION call in BASIC (or more appropriately, a subroutine call in languages such as FORTRAN or Pascal). The definition of the macrocircuit is like BASIC's DEFFN definition in that the variables used in the definition are dummy variables. When the macrocircuit is called in the logic-description input, the dummy

Text continued on page 412

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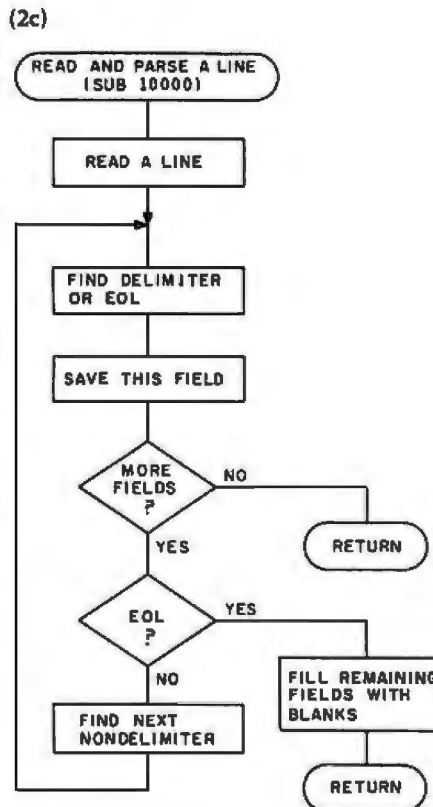
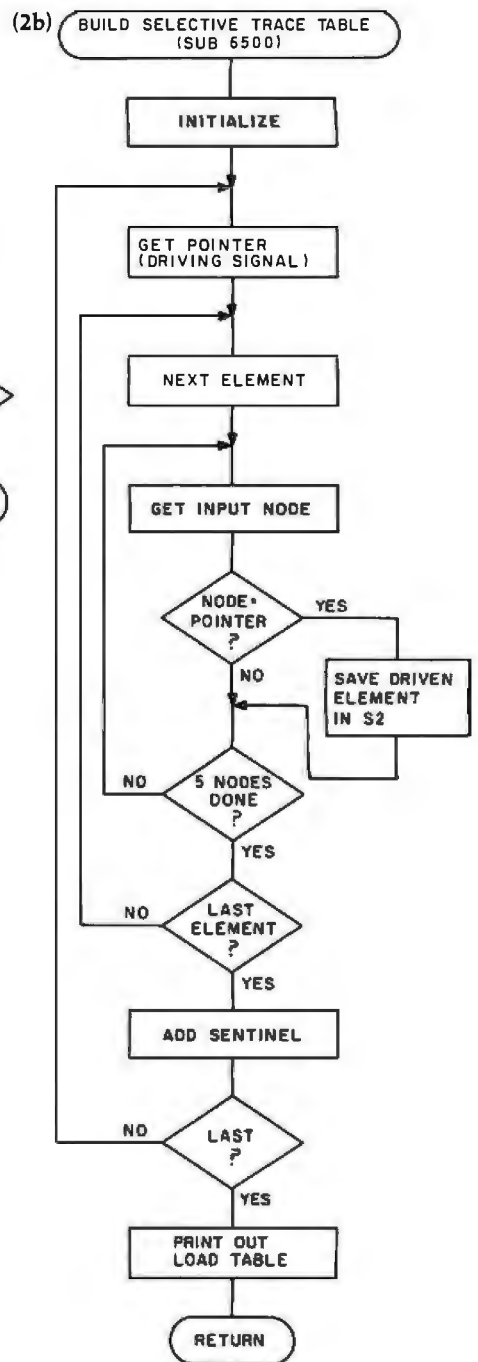
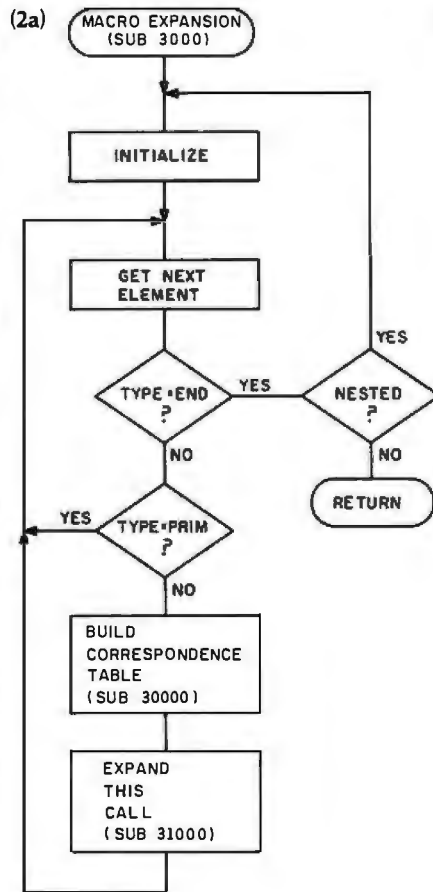
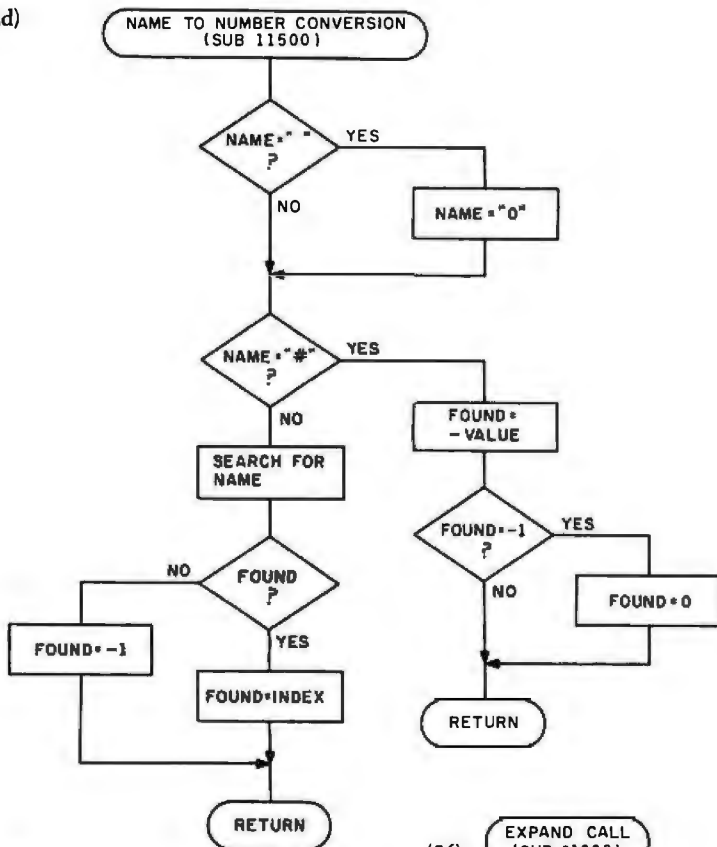
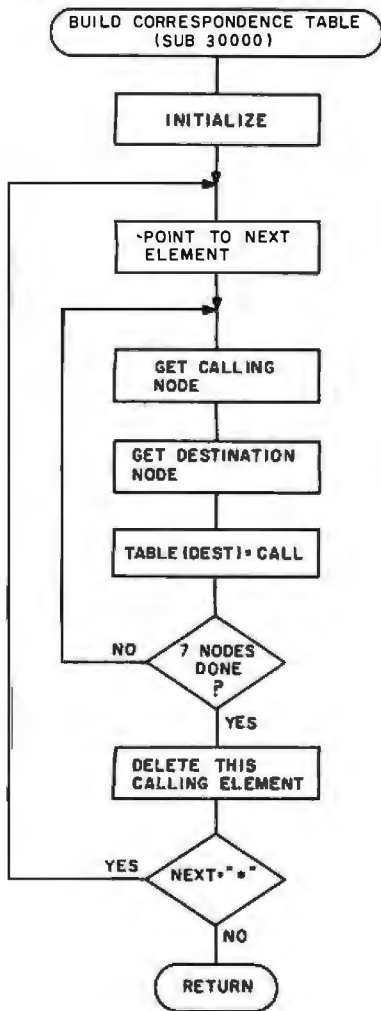


Figure 2: Flowcharts for the functions added to the advanced version of the simulator; note the line-number references to listing 1 at the top of each flowchart.

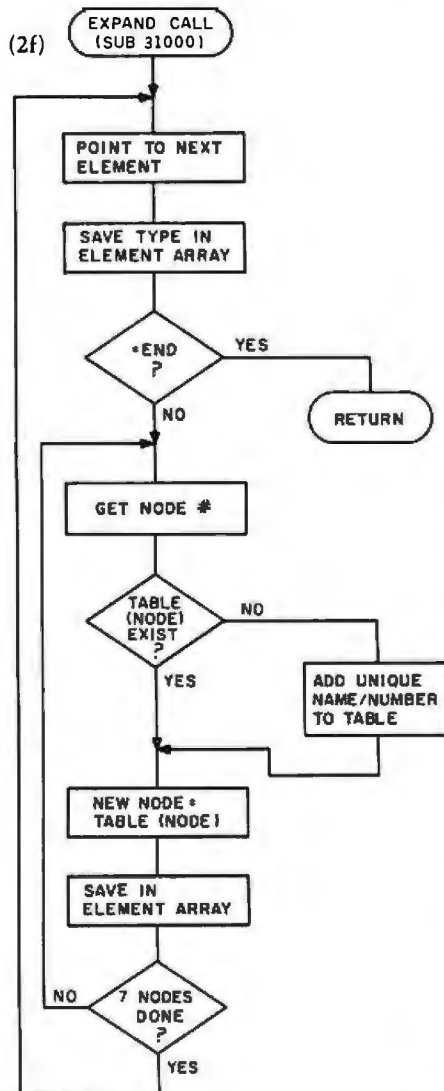
(2d)



(2e)



(2f)



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Figure 3: The fundamental logic elements predefined within the logic simulator.

(3a)

LOGIC TYPE: AND GATE

LOGIC EQUATION: $Q = A \cdot (B) \cdot (C) \cdot (D) \cdot (E)$

LOGIC SYMBOL:



TRUTH TABLE:

A	B	Q
0	0	0
0	1	0
1	0	0
1	1	1

ELEMENT CODING: AND A (B) (C) (D) (E) Q (Q)


NOTES: () DENOTES OPTIONAL FIELDS, "0" IF NOT USED.

(3b)

LOGIC TYPE: NAND GATE

LOGIC EQUATION: $Q = \overline{A \cdot (B) \cdot (C) \cdot (D) \cdot (E)}$

LOGIC SYMBOL:



TRUTH TABLE:

A	B	Q
0	0	1
0	1	1
1	0	1
1	1	0

ELEMENT CODING: NAND A (B) (C) (D) (E) Q (Q)


NOTES: () DENOTES OPTIONAL FIELDS, "0" IF NOT USED.

(3c)

LOGIC TYPE: OR GATE

LOGIC EQUATION: $Q = A + (B) + (C) + (D) + (E)$

LOGIC SYMBOL:



TRUTH TABLE:

A	B	Q
0	0	0
0	1	1
1	0	1
1	1	1

ELEMENT CODING: OR A (B) (C) (D) (E) Q (Q)


NOTES: () DENOTES OPTIONAL FIELDS, "0" IF NOT USED.

(3d)

LOGIC TYPE: NOR GATE

LOGIC EQUATION: $Q = \overline{A + (B) + (C) + (D) + (E)}$

LOGIC SYMBOL:



TRUTH TABLE:

A	B	Q
0	0	1
0	1	0
1	0	0
1	1	0

ELEMENT CODING: NOR A (B) (C) (D) (E) Q (Q)


NOTES: () DENOTES OPTIONAL FIELDS, "0" IF NOT USED.

(3e)

LOGIC TYPE: EXCLUSIVE OR GATE

LOGIC EQUATION: $Q = A \oplus B$

LOGIC SYMBOL:



TRUTH TABLE:

A	B	Q
0	0	0
0	1	1
1	0	1
1	1	0


ELEMENT CODING: XOR A B 0 0 0 Q (Q)

(3f)

LOGIC TYPE: EXCLUSIVE NOR GATE

LOGIC EQUATION: $Q = \overline{A \oplus B}$

LOGIC SYMBOL:



TRUTH TABLE:

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0	0	1
0	1	0
1	0	0
1	1	1

ELEMENT CODING: XNOR A B 0 0 0 Q (Q)

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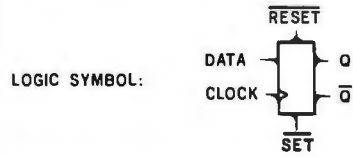


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Figure 4: Additional logic elements predefined within the advanced version of the logic simulator.

(4a)

LOGIC TYPE: D-TYPE FLIP-FLOP



TRUTH TABLE:

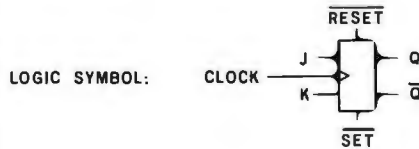
DATA	CLOCK	RESET	SET	Q	\bar{Q}
X	X	0	0	0	1
X	X	1	0	1	0
X	X	0	1	0	1
0	\uparrow	1	1	0	1
1	\uparrow	1	1	1	0
X	\downarrow	1	1	Q	\bar{Q}

ELEMENT CODING: OFF DATA 0 CLOCK ($\overline{\text{RESET}}$) ($\overline{\text{SET}}$) Q (\bar{Q})

NOTES: X= DON'T CARE.
SET AND RESET ARE ACTIVE LOW; IF UNUSED "0", THEY DEFAULT TO LOGIC 1.

(4b)

LOGIC TYPE: JK FLIP-FLOP



TRUTH TABLE:

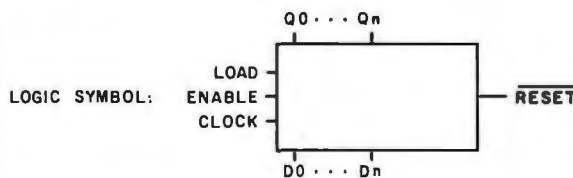
J	K	SET	RESET	Q	\bar{Q}	CLOCK	NEXT Q	\bar{Q}
1	X	1	1	0	1	\uparrow	1	0
X	0	1	1	1	0	\uparrow	1	0
0	X	1	1	0	1	\uparrow	0	1
X	1	1	1	1	0	\uparrow	0	1
X	X	1	1	X	X	\downarrow	NO CHANGE	
X	X	0	1	X	X	X	1	0
X	X	1	0	X	X	X	0	1
X	X	0	0	X	X	X	0	1

ELEMENT CODING: JKFF J K CLOCK ($\overline{\text{RESET}}$) ($\overline{\text{SET}}$) Q (\bar{Q})

NOTES: X= DON'T CARE.
SET AND RESET ARE ACTIVE LOW; IF UNUSED "0", THEY DEFAULT TO LOGIC 1.

(4c)

LOGIC TYPE: N-BIT COUNTER



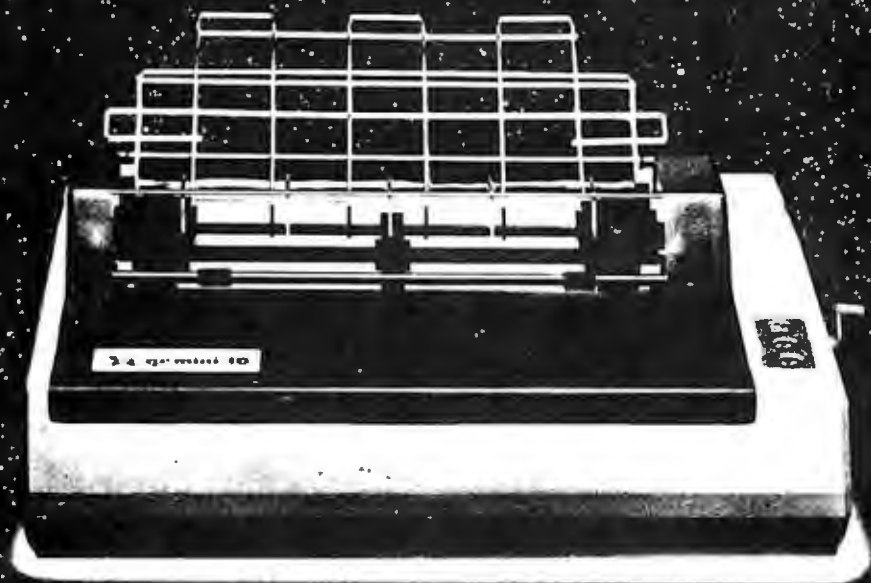
TRUTH TABLE:

DATA	LOAD	ENABLE	RESET	CLOCK	COUNT (Q0...Qn)
0	1	X	1	\uparrow	0
1	1	X	1	\uparrow	1
X	0	X	0	X	0
X	0	1	1	\uparrow	COUNT + 1
X	0	1	1	\downarrow	NO CHANGE
X	0	0	1	\uparrow	NO CHANGE

ELEMENT CODING: CNTR (D0) ENABLE CLOCK (LOAD) ($\overline{\text{RESET}}$) Q0 ($\bar{Q}0$)
* (D1) 0 0 0 0 Q1 ($\bar{Q}1$)
* 0 0 0 0 Qn ($\bar{Q}n$)
* Dn

NOTES: X = DON'T CARE. LOAD AND ENABLE ARE ACTIVE HIGH AND LOAD OVERRIDES ENABLE.

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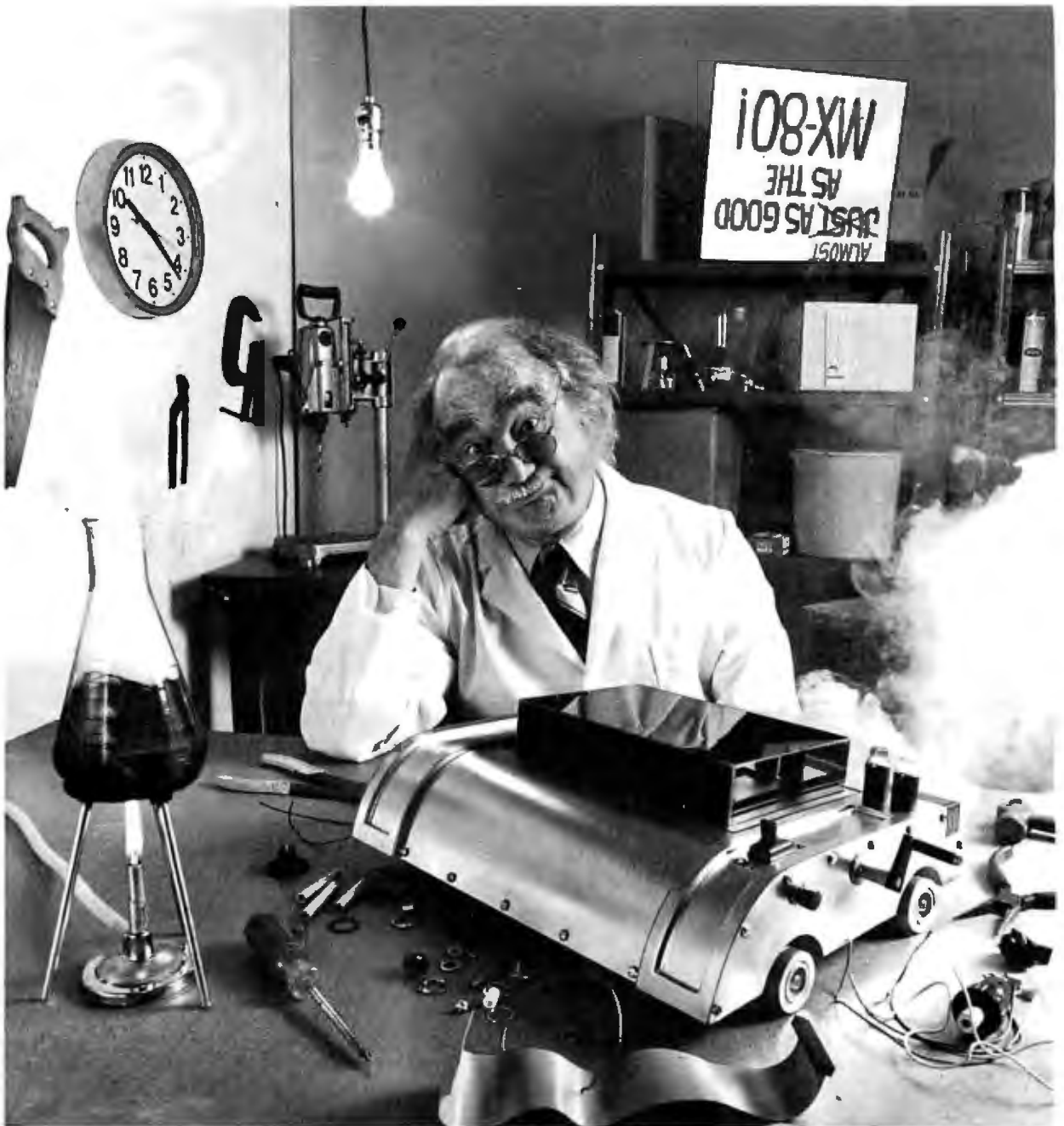
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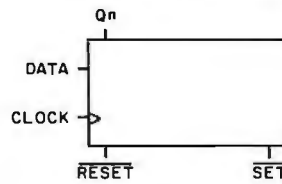
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(4d)

LOGIC TYPE:

N-BIT SHIFT REGISTER

LOGIC SYMBOL:



TRUTH TABLE:

DATA	RESET	SET	CLOCK	Q1	Qn
0	1	1	┌	0	Qn-1
1	1	1	└	1	Qn-1
X	1	1	┌	Q1	Qn NO CHANGE
X	0	1	X	0	0
X	1	0	X	1	1

ELEMENT CODING:

SREG DATA #BITS CLOCK (RESET) (SET) Qn (Qn)

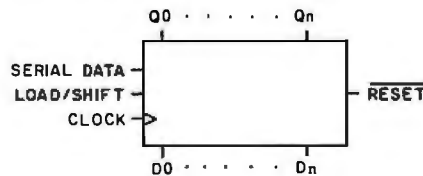
NOTES: #BITS IS THE TOTAL NUMBER OF SHIFT BITS REQUIRED, IF "0", THEN DEFAULTS TO 1.
X = DON'T CARE.

(4e)

LOGIC TYPE:

PARALLEL LOAD SHIFT REGISTER

LOGIC SYMBOL:



TRUTH TABLE:

D0	DSER	LOAD	RESET	CLOCK	Q0	Qn
X	X	X	0	X	0	0
1	X	1	1	X	1	1
0	X	1	1	X	0	0
X	0	0	1	┌	0	Qn-1
X	1	0	1	└	1	Qn-1

ELEMENT CODING:

PLSR D0 DSER CLOCK LOAD (RESET) Q0 (Q0)
* D1 0 0 0 0 Q1 (Q1)
* Qn 0 0 0 0 Qn (Qn)

NOTES: X = DON'T CARE
LOAD/SHIFT - LOAD ON HIGH, SHIFT ON LOW.

Text continued from page 402:

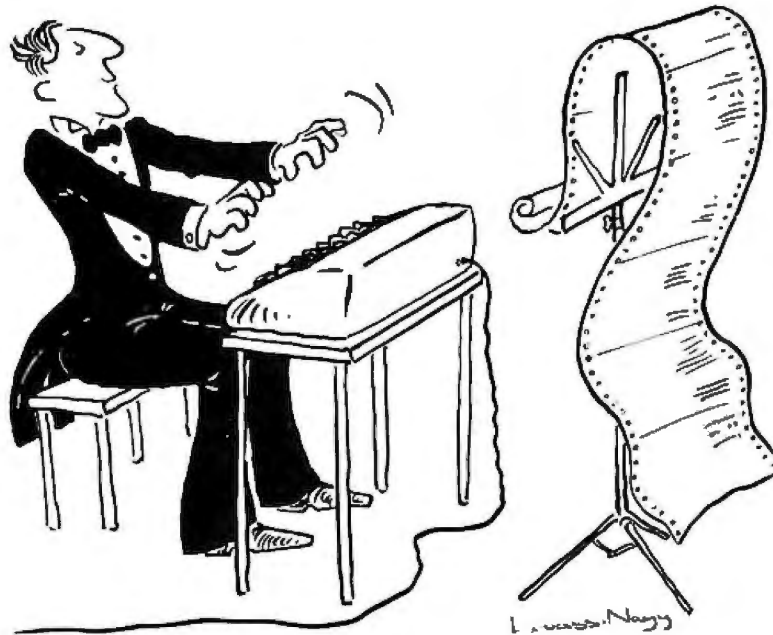
signal names are replaced by the signal names used in the actual network description.

A macrocircuit typically performs a complex logical function. Because some internal nodes may be used to hold values from previous time cycles, a separate replication of the macrocircuit is required wherever it is used in the network. The macro processor must therefore translate the defined inputs and outputs of each macrocircuit and generate unique signal numbers for the internal nodes.

A macrocircuit can be considered as a subcircuit; typically, a complex but common logical function is designed and simulated as a single cir-

cuit to verify its proper operation. Once this design is characterized with regard to the input and output pins, it can be used as a building block for other designs. This approach is comparable to structured programming, where a functional block is completely characterized by the arguments passed to and returned from it.

Because a macrocircuit is conceptually a subcircuit, the same routine used to read the logic circuit (at line 2000) is used to process the macrocircuit. Pointers are maintained to keep track of where in the logic-description array each macrocircuit starts. The NAMES\$ array is reused because the names used in each macrocircuit are



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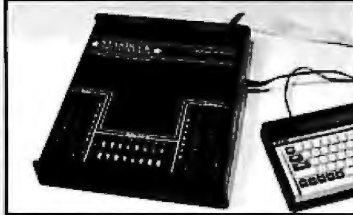


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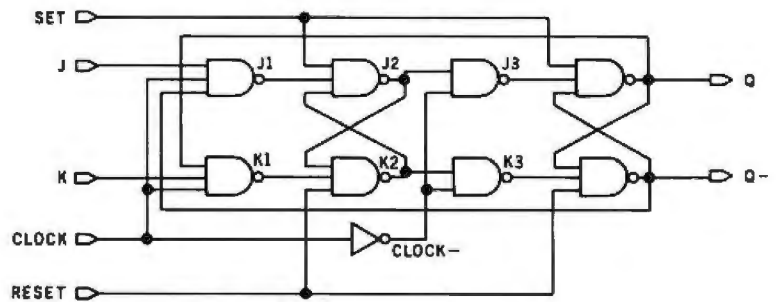
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```

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JK J K CLOCK RSET SET Q Q-
NAND J CLOCK Q- 0 0 J1 0
NAND K CLOCK Q 0 0 K1 0
NAND SET J1 K2 0 0 J2 0
NAND RSET K1 J2 0 0 K2 0
NAND J2 CLOCK- 0 0 0 J3 0
NAND K2 CLOCK- 0 0 0 K3 0
NAND J3 Q- 0 0 0 Q 0
NAND K3 Q 0 0 0 Q- 0
NAND CLOCK 0 0 0 0 CLOCK- 0
END 0 0 0 0 0 0
    
```

***** EXPANDED LOGIC DESCRIPTION *****

TYPE	INPUTS					OUTPUTS	
	1	2	3	4	5	Q	Q-
NAND	J1	CLOCK1	Q0-			88	
NAND	K1	CLOCK1	Q0			89	
NAND	SET	88	810			811	
NAND	RESET	89	811			810	
NAND	811	812				813	
NAND	810	812				814	
NAND	813	Q0-				Q0	
NAND	814	Q0				Q0-	
NAND	CLOCK1					812	
END							

Figure 5: Defining a macrocircuit. Using predefined logic elements, the JK flip-flop shown here can be described to the logic simulator once, then that description can be used wherever a flip-flop is needed; the user is not required to define the device every time it is used. (Multilevel or nested macros are also allowed.)

dummy names and need not be retained after the macrocircuit's description is stored.

The use of a macrocircuit is demonstrated in figure 5. The logic coding for a JK flip-flop was described in the January article; once its proper operation is verified, it can be used as a macrocircuit. Using the black-box approach, the user need provide only the J, K, Clock, Reset, and Set inputs and name the Q and Q- outputs. The macro processor, however, must assign unique signal numbers to the internal nodes wherever this JK flip-flop is used.

Nested macrocircuits (a macrocircuit used within a macrocircuit) add a further level of complexity in this signal-translation and node-generation procedure. One approach typically taken is to maintain a list of the defined signals on a stack and push and pop the signal names as macrocircuits are called and expanded. This pro-

cedure is efficient in that macrocircuits can be expanded as they are encountered, but typically requires either large memory for the stack or a limit to the nesting depth.

A procedure that allows for unlimited nesting depth requires multiple passes through the logic-description array: one pass to expand each level of macrocircuit. This procedure is not processor-time efficient, but the signal names need be stored only once for cross-referencing to a single macro call at any one time. One example of a nested macro would be when a 4-bit ripple counter is defined as a macrocircuit containing the JK flip-flop macrocircuit.

The macro expander (at line 3000) must perform two tasks: maintaining correspondence to the simulated circuit's signal names and generating unique signal names for other internal nodes. This process is performed by maintaining a macro-to-logic corre-

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spondence array; because the array used to store old logic values is not needed at this point, this array is used to maintain this correspondence, thus conserving memory.

The subroutine at line 30000 builds this correspondence by placing the calling signal number in the array position pointed to by the macrocircuit signal number; all other entries are set to a -1 to indicate that no correspondence has yet been made. This correspondence is location-dependent, i.e., the location of a calling signal within the calling description corresponds to a signal in the same location in the macrocircuit's definition line (the first input in the call corresponds to the first input to the macrocircuit definition, etc.).

The subroutine at line 31000 is called to expand the called macrocircuit and add it to the end of the logic-description array. If a macrocircuit name has no correspondence to a calling name, a unique number is assigned, as well as a reference name. As each macrocircuit is expanded, the

calling entry in the logic-description array is deleted by moving the array up to overwrite the calling entry. The logic-description array is repeatedly scanned for macrocircuit calls, and the above process continues until no macrocircuit calls are found.

Error Checking

The basic error checking that should be performed consists of checking that a name is not used as the output of two or more logic elements and that each named input signal is defined as either an external stimulus or the output of a logic element. These checks are applicable for macrocircuit blocks, as well as for the total expanded logic description; although an error in a macrocircuit block will be found when the total network is checked, it is easier to debug an error if its location can be easily isolated. Each macrocircuit expansion involves a separate error check (at line 1500), and the total circuit is checked after expansion (at line 5000).

The check for multiple definitions of an output is performed by scanning the element-description array for the same signal number on two or more outputs. Rather than compare each output with every other output (requiring $N \times (N-1)/2$ comparisons), a single pass through the logic-description array can identify multiple uses of the same signal. The OL array (see line 12200) is used to mark the occurrence of a signal number as an output of a logic device or as an external stimulus; if a signal is already marked, it is flagged as an error.

This same marked array is then used to check for defined inputs (at line 12300); the logic array is scanned and each input is checked for a 0 in the OL array as being undefined. Additionally, for defined signals, this entry is incremented for each occurrence of the signal as an input, providing for an indication of the load on each signal. This count is also used to determine the array requirements for selective trace, as described in the

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next section.

As each error is reported, the user is given the option to have the program ignore the error and continue with simulation. This is particularly useful when a signal appears both as the output of a logic element and as an external stimulus for initialization.

Selective Trace

A logic element's output state will not change unless a change appears at its input; this fact can be used to optimize run-time by simulating an element only when such a change occurs. On a global scale, no element need be simulated until an external stimulus is applied.

The global optimization can be easily implemented by maintaining a single *change flag* to skip the entire simulation process when no changes are noted. Additionally, if the next scheduled stimulus change time is known, the simulator clock (ripple time) can be automatically advanced to that point, skipping the intermediate (inactive) time steps. The variables C9 (change flag), E9 (next scheduled stimulus time), and S9 (next scheduled sample time) are used to determine RI (next scheduled ripple time) in the subroutine at line 7500.

Optimization at the logic-element level (selective trace) is slightly more complicated. A flag must be maintained for each logic element; the flag is set when one or more of the element's inputs changed state during the previous simulation cycle. A cross-reference array must be maintained to identify which logic elements are affected by each output signal; conceptually, an array is required where one dimension represents the logic elements and the other dimension is the number of signal nodes.

This array contains a 1 if the element is driven by the corresponding node; otherwise, it contains a 0. This array would contain primarily 0s, because few nodes would fan out to more than a few logic elements; as such, sparse-matrix techniques are used to minimize the memory requirements for such processing.

The S0, S1, and S2 arrays are used

to perform this sparse-matrix tracing and marking. S0 contains the flag for each logic element; S1 is arranged by signal number and points to entries in S2 (which contains the list of elements driven by each signal number—the drive table). On entry to the routine that builds these arrays, a check is made to see that sufficient memory remains to store these values; because selective trace is not necessary for simulation, if sufficient memory is not available, this process is skipped entirely and the ST (selective-trace flag) is cleared.

The subroutine at line 6500 creates the drive table; this table is, in effect, a form of a linked list. Because the length of the list of elements driven by a particular signal is of variable size, this list is dynamically allocated and uses a delimiter to mark the end of the list for each signal (the next entries in the array are the list of elements driven by the next signal).

During simulation, as the output signals are moved from the NEW to the OLD array, a check is made to see if a change has occurred on a signal (at line 8500); if so, C9, the global-change flag, is set (as are the change flags of the elements driven by this signal if the selective-trace flag is set—see the subroutine at line 8620). The simulation of the logic elements is skipped entirely if the global-change flag is not set (line 40010); and, if the selective-trace flag is set, each element's simulation is skipped if its individual-change flag (in array S0) is not set (line 40030). The global optimization can produce a twofold to fivefold decrease in processing time, and the element-level selective trace another twofold to tenfold decrease, depending upon the relative activity of the logic network.

Sampled Output

The primitive version of this program produced a display of each selected logic signal at each simulation cycle. To get a more global view of the operation of the logic network, however, it is often desirable to display the outputs at periodic intervals rather than at each cycle. This is comparable to the sweep control on an oscilloscope. In the simulation of a

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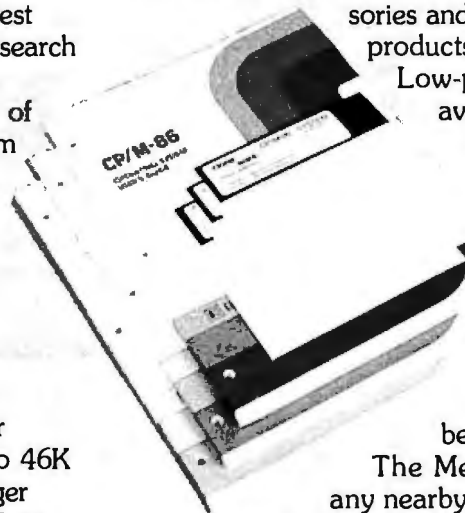
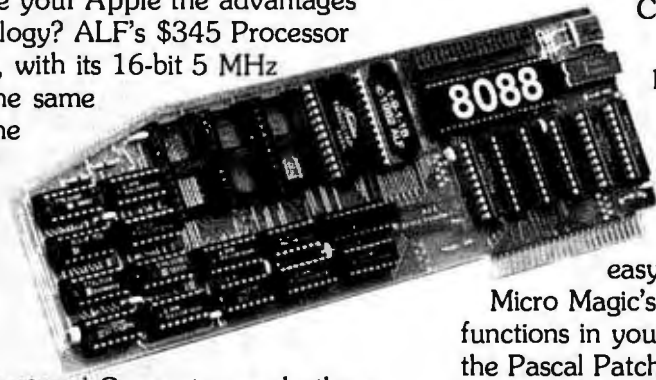
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counter, for example, it is often desirable to display the resultant count at each clock cycle rather than at each gate-simulation cycle.

This option is directly implemented by specifying the start time and the sampling interval. For every simulation cycle, the subroutine at line 9000 checks to see if a sample is required (RI=S9), and if so, displays the values. It also increments S9 for the next scheduled time and checks for a full screen. If the screen is full (50 samples displayed), the user is given options for continued processing. The simulation process can be reinitialized by typing R (restart), aborted by typing Q (quit), or the monitored points can be changed by typing C (change).

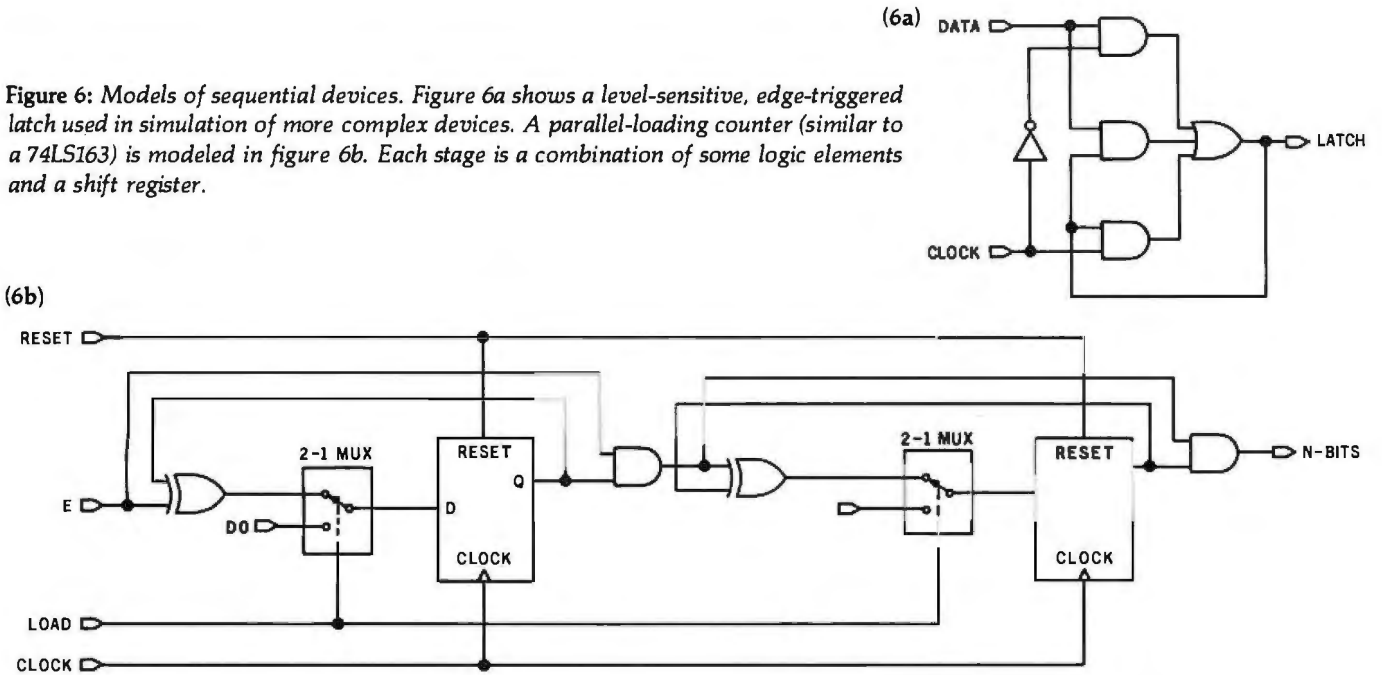
Sequential-Device Models

A logic simulator for advanced digital design must include sequential devices (flip-flops, counters, etc.) as predefined logic primitives. While sequential devices can be modeled as macrocircuits of the basic logic elements, such modeling is inefficient (requiring, for example, nine combinational devices to model a single JK flip-flop).

The combinational models previously described (AND, OR, XOR gates) each have inputs that are congruent; i.e., for a 2-input AND gate, it doesn't matter which signal is given as the first pin and which as the second. For sequential devices, however, each input has a specific function; i.e., the Clock pin operates differently from the J input pin on a JK flip-flop. To maintain this "pin significance," each sequential model uses a fixed order of signal pins in the input description shown in figure 4; in the JK flip-flop model, for example, the first input signal will be interpreted to be the J input, the second the K, third Clock, fourth Reset, and fifth Set. This assignment is used directly by the sequential models to accurately simulate the operation of these devices; in all cases, the devices are triggered on the *rising edge* of the clock and contain optional asynchronous, active-low Set and Reset pins.

The use of sequential devices as

Figure 6: Models of sequential devices. Figure 6a shows a level-sensitive, edge-triggered latch used in simulation of more complex devices. A parallel-loading counter (similar to a 74LS163) is modeled in figure 6b. Each stage is a combination of some logic elements and a shift register.



primitives requires that such devices be predefined. Thus, we must address the fact that sequential devices, by definition, contain some memory of their prior state. For example, the operation of a counter is dependent upon its prior count, as well as its immediate inputs. Each logic element in the program includes an array position for maintaining this memory value (or a pointer to another array for maintaining multiple memory values).

Each of the sequential devices described herein is a level-sensitive, edge-triggered device. When the clock goes to a logic 1, the resultant output is latched to the desired state; it cannot change value (except by asynchronous Set or Reset), except on the rising edge. Such a level-sensitive, edge-triggered operation is typically designed by using dual latches on opposing clock values. When the clock is low, the input is latched to its appropriate value while the output retains its prior latched value; when the clock is high, the input latch is disabled from changes on the input and the output is driven by this internal latch value. Figure 6 shows such a latch; this logical model is used for simulation. Because the prior output value is available from the OLD array, the program need retain only the internal latch value for proper se-

quential modeling (this is the eighth entry in the logic-description array).

The subroutine at line 45000 performs the basic latch function (a 2-to-1 multiplexer); the subroutine at line 45100 performs the basic shift register function by two calls to the latch function, returning YL as the internal latch value and Y as the second (Q output) latch value. (The shift register function also calls the routine at line 45200 to process the asynchronous Set and Reset signals, if any.)

The model of a D-type flip-flop is merely a direct call to the shift register function; note that the optional Set and Reset pins are set to a default of logic 1 by presetting the 0 entry of the OLD array to a logic 1. If the signals are unused (signal number 0), this logic 1 is read as the current input (Set and Reset are active-low).

The model of a JK flip-flop is basically some combinational logic followed by a shift register. The internal D input should be the desired Q output upon receipt of an active clock edge; the combinational logic to generate the D input is

$$(J \text{ AND } \overline{Q}) \text{ OR } (\overline{K} \text{ AND } Q)$$

To properly model a possible Q-unknown value, however, a third term (J AND \overline{K}) is included.

A parallel load counter (similar to a 74LS163) is modeled as shown in figure 6b; again, each stage is merely some combinational logic followed by a shift register. Using one line of input coding for each stage of the counter provides for a latch position for each stage; note that the use of "continue" lines for the additional stages provides for an automatic determination of the number of stages used and required, precluding the necessity of predefining the number of stages.

A parallel load shift register is identical in concept to the parallel load counter, the only difference being in the combinational logic feeding each shift register.

The N-bit shift register, however, is implemented differently. For ease of coding, as well as efficient memory use, it is unreasonable to require a separate line of input coding for each of the N stages. The second input signal to the N-bit shift register is actually a numeric value specifying N. This input is treated as a numeric value rather than a signal name by using # (number sign) as a prefix to the numeric value, and having the input processor properly handle this numeric marking. (Note that the number/signal distinction is made during input processing without regard to the logic-element type; this

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approach is more flexible than having a separate processor for an N-bit shift register—logic devices defined later may also need such numeric values.) This number is actually stored as a negative number to distinguish it from signal numbers; the sum of these negative numbers is used to dimension array ME for retaining internal memory values.

The eighth entry in the logic-description array contains a pointer to this array for each N-bit shift register used rather than containing the single latch value. The model itself is simulated by N calls to the shift register function, using and storing values in the ME array.

Enhancements

The only obvious enhancement to the program is to add primitives (such as transmission gates and buses) and dynamic array allocation. The program is structured to support the addition of logic primitives by having no fixed limit on the number of primitives used. The initialization subroutine (line 500) reads a list of primitive logic-element names, ended by pseudotype "LAST"; adding primitive names before this "LAST" entry automatically adds it to the primitive list. The statement

```
ON LT GOSUB ...
```

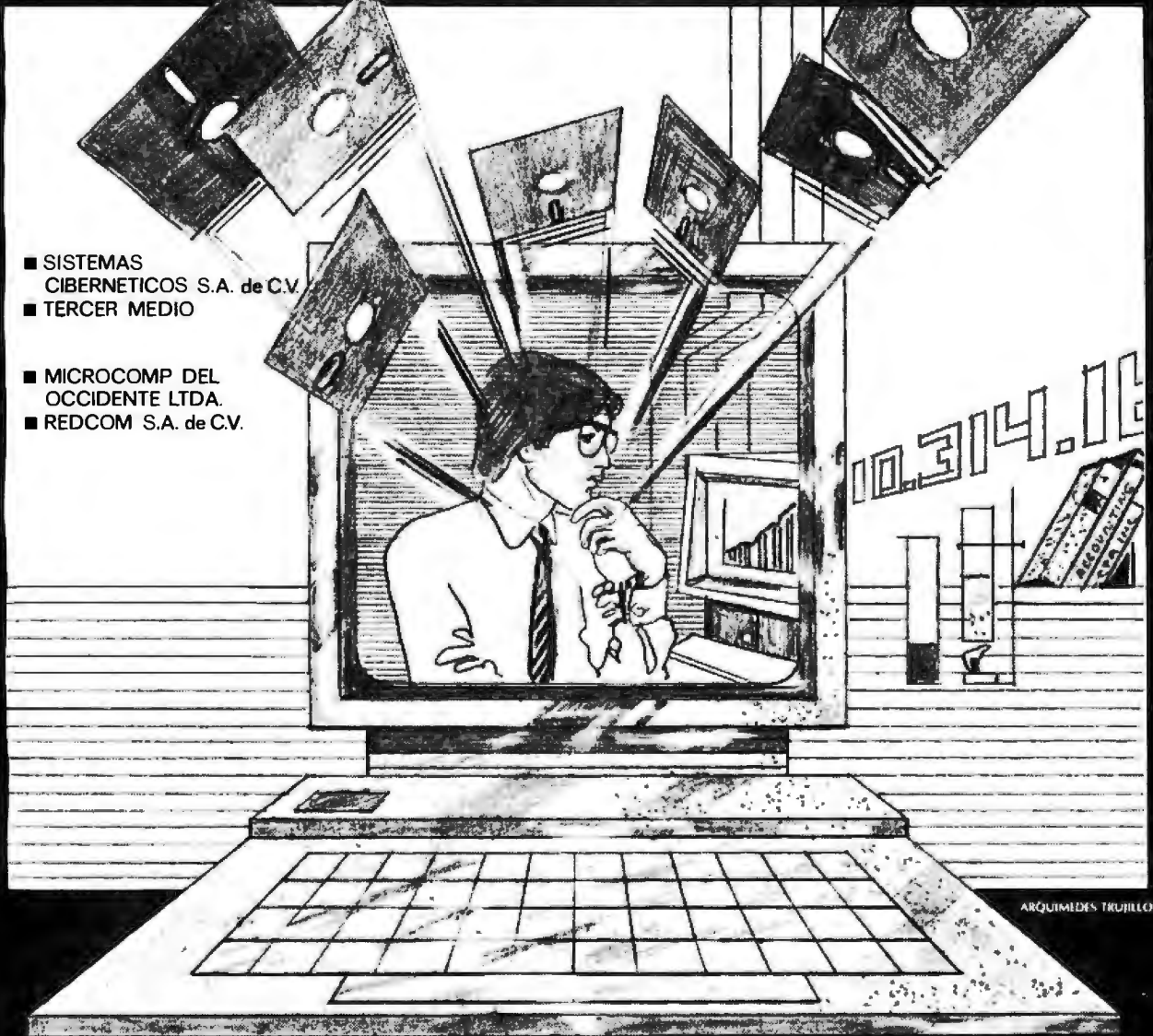
at line 40130 calls the appropriate subroutine to model each primitive; these subroutines are called with IN(1) through IN(5), containing the input signal numbers, and Q0 and Q1, containing the output signal numbers. The subroutine for the added primitive is expected to store the resultant Q output in variable Y; upon return, this value will be stored in NEW(Q0) and its complement in NEW(Q1).

For proper modeling, particularly for proper handling of logic unknowns, a proposed primitive should first be simulated as a combination of existing primitives to verify its operation. The primitive subroutine should then be coded in terms of logical operations (AND and OR), and use the LN array for logical NOTs.

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The program in listing 1 is not necessarily memory-efficient under all conditions. The maximum dimension for each array is predefined, independent of the actual number of array locations required by the circuit being simulated; some designs may contain few logic elements and many external stimuli, other designs may have many logic elements but few stimuli, yet the program preallocates a fixed portion of RAM for each array. If it is known, a priori, exactly how many logic elements are required, the dimension could be adjusted accordingly, providing more memory for external stimuli or selective trace; such a predefinition, however, is cumbersome for the user, particularly if macrocircuits are used.

Two approaches are available to optimize memory use. The most straightforward way is to perform a two-pass operation: on the first pass, the required array sizes are calculated; then the data is restored and the arrays are dimensioned to their required sizes for the second pass, which actually performs the storing

of values and the simulation.

A more efficient process is "dynamic allocation," in which a single array is used to contain all numeric data. Such an array is dimensioned to the maximum available memory and as each element or external is read, an index is maintained to point to the start of each subarray, similar to the approach taken in LO (the logic-description array), which contains both the macrocircuit definitions and the actual network logic description. The external stimuli array, for example, would follow the network description in this array with a single variable used to store the start of this array; it would then be followed by the selective-trace arrays, the old and new value arrays, and so on.

Conclusion

The use of a logic simulator can replace the use of a hardware digital breadboarding system, particularly if the higher-level modeling capabilities described in this article are included in the system. The added features

such as named nodes, macro processing, and sampled outputs make such a system easy to use and provide for a hard-copy logic description that is easier to debug than the equivalent breadboarded system.

Logic simulation is used at professional design centers to verify proper logical operation of proposed designs prior to the costly fabrication of printed-circuit boards. I find this system particularly useful for the simulation of designs presented in hobby magazines, before investing in parts to build these sometimes-untested designs.

One of the biggest advantages I find in using a software-based logic simulator is that I never run out of spare parts on a Saturday night when the local supply stores are closed, nor do I ever burn out expensive ICs by improper connections! ■

Listing 1 begins on page 428

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Listing 1: The advanced version of the logic-simulation program, written in BASIC for the Radio Shack Model III. The major subroutines are diagramed in figure 1 and figure 2; predefined logic elements are shown in the other figures. The program is very modular and can be expanded to include more predefined logic elements than it now contains. The data statements starting at line 50000 contain a sample set of input coding for a 4-bit counter using nested macros (CNTRM-MUXD-MUX) and as a logic primitive (CNTR).

```

10 REM          AN ENHANCED LOGIC SIMULATION PROGRAM
20 REM          ROBERT M. MCDERMOTT
30 REM          AUGUST 1981
40 REM
50 REM
60 REM THE FOLLOWING PROGRAM SIMULATES A DIGITAL LOGIC DESIGN
70 REM THE LOGIC DESCRIPTION MAY CONSIST OF LOGIC 'PRIMITIVES'
80 REM (AND,OR,XOR,ETC. GATES; D, JK FLIP FLOPS; N-BIT COUNTER)
90 REM OR 'MACROS' (BLOCKS OF COMMONLY USED PRIMITIVES).
100 REM EACH LOGIC ELEMENT CONTAINS 5 INPUTS AND TWO OUTPUTS,
110 REM UNUSED 'PINS' ARE CODED AS "0".
120 REM THE LOGIC IS DRIVEN BY 'EXTERNAL STIMULI'. THE STIMULI
130 REM ARE DESCRIBED AS PERIODIC OR APERIODIC, THE SIGNAL NAME,
140 REM STARTING LOGIC VALUE, START TIME, AND 5 CHANGE TIMES.
150 REM
160 REM
170 REM THE FOLLOWING PARAMETERS DEFINE THE MAXIMUM ARRAY LIMITS
180 REM THEY CAN BE ADJUSTED TO FIT A DESIGN TO AVAILABLE RAM.
185 CLEAR 1000:DEFINT A-Z
190 MNAMS=200:MLGIC=200:MEXTERN=30:MSAMPLES=14:MTYPES=50
195 PRINT"      LOGIC SIMULATOR: ";MN;" NAMES ";ML;" LOGIC DEVICES"
196 PRINT"          ";MT;" TYPES ";ME;" EXTERNAL STIMULI"
197 PRINT
198 PRINT
220 DIM NAMSS(MNAMS)          'SIGNAL NAMES
230 DIM LO(MLGIC,8)          'LOGIC DESCRIPTION
240                          '(7 SIGNALS,LATCH)
250 DIM EXTERNALS(MEXTERNALS,10) 'EXTERNAL STIMULI
260 DIM TYPES(MTYPES)        'LOGIC TYPES (PRIM&MACS)
270 DIM TYPEP(MTYPES)        'POINTERS TO LOGIC DES.
275 DIM OL(MN)               'OLD LOGIC VALUE ARRAYS
280 DIM SA(MS)               'SAMPLED NODES
290 DIM T(10),LIS(10)        'TEMP ARRAYS
300 REM ***** START OF PROGRAM *****
310 PRINT:PRINT" ***** INITIALIZING ARRAYS ***** ":GOSUB 500
'INITIALIZE POINTERS
320 PRINT:PRINT" ***** READING IN ANY MACROS ***** ":GOSUB 1000
'READ ANY MACROS
330 PRINT:PRINT" ***** READING IN LOGIC NETWORK ***** ":GOSUB 2000
'READ LOGIC NETWORK
340 PRINT:PRINT" ***** EXPANDING ANY MACROS *****":GOSUB
3000                          'EXPAND MACROS
345 GOSUB 3500                  'LIST EXPANSION
350 PRINT:PRINT" ***** READING IN EXTERNAL STIMULI *****":GOSUB 4000
'READ EXTERNALS
360 PRINT:PRINT" ***** CHECKING FOR ERRORS *****":GOSUB 5000
'CHECK FOR ERRORS

```

```

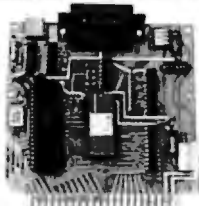
370 PRINT:PRINT" ***** READING IN NODES TO BE SAMPLED *****":GOSUB 6000
'READ SAMPLE POINTS
380 PRINT:PRINT" ***** SETTING UP FOR SIMULATION *****":GOSUB 7000
'DO SIMULATION
390 STOP
400 REM
500 REM ***** INITIALIZE POINTERS *****
510 NL=0:NTYPE=0
520 READ QS                      'LOAD PRIMITIVES
530 IF QS<>"LAST" THEN TYS(NTYPE)=QS:NTYPE=NTYPE+1:GOTO 520
540 DATA "END","AND","NAND","OR","NOR","XOR","XNOR"
550 DATA "DFF","JKFF","CNTR","PLSR","SREG","*"
560 DATA "LAST"
570 NPRIM=NTYPE:NTYPE=NTYPE+1      'NTYPE=NEXT TYPE PTR.
590 REM LOGIC PRINT VALUES AND INVERSIONS
600 LO=0:L1=3:LX=1                'INTERNAL VALUES FOR LOGIC VALS.
610 DIM LVS(3),LPS(3),LN(3)      'LOGIC INPUT SYMBOL, LOGIC PRINTSYMBOL, LOGIC
INVERSION
620 LVS(LO)="0":LPS(LO)=".":LN(LO)=L1:LVS(LO)=LO
630 LVS(L1)="1":LPS(L1)="1":LN(L1)=LO:LVS(L1)=L1
640 LVS(LX)="X":LPS(LX)="?":LN(LX)=LX:LVS(LX)=LX
680 DIM TEXS(1):FOR I=0 TO 1:READ TEXS(I):NEXT I
690 DATA "A","P"
990 RETURN
1000 REM ***** READ IN MACROS *****
1010 GOSUB 10000                  'READ AND PARSE LINE
1020 IF LEFTS(LS,3)<>"MAC" THEN RETURN 'SHOULD SAY "MAC TYPE"
1030 XS=LIS(1)                    'GET MAC TYPE
1035 PRINT:PRINT " ***** READING IN MACRO: ";XS;" *****"
1040 TPTR=-1
1050 GOSUB 11000                  'SEARCH FOR TYPE
1060 IF FOUND=-1 THEN 1100        'CHECK FOR DUPES
1065 IF TPTR=-1 THEN 1100
1070 PRINT "THIS MACRO NAME ALREADY EXISTS, SHOULD IT BE REPLACED WITH THIS
ONE?"
1080 INPUT "ENTER R(eplace) OR N(oreplace)";QS
1090 IF LEFTS(QS,1)="N" THEN 1200 'SKIP TIL NEXT END
1100 TPTR=NLGIC                  'POINT TO NEXT LOGIC LOCATION
1110 GOSUB 11100 :MT=FO          'ADD TYPE TO LIST
1150 GOSUB 2000                  'READ CKT DESCRIPTION
1160 GOSUB 1500                  'CHECK FOR MACRO ERRORS
1170 GOTO 1000                  'LOOP FOR NEXT MACRO
1200 REM *** SKIP THIS MACRO ****
1210 GOSUB 10000:IF LIS(0)<>"END" THEN GOTO 1210
1220 GOTO 1000                  'GET NEXT MACRO
1500 REM ***** CHECK FOR MACRO ERRORS *****
1510 PRINT:PRINT" ***** CHECKING MACRO ";TYS(MT);" FOR ERRORS *****"
1520 X1=TY(MT):GOSUB 12000        'CLEAR ARRAY
1530 FOR I=1 TO 5                'STEP THRU INPUTS
1540 X=LO(X1,I):GOSUB 12100      'MARK EACH SIG #
1550 NEXT I
1560 X1=X1+1
1570 X=LO(X1,0):IF TYS(X)="*" THEN GOTO 1530 'LOOP FOR CONTINUES
1580 ST=X1
1590 GOSUB 12200                  'MARK AND CHECK OUTPUTS
1600 GOSUB 12300                  'CHECK INPUTS
1610 ER=0                        'CLEAR ERROR FLAG, MAC ERRORS DONT COUNT.
1620 RETURN
2000 REM ***** READ IN LOGIC DESCRIPTION *****
2010 SL=NL:NAS(0)="0":NNAM=1     'SIGNAL 0 IS PREDEFINED

```


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Z8 BASIC COMPUTER/CONTROLLER



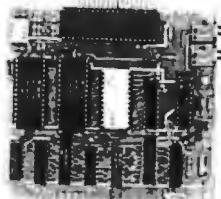
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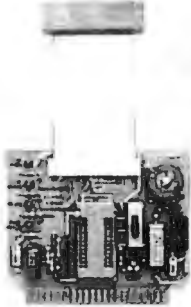
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Z8 EPROM PROGRAMMER

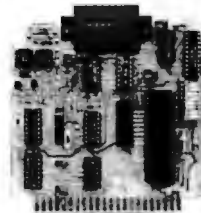


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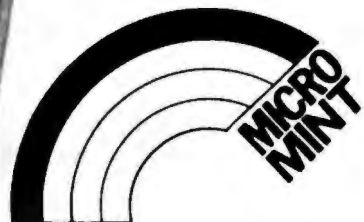
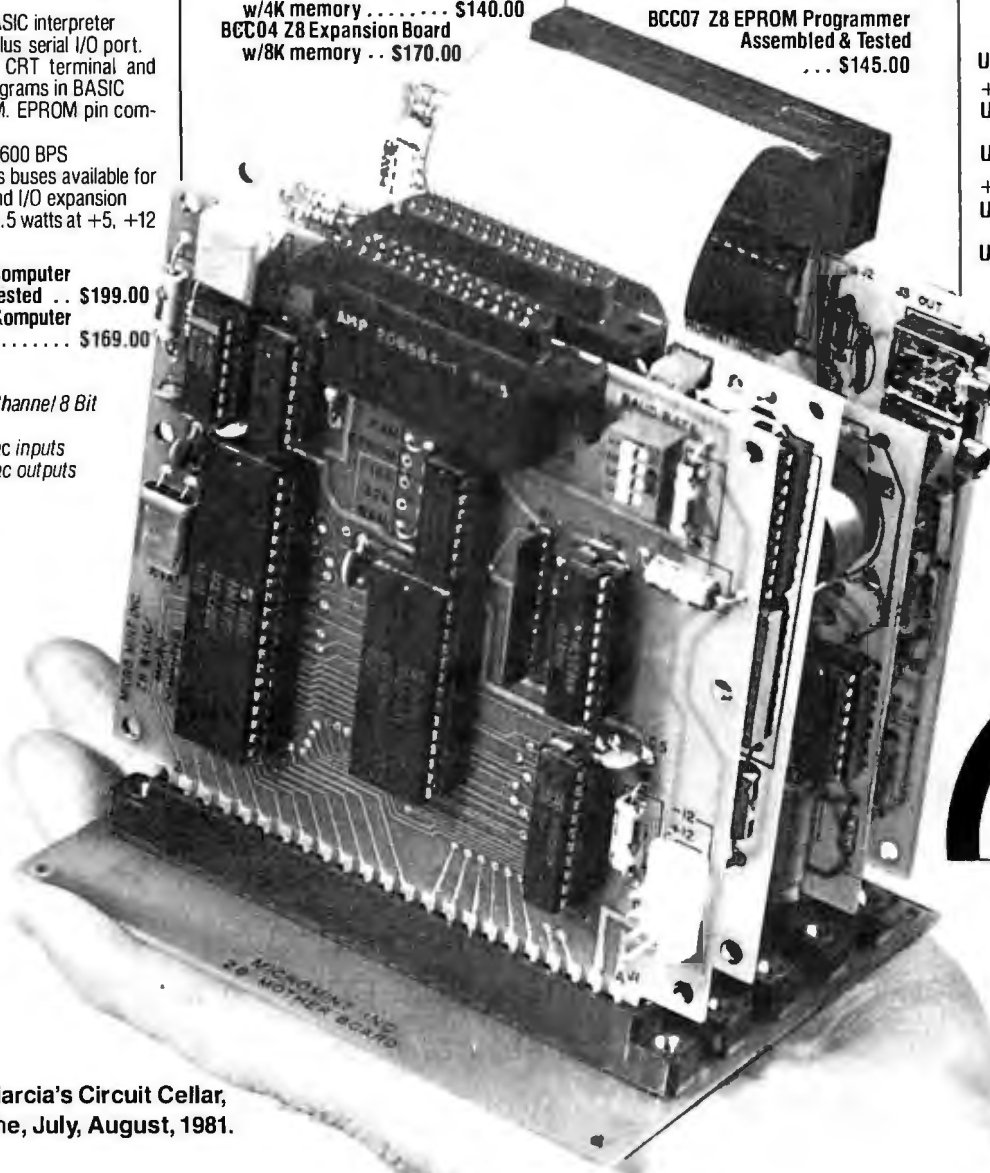
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```

2020 FOR I=1 TO MN:NAS(I)="":NEXT I      'CLEAR ALL NAMES
2040 GOSUB 10000                          'READ NEXT LINE
2050 XS=LI$(0)                            'LOOK UP TYPE
2060 GOSUB 11000:IF FO=-1 THEN GOSUB 11100 'ADD IF NOT FOUND
2070 T(0)=FO
2080 FOR I=1 TO 7                          'GET ALL NAMES
2090 XS=LI$(I):GOSUB 11500                'LOOK UP NAME
2100 IF FO=-1 THEN GOSUB 11600            'ADD IF NOT FOUND
2110 T(I)=FO:NEXT I
2120 GOSUB 20000                          'ADD T(0)-T(7) TO LO ARRAY
2130 IF T(0)<>0 THEN GOTO 2040             'GET NEXT ELEMENT
2140 RETURN                                'RETURN ON "END"
3000 REM ***** EXPAND MACROS *****
3010 ST=SLGIC:FM=0                        'START AT LOGIC ARRAY, CLEAR MAC FLAG
3020 FOR I=ST TO NLGIC-1                  'SCAN ENTIRE LIST
3030 IF LO(I,0)<=NPRIM THEN 3100          'SKIP PRIMITIVES
3040 GOSUB 30000                          'BUILD CORRESPONDENCE
3050 GOSUB 31000                          'DO EXPANSION
3060 FM=1
3100 NEXT I
3110 REM REPEAT PROCEDURE UNLESS NO MACROS WERE FOUND
3120 IF FM<>0 THEN GOTO 3000
3130 RETURN
3500 REM ***** LIST OF EXPANDED LOGIC DESCRIPTION *****
3510 CLS:PRINT " ***** EXPANDED LOGIC DESCRIPTION *****":PRINT
3511 PRINT "TYPE";TAB(20);"INPUTS";TAB(50);"OUTPUTS"
3512 FOR I=1 TO 5:PRINTTAB(8*I);I;:NEXT I:PRINTTAB(48);"Q";TAB(56);"Q-"
3515 NAS(0)=" "
3520 FOR I=SL TO NL-1
3530 PRINT TY$(LO(I,0));
3540 FOR II=1 TO 7
3550 PRINT TAB(8*II);
3552 XX=LO(I,II):IF XX<0 THEN PRINT "#";-XX;:GOTO 3560
3554 PRINT NAS(XX);
3560 NEXT II:PRINT:NEXT I
3565 NAS(0)="O"
3570 RETURN
4000 REM ***** READ IN EXTERNAL DESCRIPTION *****
4010 NEX=0:GOSUB 10000 'IGNORE "EXTERNAL"
4020 GOSUB 10000 'GET EXTERNAL DESCRIPTION
4030 IF LI$(0)="END" THEN RETURN
4040 FOR I=0 TO 1:IF LI$(0)=TEX$(I) THEN T(0)=I 'GET TYPE OF EXT
4050 NEXT I
4060 XS=LI$(1):GOSUB 11500 'GET SIGNAL NUMBER FROM NAME
4070 IF FO=-1 THEN GOTO 4020 'IGNORE IF UNDEFINED
4080 T(1)=FO
4090 FOR I=0 TO 3:IF LI$(2)=LV$(I) THEN T(2)=LV(I) 'LOGIC VALUE
4100 NEXT I
4110 FOR I=3 TO 9:T(I)=VAL(LI$(I)):NEXT I 'CHANGE TIMES
4120 GOSUB 21000 'STORE T(0)-T(9) IN EX ARRAY
4130 GOTO 4020 'LOOP TILL "END"
5000 REM ***** CHECK FOR ERRORS *****
5010 GOSUB 12000:MM=0 'CLEAR OLD ARRAY
5020 FOR I=0 TO NEX 'MARK EXTERNALS FIRST
5030 OL(EX(I,1))=1
5040 NEXT I
5050 ST=SL:GOSUB 12200 'MARK AND CHECK OUTPUTS
5060 GOSUB 12300 'CHECK ALL INPUTS
5070 RETURN
6000 REM ***** READ IN SAMPLE POINTS *****
6010 NS=0:ON ERROR GOTO 6200
6020 GOSUB 10000 'READ IN LINE (IF ANY, IF NOT, GOTO 6200
6030 GOSUB 10000 'GET REAL LINE (PRIOR ONE WAS "EXTE..")
6040 IF LI$(0)="END" THEN ON ERROR GOTO: RETURN
6050 FOR I=0 TO 10
6060 XS=LI$(I):IF XS=" " THEN 6100 'GET NAME, IGNORE BLANKS
6070 GOSUB 11500:IF FO=-1 THEN 6100 'LOOK UP NAME, IGNORE UNDEFINED
6080 IF NS<14 THEN NS=NS+1:SA(NS)=FO
6100 NEXT I
6110 GOTO 6030 'LOOP TILL "END"
6200 REM ***** ERROR TRAP FOR END OF INPUT *****
6210 LS="END":RESUME NEXT
6500 REM ***** SELECTIVE TRACE TABLE BUILD *****
6510 STF=0 'SEL. TRACE FLAG
6520 A1=(NL+NN+(TL+NN))*2 'REQUIRED RAM (NN FOR 1ST, TL+NN FOR 2ND,NL FOR OTH
6530 A2=MEM-200 'AVAILABLE (ASSUME MAX 200 NEEDED LATER)
6540 IF A2<A1 THEN RETURN 'NOT ENOUGH RAM, FORGET IT
6550 PRINT:PRINT " ***** BUILDING SELECTIVE TRACE TABLE *****":PRINT
6560 STF=1:DIM SO(NL),S1(NN),S2(TL+NN)
6570 T1=0 'T1 POINTS TO SECOND ARRAY
6580 FOR I=1 TO NN:S1(I)=T1 'FOR ALL NODES
6590 FOR J=SL TO NL:FOR K=1 TO 5 'SCAN ALL INPUTS TO LOGIC
6600 IF LO(J,K)=I THEN S2(T1)=J:T1=T1+1 'ON MATCH, SAVE LOGIC #
6610 NEXT K:NEXT J
6620 S2(T1)=-1:T1=T1+1 '-1 = "SENTINEL" BETWEEN BLOCKS
6630 NEXT I
6635 GOSUB 6700 'PRINT OUT LOAD TABLE
6640 RETURN
6700 REM **** PRINT OUT OF LOAD TABLE *****
6710 PRINT " ***** LOAD TABLE *****":PRINT "NODE DRIVEN
ELEMENTS"
6720 FOR II=1 TO NN:PRINT NAS(II);TAB(10);
6730 T1=S1(II)
6740 IF S2(T1)=-1 THEN GOTO 6760
6750 PRINT S2(T1)-SL+1;:T1=T1+1:GOTO 6740
6760 PRINT:NEXT II:RETURN
7000 REM ***** DO SIMULATION *****
7010 DIM NE(NN),ME(MM,1):IF ER<>0 THEN RETURN 'NO SIMULATION ON ERROR
7020 NN=NN-1:NL=NL-1:NE=NE-1 'POINT TO ENDS, NOT NEXT
7030 GOSUB 6500 'BUILD SELECTIVE TRACE TABLE
7040 GOSUB 7300 'INITIALIZE, GET SAMPLE TIMES
7050 GOSUB 8000 'GET EXTERNALS SCHED FOR THIS TIME
7060 GOSUB 8500 'MOVE NEW TO OLD, MARK CHANGES
7070 GOSUB 9000 'PRINT OUT OLD, GET RESPONSE
7080 IF QS="Q" THEN RETURN
7090 IF QS="R" THEN GOTO 7040 'RESTART
7100 GOSUB 40000 'SIMULATE LOGIC DEVICES
7110 GOSUB 7500 'RECALC RIPPLE TIME
7120 GOTO 7050 'LOOP
7300 REM *****INITIALIZE FOR SIMULATION *****
7310 FOR I=0 TO NN:NE(I)=LX:NEXT I 'ALL NEWS = LOGIC X
7320 FOR I=SL TO NL:LO(I,8)=LX:NEXT I 'ALL INTERNAL LATCHES =X
7330 PRINT:RI=0:INPUT "ENTER SAMPLE START TIME, INCREMENT TIME";S9,S2
7340 IF S2=0 THEN S2=1 'CANT HAVE 0 INCREMENT.
7350 E9=32767:FOR I=0 TO NEX: E3=EX(I,3):GOSUB 8200:NEXT I 'PUT
EXTERNALS START TIME INTO NEXT SCHEDULED TIME
7360 IF NS=0 THEN GOSUB 9660 'GET NAMES FOR SAMPLING IF NOT READ
7370 IF MM<>0 THEN GOSUB 7400 'SET ASIDE MEMORY FOR SREGs
7390 QS="":RETURN
7400 REM SET ASIDE MEM FOR SREGs
7410 M1=0 'M1 POINTS TO NEXT AVAIL MEM
7415 FOR I=0 TO MM:ME(I,0)=LX:ME(I,1)=LX:NEXT I

```


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Listing 1 continued:

```

7420 FOR I=SL TO NL      'THE LATCH POS. WILL CONTAIN PTR.
7430 IF TYS(LO(I,0))="SREG" THEN LO(I,8)=M1:M1=M1-LO(I,2)
7440 NEXT I:RETURN
7500 REM ***** RECALCULATE RIPPLE TIME *****
7510 IF C9=1 THEN RI=RI+1:RETURN
7520 RI=E9:IF RI>S9 THEN RI=S9 'GET MIN OF E9 (EXT) AND S9 (SAMPLE)
7530 RETURN
8000 REM ***** GET NEXT SCHEDULED EXTERNAL *****
8010 IF RI<>E9 THEN RETURN
8020 E9=32767
8030 FOR I=0 TO NEX      'SCAN EACH EXTERNAL STIMULI
8035 E3=EX(I,10)
8040 IF E3=RI THEN GOSUB 8100 'PROCESS IF SCHED.
8045 GOSUB 8200
8050 NEXT I
8060 RETURN
8100 REM *** FIND NEXT SCHED CHANGE (OR FIRST VAL) ***
8110 E0=EX(I,0):E1=EX(I,1):E2=EX(I,2):E3=EX(I,3)
8120 Y=NE(E1)           'CURRENT NEW VALUE
8130 IF RI=E3 THEN Y=LN(E2) 'FIRST SCHED VALUE
8140 NE(E1)=LN(Y)      'STORE COMPLEMENT OF NEW (OR FIRST SCHED VALUE)
8150 REM SCHEDULE NEXT CHANGE
8160 IF TEXS(E0)="P" THEN E3=EX(I,10)+EX(I,4): RETURN
8170 J=4:E3=32767      'SCAN ENTRIES OF APERIODIC SIGNAL
8175 IF J>=9 THEN RETURN
8180 IF EX(I,J)<=RI THEN J=J+1 : GOTO 8175
8190 E3=EX(I,J): RETURN
8200 REM STORE NEXT SCHED, KEEP TRACK OF MIN (E9)
8210 EX(I,10)=E3      '10TH ENTRY IS NEXT SCHED TIME FOR THIS SIGNAL
8220 IF E9>E3 THEN E9=E3 'E9 IS NEXT SCHED TIME FOR ANY SIG.
8230 RETURN
8500 REM *****MOVE NEW TO OLD, MARK CHANGES *****
8510 C9=0:IF STF<>0 THEN GOSUB 8700 'CLEAR CHANGE FLAGS
8520 FOR I=1 TO NN      'GO THRU ALL NODES
8530 IF NE(I)<>OL(I) THEN GOSUB 8600 'MARK CHANGES
8540 NEXT I
8560 RETURN
8600 C9=1:OL(I)=NE(I) 'NOTE CHANGE
8610 IF STF=0 THEN RETURN
8620 II=SL(I)          'MARK ALL DRIVEN ELEMENTS
8630 J=S2(II):IF J=-1 THEN RETURN 'RETURN ON HITTING A SENTINEL
8640 SO(J)=1:II=II+1:GOTO 8630 'MARK IT, GET NEXT LOGIC NUMBER
8700 REM CLEAR SO
8710 FOR II=SL TO NL:SO(II)=0:NEXT II
8720 RETURN
9000 REM ***** DISPLAY LOGIC VALUES
9002 PRINT @57,RI;
9005 IF S9<>RI THEN RETURN
9010 IF PC=0 THEN GOSUB 9100 'PUT NAMES ON SCREEN IF START
9020 GOSUB 9500           'PRINT VALUES DOWN SCREEN
9025 S9=S9+S2
9030 PC=PC+1:IF PC>60 THEN GOSUB 9600 'END OF SCREEN, GET INPUT
9040 RETURN
9100 REM ***** SET UP DISPLAY (NAMES AND TICS) *****
9110 PC=11
9120 CLS:GOSUB 9200      'DO TIC MARKS
9125 PRINT @5,"TIME";:PRINT @10,RI;
9130 X=128
9140 FOR I=1 TO NS:PRINT @X,NAS(SA(I));
9150 X=X+64:NEXT I
9160 RETURN

```

```

9200 REM *****PRINT TIC MARKS *****
9210 FOR X=75 TO 124:PRINT @X,CHRS(176);:NEXT X
9220 X=75
9230 FOR I=1 TO 5:PRINT @X,CHRS(191);:PRINT @X+5,CHRS(188);
9240 X=X+10:NEXT I:RETURN
9500 REM *****PRINT VALUES DOWN COLUMN *****
9510 X=PC+128          'DOWN 2 LINES
9520 FOR I=1 TO NS:Y=OL(SA(I)) 'GET LOGIC VALUE
9530 PRINT @X,LP$(Y);:X=X+64:NEXT I
9540 RETURN
9600 REM ***** FULL SCREEN, GET RESPONSE *****
9610 PRINT @15,"C(hange),R(eset),Q(uit), OR ANY OTHER KEY";
9620 QS=INKEY$:FORX=0TO100:NEXTX: PRINT @15,STRINGS(41," ");
9625 IF QS="" THEN GOTO 9610
9630 PC=0 ' RESET AND QUIT ARE HANDLED ON RETURN
9640 IF QS<>"C" THEN RETURN
9650 REM GET NEW SAMPLE NODE NAMES
9655 CLS
9660 PRINT "AS EACH CURRENT SAMPLE NODE IS DISPLAYED, HIT RETURN FOR NO
CHANGE, NEW NAME FOR CHANGE"
9670 FOR I=1 TO 14
9680 X$="":PRINT NAS(SA(I));:INPUT X$
9690 IF X$="" THEN GOTO 9720
9700 GOSUB 11500:IF FO=-1 THEN GOTO 9680
9710 SA(I)=FO
9720 IF SA(I)<>0 THEN NS=I
9730 NEXT I:RETURN
10000 REM ***** READ AND PARSE LINE *****
10010 READ L$          'INPUT IS DATA STATEMENTS, ASCII
10020 I=1:I3=1:LI=0:I2=LEN(L$) 'INITIALIZE
10030 I=I+1: IF I>I2 THEN 10050
10040 IF MID$(L$,I,1)<>" " THEN GOTO 10030 'FIND BLANK
10050 LIS(LI)=MID$(L$,I3,I-I3) 'PUT NAME IN LIS
10060 LI=LI+1
10070 IF LI>10 THEN RETURN
10080 I=I+1:IF I>I2 THEN 10120
10090 IF MID$(L$,I,1)=" " THEN GOTO 10080 'SKIP BLANKS
10100 I3=I:GOTO 10030
10120 FOR I=LI TO 10 'FILL REMAINING LISs
10130 LIS(I)="":NEXT I
10140 RETURN
11000 REM ***** LOOK UP TYPE *****
11010 FO=-1          'FOUND LOCATION
11020 FOR II=0 TO NTYPE-1
11030 IF X$=TYPES(II) THEN FO=II:TP=TYPTR(II)
11040 NEXT II
11050 RETURN
11100 REM ***** ADD TYPE *****
11110 IF FO=-1 THEN FO=NTYP:NTYP=NTYP+1
11120 IF FO>NTYP THEN NTYPE=FO
11130 TYPES(FO)=X$
11140 TYPTR(FO)=TPTR
11150 RETURN
11500 REM ***** LOOK UP SIGNAL NAME *****
11510 FO=-1:IF X$="" THEN X$="0" 'BLANK =NO SIGNAL
11515 IF LEFT$(X$,1)="#" THEN GOTO 11560 'NUMERIC INPUT
11520 FOR II=0 TO NNAM
11530 IF X$=NAMS(II) THEN FO=II
11540 NEXT II
11550 RETURN
11560 REM "NAME" IS A NUMBER, STORE AS NEGATIVE

```

Listing 1 continued on page 436

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MVP Forth is fig-FORTH updated to the FORTH-79 Standard Required Word Set. The source is public domain. Included are an editor, FORTH assembler, tools and utilities, making it compatible with the instructional book, *Starting FORTH*. Except for hardware dependencies, all high level FORTH is transportable between all systems. Modifications and extensions can be simplified through the use of MVP-FORTH Programming Aids and Meta and Cross Compilers.

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Listing 1 continued:

```

11570 XXS=RIGHTS(XS,LEN(XS)-1) 'STRIP OFF # SIGN
11580 FO=-VAL(XXS):IF FO=-1 THEN FO=0 'IGNORE N=1 (DEFAULT)
11590 RETURN
11600 REM ***** ADD NAME TO LIST *****
11610 IF FO=-1 THEN FO=NNAM:NNAM=NNAM+1
11620 IF FO>NNAM THEN NNAM=FO+1
11630 NAMS(FO)=XS
11640 RETURN
12000 REM ***** CLEAR OLD ARRAY *****
12010 FOR I=0 TO MN:OL(I)=0:NEXT I
12020 TL=0:RETURN
12100 REM ***** MARK (OUTPUTS) AND CHECK FOR DUPES *****
12110 IF X=0 THEN RETURN
12120 IF OL(X)<>0 THEN GOSUB 12150
12130 OL(X)=1:RETURN
12150 PRINT "ERROR, MULTIPLE DEFINITION OF OUTPUT ";NAS(X)
12155 GOSUB 12160:RETURN
12160 INPUT "ENTER I(gnore) TO IGNORE ERROR, ANY OTHER KEY TO PREVENT
SIMULATION";Q$
12170 IF LEFTS(Q$,1)<"I" THEN ER=1
12180 RETURN
12200 REM ***** CHECK FOR MULTIPLE OUTPUTS *****
12210 X1=ST
12220 FOR I=X1 TO NL-1
12230 FOR J=6 TO 7
12240 X=LO(I,J):GOSUB 12100 'MARK AND CHECK
12250 NEXT J:NEXT I:RETURN
12300 REM ***** CHECK FOR DEFINED INPUTS *****
12310 X1=ST
12320 FOR I=X1 TO NL-1
12330 FOR J=1 TO 5
12340 X=LO(I,J):GOSUB 12400 'CHECK FOR MARK
12345 IF X<0 THEN MM=MM-X 'KEEP TRACK OF MEM REQUIRED
12350 NEXT J:NEXT I:RETURN
12400 REM ***** CHECK FOR MARK *****
12410 IF X<=0 THEN RETURN
12420 IF OL(X)=0 THEN GOSUB 12450
12430 OL(X)=OL(X)+1:TL=TL+1:RETURN
12450 PRINT "ERROR, UNDEFINED INPUT ";NAS(X)
12460 GOSUB 12160:RETURN
12470 ER=1:RETURN
20000 REM ***** ADD T(0) THRU T(7) TO LOGIC ARRAY *****
20010 FOR II=0 TO 7
20020 LO(NL,II)=T(II)
20030 NEXT II
20040 PRINT TYS(LO(NL,0));" ";:FOR II=1 TO 7
20050 XX=LO(NL,II):IF XX<0 THEN PRINT "#";-XX;" ";:GOTO 20070
20060 PRINT NAS(XX);" ";
20070 NEXT II:PRINT:NL=NL+1:RETURN
21000 REM ***** ADD T(0) THRU T(9) TO EXTERNAL ARRAY ****
21010 FOR II=0 TO 9
21020 EX(NE,II)=T(II)
21030 NEXT II
21040 PRINT TYS(EX(NE,0));" ";NAS(EX(NE,1));" ";LVS(EX(NE,2));" ";:FOR II=3 TO
9:PRINT EX(NE,II);:NEXT II:PRINT
21050 NE=NE+1:RETURN
30000 REM ***** BUILD MACRO CORRESPONDENCE ARRAY *****
30010 REM I=EL #, J=MACRO POINTER
30020 LO=I:X=LO(I,0):J=TYPE(X):Y=LO(J,0):M1=J:OL(0)=0
30025 PRINT:PRINT" ***** EXPANDING CALL TO MACRO: ";TYS(X);" *****"
30030 REM USES OLD VALUE ARRAY FOR EXPANSION (SINCE NOT USED YET)
30040 FOR K=1 TO MNAM:OL(K)=-1:NEXT K 'CLEAR ARRAY
30100 IF X<Y THEN GOTO 30900 'ERROR IF NO MATCH ON TYPE
30110 FOR K=1 TO 5 'DO THE INPUTS FIRST
30120 I1=LO(M1,K):I2=LO(LO,K) 'I1=MAC #, I2=TRUE SIG #
30130 IF I1=0 AND I2<>0 THEN GOTO 30150 'IGNORE UNDEF. INPUTS
30140 OL(I1)=I2 'OL WILL CONTAIN TRUE SIGNAL #S
30150 NEXT K
30160 FOR K=6 TO 7 'DO OUTPUTS NOW (DIFF PROCESSING OF OS)
30170 I1=LO(M1,K):I2=LO(LO,K) 'I1=MAC, I2=TRUE
30180 IF I1<>0 AND I2=0 THEN GOTO 30195 'IGNORE UNUSED OUTS
30190 OL(I1)=I2
30195 NEXT K
30200 REM OK, GOT CORRESPONDENCE, DELETE THIS CALL
30210 GOSUB 30500 'MOVE LOGIC ARRAY UP ONE.
30220 M1=M1+1:Y=LO(M1,0):X=LO(LO,0) 'CHECK FOR CONTINUE
30230 IF TYS(Y)="" THEN GOTO 30100 'LOOP FOR CONTINUES
30240 RETURN
30500 REM ***** MOVE EL ARRAY UP ONE (DELETE CURRENT LINE) **
30510 NL=NL-1
30520 FOR K=LO TO NL-1 'DO ENTIRE ARRAY
30530 FOR K1=0 TO 8 'ALL ENTRIES
30540 LO(K,K1)=LO(K+1,K1) 'MOVE UP EACH ENTRY
30550 NEXT K1:NEXT K
30560 RETURN
30900 REM ***** MISMATCH ON MACRO CALL *****
30910 REM THIS SHOULDNT HAPPEN, BUT NEVER CAN TELL.
30920 PRINT "MISMATCH ON MACRO CALL, CANT CONTINUE"
30930 STOP
31000 REM ***** ADD EXPANDED MACRO TO ELEMENT ARRAY *****
31010 NL=NL-1 'POINT TO PREVIOUS "END"
31020 T(0)=LO(M1,0) 'TYPE
31030 FOR K=1 TO 7
31040 X=LO(M1,K) 'MACRO SIGNAL NUMBER
31045 IF X<0 THEN T(K)=X:GOTO 31070 'DIRECT STORE OF -#S
31050 IF OL(X)=-1 THEN GOSUB 31500 'ADD SIG # IF NOT DEFINED
31060 T(K)=OL(X) 'GET REAL SIGNAL NUMBER
31070 NEXT K
31080 GOSUB 20000 'STORE T(0)-T(9) INTO LOGIC ARR
31090 M1=M1+1:IF T(0)<>0 THEN GOTO 31020 'REPEAT TILL END
31100 RETURN
31500 REM ***** ADD UNIQUE NAME, NUMBER *****
31510 OL(X)=NNAM:XS=STR$(NNAM)
31520 NAMS(NNAM)=""&"RIGHTS(XS,LEN(XS)-1)
31530 NNAM=NNAM+1
31540 RETURN
40000 REM ***** SIMULATE GATES *****
40010 IF C9=0 THEN RETURN 'NO ACTIVITY
40020 L=SL
40030 IF STF<> 0 THEN IF SO(L)=0 THEN GOTO 40050
40040 GOSUB 40100 'SIMULATE THIS GATE
40050 L=L+1:IF L<=NL THEN GOTO 40030
40060 RETURN
40100 REM **** SIMULATE THIS GATE (L) *****
40110 LT=LO(L,0):FOR I=1 TO 5:IN(I)=LO(L,I):NEXT I
40120 Q0=LO(L,6):Q1=LO(L,7) 'GOT TYPE,INS,OUTS
40130 ON LT GOSUB
40100,41000,41110,41100,41210,41200,41500,41600,41700,41800,41900
40140 REM AND NAND OR NOR XOR XNOR DFF JKFF CNTR PLSR
SREG
40150 GOSUB 40200 'STORE Y INTO Q AND Y- INTO Q-
40160 RETURN

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Listing 1 continued:

```

40200 REM ***** STORE Q AND Q- *****
40210 NE(QO)=Y:NE(Q1)=LN(Y):RETURN
40300 REM *** GET Q INTO XQ *****
40310 OL(O)=LN(OL(Q1)):XQ=OL(QO):RETURN
41000 X=QO:QO=Q1:Q1=X '***** NAND GATE *****
41010 OL(O)=L1:Y=L1 '***** AND GATE *****
41020 FOR I=1 TO 5:Y=Y AND OL(IN(I)):NEXT I
41030 RETURN
41100 X=QO:QO=Q1:Q1=X '***** NOR GATE *****
41110 OL(O)=LO:Y=LO '***** OR GATE *****
41120 FOR I=1 TO 5:Y = Y OR OL(IN(I)): NEXT I
41130 RETURN
41200 X=QO:QO=Q1:Q1=X '***** XNOR GATE *****
41210 OL(O)=LX '***** XOR GATE *****
41220 YO=OL(IN(1)):Y1=LN(YO):YC=OL(IN(2)) 'DO AS MUX
41230 GOSUB 45000:RETURN
41500 REM ***** D FLIP FLOP *****
41510 GOSUB 40300:OL(O)=LX:XD=OL(IN(1)):XC=OL(IN(3)) 'GET VALUES
41520 XL=LO(L,8):OL(O)=L1:XR=OL(IN(4)):XS=OL(IN(5)) 'MORE INPUTS
41530 GOSUB 45100:LO(L,8)=YL 'SR FUNCTION CALL, YL=LATCH
41540 RETURN
41600 REM ***** J-K FLIP FLOP *****
41610 REM SET UP AS A MULTIPLEXED DFF, Q CONTROLS MUX
41620 GOSUB 40300:XM=XQ:OL(O)=LX:XC=OL(IN(3))
41630 DO=OL(IN(1)):D1=LN(OL(IN(2))) 'D=J*Q- OR K-*Q
41640 OL(O)=L1:XR=OL(IN(4)):XS=OL(IN(5)):XL=LO(L,8)
41650 GOSUB 45300:LO(L,8)=YL:RETURN 'DO AS MUX-D
41700 REM *** PARALLEL LOAD COUNTER *****
41710 OL(O)=LX:YE=OL(IN(2)):XC=OL(IN(3)):OL(O)=LO:XM=OL(IN(4))
41720 OL(O)=L1:XR=OL(IN(5)):XS=L1
41730 GOSUB 40300:XL=LO(L,8) 'GET Q AND LATCH
41740 YC=YE:YO=XQ:Y1=LN(YO) 'COUNT =COUNT- IF ENAB=1, (MUX)
41750 GOSUB 45000:DO=Y:D1=OL(IN(1)):GOSUB 45300 'MUX THEN MUXD
41760 LO(L,8)=YL:IF TYS$(LO(L+1,0))<>"*" THEN RETURN
41770 GOSUB 40200:L=L+1:IN(1)=LO(L,1):QO=LO(L,6):Q1=LO(L,7)
41780 YE=YE AND Y : GOTO 41730 'LOOP AFTER GETTING NEXT CARD
41800 REM *** PARALLEL LOAD SHIFT REGISTER *****
41810 OL(O)=LX:DO=OL(IN(2)):XC=OL(IN(3)):OL(O)=LO:XM=OL(IN(4))
41820 OL(O)=L1:XR=OL(IN(5)):XS=L1
41830 OL(O)=LX:D1=OL(IN(1)):GOSUB 40300:XL=LO(L,8):GOSUB 45300 'DO MUX-DFF
41840 LO(L,8)=YL:IF TYS$(LO(L+1,0))<>"*" THEN RETURN
41850 GOSUB40200:L=L+1:IN(1)=LO(L,1):QO=LO(L,6):Q1=LO(L,7):DO=Y
41860 GOTO 41830 'LOOP AFTER STORING Q AND GETTING NEXT
41900 REM ***** N BIT SHIFT REGISTER *****
41910 IF IN(2)=0 THEN GOTO 41500 '(1 BIT IS SAME AS DFF)
41920 OL(O)=LX:XD=OL(IN(1)):XC=OL(IN(3)) 'GET D AND CLOCK
41930 OL(O)=L1:XR=OL(IN(4)):XS=OL(IN(5)) 'GET RESET AND SET
41940 M1=LO(L,8) 'LATCH POS. IS USED TO STORE MEMLOC.
41950 FOR I=1 TO -IN(2) 'LOOP THRU FOR EACH STAGE (N IS STORED -)
41960 XL=ME(M1,0):XQ=ME(M1,1) 'GET LATCH AND Q FROM MEM
41970 GOSUB 45100:XD=XQ:ME(M1,0)=YL:ME(M1,1)=Y 'DO SR AND STORE
41980 M1=M1+1:NEXT I
41990 RETURN
45000 REM ***** MUX FUNCTION *****
45010 Y=(YO AND LN(YC)) OR (Y1 AND YC) OR (YO AND Y1)
45020 RETURN
45100 REM ***** SHIFT REGISTER FCN*****
45110 YO=XD:YC=XC:Y1=XL '1ST MUX, CLOCKS IN XD ON CLOCK LOW
45120 GOSUB 45000 :GOSUB 45200 'MUX FCN AND SET,RESET
45130 YL=Y:YO=XQ: GOSUB 45000:GOSUB 45200 ' " " " AFTER STORING LATCH
45140 RETURN
45200 REM ***** SET AND RESET FUNCTION *****
45210 Y= (Y OR LN(XS)) AND XR: RETURN
45300 REM ***** MUX AND DFF *****
45310 YO=DO:Y1=D1:YC=XM:GOSUB 45000 'DO MUX
45320 XD=Y:GOSUB 45100 'DO DFF
45330 RETURN
50000 DATA MACRO MUX
50010 DATA MUX AO A1 C 0 0 0 Q
50020 DATA AND AO C- 0 0 0 X1
50030 DATA AND A1 C 0 0 0 X2
50040 DATA AND AO A1 0 0 0 X3
50050 DATA OR X1 X2 X3 0 0 0 Q
50060 DATA NAND C 0 0 0 0 C-
50070 DATA END
50080 DATA MACRO MUXD
50090 DATA MUXD AO A1 C CLK RSET Q
50100 DATA MUX AO A1 C 0 0 0 D-IN
50110 DATA DFF D-IN 0 CLK RSET 0 Q
50120 DATA END
50130 DATA MACRO CNTRM
50140 DATA CNTRM D1 LOAD CLOCK ENAB RSET Q1
50150 DATA * D2 0 0 0 0 Q2
50160 DATA * D3 0 0 0 0 Q3
50170 DATA * D4 0 0 0 0 Q4
50180 DATA AND ENAB 0 0 0 0 E1
50190 DATA XOR E1 Q1 0 0 0 DC1
50200 DATA MUXD DC1 D1 LOAD CLOCK RSET Q1
50210 DATA AND ENAB Q1 0 0 0 E2
50220 DATA XOR E2 Q2 0 0 0 DC2
50230 DATA MUXD DC2 D2 LOAD CLOCK RSET Q2
50240 DATA AND ENAB Q1 Q2 0 0 0 E3
50250 DATA XOR E3 Q3 0 0 0 DC3
50260 DATA MUXD DC3 D3 LOAD CLOCK RSET Q3
50270 DATA AND ENAB Q1 Q2 Q3 0 0 E4
50280 DATA XOR E4 Q4 0 0 0 DC4
50290 DATA MUXD DC4 D4 LOAD CLOCK RSET Q4
50300 DATA END
50500 DATA ELEMENTS
50510 DATA CNTR DATA0 ENABLE CLOCK LOAD RSET QO
50520 DATA * DATA1 0 0 0 0 Q1
50530 DATA * DATA2 0 0 0 0 Q2
50540 DATA * DATA3 0 0 0 0 Q3
50550 DATA CNTRM DATA0 LOAD CLOCK ENABLE RSET QOM
50560 DATA * DATA1 0 0 0 0 Q1M
50570 DATA * DATA2 0 0 0 0 Q2M
50580 DATA * DATA3 0 0 0 0 Q3M
50590 DATA END
60000 DATA EXTERNALS
60010 DATA P CLOCK 0 5 10
60020 DATA A RSET 0 0 2
60030 DATA A ENABLE 1 20 100 150 170 200
60040 DATA A DATA0 0 0 10 160
60050 DATA A DATA1 1 0 10 160
60060 DATA A DATA2 0 0 10 160
60070 DATA A DATA3 1 0 10 160
60080 DATA A LOAD 1 10 20 220 250
60090 DATA END
65000 DATA OUTPUTS
65010 DATA DATA1 DATA2 CLOCK LOAD ENABLE RSET
65020 DATA QO QOM Q1 Q1M Q2 Q2M Q3 Q3M
65030 DATA END

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Information Hiding

A Brief Example

*Consider this helpful alternative
to structured programming and modular design.*

Gregg Williams
Senior Editor

While writing the display routine for a game-related program, I decided against a possible change in implementation detail because it would require me to rewrite almost the entire program. This is not an unusual situation for programmers to find themselves in. Had it not been for a vague memory that brought two words to mind, I probably would have continued to find myself in the same situation in years to come. The words were *information hiding*, recalled from an article I had read some time ago. They prompted me to do some thinking about program design, and the work I did refining the display routine algorithm became the basis for the material in this article.

The DRAWCUBE Problem

The problem was simple: I had a 3 by 3 cube (the Rubik's Cube puzzle), with each 1 by 1 square on the face of the cube being one of six colors; the task was to display the state of the cube on the video display of the computer I was programming. I quickly settled on the details of the representation: a given cube could be described by 54 consecutive bytes of

memory (the larger problem to be solved—writing a game-related program—dictated that a large number of cube images had to be simultaneously stored in memory); each 1 by 1 square (to be called a *unit* for the rest of this article) was to be stored as a number from 1 to 6 in 1 byte of memory, with the sequence of bytes

being taken as six faces of 9 bytes each and the units of a face being stored in row-major order. Also, the cube was to be displayed as a "cross" of six squares that fold together to make a cube (see figure 1).

With these representation choices already decided, I wrote the program DRAWCUBE1, shown in listing 1. The program is straightforward in design. The subroutine DRAWFACE draws one face as a 3 by 3 square, starting at the current cursor position. The subroutine UPDATEBASE positions the cursor to the upper left-hand corner of the next face to be drawn. Finally, the main program coordinates these two subroutines, thus displaying the cube represented in memory starting at the location BEGINCUBE. What could be simpler?

I found to my dismay that a lot of things could be simpler. The one change I rejected (because of the rewriting it would necessitate) led to another and another until I had a list of what-if suppositions, each of which would require major revisions to the DRAWCUBE program. For example:

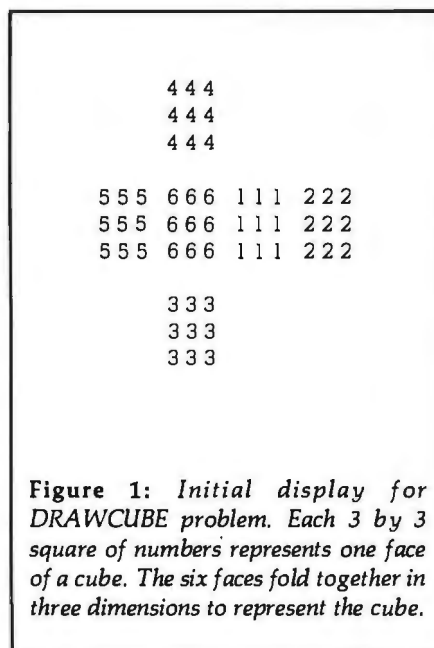


Figure 1: Initial display for DRAWCUBE problem. Each 3 by 3 square of numbers represents one face of a cube. The six faces fold together in three dimensions to represent the cube.

- What if units were packed two to a byte?
- What if I wanted a perspective display that shows only three faces of the cube?
- What if each unit that had not changed since the last display were flagged in the top bit of its representation in memory?

These and other disruptive changes are listed in table 1.

Alternate Solutions

Design by flowcharting: My first attempt at writing the DRAWCUBE program represents a superficial level of design that most of us usually work at; it could easily be called "design by flowcharting" because it draws heavily on the structure of the coded program that the programmer already has in mind.

Even though the program in listing 1 uses structured programming, which is generally considered to be good programming practice, there is something vitally wrong with it. The flaw is invisible until you extrapolate to a program a thousand times the size of this one. It then becomes obvious that the program in question requires detailed knowledge of the implementation decisions made before the program was designed or coded. A well-written program, however, should be as independent of implementation decisions as possible; it should concentrate on the details of the *algorithm*, not the details of the implementation decisions.

Design by decomposition into modules: A somewhat deeper analysis of the problem might result in the design of the program as a series of modules, each of which is as independent of the others as possible. In such a simple example as I am considering here, the modules represent the three basic actions of any program—input, process, and output—as follows: input the cube from memory into a three-dimensional array; do any processing on the array that might be required (in this example, nothing); and display (or output) the cube on the video display screen.

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This modular approach separates code *temporally*. For example, the cube contents are copied into an array before any processing or display operations take place; because of this, any change in the way a cube is stored can affect code only up to the point at which the cube is copied into the array. This temporal isolation of implementation decisions is a step in the right direction, but it is still somewhat related to the "design-by-flowcharting" philosophy. It is possible to obtain further separation by *functional* isolation of implementation decisions.

Design using information hiding:

The premise of information hiding is to write a series of modules that hide implementation decisions from all other modules. Although this cannot always be carried out fully, the attempt to hide as much implementation information as possible results in programs that are increasingly less sensitive to implementation changes.

These modules are of a different sort from those previously discussed. They are instead groups of functions that provide a certain behavior when viewed from outside the module. In this way, the main program is provided with a set of modules that appear as "black boxes" to each other: the modules (boxes) can operate knowing only *what* functions the other modules provide; ideally, they are totally independent of *how* another module accomplishes its objective.

Nor are these modules necessarily used sequentially; in many cases, the main program uses several modules repeatedly to accomplish a given task. (This is the case with the DRAWCUBE2 example given in listing 2.) This switching among modules is a potential source for a severe decrease in program speed, especially if the program is large enough so that successive modules have to be swapped in and out of memory to be executed. However, this problem can usually be avoided by proper module design.

In the case of the problem given here, program DRAWCUBE2 (see listing 2) is divided into three modules: CREATEARRAY, which creates *the appearance* of an array

CUBE (*facenum*, *rownum*, *colnum*) that allows other modules to access any unit of the cube; PROCESS-ARRAY, which manipulates the information to be displayed; and DISPLAYARRAY, which displays the processed information. These are conceptual modules that are implemented by one or several procedures and functions in this Pascal program. Table 2 lists and describes the modules and lists their component procedures and functions.

Comparison of Algorithms

The algorithm of DRAWCUBE2 is distinguished from that of DRAWCUBE1 and the modular approach discussed above in its use of *transactions* to separate the manipulation of the information to be displayed from the actual display of the same information. The subroutine GENERATETRANS generates transactions until it signals the end of the algorithm by setting the SITUATION flag to ALDONE. A transaction is defined as a quartet of numbers (*facenum*, *rownum*, *colnum*, *colornum*), which is the minimal number that can completely describe an arbitrary unit for display by the DISPLAYARRAY module.

Consider the "normal-array-with-flag" change listed in table 1. The DRAWCUBE1 program would have to be changed in several places to accept the new cube format. The hypothetical modular program (call it DRAWCUBEM, with modules READCUBE and DISPLAYCUBE) would have to change both its modules: the change to READCUBE follows from the fact that the input format has been changed; the change to DISPLAYCUBE results from the necessity of skipping over units that remain unchanged from the last display operation. (I use the word necessity because the only reason for storing the units with flags is to speed up the display process by discarding the transactions of unchanged units.)

The information-hiding DRAWCUBE2 program handles the display operation so that the main program does not have to change when the input is changed to include flagged data. It does this by burdening the

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Implementation Change	Details
1. Packed sparse Boolean array	The cube is represented as six strings of 54 bits each, one string for each color as given by a predefined sequence of colors. The 54 bits represent the 54 units (6 faces times 9 units per face) that make up the cube. A 1 bit in the 54-bit substring represents the presence of the associated color on the corresponding unit of the cube, while a 0 represents its absence. This method occupies 324 bits or 40.5 bytes to represent the cube.
2. Cube stored on disk	The 54 bytes of the original 1-byte-per-unit method are stored in one sector of a floppy disk.
3. Packed array	The cube is represented in the original manner except that the color numbers of units are represented as 4-bit numbers and packed two to a byte. This method occupies 28 bytes to represent the cube.
4. Normal array with flag	This method assumes that the cube is already displayed on the video display. The top bit of a byte representing a unit can be 1 to represent the need of updating the unit or 0 otherwise. This scheme might be used to decrease the time needed to display the new representation of the cube.
5. User viewpoint modification	Before the cube is displayed, the user can specify one of several rotations as multiples of a quarter turn around any of the three axes of the cube.
6. Printed output	The cube is to be printed out in the "cross" format instead of being displayed on the video display.
7. Perspective display	The video display shows a perspective view that leaves three faces visible. Each unit may be represented by either its color number or a diamond shape of the appropriate color.

Table 1: A list of possible implementation changes to the DRAWCUBE problem.

Module	Component Functions and Procedures	Purpose of Module
CREATEARRAY	INITARRAY CUBE	Once this module has been executed, calls to CUBE give the impression to the calling module that the contents of the given cube are stored in a three-dimensional array CUBE (<i>facenum, rownum, colnum</i>).
PROCESSARRAY	INITGENERATE GENERATETRANS	This module acts on the "array" CUBE to generate a series of transactions that, together, completely describe the cube to be displayed.
DISPLAYARRAY	INITPUT PUTTRANS FLUSHARRAY	This module contains the necessary subfunctions to ensure that the cube is displayed properly.

Table 2: Modules within program DRAWCUBE2, the Pascal procedures and functions that represent them, and their purposes.

transaction-generating routine (GENERATETRANS) with the task of discarding units that do not need to be redisplayed. Although this change is one of repositioning, not simplifying, a design guided by information-

hiding principles might indeed result in simplifying the process of program conversion if the overall program were big enough. In any case, the main program of DRAWCUBE2 seems much more solid and un-

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Change	Implementation Details Changed	Modules Needing to Be Changed (Y = yes, N = no)								
		DRAWCUBE1			DRAWCUBEM		DRAWCUBE2			PUT
		UPDB	DRAW	INIT	READ	DISP	CRTE	PROC		
1. Packed sparse Boolean array	input	N	N	Y	Y	N	Y	N	N	
2. Cube stored on disk	input	N	N	Y	Y	N	Y	N	N	
3. Packed array	input	N	N	Y	Y	N	Y	N	N	
4. Normal array with flag	input and process	N	Y	Y	Y	Y	Y	Y	N	
5. User-viewpoint modification	process	N	N	Y	N	Y	N	Y	N	
6. Printed output	output	Y	Y	Y	N	Y	N	N	Y	
7. Perspective display	output	Y	Y	Y	N	Y	N	N	Y	
Abbreviations:	INIT = INITIALIZE READ = READCUBE CRTE = CREATEARRAY	UPDB = UPDATEBASE DISP = DISPLAYCUBE PROC = PROCESSARRAY	DRAW = DRAWFACE PUT = PUTARRAY							

Table 3: A table of implementation changes and the modules affected by them.

shakable than the corresponding main programs of DRAWCUBE1 and DRAWCUBEM.

Table 3 further displays the merits of information hiding by listing the modules in the current program version that would have to be altered to accommodate the change specified in the first column. Study of the results for DRAWCUBE1 (and reflection on the duties of each module within) point up the imbalance among the modules: modules INITIALIZE and UPDATEBASE deal only with the

output phase of the task, while module DRAWFACE incorporates aspects of the input, process, and output phases. This results in its being modified for every change listed. It is true that, in all versions of the DRAWCUBE problem, all the changes discussed in this article result in only one or two modules being changed; but in a more complex problem, several modules may share the lack of information hiding displayed here by module DRAWFACE, thus making the pro-

cess of changing an existing program more difficult and unmanageable.

Similar analysis of the two modules of DRAWCUBEM shows a cleaner separation of functions as a result of an emphasis on modularity. Module READCUBE is affected only by changes in the input format, while module DISPLAYCUBE is affected by changes in the process and output phases. The modules of DRAWCUBE2, however, show the greatest separation; modules CREATEARRAY, PROCESSARRAY, and

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PUTARRAY are affected only by changes in input, process, and output phases, respectively.

Even though the differences between the modular program, DRAWCUBEM, and the information-hiding program, DRAWCUBE2, are minimal, the latter has a noticeable edge in modularity in that all the program changes discussed in tables 1 and 3 could be made without changing the main program routine. This explains the use of empty modules like INITARRAY and FLUSHARRAY; in other versions of this program, these modules might perform some needed function.

One final observation should be made about the difference in size of the program DRAWCUBE1 (which is highly implementation-dependent) when compared to DRAWCUBE2 (which is highly implementation-independent). The compactness of DRAWCUBE1 is specifically due to its ability to take shortcuts because of its knowledge of the specific implementation details. Conversely, DRAWCUBE2 is longer because it

assumes no knowledge of these details and so must work harder to accomplish the same results.

For example, consider the output sections of both programs. DRAWCUBE1 must position the cursor only once every three units because it knows that the cursor will be in position for the next (sequential) unit on the same row. DRAWCUBE2, in assuming that the transactions might come in any order, must reposition the cursor for each unit.

The Case for Information Hiding

The advantages of information hiding include the increased separation among modules and the increased ease of making large implementation-based changes to the program. Its disadvantages include the increased size and execution time of the resulting program. The following paragraphs describe several situations that indicate the use of information hiding techniques:

- You should use information hiding for large programs, especially

those designed in an uncertain environment. Examples of this are software designed before or during the choice of computer hardware and software that will be run on leased equipment, on several computer systems, or on equipment due to change.

- Information hiding is also appropriate for programs that are likely to be maintained over an indefinite period of time, especially programs written for a business environment. For example, it makes more sense to use information hiding if you know that someone will probably be modifying the program five years from now; it makes less sense if the program will be written, used several times, then discarded.

- Information hiding is useful if the amount of data being manipulated by the program might greatly increase in the future. Such an increase indicates the possibility of changing to another form of data storage, and such a change might be feasible only if the existing program has been designed to anticipate it.

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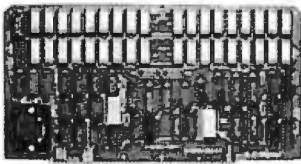


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Conclusions

Information hiding is a technique of program design that confines implementation-dependent details to as few modules as possible and organizes the modules to present a predefined appearance to all other modules. Because the implementation details are not visible to other modules, the program can be modified by changing only those modules that hide the pertinent details.

Information hiding is most appropriate to large programs that are to be maintained over long periods of time. The advantage of flexibility in the face of unknown future changes is offset by the disadvantages of larger program size and longer execution time, but these disadvantages can be controlled given proper planning.

Due to the necessary limitations in its size for tutorial purposes, the example given here does not correctly show the relative advantages and disadvantages of using information hiding; the advantages are more pronounced in a larger program (where a version of the program not using these techniques might be less recep-

tive to implementation changes and where the increase in program size becomes proportionally smaller as the program size increases).

The disadvantages of increased program size and execution times are minimized by the extremely low cost of computer memory and the increasingly faster computers currently being manufactured. The most significant expense today is the time spent by the programmer in writing and, more important, *maintaining* a program. Any techniques (of which information hiding is only one) that increase a programmer's productivity should be seriously considered. ■

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2. Ross, D. T., J. B. Goodenough, and C. A. Irvine. "Software Engineering: Process, Principles, and Goals." In P. Freeman and A. I. Wasserman (eds.), *Tutorial on Software Design Techniques* (3rd ed.). New York: IEEE Computer Society, 1980.

Listing 1: Program DRAWCUBE1.

```
PROGRAM DRAWCUBE1;

{ The purpose of this program is to simulate
  an algorithm that draws onscreen the six
  faces of a 3 by 3 by 3 cube stored in memory.
  In this implementation, each 1 by 1 "unit"
  is represented as a number from 1 through 6,
  and the cube is drawn on the screen as shown
  in figure 1. }

CONST RANK=3;
      MAXFACES=6;

TYPE SCREENCONSTANTS=ARRAY[1..6] OF INTEGER;

      ONE_TO_MAXFACES=1..MAXFACES;

      ONE_TO_RANK=1..RANK;

VAR  BASEROW, BASECOLUMN, CURRENTFACE,
      CUBEBEGIN, MEMPOINTER: INTEGER;

      MEMORY: ARRAY[1..180] OF ONE_TO_MAXFACES;

      FACE_ROW_BEGIN, FACE_COL_BEGIN:
      SCREENCONSTANTS;
```


Listing 1 continued:

```
PROCEDURE SIMULATEMEMORY;

{ This procedure is included only for the
purpose of simulating the computer memory
used to store the characteristics of one
or more cubes. Strictly speaking, this
routine is not part of the DRAWCUBE
algorithm. }

VAR I, J, SUBSC: INTEGER;

BEGIN

CUBEBEGIN:=19;
MEMPOINTER:=CUBEBEGIN;

FOR I:=1 TO 20 DO
  FOR J:=1 TO 9 DO
    BEGIN
      SUBSC:=J+9*(I-1);
      MEMORY[SUBSC]:=(I MOD 6)+1
    END;
  END { SIMULATEMEMORY };

PROCEDURE INITIALIZE;

{ FACE_ROW_BEGIN[N] and FACE_COL_BEGIN[N]
give the row and column position of the
cursor at the beginning of the Nth face. }

BEGIN
  FACE_ROW_BEGIN[1]:=3; FACE_COL_BEGIN[1]:=13;

  FACE_ROW_BEGIN[2]:=FACE_ROW_BEGIN[1] + 5;
  FACE_ROW_BEGIN[3]:=FACE_ROW_BEGIN[1] + 5;
  FACE_ROW_BEGIN[4]:=FACE_ROW_BEGIN[1] + 5;
  FACE_ROW_BEGIN[5]:=FACE_ROW_BEGIN[1] + 5;
  FACE_ROW_BEGIN[6]:=FACE_ROW_BEGIN[1] + 10;

  FACE_COL_BEGIN[2]:=FACE_COL_BEGIN[1] - 8;
  FACE_COL_BEGIN[3]:=FACE_COL_BEGIN[1];
  FACE_COL_BEGIN[4]:=FACE_COL_BEGIN[1] + 8;
  FACE_COL_BEGIN[5]:=FACE_COL_BEGIN[1] + 16;
  FACE_COL_BEGIN[6]:=FACE_COL_BEGIN[1]

END { INITIALIZE };

PROCEDURE UPDATEBASE;

{ This procedure updates variables BASEROW
and BASECOL to the correct values for the
beginning of the next face. }

BEGIN
  BASEROW:=FACEROWBEGIN[CURRENTFACE];
  BASECOLUMN:=FACECOLBEGIN [CURRENTFACE];
END;

PROCEDURE DRAWFACE;

{ This procedure draws one face (9 units)
of a cube starting at the current cursor
and BASEROW positions. }

VAR CURROW, CURRCOL:INTEGER;

BEGIN
  FOR CURROW:=1 TO 3 DO
    BEGIN
      BASEROW:=BASEROW+1;
      GOTOXY (BASECOLUMN, BASEROW);
```

Listing 1 continued on page 450

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Listing 1 continued:

```

FOR CURRCOL:=1 TO 3 DO
  BEGIN

  WRITE (MEMORY [MEMPOINTER]);
  WRITE ( ' ');
  MEMPOINTER:=MEMPOINTER+1;

  END;

WRITELN;

END;

END { DRAWFACE };

BEGIN { MAIN PROGRAM }

SIMULATEMEMORY;
INITIALIZE;

FOR CURRENTFACE:=1 TO 6 DO

  BEGIN
    UPDATEBASE;
    DRAWFACE;
  END;

END { MAIN PROGRAM }.

```

Listing 2: Program DRAWCUBE2.

```

PROGRAM DRAWCUBE2;

{ The purpose of this program is to simulate
an algorithm that draws onscreen the six
faces of a 3 by 3 by 3 cube stored in memory.
In this implementation, each 1 by 1 "unit"
is represented as a number from 1 through 6,
and the cube is drawn on the screen as shown
in figure 1. }

CONST RANK=3;
      MAXFACES=6;

TYPE TYPESITN=(BEGINNING, NEXTCOL, NEXTROW,
NEXTFACE, ALLDONE);

SCREENCONSTANTS=ARRAY[1..6] OF INTEGER;

ONE_TO_MAXFACES=1..MAXFACES;

ONE_TO_RANK=1..RANK;

VAR COLORNUM:ONE_TO_MAXFACES;

    FACENUM :ONE_TO_MAXFACES;

    ROWNUM, COLNUM:ONE_TO_RANK;

    SITUATION:TYPESITN;

    FACE_ROW_BEGIN, FACE_COL_BEGIN;
    SCREENCONSTANTS;

```

Listing 2 continued:

```

      CUBEBEGIN:INTEGER;

      MEMORY:ARRAY[1..180] OF ONE_TO_MAXFACES;

PROCEDURE SIMULATEMEMORY;

{ This procedure is included only for the
purpose of simulating the computer memory
used to store the characteristics of one
or more cubes. Strictly speaking, this
routine is not part of the DRAWCUBE
algorithm. }

VAR I, J, SUBSC: INTEGER;

BEGIN

  CUBEBEGIN:=19;

  FOR I:=1 TO 20 DO
    FOR J:=1 TO 9 DO
      BEGIN
        SUBSC:=J+9*(I-1);
        MEMORY[SUBSC]:=(I MOD 6)+1
      END;

  END { SIMULATEMEMORY };

{ ----- begin module CREATEARRAY ----- }

PROCEDURE INITARRAY;

BEGIN

  { In this version, INITARRAY
  is empty. }

END { INITARRAY };

FUNCTION CUBE (FACENUM, ROWNUM, COLNUM: INTEGER)
              :INTEGER;

{ This function returns the value of the unit
that is in face FACENUM, row ROWNUM, and
column COLNUM of the current cube as defined
by the pointer CUBEBEGIN. }

VAR UNITS_IN_FACE:INTEGER;
    UNITS_IN_ROW :INTEGER;
    CURRENTUNIT:INTEGER;

BEGIN

  UNITS_IN_FACE:=RANK*RANK;
  UNITS_IN_ROW :=RANK;

  CURRENTUNIT:=CUBEBEGIN
  + (FACENUM-1) * UNITS_IN_FACE
  + (ROWNUM -1) * UNITS_IN_ROW
  + (COLNUM -1);

  CUBE:=MEMORY[CURRENTUNIT]

END { CUBE };

{ ----- begin module PROCESSARRAY ----- }

PROCEDURE INITGENERATE;

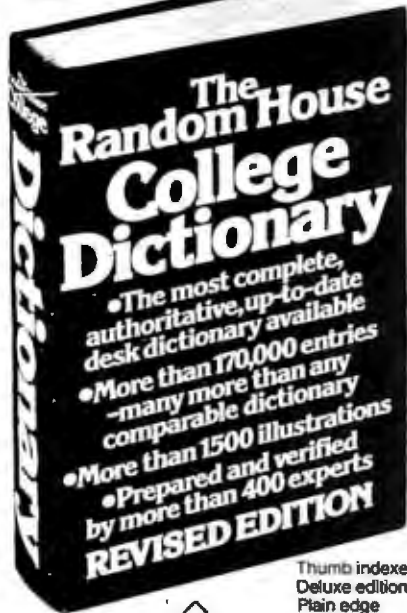
{ This procedure must be executed once
before GENERATETRANS is valid. }

BEGIN

```

Listing 2 continued on page 452

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Listing 2 continued:

```
SITUATION:=BEGINNING
END ( INITGENERATE );

PROCEDURE GENERATETRANS;

{ This procedure generates one 4-tuple
  (facenum, rownum, colnum, colornum)
  to be processed by PUTTRANS. }

BEGIN

  IF (SITUATION <> BEGINNING) THEN
    BEGIN
      IF (COLNUM < RANK) THEN SITUATION:=NEXTCOL;

      IF (COLNUM >= RANK) AND (ROWNUM < RANK) THEN
        SITUATION:=NEXTROW;

      IF (COLNUM >= RANK) AND (ROWNUM >= RANK)
        AND (FACENUM < MAXFACES) THEN
        SITUATION:=NEXTFACE;

      IF (COLNUM >= RANK) AND (ROWNUM >= RANK)
        AND (FACENUM >= MAXFACES) THEN
        SITUATION:=ALLDONE
    END;

  CASE SITUATION OF

    BEGINNING: BEGIN
      FACENUM:=1;
      ROWNUM :=1;
      COLNUM :=1;
      SITUATION:=NEXTCOL
    END;
```

Listing 2 continued:

```
NEXTCOL : COLNUM:=COLNUM + 1;

NEXTROW : BEGIN
  COLNUM:=1;
  ROWNUM:=ROWNUM + 1
END;

NEXTFACE : BEGIN
  COLNUM:=1;
  ROWNUM:=1;
  FACENUM:=FACENUM + 1
END;

ALLDONE : ( DO NOTHING )

END ( CASE );

COLORNUM:=CUBE(FACENUM, ROWNUM, COLNUM)

END ( GENERATETRANS );

( ----- begin module DISPLAYARRAY ----- )

PROCEDURE INITPUT;

{ This module initializes the two arrays
  FACE_ROW_BEGIN and FACE_COL_BEGIN, which
  are used to simplify cursor position
  calculations within PUTTRANS. }

BEGIN

  FACE_ROW_BEGIN[1]:=3; FACE_COL_BEGIN[1]:=13;
```

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Listing 2 continued:

```
FACE_ROW_BEGIN[2]:=FACE_ROW_BEGIN[1] + 5;
FACE_ROW_BEGIN[3]:=FACE_ROW_BEGIN[1] + 5;
FACE_ROW_BEGIN[4]:=FACE_ROW_BEGIN[1] + 5;
FACE_ROW_BEGIN[5]:=FACE_ROW_BEGIN[1] + 5;
FACE_ROW_BEGIN[6]:=FACE_ROW_BEGIN[1] + 10;

FACE_COL_BEGIN[2]:=FACE_COL_BEGIN[1] - 8;
FACE_COL_BEGIN[3]:=FACE_COL_BEGIN[1];
FACE_COL_BEGIN[4]:=FACE_COL_BEGIN[1] + 8;
FACE_COL_BEGIN[5]:=FACE_COL_BEGIN[1] + 16;
FACE_COL_BEGIN[6]:=FACE_COL_BEGIN[1];

END { INITPUT };

PROCEDURE PUTTRANS(FACENUM, ROWNUM,
                  COLNUM, COLORNUM: INTEGER);

{ This procedure puts one transaction to the
  output device. }

VAR  CURR_ROW_LOCATION: INTEGER;
      CURR_COL_LOCATION: INTEGER;

BEGIN

  CURR_ROW_LOCATION:=FACE_ROW_BEGIN[FACENUM]
                    + (ROWNUM - 1);

  CURR_COL_LOCATION:=FACE_COL_BEGIN[FACENUM]
                    + 2 * (COLNUM - 1);

  GOTOXY(CURR_COL_LOCATION, CURR_ROW_LOCATION);

  WRITELN(COLORNUM)

END { PUTTRANS };
```

Listing 2 continued:

```
PROCEDURE FLUSHARRAY;

{ This routine is used to trigger stored
  results to be output (in versions that
  cannot completely process a transaction
  within PUTTRANS). }

BEGIN
  { In this version, FLUSHARRAY
    is empty. }
END { FLUSHARRAY };

{ ----- begin main program ----- }

BEGIN { MAIN PROGRAM }

  SIMULATEMEMORY;

  INITARRAY;
  INITGENERATE;
  INITPUT;

  WHILE SITUATION <> ALLDONE DO

    BEGIN

      GENERATETRANS;
      PUTTRANS (FACENUM, ROWNUM, COLNUM,
                COLORNUM)

      END;

    FLUSHARRAY

  END { MAIN PROGRAM }.
```

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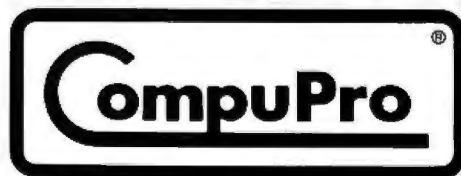
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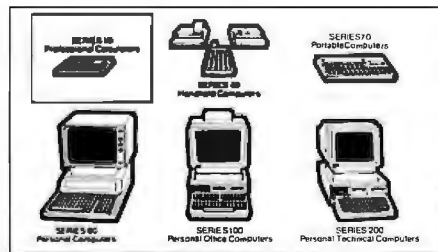
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News and Speculation about Personal Computing

Conducted by Sol Libes

Random Rumors:

Microsoft Inc. and Micropro International Corp. are both working on products to compete with the new Visi On system expected from VisiCorp this summer. Visi On is a highly intelligent operating environment for the IBM Personal Computer that allows cursor control using a mouse device. . . . Seagate Technology is expected to introduce shortly two new 5¼-inch Winchester disk drives with capacities of 25 and 33 megabytes. . . . Hitachi Ltd. is reportedly readying an IBM-compatible personal computer for introduction this spring. . . . IBM and TI (Texas Instruments) are said to be jointly working on an IC (integrated circuit) for use in the new IBM LAN (local-area network) system.

It is predicted that at next month's NCC (National Computer Conference) at least 20 companies will introduce 68000-based computer systems running versions of the Unix operating system, at least two firms will demonstrate high-capacity optical disk mass-storage systems, and two or three new portable systems will emerge (probably compatible to some degree with the IBM Personal Computer).

TI is expected to drop the list price of the 99/4A to \$149 soon and to introduce a new 64K-byte memory capacity computer with the hope of selling over 1 million computers this year. . . . It is believed that Commodore will also drop the price of the Commodore 64 when it introduces its P500, a 128K-byte machine, at \$795. Look for

the Commodore 64's price to drop to \$399. . . . The price of the Timex/Sinclair 1000 is expected to drop to around \$85, which means that we may see it discounted to as low as \$60.

Apple Doings: Apple Computer Inc. has committed itself to using the Ethernet LAN system—at least for the coming year. It's rumored that Apple is working on its own LAN system for introduction in 1984. The selection of Ethernet was no doubt based on Apple's attempt to appeal to large corporations, particularly with its Lisa, Mackintosh, and Apple III systems. Apple has entered into a contract with 3Com Corp. to supply the Ethernet hardware, which Apple will then "private label" for resale. The Ethernet interface cards are expected to be available this summer and will sell for between \$900 and \$1000 apiece. Apple will publish its protocols to encourage the development of Ethernet software by independent software houses.

Sales of the Apple III have no doubt been a big disappointment to Apple. An estimated 60,000 units have been sold in the two years it has been on the market. Sales picked up in the second half of 1982 when Apple cut the price significantly and upgraded the product with larger-capacity floppy-disk drives, an IBM-3270 emulator, and an accounting package. In an attempt to further stimulate sales of the Apple III, Apple offered \$100

rebates to floor salesmen on each Apple III they sold.

Analysts and dealers generally agree that the Apple III's lackluster sales are due to a lack of applications software from the independent software industry. They attribute this to the fact that independent software suppliers turned their attention to the IBM Personal Computer and ignored the Apple III. For example, VisiCorp and Lotus Development Corp. both introduced significant new software packages for the IBM Personal Computer but do not plan to introduce versions for the Apple III. Their reasoning is that there are already four times as many IBM Personal Computers in operation as there are Apple IIIs and that the ratio is likely to tip even more in IBM's favor by the end of this year. Certainly the already introduced Lisa and the soon-to-be-introduced Mackintosh will have a further impact on sales of the Apple III.

In January, Apple officially introduced its 68000-based Lisa system. The primary marketing effort for this \$10,000 machine will be directed to the large-corporation marketplace, traditionally dominated by IBM. No doubt IBM will fight hard to keep it that way. IBM, again demonstrating its marketing prowess, introduced a 68000-based machine more than a month before Apple. The IBM system, however, is directed more to the scientific community, while Apple's Lisa, intended for use as a very intelligent workstation, will be spearheading the "office-of-the-future." Apple

appears to have established itself well in the corporate market and is expected to be much more successful with the Lisa than with the Apple III system.

In many ways, the Lisa resembles the Xerox 8010 (the Star), introduced in 1981. The 8010, which sells for \$16,000, is at best only a modest commercial success. To ensure the success of the Lisa, Apple has doubled its sales force (now up to 100 people) selling directly to big national customers. Also, Apple has qualified about 200 dealers to sell the Lisa (a move that has angered some of Apple's other 1400 dealers).

In the meantime, the new Apple IIe, the long-awaited upgrade of the Apple II, is having an impact on suppliers of Apple II memory boards. The Apple IIe includes an enhanced memory that makes many current add-on memory boards obsolete. Two of the seven memory-board manufacturers have already decided to cease production of these boards when the demand lessens: Microsoft and Advanced Logic Systems have announced that they do not plan any new Apple II memory boards.

The Apple IIe has one less I/O expansion slot (slot zero is missing) than its predecessor. This position was previously used for the memory-expansion board. Further, the system contains 64K bytes of memory. Several of the other memory-board manufacturers plan to continue to make memory boards to extend the IIe's memory beyond 64K bytes (e.g., for disk emula-

tion).

Apple also cut costs on the Apple IIe by reducing the number of ICs from 109 to 31; however, the retail price of the Apple IIe is \$45 more than the old Apple II's \$1350. Last year I predicted that the IIe would have an 80-column display (see the October 1982 BYTELINES, page 456); however, Apple has decided to keep the 40-column format but offers the 80-column format as an option. Apple can expect tough competition from IBM, which is expected to introduce two new systems this summer—one lower in price and performance than the current Personal Computer and the other more powerful.

Congress defeated what has been referred to as "the Apple Computer Bill," which would have offered tax breaks to computer manufacturers for donating computers to schools. Opponents argued that the bill would have given Apple a marketing advantage and that the tax benefit would have cost the government \$36 million in lost revenues, transferring the cost burden from corporations to the government. Apple Computer Inc. chairman Steve Jobs, who had promoted the bill, had stated publicly that "Congress would be crazy not to take us up on this." It is expected that the bill will be reintroduced in this year's Congress.

Market Share for the PC: International Data Corp., a market-research firm, estimates that, in its first full year of selling the Personal Computer, IBM sold almost 200,000 systems and that this year sales should rise to 350,000 systems. Thus the firm estimates that the IBM Personal Computer has already gained 17.3% of the market, behind Apple's 26.6% and Tandy's 23.3%.

International Data Corp. also predicts that next year IBM will be the leader in the personal computer market, a market that keeps doubling each year. It has been estimated that 10% of the IBM Personal Computer systems sold have gone to IBM employees, who get discounts and payment plans for the system. The discount policy encourages IBM employees to write software for the system, often for extra pay.

IBM already dominates the medium-performance \$3000-to-\$5000 segment of the personal computer market. Already two dozen IBM-compatible machines have been introduced. The standard memory size for IBM-compatible machines now seems to be 256K bytes. Doubtless IBM's new machine, expected this summer, will have 256K bytes of memory onboard.

Although much lower than IBM in dollar volume, Commodore, TI, and Timex Computer Corp. are the leaders in unit volume. Timex Computer is estimated to have shipped 750,000 units last year, and Commodore and TI about 600,000 computers each. Radio Shack and Atari were not far behind. Thus it appears that close to 3 million personal computers were sold last year. With Timex Computer, Commodore, and TI each expected to sell over 1.5 million computers in 1983, we may see over 6 million computers sold this year.

Total sales for this year are expected to top \$3 billion. Both Apple and Tandy have disclosed that they are shooting for \$1 billion in sales, a 50% increase over last year. Tandy anticipates that its 1983 sales of home systems will top its sales of business systems for the first time. Apple is expected to introduce an under-\$500 computer for the home market.

The Year of the Mouse: 1983 will surely go down as the "year of the mouse." Many of the new personal computers due for introduction at next month's NCC will have them as standard features of the system. Apple's new Lisa has a mouse, and it will no doubt be an option on the soon-to-be-announced Mackintosh. Televideo and several others are expected to show their mouse offerings at NCC.

IBM Buys Into Intel: IBM has bought a 12% stake in Intel Corp. The price was \$250 million. IBM will have an option to increase this to 30% in eight years, and the firm will also get one representative on the Intel board of directors. No doubt this will tighten the association between the two companies. Intel is the primary supplier of add-on memory boards to IBM and a leading supplier of 64K-bit dynamic-memory ICs. Further, the microprocessor and many of the support ICs used in IBM's Personal Computer, Displaywriter, and Datamaster systems are furnished by Intel. IBM has also purchased rights to some manufacturing technologies from Intel. IBM, which has in the past grown by internal expansion, making virtually all of its own ICs, has become increasingly dependent on outside IC suppliers.

Many other IC makers have been acquired or invested in by large customers. For example: General Electric bought Intersil, Schlumberger Ltd. bought Fairchild, United Technologies bought Mostek, and Siemens Corp. owns a 16% interest in Advanced Micro Devices.

Intel, like other IC makers, has been in a slump for the past two years due to the recession and severe price competition from Japan.

While other IC makers resorted to layoffs, Intel increased its staff by 3000 last year, anticipating an upturn that never came. For this year, Intel has cut all salaries by 10% and frozen them for the year. The firm has needed substantial amounts of capital to continue its aggressive research and product development programs. Thus experts speculate that IBM decided to buy a stake in Intel to boost this R & D and thwart a buy-in by a competitor such as AT & T (American Telephone and Telegraph, recently freed from an anti-trust suit and reorganized).

Prices Drop: Commodore has been selling its VIC-20 in the U.S. for close to a year at a list price of \$180; the price is expected to drop soon to \$150 (hence it will be selling for the same price as the Timex Sinclair 2000). The VIC-20 has a better keyboard and better color graphics but less memory. Further, Commodore offers options that include a disk drive. TI is dropping the price of its 99/4A and bringing out a new lower-cost machine, called the 99/2, with a list price of \$100. TI will shortly introduce a high-speed tape-storage unit for both the 99/4 and 99/2 with a list price of \$140.

Sinclair has been talking about a microfloppy-disk drive for its color system that will sell for under \$80. Although the drive will be slow (taking about 4 seconds to load a program), it will store about 100,000 bytes. When this unit becomes available, it should make the Spectrum and its American counterpart, the Timex Sinclair 2000, highly competitive with the VIC-20 and TI units. The machine is expected to be introduced in England this spring and in this country

later this year.

In England the ZX81 is reportedly still outselling the Spectrum (with its color capability) by about 3 to 1. This may be because other systems are competing for the Spectrum's part of the market, especially the Commodore VIC, the BBC Computer, and the Dragon 32 (the latter two sold only in England).

In the meantime, I have seen ads offering the Timex Sinclair 1000 for as low as \$74. At this price, the unit may start cutting into the calculator market. Rumor has it that Memotech, a maker of add-on memory units for the ZX81, is working on a 5¼-inch floppy-disk drive add-on that will include the CP/M disk operating system and an enhanced keyboard. Memotech hopes to sell it for about \$300, which means that a minimal CP/M system could be put together for under \$800. Imagine

spending \$80 for the computer and another \$740 for the rest of the system. In other words, the computer will be the cheapest component in the system.

VIC-20 Tops a Million:

Commodore is boasting that more than 1 million VIC-20 machines have already been sold internationally, which would make it the most popular personal computer to date. Commodore admits that most of the VIC-20s have been purchased to play games and that only a small percentage of buyers use the system for educational or personal computer use.

Commodore has determined that its typical customers are young couples, with children between the ages of 9 and 18, who buy the VIC-20 for game playing, with the hope that it will also help educate their children in

computer basics. Also, the widespread introduction of personal computers in schools has caused children to pester their parents for home computers because of the necessarily limited access in the school environment. Often parents feel that their children will be deprived if they do not have their own systems; however, parents have found that children are mainly interested in playing games rather than programming.

Computer Hobbyists

Meet: On Saturday and Sunday, April 16 and 17, an estimated 15,000 computer hobbyists will flock to their largest annual gathering. The big attraction is an outdoor flea market that covers close to 20 acres. The annual event is now in its eighth year and

owns the distinction of being the first of the personal computer shows ever held. Called the Trenton Computer Festival, it will be held on the campus of Trenton State College, Trenton, New Jersey. Buyers, sellers and traders of personal computer equipment set up tables or sell from the tail-gates of their cars everything from complete computer systems to tiny electronic parts.

Speakers, user-group meetings, an indoor commercial exhibitor area, and a banquet will also be featured. The Festival is sponsored by three nonprofit computer clubs: the Amateur Computer Group of New Jersey, Philadelphia Area Computer Society, and Trenton State Computer Society; the funds raised help support these organizations. For information, call (609) 771-2487 or write to TCF-83, Trenton State College, Trenton, NJ 08625.

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Clubs and Newsletters

Forum for Sinclair Users

Sinclair Micronews contains programs, tutorials, and user reports on hardware and software for the ZX81 microcomputer and the Timex/Sinclair 1000. The newsletter also provides a forum for users to exchange original ideas and programs. To receive more information and a sample issue, send \$2 to *Sinclair Micronews*, 1280 Paddington Way, San Jose, CA 95127.

VIC-20 Only

The *Vic-Nic-News* is produced by the Byte House for owners and users of the Commodore VIC-20 home computer. The newsletter features news, programs, and information about the VIC. For a free copy, send a self-addressed stamped envelope to the Byte House, POB 981, Salem, NH 03079.

Update on Electronics

The American Electronics Association (AEA) is a non-profit trade organization that produces a monthly news journal, *Update*, which discusses electronics in relation to the environment and announces relevant seminars in its calendar. For further information, contact Leslie Conley, 2680 Hanover St., Palo Alto, CA 94304, or call (415) 857-9300.

Attention: Software Authors

The Software Author, a special-interest group that meets on the Compuserve Information Service, provides

contacts for freelance programmers, publishers, and software authors. The Software Author includes an electronic bulletin board and databases of market reports. Regular online conferences with guests from the publishing industry allow members to ask questions. The Software Author is open to any Compuserve subscriber; membership is free. Access the Software Author with a "G PCS-117" command from any prompt or select option 13 from the group's menu on PCS-50.

Next: NECS

The New England Computer Society (NECS) produces a monthly newsletter and welcomes exchanges with other clubs. It meets on the first Wednesday of each month at 7 p.m. in Bedford, Massachusetts. Annual dues are \$10. For further details, contact the New England Computer Society, POB 198, Bedford, MA 01730.

Pascal for DEC Owners

USUS (the UCSD Pascal-System User's Society) has formed a special-interest group (SIG) for users of the UCSD p-System on DEC (Digital Equipment Corporation) computers. The DEC SIG will serve as a clearinghouse for information relating to the implementation, optimization, and use of the p-System on DEC computers. Individual membership in USUS is \$20 a year; membership in DEC SIG is free to USUS members. For further information, contact Eli Willner, Datronics Inc., 675 Third Ave., New York, NY 10017.

Microcomputing In British Columbia

The Island Microcomputer Society seeks beginners and experts to join a Canadian microcomputing club. In addition to the monthly newsletter, *The Datafile*, the club offers a library of computer magazines and books, a bulletin board, and an annual computer fair. For further information, call Gil Phillips at (604) 385-4063, or write to the Island Microcomputer Society, Station E, POB 1822, Victoria, British Columbia V8W 2Y3, Canada.

VIC Club In Chicago

An international clearinghouse in Chicago, Illinois, is devoted to the Commodore VIC-20, 64, and Max computers. The VIC International Computer Knowledge Information Exchange (VICKIE) membership fee is \$20 a year and \$17.50 for students. Sample newsletters are available for \$1. For further information, write to John Rosengarten, VICKIE, 3822 North Bell Ave., Chicago, IL 60618.

Using the Osborne 1

The *Os/Tech* newsletter is designed to pass along tips that owners of the Osborne 1 have learned as well as to announce new products and software. It is produced six times a year. Subscriptions are \$9 within the U.S. *Os/Tech* will be produced in Spanish if there is enough demand. For more information, contact *Os/Tech*, POB 517, Clearwater, FL 33517, or call (813) 146-7239.

The Photoletter sends newsletters and photos via computer. The twice-monthly market letter pairs buyers with photographers. Subscribers are charged \$24 per hour of access time or a \$15 monthly minimum. For more information, write to Rohn Engh, Pine Lake Farm, Osceola, WI 54020, or call (715) 248-3800.

NEC Group In San Francisco

Users of the NEC (Nippon Electric Company) PC-8001 series of computers have formed the NEC Computer Users group in the San Francisco area, which produces a newsletter containing technical articles on NEC PC-8000 components. Members meet monthly to exchange software and solutions to problems. Dues are \$15 a year in the U.S. For more information, write to NEC Computer Users, POB 500, Benicia, CA 94510.

Alternate with the Update

Computer Update is produced every other month by the Boston Computer Society (BCS). Subscription to the magazine is free with BCS membership. BCS contains 19 user/interest groups. Annual membership is \$20, students are \$12, and the international fee is \$40. For further information, write to the Boston Computer Society Inc., Three Center Plaza, Boston, MA 02108, or call (617) 367-8080.

Ask BYTE

Conducted by Steve Clarcia

More on VIC Adapters

Dear Steve,

Your response to Mr. McIlwee's question about VIC-20 cassette adapters bears greater amplification. (See "VIC Cassette Adapter," October 1982 BYTE, page 453.)

For example, the VIC's F-6 pinout must be used to signal the computer that cassette operation is in progress. In addition, I found that the write signal tends to overdrive the recorder and must be attenuated and rolled off in frequency.

Figure 1 is a circuit that I

devised which worked well with a Radio Shack Realistic recorder. The volume control must be set for 6 or above to assure a saturated (square wave) signal to the VIC-20.

When the computer requests "press record and play on tape," the operator reacts accordingly, and the play switch signal (S1) to the computer is closed. At the end of a save, the recorder is stopped and S1 opened. A similar action is taken during a load operation.

I don't know if this circuit will work with all recorders.

Charles A. King
McLean, VA

The VIC-20 is designed for digital input signals and not the normal analog output of the standard recorder. It can be made to work with a standard recorder, but it's very finicky and recorder-dependent.

A standard cassette recorder can be made to work properly with the VIC-20 if a simple interface circuit is used. William R. Hale's article "Add a Cassette Interface to Your VIC-20" (March 1982 BYTE, page 272) gives the necessary information. Note that the Play switch must be grounded during playback or the VIC

will not know that the recorder is running. The volume level is rather touchy for proper operation and can be more easily adjusted if a pair of LEDs (light-emitting diodes) are connected back-to-back across the recorder audio output (i.e., earphone jack or equivalent). Also see Dr. Milan D. Chepko's article "How to Build an Inexpensive Cassette Level Indicator" (September 1981 BYTE, page 435). Adjust the volume control until one of the LEDs begins to flicker steadily and all will work fine. . . . Steve

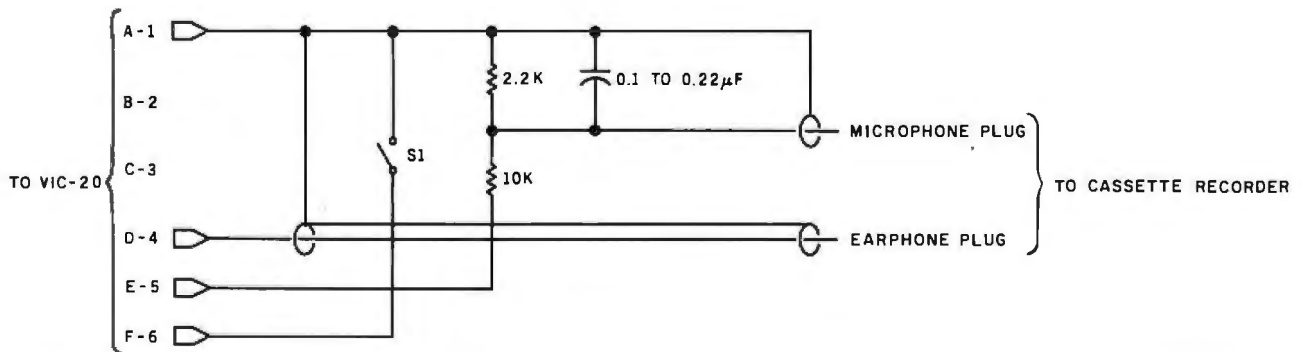


Figure 1: Mr. King's circuit.

Expanding the Z80 Computer

Dear Steve,

I am a graduate student in mathematics at the University of Tennessee. I have supplemented my education with personal and academic study in computer science and electrical engineering. I purchased your book, *Build Your Own Z80 Computer* (available for \$17.95 from BYTE Books/McGraw-Hill, POB 400, Hightstown, NJ 08520). Using it and other sources, I have designed my own version. I have two partners who agree to finance its construction. If could add a disk controller for

some 5¼- or 8-inch floppy-disk drives, it would be a much more useful product to us.

Do you have any information on the design of a floppy-disk controller, or can you point me toward some literature on the subject? I think there may be some BYTE articles on the subject; however, I wouldn't have the issues because my subscription began a little more than a year ago.

Also, in your book, you explain some of the important aspects of a serial interface. However, I would like to purchase a Heath/Zenith or RCA terminal and simply plug it in. Do you have any information

on how to wire standard RS-232C plugs? Is there a source to explain RS-232C protocol?

Finally, in an Ask BYTE column, you mentioned that you can obtain disk access by configuring the computer to an S-100 bus. (See "Build Your Own," March 1982 BYTE, page 444.) That sounds great, but where can I find the specifics for doing that?

Thanks.
Wallace G. Hynds
Knoxville, TN

The June 1980 BYTE contained an article on serial interfaces, "I/O Expansion for the TRS-80, Part 2: Serial Ports" (page 42), that defines

the pertinent RS-232C pinouts and gives theory and construction information on serial ports for a Z80-based system. Also, an excellent book that describes the interfacing of many computer buses to the S-100 is *The S-100 & Other Micro Buses*, by Elmer C. Poe and James C. Goodwin (available for \$9.95 from Howard W. Sams & Co. Inc., 4300 West 62nd St., POB 7092, Indianapolis, IN 46206).

Here's a list of articles and books on floppy-disk controllers and interfacing the S-100 bus:

"Build the Disk-80: Memory Expansion and Floppy-

Ask BYTE

Disk Control," by Steve Ciarcia, March 1981 BYTE, page 36.

"Interface a Floppy-Disk Drive to an 8080A-Based Computer," by John Hoepfner, May 1980 BYTE, page 72.

Interfacing to S-100/IEEE 696 Microcomputers, Sol Libes and Mark Garetz. Berkeley, CA: Osborne/McGraw-Hill, 1981, \$15.

"Build a Super Simple Floppy-Disk Interface," by James Nicholson and Roger Camp, Part 1: May 1981 BYTE, page 360; Part 2: June 1981 BYTE, page 302. . . Steve

Multichannel A/D Converters from Single Channels

Dear Steve,

Can I use transistors connected to the address lines of a

computer to make a multichannel A/D (analog-to-digital) converter out of a single-channel A/D?

Joel Chaney
North Kingsville, OH

The answer to your question is yes. However, a simpler method uses a CMOS (complementary metal-oxide semiconductor) 4051-type bilateral switch. This device is

the electronic equivalent of an 8-position rotary switch. When it is enabled, you simply send it a 3-bit address, which allows the voltage level on the corresponding input line to pass through to its single output line.

The 4051, along with its pin assignments, is shown in figure 2. To enable the device, you must ground the inhibit pin. To get it to work with negative-going analog signals, you must connect pin 7 to a -5-volt supply. This pin can be grounded with positive-only voltages.

If you are interested in learning more about CMOS devices, pick up a copy of the CMOS Cookbook, by Don Lancaster. It costs \$13.95 and is published by Howard W. Sams & Company. . . Steve

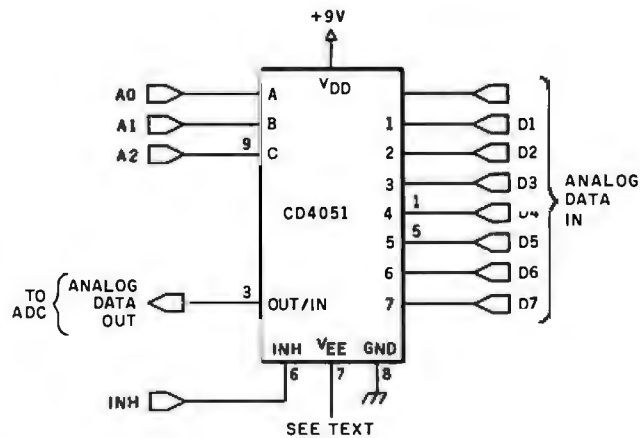


Figure 2: The 4051-type bilateral switch and its pin assignments.

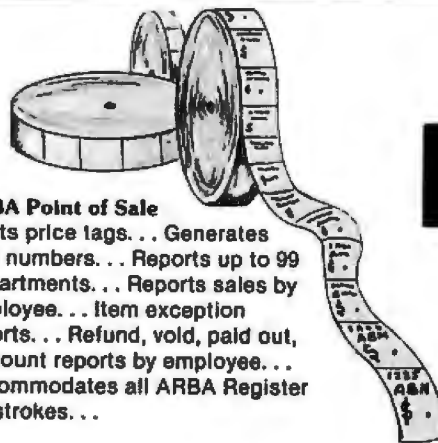
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DEALER INQUIRIES WELCOME

Homebrewer's Nightmare

Dear Steve,

I have been attempting to interface National Semiconductor's MM58167A real-time clock integrated circuit to an Apple II I/O expansion bus. I have been using your article "Everyone Can Know the Real Time" as a reference (May 1982 BYTE, page 34). I have constructed a circuit (figure 3) on a Vector Plugboard. The MM58167A MOS (metal-oxide semiconductor) is sensitive to static, so it requires special handling procedures. When I installed the clock device, I found that only two of the seven registers could be accessed correctly. Some of the counters and registers were stuck on illegal values (only binary-coded decimal values are allowed), but the thing was apparently keeping time.

I asked the vendor, Jameco, of Belmont, California, to replace the device, which it did. The new chip's registers can be accessed properly, and it, too, seems to keep time. However, it doesn't respond to the GO command, so I can't set it. Finally, the seconds output is stuck on hexadecimal FF.

In both cases, I was careful

to take all the precautions necessary with MOS devices, so I'm sure that I haven't caused the problem. How can I tell if it's the chip or the interface that's the culprit? Also, what is the "test mode" listed in table 1 of your article?

Edward Beighe
Bethlehem, PA

You have just experienced the dilemma of every hardware buff: "is it me or is it the chip?" The best way to test an LSI (large-scale integration) chip is to substitute another. The specification sheets describe the function of the device, and it's usually possible to set up a known condition on the input side and test for a correct output. If some of the outputs are correct and some are not, the chip can usually be suspected.

From the symptoms that you describe, it sounds like you have a defective chip. While you may have taken the proper handling precautions, it's possible that someone before you did not.

Other clock chips use the test mode for production testing. It speeds up certain functions so that the counting rate can be verified. It is not intended to be used in normal operation. . . . Steve

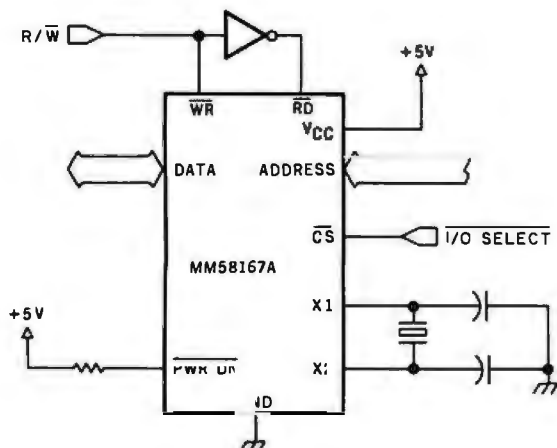


Figure 3: Mr. Beighe's circuit.

Where to Catch the S-100 Bus Standard

Dear Steve,

How can I get a copy of the IEEE S-100 bus standard?

Chip Wiggs
Miami, FL

Order copies of IEEE-696, as the S-100 bus standard is known, from the IEEE Service Center, 445 Hoes Lane, Piscataway, NJ 08854, (201) 981-0060. Write or call for the latest price and shipping details.

Information on this bus and many other buses can be found in the excellent book The S-100 & Other Micro Buses, by Elmer C. Poe and James C. Goodwin. It's published by Howard W. Sams & Company (1981). Also see "The IEEE Standard for the S-100 Bus," by Mark Garetz (February 1983 BYTE, page 272). . . . Steve

In "Ask BYTE," Steve Ciarcia answers questions on any area of microcomputing. The most representative questions received each month will be answered and published. Do you have a nagging problem? Send your inquiry to:

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POB 582
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Event Queue

April 1983

April-May

Courses in C Language and Unix, various sites throughout the U.S. Three 5-day courses are offered by Plum Hall Inc. The "C Programming Workshop," a hands-on course, covers all aspects of the C language for individuals able to program in another language. The "Advanced C Topics Seminar" covers efficiency, portability, readability, debugging, packaging, and interfacing. The "Unix Workshop" is an introductory course that focuses on software development. Each course fee is \$1000. For details, contact Joan Hall, Plum Hall Inc., 1 Spruce Ave., Cardiff, NJ 08232, (609) 927-3770.

April-May

Information Processing Seminars, various sites throughout the U.S. Datapro Research Corporation offers more than 35 seminars about information processing. Among the titles are "Optimizing Source Data Entry: Design Techniques," "User Friendly Information Delivery: Approaches to Online Systems Development," and "Distributed Systems Design: Microcomputers to Mainframes." These courses can be presented on an in-house basis. For a seminar catalog, contact Datapro Research Corp., 1805 Underwood Blvd., Delran, NJ 08075, (800) 257-9406; in New Jersey, (609) 764-0100.

April-June

Computer Literacy for Lawyers, various sites throughout the U.S. This seminar is intended to introduce attorneys to basic computer concepts and their application to the practice of law. Subjects covered include specific ways

that computers can assist in operating legal practices, how computers can help lawyers service clients more effectively, and the uses, costs, and benefits of using computers in legal practice. The fee for each participant is \$550, which includes reference materials. Group discounts are available. For further information, contact Kathryn Mann, Center for Legal Studies, 1926 Arch St., Philadelphia, PA 19103, (215) 732-6999.

April-June

Computer Showcase Expos, various sites throughout the U.S. This popular show will be held in several major cities between April and June. For a schedule, contact The Interface Group, 160 Speen St., POB 927, Framingham, MA 01701, (800) 225-4620; in Massachusetts, (617) 879-4502.

April-June

Courses from Q.E.D. Information Sciences, various sites throughout the U.S. Some of the courses listed are "Systems Analysis Workshop," "Project Management and Control," and "Data Analysis." Address inquiries to Priscilla Goudreault, Q.E.D. Information Sciences Inc., Q.E.D. Plaza, POB 181, Wellesley, MA 02181, (800) 343-4848; in Massachusetts, (617) 237-5656.

April-June

Data Processing Courses, the Hartford Graduate Center, Hartford, CT. Among the courses being offered are "ANS COBOL Programming Workshop 1" and "CICS/VS Command Level Coding Workshop." Hartford Graduate Center data-processing courses are available for on-site presentation. For details, contact Don Florek, The Hartford Graduate Center,

275 Windsor St., Hartford, CT 06120, (203) 549-3600, ext. 252, 253, or 254.

April-June

Fourth Generation Methodologies and Seminars of Excellence, various sites throughout the U.S. The five-day "Fourth Generation Methodologies" seminar explores information engineering, application creation methodologies, and management patterns. James Martin will be the seminar leader. The fee is \$1495.

Some of the areas covered by the "Seminars of Excellence" are local data networks, relational databases, and distributed database systems. Fees range from \$795 to \$950. Details on these seminars are available from the Technology Transfer Institute, 741 10th St., Santa Monica, CA 90402, (213) 394-8305.

April-June

Intel Microcomputer Workshops, various sites throughout the U.S. Among the workshops to be held are "Introduction to Microprocessors" and "iAPX 86, 88, 186 Microprocessors." Intel Customer Training Courses are available for on-site presentation. For details, contact Intel Corp., Mail Stop SV3-1, 3065 Bowers Ave., Santa Clara, CA 95051.

April-June

Intensive Seminars of Interest to Data Processing Professionals, Boston metropolitan area. Among the two- to five-day seminars offered are "Project Management" and "Systems Design." Registration fees range from \$495 to \$975. For a seminar bulletin, contact Ms. Ginny Bazarian, Office of Continuing Education, Higgins House, Worcester Polytechnic Institute, Worcester, MA 01609, (617) 793-5517.

April-June

Management Development Programs, Providence, RI, Boston, MA, and Hartford, CT. The Center for Management Development offers seminars in a variety of areas, including communications, industrial relations, and electronic data processing. Many of the Center's programs can be conducted on location for your organization. For complete information, contact The Center for Management Development, Bryant College, Smithfield, RI 02917, (401) 231-1200, ext. 314.

April-June

Professional Development Seminars, various sites throughout the U.S. Data communications, database management, software and systems, and computer-aided design/manufacturing are some of the areas investigated in seminars offered by the Institute for Advanced Technology. For a detailed catalog, contact the Registrar, Institute for Advanced Technology, Control Data Corp., 6003 Executive Blvd., Rockville, MD 20852, (800) 638-6590; in Maryland, (301) 468-8576.

April-June

Seminars in Simulation, Management, Statistics, and Computer Science, various sites throughout the U.S. "Simulation Modeling for Decision Making," "Database Design," and "Satellite Communications Technology" are some of the topics to be presented. For information, contact the Institute for Professional Education, POB 756, Arlington, VA 22216, (703) 527-8700.

April-July

Courses from Integrated Computer Systems, various sites throughout the U.S. Course titles include "Com-

puter-Aided Design and Manufacturing," "Computer Graphics," "Hands-On Pascal Workshop," "Defining Software Requirements, Specifications, and Tests," and "Computerized Robots." Fees range from \$695 to \$845. For information, contact Ruth Dordick, Integrated Computer Systems, 3304 Pico Blvd., POB 5339, Santa Monica, CA 90405, or call (213) 450-2060.

April-July

Productivity '83, various sites throughout the U.S. and Canada. This is Hewlett-Packard's hands-on showcase of more than 32 computer products and 17 seminars. It's designed to provide data-processing professionals and novices answers to problems confronting the industry. For details, call (800) 453-9500.

April-July

Technical Courses from Zilog, Campbell, CA. A wide variety of such courses as "The Computer: A Survey Course" and "C Programming" are offered. Fees range from \$175 to \$875. For a complete schedule, contact Zilog Inc., Training and Education Department, 1315 Dell Ave., Campbell, CA 95008, (408) 370-8092.

April-October

Courses from the AMA, various sites throughout the U.S. The American Management Associations (AMA) offers an on-going series of seminars in such areas as human resources, information systems, and manufacturing and technology management. In-house development and training seminars can be arranged. For information on AMA membership or seminar particulars, contact the American Management Associations, 135 West 50th St., New York, NY 10020, (212) 586-8100.

April-December

IEEE Conferences and Meetings, various sites around the world. The Institute for Electrical and Electronics Engineers (IEEE) sponsors conferences, meetings, and workshops covering high-technology issues. For details, contact the IEEE Computer Society, Suite 300, 1109 Spring St., Silver Spring, MD 20910, (301) 589-8142.

April 10-13

APL83, Sheraton Washington Hotel, Washington, DC. This conference and exhibition includes hands-on displays and presentations of technical papers. For details, contact D & S Whyte Associates, Conference and Exhibits Manager, Suite 200, 117 King St., Alexandria, VA 22314, (703) 548-2802.

April 10-15

Data Processing Training Managers' Workshop, Dallas, TX. This workshop is intended for individuals with less than 18 months of experience in coordinating data-processing programs. Participants will learn how to establish in-house education programs that meet management's objectives and ensure a high return on their organization's investment in training. The fee is \$1000. Contact Deltak Inc., 1751 West Diehl Rd., Naperville, IL 60566, (312) 369-3000.

April 11-13

Gate Arrays, Boston, MA. For full details, contact the Continuing Education Institute, Oliver's Carriage House, 5410 Leaf Treader Way, Columbia, MD 21044, (301) 596-0111; on the West Coast, call (213) 824-9545.

April 11-13

IBM-MVS Training Seminars, Chicago, IL. Two seminars are offered: "MVS Internals Overview for Data Processing and Operations Man-

agement" and "MVS Internals for Systems Programmers." These courses run for 1½ and 2½ days, respectively. For complete information, contact ACTS Corp., 11910 Gate Way, Austin, TX 78759, (512) 258-7869.

April 11-13

Personal Computers for Scientists and Engineers, Center for Professional Advancement, East Brunswick, NJ. Participants will learn how to use disk-operating systems, electronic spreadsheets, filing systems, and a word processor. Other programs will be demonstrated. Each attendee will work with an Apple II Plus computer. Two session formats are available. The fee is approximately \$750. Contact the Center for Professional Advancement, General Information, POB H, East Brunswick, NJ 08816, (201) 249-1400.

April 11-15

Intergraphics '83, Takanawa Prince Convention Center, Tokyo, Japan. This conference and exhibition will cover a wide range of computer-graphics topics, including business and management graphics, virtual machine languages, and chemical and biochemical applications of computer graphics. Complementing formal programs will be speakers, discussions, and tutorials. For complete details, contact the World Computer Graphics Association, Suite 250, 2033 M St. NW, Washington, DC 20036, (202) 775-9556.

April 12-13

Selecting a Microcomputer for Scientific and Engineering Applications, Golden, CO. This short course reviews hardware and software technology for potential buyers of microcomputers in relation to specific scientific and engineering applications. The

fee is \$195. Contact the Space Office, Colorado School of Mines, Golden, CO 80401, (303) 273-3321.

April 12-13

The Seventh Annual University of Dayton Computer Fair, University of Dayton Arena, OH. This fair is sponsored by the Office for Computing Activities of the University of Dayton. It features terminals, computers, and word processors. Further information can be obtained from Don Schumacher, University of Dayton, 300 College Park Ave., Dayton, OH 45469, (513) 229-3511.

April 12-14

The Ninth Annual Federal Data Processing Expo, Convention Center, Washington, DC. More than 150 companies will display and demonstrate computer and communications products and services. The conference portion of this event will offer 46 sessions on a variety of topics of interest to federal data-processing professionals. For further information, contact The Interface Group, 160 Speen St., POB 927, Framingham, MA 01701, (800) 225-4620; in Massachusetts, (617) 879-4502.

April 12-14

The Sixth Annual Southwest Computer Conference-SWCC, Myriad Convention Center, Oklahoma City, OK. The theme of this conference is "Managing Information Technology in the '80s." Seminars and an exhibition area are planned. For details, contact SWCC, POB 950, Norman, OK 73070, (405) 329-3660.

April 13-15

Local Area Networks: Design and Management, Hyatt Hotel, Los Angeles, CA. This seminar is intended to provide an understanding of the theory and practical implementations of local-area net-

Event Queue

works. Areas of interest include techniques of evaluating proposals for systems, methods in analyzing conflicting information, and probable future developments. The fee is \$595; group discounts are available. This seminar can be presented within your organization. Contact the Center for Advanced Professional Education Inc., 11928 North Earlham, Orange, CA 92669, (714) 633-9280.

April 13-20

Hanover Fair '83—Cebit '83, Hanover, West Germany. The Hanover Fair is one of the world's largest industrial trade fairs. Attention will be paid to office equipment and data-processing technology. More than 1200 exhibitors from 30 countries will display their products to a crowd of more than 200,000. Full information is available from the Hanover Fairs Information Center,

Salem Industrial Park, POB 338, Whitehouse, NJ 08888, (800) 526-5978; in New Jersey, (201) 534-9044.

April 14-17

The Second Annual New York Computer Show and Software Exposition, Nassau Coliseum, Uniondale, NY. This show features printers, software, hard disks, modems, memory cards, cartridges, publications, support services, and other peripherals and accessories. Admission is \$5 for adults and \$3 for children. Contact Northeast Expositions, 822 Boylston St., Chestnut Hill, MA 02167, (617) 739-2000.

April 15-16

The Thirteenth Annual Virginia Computer Users Conference—VCUC, Marriott Hotel, Blacksburg, VA. This conference is organized and run by the Virginia Tech Student

Chapter of the Association for Computing Machinery in cooperation with the Virginia Polytechnic Computer Science Department. Topics of interest include Ada, human factors, and computer graphics. For more information, contact Luanne Melown or Paula Brimer, Virginia Polytechnic Institute and State University, 562 McBryde Hall, Blacksburg, VA 24061, (703) 961-6931.

April 15-17

Applefest, Convention Center, Anaheim, CA. This event features conferences, workshops, and panel discussions designed to show users how to effectively use their Apples. Approximately 350 exhibitors will participate. For more information, contact Northeast Expositions, 826 Boylston St., Chestnut Hill, MA 02167, (800) 841-7000; in Massachusetts, (617) 739-2000.

April 15-17

The Use of Computers in Psychology, Hilton, Wilmington, NC. With a focus on microcomputers, the five planned symposia will cover such issues as statistical and therapeutic applications and the use and misuse of microcomputers in psychological assessment. For complete details, write to Steven R. Edelman, Association of Eastern North Carolina Psychologists, 105 Lou Dr., Goldsboro, NC 27530.

April 16

The First Annual Oak Ridge Hamfest/Computerfest, Civic Center, Oak Ridge, TN. Manufacturer displays, trading opportunities, technical talks, demonstrations, and hourly door prizes will highlight this show. For further information, write to the Oak Ridge Amateur Radio Club Inc., POB 291, Oak Ridge, TN 37830.

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April 16-17

The Eighth Annual Trenton Computer Festival, Trenton State College, NJ. This festival includes short courses, user group meetings, demonstrations, commercial exhibits, and a flea market. Admission for the two days is \$5. Contact Dr. Allen Katz, Trenton State College, Hillwood Lakes CN 550, Trenton, NJ 08625, (609) 771-2487.

April 18-20

Personal Computers for Scientists and Engineers, East Brunswick, NJ. For details, see April 11-13.

April 18-21

The Thirteenth International Symposium on Industrial Robots and The Robots 7 Conference and Exposition, Conrad Hilton Hotel and McCormick Place, Chicago, IL. The theme for this event, "Robotics: The Emerging Challenge," will be investigated

through more than a dozen conference sessions, four special forums, and three basic sessions. More than 150 companies will exhibit industrial robots and components. This event is cosponsored by Robotics International of the Society of Manufacturing Engineers (RI/SME) and the Robot Institute of America (RIA). Details are available from Ms. Pat Van Doren, SME Technical Activities, One SME Dr., POB 930, Dearborn, MI 48128, (313) 271-1500, ext. 369.

April 18-22

Auditing in the Contemporary Computer Environment, Las Vegas, NV. This course is designed for internal auditors and financial and data-processing professionals. Participants will learn a comprehensive audit approach for computer-based systems, including how to evaluate controls and how to design a pro-

gram of tests using questionnaires, checklists, software tools, and flowcharts. Contact Marge Umlor, EDP Auditors Foundation, 373 South Schmale Rd., Carol Stream, IL 60187, (312) 682-1200.

April 18-22

Auditing Integrity Controls in the Contemporary Computer Environment, Las Vegas, NV. This program is designed to provide an overview of the computer environment, its controls, and its interrelationships. It covers theoretical and practical approaches for electronic data-processing auditing, with an emphasis on integrity controls and related operational concerns. Further details are available from Marge Umlor, EDP Auditors Foundation, 373 South Schmale Rd., Carol Stream, IL 60187, (312) 682-1200.

April 18-22

Digital Communication and

Satellite Systems, University of California, Los Angeles. For details on this short course, contact the UCLA Extension Short Course Program, POB 24901, Los Angeles, CA 90024, (213) 825-1295 or (213) 825-3344.

April 19-20

Workspace 83, Civic Auditorium, San Francisco, CA. This show will feature the latest in electronic office furnishings, systems, and services for corporate, institutional, and commercial offices. Exhibits will include open-plan systems, lighting, fabrics, accessories, and telephone systems. Seminars and workshops relating to automated office space will be held. For details, contact The Charles Co., Suite 500, 44 Montgomery St., San Francisco, CA 94104, (415) 931-8255.

April 19-21

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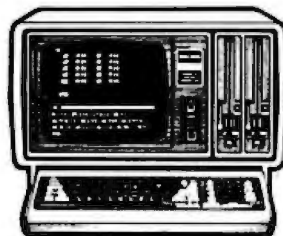
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Electronics Exhibition and Convention, Coliseum and Sheraton Centre, New York, NY. This show runs concurrently with the Mini/Micro-Northeast exposition. For information, contact Electronic Conventions Inc., 999 North Sepulveda Blvd., El Segundo, CA 90245, (800) 421-6816; in California, (800) 262-4208 or (213) 772-2965.

April 19-21

Infocom 83, Town and Country Hotel, San Diego, CA. The theme for this second annual joint conference of the IEEE Computer and Communications Societies is "Computers and Communications Integration: Reality and Illusion." Topics of interest include computer network architectures, computer communications standards, and integrated services digital networks. A series of tutorials will be held the day before this conference begins. For further information, contact the IEEE Computer Society, POB 639, Silver Spring, MD 20901, (301) 589-3386.

April 19-22

Applied Time Series Analysis, Columbia Inn, Columbia, MD. For full details, contact the Continuing Education Institute, Oliver's Carriage House, 5410 Leaf Treader Way, Columbia, MD 21044, (301) 596-0111; on the West Coast, call (213) 824-9545.

April 20-22

Local Area Networks: Design and Management, Hilton Inn, Natick, MA. For details, see April 13-15.

April 20-22

Symposium on Computer-Aided Geometry Modeling, Hampton, VA. For information, contact John Shoosmith, Mail Stop 125, NASA Langley Research Center, Hampton, VA 23665, (804) 827-3466.

April 21-22

Broadband Local Networks, Washington, DC. This program is the first of four parts in the Architecture Technology Corporation's 1983 Forum Series. The series will bring together manufacturers and users of local network schemes to exchange views and information in an informal setting. The format includes presentations, panel discussions, and a technological summary. The cost is \$395 per person. For additional information, contact the Architecture Technology Corp., POB 24344, Minneapolis, MN 55424, (612) 935-2035.

April 21-22

Computers in Construction, New York, NY. This seminar is designed to assist construction contractors and construction management firms in acquiring computer systems. The registration fee is \$395. For further information, contact CIP Information Services Inc., 1105-F Spring St., Silver Spring, MD 20910, (301) 589-7933.

April 21-22

Individualized Language Teaching Through Microcomputer-Assisted Instruction, Tampa, FL. This seminar will provide the theoretical background and hands-on experience necessary to enable participants to make practical use of microcomputer-assisted language instruction. For a brochure, contact Ms. Anita Mires, American Language Academy, Suite 200, 11426 Rockville Pike, Rockville, MD 20852, (301) 984-3400.

April 21-24

Virginia/Carolinas Computer Show and Office Equipment Exposition, Pavilion Exhibition Center, Virginia Beach, VA. For details, contact Dee Harris, Computer Expositions

Inc., POB 3315, Annapolis, MD 21403, (800) 368-2066; in Maryland, (301) 263-8044.

April 22

Microcomputers in Physics Instruction, Wilkes College, Wilkes-Barre, PA. This session is sponsored by the Central Pennsylvania Section of the American Association of Physics Teachers. For information, contact F. J. Donahoe, Wilkes College, Box 111, Wilkes-Barre, PA 18766.

April 22-23

The Third Annual Role of the Computer in Education Conference, New Trier High School-West, Northfield, IL. This show is sponsored by Micro-Ideas. The keynote speaker will be Arthur Luehrmann. Further information is available from Richard Nelson, Micro-Ideas, 1335 North Waukegan Rd., Glenview, IL 60026, (312) 998-5065.

April 24-29

Data Processing Training Managers' Workshop, San Francisco, CA. For details, see April 10-15.

April 24-29

The HP 3000 International Users Group Conference, Montreal, Quebec, Canada. The theme for this conference is "Systems Designed with Users in Mind." Technical papers, vendor exhibits, and a lecture by Isaac Asimov will highlight this conference. Full details are available from Ms. Renaye Lee, Conference Manager, HP 3000 IUG, Suite 205, 289 South San Antonio Rd., Los Altos, CA 94022, (415) 941-9960.

April 25-27

The 1983 Symposium on Security and Privacy, Clare-

mont Hotel, Oakland/Berkeley, CA. Papers and panel sessions will explore such topics as security testing and evaluation, application security, and cryptographic protocol. For further details, contact the IEEE Computer Society, POB 639, Silver Spring, MD 20901, (301) 589-3386.

April 25-27

Workshop on Software Engineering Technology Transfer, Konover Hotel, Miami Beach, FL. This workshop will probe some of the problems affecting the use of software engineering tools, techniques, and methodologies, in such areas as marketing, engineering, sales, and customer service. For further information, contact the IEEE Computer Society, POB 639, Silver Spring, MD 20901, (301) 589-3386.

April 25-29

Auditing in the Contemporary Computer Environment, Oklahoma City, OK. For details, see April 18-22.

April 26-28

Exploitation '83—The HP1000 International User Group Conference, Heathrow Penta Hotel, Heathrow, London, England. Papers and commercial exhibits about getting the most from your system will be featured. For full details, contact the HP1000 Conference Centre, Conference Services Ltd., 3 Buté St., London SW7 3EY, England; tel: 01-584 4226; Telex: 916054.

April 26-28

Info/Manufacturing and Hi-Tech 83, McCormick Place, Chicago, IL. These joint conferences and expositions cover information systems and advanced manufacturing technologies. The intent is to coordinate efforts and solve common problems confronting manufacturing technology

and information system companies. More than 50 conference sessions are planned. Topics on the agenda include database management and systems integration, office automation, and artificial intelligence expert systems. Conference programs are available from Clapp & Poliak, 708 Third Ave., New York, NY 10017, (212) 370-1100.

April 26-29

Comdex/Spring, Georgia World Congress Center and the Apparel Mart, Atlanta, GA. More than 600 companies will display and demonstrate computers, word-processing systems, peripherals, software, media, supplies, services, and other computer-related items. This third annual conference will offer 56 sessions on business, marketing, and financial subjects of interest to ISOs (independent sales organizations). Contact The Interface Group, 160 Speen St., POB 927, Framingham, MA 01701, (800) 225-4620; in Massachusetts, (617) 879-4502.

April 28-30

Ed Com/Spring '83, Washington, DC. In more than 300 session hours educators will address, evaluate, and analyze the development of computers in education. Demonstrations, seminars, hands-on experience, and panel sessions will display hardware, software, and publications. For more information, contact Carol Houts, Judco Computer Expos Inc., Suite 201, 2629 North Scottsdale Rd., Scottsdale, AZ 85257, (800) 528-2355; in Arizona, (602) 990-1715.

April 28-30

Microcomputers in Education, Cambridge, MA. This hands-on workshop is designed for teachers and administrators at all levels.

Topics include microcomputers in science and mathematics instruction, Logo, Pascal, machine language, and microcomputers and the education of students with special needs. Contact Ms. Sharon Woodruff, Technical Education Research Centers, 8 Eliot St., Cambridge, MA 02138, (617) 547-3890.

April 28-30

Teaching Math with Microcomputers, Chicago, IL. This seminar is designed to inform elementary, intermediate, and secondary school educators how to effectively use the microcomputer as a tool in mathematics teaching. Participants will be divided into workshop groups by academic levels. Guest speakers will explore such areas as computer literacy and awareness, software, programming, and hardware selection. For members of the National Council of Teachers of Mathematics (NCTM), the registration fee is \$145. For nonmembers, the fee is \$245. Address inquiries to NCTM '83 Seminar Series, 1906 Association Dr., Reston, VA 22091, (703) 620-9840.

April 28-May 1

The Third Annual Southwest Computer Show and Software Exposition, Market Hall, Dallas, TX. This show features printers, modems, video displays, plug-in boards, cartridges, software, and support services. Admission is \$5 for adults and \$3 for children. Full details are available from Northeast Expositions, 822 Boylston St., Chestnut Hill, MA 02167, (617) 739-2000.

May 1983

May 1-4

The Thirtieth International Technical Communication

Conference, Sheraton-St. Louis Hotel, St. Louis, MO. This conference is sponsored by the Society for Technical Communication (STC). It will focus on such issues as industrial instruction, consumer education, and safety. For full details, contact the STC, 815 15th St. NW, Washington, DC 20005, (202) 737-0035.

May 2-5

Test and Measurement World Expo, Convention Center, San Jose, CA. More than 50 workshops will explore instruments and techniques critical to performing timely and cost-effective failure analyses of microelectronic circuits and components. Topics to be addressed include X-ray microradiography and surface analysis techniques. Full particulars are available from Meg Bowen, Test and Measurement World Expo, 215 Brighton Ave., Boston, MA 02134, (617) 254-1445.

May 2-6

Auditing Integrity Controls in the Contemporary Computer Environment, Oklahoma City, OK. For details, see April 18-22.

May 2-6

Systematic Software Maintenance in COBOL, Chicago, IL. This seminar incorporates a mixture of structured methodologies, management strategies, solutions for effective testing, criteria development, analysis, and feedback accountability. Contact Edu-teach Inc., Suite 907, 162 North State St., Chicago, IL 60601, (312) 641-1370.

May 4-6

The Sixth Annual Rocky Mountain Data Processing Expo and Conference, Currihan Hall, Denver, CO. Some of the products to be

exhibited include computers, word processors, graphics systems, peripherals, and support services. Complete particulars are available from Industrial Presentations West, Suite 304, 3090 South Jamaica Court, Aurora, CO 80014, (303) 696-6100.

May 5-7

Teaching Math with Microcomputers, New York, NY. For details, see April 28-30.

May 9-13

The Twenty-fourth ADCIS International Conference, Marriott City Center, Denver, CO. The annual conference of the Association for the Development of Computer-based Instructional Systems (ADCIS) features workshops, novice and technical programs, presentations, poster sessions, and exhibits. For more information, contact the ADCIS International Headquarters, Miller Hall 409, Western Washington University, Bellingham, WA 98225, (206) 676-2860.

May 10-11

Selecting a Microcomputer for Scientific and Engineering Applications, Golden, CO. For details, see April 12-13.

May 10-12

Mini/Micro-Northwest, Portland, OR. Running concurrently with Northcon/83, this show addresses such topics as aerospace electronics, laser applications, and signal and image processing. Contact Electronic Conventions Inc., Suite 410, 999 North Sepulveda Blvd., El Segundo, CA 90245, (800) 421-6816; in California, (800) 262-4208 or (213) 772-2965.

May 11-15

Computa '83: The Third International Exhibition on Computer and Information Processing Technology, World Trade Centre, Singa-

pore. Complete information is available from Kallman Associates, 5 Maple Court, Ridgewood, NJ 07450, (201) 652-7070.

May 12-13

The Fourth Annual Computer Law Institute, University of Southern California Law Center, Los Angeles. This year's Institute will present a program on structuring agreements for the distribution of computer products domestically as well as internationally. Other topics include proprietary rights, anti-trust issues, and major systems procurement. An optional session on the basics of computer products and technology will be offered. Contact Ami Silverman, USC Law Center, University Park, Los Angeles, CA 90007, (213) 743-2582.

May 13-15

Applefest, Bayside Exposition Center, Boston, MA. This is the third annual Boston Applefest. More than 400 displays and booths of Apple-compatible products will be featured. Complementing the exposition will be seminars, conferences, workshops, and panel discussions. Call or write Northeast Expositions, 826 Boylston St., Chestnut Hill, MA 02167, (800) 841-7000; in Massachusetts, (617) 739-2000.

May 14-15

Toronto PET User's Group Conference, George Brown College, Casa Loma campus, Toronto, Ontario, Canada. Speakers, workshops, a trader's corner for used equipment, and exhibits of hardware, software, and accessories highlight this event. Contact Chris Bennett, TPUG Corresponding Secretary, 381 Lawrence Ave. W, Toronto, Ontario M5M 1B9, Canada, (416) 782-9252.

May 16-18

Computer Graphics for Engineering/Drafting Practice, University of Texas, Austin. This course will stress developing the ability to prescribe and implement computer graphics equipment for specific engineering applications. A two-day hands-on workshop follows the course. Contact the College of Engineering, University of Texas, Austin, TX 78712, (512) 471-3396.

May 16-18

Mini-Conferences and Professional Growth Seminars, Loews Anatole, Dallas, TX. A special feature of this event will be the introduction of the data-entry certification program. Among the topics to be addressed are motivation, training, and interviewing. Contact Marilyn S. Bodek, Data Entry Management Association, POB 3231, Stamford, CT 06905, (203) 322-1166.

May 16-19

National Computer Conference, Anaheim and Disneyland Hotel Convention Centers, Anaheim, CA. This show features exhibits of computer products and services, technical sessions, seminars, and formal addresses. For complete information, contact the American Federation of Information Processing Societies Inc., 1815 North Lynn St., Arlington, VA 22209, (703) 558-3624.

May 16-19

Patent Your Software for Profit, Anaheim, CA. This seminar, which runs concurrently with the National Computer Conference, will explore software patent examples and offer advice on patenting and licensing software. Patent reference materials will be provided. Full details are available from

Delbert L. Keenon, Automation Inc., 3410 Mona Lee, Houston, TX 77080, (713) 462-4151.

May 16-20

Auditing in the Contemporary Computer Environment, New York, NY. For details, see April 18-22.

May 16-20

Auditing Integrity Controls in the Contemporary Computer Environment, Washington, DC. For details, see April 18-22.

May 17-20

Technology/Invention New Product Expo, Expo Mart, Monroeville, PA. This show will feature everything from diesel fuel-injection systems to spring-loaded fly swatters. Further details can be obtained from Gary F. Brown, Technology/Inpex, Suite 400, 701 Smithfield St., Pittsburgh, PA 15222, (412) 288-1344.

May 18-20

The Fifth National Conference of the Cognitive Science Society, University of Rochester, Rochester, NY. This conference will consist of lectures, panels, commentaries, and papers. Contact the Cognitive Science Conference, Dewey Hall, University of Rochester, Rochester, NY 14627, (716) 275-5402.

May 18-20

Man Machine Interface, Palo Alto, CA. For full details, contact the Continuing Education Institute, Oliver's Carriage House, 5410 Leaf Treader Way, Columbia, MD 21044, (301) 596-0111; on the West Coast, call (213) 824-9545.

May 18-20

Mipro-83: The Sixth Microprocessors/Microcomputers Course/Conference, Con-

gress Center, Hotel Adriatic, Opatija, Yugoslavia. The theme for this conference is "Advanced Microcomputer Application Techniques and New Trends." It is geared toward hardware and software specialists and managers involved with the development, production, and management of microcomputer-based systems. For details, contact Mr. P. Dragojlović, Mipro Secretariat, Trg P. Togliatti 4, 51000 Rijeka, Yugoslavia.

May 19-20

Computers in Construction, Denver, CO. For details, see April 21-22.

May 19-22

Maryland Computer Show and Office Equipment Exposition, Convention Center, Baltimore, MD. Address inquiries to Dee Harris, Computer Expositions Inc., POB 3315, Annapolis, MD 21403, (800) 368-2066; in Maryland, (301) 263-8044.

May 20-22

Computers and Personal Values: Sharing from Experience, Sign of the Dove, Temple, NH. This workshop offers individuals in the computer community the opportunity to examine personal, ethical, or moral questions associated with their work and with the impact of computers on society. The format includes small and large discussion groups and invited speakers. The cost is \$150. For more information, contact Arthur Fink, Prince St., Box 614, Wilton, NH 03086, (603) 654-6518.

May 21

The Sixth Annual Spring Microcomputer Show & Tell Conference, University of Oklahoma, Norman. This conference is designed to let computer enthusiasts share

ideas and information. Six show and tell periods allow speakers to demonstrate their devices and field questions from the audience. Also featured is an on-the-spot programming contest. For additional information, contact Dr. Richard V. Andee, Mathematics Department, University of Oklahoma, Norman, OK 73019, (405) 325-3410.

May 22-25

The Eighteenth Annual Meeting and Exhibit Program of the AAMI, Loews Anatole, Dallas, TX. Topics on the docket include anesthesia instrumentation and technology, computer applications, personnel management, and technology transfer. Roundtable discussions, tutorials, and an exhibit program will be featured. For details, contact the Association for the Advancement of Medical Instrumentation, Suite 602, 1901 North Fort Meyer Dr., Arlington, VA 22209, (703) 525-4890.

May 23-27

Auditing Integrity Controls in the Contemporary Computer Environment, New York, NY. For details, see April 18-22.

May 24-26

Microprocessor Background for Management Personnel, Palo Alto, CA. The fee for this course is \$565, which includes text and program materials. Contact Continuing Education in Engineering, Department 532N, University of California Extension, 2223 Fulton St., Berkeley, CA 94720, (415) 642-4151.

May 31-June 2

The Second Canadian Computer-Aided Design/Computer-Aided Manufacturing and Robotics Exposition and Conference, International Centre of Commerce, Toron-

to, Ontario, Canada. Leading international companies will demonstrate industrial robots, automatic assembly equipment, optical scanners, and numerically controlled machine tools. Technical papers will focus on such topics as robot-vision systems and design analysis. For information, contact Hugh F. Macgregor & Associates, 662 Queen St. W, Toronto, Ontario M6J 1E5, Canada, (416) 363-2201.

May 31-June 4

The Twelfth Annual MUMPS Users' Group Meeting, Hilton Hotel, San Francisco, CA. Introductory and advanced tutorials, workshops, roundtable discussions, site visits, and hardware, software, and systems demonstrations and exhibits will be offered. Registration information is available from Charles White, Professional Associates, 2012 Big Bend Blvd., St. Louis, MO 63117.

June 1983

June

Continuing Engineering Education Courses, George Washington University, Washington, DC. Among the courses available are "Database and File Management for Microcomputers," "Computer Communications Systems and Networks," and "A Phased Approach to Software Conversion." For information, contact Douglas Green, Continuing Engineering Education, George Washington University, Washington, DC 20052, (800) 424-9773; in the District of Columbia, (202) 676-8512.

June 1-4

The First Annual Sunbelt Educational Computing Conference, Texas Tech Univer-



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sity, Lubbock. The theme for this conference is "Practical Applications and Current Issues in Educational Computing." For complete details, write to Dr. Cleborne E. Maddux, College of Education, Texas Tech University, POB 4560, Lubbock, TX 79409.

June 5-8

Consumer Electronics Show (CES), McCormick Place, Chicago, IL. This show is sponsored by the Electronic Industries Association (EIA). For information on this popular event, contact the Consumer Electronics Shows Office, Suite 1607, Two Illinois Center, 233 North Michigan Ave., Chicago, IL 60601, (312) 861-1040.

June 5-8

Mini-Conferences and Professional Growth Seminars, Registry Resort Hotel, Scottsdale, AZ. For details, see May 16-18.

June 5-9

The Twelfth Annual International Software AG Users' Conference, Fairmont and Royal Sonesta Hotels, New Orleans, LA. This conference will feature speakers, presentations, workshops, and tutorials. Contact Paula J. Brooks, Software AG of North America Inc., 11800 Sunrise Valley Dr., Reston, VA 22091, (703) 860-5050.

June 6-8

The Fifth Annual National Educational Computing Conference-NECC 83, Towson State University, Baltimore, MD. This conference provides a broad forum for discussion among individuals at all levels and from all institutions sharing an interest in educational computing. Papers will address such issues as computer education for

teachers, computer education and job opportunities for the handicapped, and accreditation and certification programs. Tutorials will be held, and demonstration and exhibit areas will emphasize computer uses in instruction. For registration forms, contact Doris K. Lidtke, NECC 83, Department of Mathematics and Computer Science, Towson State University, Baltimore, MD 21204.

June 6-8

The Sixth International Conference on Computers and the Humanities-ICCH/83, North Carolina State University, Raleigh, NC. This conference serves as a forum for the exchange of ideas on the use of computers in all areas of the humanities. Features include formal sessions and related activities, discussion groups, tutorials, workshops, and exhibits. For details, write to Dr. Sarah K. Burton, Department of English, POB 5308, North Carolina State University, Raleigh, NC 27650.

June 7-8

International Conference on the Use of Micros in Fluid Engineering, Tara Hotel, London, England. All aspects of the use of microcomputers and microprocessors in fluid engineering will be covered. Subjects of interest include developing software for fluid-engineering design, rapid response controllers, and data-acquisition and analysis on-site. Full details are available from the Organizing Secretary, Micros in Fluid Engineering, BHRA Fluid Engineering, Cranfield, Bedford MK43 0AJ, England; tel: (0234) 750422; Telex: 825059.

June 7-9

International Computer Show, Velodrome, Olympic site, Montreal, Quebec, Canada. This trade show is designed for businesses wish-

ing to identify or compare computers and equipment for automating the office or for industrial activities. The public is invited. Contact Industrial Trade Shows of Canada, 20 Butterick Rd., Toronto, Ontario, M8W 3Z8, Canada, (416) 252-7791.

June 7-9

Maptek Europe 1983: Annual Strategy Conference, Hotel Excelsior, Venice, Italy. This meeting will provide detailed market forecasts and strategic recommendations for computer systems, network information services, communications and teleconferencing, office systems, and departmental integration. Contact Robert B. King, Quantum Science Corp., 1114 Avenue of the Americas, New York, NY 10036, (212) 997-0070. In Europe, contact Constantine E. Adraktas, Quantum Science Corp., 16 Charles II St., London SW1Y 4QU, England; tel: (01) 839-5347.

June 7-11

The Third Rochester FORTH Applications Conference, Laboratory for Laser Energetics, University of Rochester, NY. This conference is sponsored by the Institute for Applied FORTH Research Inc. Guest speakers will cover robotics and FORTH in a special one-day session. For complete details, contact Diane Ranocchia, Institute for Applied FORTH Research Inc., 70 Elmwood Ave., Rochester, NY 14611, (716) 235-0168.

June 8-10

The International Conference on Consumer Electronics-ICCE, Ramada the O'Hare Inn, Des Plaines, IL. Technical papers and panel discussions will address such issues as personal computing, low-cost printers, and computer-aided design/manufacturing techniques. Products will be displayed. This conference is sponsored by the Consumer

Electronics Society of the Institute of Electrical and Electronics Engineers. Contact ICCE, POB 149, Bloomington, IL 60108.

June 9-11

Microcomputers in Education, Watertown, CT. For details, see April 28-30.

June 13-15

Analysis and Design-Oriented Techniques, Los Angeles, CA. For details on this power electronics course, contact Teslaco, Suite 6, 490 South Rosemead Blvd., Pasadena, CA 91107, (213) 795-1699.

June 13-15

Systematic Software Maintenance, Chicago, IL. Topics to be addressed include structured methodologies, solutions for effective testing, resource allocation, and status determination. Full details are available from Eduteach Inc., Suite 907, 162 North State St., Chicago, IL 60601, (312) 641-1370.

June 14-16

Introduction to Microprocessors, University of Texas, Austin. This course will stress basic concepts and hands-on experience. Participants will write and run simple programs on a Z80-based Micro-Professor training system. Contact the College of Engineering, University of Texas, Austin, TX 78712, (512) 471-3396.

June 14-16

Ohmcon/83, High-Technology Electronics Exhibition and Convention, Cobo Hall, Detroit, MI. For information, contact Electronic Conventions Inc., 999 North Sepulveda Blvd., El Segundo, CA 90245, (800) 421-6816; in California, (213) 772-2965.

June 14-18

Tectronica, Earls Court Exhibition Centre, London, England. This exhibition on

laboratory technology, aims to show the latest in instrumentation, equipment, and services for life and physical sciences. For details, contact Good Relations Ltd., 15 Adeline Place, London WC1B 3AJ, England; tel: (01) 636-6561; Telex: 265903.

June 15-17

Basics of Power Electronics, Los Angeles, CA. For information on this course, contact Teslaco, Suite 6, 490 South Rosemead Blvd., Pasadena, CA 91107, (213) 795-1699.

June 15-17

The Twenty-first Annual Meeting of the Association for Computational Linguistics, Massachusetts Institute of Technology, Cambridge, MA. Papers to be presented will address syntax, the representation of knowledge,

machine and machine-aided translation, and other linguistically and computationally significant topics. Information is available from Don Walker, Artificial Intelligence Center, SRI International EJ278, Menlo Park, CA 94025, (415) 859-3071.

June 15-18


1984 Oceania Party Nominating Convention, London. Delegates to this plenipotentiary assembly will discuss the latest developments in viewscreen technology and select candidates for Inner-Party offices and for the office of Big Brother. For information, contact Eric Arthur Blair, Ministry of Truth, Wigan Pier, Craighouse, Jura, UK.

June 16-17

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Model 16 2DR 128K	4799	Okidata 80	1569	Brand Name Software +	
DT-1 Data Terminal	599	Okidata 82A	320	Send for listing	
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MODEMS		Okidata 83A	655		
Lynx Direct Connect MII/III	235	Okidata 92	599		
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Event Queue

Towsley Center for Continuing Medical Education, Ann Arbor, MI. Course credit will be offered. Contact the Office of Continuing Medical Education, Towsley Center Box 057, University of Michigan Medical School, Ann Arbor, MI 48109, (313) 763-1400.

June 17-19
PC '83/West, Brooks Hall/Civic Center Complex, San Francisco, CA. This show will bring together users, developers, distributors, and retailers of products compatible with the IBM Personal Computer. Seminars, workshops, demonstrations, and a conference program will aim to educate users on product features and capabilities. Conference information is available from Northeast Expositions, 826 Boylston St., Chestnut Hill, MA 02167, (800) 841-7000; in Massachusetts, (617) 739-2000.

June 19-23
Conference on Computer Vision and Pattern Recognition-CVPR '83, Crystal City Hyatt, Arlington, VA. This program was formerly known as the Pattern Recognition and Image Processing Conference. Papers on vision, pattern recognition, and image processing will be delivered. For full details, write to CVPR '83, POB 639, Silver Spring, MD 20901.

June 23
The Twenty-second Annual Technical Symposium of the Washington DC Chapter of

the Association for Computing Machinery, National Bureau of Standards, Gaithersburg, MD. The theme for this event is "Microcomputer Systems: Tools or Toys?" Topics of interest include systems software, human factors, and office systems. Contact Howard Weeks Associates, 15201 Shady Grove Rd., Rockville, MD 20850.

June 27-30
The World of CAD/CAM, Marriott Resort, Newport Beach, CA. This seminar consists of four one-day presentations: computer-aided engineering (CAE), computer-aided design (CAD), computer-aided manufacturing (CAM), and computer-integrated manufacturing (CIM). It seeks to give a complete overview of how manufacturing will change in the future as the automated factory becomes a reality. For a brochure, write or call the Center for Manufacturing Technology, 4170 Crossgate Dr., Cincinnati, OH 45236, (513) 791-8801.

June 28-30
National Educational Computer Conference, New York Statler, New York, NY. The theme is "Higher Instructional Techniques in Education." Seminars, exhibits, hands-on demonstrations, and workshops will highlight this event. Further information is available from the National Educational Computer Library, POB 293, New Milford, CT 06776, (203) 354-7760. ■

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Books Received

Apple II Assembly Language Exercises, Leo J. Scanlon. New York: John Wiley & Sons, 1982; 205 pages, 50 by 66 cm, softcover, ISBN 0-471-86598-2, \$9.95.

BASIC Analysis of Variance Programs for Microcomputers, Allen H. Wolach. Monterey, CA: Brooks/Cole Publishing Co., 1983; 162 pages, 44 by 55 cm, softcover, ISBN 0-534-01423-2, \$8.95.

Basic Mathematics for Electronics, 5th edition, Nelson M. Cooke, Herbert F. R. Adams, and Peter B. Dell. New York: Gregg/McGraw-Hill, 1982; 698 pages, 46 by 58 cm, hardcover, ISBN 0-07-012514-7, \$21.65.

The Computer Tutor, Learning Activities for Homes and Schools, Gary W. Orwig and William S. Hodges. Boston, MA: Little, Brown and Company, 1982; 203 pages, 50.5 by 66 cm, softcover, ISBN 0-87626-147-0, \$10.95.

The Cosmic Mind-Boggling Book, Neil McAleer. New York: Warner Books, 1982; 207 pages, 31.6 by 47.6 cm, softcover, ISBN 0-446-97663-6, \$7.95.

CP/M Simplified, Jeffrey R. Weber. Cleveland, OH: Weber Systems Inc. (8437 Mayfield Rd.), 1982; 316 pages, 32 by 51 cm, softcover, ISBN 0-938862-04-9, \$13.95.

Developing Computer Solutions for Your Business Problems, Henry H. Petersohn. Englewood Cliffs, NJ: Prentice-Hall, 1982; 157 pages, 41 by 56 cm, softcover, ISBN 0-13-204305-X, \$14.95.

The 8086/8088 Primer, 2nd edition, Stephen P. Morse. Rochelle Park, NJ: Hayden Book Co., 1982; 276 pages, 36.6 by 54 cm, softcover, ISBN 0-8104-6255-9, \$10.95.

Engineering a Compiler, VAX-11 Code Generation

and Optimization, Patricia Anklam, David Cutler, Roger Heinen Jr., and M. Donald MacLaren. Bedford, MA: Digital Press, 1982; 269 pages, 39 by 58 cm, hardcover, ISBN 0-932376-19-3, \$24.

Exploring the Worlds of Computers, Donald D. Spencer. Ormond Beach, FL: Camelot Publishing Co., 1982; 102 pages, 37 by 56 cm, hardcover, ISBN 0-89218-055-2, \$10.95.

49 Explosive Games for the ZX81, Tim Hartnell, ed. Reston, VA: Reston Publishing Co., 1981; 140 pages, 36 by 54 cm, softcover, ISBN 0-8359-2086-0, \$10.95.

Fundamentals of Microcomputer Programming, Including Pascal, Daniel R. McGlynn. New York: John Wiley & Sons, 1982; 332 pages, 35 by 54 cm, softcover, ISBN 0-471-08769-6, \$14.95.

How to Write and Publish Engineering Papers and Reports, Herbert B. Michaelson. Philadelphia, PA: ISI Press, 1982; 155 pages, 37 by 55 cm, hardcover, ISBN 0-89495-016-9, \$17.95.

How to Write a TRS-80 Program, Ed Faulk. Chatsworth, CA: Datamost Inc. (9748 Cozycroft Ave.), 1982; 220 pages, 32 by 49.5 cm, softcover, ISBN 0-8359-2992-2, \$14.95.

Introduction to Modern Information Retrieval, Gerard Salton and Michael J. McGill. New York: McGraw-Hill, 1983; 448 pages, 41 by 57.6 cm, hardcover, ISBN 0-07-054484-0, \$32.95.

Invasion of the Space Invaders, Martin Amis. London, England: Hutchison & Co. Ltd. (17-21 Conway St.), 1982; 128 pages, 50 by 70 cm, softcover, ISBN 0-09-047841-3, \$9.95.

Invitation to Ada & Ada Reference Manual, Harry

Katzan Jr. Princeton, NJ: Petrocelli Books, 1982; 429 pages, 43 by 62 cm, hardcover, ISBN 0-89433-132-9, \$29.95.

Language Translators, John Zarella. Suisun City, CA: Microcomputer Applications (POB E), 1982; 200 pages, 36 by 54 cm, softcover, ISBN 0-935230-06-8, \$12.95.

Mastering Machine Code on Your ZX81, Toni Baker. Reston, VA: Reston Publishing Co., 1981; 180 pages, 36 by 54 cm, softcover, ISBN 0-8359-4261-9, \$12.95.

The Microchip: Appropriate or Inappropriate Technology? Alan Burns. New York: Halsted Press, 1981; 180 pages, 36 by 55 cm, hardcover, ISBN 0-470-27206-6, \$39.95.

Micro Cookbook, Volume 1: Fundamentals, Don Lancaster. Indianapolis, IN: Howard W. Sams & Co., 1982; 381 pages, 32 by 51 cm, softcover, ISBN 0-672-21828-3, \$15.95.

Microprocessor Data Book, S. A. Money. New York: McGraw-Hill, 1982; 264 pages, 51 by 66 cm, hardcover, ISBN 0-07-042706-2, \$38.

Microprocessor Operating Systems, volume II, John Zarella, ed. Suisun City, CA: Microcomputer Applications (POB E), 1982; 158 pages, 36 by 54 cm, softcover, ISBN 0-935230-04-1, \$12.95.

101 Pocket Computer Programming Tips & Tricks, Jim Cole. Woodsboro, MD: Arcsoft Publishers, 1981; 128 pages, 33 by 51 cm, soft-

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Books Received

cover, ISBN 0-86668-004-7, \$7.95.

Osborne CP/M User Guide, 2nd edition, Thom Hogan. Berkeley, CA: Osborne/McGraw-Hill, 1982; 280 pages, 39 by 55 cm, softcover, ISBN 0-931988-82-9, \$15.95.

PATCA, Directory of Consultants, San Jose, CA: PATCA (Professional and Technical Consultants Association, Suite 3, 1190 Lincoln Ave.), 1982; 110 pages, 33 by 51 cm, softcover, ISBN 0-939-840-01-4, \$5.

The PET Index, Michael A. F. Ryan. Aldershot, Hampshire, England: Gower Publishing Ltd. (Gower House, Croft Rd.), 1982; 194 pages, 49.6 by 70 cm, softcover, ISBN 0-566-03426-3, \$12.50.

The Power of Supercalc, Robert E. Williams and Bruce J. Taylor. Englewood Cliffs, NJ: Prentice-Hall, 1982; 110

pages, 50 by 64.6 cm, softcover, ISBN 0-13-687301-4, \$9.95.

The Power of Visicalc, Robert E. Williams and Bruce J. Taylor. Englewood Cliffs, NJ: Prentice-Hall, 1981; 88 pages, 50 by 64.6 cm, softcover, ISBN 0-13-687418-5, \$9.95.

The Power of Visicalc, Real Estate, Patricia J. Hughes and Kaz Ochi. Englewood Cliffs, NJ: Prentice-Hall, 1981; 166 pages, 50.6 by 65 cm, softcover, ISBN 0-13-687350-2, \$14.95.

The Power of Visiplot-Visicalc-Visifile, Patricia J. Hughes and Kaz Ochi. Englewood Cliffs, NJ: Prentice-Hall, 1981; 154 pages, 50.6 by 65 cm, softcover, ISBN 0-13-687368-5, \$14.95.

Programming Concepts with the Ada Language, Roy S. Freedman. Princeton, NJ:

Petrocelli Books, 1982; 162 pages, 33 by 49 cm, softcover, ISBN 0-89433-190-6, \$12.

Programming the 6809, Rodnay Zaks and William Labiak. Berkeley, CA: Sybex, 1982; 362 pages, 35 by 54 cm, softcover, ISBN 0-89588-078-4, \$14.95.

Programming Microcomputers with Pascal, M. D. Beer. New York: Van Nostrand Reinhold, 1982; 256 pages, 36 by 56 cm, softcover, ISBN 0-442-21368-9, \$13.95.

Software Manual Production Simplified, Richard Zaneski. Princeton, NJ: Petrocelli Books, 1982; 190 pages, 33 by 51 cm, hardcover, ISBN 0-89433-180-9, \$20.

So You Are Thinking About a Small Business Computer, R. G. Canning and N. C. Leeper. Englewood Cliffs, NJ: Prentice-Hall, 1982; 203 pages, 51 by 66 cm, softcover, ISBN 0-13-823617-

8, \$10.95.

SPPC Manual, A Statistical Package for the Pocket Calculator, Walter W. Hudson. Tallahassee, FL: Walmyr Publishing Co. (POB 3554, Leon Station), 1982; 330 pages, 36 by 54 cm, softcover, ISBN 0-942390-01-6, \$14.95.

Using Computers in Mathematics, Gerald H. Elgarten, Alfred S. Posamentier, and Stephen E. Moresh. Reading, MA: Addison-Wesley, 1983; 575 pages, 52 by 57 cm, hardcover, ISBN 0-201-10450-4, \$18.60.

Z8000 Handbook, Martin L. Moore. Englewood Cliffs, NJ: Prentice-Hall, 1982; 398 pages, 41 by 55 cm, softcover, ISBN 0-13-983866-X, \$14.95.

The ZX81 Pocket Book, Trevor Toms. Reston, VA: Reston Publishing Co., 1981; 128 pages, 36 by 54 cm, softcover, ISBN 0-8359-9524-0, \$10.95. ■

a message to our subscribers

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This is a list of books received at BYTE Publications during this past month. Although the list is not meant to be exhaustive, its purpose is to acquaint BYTE readers with recently published titles in computer science and related fields. We regret that we cannot review or comment on all the books we receive; instead, this list is meant to be a monthly acknowledgment of these books and the publishers who sent them.

BYTE's Bits

Computers Sparkle In Pearl City

A new pearl was added to the Pearl of New Jersey's string of casinos, hotels, and visitor attractions late last month. The grand opening of Ocean One, a three-level shopping, restaurant, entertainment, and exhibition hall resembling a 900-foot oceanliner, was held at the end of March.

The highlight of Ocean One is Computerama 21, a year-

round computer show featuring products from more than 30 computer manufacturers. Printers, software, and accessories will be on display, and a staff of trained technical personnel are on hand to answer questions.

Computerama is open 7 days a week, 14 hours a day. It's located on Arkansas Avenue, near the boardwalk. ■

Software Received

Apple

Accounts Payable, an accounting package. This module will maintain accounts-payable records and link with other State of the Art accounting packages. For the Apple III; floppy disk, \$595. State of the Art, 3183-A Airway Ave., Costa Mesa, CA 92626.

A. E., an arcade-type game. The robots are running amuck, and you must destroy them or force them away from the earth. For the Apple II; floppy disk, \$34.95. Broderbund Software Inc., 1938 Fourth St., San Rafael, CA 94901.

Air Navigation Trainer, a flight-simulation program. Pilots can watch a simulation of their flying techniques using navigation aids and making course corrections. For the Apple II and III; floppy disk, \$40. Space-Time Associates, 20-39 Country Club Dr., Manchester, NH 03102.

Apple II Business Graphics, a utility package that performs data analyses and transforms numerical data into simple illustrations. For the Apple II; floppy disk, \$175. Apple Computer Inc., 20525 Mariani Ave., Cupertino, CA 95014.

Bank Street Writer, a home-oriented word-processing system. This package includes all essential word-processing functions and features an interactive tutorial program on the disk. For the Apple II; floppy disk, \$69.95. Broderbund Software Inc. (see address above).

BASIC Compiler+, a utility program to convert Apple-soft BASIC programs into machine-language files. True integer arithmetic, array vectors, and optimal memory utilization are provided. For the Apple II; floppy disk, \$99.95. Hayden Software Co., 600 Suffolk St., Lowell, MA 01853.

Bellhop, an arcade-type

game. The object of this game is to pick up one piece of luggage at a time and deliver it to the correct suite until all seven pieces are delivered. Your tips depend on speed. For the Apple II; floppy disk, \$34.95. Hayden Software Co. (see address above).

Black Jack Strategy, a program that allows you to test and analyze various strategies of playing blackjack. You set up the bets and the game-playing simulation to develop a winning strategy. For the Apple II; floppy disk, \$69.95. Soft Images, 200 Route 17, Mahwah, NJ 07430.

Black/Kayles, an educational game. Play with a friend or against the computer to fill in the puzzle. The game helps students develop their mathematical strategies. For the Apple II Plus; floppy disk, \$25. Island Software, Department B, POB 300, Lake Grove, NY 11755.

Championship Golf, a golf-simulation game for one to four players. Each hole is displayed from two angles. Players have a choice of 20 clubs. For the Apple II; floppy disk, \$24.95. Hayden Software Co. (see address above).

Crime Stopper, an adventure-type game. You assume the role of a detective who must overcome many obstacles to locate a kidnapped heiress. For the Apple II; floppy disk, \$34.95. Hayden Software Co. (see address above).

Crystal Caverns, an adventure-type game. Without a map, you must hunt for treasure in the caves beneath an old mansion. For the Apple II; floppy disk, \$34.95. Hayden Software Co. (see address above).

Datafax, an unconstructed database-management system that uses keywords to organize non-numeric information. You can categorize and cross-reference information. For the Apple II and III; flop-

py disk, \$199 and \$249, respectively. Link Systems, 1640 19th St., Santa Monica, CA 90404.

Data Plotting Software for Micros, data-analysis tools. This collection of 21 data-plotting programs will help you analyze data and produce a variety of charts. For the Apple II; floppy disk, \$19.95. Kern Publications, 190 Duck Hill Rd., POB 1029, Duxbury, MA 02332.

dBRx, a package of routines to expand the functional capabilities of Ashton-Tate's dBASE II. New functions include sine, cosine, logarithm, exponentiation, and square root. For the Apple II; floppy disk, \$150. Gryphon Micro-products, POB 6543, Silver Spring, MD 20906.

Evolution, an adventure-type game. Work your way up the evolutionary ladder from amoeba to human while avoiding various predators. For the Apple II; floppy disk, \$39.95. Sydney Development Corp., 600-1385 West 8th Ave., Vancouver, British Columbia V6H 3V9, Canada.

Final Conflict, a simulation game. You must program an army of robots to invade and destroy the enemy's central controller. Requires game paddle. For the Apple II; floppy disk, \$34.95. Hayden Software Co. (see address above).

Financial Planning for Multiplan, a set of 17 templates to use with the Multiplan electronic-spreadsheet system. For the Apple II; floppy disk, \$69.95. Howard W. Sams & Co. Inc., 4300 West 62nd St., POB 7092, Indianapolis, IN 46206.

Financial Planning for Visicalc, a set of 17 templates for use with the Visicalc electronic-spreadsheet system. For the Apple II; floppy disk, \$69.95. Howard W. Sams & Co. Inc. (see address above).

Flip Out, an arcade-type strategy game. You are given

10 marbles. You must drop your marbles into the flip-out course in such a way that all your marbles exit before your opponent's. For the Apple II; floppy disk, \$29.95. Sirius Software Inc., 10364 Rockingham Dr., Sacramento, CA 95827.

Foreign Language Series, a French or Spanish vocabulary drill package. Students can respond to quizzes by answering in either English or a foreign language. Special drills can be created. For the Apple II Plus; floppy disk, \$80. Island Software (see address above).

General Ledger, an accounting package. This module will maintain a general ledger with simplified journal entry and audit trails, and will link with other State of the Art accounting packages. For the Apple III; floppy disk, \$595. State of the Art (see address above).

Jigsaw, a set of four picture puzzles to assemble. Each puzzle has 24 pieces that you assemble on the screen. The set increases in difficulty. For the Apple II Plus; floppy disk, \$25. Island Software (see address above).

Know Your Apple, an educational program that uses high-resolution pictures to demonstrate how the Apple computer works. For the Apple II; floppy disk, \$34.95. Muse Software, 347 North Charles St., Baltimore, MD 21201.

Magic Mailer, a mailing-list management system. This program can merge a form-letter file with a data file or keyboard input to create customized form letters. For the Apple II Plus; floppy disk, \$69.95. Artsci Inc., 5547 Sattsuma Ave., North Hollywood, CA 91601.

Magic Window Diablo, a printer-driver program for the Diablo series of printers that uses the Magic Window word-processing system. For

Software Received

the Apple II; floppy disk, \$19.95. Artsci Inc. (see address above).

Magic Window NEC, a printer-driver program for the NEC Spinwriter that uses the Magic Window word-processing system. For the Apple II; floppy disk, \$19.95. Artsci Inc. (see address above).

Magic Window II, a word-processing system. This improved version of the Magic Window system features a 70-column uppercase and lowercase display, 160-character line length, and hard-disk support. For the Apple II; floppy disk, \$149.95. Artsci Inc. (see address above).

Magic Words, a spelling-checker system. This program features a 14,000-word dictionary that can be customized. It works with any Apple-compatible word-processing program that uses standard Apple DOS. For the Apple II; floppy disk, \$69.95. Artsci Inc. (see address above).

Microbe: The Anatomical Adventure, an adventure game based on medical facts. You command a miniature submarine through your patient's body, fighting off deadly organisms as you go. For the Apple II; floppy disk, \$44.95. Synergistic Software, Suite 201, 830 North Riverside Dr., Renton, WA 98055.

Micro Mother Goose, a set of games and animated stories. Designed for children aged 3 to 9 years, this package provides three games and nine animated comics with traditional music. For the Apple II; floppy disk, \$39.95. Software Productions Inc., 2357 Southway Dr., POB 21341, Columbus, OH 43221.

Modula-2, a general-purpose programming language designed for systems implementation. Written by Niklaus Wirth, the author of Pascal, Modula-2 is based in part on Pascal and features modules and separate compilation. For the Apple II and III; floppy disk, \$550. Volition

Systems, POB 1236, Del Mar, CA 92014.

Paint Master, a design utility program that allows you to draw or paint high-resolution pictures on the screen, fill in colored sections, and save the drawings on disk. For the Apple II Plus; floppy disk, \$34.95. Avant-Garde Creations, POB 30160, Eugene, OR 97403.

Pandemonium, a challenging word game that contains a built-in dictionary. See how many words you can spell from the letters in a 5 by 5 grid. For one or more players. For the Apple II; floppy disk, \$39.95. Soft Images (see address above).

The Prime Plotter, a statistical-analysis and graphics development package. Using menu-driven commands, you can create a variety of charts and have them printed or drawn by a plotter. For the Apple II Plus; floppy disk, \$239.95. Primesoft Corp., POB 40, Cabin John, MD 20818.

Puss in Boot, an educational program to teach positional concepts to children from preschool through the primary grades. Graphics appear at random to demonstrate In, Out, Left, Right, On, Off, Over, Under, and more. For the Apple II Plus; floppy disk, \$25. Island Software (see address above).

Repton, an arcade-type game. You control the Star Fighter *Armageddon*. Your mission is to save Repton from the Quarriors. You have a laser gun, radar screen, and energy shields. For the Apple II; floppy disk, \$39.95. Sirius Software Inc. (see address above).

Roadsearch, a computerized road atlas. This database of 406 cities and road junctions in the U.S. and Canada allows you to enter a starting point and a destination. You receive a detailed route plan for your next trip by car and save time, money, and gas.

For the Apple II Plus; floppy disk, \$34.95. Columbia Software, POB 2235, Columbia, MD 21045.

Sea Dragon, an arcade-type game. You must navigate the nuclear submarine *Sea Dragon* through a sea filled with deadly obstacles. For the Apple II; floppy disk, \$34.95. Adventure International, POB 3435, Longwood, FL 32750.

Senior Analyst, a modeling program that allows financial planners to analyze and review data. Create models from a common database within the program, or combine many models into one. For the Apple II; floppy disk, \$225. Apple Computer Inc. (see address above).

U.S. Cities, an educational program. Students learn to use a map of the United States. Coordinate locations of major cities are shown on high-resolution displays. For the Apple II Plus; floppy disk, \$25. Island Software (see address above).

Wavy Navy, an arcade-type game. You pilot a PT boat in 30-foot waves while surrounded by enemy planes, helicopters, mines, and missiles. For one to four players. For the Apple II; floppy disk, \$34.95. Sirius Software Inc. (see address above).

Atari

Bulldog Pinball, an arcade-type game. This computer version of a pinball game lets you score points, use flippers, and control ball speed. It features graphics and sound. For the Atari 400/800; cassette, \$29.95. Hayden Software Co., 600 Suffolk St., Lowell, MA 01853.

Castle Wolfenstein, an adventure-type game. You have been captured by Nazis and taken to Castle Wolfenstein for interrogation. You must find the secret war plans and escape. For the Atari 400/800; floppy disk, \$29.95. Muse Software, 347 North Charles

St., Baltimore, MD 21201.

Dragonfire, a video game. Help the prince reclaim the king's treasures. Cross bridges and dodge dragon fire in the quest. For the Atari Video Computer System; cartridge, \$32.95. Imagic, 1875 Dobbin Dr., San Jose, CA 95133.

River Raid, an arcade-type game. You are piloting a B-1 strato-wing assault jet. Your mission is to seek and destroy enemy targets on a dangerous river course. For the Atari Video Computer System; cartridge, \$31.95. Activision Inc., Drawer #7286, Mountain View, CA 94042.

Sea Dragon, an arcade-type game (see description under Apple). For the Atari 400/800; floppy disk, \$34.95. Adventure International, POB 3435, Longwood, FL 32750.

Serpentine, an arcade-type game. You control three blue serpents. Your object is to destroy the hostile orange serpents and create more blue ones. For the Atari 400/800; floppy disk, \$34.95. Broderbund Software Inc., 1938 Fourth St., San Rafael, CA 94901.

Speed Track, a simulation game. Place your bets, watch six horses race toward the finish line, and collect your winnings. For up to eight players. For the Atari 400/800; cassette, \$19.95. Brenner, POB 459, Plainview, NY 11803.

Stratos, an arcade-type game. One or two players can defend a futuristic city from attack by alien spacecraft. For the Atari 400/800; floppy disk, \$34.95. Adventure International (see address above).

Wayout, an arcade-type game. You have a choice of 26 three-dimensional mazes to explore. Look for the fireflies, but beware of the Cleptangle. Wayout glasses and compass included. For the Atari 400/800; floppy disk, \$39.95. Sirius Software, 10364 Rockingham Dr., Sacramento, CA 95827.

Commodore

AC Network Analysis, a program to analyze an AC network with both passive components and transistors. Results are in decibel magnitude, return loss, and phase. For the Commodore 64, PET, and VIC-20; cassette, \$25. R. K. Altenbach, 31 Garner Rd., Stow, MA 01775.

Beginners Assembly Language Programming, a book and software combination that teaches the basics of assembly-language programming. For the Commodore VIC-20; cassette. Price not available. Honeyfold Software Ltd., Standfast House, Bath Place, High St., Barnet, London, England.

Conquer, a medieval strategy game. The object of this game is to conquer as many countries as possible. For 1 to 15 players. For the Commodore VIC-20; floppy disk or cassette, \$16.95. Computer Knowledge, 100 Grove St., Worcester, MA 01605.

The Dungeon, an arcade-type game. Escape an ever-expanding dungeon while meeting monsters, thieves, trap doors, secret keys, coffins, gold, swords, and much more. For the Commodore VIC-20; cassette, \$15. Softwar III, 1307 Douglas Dr., Sterling, IL 61081.

Vanilla PILOT, an implementation of the PILOT language. This interpreter-based package features turtle graphics and enhanced editing commands. For the Commodore 64 and VIC-20; floppy disk, \$29.95. Tamarack Software, Water St., Darby, MT 59829.

CP/M

Compress, a data-compression program for CP/M files. Storage requirements can be reduced 30 to 40 percent. It is based on a logarithmic relation between relative-letter frequency and bit length. For CP/M-based systems; floppy disk, \$59.95. Digital Marketing Inc., 2670 Cherry Lane,

Walnut Creek, CA 94596.

DES-Crypt Version 1.0, an implementation of the National Bureau of Standards' Data Encryption Standard (DES). This menu-driven package encrypts and decrypts your files. For CP/M-based systems; floppy disk, \$149. Trigram Systems, 3 Bayard Rd. #66, Pittsburgh, PA 15213.

Disk Inspector, a full-screen editor for CP/M-based files. It displays selected sectors in both ASCII and hexadecimal formats. Make changes and rewrite the sector by moving the cursor. For CP/M-based systems; floppy disk, \$29.95. Overbeek Enterprises, POB 726, Elgin, IL 60120.

Peachtext Word Processor, a full-featured word-processing package. It provides menu selection for functions, help display, print formatting, and self-teaching lessons. For CP/M-based systems; floppy disk, \$500. Peachtree Software Inc., Suite 1300, 3445 Peachtree Rd. NE, Atlanta, GA 30326.

Solomon Series Software, an integrated accounting system that includes general ledger, accounts receivable and payable, invoicing, payroll, address and job-cost management. For CP/M-based systems; floppy disk, \$3495. Computech Group Inc., Main Line Industrial Park, Lee Blvd., Frazer, PA 19355.

Spelling Proofreader, a spelling-checker package. Based on the *Random House Dictionary*, this program works with the Peachtext word-processing system to check the spelling of your documents. For CP/M-based systems; floppy disk, \$300. Peachtree Software Inc. (see address above).

Y-Wing II, an arcade-type game. Stormslayer has enslaved all creatures under the sea. Your mission is to fly your Y-Wing fighter through the Stygian Sea and slay the

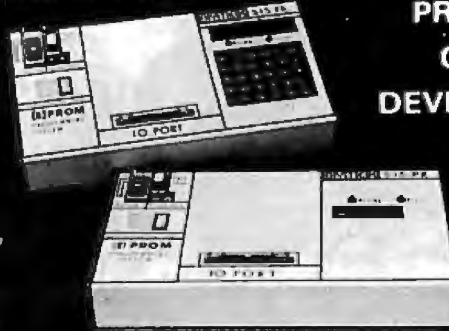
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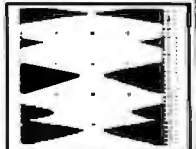
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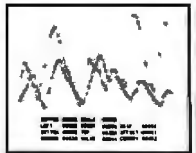


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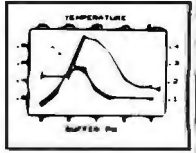
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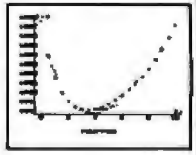


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Software Received

sea giant himself. For CP/M-based systems; floppy disk, \$21.50. Evryware, POB 60802, Sunnyvale, CA 94088.

Heath/Zenith

Empire, a simulated war game. Your army is fighting the computer's army. As the forces move over a grid of unknown territory, your task is to contact and destroy the enemy. For the Heathkit H-11; 8-inch floppy disk, \$40. Northwest Software, 15343 Southeast 43 Place, Bellevue, WA 98006.

Extended Tiny BASIC Compiler, a BASIC compiler program. Convert your BASIC programs into fast machine language. Requires HDOS 1.6. For Heath/Zenith computers; floppy disk, \$31.95. O'Connor Software, 191 Oakridge Dr., Lower Burrell, PA 15068.

Y-Wing II, an arcade-type game (see description under CP/M). For Heath HDOS-based systems; floppy disk, \$21.50. Evryware, POB 60802, Sunnyvale, CA 94088.

IBM Personal Computer

Air Traffic Controller, a simulation game. You must direct air traffic. Several options allow you to tailor the game to your preferences: successfully land planes or cause crashes for a high score. For the IBM Personal Computer; floppy disk, \$29.95. Avant-Garde Creations, POB 30160, Eugene, OR 97403.

Data Plotting Software for Micros, a data-analysis program (see description under Apple). For the IBM Personal Computer; floppy disk, \$19.95. Kern Publications, 190 Duck Hill Rd., POB 1029, Duxbury, MA 02332.

Deadline, an interactive program in which you are a detective who must solve a murder within 12 game hours. The program gives you all the clues you need. For the IBM Personal Computer; 5¼- and 8-inch floppy-disk formats,

\$49.95 and \$59.95, respectively. For information, contact Infocom, 55 Wheeler St., Cambridge, MA 02138.

Federation, an arcade-type game. You command a Federation fleet. Your mission is to wipe out invading Drorn Drones. For the IBM Personal Computer; floppy disk, \$29.95. Avant-Garde Creations (see address above).

Financial Planning for Multiplan (see description under Apple). For the IBM Personal Computer; floppy disk, \$79.95. Howard W. Sams & Co. Inc., 4300 West 62nd St., POB 7092, Indianapolis, IN 46206.

Financial Planning for Supercalc, a set of 17 templates for use with the Supercalc electronic-spreadsheet system. For the IBM Personal Computer; floppy disk, \$79.95. Howard W. Sams & Co. Inc. (see address above).

Financial Planning for Visicalc (see description under Apple). For the IBM Personal Computer; floppy disk, \$79.95. Howard W. Sams & Co. Inc. (see address above).

Label Kit PC Disk Organizer, a user-friendly system that prints labels of your alphabetically arranged files. Kit includes a program disk, 300 pin-feed labels, and instructions. For the IBM Personal Computer; floppy disk, \$59.95. PC Goodie Co., Suite 10, 15445 Ventura Blvd., Sherman Oaks, CA 91413.

Lazermaze, an arcade-type game. In the Arena Grid of Justice, your laser will reflect off many obstacles. A keen eye and trigger finger mean victory. For the IBM Personal Computer; floppy disk, \$29.95. Avant-Garde Creations (see address above).

Name & Address List Management System, a simple database-management program designed to maintain lists of names and addresses. You can print listings and mailing labels according to several options. For the IBM

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Personal Computer; floppy disk, \$29.95. M & J Automation, POB 205, Plainsboro, NJ 08536.

Starcross, an adventure-type game. You must explore an alien starship and solve the complex and puzzling alien mysteries. For the IBM Personal Computer; floppy disk, \$39.95. Infocom (see address above).

Terran Jeopardy, an arcade-type game. Pit your strategic skills against the Black Nebula Horde. Terra's fate is in your hands as you defend your base from alien attack. For the IBM Personal Computer; floppy disk, \$29.95. Avant-Garde Creations (see address above).

Zork I: The Great Underground Empire, an adventure-type game. Strive to discover the Twenty Treasures of Zork and escape with them and your life. The game features a Save option for continued play. For the IBM Personal Computer; 5¼- and 8-inch floppy-disk formats, \$39.95 and \$49.95, respectively. Infocom (see address above).

Zork II: The Wizard of Frobozz, an adventure-type game. A continuation in the series, this game takes you deeper into the subterranean realm where you meet the powerful Wizard. For the IBM Personal Computer; 5¼- and 8-inch floppy-disk formats, \$39.95 and \$49.95, respectively. Infocom (see address above).

Zork III: The Dungeon Master, an adventure-type game. This is the final test in the series. You must fight the Dungeon Master himself. For the IBM Personal Computer; 5¼- and 8-inch floppy-disk formats, \$39.95 and \$49.95, respectively. Infocom (see address above).

Texas Instruments

Data Rescue, an arcade-type game. See if you can recover the stolen data-bank models and return them to

earth. For the TI-99/4A; cassette, \$9.95. Kuhl Software, 412 15th Ave. SW, Rochester, MN 55901.

The Dungeon, an arcade-type game (see description under Commodore). For the TI-99/4A; cassette, \$15. Software III, 1307 Douglas Dr., Sterling, IL 61081.

TRS-80

Alphabet Soup, a competitive spelling game with nine skill levels. Once the program generates 5 to 14 letters, you have 200 seconds to spell as many words as you can. For the TRS-80 Color Computer; cassette, \$14.95. Creative Technical Consultants, 16-8 Sangre de Cristo, POB 652, Cedar Crest, NM 87008.

Cyberchess System Program, a chess-tutorial program. This chess-analysis system will play games according to your level of expertise, set up classic games, and rate a player's ability. For the TRS-80 Models I and III; floppy disk, \$29.95. I.J.G. Inc., 1953 West 11th St., Upland, CA 91786.

ZX80/ZX81

Bon Mot, an educational game that teaches vocabulary and spelling skills. Up to 6 players can choose from 11 different anagram games. For the ZX80/ZX81; cassette, \$9.99. Luther A. Gotwald Jr., POB 404, Davidsville, PA 15928.

Musical Scales, a program to convert any series of notes from one musical scale to another. Scales included are Ionian, Dorian, Phrygian, Lydian, Mixolydian, Aeolian, Locrian, and harmonic minor. For the Timex/Sinclair 1000 and ZX81; cassette, \$14.95. Rave Records, 1005 Mechanic St., Decorah, IA 52101.

Schedi-Mort, an amortization-scheduler program. You can compute complete schedules of payments, principal, interest, and remaining

balance on any loans. For the Timex/Sinclair 1000 and ZX81; cassette, \$20. E. Arthur Brown Co., 1702 Oak Knoll Dr., Alexandria, MN 56308.

Other Computers

Dragonfire, a video game (see description under Atari). For the Mattel Intellivision; cartridge, \$39.95. Imagic, 1875 Dobbin Dr., San Jose, CA 95133.

Empire, a simulated war game (see description under

Heath/Zenith). For the Digital Equipment Corporation LSI-11, 8-inch floppy disk, \$40. Northwest Software, 15343 Southeast 43 Place, Bellevue, WA 98006.

Recipe Organizer, a program that stores and retrieves up to 200 recipes on one disk. For the Intertec Superbrain; floppy disk, \$29.95. The Office Partner Inc., 6736 Brookcrest Dr., Charlotte, NC 28210. ■



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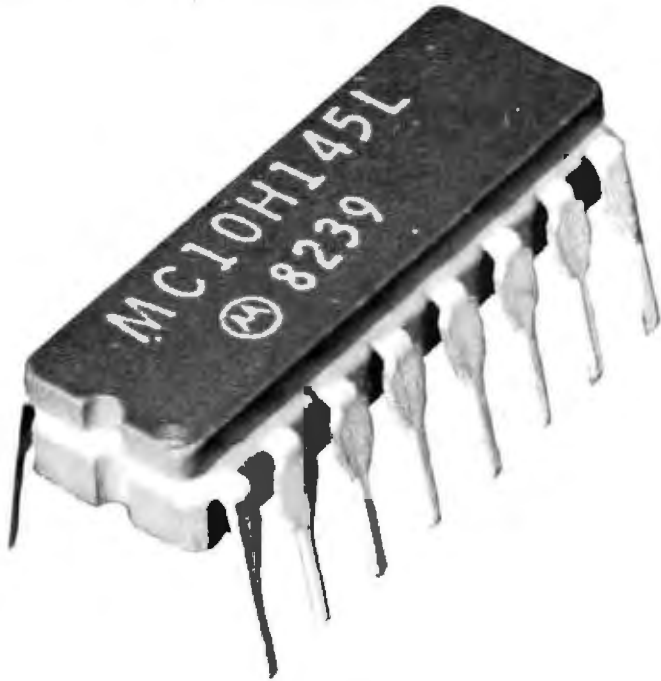
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See other ad on page 178.

What's New?



RAM Has 3-Nanosecond Access Time

Motorola's 64-bit MC10H145 bipolar ECL RAM (random-access read/write memory) can be used in any memory storage system requiring high-speed access times. This device, a member of the MECL 10KH family, has a 3-ns (nanosecond) address access time (typical) with 6 ns maximum. It's organized as a 16 by 4 memory array and engineered with Motorola's MOSAIC (Motorola oxide self-aligned implanted circuit) oxide-isolated process, which achieves a purported smaller device geometry, improved bandwidth, and reduced parasitic capacitances. It's completely compatible with the Motorola MECL 10K family and offers an improved noise margin (150 millivolts) and voltage consumption. The memory cell

array features a write and data input buffer, an address buffer and decoder, data output buffers, and a chip select.

Prototype quantities of the MC10H145 are available in ceramic and plastic DIPs (dual-inline packages). In 100-unit lots, these versions cost \$10.65 and \$9.25 each, respectively. Contact Motorola Semiconductor Products Inc., 5005 East MacDowell Rd., Phoenix, AZ 85008, (602) 962-2202.

Circle 550 on inquiry card.

High-Speed Math Chip

Oki Semiconductor's general-purpose 8-bit MSM6203 mathematics circuit is said to be fast enough for radar data cor-

relation and industrial process-control systems. It is built with silicon-gate CMOS (complementary metal-oxide semiconductor) technology and has eight bidirectional I/O pins. It readily connects to such 8-bit microprocessors as Oki's 80C85A. The MSM6203 can perform 8-by-8-bit multiplication or 16-by-8-bit division operations in 3.3 microseconds. Power consumption is 6.5 milliwatts per MHz during arithmetic operation, and the maximum operating frequency is 4 MHz (50% duty cycle). It's housed in an 18-pin plastic DIP (dual-inline package).

The MSM6203 costs \$7.50 each, in 100-piece quantities. Contact Oki Semiconductor Inc., Suite 401, 1333 Lawrence Expressway, Santa Clara, CA 95051, (408) 984-4842.

Circle 551 on inquiry card.

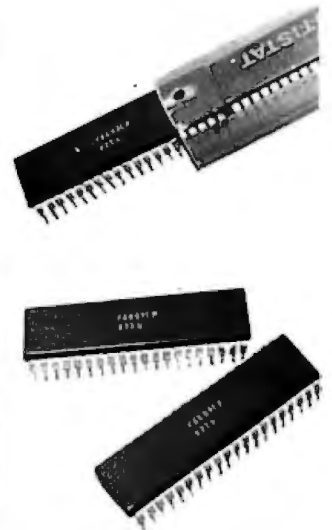
Speedy PROM

The 6353-2 is a 4K-byte nickel chromium PROM (programmable read-only memory) from Monolithic Memories. This chip, organized as 1024 words of 4 bits each, features an address access time of 50 ns (nanoseconds) worst case; 35 ns (typical). Its power consumption is 140 mA (milliamperes), and output leakage current is 40 μ A (microamperes). According to the company, the 6353-2 can be used as a logic element because of its speed. Other applications include program or microcode storage, lookup

tables, and character generators. The 6353-2 PROM is housed in an 18-pin 0.3-inch-wide ceramic package.

In lots ranging from 100 to 999, the 6353-2 costs \$5.25 each. Monolithic Memories Inc., 1165 East Arques Ave., Sunnyvale, CA 94086, (408) 739-3535.

Circle 552 on inquiry card.



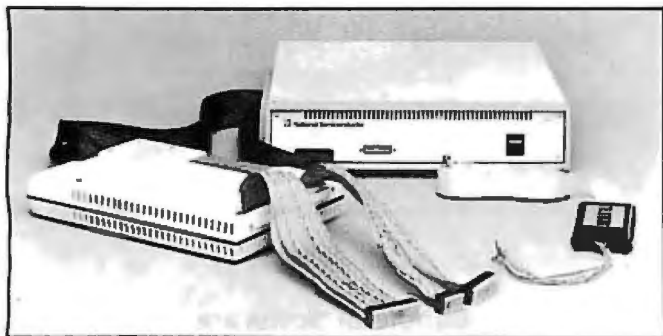
New Member of F6800 Family

Fairchild has added the F6809E to its 8-bit F6800 microprocessor family. This high-performance chip features 16-bit registers, dual 8-bit data paths, 59 basic instructions, the ability to recognize 1464 different variations of instructions and addressing modes, and external clock inputs that permit synchronization with peripherals, systems, or other microprocessors. The F6809E is compatible at the hardware and software levels with the F6800 family.

What's New?

The F6809E microprocessor is available in three speeds: 1, 1.5, and 2 MHz. Quantities can be ordered through local sales offices or franchised distributors. For **further** details, contact

Product Marketing, Fairchild Microprocessor Division, 3420 Central Expressway, Santa Clara, CA 95051, (408) 773-2102. Circle 553 on inquiry card.



In-System Emulator

The NS-ISE-16 is the vanguard of National Semiconductor's series of In-System Emulators (ISE) for its 16/32-bit NS16000 microprocessor family. A multihost emulator family, the ISE/16 line lets users test and debug both hardware and software on their own 16000-family-based designs. The NS-ISE-16 provides real-time emulation of the NS16032 processor, the NS16201 TCU (timing-control unit), and the NS16082 MMU (memory-management unit). The package has three basic components: an emulation support box, an emulation pod, and a TTL (transistor-transistor logic) status pod. Also provided is the IDBG16 software debugging program, resident on the host computer system. (The IDBG16 is a superset of the NS16000 cross-software debugger, DGB16.)

The NS-ISE-16 currently communicates with a

Digital Equipment Corporation VAX/11 host system. Its two RS-232C ports permit transparent mode communication with the host computer. This means that one port is connected to the VAX while the other connects with the user's terminal, permitting direct communication between the ISE and the VAX for faster response. The user's terminal functions as a command console.

The NS-ISE-16 is supplied with an IEEE-488 GPIB port that will allow it to communicate with future host systems. Other standard features include up to 30K bytes of memory-mapping space, write protect/detect of 2K-byte blocks, and program-flow trace of up to 256 nonsequential fetches. This device is presently specified for operation at speeds of up to 6 MHz, with future upgrades planned to operate at 10 MHz.

The NS-ISE-16 costs \$7500, including the interactive debugger program. Contact National Semiconductor, 2900 Semiconductor Dr., Santa Clara, CA 95051, (408) 721-5000. Circle 554 on inquiry card.

SYSTEMS

Complete Color Graphics System

The Executive Presentation System (EPS) from Intelligent Systems Corporation is said to provide all the hardware and software you need to prepare presentation-quality color graphic visuals. With EPS, you can create overhead projector transparencies, 35 mm slides, and paper prints and plots. EPS software includes CP/M, Microsoft BASIC, and a graphics language that uses such English-statement commands as pie, bar, and line. EPS is device-independent, which lets you use a variety of output peripherals, including color plotters, camera systems, and ink-jet printers. This system is built around the Intecolor 8001R color graphics terminal and the Intecolor 7000 computer.

The Intecolor 8001R features individual dot addressability, 96K bytes of RAM (random-access read/write memory) with red/green/blue readable bit map, a 4K-byte graphics command processor in ROM (read-only memory) with 20 functions, 4K bytes of command software in

ROM to handle routines, and an 8K-byte RAM-based low-resolution memory plane for alphanumeric and graphics, with 96 uppercase and lowercase ASCII characters. Its hardware includes two RS-232C ports, one 8-bit parallel printer port, and a 177-key ASCII keyboard with 28 function keys. The Intecolor 7000 offers 128K bytes of RAM, a scrolling text editor, and dual 8-inch floppy-disk drives with 2.4 megabytes of data space and full-track disk buffer for fast throughput.

An 8-pen color plotter, a color camera system, and a color ink-jet printer are available as options. Prices begin at \$18,000, which includes an output option. For details, contact Intelligent Systems Corp., 225 Technology Park/Atlanta, Norcross, GA 30092, (404) 449-5961. Circle 555 on inquiry card.

Eagles Are IBM PC-Compatible

The Eagle 1600 Series of 16-bit computers is compatible with the IBM Personal Computer. According to the company, this series combines all the features of the PC at up to four times the operating speed. The 1600 computers are fully upgradable and come with networking capabilities and word-processing and financial planning software.

The basic system, the Model 1630, has 128K bytes of RAM (random-access read/write memory), 1

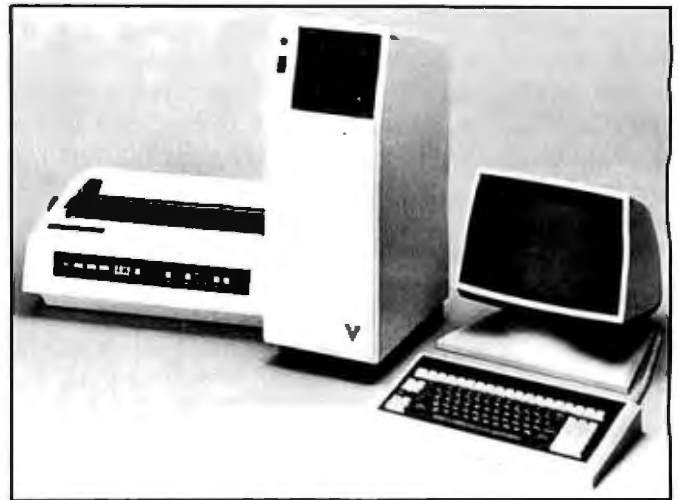
What's New?

megabyte of 5¼-inch floppy-disk storage, 12.5 megabytes of hard-disk storage, a detachable 105-key keyboard with 24 user-definable keys, and a separate monitor and 8086 microprocessor, which operates at 8 MHz. Its internal memory is expandable to 512K bytes, and up to eight PC plug-compatible boards can be added for

peripherals. Additional software available from Eagle includes general accounting, medical and dental practice management, and CPA accounting.

The Model 1630 costs \$6995. Contact Eagle Computer Inc., Building C, 983 University Ave., Los Gatos, CA 95030, (408) 395-5005.

Circle 556 on inquiry card.



Atari 1200XL

The Atari 1200XL home computer comes with 64K bytes of RAM (random-access read/write memory), 12 user-programmable function keys, and built-in diagnostics. Its keyboard permits shifting into an integral European character set that includes special currency and character symbols. A Help key is standard as are one-touch cursor controls, 256 available colors for a monitor, and a speaker with 4 voices and a 3½-octave range. The 1200XL is compatible with Atari peripherals and software products.

Options for the 1200XL include a cassette memory system, an 80-column printer, and a 40-column printer/plotter. The mem-

ory system, the Model 1010 Program Recorder, uses standard audio cassettes and features two channels for both a program and sound effects. The Model 1025 printer prints dot-matrix characters at 40 cps (characters per second) and accepts single-sheet, fan-fold, and rolled paper. The Model 1020 Color Printer/Plotter produces four-color text, complex charts, and graphs to any set of X,Y coordinates. Prices range from \$99.95 to \$549. The 1200XL costs less than \$1000. Full details are available from Atari Inc., 1265 Borregas Ave., POB 427, Sunnyvale, CA 94086.

Circle 557 on inquiry card.

Bundle of Software Comes with Business System

The Voyager 4000 series of small business computers comes with the CP/M operating system and word processing, spreadsheet with graphics, database management, mailing list, payroll, Telex, and time management software. The basic Voyager has RS-232C and RS-422A ports, dual 5¼-inch double-sided double-density floppy-disk drives (1.2 megabytes of storage), and an 8085 central processor that addresses 64K bytes of RAM (random-access read/write memory). The central processor is upgradable to 8085/8088-based 8- and 16-bit coprocessor operation, addressing 1000K bytes of RAM. Up to 20 megabytes of plug-in hard-disk storage is available. The series also features an adjustable 12-inch non-glare video monitor with dedicated memory and an 8 by 12 matrix on a 10 by 14 grid with a choice of three colors. The computer's detachable key-

board has 100 five-function keys and a 10-key numeric pad.

The Voyager 4000 costs \$4995, including the software. Dealer and OEM (original equipment manufacturer) discounts are available. Contact Voyager Systems Inc., 2192 Anchor Court, Newbury Park, CA 91320, (213) 991-9028.

Circle 558 on inquiry card.

Multiuser Telesystem Runs Unix III

A Motorola MC68000-based computer running the Unix III operating system is being marketed by Televideo Systems Inc. The Telesystem II supports up to 16 users and offers interface flexibility by means of 15 serial ports, one RS-422A port, a Centronics-compatible parallel port, and bus expansion capabilities. Standard features include 512K bytes of RAM (random-access read/write memory) and an 8-inch 40-

What's New?

or 80-megabyte Winchester hard-disk drive backed up by a 17.5-megabyte streaming cartridge tape. RAM memory can be expanded to 1 megabyte in 256K-byte increments, and an additional 40- or 80-megabyte drive can be attached for a total storage capacity of 160 megabytes. The operating speed is 8 MHz, and the MC68000 is complemented with an MMU (memory-management unit)

chip. Software available includes COBOL, Pascal, C, and FORTRAN-77.

The Telesystem II costs less than \$14,000, which includes 40 megabytes of disk storage, the backup tape drive, Unix III, and two Televideo displays. Further details are available from Televideo Systems Inc., 1170 Morse Ave., Sunnyvale, CA 94086, (408) 745-7760.

Circle 559 on inquiry card.

Zilog Z80 and Intel's 16-bit 8086 for its main processors. The Z80 runs the CP/M 2.2 operating system, while the 8086 supports up to 1 megabyte of memory.

Mass storage is supplied by dual 5¼-inch floppy-disk drives, each capable of handling more than 312K bytes of formatted data. User memory is provided by 125K bytes of parity-checking RAM (random-access read/write memory), expandable to 1 megabyte. This system has high-resolution color graphics capabilities that are backed by more than 50K bytes of support RAM. Its dedicated display processor generates high-resolution (640 by 200) color graphics. Other standard features are parallel and serial output ports and a typewriter-style detachable keyboard with a separate numeric keypad and 10 programmable function keys.

The Micro 16S comes with the CP/M-86 operating system, a word processor, an electronic spreadsheet, and a color monitor. Options include a 10-megabyte 5¼-inch Winchester-disk drive, a link to Corvus Systems' Omninet network, and Concurrent CP/M-86, which lets the Micro 16S run four jobs simultaneously with each task using up to 250K bytes of memory. Its base price is \$3995. For full details, contact Fujitsu Ltd., Professional Microsystems Division, 2840 San Tomas Expressway, Santa Clara, CA 95051, (408) 980-0755.

Circle 560 on inquiry card.

SOFTWARE

Software Line for Lisa Unveiled

Open Systems will distribute Xenix-based software products for Apple Computer's recently announced Lisa computer. This line, targeted at the small-business market, will include Science Management Corporation's (SMC's) Business BASIC interpreter, seven interactive accounting applications packages, and a report writer. The accounting packages include order processing, general ledger, accounts receivable with billing and sales analysis, payroll, and job cost. The report writer, to be marketed under the name The Team Manager, will link the accounting applications to a comprehensive data dictionary, which will allow creation of simple or complex reports from all files within the accounting system. It will also permit reformatting of data from the accounting applications for use by word processing, spreadsheet, and other productivity applications available under Xenix.

Open Systems will directly license the Xenix-based software to Apple dealers. In addition, it will provide all packaging, training, and support. For further details, contact Open Systems Inc., 430 Oak Grove, Minneapolis, MN 55403, (612) 870-3515.

Circle 561 on inquiry card.

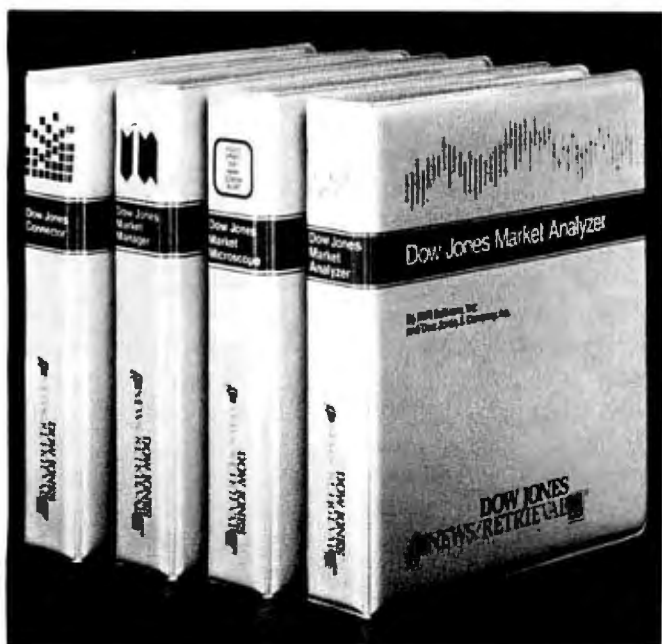


Dual Processors Provide Flexibility

The Micro 16S personal business computer from Fujitsu Ltd. gives you inte-

grated 8- and 16-bit processing power flexibility. The Micro 16S uses the

What's New?



Dow Jones Markets Software

Dow Jones & Company offers software programs designed to meet the business and investment needs of personal computer users. Dow Jones software runs on such systems as the Apple II and the IBM Personal Computer. Customer and dealer support includes a one-year warranty and a toll-free customer service department.

The Dow Jones Market Analyzer automatically collects, stores, and updates stock market data that can be used to construct charts for technical analysis. The Market Microscope sorts and ranks companies and industries by 68 financial indicators. For automatic updates and monitoring of investment portfolios, the Market Manager is offered. Also available is the Dow Jones Connector, which provides users of most microcomputers with access to news, information,

and data contained in the Dow Jones News/Retrieval database.

Prices range from \$95 to \$700. For full hardware details or purchasing information, contact Dow Jones & Co. Inc., POB 300, Princeton, NJ 08540, (800) 257-5114; in New Jersey (609) 452-1511. Circle 562 on inquiry card.

Smart Terminal Program Housed in ROM

The Colorcom/E from Spectrum Projects is a smart terminal program for the Radio Shack Color Computer. Colorcom/E, housed in a ROM (read-only memory) cartridge, provides you with online and offline scrolling, offline printing of data, full- and half-duplex operation, and the ability to receive and send cassette files. It will

support any serial printer, and it permits easy editing before data is printed or written to cassette.

A word mode that eliminates word wrap is offered as an option. Colorcom/E costs \$49.95 and is available from Spectrum Projects, 93-15 86th Dr., Woodhaven, NY 11421, (212) 441-2807.

Circle 563 on inquiry card.

Graphics System for dBASE II

Fox & Geller's dGraph lets you produce high-quality charts from any Ashton-Tate dBASE II database. According to the manufacturer, all you have to do is enter the data or the name of the dBASE II database you wish to chart and dGraph will do the rest. A chart-description procedure lets you create bar, pie, line, and pie-bar charts that include such information as the percent of total based on summing or counting. Other possible uses include summing, counting, and averaging of data fields and automatic selection of data based on ranges and on matched values. dGraph can function as a stand-alone system, and it supports a variety of printers and plotters, including Epson MX-70/80/100, Okidata Microline, and Xerox/Diablo 1750.

The dGraph system runs on CP/M-, CP/M-86-, or MS-DOS-based computers with 64K bytes of memory. A video terminal with clear

screen and cursor-addressing and 240K bytes of disk capacity are required. The suggested retail price is \$295. For further details, contact Fox & Geller Inc., 604 Market, Elmwood Park, NJ 07407, (201) 794-8883.

Circle 564 on inquiry card.

Financial Forecasting Tool

Ashton-Tate's Bottom Line Strategist is an economic forecasting tool. Developed to serve Fortune 1000 forecasting needs, this program generates bottom-line answers for future business ventures without programming, formulas, or complex spreadsheets. It provides complete, sophisticated models that assist executives in analyzing and tracking business scenarios. The Strategist uses direct user input of business assumptions and displays 11 different financial and marketing forecasts. Key considerations include how profitable a business will be, how much money is being risked, and when break-even points will be established.

The Bottom Line Strategist, designed for the IBM Personal Computer and CP/M-based systems, is available for \$400 through Ashton-Tate dealers and distributors. Contact Ashton-Tate, 10150 West Jefferson Blvd., Culver City, CA 90230, (213) 204-5570.

Circle 565 on inquiry card.

What's New?

Database Program for Nonprogrammers

Infostar is a database-management system that doesn't force you to learn a programming language. Produced by Micropro International, this business-applications development package provides onscreen English-language menus that guide you through each step of data-entry form design and report generation. For data entry, a cursor is used to draw forms on the screen. Generating custom applications is said to be four times faster than with other programs because you do not have to write and debug code.

Infostar can generate a preformatted quick report in approximately 60 seconds and has the ability to incorporate data from multiple files. It provides up to nine control breaks, arithmetic calculations within reports, and four levels of help menus. It can sort a file of up to 32 key fields at speeds approaching 560 records per minute, and its report writing and editing feature lets you move data fields, change headings, and insert dollar signs and decimal points. Able to work with dot-matrix or letter-quality printers, Infostar's print features include boldface and underlining of selected data fields. Other specifications include variable-length records and Wordstar compatibility.

Infostar runs on 48K-byte CP/M 2.2-based systems. Dual floppy-disk drives or a single floppy disk with a hard disk is rec-

ommended. With a training guide, Infostar costs \$495. It's available from Micropro International Corp., 33 San Pablo Ave., San Rafael, CA 94903, (415) 499-1200.

Circle 566 on inquiry card.

Xenix Now Standard on TRS-80 Model 16

Radio Shack has announced that it will use Microsoft's multiuser, multitasking Xenix operating system as the standard DOS on its TRS-80 Model 16. A Model 16 equipped with Xenix can be expanded to accommodate three users, with all users running programs or sharing the same program, data, or peripherals.

Xenix features tree-structured directories, device-independent I/O, chaining of program input and output, and foreground and background execution. It requires 256K bytes of memory and a hard-disk drive. Xenix can also run on TRS-80 Model 11s outfitted with a hard disk and a Model 16 upgrade kit. All applications software currently offered by Radio Shack for the Model 16 can be moved to the Xenix system. Radio Shack will supply Xenix at no cost to Model 16 owners and include it in all new Model 16 production.

In a related development, Radio Shack also announced that it intends to introduce several multiuser application packages for Xenix-equipped Model 16s.

Future plans call for several interactive accounting programs, a high-capacity inventory control system, versions of Microsoft's BASIC and Multiplan spreadsheet, and a Xenix development system that includes the C language.

For complete details, contact your local Radio Shack Computer Center, selected Radio Shack stores, and participating dealers. Radio Shack 1800 One Tandy Center, Fort Worth, TX 76102.

Circle 567 on inquiry card.

Appointments and Records Filed in Shoebox

Shoebox 2.0, an appointment manager and expense recording system from Techland Systems, can track tasks and appointments for any number of executives, limited only by storage capacity. It offers such features as a schedule-handler for tasks that are not appointments, expense recording keyed to particular appointments and categories, reminders for recurring schedule items, and the ability to produce printouts of schedules and expense reports. Using a minimum number of keystrokes, you can review past appointments or reminders involving a given subject or person. Shoebox has the ability to remind you of events up to six months ahead of time, and its multiuser option offers password-protection and a coordinator mode

that allows nonsensitive data to be manipulated. Programming knowledge is not required because most Shoebox commands are single keystrokes.

Shoebox 2.0 runs on 50K-byte MS-DOS-based systems. A cursor-addressable terminal and one or more 160K-byte disk drives are required. An 80-character-per-line printer is recommended. Shoebox costs \$195 and is available from Techland Systems Inc., 39 Carwall Ave., Mount Vernon, NY 10552, (914) 699-8467.

Circle 568 on inquiry card.

L. A. W. S. Support for Law Offices

L. A. W. S. (Litigation support, Accounting, Word processing System) software for law offices is available from Legal Systems Development. Litigation support modules range from a database that stores, manipulates, and retrieves depositions, transcripts, and evidence to a trial preparation program that provides a variety of summary reports. Accounting packages include accounts receivable and payable, billing, and payroll. Lexisoft's Spellbinder is available through Legal Systems Development. This word processor features letter-quality printer support, simple cursor moves, office and data management abilities, and an optional spelling checker. Other modules in the L. A. W. S. product line include a docket-con-

What's New?

trol system and communications software.

The manufacturer recommends a computer system with 10 megabytes of disk storage, 64K bytes of RAM (random-access read/write memory), CP/M, a printer, and a terminal. Prices for individual

modules range from \$100 to \$2495. The complete L. A. W. S. product line can be purchased for \$5295. For full details, contact Legal Systems Development, 460 Main St., Placerville, CA 95667, (916) 626-3351. Circle 569 on inquiry card.

PERIPHERALS



Matrix Printers from GE

The GE 3010 and 3014 are the latest additions to the General Electric GE 3000 series of dot-matrix printers. These microprocessor-based printers are plug-to-plug compatible with such microcomputers as Apple, IBM, and Televideo. They can print up to four copies bidirectionally at 160 cps (characters per second). Each 136-column printer is supplied with a 2K-byte print buffer, a 9-wire printhead for continuous underscoring and lowercase descenders, and selectable print densities and paper widths. Both machines print 6 or 8 lines per vertical inch.

The GE 3010 uses a 4-pin tractor for paper feed-

ing, while the 3014 has a tractor and a friction cut-sheet roller arrangement. The 3014 also features a high-resolution print mode that produces overlapping dots for near-letter-quality printing at 40 cps and a horizontally enhanced 80-cps memo mode. A carbon-film ribbon is being developed for the 3014. Volume pricing ranges from \$850 to \$1150, depending upon model and quantity. Additional information is available from General Electric Co., Data Communication Products Department, Waynesboro, VA 22980, (800) 368-3182; in Virginia, (703) 949-1183.

Circle 570 on inquiry card.



Graphos: Desktop Graphics Terminal

Graphos, a desktop color graphics terminal that can display and manipulate 16 windows, is produced by Ithaca Intersystems. It features resolution of 640 by 480 pixels, two-dimensional segment transformations, high-level primitives, a Motorola MC68000-based device-independent graphics subsystem, multiple fonts, and individual scroll, pan, zoom, and graphics overlay for each window. Input support includes tablets, joysticks, and track balls. Standard alphanumeric support includes character and background color, insert and delete line, and VT-100 compatibility. Three I/O function modules can be incorporated into Graphos, providing a means for such interfaces as RS-232C, RS-422A, and 8- or 16-bit parallel.

The concept behind Graphos is known as Shiftable Cell. The Shiftable Cell, which combines alphanumeric and bit-mapping architecture, dynamically

assigns cells to the 16 on-screen windows. It permits text and graphics scrolling under any fixed window and independent manipulation of any window. Segments are retained in the terminal's memory, enabling them to be rotated, recalled, or shifted without retransmission from the host computer.

A 9-slot card cage is available as an option. Graphos is priced at less than \$8000. For further details, contact Ithaca Intersystems Inc., 1650 Hanshaw Rd., POB 91, Ithaca, NY 14850, (800) 847-2088; in New York, (607) 257-0190.

Circle 571 on inquiry card.

Disk Drive for Atari

The Percom Data AT-88 disk-drive system is compatible with Atari 400/800 computers. This single-density drive offers 88K bytes of formatted storage and features Atari plug compat-

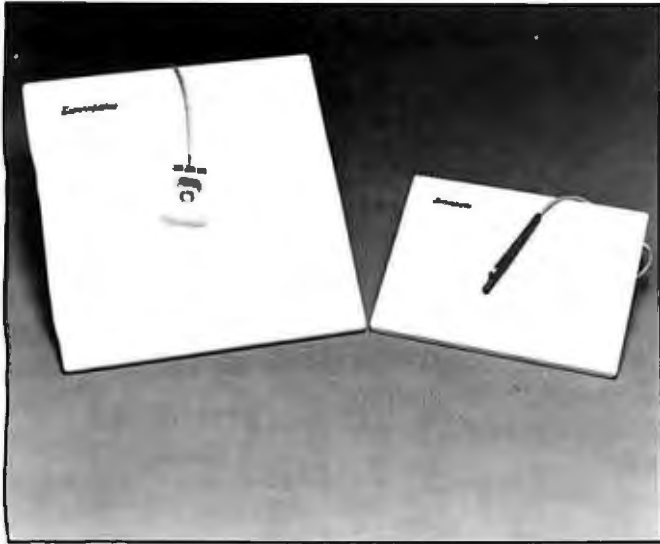
What's New?

ibility and an integral power supply. The AT-88 can use Atari operating system software without modification.

The AT-88 is shipped with the OSA/Plus operat-

ing system. It costs \$488. For further information, contact Percom Data Co. Inc., 11220 Pagemill Rd., Dallas, TX 75243, (214) 340-7081.

Circle 572 on inquiry card.

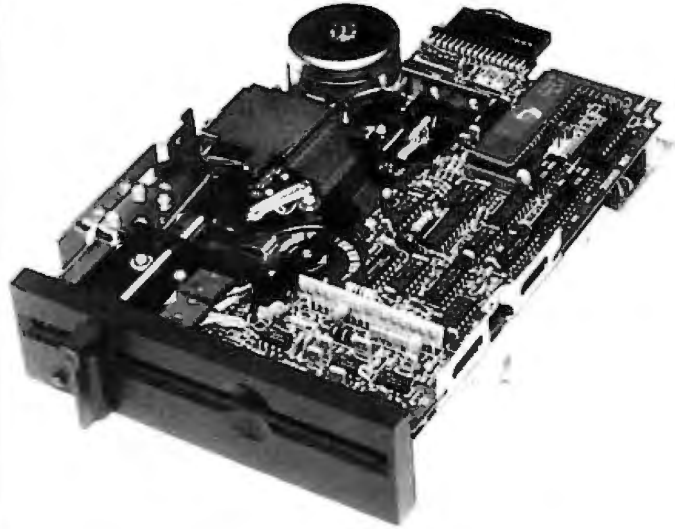


Compact Digitizers for OEM Market

Summagraphics has announced a family of compact, ergonomically designed digitizers for the OEM (original equipment manufacturer) graphics systems market. The MM series will perform all cursor steering, menu picking, and graphics digitizing tasks. The digitizers can provide absolute and delta coordinate output and can automatically scale output both horizontally and vertically to match video-display resolution and orientation. Standard features include resolution of up to 500 lines per inch, single printed-circuit grid electronics, and built-in diagnostic modes to check electronics, communications, tablet, and stylus or cursor. A three-button cursor that

can be used either as a mouse or as a digitizer cursor is supplied with this system. The stylus is equipped with a pen-tip switch and a user-assignable barrel activation button.

Interface options include either RS-232C or TTL (transistor-transistor logic) ports. The MM 960 digitizer has a 6- by 9-inch (152- by 228-mm) active area that provides 3000 by 4500 points of resolution. The MM 1200's active area measures 12 by 12 inches and offers 6000 by 6000 points of resolution. For detailed price and product information, contact Summagraphics Corp., 35 Brentwood Ave., POB 781, Fairfield, CT 06430, (203) 384-1344. Circle 573 on inquiry card.



Half-Height Drives Handle Full Load

The storage capacity and performance of the Tandon TM55 Thinline family of half-height 5 1/4-inch floppy-disk drives are said to be equivalent to that of Tandon's full-sized drives. TM55 Thinline drives are 1 5/8 inches tall, 5 3/4 inches wide, and 8 inches long. They weigh 3 pounds. Standard features include maximum data storage of up to 1 megabyte, a 3-millisecond track-to-track access time, and a transfer rate of 250,000 bytes per second. An on-board microprocessor controls spindle speed, centers the media, positions the head for minimum hysteresis, and switches the write current for optimum recording quality. TM55 drives use IBM-formatted 5 1/4-inch floppy disks.

Two models are offered. The Thinline TM55-2, a double-sided 48-tpi (track-per-inch) drive, has a storage capacity of half a megabyte. The TM55-4 is a double-sided 96-tpi drive with 1 megabyte of stor-

age. Prices begin at less than \$200. Complete technical specifications are available from Tandon Corp., 20320 Prairie St., Chatsworth, CA 91311, (213) 993-6644.

Circle 574 on inquiry card.



Pint-Size Modem Fits Anywhere

Novation is marketing a 300-bit-per-second direct-connect automatic ans-

What's New?

wer/originate modem that's almost one-fifth the size of conventional units. The J-Cat measures 5 by 1.9 by 1.3 inches, small enough to fit almost anywhere. It plugs into any modular RJ11C telephone jack and has the ability to automatically switch into answer or originate modes. J-Cat comes with an audio beep that sounds for busy signals, dial tones, and when a carrier is detected.

Built-in features include LED (light-emitting diode) status displays, a disconnect/test key, a connect/break key, and self-test. J-Cat is RS-232C-compatible.

The suggested retail price for the J-Cat modem is \$149. Address inquiries to Novation Inc., 18664 Oxnard St., Tarzana, CA 91356, (800) 423-5419; in California, (213) 996-5060. Circle 575 on inquiry card.

PUBLICATIONS



Jameco Issues Catalog

Jameco Electronics has produced a 64-page illustrated catalog listing more than 2000 electronic products ranging from integrated circuits to power

supplies. For a copy, contact Jameco Electronics, 1355 Shoreway Rd., Belmont, CA 94002, (415) 592-8097. Circle 576 on inquiry card.

Software Guide

The Online Micro-Software Guide and Directory, 1983-84, is available from Online Inc., publisher of Database magazine. Edited by Helen A. Gordon, this guide contains full-page descriptions of software packages, resource information, an annotated bibliography, and listings of resources. To assist readers in locating programs for specific needs, four indices are provided: applications, software, producer, and distributor. Also included are nontechnical articles that address such topics as software applications in a corporate headquarters environment and the role of the software consultant.

Each copy of the Online Micro-Software Guide and Directory comes with an up-to-the-minute addendum that includes new benchmarks and less familiar programs. Single copies cost \$40. Four or more copies are \$30 each, including the annual supplements. Two annual supplements cost \$30 each. Contact Online Inc., 11 Tannery Lane, Weston, CT 06883, (203) 227-8466. Circle 577 on inquiry card.

Guide Aids Standards Developers

A FORTRAN coding guide that assists software departments in formulating standards has been produced by Associated Technology. This 46-page reference work is said to pro-

vide software managers, designers, and quality-assurance teams a methodology made up of a set of company standards and examples. The publisher asserts that these features ensure the construction of top-down programs that are structured, testable, and easily maintainable.

The FORTRAN guide costs \$20. It's available from Associated Technology, Route 2, Box 448, Estill Springs, TN 37330. Circle 578 on inquiry card.

Armchair BASIC

Armchair BASIC by Annie and David Fox is an introductory book on the BASIC programming language from Osborne/McGraw-Hill. It's written for computer neophytes who do not have access to microcomputers but who want to be familiar with programming concepts. This 180-page book presents programming fundamentals that are applicable to any computer that runs BASIC, such as the Apple or Commodore PET. Topics covered include the working parts of a computer, variables, data inputs, if... then statements, controlled loops, random numbers, and sub-routines.

Armchair BASIC is available in paperback for \$11.95. Contact Osborne/McGraw-Hill, 630 Bancroft Way, Berkeley, CA 94710, (415) 548-2805. Circle 579 on inquiry card.

What's New?

MISCELLANEOUS



Robot Recalls Its Actions

RB5X, an intelligent robot, detects and responds to objects in its path. Manufactured by RB Robot Corporation, RB5X has 8K bytes of memory, programs, and tactile sensors. The company asserts that once RB5X achieves a successful random response, it remembers its actions and repeats the correct response when confronted with the same situation again.

For program entry and data transfers, RB5X is supplied with an RS-232C port, making it compatible with such microcomputers as the Apple, Radio Shack TRS-80, and IBM Personal Computer. This port, for example, lets you transfer RB5X's memory to your computer, where you can study and alter its patterns and programs. RB5X is

equipped with a circuit that automatically charges its batteries. Other standard features include a sonar sensor and a pulsating light. It has an aluminum body with polycarbonate dome and measures 13 by 24 inches. RB5X weighs 10 pounds and uses two rechargeable 6-volt gelled electrolyte batteries (supplied).

Options include 16K bytes of additional memory, data telemetry, and a mechanical arm. A voice-recognition system and a speech synthesizer are under development. The basic RB5X is \$1495. Address all inquiries to RB Robot Corp., Suite 201, 14618 West Sixth Ave., Golden, CO 80401, (303) 279-5525.

Circle 580 on inquiry card.

Data Encryption Board

The Encryptor from Jones Futurex is a high-speed data encryption/decryption plug-in board. Practical applications include protecting financial statistics, market strategies, and technical and personal records. It has a transfer rate of 1.1 megabits per second and offers programmed I/O operation for key, data, commands, and states. The Encryptor is said to be able to encrypt or decrypt 8 bytes of data in less than 50 microseconds. No cables are required. The Encryptor provides supporting software for CP/M, MP/M, and Oasis operating systems and works with S-100, Apple, and IBM Personal Computers.

The Encryptor, model number ENC 300, uses the Western Digital Data Encryption/Decryption VLSI (very large-scale integration) device, as certified by the National Bureau of Standards. It costs \$299.95 and is available from Jones Futurex Inc., Suite G, 9700 Fair Oaks Blvd., Fair Oaks, CA 95628, (916) 966-6836. Circle 581 on inquiry card.

Intelligent Clocking Machine

Digitech's DC-999 is an intelligent clocking ma-

chine that can be controlled by any computer through an RS-232C port. It's suitable for applications involving time-recording and card identification, such as security access and professional time tracking. The DC-999 responds to a set system of commands, and it can be reprogrammed for different applications. Standard features include a built-in microprocessor and memory and the ability to handle all front-end processing independently or to work as a stand-alone terminal. It's able to collect, check, edit, compute, store, and transfer data to a host computer. Data is collected through an optical card reader or through keyboard entry. The DC-999 has LED (light-emitting diode) displays for verifying data entry and a buzzer alarm that alerts the key operator of misuse or tampering.

A 15-column printer and a magnetic tape drive are offered as backup storage options. A 12-digit version with programmable digit length for job-costing and a keyboard option for entering external data relating to an incoming card number are also available. The suggested price is \$1500; dealer inquiries are invited. Contact Digitech PTE Ltd., 303 Pearls Center, 100 Eu Tong Sen St., Singapore 0105, Republic of Singapore; tel: 2237740; Telex: RS28171 DGTECH. In the U.S., contact Hiram H. Samuel, Onondaga International, (315) 471-1251. Circle 582 on inquiry card.

What's New?



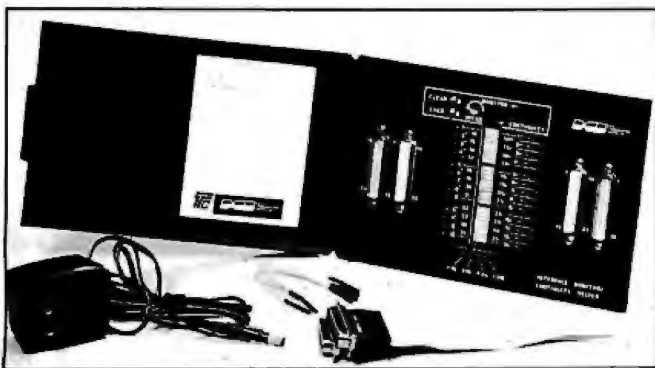
Hardwood Disk Storage Box

Systems Integration's Disk Niche is a solid hardwood storage box for 5¼-inch floppy disks. It provides a dust-proof, static-free environment for as many as 50 floppy disks and has 5 movable, tabbed dividers to aid organization.

The Disk Niche is avail-

able in walnut, cherry, or oak, with a hand-rubbed oil finish. It costs \$49.95, plus \$3 postage and handling. Contact Systems Integration, 1519 North Nevada Ave., Colorado Springs, CO 80907, (303) 635-4477.

Circle 583 on inquiry card.



Cable Tester Doubles As Breakout Box

The CT-1 Cable Tester and Breakout Box lets your technicians test RS-232C cables on-site. Made by Data Communications Brokers, the CT-1 checks for cable continuity and indicates leads that are tied together or crossed over. A speed adjustment for setting the rate for cable tester scans and an LED

(light-emitting diode) for each of the RS-232C's 25 connections are provided. The CT-1 can be placed into an RS-232C link and used as a breakout box by flipping a switch.

The CT-1 comes with jumpers, a short extension cable, rechargeable batteries, and a battery charger. It costs \$255 and

can be purchased directly from Data Communications Brokers, 3000 Research Rd., POB 3658, Champaign, IL 61820, (800) 637-1127; in Illinois, (217) 352-3207.

Circle 585 on inquiry card.

Compact Disk Has Large Disk Abilities

The CFD (compact floppy disk) is a 3-inch floppy disk from Maxell Corporation of America. The CFD's rotation speed, data transfer rate, recording capacity per track, and other technical specifications are identical to those of 5¼-inch floppy disks. The CFD has a high-recording-density magnetic coating with the same capacity as that of a standard disk, which lets you transfer all the data from a 5¼-inch disk to it. The magnetic coating features a hardened plastic center for improved reliability.

The CFD, which was released late last month, is designed to work with such 3-inch disk drives as the one manufactured by Hitachi. Each CFD costs approximately \$6.50. Further information is available from Maxell Corporation of America, Computer Products Division, 60 Oxford Dr., Moonachie, NJ 07074.

Circle 584 on inquiry card.

Slot-Independent Bubble Memory for the Apple II

Ap-Bub, a slot-independent 128K-byte nonvolatile bubble-memory module for

the Apple II, is marketed by MPC Peripherals Corporation. Standard features include disk-emulation software for DOS 3.3 and a boot PROM (programmable read-only memory) that permits the user to boot directly from the module. Ap-Bub is said to be able to execute DOS read and write commands at speeds three times faster than the standard floppy-disk drive. Its data reliability is purported to be 1000 times greater than that of tapes and disks.

Ap-Bub has an \$875 suggested retail price. For more information, contact MPC Peripherals Corp., 9424 Chesapeake Dr., San Diego, CA 92123, (619) 278-0630.

Circle 586 on inquiry card.

Where Do New Products Items Come From?

The information printed in the new products pages of BYTE is obtained from "new product" or "press release" copy sent by the promoters of new products. If in our judgment the information might be of interest to the personal computing experimenters and homebrewers who read BYTE, we print it in some form. We openly solicit releases and photos from manufacturers and suppliers to this marketplace. The information is printed more or less as a first-in first-out queue, subject to occasional priority modifications. While we would not knowingly print untrue or inaccurate data, or data from unreliable companies, our capacity to evaluate the products and companies appearing in the "What's New?" feature is necessarily limited. We therefore cannot be responsible for product quality or company performance.

DISK DRIVE For APPLE!!

- metal cabinet ☆☆☆
- 35 track \$279.95
- w/cable

Computer Games:
APPLE & ATARI (specify)

Choplifter → \$24.95ea.
Frogger → \$24.95ea.
Apple Panic → \$21.95ea.
Crossfire → \$21.95ea.
Raster Blaster → \$21.95ea.

SUPER 3.5amp POWER SUPPLY
for APPLE → \$95.00 ☆

Diskette Storage BOX

5 1/4 in. → \$2.50ea.
5 1/4 in. → \$10.00
8 in. → \$3.50
8 in. → \$15.00

Bare Bones APPLE II EURO
= 48K RAM =
w/o Keyboard \$399.
w/o Pwr. Supply

Microswitch: \$75.00
Power Supply: \$89.00
APPLE Purchase: \$180.00
Reference Manl.

SPECIALS

3inch Mini FAN → \$8.95
2111 → \$2.45
B155 → \$11.50
ER2501 → \$4.95
AY5 1013A → \$2.95
B202 → \$29.95
B522 → \$5.25

8255 → \$4.50
8748-B → \$31.00
MC6800 → \$7.75
MC6802 → \$14.95
MC6850 → \$4.50
MC6821 → \$4.95
6331 → \$1.25

4116-2 → 8/9.95
2716(5v) → 3.25ea
2732(5v) → 5.25ea
2532(5v) → 8.75ea.
Z80 A CPU → 5.25ea.
IC. Master \$49.95

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ANAHEIM CA 92806
714 632-6790 CHECK-M-O

10 MIN. ORDER. C.A. RES. ADD. 5% I.D. 10% N.E.T. 5% I.T.
Freight \$10.49 → \$200 → \$99 → \$99. send \$100
50 - 99 → 4.00 500 - 999 → 1.00
100 - 740 → 8.00 1000 - UP → Call catalog

MONITORS ☆☆☆
ZENITH # ZVM-121
12in. 15MHz./GREEN Phos
I → \$99.00 ☆

BMC # BM-1200SU
12in. 18MHz./GREEN Phos.
Non-Glare Screen
I → \$118.00 ☆

BMC # BM1401RGB
13in. "RGB" COLOR
with Apple interface!!
I → \$425.00 ☆

Diskette SALE!!
"Wabash"

5 1/4 8inch
SS/SD 18.50 21.50
soft
SS/DD 27.40 30.40
DS/SD 0 34.90
DS/DD 32.40 37.40

REAL-TIME CLOCK CALENDAR (MSM 5832)
\$6.25 / \$1.25 xtal.

Syntron II Computer
★ 48K RAM
★ Runs Apple Software
\$699.00

COMPONENTS

7400 SERIES		74S SERIES	
7400	18	7454	19
7401	18	7470	30
7402	18	7471	30
7403	21	7472	30
7404	23	7473	30
7405	23	7474	30
7406	23	7475	30
7407	23	7476	30
7408	23	7477	30
7409	23	7478	30
7410	23	7479	30
7411	23	7480	30
7412	23	7481	30
7413	23	7482	30
7414	23	7483	30
7415	23	7484	30
7416	23	7485	30
7417	23	7486	30
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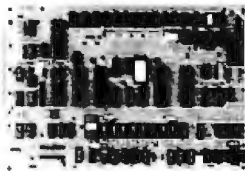
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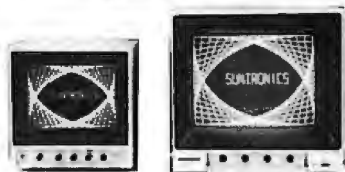
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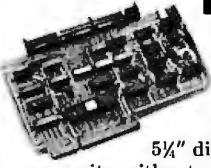
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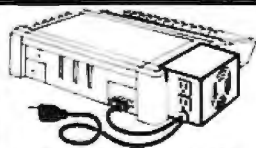
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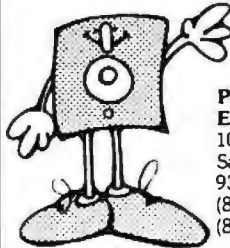
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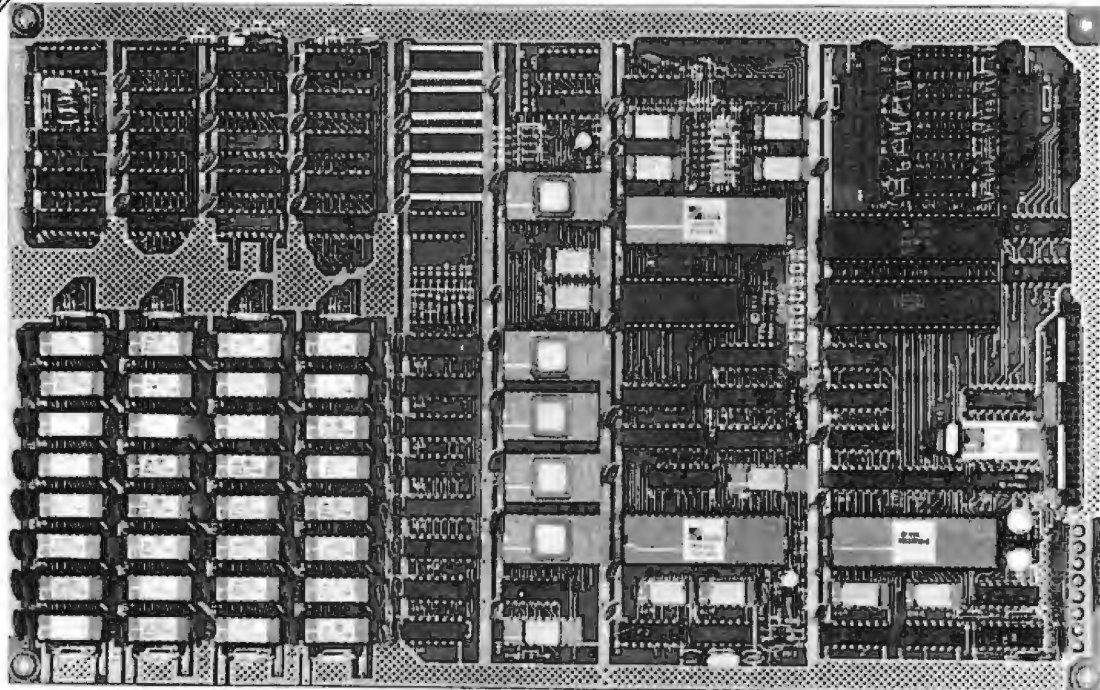
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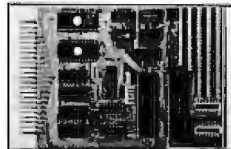


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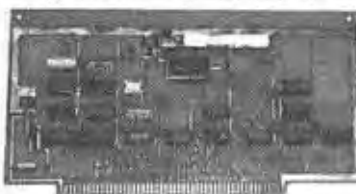
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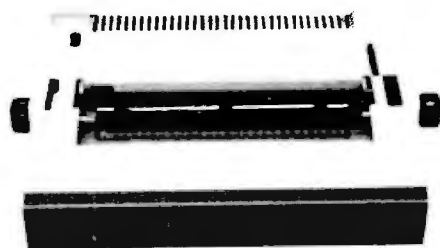
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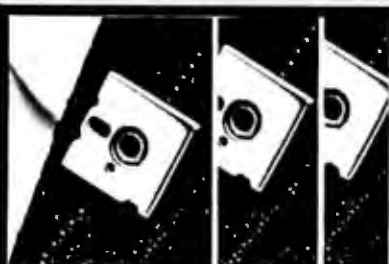
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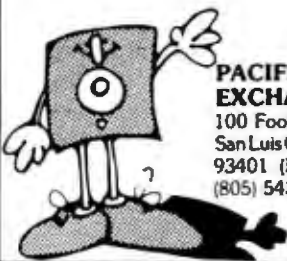


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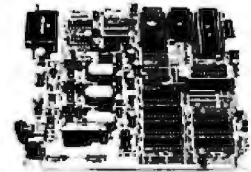
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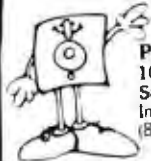
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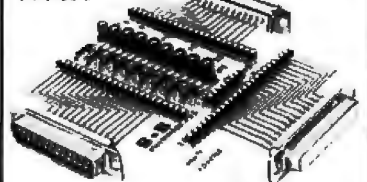
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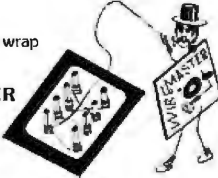
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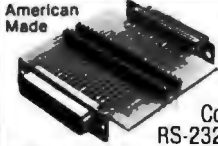
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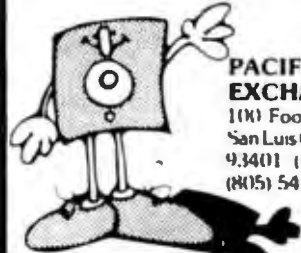
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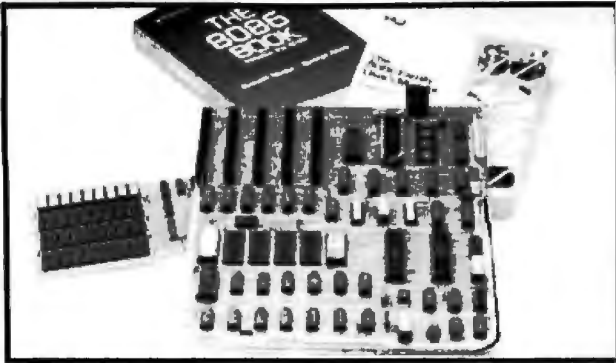


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LEARN 16 BIT TECHNOLOGY IN EASY LOW-COST STEPS. This 2-board system features (1) an 8088 mother board with a 5-slot expansion bus that will accept any hardware designed for the IBM personal computer and (2) a 64K (expandable to 256K) memory board that also features an IBM compatible RS 232 communications port. All circuits are functionally equivalent to the IBM except for the cassette ROMS. This means that all programs written in basic designed to run on an IBM can be compiled to run in this system and that any disk-operating system that will run on an IBM will work directly in the EXPLORER 88-PC. The system monitor ROM included in the Starter's system features a user-friendly operating system that allows easy program generation and debugging. The commands include display/modify memory... display/modify registers...input/output data to I/O ports...block moves...single-step trace mode...go/run with optional breakpoint and register reports...cassette load/save with file labels...plus a complete system test program that tests and reports condition of ROM, RAM, cassette interface, timer, DMA controller, interrupt controller, and the communications port. These test programs not only allow easy debugging of software but they serve as hardware and software learning tools.

The EXPLORER 88-PC STARTER'S KIT includes a mother board, memory/ I/O board, all components needed, sockets for IC's used, one 62-pin bus connector and complete assembly/test instructions. All you need is a soldering iron, solder, a +5 volt @ 3 amps & -5 & +/- 12 volt @.5 amp power supply, and a standard RS 232 terminal (Netronics has 2 low-cost ones to choose from).

□ Explorer 88-PC Starter's Kit ...\$399.95 + 10.00 p&i (wired & tested, odd 100.00).

□ Extra 62-pin connectors @ 4.25 ea. + 1.00 p&i.

If you do not own a terminal you may want to consider using our IBM compatible keyboard (see photo) in conjunction with an IBM compatible color graphics board. This combination, although not necessary at the introductory level, may be desirable if you plan to expand the EXPLORER 88-PC to be fully IBM compatible. These items require additional power and are only available wired and tested as follows:

- IBM compatible keyboard...\$299.95 + 10.00 p&i
- IBM compatible color board...\$299.95 + 10.00 p&i
- Additional ROM required...\$35.00



The EXPLORER 88-PC can be expanded at any pace you decide. Invest and learn at a pace that is comfortable for you. Netronics is dedicated to supplying the finest hardware and software to make this a meaningful learning experience. Hard disks, built-in modem board, eeprom burner, print buffer system plus more will be available shortly. The following items are available now:

Deluxe heavy-duty steel cabinet that houses either two 5 1/4" floppies or a 5 1/4" hard disk with one floppy. This cabinet features a brush-finish front panel and a wood-grained sleeve that gives the unit a real professional look.

EXPLORER 88-PC Cabinet...\$199.95 + 18.00 p&i.

A heavy-duty open frame power supply with fan that can be used in your own cabinet or installed into the Netronic cabinet is available as follows:

10 amp power supply for system + 2 floppies...\$149.95 + 8.00 p&i.

As above + extra power for 1 hard disk...\$169.95 + 8.00 p&i.

IBM compatible disk controller board. Controls four 5 1/4" floppy drives (w/2 drive cable)

□ Available wired and tested only...\$250.00 + 8.00 p&i.

□ The monitors and BIOS source listings are available on either disk or hard copy of \$35.00. Please specify format and system required.

INTEL 8086 8088 user manual...\$15.00 + 1.50 p&i.

THE 8086 BOOK by RECTOR & ALEX...\$16.00 + 1.50 p&i.

Special IBM compatible system: with keyboard, color graphics board, floppy disk controller, 64K RAM, cabinet, standard power supply and a single 5 1/4" floppy drive...\$1899.95 + 25.00 p & i.

*IBM PC is a registered trademark of IBM Corporation

EXPLORERS

Learn computing from the ground up. Start with the Explorer/85 Level 'A' kit which includes an expandable mother board. The Kit Includes the 8085 CPU, 2K Monitor program used to enter, test, run and save programs plus the parts to allow you to start programming. Just add a power supply and terminal or hex keyboard. □ LEVEL A Terminal version or □ Hex Keypad version 129.95 + 3.00 p&i. Add □ Level 'B' 49.95 + 2.00 + two 100 pin connectors @ 4.85 ea. and have a power supply 100 computer. Add □ Level 'C' 39.95 + 2.00



p&i + five 100 pin connectors to increase S-100 slots to 6. Add memory using the JAWS 16-64K S-100 board or add □ Level 'D' 4K to main board 49.95 + 2.00 p&i. □ Level 'E' 5.95 + 1.50 p&i adds decoding for 8K of 2716 eeproms. Need a power supply? Use the 5 amp AP-1 at 39.95 + 2.00 p&i. Select one of our low-cost terminals or use the Hex keypad w/display at 69.95 + 2.00 p&i. □ Deluxe system cabinet 49.95 + 3.00 p&i. Optional tan 16.50. Now add Micro-soft 8K basic & a powerful Text editor/Assembler in ROMS, just 99.95 ea. Add □ 8" floppy 49.95 + 12.00 p&i. Floppy controller board 199.95 + 2.00 p&i. Floppy cabinets & power supply 69.95 + 3.00 p&i. Two drive cable 29.95 + 1.50 p&i. Hard disk also available (see insert).

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□ Add to any of above Explorer steel cabinet. AP-1 five amp. power supply, Level C with two S100 connectors, disk drive cabinet and power supply, two sub-D connectors for connecting your printer and terminal...(Reg. \$225.95) SPECIAL \$199.95 plus \$13 p&i.

Complete 64K System. Wired & Tested... \$1650.00 plus \$26 p&i.

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*Add \$2.00 p&i to all above.

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8K 2716 EPROM BOARD. Addressable on 8K page boundaries complete with sockets 69.95 + 2.00 p&i.

S-100 ELECTRIC MOUTH. Give your computer the power of speech. Uses National's DIGITALKER □ with 143 words 99.95 + 2.00 p&i. □ second word set 39.95 + 1.00 p&i. Board accepts up to 4 word sets or your own custom word ram chips.



Use 90 preprogrammed words or generate your own words using phonemes. Perfect for any project that needs speech or for speech development system. Connects to any RS 232 serial or 8 bit parallel port or can be used in a stand alone mode. □ Speak-easy (board only) 159.95 + 3.00 p&i. Cabinet and power transformer 25.00 + 2.00 p&i. **TRS 80 ELECTRIC MOUTH.** Plugs into the expansion slot on the TRS 80 models 1 or 3 (specify type) □ with 143 word set 119.95 + 3.00 p&i. Includes separate power supply, second word set 39.95 + 1.00 p&i, same specs as S-100 model.

APPLE ELECTRIC MOUTH. Same as above except this board plugs into any of the Apple expansion slots □ with 143 word set 99.95 + 3.00 p&i. □ second word set 39.95 + 1.00 p&i. Accepts 3 word sets or custom word ROMs.

TERMINALS & VIDEO

FASTERM 80 199.95 + 3.00 p&i. Display format: 64 or 32 char/16 lines...96 ASCII characters (w/ case)...8 baud rates, 150 to 19,200...line output: RS 232-C or 20 ma loop...video output: 1V P/P □ cursor modes: home



& clear screen, erase to end of line, erase cursor line, cursor up and down, auto carriage return/line feed at ends of line and auto scrolling...reverse video...blinking cursor...parity: off, even, or odd...stop bits: 1, 1.5, 2...data bits per character: 5, 6, 7 or 8...printer output: prints all incoming data...1k on-board RAM...2k on-board ROM...complete with power supply, cabinet & 56-key ASCII encoded keyboard. □ Optional graphics mode: includes 34 Greek & math plus 30 special graphic characters: 19.95 prepaid.

□ **FASTERM VIDEO BOARD:** 99.95 + 3.00 p&i. **SMARTERM 80** □ 299.95 + 3.00 p&i. Display format: specify either 80 by 24 or 40 by 16...128 ASCII characters (w/ & case)...8 baud rates: 110 to 19,200...line output: RS232C or 20 ma current loop...video output: 1V P/P...editing features: insert/delete line, insert/delete character, forward/back tab...line or page transmit...page print function...cursor positioning: up, down, right, left, plus absolute cursor positioning with read back...visual attributes: underline, blink, reverse video, half intensity & blank...graphics: 12,000 pixel resolution block plus line graphics...on-screen parity indicator...parity: off, even or odd...stop bits: 110 baud 2, all others 1...printer output...60 or 50 Hz vertical re-

fresh...blinking block cursor...2k on-board RAM...ASCII encoded keyboard: 56 keys, 128 characters...4k on-board ROM...complete with power supply & cabinet.

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MSM-551002 TM100-2 double sided \$294.95

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IOI-8100A Card with 1 port \$159.95
IOI-8101A Card with 2 ports \$189.95

SERIAL/PARALLEL for IBM PC - Profit Sys

Two asynchronous serial RS-232C I/O ports, one parallel printer I/O port, real time clock-calender, includes software
IOI-8110A 1 serial & 1 parallel \$199.95
IOI-8111A 2 serial & 1 parallel \$229.95

EXTENDER CARD for IBM PC - Profit System

All bus signals extended, signal names silk screened on top of board, gold-plated card edge, low noise
TSX-300A IBM PC extender \$45.00

PROTOTYPING CARD for PC - Profit Systems

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VDM-201201 List price \$189.95 \$115.95

HI-RES GREEN MONITORS - NEC

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VDM-651260 Economy 12" \$149.95
VDM-65092 Deluxe 9" \$179.95

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18 MHz high resolution RGB color monitors fully compatible with Apple II and IBM PC, unlimited colors available.
VDC-821210 RGBvision I, 380 lines \$389.95
VDC-821230 RGBvision III, 630 lin. \$689.95
VDA-821200 RGB card for Apple II \$99.95

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Reasonably priced color video monitors.
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VDC-801320 13" Color II \$894.95
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VDM-751210 12" Amber phosphor \$139.95
VDM-751220 12" Green phosphor \$129.95
VDM-750910 9" Amber phosphor \$129.95
VDM-750920 9" Green phosphor \$89.95

EPROM Boards

SUPERQUAD - Adv. Micro Digital

Single board, standard size S-100 computer system, 4 MHz Z-80A, single or double density disk controller for 5 1/4" or 8" drives, 64K RAM, extended addressing, up to 4K of EPROM, 2 serial & 2 parallel I/O ports, real time interrupt clock, CP/M compatible.
CPC-30800A A & T \$724.95
IOX-4232A Serial I/O adapter \$299.95

Disk Sub-Systems - Jade

Handsome metal cabinet with proportionally balanced air flow system, rugged dual drive power supply, power cable kit, power switch, line cord, fuse holder, cooling fan, neoprene rubber feet, all necessary hardware to mount 2-8" disk drives, power supply, and fan, does not include signal cable.

Dual 8" Sub-Assembly Cabinet

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END-000421 Cabinet kit \$199.95
END-000431 A & T \$249.95

8" Sub-Systems - Single Sided, Double Density

END-000423 Kit w/2 FD100-8Ds \$650.00
END-000424 A & T w/2 FD100- \$695.00
END-000433 Kit w/2 SA-801Rs \$999.95
END-000434 A & T w/2 SA-801 \$1195.00

8" Sub-Systems - Double Sided

END-000426 Kit w/2 DT-8s \$1224.95
END-000427 A & T w/2 DT-8s \$1424.95
END-000436 Kit w/2 SA-851Rs \$1274.95
END-000437 A & T w/2 SA-851Rs \$1474.95

Slimline Sub-Systems

Dual Slimline Sub-Systems - Jade

Handsome vertical cabinet with scratch resistant baked enamel finish, proportionally balanced air flow system, quiet cooling fan, rugged dual drive power supply, power cables, power switch, line cord, fuse holder, cooling fan, all necessary hardware to mount 2-8" slimline disk drives, does not include signal cable.

Dual 8" Slimline Cabinet

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END-000822 A & T w/o drives \$179.9

Dual 8" Slimline Sub-Systems

END-000823 Kit w/2 TM848-1 \$919.95
END-000824 A & T w/2 TM848-1 \$949.9
END-000833 Kit w/2 TM848-2 \$1149.9
END-000834 A & T w/2 TM848 \$1179.9

5 1/4" Disk Drives

Tandon TM100-1 single-sided double-density 48 TPI
MSM-551001 \$219.95 ea 2 for \$199.95 ea

Shugart SA400L single-sided double-density 40 track
MSM-104000 \$234.95 ea 2 for \$224.95 ea

Shugart SA455 half-size double-sided 48 TPI
MSM-104550 \$349.95 ea 2 for \$329.95 ea

Shugart SA465 half-size double-sided 96 TPI
MSM-104650 \$399.95 ea 2 for \$379.95 ea

Tandon TM double-sided double-density 48 TPI
MSM-551002 \$294.95 ea 2 for \$269.95 ea

Shugart SA450 double-sided double-density 35 track
MSM-104500 \$349.95 ea 2 for \$329.95 ea

Tandon TM100-3 single-sided double-density 96 TPI
MSM-551003 \$294.95 ea 2 for \$269.95 ea

Tandon TM100-4 double-sided double-density 96 TPI
MSM-551004 \$394.95 ea 2 for \$374.95 ea

MPI B-51 single-sided double-density 40 track
MSM-155100 \$234.95 ea 2 for \$224.95 ea

MPI B-52 double-density 40 track
MSM-155200 \$344.95 ea 2 for \$334.95 ea

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END-000216 Single cab w/power supply \$69.95
END-000226 Dual cab w/power supply \$94.95

EPROM Boards

PB-1 - SSM Microcomputer

2708, 2716 EPROM board with on-board programmer.
MEM-99510K Kit with manual \$154.95
MEM-99510A A & T with man. \$219.95

PROM-100 - SD Systems

2708, 2716, 2732 EPROM programmer with software.
MEM-99520K Kit with software \$189.95
MEM-99520A A & T with software \$249.95

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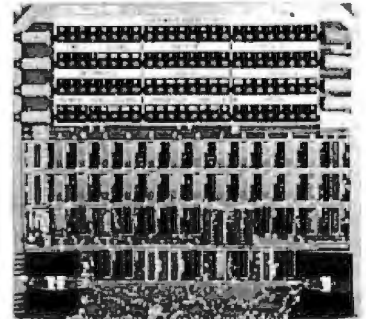
Better than Hayes!! Better than Novation!! Direct connect ModemCard plugs directly into Apple - no external components, auto-dial, auto-answer, Bell 103 compatible, full and half duplex, touch-tone or pulse dialing generated on board, Micromodem II software compatible, displays modem information on screen, audio monitoring of phone line, no serial-port required, two year factory warranty, FREE Source Subscription with purchase of Transend software.

IOM-2430A ModemCard	_____	\$289.95
SFA-55770010M Transend 1 w/Source	_____	\$79.95
SFA-55770010M Transend 2 w/Source	_____	\$129.95
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Expand your Apple II to 64K, use as language card, full 1 year warranty. Why spend \$175.00?
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Two computers in one, Z-80 & 6502, more than doubles the power and potential of your Apple, includes Z-80 CPU card CP/M 2.2 and complete manual set, Pascal compatible, utilities are menu-driven, one year warranty.
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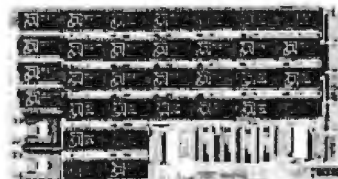
30 column x 24 line video card for Apple II, addressable 25th status line, normal/inverse or high/low video, 128 ASCII characters, upper and lower case, 7 x 9 dot matrix with true descenders, standard Data Media terminal control codes, CP/M Pascal & Fortran compatible, 50/60 Hz, 40/80 column selection from keyboard.
IOV-2500A ALS Smarterm II _____ \$169.95

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Full feature serial card for modems & printers, baud rates from 110 to 19,200, CTC/RTS & X-on/X-off protocols, auto line feed, RS-232C cable interface included.
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CPX-62810A A.L.S. CP/M Card _____ \$349.95



S-100 VIDEO BOARD S

64K STATIC RAM - Jade

Uses new 2K x 8 static RAMs, fully supports IEEE 696 24 bit extended addressing, 200ns RAMs, lower 32K or entire board phantomable, 2716 EPROMs may be subbed for RAMs, any 2K segment of upper 8K may be disabled, low power typically less than 500ma.

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MEM-99152K Kit less RAM	_____	\$99.95
MEM-32152K 32K kit	_____	\$199.95
MEM-56152K 56K kit	_____	\$289.95
MEM-64152K 64K kit	_____	\$299.95
Assembled & Tested	_____	add \$50.00

256 RAMDISK - SD Systems

ExpandoRAM III expandable from 64K to 256K using 64Kx1 RAM chips, compatible with CP/M, MP/M, Oasis, & most other Z-80 based systems, functions as ultra-high speed disk drive when used with optional RAMDISK software.

MEM-65064A 64K A & T	_____	\$474.95
MEM-65128A 128K A & T	_____	\$574.95
MEM-65192A 192K A & T	_____	\$674.95
MEM-65256A 256K A & T	_____	\$774.95
SFC-55009000F RAMDISK sl/wr CP/M 2.2	_____	\$44.95
SFC-55009000F RAMDISK with EXRAM III	_____	\$24.95

64K RAM BOARD - C.C.S.

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S-100 VIDEO BOARDS

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Inexpensive S-100 Diagnostic Analyzer

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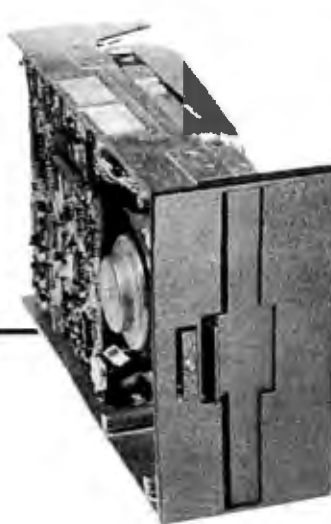
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4164 150ns 64K 128 refresh	ICM-4164150	1.75	1.65	1.50
41255 150ns 256K	ICM-41256150	6.95	6.50	5.00

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21L02 450ns 1K static	ICM-21L02450	1.29	1.15	.99
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2716 450ns 2K x 8	ICE-2716	4.95	4.75	4.55
2716 TMS450ns Tri-voltage	ICE-2716TMS	7.95	7.65	7.25
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SHUGART SA801R	\$395	385	375
SIEMENS FDD100-8	259	259	225
TANDON 848-1 SLIMLINE	379	369	359

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SHUGART SA851R	525	495	475
QUME DATA TRACK 8	525	495	475
MITSUBISHI M2894-63	485	475	469
OLIVETTI 802/851	369	359	349
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SHUGART 860 THINLINE	569	549	539

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SHUGART SA400	215	209	199
TANDON TM 100-1	209	199	195

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TANDON TM 100-2	295	269	259
TANDON 96TPI TM100-4	369	355	350
OLIVETTI 502 2/3 height	239	225	215

Three Inch Rigid Floppy

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Two Siemens FDD100-8 disk drives with power supply, 4" exhaust fan complete with all necessary power cables.

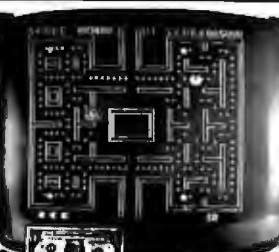
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SM7401N	14	19	SM7473N	14	35	SM74157N	16	59
SM7402N	14	25	SM7474N	14	35	SM74160N	16	69
SM7403N	14	25	SM7475N	14	35	SM74161N	16	69
SM7404N	14	25	SM7476N	14	35	SM74162N	16	69
SM7405N	14	25	SM7477N	14	45	SM74163N	16	69
SM7406N	14	29	SM7478N	14	45	SM74164N	16	69
SM7407N	14	29	SM7479N	14	45	SM74165N	16	69
SM7408N	14	25	SM7480N	14	45	SM74166N	16	69
SM7409N	14	25	SM7481N	14	45	SM74167N	16	69
SM7410N	14	25	SM7482N	14	45	SM74168N	16	69
SM7411N	14	25	SM7483N	14	45	SM74169N	16	69
SM7412N	14	35	SM7484N	14	45	SM74170N	14	45
SM7413N	14	35	SM7485N	14	45	SM74171N	14	45
SM7414N	14	35	SM7486N	14	45	SM74172N	14	45
SM7415N	14	35	SM7487N	14	45	SM74173N	14	45
SM7416N	14	35	SM7488N	14	45	SM74174N	14	45
SM7417N	14	25	SM7489N	14	45	SM74175N	14	45
SM7420N	14	19	SM7490N	14	45	SM74176N	14	45
SM7421N	14	35	SM7491N	14	45	SM74177N	14	45
SM7422N	14	45	SM7492N	14	39	SM74178N	14	45
SM7423N	16	59	SM7493N	14	39	SM74179N	14	45
SM7424N	16	59	SM7494N	14	39	SM74180N	14	45
SM7425N	16	59	SM7495N	14	39	SM74181N	14	45
SM7426N	16	59	SM7496N	14	39	SM74182N	14	45
SM7427N	16	59	SM7497N	14	39	SM74183N	14	45
SM7428N	14	49	SM7498N	14	39	SM74184N	14	45
SM7429N	14	49	SM7499N	14	39	SM74185N	14	45
SM7430N	14	25						
SM7431N	14	25						
SM7432N	14	25						
SM7433N	14	25						
SM7434N	14	25						
SM7435N	14	25						
SM7436N	14	25						
SM7437N	14	25						
SM7438N	14	25						
SM7439N	14	25						
SM7440N	14	19						
SM7441N	16	89						
SM7442N	16	89						
SM7443N	16	89						
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SM7445N	16	89						
SM7446N	16	89						
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SM7462N	16	89						
SM7463N	16	89						
SM7464N	16	89						
SM7465N	16	89						
SM7466N	16	89						
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SM7468N	16	89						
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Part No.	**Pins	Price	Part No.	**Pins	Price
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SM7472N	14	25	SM74192N	14	45
SM7473N	14	25	SM74193N	14	45
SM7474N	14	25	SM74194N	14	45
SM7475N	14	25	SM74195N	14	45
SM7476N	14	25	SM74196N	14	45
SM7477N	14	25	SM74197N	14	45
SM7478N	14	25	SM74198N	14	45
SM7479N	14	25	SM74199N	14	45
SM7480N	14	25	SM74200N	14	45
SM7481N	14	25	SM74201N	14	45
SM7482N	14	25	SM74202N	14	45
SM7483N	14	25	SM74203N	14	45
SM7484N	14	25	SM74204N	14	45
SM7485N	14	25	SM74205N	14	45
SM7486N	14	25	SM74206N	14	45
SM7487N	14	25	SM74207N	14	45
SM7488N	14	25	SM74208N	14	45
SM7489N	14	25	SM74209N	14	45
SM7490N	14	25	SM74210N	14	45
SM7491N	14	25	SM74211N	14	45
SM7492N	14	25	SM74212N	14	45
SM7493N	14	25	SM74213N	14	45
SM7494N	14	25	SM74214N	14	45
SM7495N	14	25	SM74215N	14	45
SM7496N	14	25	SM74216N	14	45
SM7497N	14	25	SM74217N	14	45
SM7498N	14	25	SM74218N	14	45
SM7499N	14	25	SM74219N	14	45
SM7500N	14	25	SM74220N	14	45
SM7501N	14	25	SM74221N	14	45
SM7502N	14	25	SM74222N	14	45
SM7503N	14	25	SM74223N	14	45
SM7504N	14	25	SM74224N	14	45
SM7505N	14	25	SM74225N	14	45
SM7506N	14	25	SM74226N	14	45
SM7507N	14	25	SM74227N	14	45
SM7508N	14	25	SM74228N	14	45
SM7509N	14	25	SM74229N	14	45
SM7510N	14	25	SM74230N	14	45
SM7511N	14	25	SM74231N	14	45
SM7512N	14	25	SM74232N	14	45
SM7513N	14	25	SM74233N	14	45
SM7514N	14	25	SM74234N	14	45
SM7515N	14	25	SM74235N	14	45
SM7516N	14	25	SM74236N	14	45
SM7517N	14	25	SM74237N	14	45
SM7518N	14	25	SM74238N	14	45
SM7519N	14	25	SM74239N	14	45
SM7520N	14	25	SM74240N	14	45
SM7521N	14	25	SM74241N	14	45
SM7522N	14	25	SM74242N	14	45
SM7523N	14	25	SM74243N	14	45
SM7524N	14	25	SM74244N	14	45
SM7525N	14	25	SM74245N	14	45
SM7526N	14	25	SM74246N	14	45
SM7527N	14	25	SM74247N	14	45
SM7528N	14	25	SM74248N	14	45
SM7529N	14	25	SM74249N	14	45
SM7530N	14	25	SM74250N	14	45
SM7531N	14	25	SM74251N	14	45
SM7532N	14	25	SM74252N	14	45
SM7533N	14	25	SM74253N	14	45
SM7534N	14	25	SM74254N	14	45
SM7535N	14	25	SM74255N	14	45
SM7536N	14	25	SM74256N	14	45
SM7537N	14	25	SM74257N	14	45
SM7538N	14	25	SM74258N	14	45
SM7539N	14	25	SM74259N	14	45
SM7540N	14	25	SM74260N	14	45
SM7541N	14	25	SM74261N	14	45
SM7542N	14	25	SM74262N	14	45
SM7543N	14	25	SM74263N	14	45
SM7544N	14	25	SM74264N	14	45
SM7545N	14	25	SM74265N	14	45
SM7546N	14	25	SM74266N	14	45
SM7547N	14	25	SM74267N	14	45
SM7548N	14	25	SM74268N	14	45
SM7549N	14	25	SM74269N	14	45
SM7550N	14	25	SM74270N	14	45
SM7551N	14	25	SM74271N	14	45
SM7552N	14	25	SM74272N	14	45
SM7553N	14	25	SM74273N	14	45
SM7554N	14	25	SM74274N	14	45
SM7555N	14	25	SM74275N	14	45
SM7556N	14	25	SM74276N	14	45
SM7557N	14	25	SM74277N	14	45
SM7558N	14	25	SM74278N	14	45
SM7559N	14	25	SM74279N	14	45
SM7560N	14	25	SM74280N	14	45
SM7561N	14	25	SM74281N	14	45
SM7562N	14	25	SM74282N	14	45
SM7563N	14	25	SM74283N	14	45
SM7564N	14	25	SM74284N	14	45
SM7565N	14	25	SM74285N	14	45
SM7566N	14	25	SM74286N	14	45
SM7567N	14	25	SM74287N	14	45
SM7568N	14	25	SM74288N	14	45
SM7569N	14	25	SM74289N	14	45
SM7570N	14	25	SM74290N	14	45
SM7571N	14	25	SM74291N	14	45
SM7572N	14	25	SM74292N	14	45
SM7573N	14	25	SM74293N	14	45
SM7574N	14	25	SM74294N	14	45
SM7575N	14	25	SM74295N	14	45
SM7576N	14	25	SM74296N	14	45
SM7577N	14	25	SM74297N	14	45
SM7578N	14	25	SM74298N	14	45
SM7579N	14	25	SM74299N	14	45
SM7580N	14	25	SM74300N	14	45

DT1050 — Applications: Teaching aids, appliances, clocks, automotive, telecommunications, language translators, etc.
 The DT1050 is a standard DIGITALIZER word encoder with 137 separate and useful words, 2 tones, and 5 different signal durations. The words and tones have been assigned discrete addresses, making it possible to input single words or words concatenated into phrases or even sentences. The "voice" output of the DT1050 is a highly intelligible male voice. Female and children's voices can be synthesized. The vocabulary is chosen so that it is applicable to many products and markets.
 The DT1050 consists of a Speech Processor Chip, MM54104 (40-pin) and two I/O Speech ROMs: MM54104SR1 and MM54104SR2 (24-pin) along with a Master Word List and a recommended schematic diagram on the application sheet.
DT1050 Digitalker™ \$34.95 ea.

DT1057 — Expands the DT1050 vocabulary from 137 to over 260 words, incl. 2 ROMs and specs.
DT1057 \$24.95 ea.

RADIO CONTROL CIRCUITS
 Ideal to use for:
 • Toys, hobby crafts, robots, trains
 • Remote alarm systems
 • Remote slide projector control
 • Consumer remote data links
 • Energy-saving, remotely switched lighting systems



A complete 6-channel digital encoder and RF transmitter; low power, at frequency of 27MHz or 49MHz, a field strength of 10,000µV/meter at 10 meters. 9V operation on chip RF oscillator/transmitter, on chip RF receiver. Up to 50MHz carrier frequency operation.
LM1872N RC Encoder/Transmitter Chip \$1.95
 A complete RF receiver/decoder, used at either 27MHz, 49MHz or 74MHz. It provides 4 independent channels when used with LM825 (2 analog, 2 dig.) operates from four 1.5V cells. Crystal controlled.
LM1872N RC Receiver/Decoder Chip \$2.49
SRX1504 49.435MHz Crystal (LM1872N) \$3.95
SRX1505 49.890MHz Crystal (LM1871N) \$3.95

Part No.	**Pins	Function	Price
7045PI	28	CMOS Precision Timer	14.95
7045KH/XX	28	Stomach-Chip, XTL	14.95
7065CPL	40	3 1/2 Digit A/D (D/L) Decoder	9.95
7065KH/XX	40	IC, Circuit Board, Desktop	34.95
7107CPL	40	3 1/2 Digit D/L Decoder	11.95
7107KH/XX	40	IC, Circuit Board, Desktop	34.95
7116CPL	40	3 1/2 Digit A/D (D/L) Decoder	15.95
7117CPL	40	3 1/2 Digit A/D (D/L) Decoder	15.95
7205CPL	24	4 Func. Stopwatch/Timer	2.25
7205KH/XX			

Portable Speakers For "Walkman" Style Stereos



Portable Stereo Speakers with Carrying Case

After skating, skiing, jogging or any other outdoor activity, just plug these portable stereo speakers into your stereo and you and your friends can enjoy your favorite tunes reproduced by their full range speakers. Great for motel rooms, the beach, or in your car. They weigh just 1.3 lbs. and measure 5 1/2" x 4 1/2" x 2 1/2". This unit uses 3" x 5" 80hm speakers with a 3 ohm magnet. Speaker system includes two speakers, a carrying case, auxiliary speaker connector cable, and signal connector cable. Uses 8 "AA" batteries. Can be used with both portable stereos shown below, and is compatible with most portable stereo cassettes and FM stereo units.

Part No. TSU-012 \$29.95
AM3-B 8 AA Alkaline Batteries 8 for \$7.90

Stereo Cassette Player with FM Stereo Tuner Pack

- Lightweight Headphones
- Cr20/Metal/Normal Tape Selector
- Anti-Rolling Mechanism

FEATURES: • Blue carrying case, shoulder strap, belt slider, lightweight headphones, FM stereo tuner pack & instruction manual • Talkline • Tone selector • Cr20/Metal/Normal tape selector • LED operation indicator • Built-in microphone • Stop/Eject, play, rewind indicator • Fast forward/stop, tape/record selector functions • Vol. control • Ext. power input jack • Headphone jack • Auto-stop mechanism (shuts off player when tape ends) • Anti-rolling mechanism (prevents sound from quivering when walking, jogging, etc.) • Weight: 13 oz. • Requires 4 AA batteries (not included) • Size: 6 1/2" x 4 1/2" x 1 1/8"

Model TWF-802 \$69.95
AM3-A 4 AA Alkaline Batteries 4/\$3.95

CREDIT CARD AM/FM RADIO

World's Thinnest Stereo HI-FI

This is a pocketable AM/FM stereo radio with a folding stereo head-phone. It weighs just 5 oz. and measures 4 1/2" x 2 1/2" x 1/4". Comes complete with radio, headphones and headphone case. Uses two AAA batteries (not included).

Part No. TCR-809 \$29.95 each

JOYSTICKS

JS-5K 5K Linear Tapper Pots	\$5.25
JS-100K 100K Linear Tapper Pots	\$4.95
JS-150K 150K Linear Tapper Pots	\$4.75
JVC-40K (2) Video Controller in Case	\$4.95

JS KNOB Knob for JS5K, 100K, 150K \$3.99 ea.
JVC KNOB Knob for JVC-40 \$3.99 ea.

Digital Thermometer Kit

Dual sensors - switch controls for indoor/outdoor or dual monitoring - can be extended to 500 feet. Continuous LED 8" ht. display. Range: -40°F to 199°F, -40°C to 100°C. Accuracy ±1° nominal. Calibrate for Fahrenheit or Celsius. Simulated walnut case. AC wall adapter included. Size: 6 1/2" x 3 1/2" x 1 1/2".

JE300 \$39.95

BOOKS

NATIONAL SEMICONDUCTOR - INTERSIL - INTEL	
30001 National CMOS Data Book (1981) (640 pages) 74C, CD4000, and A/D Converters	\$6.95
30002 National Interface Data Book (1981) (704 pages) DR, DS8000, DS3500, DS5700, etc.	\$8.95
30003 National Linear Data Book (1982) (1376 pages) LM, LF, AD, OAC, LV, L Series	\$11.95
30004 National Series 80 - National Level Converter (1980) (224 pages)	\$4.95
30005 National TTL Logic Data Book (1981) (624 pages) 7400, LS, H, S, and DM8000	\$9.95
30006 Above (3) 30001, 3, 5 as set \$24.95	
30008 National Memory Data Book (1980) (464 pages) RAMs, ROMs, PROMs, EPROMs Series	\$8.95
30009 Interdata Data Book (1983) (1356 pages) Complete line.	\$9.95
30010 National Audio/Radio Handbook (1980) (240 pages) Pre-Amps, AM, FM & Hi-Fi Stereo, Power Amps	\$9.95
30011 National Linear Application Handbook (1981) (738 pages) Application Notes, Linear Briefs, etc.	\$15.95
30012 National PAL Data Book (1982) (176 pages) Data Sheet, PAL Design	\$4.95
30013 Zilog Data Book (1983) (841 pages) Microprocessors and Support Chips	\$7.95
01040 Intel Component Data Book (1982) (145 pages) Full data sheets for Intel's products including memories, microproc., periph. & ind. mil. products	\$14.95
20510 Intel Peripheral Design Handbook (1981) (828 pages) Full data sheets, application notes for Intel peripheral device components	\$9.95

Universal Computer Keyboard Enclosures

"DTE" Blank Desk Top Enclosures are designed for easy modification. High strength epoxy resin and pieces in moka brown finish. Sliding rear/bottom panel for service/component access. Top/bottom panels 0.80" thick alum. alodine type 1200 finish (gold in color) for best paint adhesion after modification. Venting top & bottom panels for cooling efficiency. Rigid construction provides unlimited applications. Assembly instructions included.

DTE-8 Panel Width 7.5"	\$24.95
DTE-11 Panel Width 10.13"	\$27.95
DTE-14 Panel Width 13.5"	\$29.95
DTE-20 Panel Width 19.25"	\$34.95

KEYBOARDS — POWER SUPPLIES

DATAMATE 73-KEY KEYBOARD (ASCII) Data Entry Keyboard uses IBM5740 EBCDIC encoder chip (included). 73-Key Keyboard features 11-key numeric keypad, SPST switching, 24-pin edge card connection. Includes pin-out. Part No. KM261 (Pins DTE-20 Enclosure) \$49.95 each	Apple Compatible Data Entry Keyboard, Encoded Output, 8-bit Parallel EBC DIC Switching, Mail Effect, 24-pin Edge Card Connection. Complete w/Pin Connection. Can easily be modified to ASCII code. Part No. KB69SD12-Z (Fits into DTE-20 Enclosure) \$19.95 each
MICRO SWITCH 69-KEY KEYBOARD SPST switching, mechanical, momentary hearing, charcoal grey keycaps. Keyboard is not mounted on circuit board (each key is individually accessible). Part No. K-58 (176 DTE-14 Enclosure) \$19.95 each	MICRO SWITCH 85-KEY KEYBOARD Micro Processing Keyboard, 28 Pin Edge Card Connection. Supply Voltage = 5VDC. Main Keyboard & Keyboard. Additional Key Pads for Center and word processing functions. Part No. 85SD13-1 \$29.95 each
HI-TEK 50-KEY KEYBOARD SPST switching, mechanical, momentary hearing, charcoal grey keycaps. Keyboard is not mounted on circuit board (each key is individually accessible). Part No. K-58 (176 DTE-14 Enclosure) \$19.95 each	HI-TEK 14-KEY NUMERIC KEYPAD SPST switching, Charcoal grey keycaps. matches HI-TEK K-58 Keyboard (above). Mounted on printed circuit board. Part No. K-14 \$9.95 each
ALPS 29-KEY CALCULATOR KEYBOARD Features one 3-position decimal value switch, one 3-position numeric, and two 2-position numeric, mechanical SPST. 24-pin edge card connection. Pin-out included. Part No. KB297848 (Pins DTE-14 Enclosure) \$4.95 each	POWER SUPPLY + 5VDC @ 1 AMP REGULATED Transaction Tech Output = 5VDC @ 1A (max +30VDC) reg. Input 115VAC 60Hz. 2-Input (Black/Red) self-protected block power cord. 6 1/2" x 7 1/2" x 2 1/2" H. Wt. 3 lbs. Data sheet sent. Part No. P551194 \$19.95 each
POWER SUPPLY + 5VDC @ 3 AMP REGULATED Deltron Input: 115VAC 47-480Hz. Output: 5VDC Adjustable @ 3 amp. 5VDC @ 2.5 amp. Adjustable current load. Regulator: 100% rms. S.M.V. p-p. 3 mounting surfaces. UL recognized. Size: 4 1/2" x 7 1/2" x 1 1/2" H. Wt. 2 lbs. Data sheet included. Part No. QP5-1 \$29.95 each	POWER SUPPLY + 5VDC @ 7.5 AMP. 12VDC @ 1.5 AMP SWITCHING Input: 115VAC 47-480Hz. Output: 5VDC @ 7.5 amp. 12VDC @ 1.5 amp. Fan and power supply self-protected (115/230VAC). Output: 5VDC @ 7.5 amp. 12VDC @ 1.5 amp. Ht. 2 1/2" x 7 1/2" x 1 1/2" H. Wt. 8 lbs. Part No. PS34V0 \$49.95 each
POWER SUPPLY 4-Channel Switching Power Supply Microprocessor, multi-computer, terminal, medical equipment and process control applications. Input: 115/230VAC 47-480Hz. Output: +5VDC @ 3A, -5VDC @ 1A, +12VDC @ 1A, -12VDC @ 1A. Line reg. ±0.3%. Ripple: 30mV p-p. Load reg. ±1%. Overcurrent protection. Adj. 5V load output: 0-10%. 0-2.0A. I/O: 1.7A. I/O: 1.7A. I/O: 1.7A. I/O: 1.7A. Wt. 1 1/2 lbs. Part No. FCS-004A \$69.95 each	POWER SUPPLY Adjustable Switching 4-24VDC to 5 Amps Input: 115VAC 50-60Hz @ 3 amp. 230VAC 50/60Hz @ 1.5 amp. Fan and power supply self-protected (115/230VAC). Output: 5VDC @ 4A, 8VDC @ 4A, 12VDC @ 3A, 18VDC @ 1.5A, 24VDC @ 1.5A. 4.25" x 7.25" x 1.5" H. Wt. 3.25 lbs. JE224 KR \$79.95 each JE224A Assembled & Tested \$99.95 each

84-Key Keyboard White, Yellow CA153A \$69.95	CONTROL DATA Data Entry Keyboards Parallel Output FTZ Shielded Base SPST Switching CA153A \$69.95	104-Key Keyboard CA148 \$99.95
95-Key Keyboard CA154A \$79.95	ASCII OUTPUT 30" Interface Cable Attractive Case CA150C \$89.95	80-Key Keyboard CA150C \$89.95

Color; keycaps: black, blue, red - cover: black w/beige base. 21 1/2" x 9" x 3 1/2". 6lbs.

BUG BOX™ — 30 individual compartments • Stores 60 8 pin or 30 14- or 16-pin DPs • Bug Rugs not included • Clear plastic cover slides & locks • Cover marked w/numbers 1-30 • Dimensions: 5 1/2" x 7 1/2" x 5 1/2" deep • Box size: 4 3/4" x 3 1/2" x 5 1/2" • Weight: 1.75 oz.

BUG BOX™ — 12 locations store Bug Boxes, Big Bug Boxes or Bug Trays • Modular and interlocking • Heavy duty injection molded plastic • Each cage has 6 slots or locations • 2 3/8" x 6 1/2" pkg. • Cage size: 6-1/8" x 6 1/2" x 3/8" • 4 colors available — please specify color code: (B) Blue, (R) Red, (W) White, (Y) Yellow

Part No./Color Code Price

BGC-001-1 (2 Cages/6 loc. ea.)	\$11.95/pkg.
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BUG TRAY™ — Stores in Bug Cage. Molded plastic • Three styles: Open (1 compartment 3 1/2" x 4 1/2" x 6 1/2") Vertical (5 compartments 5 1/2" x 4 1/2" x 6 1/2") and Horizontal (8 compartments 4 1/2" x 3 1/2" x 6 1/2") • Ideal for tools, hardware, components, etc. • Tray size: 3 1/2" x 5 1/2" x 6 1/2" • Black color only

Part No./Color Code Price

BTH-001 Horizontal Bug Tray	\$1.85
BTV-001 Vertical Bug Tray	1.85
BTO-001 Open Bug Tray	1.95
BTK-003 1 of each Bug Tray(s)	4.98

BUG BAG™ — Static discharge protection for CMOS and MISFET devices • Pre-cut to dimensions of BUG BOX (1" x 3 1/2")

Part No. Description Price

BRG-030 30 Isom rectangles for Bug Box	\$1.50
BRB-036 6 foam req. for LSI Bug Box	1.88

CAGE KEEPER™ — Pins column of Bug Boxes in Bug Cage. Price:

CKP-006 6 inch	\$4.80/pkg.
CKP-010 10 inch	6.80/pkg.

★★ BUG BOX SYSTEMS INTRODUCTORY SPECIAL ★★

Year choice: regular or anti-static. Includes 2 Bug Cages (12 locations), 5 Bug Boxes, 3 LSI Bug Box Buses, 1 Horizontal Bug Tray, 1 Vertical Bug Tray, 1 Vertical Bug Tray, 1 package Bug Box for regular Bug Boxes, 1 package Bug Box for LSI Bug Boxes, 1 package Blank Labels (500 each). Color: Bug Boxes and Cages - Blue, Bug Trays - Black.

SP-BUG Regular (Retail value \$59.45) Sale Price \$49.95
SP-BUG-AS Anti-Static (Retail value \$67.45) Sale Price \$59.95

\$10.00 Minimum Order — U.S. Funds Only
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8K, 16K, 32K, 64K EPROM Programmer



2705, 2718, 2732 & 2764 EPROM Programmer
JE664 EPROM PROGRAMMER
8K TO 64K EPROMS — 24 AND 28 PIN PACKAGES
Self-Contained — Requires No Additional Systems for Operation

• Programs, verifies, and checks for properly erased EPROMs • Erases EPROMs or EPROMs • RS232C Computer Interface for setup/program loading • Loads data into RAM by keyboard • Changes data in RAM by keyboard • Loads data from an EPROM • Copies EPROMs for content differences • Copies EPROMs • Power on: 115VAC, 60Hz, ~10W power consumption • Enclosure: Color-coated, light tan panels w/rolled moka brown end pieces • Size: 15.5" x 8 1/2" x 2 1/2" H. Wt. 5 1/2 lbs.

JE664-A EPROM Programmer \$995.00
Assembled & Tested (Includes JM16A Module)

JE665 — RS232C INTERFACE OPTION — The JE665 RS232C Interface Option implements computer access to the JE664's RAM. Sample software written in BASIC provided for TRS 80® Model I, Level II Computer. Baud rate 9600. Word length 8 bits - odd parity. Stop bits 2. Option may be adapted to other computers.

JE664-ARS EPROM Prog. w/RS232C Option \$1195.00
Assembled & Tested (Includes JM16A Module)

EPROM JUMPER MODULES — The JE664 JUMPER MODULE (Presently Module) is a plug-in Module that pre-sets JE664 for proper programming pulses to the EPROM & configures EPROM socket connections for that particular EPROM Part No.

Part No.	EPROM	EPROM MANUFACTURER	PRICE
JM20A	2700	AMD/Motorola/National/Intel/Ti	\$14.95
JM16A	2716 TMS2516	Intel/Motorola/National/NEC/Ti	\$14.95
JM16B	TMS2716	Motorola/Ti (+5, -12, +12)	\$14.95
JM32A	TMS2532	Motorola/Ti	\$14.95
JM32B	2732	AMD/Fujitsu/NEC/Hitachi/Intel	\$14.95
JM64A	MC68016/64	Intel	\$14.95
JM64B	2764	Motorola	\$14.95
JM64C	TMS2564	Ti	\$14.95

8" Floppy Disk Drive

- Shugart 801R compatible
- Single-Sided
- 77 Tracks
- 400/800K Bytes Capacity
- Industry Standard

The FDD100-8 8" Floppy Disk Drive (Industry Standard) features single or double density. Recording mode: FM single, MFM double density. Transfer rate: 250K bits/sec. single density; 500K bits/sec. double density. The FDD100-8 is designed to work with the single-sided soft sectorized IBM Diskette I, or, disk cartridge. Power: 115VAC @ 50/60Hz, +24VDC @ 1.7 amps max., +5VDC @ 1.2 amps max. Unit as pictured above (does not include case, power supply, or cables). Size: 8.55" W x 14" L x 4.5" H. Weighs 12 lbs. incl. 96pg. manual. Part No. Price

FDD100-8 Buy 1 for \$269.95 each
FDD100-8 Buy 2 for \$259.95 each
FDD100-8 Buy 10 for \$249.95 each

5 1/4" Mini-Floppy Disk Drive

FOR TRS-80 MODEL I (Industry Standard) Features single or double density. Recording mode: FM single, MFM double density. Power: +24VDC (±0.5V) 1.6A max., +5VDC (±0.25V) 0.8A max. Unit as pic. left (does not incl. case, power supply, cables, 30pg. manual, 100pg. manual, 100pg. manual, 100pg. manual). Unit as pictured above (does not include case, power supply, or cables). Size: 8.55" W x 14" L x 4.5" H. Weighs 12 lbs. incl. 96pg. manual. Part No. Price

FDD100-8 Buy 1 for \$269.95 each
FDD100-8 Buy 2 for \$259.95 each
FDD100-8 Buy 10 for \$249.95 each

EXPAND YOUR MEMORY

TRS-80 to 16K, 32K, or 48K
**Model 1 = From 4K to 16K Requires (1) One Kit
**Model 3 = From 4K to 48K Requires (3) Three Kits
**Model 3 = From 4K to 16K Requires (1) One Kit
**Model 1 equipped with Expansion Board up to 48K Two Kits Required — One Kit Required for each 16K Expansion.

TRS-16K3 *20ms for Color & Model III \$12.95
TRS-16K4 *20ms for Model I \$10.95

TRS-80 Color 32K or 64K Conversion Kit
Kit comes complete with 8 each 4164-2 (200ns) 64K dynamic RAMs and conversion documentation. Converts TRS-80 color computers with D and E circuit boards, and all new color computers to 32K. Minor modifications to 32K memory will allow the use of all 64K of the dynamic RAM.

TRS-64K2 \$54.95

Sprite-style Fan

- 36cfm free air delivery
- 3.125" sq. x 1.665" depth
- 10 yrs. cont. duty at 20°C
- 115V 50/60Hz 14W Wt. 17 oz.

PWS2107U (tested & used) \$ 9.95 ea.
*PWS2107F (New) \$14.95 ea.

Muffin-style Fan

- 105cfm free air delivery
- 4.60" sq. x 1.50" depth
- 9 yrs. cont. duty at 20°C
- impedance protected ambient to 70°C
- 115V 50/60Hz 14W Wt. 17 oz.

MU2A1-U (Checked & tested) \$9.95 ea.
*MU2A1-N (New) \$14.95 ea.

Mostek DC/DC Converter

+5 VOLTS TO -9 VOLTS
input: +5V, output: -9V regulated @ 30mA.
Printed circuit mounting. Specifications incl.
DC10 \$2.95 ea. or 2/\$4.95

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BARE BOARD 14.00
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74LS00	.23	74LS123	.94	74LS253	.58
74LS01	.23	74LS124	2.89	74LS257	.58
74LS02	.23	74LS125	.94	74LS258	.78
74LS03	.23	74LS126	.78	74LS259	2.74
74LS04	.23	74LS132	.74	74LS260	.59
74LS05	.23	74LS136	.48	74LS266	1.48
74LS08	.23	74LS137	.74	74LS273	1.48
74LS10	.23	74LS138	.94	74LS275	3.20
74LS11	.29	74LS139	.74	74LS279	.48
74LS12	.29	74LS145	.74	74LS280	1.94
74LS13	.39	74LS147	1.09	74LS283	.94
74LS14	.58	74LS148	2.19	74LS290	.88
74LS15	.29	74LS151	1.19	74LS293	.88
74LS20	.23	74LS153	.54	74LS295	.98
74LS21	.29	74LS154	.74	74LS298	.88
74LS22	.23	74LS155	1.74	74LS324	1.74
74LS26	.29	74LS156	.68	74LS352	1.28
74LS27	.24	74LS157	.64	74LS353	1.28
74LS28	.29	74LS158	.58	74LS363	1.34
74LS30	.24	74LS160	.68	74LS364	1.94
74LS32	.28	74LS161	.64	74LS365	.48
74LS33	.54	74LS162	.68	74LS366	.48
74LS37	.54	74LS163	.68	74LS367	.44
74LS38	.34	74LS164	.68	74LS368	.44
74LS40	.24	74LS165	.68	74LS373	.98
74LS42	.48	74LS166	1.94	74LS374	.98
74LS47	.74	74LS168	1.68	74LS377	1.39
74LS48	.74	74LS169	1.68	74LS378	1.14
74LS49	.74	74LS170	1.68	74LS379	1.34
74LS51	.24	74LS173	.68	74LS385	1.88
74LS54	.24	74LS174	.54	74LS386	.44
74LS55	.28	74LS175	.88	74LS390	1.18
74LS63	1.19	74LS181	1.48	74LS393	1.18
74LS73	.35	74LS189	8.90	74LS395	1.18
74LS74	.38	74LS190	.78	74LS399	1.58
74LS75	.38	74LS191	.88	74LS424	2.88
74LS76	.38	74LS192	.68	74LS447	.36
74LS78	.48	74LS193	.68	74LS490	1.88
74LS83	.59	74LS194	.88	74LS668	1.64
74LS85	.95	74LS195	.74	74LS669	1.84
74LS86	.38	74LS196	.78	74LS670	1.48
74LS90	.54	74LS197	.78	74LS674	9.45
74LS91	.74	74LS221	1.09	74LS682	2.98
74LS92	.54	74LS240	.94	74LS683	2.38
74LS93	.54	74LS241	.94	74LS684	2.38
74LS95	.74	74LS242	.64	74LS685	2.38
74LS96	.78	74LS243	.64	74LS688	2.38
74LS107	.38	74LS244	.89	74LS689	2.38
74LS109	.38	74LS245	1.88		
74LS112	.38	74LS247	.74	81LS95	1.48
74LS113	.38	74LS248	1.19	81LS96	1.48
74LS114	.38	74LS249	.88	81LS97	1.48
74LS122	.44	74LS251	.58	81LS98	1.48

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2112	450ns	2.68
2114	450ns	1.74
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dBASE II	439	Canyon Clamber	24
SuperCalc	169	Aztec	29
FFS, Report II	95	Makend the Sun	29
FFS, Report III	115	Canonball Blitz	29
Aoc Plus G/L	299	Knight Diamonds	29
G/L, A/P, A/R	599	Zork I	29
Above/Inventory	799	Zork II	29
Magic Window	115	Serpentine	29
HOME	59	Star Blazer	29
Home Accountant	59	Deadline	29
Transend I	76	Deadline	29
Transend II	119	Tubeway	25
Data Capture 4.0	49	Flight Simulator	25
Vistrium	89	Space Vikings	29
Per. Finance Mgr	85	Sargon II	29
ASCII Exprs. Prof.	99	Spitfire Simulator	29
Electronic Duel	25	Apple Panic	22
Tax Prep. 1983	149	Olympic Death	23

Item	LIST	ACP
Apple II Plus w/48K	\$1530.00	\$999.00
Apple II Plus w/64K	1729.00	1049.00
Apple II System Special w/64K		
Z80Card, Vision80	2519.00	1499.00
Apple II w/128K	3485.00	2695.00
Apple III w/256K	4295.00	2995.00
Profile Hard Disk Drive	3499.00	2095.00
Vista Apple III Tricard	195.00	169.00

APPLE HARDWARE

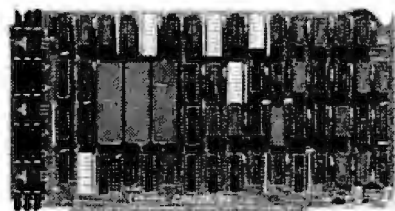
Item	List	ACP
Apple II Disk II w/Control	\$645.00	\$449.00
Apple II Disk II w/o	525.00	389.00
Apple Family System	2495.00	CALL
Prototype Card	24.00	21.95
IEEE-488 Interface	450.00	375.00
Extended Warranty - 1 yr	225.00	199.00
Super Serial Card	195.00	174.95
Language Card	195.00	149.95
Graphic Tablet w/I/O	795.00	695.00

MORE HARDWARE

Item	LIST	ACP
MICROSOFT Z80 Software	\$395.00	\$249.00
16K Ramcard	195.00	89.00
The Premium Package	899.00	579.00
SSM AIO II-4 Function Serv/Parallel	225.00	179.00
AIO Serial/Parallel	195.00	165.00
KEYBOARD COMPANY Numeric Keypad	149.95	124.95
Apple II Joystick	49.95	44.50
Apple II Handcontrollers	29.95	25.95
KRAFT Joystick	49.00	49.00
Hand Controller	40.00	40.00
PROMOTECH VERSABox Spool/Bufr	249.00	199.00
VERSACard Four-in-1	199.00	166.00
AUT-O-DOC diagnostics	99.00	82.00
VISTA A COMPUTER CO. Vision 80 80x24 Card	395.00	269.00
Vision 40 40x24 Card	199.00	149.00
enhance	29.95	25.00
Vision 20 Lo case ROM	595.00	399.00
AB00 8" DS, DD	699.00	699.00
Quartet Disk Drive	499.00	499.00
Dual Disk Drive	269.00	269.00
Solo Disk Drive	40	35.00
40 Char Type-ahead	49.95	35.00
Wild Card	129.95	115.00
VIDEX Videoterm 80x24 Card	345.00	279.00
Keyboard Enhancer II	149.00	129.00
Soft Switch	35.00	30.00
Function Slip Keys	79.00	69.00
PRACTICAL PERIPHERALS 16K Microbuffer	259.00	220.00
32K Microbuffer	299.00	253.00
Snapshot Option	149.00	109.00
VOTRAX Type n Talk Speech	375.00	339.00
SCOTT INSTRUMENTS Voice Recogniz'n VEF80	799.00	675.00
CORVUS 5 Mb Hard Disk	3750.00	2495.00
10 Mb Hard Disk	5350.00	2895.00
20 Mb Hard Disk	6450.00	3995.00
ORANGE MICRO The Grappler V/Q (Plus)	195.00	129.95
SATURN SYSTEMS 32K RAM Card	239.00	189.00
64K RAM Card	425.00	355.00
128K RAM Card	599.00	505.00
NOVA TION Apple-Cat I	389.00	329.00
Apple-Cat 212	625.00	525.00
HAYES MICROCOMPUTER Hayes Chronograph	249.00	229.00
Micromodem II	348.00	289.00
Smartmodem	2	

THERE ARE NO BETTER BOARDS — THERE ARE NO BETTER PRICES!

CompuPro FROM PRIORITY ONE ELECTRONICS



**CPU BOARDS
CO-PROCESSOR 8086/8087**

16 bit 8 or 10 MHz 8086 CPU with sockets for 8087 and 80130

Part No.	Description	List Price	Our Price
BPGBT186A	A&T 8MHz 8086 only	\$750.00	\$669.00
BPGBT186C	CSC 10MHz 8086 only	\$850.00	\$764.89
BPGBT186A87	A&T with 8087 option	\$1050.00	\$939.00
BPGBT186C87	CSC with 8087 option	\$1150.00	\$1065.00

(818) DUAL PROCESSOR 8085-8088
6 or 8 MHz provides true 16 Bit Power with a standard 8 bit S-100 bus

BPGBT1612A	A&T 6MHz	\$495.00	\$439.00
BPGBT1612C	CSC 6/8 MHz	\$595.00	\$529.00

68K - 68000 16 BIT CPU

16 bit 8 or 10 MHz on-board sockets for 2716, 2732, or 2764 EPROMs for up to 8K x 16 of memory

BPGBT184A	A&T 8MHz	\$695.00	\$625.00
BPGBT184C	CSC 10MHz	\$850.00	\$765.00

FORTH OPERATING SYSTEM FOR 68K CPU

Requires a DISK 1, 64K of CompuPro memory, and an INTERFACER 3 or 4.

BPGBT68KDS	FORTH operating system		\$200.00
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CPUZ - Z80D CPU NOW 6MHz!

3/6 MHz Z80B CPU with 24 Bit Addressing. FASTEST Z80 CPU AVAILABLE!

BPGBT160A	3/6 MHz A&T	\$325.00	\$289.00
BPGBT160C	3/6 MHz CSC	\$425.00	\$379.00



*When 2 or more 8" disk drives are purchased with Disk 1 Controller.

DISK CONTROLLERS

DISK 1 FLOPPY CONTROLLER - OUR DEST!
Fast DMA, Soft Sector, Controls Up to Four 8" or 5 1/4" Single or Double Density Drives.

BPGBT17IACPM	A&T w/CPM 2.2 & BIOS	\$670.00	\$495.00
	*When purchased with two 8" disk drives only.		\$450.00

BPGBT171CCPM	CSC w/CP/M 2.2 & BIOS	\$770.00	\$595.00
BPGBT171A	Disk 1 Controller A&T	\$495.00	\$449.89
BPGBT171C	Disk 1 Controller CSC	\$595.00	\$550.00
BPGBTCPMBD	CP/M 2.2 for Z80/8085 w/manual & BIOS 8" S/D disk		\$174.89
BPGBTCPMB6	CP/M 2.2 for 8086 w/manuals & BIOS 8" S/D disk.		\$299.89

**DISK 2/SELECTOR CHANNEL
HARD DISK CONTROLLER**

Fast DMA 2 board set, controls 4 Shugart 4000 series or Fujitsu 2300 type drives. Includes CP/M 2.2.

BPGBT177A	Assembled & Tested	\$795.00	\$750.00
BPGBT177C	CSC	\$895.00	\$850.00



CMOS RAM SALE!

RAM 17 - 64K CMOS STATIC RAM

12 MHz, RAM 17, 2 Watt, DMA Compatible 24 Bit Addressing

Part No.	Description	List Price	Our Price
BPGBT175A64	64K A&T 12MHz	\$499.00	\$460.00
BPGBT175C64	64K CSC 12MHz	\$599.00	\$550.00

RAM 16 - 32K x 16 BIT CMOS STATIC RAM

8 and/or 16 Bit
(818) 12 MHz, RAM 16, 32K x 16 or 64K x 8 IEEE/696 16 Bit 2 Watt, 24 Bit Addressing

BPGBT160A	64K A&T 12MHz	\$550.00	\$510.00
BPGBT160C	64K CSC 12MHz	\$650.00	\$610.00



NEW! RAM 21 - 128K STATIC RAM

(818) 816 RAM 21 12MHz, 128K x 8 or 64K x 16 IEEE/696 8 or 16 Bit, 1.2 Amps, 24 Bit Addressing

BPGBT190A	128K A&T	\$1095.00	\$995.00
BPGBT190C	128K CSC	\$1245.00	\$1125.00

**M-DRIVE SOLID STATE DISK DRIVE,
3500% FASTER!!**

Not really, but the next best thing for CompuPro 8085/88 Users. Call for Details on M-Drive.

M-Drive requires a 6MHz CPU 8085/88 dual processor. Disk 1 DMA disk controller and System Support 1 Multifunction Board.

BPGBTM0128KA	128K of A&T memory & M-Drive Software	\$1198.00
BPGBTM0128KC	128K of CSC memory & M-Drive Software	\$1398.00
BPGBTM0256KA	256K of A&T memory & M-Drive Software	\$2395.00
BPGBTM0256KC	256K of CSC memory & M-Drive Software	\$2795.00

M-DRIVE/H HARDWARE LOGICAL DISK SYSTEM

Interfaces through two I/O ports, and runs at 10MHz. IEEE 696 compatible. Requires any CompuPro CPU and a Disk 1. Each board contains 512K of fast, low power (900mA) RAM, with parity checking.

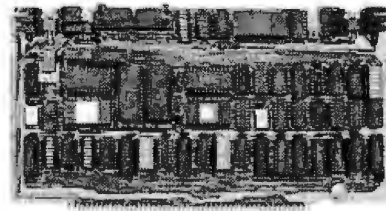
BPGBT197A	M-DRIVE/H w/software, A&T	\$1895.00	\$1295.00
BPGBT197C	M-DRIVE/H w/software, CSC	\$2095.00	\$1495.00



S-100 MAINFRAME

110V 60Hz CVT Mainframe uses famous 20 slot CompuPro Motherboard (55 lbs.)

BPGBTENC20RM	20 Slot Rackmount	\$895.00	\$825.00
BPGBTENC20DK	20 Slot Desk Top	\$825.00	\$760.00



I/O BOARDS

SYSTEM SUPPORT 1 MULTIFUNCTION BOARD

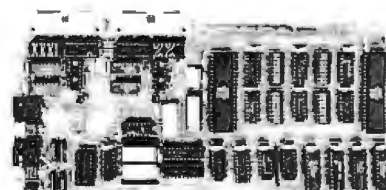
Serial port (software prog. baud), 4K RAM included, 15 levels of interrupt, real time clock, optional math processor.

Part No.	Description	List Price	Our Price
BPGBT162A	Assembled & Tested	\$450.00	\$395.00
BPGBT162C	CSC	\$550.00	\$495.00
BPGBT231	Math Chip		\$195.00
BPGBT232	Math Chip		\$195.00
BPGBT162AM1	A&T w/8231 Math Chip		\$570.00
BPGBT162CM1	CSC w/8231 Math Chip		\$670.00
BPGBT162AM2	A&T w/8232 Math Chip		\$570.00
BPGBT162CM2	CSC w/8232 Math Chip		\$670.00

MPX CHANNEL BOARDS

I/O Multiplexer, using 8085A-2 CPU on board w/16K RAM

BPGBT166A16	Assembled & Tested	\$649.00	\$584.89
BPGBT166C16	CSC	\$749.00	\$674.89



INTERFACER 1

Two Serial I/O

BPGBT133A	Assembled & Tested	\$295.00	\$259.00
BPGBT133C	CSC	\$370.00	\$329.00

INTERFACER 2

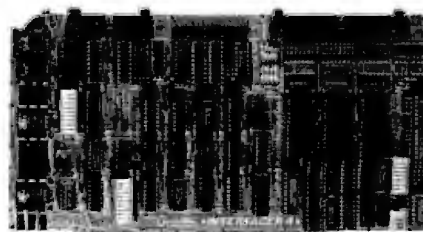
Three parallel, one serial I/O board

BPGBT150A	Assembled & Tested	\$325.00	\$289.00
BPGBT150C	CSC	\$399.00	\$359.00

INTERFACER 3

Eight-channel multi-user serial I/O board

BPGBT1748A	Assembled & Tested	\$699.00	\$628.89
BPGBT1748C	CSC 200 hr. 8 port	\$849.00	\$748.89
BPGBT1745A	Assembled & Tested	\$599.00	\$558.89
BPGBT1745C	CSC 200 hr. 5 port	\$699.00	\$628.89



INTERFACER 4

Three Serial, 1 Parallel, 1 Centronics Parallel

BPGBT187A	Assembled & Tested	\$450.00	\$399.00
BPGBT187C	CSC	\$540.00	\$479.00

S-100 MOTHERBOARDS

Active termination, 6-12-20 Slot

BPGBT153A	A&T 6 slot, 2 lbs.	\$140.00	\$125.00
BPGBT153C	CSC 6 slot, 2 lbs.	\$190.00	\$155.00
BPGBT154A	A&T 12 slot, 3 lbs.	\$175.00	\$155.00
BPGBT154C	CSC 12 slot, 3 lbs.	\$240.00	\$220.00
BPGBT155A	A&T 20 slot, 4 lbs.	\$265.00	\$235.00
BPGBT155C	CSC 20 slot, 4 lbs.	\$340.00	\$310.00

PRIORITY ONE ELECTRONICS



WORLD'S BEST SELLING TERMINAL
Extra Memory Pages
FREE!

- BPPD7LV9252P* \$749.00
*TeleVideo 925 w/free 2nd page memory kit, a \$95.00 Value!
- BPPD7LV9504P* \$849.00
*TeleVideo 950 w/free 2nd, 3rd & 4th page memory kit, \$285.00 value!
- BPTLV910 \$649.00
With emulations & foreign languages



BEST BUYS!

1200 BAUD AUTO-DIAL
HAYES SMARTMODEM COMPATIBLE

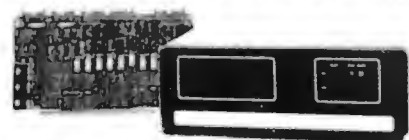


MODEMS
\$495.00

The AUTO DIAL 212A Modem is a direct connect 0-300 or 1200 baud modem capable of dialing and calling for you. The AUTO DIAL 212A is compatible in function to the DC Hayes SMARTMODEM™.

Part No.	Description	List	SALE Price
BPPSRADIAL212A-0-300	1200 baud dialing modem	\$599.00	\$495.00

SIERRA DATA SCIENCES & MICROPOLIS
Z80 35MB SUBSYSTEM



- Z80A 4MHz CPU • 64K RAM • 35 MegaByte Winchester Hard Disk Drive, Cabinet, and Power Supply • Hard Disk Drive BIOS • 2 RS-232 I/O Ports • Floppy Disk Controller • user Friendly Menu Driven CP/M 2.2™ • Drive Interface Cable

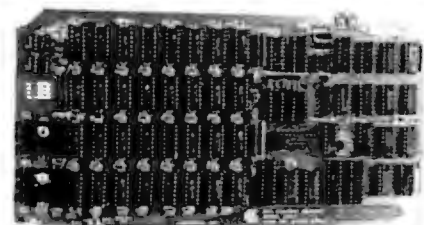
ALL OF THIS FOR ONLY:

\$4495.00 **SAVE \$950!!**

If purchased separately: \$5445.00
BPPDSBGSYS1 (Shipped Freight Collect)



64K IEEE/S-100 DYNAMIC RAM



2 or 4MHz BANK SELECTABLE

- 2 or 4MHz operation • Designed to IEEE proposed S-100 bus standard • Operates with either an 8080 or Z-80 based S-100 system providing processor transparent refreshes with both • Bank-select system allows system memory expansion • Any 16K block can be made bank-independent • All 64K can be made bank-enabled on and reset • Supports DMA • Jumper-selectable Phantom input • Assembled & Tested • Uses Popular 4116 RAMs

REGULAR LIST PRICE IS \$375.00

\$199.00

BPPCS20653 (Sh. Wt. 2 lbs.)

DUAL QUME 8" FLOPPY DRIVE,
CABINET, DMA S-100
CONTROLLER,
AND CP/M®
FROM

CompuPro



YOU SAVE
\$1419.77!!

ABSOLUTELY THE MOST COST EFFECTIVE
DISK SUBSYSTEM EVER OFFERED
BY PRIORITY ONE ELECTRONICS!!

- 2 Double sided 8" QUME DTS disk drives
 - DMA Floppy Controller (controls up to 4 drives)
 - CP/M™ 2.2 w/bas written for the Disk 1 Controller
 - Cabinet includes power supply & internal data cable
 - External data cable included
- (Shipping Charge: \$21.00, shipped in two boxes)
- | | List Price |
|------------|------------------|
| 1 8BT208SP | \$2325.00 |
| 1 8BT171A | \$495.00 |
| 1 8BTCP880 | \$175.00 |
| 1 PCS05803 | \$ 18.77 |
| | \$3014.77 |

CABINET AND 2 QUME DT8 DOUBLE SIDED DRIVES \$1295.00
PROVIDE 2.4 MBYTES OF MASS STORAGE!!

CompuPro™ UN-SYSTEM 816

FOR THOSE WHO DEMAND
EXCELLENCE!



Each CompuPro system contains the same nucleus of common hardware and software. This insures compatibility between systems as well as allowing you to expand as your needs grow. The following is a list of the basic hardware components as well as software.

- HARDWARE:**
- Desk top Enclosure 20 slots
 - Floppy disk enclosure with 2 Qume DT8 drives
 - DMA Floppy Controller
 - 8085/8088 CPU operates 8 or 16 software
 - Memory in the form of RAM 17s
 - System support 1 (Clock calendar, RAM/ROM/math processor options, RS-232 Serial port, dual interrupt controllers, triple interval timers and more!)
 - All internal cables

- SOFTWARE:**
- CP/M 2.2™ and CP/M 86™
 - M Drive Software - allows the use of memory as another disk drive
 - Sorcim's SUPERCALC 86™
 - Ashton Tate's DBase II

DIG DEEP!! Now is the time to buy
the CompuPro UN-SYSTEM 816!!

SAVE MONEY, and have an UN-SYSTEM 816 for your very own! All UN-SYSTEMS contain the very same components as the SYSTEM 816s listed in our Winter 1983 Engineering Selection Guide, but are not installed or configured. All it takes is your professional computer experience and knowledge to have the highest performing S-100 computer system on the market today. BEWARE! This is not for the novice and inexperienced user, as it requires a well-matured knowledge in system integration procedures.

So, WHY WAIT!? Don't Pass Up This
Incredible Deal!!

Each component of the UN-SYSTEM 816 has been assembled and individually tested. Final installation and configuration are the sole responsibility of the purchaser

UN-SYSTEM 816/A
ENTRY LEVEL - SINGLE USER

Disk storage 2.4 Megabytes. Expandable to 4.8 Megabytes.
Main memory: 128K - expandable to 1 Megabyte
Serial Ports: 4 / Parallel Ports: 1
Centronics/Epson ports: 1
Software: CP/M 2.2™, CP/M-86™, M-Drive, SuperCalc-86, dBase.
Component List Price: \$6705.00 **BPEBUNSYS1A18**

OUR SALE PRICE:
\$4795.00 **SAVE \$1910.00!!**

UN-SYSTEM 816/B
ENHANCED HIGH PERFORMANCE
SINGLE USER SYSTEM

Disk Storage 2.4 Megabytes. Expandable to 4.8 Megabytes.
Main memory 256K - expandable to 1 Megabyte
Serial ports: 6
Software: CP/M 2.2™, CP/M-86™, M-Drive, SuperCalc-86™, dBase II™
Component List Price: \$8497.00 **BPEBUNSYS1B18**

OUR SALE PRICE:
\$5795.00 **SAVE \$2702.00!!**

UN-SYSTEM 816/C
HIGH PERFORMANCE MULTI-USER SYSTEM

Disk storage: 2.4 Megabytes. Expandable to 4.8 Megabytes.
Main memory: 384K - expandable to 1 Megabyte
Serial ports: 9
Software: CP/M 2.2™, CP/M-86™, MP/M 8-16™, M-Drive, SuperCalc-86™, dBase II™
Component List Price: \$10,636.00 **BPEBUNSYS1C18**

OUR SALE PRICE:
\$7595.00 **SAVE \$3041.00!!**

PRIORITY ONE ELECTRONICS

ORDER TOLL FREE (800) 423-5922 - CA, AK, HI CALL (213) 709-5111

Terms: U.S. VISA, MC, BAC. Check, Money Order, U.S. Funds Only. CA Resident s add 6 1/2% Sales Tax. MINIMUM PREPAID ORDER \$15.00. Include MINIMUM SHIPPING & HANDLING of \$3.00 for the first 3 lbs. plus 40¢ for each additional pound. Orders over 50 lbs. sent freight collect. Just in case, please include your phone number. Prices subject to change without notice. We will do our best to maintain prices through April, 1983. Credit Card orders will be charged appropriate freight. If you haven't received your Winter '83 Engineering Selection Guide, send \$1.00 for your copy today! Sale prices for prepaid orders only.

RETAIL STORE PHONE NUMBERS: (Chatsworth:) (213) 709-5464 - (Irvine:) (714) 660-1411

SIEMENS FDD100-8
8" FLOPPY DISK DRIVE
 SINGLE SIDED, DOUBLE DENSITY
 SHUGART 801R COMPATIBLE
90 DAY WARRANTY!

ONCE AGAIN YOU RECEIVE THE BENEFIT OF OUR UNEQUALLED PURCHASING POWER!



Eq. \$225.00
 2-9 \$199.00
 10+ CALL

DEM INQUIRIES INVITED
 (Include \$7.00 per drive for shipping)
 BPSIEFDD100B

ORDER NOW AND SAVE!

MPI **NEW LOW PRICES!**



5 1/4" DISK DRIVES

BPMPI51*	Single-Sided Double-Density 48 TPI	\$200.00
BPMPI52*	Double-Sided Double-Density 48 TPI	\$270.00
BPMPI91*	Single-Sided Double-Density 96 TPI	\$275.00
BPMPI92*	Double-Sided Double-Density 96 TPI	\$400.00

*Replace "" when ordering, with "m" for MPI style bezel, or "s" for Shugart style bezel. (Shipping Weight 5 lbs.)

2" HIGH 8" DISK DRIVES



The first 2" high 8" disk drive allows for mounting under the keyboard on CRT, etc.
 NO AC Required +5V +24VDC only
 FAST 3 msec track to track!

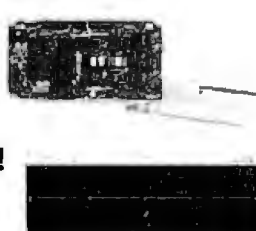
BPMPI41M	1/2 High 1 side double-density	\$380.00
BPMPI42M	1/2 High 2 side double-density	\$480.00
BPMPI41S	Full height 1 side single drive, dble-density	\$380.00
BPMPI42S	Full height 2 sided single drive, dble-density	\$480.00
BPMPI410	Full height 1 side dual drive, dble-density	\$780.00
BPMPI420	Full height 2 side dual drive, dble-density	\$920.00

(Shipping Weight 11 lbs. per drive)

S-100 DUAL 8" SUBSYSTEM

BPCS2422A	S-100 Disk Controller with CP/M 2.2	1 \$399.00
BPSIEFDD100B	Siemens Double Density 8" drive	2 \$398.00
BPIHFDE002	Dual Horizontal Cabinet with Power Supply and Data Cable	1 \$295.00

1 \$ 35.00
\$1127.00



SAVE \$132.00!!
\$995.00
 (include \$30.00 for shipping)

DON'T MISS OUT!
 Order No. BPPOBSIESUB1

BUY DRIVE AND CABINET TOGETHER AND SAVE!

DUAL 8" SIEMENS FDD100B, DUAL 8" CABINET POWER SUPPLY AND INTERNAL POWER CABLES

IF BOUGHT SEPARATELY: \$890.00

PRICED AT: \$675.00

BPPOBIISIE ENVIRONMENT MONITOR PANEL

Temperature and voltage monitor with visual and audible alarm for overtemp condition. Direct Digital Readout of Internal Temperature in C on standard DVM

BP IIFDE002	CABINET ONLY (SH Wt 38 lbs)	\$295.00
BP POBSIEEM	2 Drives, Cabinet & disk environment monitor	\$775.00
BPIHFDE002EM	Cabinet only with disk environment monitor	\$375.00
BPPDBSOM18E18E	Dual Data Cable	\$ 31.15
BPPGCS05605	External Data Cable	\$ 18.77

• Positive Pressure Filter Cooling
 • Power Supply 4A @ +5V 3A @ +24V 1A @ -5V
 • Each output is individually fused

• Hinged top for easy access
 • Heavy non-flex .090 aluminum base
 • Modular power connectors



OUR FINEST 8" DUAL DISK DRIVE CABINET

INTERNATIONAL INSTRUMENTATION INCORPORATED

Compare these features listed and you'll see why this cabinet is our **FINEST DISK CABINET**

FEATURES

- Positive pressure forced air cooling for reliable disk drive operation
- AC input via 3 wire 7 foot international cord/socket set
- AC input EMI filtered to six amps to help prevent disk crashes due to power spikes and line noise
- 14 gauge main chassis
- Integral power supply with 5V @ 6A/5V 3 1A/24V @ 6A
- Double-sided custom PC power board and supply
- Each DC supply and AC separately fused

STANDARD UNIVERSAL DISK ENCLOSURE

	List Price	OUR Price
BPIIUE004	\$495.00	\$425.00

With augmented power supply to handle Tandem Slimline, or Winchester disk drives. Includes the disk environment monitor.

BPIIUE00844UG	\$733.00	\$625.00
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With Disk Environment Monitor for cool, reliable operation.

BPIIUE004EM	\$584.95	\$495.00
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Tandon

8-INCH THIN LINE

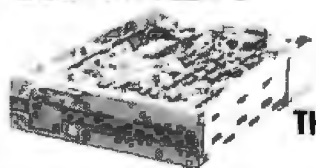
Exactly one-half the height of any other model
 Proprietary, high-resolution, read-write heads patented by Tandon
 D.C. only operation - no A.C. required
 industry standard interface
 Three millisecond track-to-track access time (9 lbs.)

TANDON 8" DRIVES

BPTNDTM8481	Single Sided: \$380.00	2 or more: \$370.00 ea.
BPTNDTM8482	Double Sided: \$495.00	2 or more: \$485.00 ea.

TANDON 5 1/4" DRIVES

BPTNDTM1001	Single Sided, 250KB (5 lbs)	\$220.00 ea.
	2 or More: \$200.00 each	
BPTNDTM1002	Double Sided, 500KB	\$295.00 ea.
	2 or More: \$270.00 each	
BPTNDTM1003	Single Sided, 500KB	\$295.00 ea.
	2 or More: \$270.00 each	
BPTNDTM1004	Double Sided, 1000KB	\$395.00 ea.
	2 or More: \$375.00 each	



DUAL 8" HALF HEIGHT FLOPPY CABINET

• 24V @ 4A 5V @ 3A
 -5V @ 800ma
 • Fan cooled
 • Socketed power connections
 • All supplies regulated

INTERNATIONAL INSTRUMENTATION INC.

List Price **SALE**

BPIIIDL002	Dual Thin Line Cabinet (12 lbs)	\$225.00	\$165.00
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BUY THE CABINET & DRIVES AND SAVE!
 With 2 Tandem Thinlines

BPPDBIITND1	Cabinet w/2 TNDTM8481 - 1 sided (30 lbs)	\$885.00
BPPDBIITND2	Cabinet w/2 TNDTM8482 - 2 sided (30 lbs)	\$1115.00

With 2 MPI Slimlines

BPPDBIIMP11	Cabinet w/2 MPI41M - 1 sided (30 lbs)	\$920.00
BPPDBIIMP12	Cabinet w/2 MPI42M - 2 sided (30 lbs)	\$1080.00

Options

BPIIIDLMPKIT	MPI drive adaptor mounting kit (2 lbs.)	\$24.95
BPIIIDCCSHU	Shugart / AC/DC power connector kit (2 lbs.)	\$14.95

(For full size single S801 or compatible drives)

PRIORITY ONE ELECTRONICS

SANYO
12" DATA DISPLAY MONITOR
24 Lines x
64 Characters



SAVE OVER 50% !!

BPSYODM2112 List Price: \$160.00

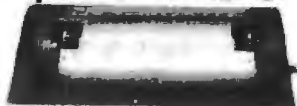
SALE PRICE:

\$75.00 !!

SAVE \$85.00!!
(Sh. Wt. 16 lbs.)

LOWEST COST PRINTERS AVAILABLE

\$299.00 !!



COEX 80 F/T
(Sh. Wt. 21 lbs.)

- 80 cps • 10, 12 or 16.5 cpi • 3 selectable line spacing • Vertical format control • Centronics parallel or RS232C serial interface • Uses a standard Underwood spooled ribbon • Friction and tractor feed

	List Price	OUR Price
BPCOX80FT Parallel int.	\$399.00	\$299.00
BPCOX80FTSER Serial int.	\$399.00	\$299.00
BPCOXAPLINTP Appl. parallel interface w/cable		\$49.95

\$229.00

AXIOM
AXIOM CORPORATION



SAVE \$160.00!!
(Sh. Wt. 11 lbs.)

- 5 x 7 Dot Matrix • Parallel interface (Centronics) • Tractor Feed • Dot Addressable Graphics • Up to 3-Part Paper • Self Test • One Year Warranty • 30 CPS 80 Column Unidirectional • Uses Regular Paper

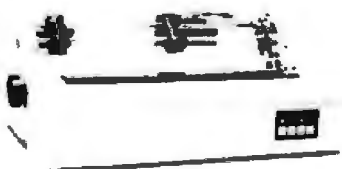
BPAXNGP100A Dot Matrix Printer \$389.00 **\$229.00**

THE COMPATIBLE P1350

TOSHIDA

100 CPS LETTER QUALITY, 200 CPS DRAFT MODE

LETTER QUALITY DOT MATRIX PRINTER!



\$1895.00

BPCCCP1350 List Price: \$2195.00

- Serial Interface
- Fast 200 cps draft mode
- High quality Word Processing mode for letter quality
- Full graphics capabilities (dot addressable)
- Software or switch selectable type styles
- Complete plotter capability with bidirectional tractor
- Unique 24 pin MICRO DOT matrix print head

List Price OUR Price

BPCCCP1350T Bidirectional tractor \$295.00 **\$275.00**

You won't believe the print quality of the COMPATIBLE in its letter quality mode! If we didn't tell you it was dot matrix, you would have never known!
(Shipping Weight 48 lbs.)

IBM MULTICARD

Vista™ MEMORY & I/O CARD



- 64 K RAM Expandable to 256K
- One RS232C Serial Port
- One Parallel Printer Port
- Real Time Clock Calendar with Battery Backup
- (Sh. Wt. 1 lb.)

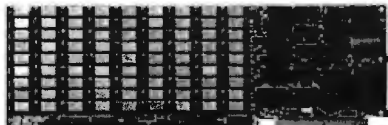
BPVIS025665 List Price \$595.00

SALE PRICE:

\$399.00

IBM MAXICARD

Vista™ PERSONAL COMPUTER RAM CARD
POPULATED IN 64K, 256K, or 576K



- Runs at full speed with no wait states
- Parity can be disabled at User's option
- On board parity bit on each Byte
- Fully expanded, a full 576KB on one card
- One board fills entire primary RAM address space available
- Full Vista 120 Day Warranty

64K \$199.00
BPVIS057664 List Price \$379.00
SAVE \$180.00

256K \$449.00
BPVIS0576256 List Price \$789.00
SAVE \$340.00

576K \$950.00
BPVIS0576576 List Price \$1299.00
SAVE \$349.00

(IBM is a trademark of International Business Machines)

EIA/RS232 WALL PLATES

(Does not include connectors)

BP11WPDB251 Single punched

4/\$10.00

BP11WPDB252 Dual Punched

4/\$12.00



RS-232 "D" SUB-MINIATURE CONNECTORS

	1-9	10-24	25-99	100-UP
BPCNDB25P 25 Pin Male	\$2.75	\$2.50	\$2.25	\$1.95
BPCNDB25S 25 Pin Female	\$4.00	\$3.50	\$3.25	\$3.00
BPCNDB51212 1 Pc Grey Hood	\$1.85	\$1.40	\$1.25	\$1.15
BPCNDB25H 2 Pc Grey Hood	\$1.50	\$1.25	\$1.10	\$1.00
BPCNDB51226 2 Pc Black Hood	\$1.75	\$1.50	\$1.35	\$1.20
BPCNDB020418 Hardware set 2/Pr	\$1.00	\$.60	\$.70	\$.60

TEXA INSTRUMENTS

16 PIN GOLD AND TIN DIP SOLDER TAIL SOCKETS

	TIN	GOLD
QTY BPTIS16LP BPTIG16LP		
50 \$	\$ 8.00	\$ 10.00
1000 \$	\$ 60.00	\$ 80.00
4500 \$	\$225.00	\$315.00

DIRECT CONNECT MODEM

\$79.00
0 - 300 BAUD MURA MM-100



- 0 - 300 baud
- RS232C interface
- Full duplex
- Carrier detect indicator
- Bell 103 compatible
- Low voltage
- Originate/Answer switch selectable

	List Price	SALE
BPMMURM100 0 - 300 baud modem (Shipping Weight: 2 lbs.)	\$99.95	\$78.00
BPCNDRS2328F RS232C cable		\$19.95

SUPER LOW PRICES! 5 1/4" FLOPPY DISKETTES LIFETIME WARRANTY!

DOUBLE DENSITY!

- FEATURES:**
- Includes reinforcement ring
 - Write protect with tabs
 - 100% Surface tested
 - Lifetime warranty



SALE!

Description	Box of 10	2 Boxes	10 Boxes
BPULT52401 Soft sector, 40 track, 2 side	\$35.00	\$60.00	\$280.00
BPULT52410 10 sector, 40 track, 2 side			
BPULT52416 16 sector, 40 track, 2 side			
BPULT51801 Soft sector, 80 track, 1 side	\$30.00	\$50.00	\$220.00
BPULT51810 10 sector, 80 track, 1 side			
BPULT51816 16 sector, 80 track, 1 side			
BPULT52801 Soft sector, 80 track, 2 sided	\$40.00	\$70.00	\$320.00
BPULT52810 10 sector, 80 track, 2 sided			
BPULT52816 16 Sector, 80 track, 2 sided			

(Sh. Wt. 2 lbs.)

(Sh. Wt. 4 lbs.)

(Sh. Wt. 20 lbs.)

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Circle 472 on inquiry card.

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S-100 16MBYTE DMA HARAD DISK SUBSYSTEM

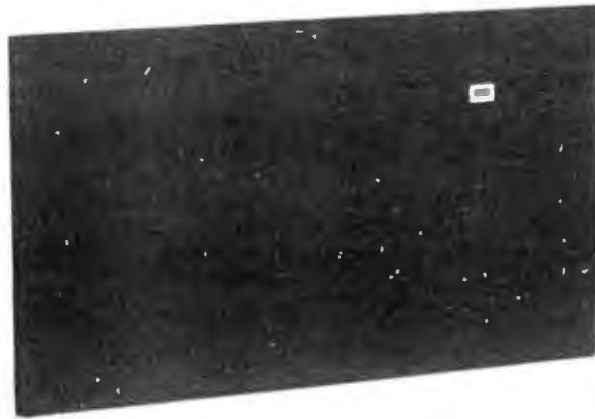
\$1595.00

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DESIGNS**

SAVE OVER 45% !!

There are price barriers to be broken, and then there are PRICE BARRIERS TO BE **S-H-A-T-T-E-R-E-D!!** Priority One Electronics prides itself on breaking price barriers — but never like the one you see here! We're talking about 16 **M-E-G-A-B-Y-T-E-S** FOR ONLY **\$1595.00!!**

That's the storage capacity of THIRTY TWO Shugart SA801Rs — at one tenth the price! And there can be no comparisons between the performance of this system and floppy disk drives!



BPMSDMM16

PURE SPEED

That's what you get when you operate this subsystem. Imagine data access virtually without wait! By using DMA technology, the actual time required to send and retrieve data is greatly reduced. With the additional speed and high density of the 5¼" Winchester disk drive from COMPUTER MEMORIES, you will have enormous files at your own fingertips without the frustration of searching for the right floppy disk! The throughput of this subsystem is further increased by having all low level disk drive routines resident on the DMA controller, thus relieving the computer for other tasks.

COMPATIBILITY

MORROW DESIGNS engineers have invested thousands of man-hours to assure that this M16 hard disk subsystem will be compatible with almost all S-100 IEEE/696 computer systems. Each M16 hard disk subsystem is supplied with CP/M 2.2™, and MICROSOFT BASIC V5.2™. **MORROW DESIGNS** has even included an INSTALL program on 8" disk so you can easily custom configure your M16 subsystem to operate flawlessly with any system that is fully IEEE/696 compatible and has no other DMA devices on line.

EXPANDABLE

The M16 subsystem can grow with your needs. The DMA controller can operate up to four drives at one time. Just imagine — 64 MBytes on line! Also, as technologies progress, you will be prepared with a controller designed with the future in mind!

KEY FEATURES:

DISK DRIVE:

- DISCUS M16 Computer Memories CMI5616, 16Mb formatted capacity
- Same physical size and mounting as the minifloppy
- Same DC voltages as the minifloppy
- Band actuator and stepper motor head positioning
- 5.0 megabit/second transfer rate
- Same track capacity as a double density 8 inch floppy
- 170 millisecond random average access time, reduceable to 95 ms via a simple software algorithm

CONTROLLER:

- Fully compatible with high speed 6MHz and 8 MHz CPU of today and tomorrow
- DMA bus arbitration as outlined by the IEEE 696 standard
- Controls 1 to 4 soft sectored Winchester drives
- Variable sector length (256, 512, 1024, or 2048 byte sectors)
- Automatic CRC generation and checking
- Addresses 1 to 16 heads
- Addresses an infinite number of tracks
- 24-bit address burst DMA transfers
- Due to this high transferrate, a minimum CPU speed of 2.5MHz is required

**WITH CP/M 2.2™ AND
MICROSOFT
BASIC V5.2™!**

NO KIDDING!
16,000,000 BYTES FOR

**ONLY
\$1595.00
SAVE \$1400.00!!**

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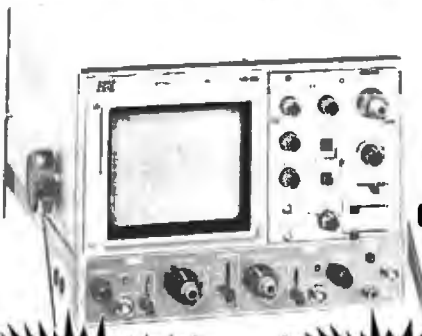
NO ONE ELSE HAS LOWER SCOPE PRICES!



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2 Probes Included With Each Scope!

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\$75.00 REBATE!

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DUAL TIME BASE! CALIBRATED DELAYED SWEEP!

- 100MHz BKP1590, 70MHz BKP1570
- 1mV/division sensitivity
- 500 μV/division cascade sensitivity
- Four-input operation provides trigger view on 4 separate inputs
- Alternate time base operation
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- Lighted function pushbuttons employing electronic switching with non-volatile RAM memory
- 8 x 10 cm internal graticule CRT
- Video sync separator standard
- Dual intensity controls
- Voltage and current probe calibrators (BKP1590 only)



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8 TRACE - 4 CHANNEL
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DUAL TRACE - TRIGGERED
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SAVE \$430.00!!
INCLUDING REBATE

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BPBKP1530 List Price: \$875.00
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SAVE \$301.00!!
INCLUDING REBATE

BKP1535 SPECIFICATIONS:

- 35MHz response; usable beyond 50 MHz • 2 mV/cm vertical sensitivity • Signal delay line for accurate view of high frequency pulse leading edge
- Alternate trigger capability • Automatic or manual selection of CHOP AND ALTERNATE dual-trace display • Variable hold-off for accurate pulse train display • Video sync separators standard • Built-in triggering filters • PDA CRT with P31 phosphor • 10:1/ref/direct probes included • Differential input capability

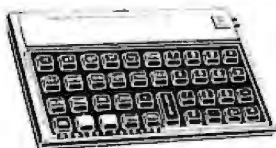
BKP1530 SPECIFICATIONS:

- Delayed sweep operation for sweep expansion up to 1000V • 5 mV division sensitivity selectable 2 mV to 20MHz • Variable hold-off pulse train display • Single-sweep for nonrepetitive waveforms • Built-in triggering filters • Video sync separator standard • CHOP or ALTERNATE display • Differential input capability • 11.7 nS rise time for short duration pulses • Alternate trigger capability • Front panel x-y operation • 10:1/reference/direct probes included

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SERIES 10 - Programmable Calculators

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Part No.	Description	List Price	SALE
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BP HP-11C	Advanced Scientific (3 lbs.)	\$ 90.00	\$ 79.00
BP HP-12C	Advanced Financial	\$120.00	\$ 99.00
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HP-41C/CV - Handheld Computer System

hp HEWLETT PACKARD SUPER LOW PRICES - FREE EXTRAS!*

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Get One of These Enhancement Modules FREE!*

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BP HP82180A	Extended Functions/Memory Module	\$ 75.00	\$59.00
BP HP82181A	Extended Memory Module	\$ 75.00	\$59.00
BP HP82182A	Time Module	\$ 75.00	\$59.00

*Each Computer or Peripheral is shipped with a coupon for free Enhancement Module direct from Hewlett-Packard (Offer expires 4/30/83).

hp HEWLETT PACKARD HP-75C Portable Computer



- Accepts 48K of applications ROM
- Touch-type typewriter-like keyboard
- Powerful BASIC Language
- Uses same peripherals as Series 40

BP HP-75C (Sh. Wt. 5 lbs.) List Price: \$995.00

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Choose the System that fits your needs! A complete computer system ready to add on a terminal and printer. All Systems include CP/M® software and system manual set. Full six-month parts and labor warranty excluding drives which carry the full O.E.M. manufacturers warranty.

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Only \$1395.00 COMPLETE



- ★ with 48 TPI single sided double density 5¼" . . . \$1395.00
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These S-100-4 Systems may be very small in size (9"H x 9½"W x 18½"L) but look at the size of the ATASI® 5¼" Winchester hard disks we offer!

4 models to choose from

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- ★ #3046 36 Megabyte* System \$4495.00

The above systems include a 96 TPI double sided double density 5¼" floppy as standard. The hard disk is controlled via Western Digital's controller for hard disks. Other features are the same as system at left. *Megabyte sizes mentioned above are the available storage space after formatting.



California Computer Systems
SPECIAL!
CCS SYSTEM 2410 . . \$1995.00

- Includes CP/M® 2.2
- 2-Serial/1-Parallel Port
- DMA Disk Controller
- Hardware Vectored Interrupts
- 2-Real Time Clocks
- Supports CP/M®, MP/M®, OASIS

CCS 2300 System, A & T.. 1695.00

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- CCS Apple Boards . . . Call Toll Free For Prices

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WITH HARD DISK Only \$4250.00 COMPLETE



Now available through U.S. Micro Sales, the XOR IRWIN 510 S-100-4 tape backup system with 10 megabytes of hard disk storage. Back up your hard disk on a mini-tape (we're talking 10 meg.) in less than 3½ minutes! The above system includes a 96 TPI DS/DD floppy drive and this system's modular design allows you to add a second floppy for only \$395.00.

A MAJOR BREAKTHROUGH IN TECHNOLOGY . . .

IOMEGA™ CORP. ANNOUNCES THE ALPHA-10™



10 Megabyte Flexible Media Storage Sub-System

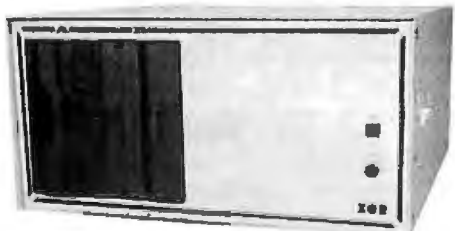
IOMEGA Technology

IOMEGA has combined the reliability of Winchester Technology with the low cost removability of flexible media recording to create a new generation of information storage technology. A unique system of media stabilization enables the flexible media to fly at close proximity to the head, resulting in high density, non-contact recording. Embedded servo and IOMEGA's Parity-Sector Error Correction further enhance the high density and data reliability achieved with the new technology. IOMEGA TECHNOLOGY is the step forward the industry has been awaiting.

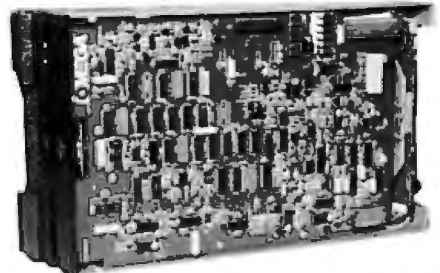
Highest performance and reliability of any Removable Disk Drive. Lowest-cost 10 megabyte Disk Cartridge. More resistant to shock and vibration than any other Fixed or Removable Disk Drive. More resistant to contamination than any other Removable Disk Drive. Fastest start/stop (cartridge replacement) time of any high performance Disk Drive. Only Disk Cartridge Subsystem (drive, controller and cartridge) to dimensionally conform to the diskette standard. (size and mounting), i.e. identical size to Shugart 801/851.

Below is pictured XOR Data Science brand new S-100-12PLUS employing a fantastic 10 Meg floppy system. This new product is absolutely the greatest thing to hit the market in the last five years! Think of it, no more backup problems or head crash! 100 Meg of your data in the space the size of a shoe-box — and you can take it home with you. Call and ask for our folder before you buy your new computer system. It is definitely the best investment you can make.

(#S1000-75) Complete \$3995.00



* Extra cartridges available (#M-2000-51). \$50.00
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IOMEGA Alpha 10

- 10 megabyte formatted capacity.
- Removable 10 megabyte flexible media cartridge.
- 1.13 megabyte/sec. data rate (instantaneous)
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- Dimensions: Disk Drive 4.5" x 8.5" x 14.3" Cartridge ¾" x 8.23" x 11"



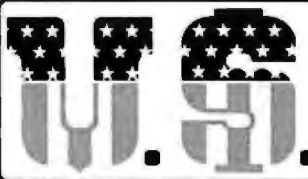
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For Big Board, Apple or Aim 65
+5VDC @ 3 Amps
+12VDC @ .750 Amps
-12VDC @ .750 Amps
-5VDC @ .500 Amps
Dimensions: 4" x 4" x 11"

\$69.95

DISK DRIVE POWER SUPPLY

For 2 - 8" or 5" Drives
+ 5VDC @ 4 Amps
+24VDC @ 3 Amps
- 5VDC @ 1 Amp



AC Cables for 2 Drives \$7.50

Dimensions: 4" x 4" x 11"

\$59.95

S-100 POWER SUPPLY



+8VDC @ 30 Amps
+16VDC @ 6 Amps
-16VDC @ 6 Amps
PC Board Design

\$89.50

Dimensions: 5" x 6" x 11"

TERMINALS

Televideo 910+ with green screen... \$575.00
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Zenith Z-19 740.00

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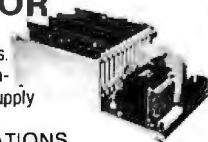
Okidata 82A 80 Column 465.00
Okidata 83A 132 Column 745.00
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Gemini 10 Serial \$130 OFF
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8" DISK DRIVES

Shugart 801R... \$388.00ea. Two for \$379.00ea.
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S-100 MOD KIT
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For test or systems applications.
Complete S-100 12 Slot Main-frame with Disk Drive Power Supply for 4 Drives.



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Unregulated	Regulated
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±16V @ 6A	+24V @ 3A
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\$225.00 Kit with 12 S-100 Bus Connectors
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\$15.00 AC/DC Drive Cable Set for 2 Drives
Dimensions 6" x 10" x 18" - Shipping Weight 25 lbs.

Cooling Power
4 1/8"



Low Velocity
Whisper® Fans
Only \$18.00 ea.
Finger Guards
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XOR
S-100 MOD

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S-100-4



\$1695.00

- ★ 4 Slot S-100 Bus
- ★ Two Separate Power Supplies
- ★ XOR S-100 Board Set
- ★ Includes CP/M® 22 and Mani
- ★ All Cables Provided
- ★ Dimension only 9" x 9" x 18 1/2"

S-100-4 System Complete with:

2-Tandon Thinline 8" (Model TM-848-1 SS/DD)
Part #S-1000-40 **\$1695.00**
2-Tandon Thinline 8" (Model TM-848-2 DS/DD)
Part #S-1000-39 **\$1950.00**

★★★ SPECIAL OF THE MONTH ★★★

8" Dual Drive Subsystem 1.2 Meg Includes two Siemens 120-8 SS/DD Drives, Cables, Power Supplies and Cabinet. A & T **Only—\$675.00**

S-100-8



\$1795.00

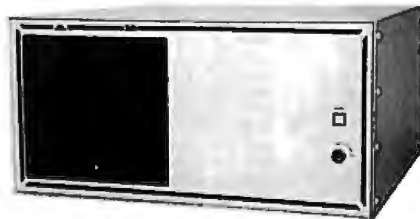
- ★ Feather Touch Capacitance Kybrd
- ★ SOROC Type Screen Attribute Set
- ★ Hall Intensity
- ★ 60 Key Standard ASCII
- ★ 8 Special Function Keys
- ★ 20 Screen Editing Keys

COMPUTER

★ XOR S-100 Board set
★ Programmable Keyboard Set
★ Includes CP/M® 2.2
★ 8 Slot S-100 Bus
S-100-8 System Complete With:
Shugart 801R Subsystem* (#S-1000-22) ... \$2675.00
Shugart 851R Subsystem* (#S-1000-23) ... 2925.00
Qume DT-8 Subsystem* (#S-1000-24) 2950.00
Shugart SA 400 Minis (#S-1000-25) 2350.00
Complete System, No Drives (#S-1000-21) .. 1795.00

*Available in Horizontal or Vertical Cabinet

S-100-12



\$1350.00

- ★ With the XOR S-100 MOD
- ★ 12 Slot Motherboard and Card Cage
- ★ +8V @ 30A
- ★ DC Power to Run up to 4 Drives
- ★ XOR S-100 Board set
- ★ Includes CP/M® 2.2 Software and Manual
- ★ All Cables Provided
- ★ Complete Manual Set

S-100-12 System Complete With:

2-Shugart 801R (#S-1000-30) \$ 2125.00
2-Shugart 851R (#S-1000-31) 2425.00
2-Qume DT-8 (#S-1000-32) 2450.00
Complete System, no drives 1350.00
Cabinet only - Includes Switches, Fan & AC/DC Wiring (#S-1000-28) 250.00
Dimensions 11" x 21" x 22"

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ZVX4 Dual Density, Single & Double Sided - Auto Boot
Disk 2 + 2 Single Density Single or Dual Sided
SVA **300.00**

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Hayes-Smart Modem 300 Baud Orig/Ans Director 250.00
Novation-DCAT300 Baud Direct Con. Ans/Orig. 165.00
Novation-AUTOCAT Auto/Ans/Orig Direct Con. 235.00
Novation-APPLECAT 300/1200 Baud Direct Con. 350.00
PMMI-MM103 300/600 Baud (S-100 BUS) ... 359.00

SOFTWARE

BASIC 80 **\$290.00**
BASIC COMPILER 320.00
CALCSTAR 150.00
C BASIC 118.00
C COMPILER 175.00
MACRO ASSEMBLER 90.00
MAILMERGE 115.00

4164 64K DYNAMIC \$595
200 NS

TMM2016 2KX8 STATIC \$415
200 NS

STATIC RAMS

2101	256 x 4 (450ns)	1.95
5101	256 x 4 (450ns) (cmos)	3.95
2102-1	1024 x 1 (450ns)	.89
2102L-4	1024 x 1 (450ns) (LP)	.99
2102L-2	1024 x 1 (250ns) (LP)	1.49
2111	256 x 4 (450ns)	2.49
2112	256 x 4 (450ns)	2.99
2114	1024 x 4 (450ns)	8/9.95
2114L-4	1024 x 4 (450ns) (LP)	8/12.95
2114L-3	1024 x 4 (300ns) (LP)	8/13.45
2114L-2	1024 x 4 (200ns) (LP)	8/13.95
2147	4096 x 1 (55ns)	4.95
TMS4044-4	4096 x 1 (450ns)	3.49
TMS4044-3	4096 x 1 (300ns)	3.99
TMS4044-2	4096 x 1 (200ns)	4.49
MK4118	1024 x 8 (250ns)	9.95
TMM2016-200	2048 x 8 (200ns)	4.15
TMM2016-150	2048 x 8 (150ns)	4.95
TMM2016-100	2048 x 8 (100ns)	6.15
HM6116-4	2048 x 8 (200ns) (cmos)	4.75
HM6116-3	2048 x 8 (150ns) (cmos)	4.95
HM6116-2	2048 x 8 (120ns) (cmos)	8.95
HM6116LP-4	2048 x 8 (200ns) (cmos)(LP)	5.95
HM6116LP-3	2048 x 8 (150ns) (cmos)(LP)	6.95
HM6116LP-2	2048 x 8 (120ns) (cmos)(LP)	10.95
Z-6132	4096 x 8 (300ns) (Qstat)	34.95

LP = Low Power Qstat = Quasi-Static

DYNAMIC RAMS

TMS4027	4096 x 1 (250ns)	1.99
UPD411	4096 x 1 (300ns)	3.00
MMS280	4096 x 1 (300ns)	3.00
MK4108	8192 x 1 (200ns)	1.95
MMS298	8192 x 1 (250ns)	1.85
4116-300	16384 x 1 (300ns)	8/11.75
4116-250	16384 x 1 (250ns)	8/11.95
4116-200	16384 x 1 (200ns)	8/12.95
4116-150	16384 x 1 (150ns)	8/14.95
4116-120	16384 x 1 (120ns)	8/29.95
2118	16384 x 1 (150ns) (5v)	4.95
4164-200	65536 x 1 (200ns) (5v)	5.95
4164-150	65536 x 1 (150ns) (5v)	6.95

5V = single 5 volt supply

EPROMS

1702	256 x 8 (1us)	4.50
2708	1024 x 8 (450ns)	3.85
2758	1024 x 8 (450ns) (5v)	5.85
2716	2048 x 8 (450ns) (5v)	3.95
2716-1	2048 x 8 (350ns) (5v)	5.85
TMS2516	2048 x 8 (450ns) (5v)	5.50
TMS2716	2048 x 8 (450ns)	7.85
TMS2532	4096 x 8 (450ns) (5v)	5.95
2732	4096 x 8 (450ns) (5v)	4.95
2732-250	4096 x 8 (250ns) (5v)	8.95
2732-200	4096 x 8 (200ns) (5v)	11.95
2764	8192 x 8 (450ns) (5v)	9.95
2764-250	8192 x 8 (250ns) (5v)	14.95
2764-200	8192 x 8 (200ns) (5v)	24.95
TMS2564	8192 x 8 (450ns) (5v)	17.95
MC68764	8192 x 8 (450ns) (5v)(24 pin)	39.95

5v = Single 5 Volt Supply

EPROM ERASERS

	Timer	Capacity Chip	Intensity (uW/Cm ²)	
PE-14		6	5,200	83.00
PE-14T	X	6	5,200	119.00
PE-24T	X	9	6,700	175.00
PL-265T	X	20	6,700	255.00
PR-125T	X	16	15,000	349.00
PR-320	X	32	15,000	595.00

Z-80

2.5 Mhz

Z80-CPU	3.95
Z80-CTC	4.49
Z80-DART	10.95
Z80-DMA	14.95
Z80-PIO	4.49
Z80-SIO/0	16.95
Z80-SIO/1	16.95
Z80-SIO/2	16.95
Z80-SIO/9	16.95

4.0 Mhz

Z80A-CPU	4.95
Z80A-CTC	4.95
Z80A-DART	11.95
Z80A-DMA	16.95
Z80A-PIO	4.95
Z80A-SIO/0	16.95
Z80A-SIO/1	16.95
Z80A-SIO/2	16.95
Z80A-SIO/9	16.95

6.0 Mhz

Z80B-CPU	11.95
Z80B-CTC	13.95
Z80B-PIO	13.95
Z80B-DART	19.95

ZILOG

Z8132	34.95
Z8671	39.95

8000

8035	5.95
8039	6.95
INS-8060	17.95
INS-8073	24.95
8080	3.95
8085	5.95
8085A-2	11.95
8086	29.95
8087	CALL
8088	39.95
8089	89.95
8155	6.95
8155-2	7.95
8156	6.95
8185	29.95
8185-2	39.95
8741	39.95
8748	24.95
8755	24.95

8200

8202	24.95
8203	39.95
8205	3.50
8212	1.80
8214	3.85
8216	1.75
8224	2.25
8226	1.80
8228	3.49
8231	call
8237	19.95
8237-5	21.95
8238	4.49
8243	4.45
8250	10.95
8251	4.49
8253	6.95
8253-5	7.95
8255	4.49
8255-5	5.25
8257	7.95
8257-5	8.95
8259	6.90
8259-5	7.50
8271	39.95
8272	39.95
8275	29.95
8279	8.95
8279-5	10.00
8282	6.50
8263	6.50
8284	5.50
8286	6.50
8287	6.50
8288	25.00
6289	49.95

DISC CONTROLLERS

1771	16.95
1791	24.95
1793	26.95
1795	49.95
1797	49.95
2791	54.95
2793	54.95
2795	59.95
2797	59.95
6843	34.95
8272	39.95
UPD765	39.95
1691	17.95
2143	18.95

CONNECTORS

RS232 MALE	2.50
RS232 FEMALE	3.25
RS232 HOOD	1.25
S-100 ST	3.95

6800

68000	59.95
6800	3.95
6802	7.95
6808	13.90
6809E	19.95
6809	11.95
6810	2.95
6820	4.35
6821	3.25
6828	14.95
6840	12.95
6843	34.95
6844	25.95
6845	14.95
6847	11.95
6850	3.25
6852	5.75
6860	9.95
6862	11.95
6875	6.95
6880	2.25
6883	22.95
68047	24.95
68488	19.95

6800 = 1MHZ

68B00	10.95
68B02	22.25
68B09E	29.95
68B09	29.95
68B10	6.95
68B21	6.95
68B45	19.95
68B50	5.95

6800 = 2 MHZ

6500

1 MHZ	
6502	4.95
6504	6.95
6505	8.95
6507	9.95
6520	4.35
6522	7.95
6532	9.95
6545	22.50
6551	11.85
2 MHZ	
6502A	6.95
6522A	9.95
6532A	11.95
6545A	27.95
6551A	11.95
3 MHZ	
6502B	14.95

UARTS

AY3-1014	6.95
AY5-1013	3.95
AY3-1015	6.95
PT1472	9.95
TR1602	3.95
2350	9.95
2651	8.95
TMS6011	5.95
IM6402	7.95
IM6403	8.95
INS8250	10.95

GENERATORS

BIT-RATE

MC14411	11.95
BR1941	11.95
4702	12.95
COM5016	16.95
COM8116	10.95
MM5307	10.95

FUNCTION

MC4024	3.95
LM566	1.49
XR2206	3.75
8038	3.95

74LS00

74LS00	.24	74LS173	.69
74LS01	.25	74LS174	.55
74LS02	.25	74LS175	.55
74LS03	.25	74LS181	2.15
74LS04	.24	74LS189	8.95
74LS05	.25	74LS190	.89
74LS08	.28	74LS191	.89
74LS09	.29	74LS192	.79
74LS10	.25	74LS193	.79
74LS11	.35	74LS194	.69
74LS12	.35	74LS195	.69
74LS13	.45	74LS196	.79
74LS14	.59	74LS197	.79
74LS15	.35	74LS221	.89
74LS20	.25	74LS240	.95
74LS21	.29	74LS241	.99
74LS22	.25	74LS242	.99
74LS26	.29	74LS243	.99
74LS27	.29	74LS244	.99
74LS28	.35	74LS245	1.49
74LS30	.25	74LS247	.75
74LS32	.29	74LS248	.99
74LS33	.55	74LS249	.99
74LS37	.35	74LS251	.59
74LS38	.35	74LS253	.59
74LS40	.25	74LS257	.59
74LS42	.49	74LS258	.59
74LS47	.75	74LS259	2.75
74LS48	.75	74LS260	.59
74LS49	.75	74LS266	.55
74LS51	.25	74LS273	1.49
74LS54	.29	74LS275	3.35
74LS55	.29	74LS279	.49
74LS63	1.25	74LS280	1.98
74LS73	.39	74LS283	.69
74LS74	.35	74LS290	.89
74LS75	.39	74LS293	.89
74LS76	.39	74LS295	.99
74LS78	.49	74LS298	.89
74LS83	.60	74LS299	1.75
74LS85	.69	74LS323	3.50
74LS86	.39	74LS324	1.75
74LS90	.55	74LS352	1.29
74LS91	.89	74LS353	1.29
74LS92	.55	74LS363	1.35
74LS93	.55	74LS364	1.95
74LS95	.75	74LS365	.49
74LS96	.89	74LS366	.49
74LS107	.39	74LS367	.45
74LS109	.39	74LS368	.45
74LS112	.39	74LS373	.99
74LS113	.39	74LS374	.99
74LS114	.39	74LS377	1.39
74LS122	.45	74LS378	1.18
74LS123	.79	74LS379	1.35
74LS124	2.90	74LS385	1.90
74LS125	.49	74LS386	.45
74LS126	.49	74LS390	1.19
74LS132	.59	74LS393	1.19
74LS133	.59	74LS395	1.19
74LS136	.39	74LS399	1.49
74LS137	.99	74LS424	2.95
74LS138	.55	74LS447	.37
74LS139	.55	74LS490	1.95
74LS145	1.20	74LS624	3.99
74LS147	2.49	74LS640	2.20
74LS148	1.35	74LS645	2.20
74LS151	.55	74LS668	1.69
74LS153	.55	74LS669	1.89
74LS154	1.90	74LS670	1.49
74LS155	.69	74LS674	9.65
74LS156	.69	74LS682	3.20
74LS157	.65	74LS683	3.20
74LS158	.59	74LS684	3.20
74LS160	.69	74LS685	3.20
74LS161	.65	74LS688	2.40
74LS162	.69	74LS689	3.20
74LS163	.65	74LS783	24.95
74LS164	.69	81LS95	1.49
74LS165	.95	81LS96	1.49
74LS166	1.95	81LS97	1.49
74LS168	1.75	81LS98	1.49
74LS169	1.75	25LS2521	2.80
74LS170	1.49	25LS2569	4.2

2114

450 NS

8/\$995

2114

250 NS

8/\$1095

7400

Table of 7400 series components with columns for part number and price.

LINEAR

Table of Linear components including LM301, LM301H, LM307, etc.

RCA

Table of RCA components including CA 3023, CA 3039, etc.

CMOS

Table of CMOS components including 4000, 4001, 4002, etc.

TI

Table of TI components including TL494, TL496, etc.

BI FET

Table of BI FET components including TL071, TL072, etc.

H = TO-5 CAN T = TO-220 K = TO-3

74S00

Table of 74S00 series components including 74S00, 74S02, etc.

INTERFACE

Table of Interface components including 8T26, 8T28, etc.

VOLTAGE REGULATORS

Table of Voltage Regulators including 7805T, 7808T, etc.

MISC.

Table of Miscellaneous components including ULN2003, 3242, etc.

T = TO-220 K = TO-3 L = TO-8

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- Computer managed inventory - virtually no back orders!
Very competitive prices!
Friendly staff!
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CLOCK CIRCUITS

Table of Clock Circuits including MMS314, MMS369, etc.

INTERSIL

Table of Intersil components including ICL7103, ICL7106, etc.

9000

Table of 9000 series components including 9316, 9334, etc.

EXAR

Table of EXAR components including XR 2206, XR 2207, etc.

DATA ACQUISITION

Table of Data Acquisition components including ADC0800, DAC0808, etc.

SOUND CHIPS

Table of Sound Chips including 76477, 76489, etc.

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ALL MERCHANDISE 100% GUARANTEED

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2732 32K EPROM

\$495

2764 64K EPROM

\$995

CAPACITORS

TANTALUM

	6V	10V	15V	20V	25V	35V	50V
.22uf						.40	
.27						.40	
.33						.40	.45
.47			.35			.50	
.68				.45	.50		
1.0		.40	.40	.45	.45		
1.5			.45	.50	.60		
1.8				.75			
2.2		.35	.40	.45		.65	.85
2.7		.40	.45			.90	
3.3		.45	.50	.55	.60	.65	.90
3.9		.45					
4.7	.45	.55		.60	.65	.85	.90
6.0		.60					
6.8		.70	.75				
8.2							1.00
10	.55	.65	.80	.85	.90	1.00	
12	.65		.85	.90			
15	.75	.85	.90				
18			1.25				
22		1.00	1.35				
27			2.25				
39		1.50					
47	1.35						
56	1.75						
100		3.25					
270	3.75						

DISC

22	50V	.05	470	50V	.05
25	50V	.05	560	50V	.05
27	50V	.05	680	50V	.05
33	50V	.05	820	50V	.05
47	50V	.05	.001uf	50V	.05
56	50V	.05	.0015	50V	.05
68	50V	.05	.0022	50V	.05
82	50V	.05	.005	50V	.05
100	50V	.05	.01	50V	.07
220	50V	.05	.02	50V	.07
330	50V	.05	.05	50V	.07
	50V	.05	.1	12V	.10
				50V	.12

MONOLITHIC

.1uf-mono	50V	.18	.47uf-mono	50V	.25
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ELECTROLYTIC

RADIAL			AXIAL		
.47uf	50V	.14	1uf	50V	.14
1	25V	.14	4.7	16V	.14
2.2	35V	.15	10	16V	.14
4.7	50V	.15	10	50V	.16
10	50V	.15	22	16V	.14
47	35V	.18	47	50V	.20
100	16V	.18	100	15V	.20
220	35V	.20	100	35V	.25
470	25V	.30	150	25V	.25
2200	16V	.60	220	25V	.30
			330	16V	.40
			500	16V	.42
			1000	16V	.60
			1500	16V	.70
			6000	16V	.85

COMPUTER GRADE

26,000uf	30V	3.95	6000	16V	.85
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WIREWRAP CARDS

FR-4 Epoxy Glass Laminate
With Gold-Plated Contact Fingers

S-100 BUSS

P100-1	Bare — No Foil Pads	15.95
P100-2	Horizontal BUSS	22.95
P100-3	Vertical BUSS	22.95
P100-4	Single Foil Pads Per Hole	23.95

APPLE

P500-1	Bare — No Foil Pads	15.95
P500-3	Horizontal BUSS	22.95
P500-4	Single Foil Pads Per Hole	23.95

IBM

IBM-PR	BUSS Lines + Pads	55.00
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GENERAL PURPOSE

22/44 PIN (.156" SPACING)

P441-3	Vertical BUSS, 4.5" x 6"	13.95
P442-3	Vertical BUSS, 4.5" x 9"	14.95
36/72 PIN (.1" SPACING)		
P721-3	Vertical BUSS, 4.5" x 8"	13.95
P722-3	Vertical BUSS, 4.5" x 9"	14.95

IF YOU CAN FIND A PRICE LOWER ELSEWHERE, LET US KNOW AND WE WILL MEET OR BEAT THEIR PRICE! (SEE TERMS BELOW)

OPTO-ISOLATORS

4N26	1.00	MCA-7	1.50
4N27	1.10	MCA-255	1.75
4N28	.69	IL-1	1.25
4N33	1.75	ILA-30	1.25
4N35	1.25	ILQ-74	2.75
4N37	1.25	H11C5	1.25
MCT-2	1.00	TIL-111	1.00
MCT-6	1.50	TIL-113	1.75

DIODES

1N751	5.1 volt zener	.25
1N759	12.0 volt zener	.25
1N4148	(1N914) switching	25/1.00
1N4004	400PIV rectifier	10/1.00
KBP02	200PIV 1.5amp bridge	.45
KBP04	400PIV 1.5amp bridge	.55

MUFFIN FANS NEW UN-USED

4.68" Square	14.95
3.125" Square	14.95

SWITCHES

SPDT mini-toggle	1.25
DPDT mini-toggle	1.50
SPDT push-button	1.49

TRANSISTORS

2N918	.50	MPS3706	.15
MPS918	.25	2N3772	1.85
2N2102	.50	2N3903	.25
2N2218	.50	2N3904	.10
2N2218A	.50	2N3906	.10
2N2219	.50	2N4122	.25
2N2219A	.50	2N4123	.25
2N2222	.25	2N4249	.25
PN2222	.10	2N4304	.75
MPS2369	.25	2N4401	.25
2N2484	.25	2N4402	.25
2N2905	.50	2N4403	.25
2N2907	.25	2N4857	1.00
PN2907	.125	PN4916	.25
2N3055	.79	2N5086	.25
3055T	.69	PN5129	.25
2N3393	.30	PN5139	.25
2N3414	.25	2N5209	.25
2N3563	.40	2N6028	.35
2N3565	.40	2N6043	1.75
PN3565	.25	2N6045	1.75
MPS3638	.25	MPS-A05	.25
MPS3640	.25	MPS-A06	.25
PN3643	.25	MPS-A55	.25
PN3644	.25	TIP29	.65
MPS3704	.15	TIP31	.75
		TIP32	.79

HEAT-SINKS

TO-3 style	.85
TO-220 style	.35

IC SOCKETS

8 pin ST	1.99	100
14 pin ST	.13	.11
16 pin ST	.15	.12
18 pin ST	.17	.08
20 pin ST	.20	.16
22 pin ST	.29	.27
24 pin ST	.30	.27
28 pin ST	.40	.32
40 pin ST	.49	.39
64 pin ST	4.25	call
ST = SOLDER TAIL		
8 pin WW	.59	.49
14 pin WW	.69	.52
16 pin WW	.49	.49
18 pin WW	.99	.90
20 pin WW	1.09	.98
22 pin WW	1.39	1.28
24 pin WW	1.49	1.35
28 pin WW	1.69	1.49
40 pin WW	1.99	1.80
WW = WIREWRAP		
16 pin ZIF	6.75	call
24 pin ZIF	9.95	call
28 pin ZIF	10.95	call
ZIF = TEXT TOOL (Zero Insertion Force)		

DIP SWITCHES

4 POSITION	.85
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8 POSITION	.85

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	1-99	100-up
Jumbo Red	.10	.09
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HP 5082-7760	.6"	CC	1.29
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MAN 74	.3"	CC	.98
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FND-507 (510)	.5"	CA	1.49

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RS232 FEMALE RIGHT ANGLE	5.25
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S-100 WW	4.95
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44 pin WW	4.95
72 pin ST	6.95
72 pin WW	7.95

RIBBON CABLE

CONTACTS	SINGLE COLOR		COLOR CODED	
	1'	10'	1'	10'
10	.50	4.40	.83	7.30
20	.65	5.70	1.25	11.00
26	.75	6.60	1.32	11.60
34	.98	8.60	1.65	14.50
40	1.32	11.60	1.92	16.80
50	1.38	12.10	2.50	22.00

D-SUBMINIATURE

DESCRIPTION	SOLDER		RIGHT ANGLE SOLDER		RIBBON CABLE		HOODS		
	MALE	FEMALE	MALE	FEMALE	MALE	FEMALE	BLACK	GREY	
ORDER BY	DBxxP	DBxxS	DBxxPR	DBxxSR	IDBxxP	IDBxxS	HOOD-B	HOOD	
CONTACTS	9	2.08	2.66	1.65	2.18	3.37	3.69	—	1.60
	15	2.69	3.63	2.20	3.03	4.70	5.13	—	1.60
	25	2.50	3.25	3.00	4.42	6.23	6.84	1.25	1.25
	37	4.80	7.11	4.83	6.19	9.22	10.08	—	2.95
	50	6.06	9.24	—	—	—	—	—	3.50

For order instructions see "IDC Connectors" below.

IDC CONNECTORS

DESCRIPTION	SOLDER HEADER	RIGHT ANGLE SOLDER HEADER	WW HEADER	RIGHT ANGLE WW HEADER	RIBBON HEADER SOCKET	RIBBON HEADER	RIBBON EDGE CARD
ORDER BY	IDHxxS	IDHxxSR	IDHxxW	IDHxxWR	IDSxx	IDMxx	IDExx
CONTACTS 10	.82	.85	1.86	2.05	1.15	—	2.25
20	1.29	1.35	2.98	3.28	1.86	5.50	2.36
26	1.68	1.76	3.84	4.22	2.43	6.25	2.65
34	2.20	2.31	4.50	4.45	3.15	7.00	3.25
40	2.58	2.72	5.28	4.80	3.73	7.50	3.80
50	3.24	3.39	6.63	7.30	4.65	8.50	4.74

ORDERING INSTRUCTIONS: Insert the number of contacts in the position marked "xx" of the "order by" part number listed. Example: A 10 pin right angle solder style header would be IDH10SR.

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Unclassified Ads

WANTED: A French computer science student who has experimented both with minicomputers, Apples, TRS-80s and programming in COBOL, BASIC, ASM seeks a computer-related vacation in the U.S. from July through September 1983. Marchal Patrick, 56 A route de Schirmeck 67200, Strasbourg, France.

WANTED: An owner of an Apple 48K CP/M who is a French computer science student seeks people willing to correspond and to exchange software ideas. Holtzmann Thierry, 24 Grand Rue 68320, Urschenheim, France.

WANTED: A position in a U.S. computer company during the summer of '83 is sought by a French computer science student with experience in CP/M, minicomputers, COBOL, BASIC, FORTRAN, Pascal, Assembler, and PL1. Meyer Eric, 2 rue Lamartine 68460, Lutterbach, France.

WANTED: Tax-deductible contribution of any home computer equipment to a nonprofit youth organization for use by a disabled teenager in our program. Dan Seidel, Youth Advocates, Foster Care Program, 2317 East John, Seattle, WA 98112, (206) 322-7838.

WANTED: Consider a tax-deductible donation by yourself or your company of obsolete but functional hardware and/or software. Tax-exempt nonprofit historical-preservation organization in archaeology needs data processing, word processing, and accounting capabilities. Our references and IRS information on request. Darrell Fulmer, Mitchell National Historic Landmark, 305 Medical Arts Building, POB 621, Mitchell, SD 57301, (605) 996-5473.

WANTED: A microcomputer user interested in spending a holiday in Italy for free. I am interested in computer science: studying microelectronics, programming mostly in Pascal, and own an Apple II Plus. I will graduate from the University of Turin. He/she will offer me an equal holiday in the States. Send a short curriculum vitae. Roberto Tonetti, POB 9, Brusnengo, VC 13060, Italy.

FOR SALE: Texas Instruments 745 terminals, used. Russ White, (212) 997-6075.

WANTED: New Apple owner would like to purchase back issues of Nibble. Needed are all of volume 1 and all of volume 2 except No. 6. Please send list of available issues and prices requested. Bob Steinberg, 9030 Niles Center Rd., Skokie, IL 60076.

FOR SALE: Full ASCII keyboard, \$50; Dynabyte naked terminal board (Model 57), \$150; Processor Technology 3 parallel and serial I/O board, \$150; New SDS Expandoram 64K board, 150 ns, \$400. New DRC 16K EPROM board, \$175. Send cashier's check or money order plus \$5 shipping and handling per board. William Whitney, 2063-43rd Ave., San Francisco, CA 94116.

FOR SALE: IMSAI 5-100 system includes DIO-C, VIO-C, MPU-B, RAM 64, in a 10-slot mainframe; monitor; keyboard; and two sets of Perci dual 8-inch drives. Purchased new in 1981, scarcely used, \$3200 firm. Will sell system with one set of dual 8-inch drives for \$2500, or one set of drives for \$700. Greg Baker, POB 3044, Clinton, IA 52732.

WANTED: Ideas for interesting but not too complex games that I can write for personal use. Games can be of any type. I don't want listings, just ideas. Games will be written for the Commodore VIC-20. A copy of the finished project will be mailed to sender on request. David Alexander, 1667 Midland Dr., East Meadow, NY 11554.

FOR SALE: First 16 issues of BYTE (September 1975 through December 1976). This includes charter issue, #1. Like-new condition. Best offer over \$80. Paul Silagy, 83 Needletree Lane, Gastonbury, CT 06033.

FOR SALE: Sinclair ZX81 BK ROM/16K RAM with full-size typewriter-style keyboard, like new. Have many programs including assembler/disassembler, graphics utility, and games. Will include these programs free with purchase of computer. Best offer. R. Beaber, 803 Euclid, Centralia, WA 98531.

WANTED: Used ZX81 microcomputer in good condition. Derry Bryson, POB 433, Wendell, ID 83355.

FOR SALE: Apple II Plus with 64K RAM. System includes 48K computer (Revision 7), Microsoft Ramcard, Apple II disk with controller, Sup 'R' Mod II, Videx Keyboard Enhancer II, E-Z Port (adds game I/O socket outside computer), all cables and manuals, and over 40 program-filled disks worth over \$1500. Best offer. Also, have Integer Firmware card with old monitor ROM. Best offer. Jonathon Cone, 7921 Garner St., Long Beach, CA 90808, (213) 596-5228.

WANTED: Manuals or tapes with program listings for Central Data Co. 2650 BASIC interpreter, BK and/or extended version. Also, want other Central Data information and documentation, such as manuals/listings for debugger, editor/assembler, assembly-language package, character generator program, disk-operating system, printer interface, etc. G.A. Luce, 2907 Greenlawn Parkway, Austin, TX 78757.

WANTED: Commodity Trading Systems. I am a marketing genius without a system, looking for a programming genius without a market. System must be fully developed, previously unmarketed, extensively tested, and extraordinarily successful. Send details and financial requirements. Hugh Martin, 305 San Anselmo Ave., San Anselmo, CA 94960.

WANTED: Apple II peripherals. Modem, double-density disk drive, color monitor, printer buffer, 80-column board, letter-quality printer, etc. Will trade for what you need. I am a member of a barter/exchange: tell me what you have and what you want. Walter Bristow, Box 11278, Eugene, OR 97440, (503) 485-7001 or 741-1464.

FOR SALE: AIM 65 with Video 1 board, power supply, 16K of memory, and case. Asking \$500. Joe Hootman, 3022 Clover Dr., Grand Forks, ND 58201, (701) 775-8353.

FOR SALE: HP 9845A computer, 16-bit microprocessor, 62K-byte core memory, high-resolution display, built-in printer, two cassette tape I/O, graphics, 4 years old, excellent condition, original price about \$21,000, asking \$6000. R.O. Prindle, 54 Crest Rd., Piedmont, CA 94611, (415) 845-3800 days.

FOR SALE: Z80 Starter Kit with 2K RAM in good condition, \$200. Also, several Tektronix and Hewlett-Packard oscilloscopes, not working: \$50 each. Also, assorted test equipment; send SASE for complete list. Bill Stottmyer, Rt. 1, Box 125, Corinth, MS 38834.

FOR SALE: PR1AM 15450, 150-MB disk drive, SMART-E controller, power supply and rack slides, all new in the box: \$6200. New Shugart SA-400 disk drive: \$100. Old SD Sales 4K memory boards: \$10 each. Polymorphics 64 by 16 S-I/O video board, new factory-assembled and -tested: \$20. Jim Amick, 3009 Collin Court, Plano, TX 75075, (214) 596-3788 evenings.

FOR SALE: Commodore 2001 computer with 32K and assorted software. Also, Commodore 8050 dual-disk drive and Commodore cassette drive. All in mint condition. Items sold individually or as a set. Make an offer. Donald Lemma, POB 130, Holmdel, NJ 07733, (201) 946-8735.

WANTED: To complete my collection of BYTE I need November 1978 and November 1977. In return, I offer BYTE 1976: Numbers 13, 14, 15, 16, and BYTE 1977: Numbers 8 and 10. I am also interested in back issues of Creative Computing, Interface Age, Radio Electronics, and Popular Electronics Jaroslav Zudinsky, Palackeho 956, 282 Ol Cesky Brod, Czechoslovakia.

WANTED: I would like to correspond with someone familiar with both Centronics 700 series printers and Data General equipment, mainly Dasher D-200 video displays. Kleber Viana, 440 Park Ave. S. Apt. 1317, New York, NY 10016, (212) 686-2206.

FOR SALE: Godbout S-100 boards: RAM 20 (32K), \$225; Interface I (two serial I/O), \$140; Spectrum with B105 routine for Epson parallel and Sublogic 2D and 3D software, \$225. Heath H-14 printer, \$250. Zenith green monitor, \$95. All perfect. Jack Hersh, (415) 549-3257.

WANTED: SOL units and 5 1/4-inch floppy-disk readers for use and replacement parts. Tax-deductible donations are most welcome. Mr. Walter Hoy, Principal, Campolindo High School, 300 Moraga Rd., Moraga, CA 94556.

WANTED: 9-inch black-and-white Panasonic video monitor (TR-930), in good condition: \$125 or best offer. HP-34C advanced programmable scientific calculator with continuous memory, owner's handbook, mathematics and statistics applications books: \$70 or best offer. David Body, 1530 Cambridge St. #2, Cambridge, MA 02139.

WANTED: Documentation on programming home video game cartridges for the Atari VCS, Intellivision, etc. Particularly interested in schematics and instruction manuals for the discontinued Magicard module advertised page 450 August 1981 BYTE. Will cover your shipping and printing costs. Rick Robertson, 903 Danville Circle, Knoxville, TN 37923, (615) 690-7765.

FOR SALE: BYTE collection: second issue through current issue. All are in excellent condition with over 80 issues. \$120 plus cost of shipping. J.D. Gray, 6951 North Oatman Ave., Portland, OR 97217, (503) 289-6783. No collect calls.

FOR SALE: 32K Commodore PET with display, 40 columns, and cassette. Includes many programs and games. Asking \$900 plus shipping. Peter Giroux, 2820 Route 158, Ste. Sophie, Quebec, Canada, (514) 436-7214.

WANTED: Atari computer games or other software to swap. Send name, address, and cassette and I'll return different programs. Jim Klein, 1552 Woodbridge Apt. 210, St. Paul, MN 55117.

FOR SALE: OSI C1P, 32K static RAM, disk drive, Model 35 Teletype software includes OS65D operating system (V 3.1 and V 3.3), HEXDOS, S-FORTH, Assembler, Extended Monitor, games, and applications: \$750 or best offer. Computerist Video plus board, new: \$150. Steve McCaughey, 524 East Broadway, Enid, OK 73701, (405) 242-2606, weekends only.

FOR SALE: RCA VP711 microcomputer with 4K static RAM, RF modulator, three programming manuals, game manual, power supply, all necessary cables, hex keypad, CHIP-8, CHIP-8X, and many games on cassette tape. Will sell for \$140 or will trade for a working Shugart 801 disk drive. Tom Babaian, 1450 Beaver Rd., Southampton, PA 18966.

WANTED: New or used Atari 800 with 16K RAM or more. Manuals must be included. Would also like extra peripherals such as the BI O disk drive, Epson MX100 printer (or similar), color monitor, languages, joysticks, paddles, lightpen, or games, etc. Will cover shipping if in Western U.S. Make offer on package. Timothy Hood, 1769B Walnut St., Fountain Valley, CA 92708, (714) 964-7206.

Unclassified Ads

FOR SALE: TRS-80 Model III with two double-sided double-density disk drives; RS-232C interface; Daisy Wheel 2 printer; NEWDOS-80; Scripsit/QWERTY word processor; Scripsit Dictionary; other assorted software including mailing lists, utility programs, and several games. Less than one year old. Get the works for only \$3750. Ron Jones, (801) 966-6879.

FOR SALE: Heath H-B computer, 24K, 4-port serial I/O board (H-B-4) and serial/cassette interface board (H-B-5). Includes all manuals: \$250. Ralph Seiler, 70 East Sunset Ave. #1, Salt Lake City, UT 84115, (801) 484-6808.

FOR SALE: Digital Research PL/I (unopened) with update and manuals for 8-bit system, \$350. Visicalc and FORTRAN with manuals for TRS-80 Model I, \$50 each. Omikron Mapper II (unused) for TRS-80 Model I, \$100. IBM 735 I/O Selectric, black (excellent condition), modified for TRS-80 Model I by Virginia Microsystems, operates as printer or typewriter, \$450. Syd Spain, POB 10107, College Station, TX 77840, (713) 693-2835.

FOR SALE: NEC Spinwriter 7710, with tractor, new, \$2200. IBM PC asynchronous communications, \$100. Ron Swenson, Box 701, Boston, MA 02102, (617) 242-9213, evenings.

WANTED: Users of IBM 5100, 5110, or 5120 or users group to exchange information. I also want to purchase a spreadsheet-type program for this model. Stephen Pottie, POB 697, Montague, Prince Edward Island COA 1R0, Canada, (902) 838-2070 or 962-2279.

FOR SALE: Teletype Model 43 30-cps dot-matrix printer terminal. RS-232C interface, pinfeed, Hall-effect keyboard. Almost new condition. With service and circuit diagram manuals: \$595. Ron Mauceri, 14433 Dickens St., Sherman Oaks, CA 91423, (213) 906-3517.

WANTED: Consultant to aid in implementation of dial-up database system. Dr. L. Huber, Hampshire Educational Collaborative, 58 Pleasant St., Northampton, MA 01060.

FOR SALE: Novation Cat modem, 300 bps, good condition: \$100 or best offer. Jim Larus, Apt. 4, 2415 College Ave., Berkeley, CA 94704.

WANTED: Commodore 64 owners, send me your games, music, or graphics programs on cassette, with your name and address, and I'll send back your cassette with my adventure game, "Horror Hotel." Would also like to correspond with anyone using the Commodore 64 for music synthesis. Phil Nelson, 3801 Garfield Ave. S, Minneapolis, MN 55409.

FOR SALE: Radio Shack Line Printer IV [same as Centronics 747] in excellent condition. Highest offer or best trade-in bid for daisy-wheel printer, new or used. Isai Kamen, 11 Sherman Ave., White Plains, NY 10605.

FOR SALE: Atari 800, new: \$670 COD. Also, every computer magazine available. Send SASE. Jack Gindi, REF301, 2079 East 3 St., Brooklyn, NY 11223.

WANTED: I am interested in obtaining the following publications: PC—The Independent Guide to IBM Personal Computers—Vol. 1, No. 2. 80 Microcomputing—Vol. 2, No. 2 (February 1981). Send asking price. Thomas Kariya, POB 33, Brookeville, MD 20833.

FOR SALE: Back issues of BYTE. January '81, July '81 through July '82: \$10. Nat Stevens, 46 Elm St., North Andover, MA 01845, (617) 687-3421.

FOR SALE: Radio Shack Color Computer plastic dust cover, \$4 with Radio Shack Cassette recorder cover. Also, would like a copy of Eliza written in Microsoft BASIC under 20K. Send price. Bosco T. Tsang, 575 University Ave. W #505, Windsor, Ontario N9A 5R4, Canada.

FOR SALE: SwTPC 6800 with 28K RAM socketed for 48K, three serial I/O ports, LFD-400 disk drive with INDEX DOS, CT-64 terminal with VT-VM green screen monitor and software: \$1400. Jim Benson, 1719 North Woodlawn, Derby, KS 67037, (316) 788-5756.

FOR SALE: ABT Softkey pad for Apples. Accessory-programmable keypad plugs into game port. Can be used as numeric pad or keys may be programmed as command keys. With all documentation, like new (never used). First \$100 takes. Evan Julber, Numismatics Ltd., Suite 600, 9665 Wilshire Blvd., Beverly Hills, CA 90212, (800) 421-0678 or (213) 550-1766.

FOR SALE: S-100 boards. Flashwriter II, \$150. Cromemco Bytesaver, \$100. IMSAI SIO, \$25. Processor Technology: PROM board, \$50; CUTS, \$25; VDM-1 video, \$25. Tarbell cassette I/O, \$25. Percom cassette I/O, \$25. Jay Dowling, 804 Bristol Court, Richardson, TX 75080, (214) 690-1752.

FOR SALE: 32K Commodore PET with interfacing and software to control lights, motors, etc. Many games. Asking \$400 or best offer. Ed Jemmings, 688 Ida-Maybee Rd., Monroe, MI 48161, (616) 269-2133.

FOR SALE: TRS-80 Color Computer, 32K Ext. BASIC, original packing. Plus approximately \$400 worth of software, including CBUG, Editor/Assembler, Colorcom[E] V3, Telewriter Word-processor, Space Invaders, Asteroids, Pacman, Berserk, Chess, and many more. Includes manuals. Asking \$525. J.A. Czryca, 6014 County Line Rd., Perry, NY 14530.

FOR SALE: Universal Data Systems 212LP: 1200 bps, direct-connect, full-duplex modem. New, in original carton, never used. List price is \$495, will sell for \$300 (postpaid), or best offer. Harold Miller, Tumbling Waters, Route 2, Box 2330, Clayton, GA 30525, (404) 782-2843.

FOR SALE: Commodore VIC-20 Color Computer with these extras: 8K memory cartridge, Commodore cassette player, joystick, three games, and two instruction books. All like new. \$225 or trade for accessories and equipment for my TRS-80 Color Computer. Hal Mermelstein, RFD 2, Webb Rd., South Windham, ME 04082, (207) 892-9042.

FOR SALE: Qume Sprint 5 daisy-wheel printer in excellent condition. Two printwheels included: \$2000. Steve Kaplan, 661 Wingate Dr., Sunnyvale, CA 94087, (408) 733-4139.

BOMB BYTE's Ongoing Monitor Box

Article #	Page	Article	Author(s)
1	28	Build an RS-232C Breakout Box	Ciarcia
2	53	The National Semiconductor NS16000 Microprocessor Family	Leedy
3	70	Design Philosophy Behind Motorola's MC68000, Part 1	Starnes
4	96	The CRT 9007 Video Processor and Controller	Cayton, Hermon Lemmons
5	110	New Japanese Microcomputers	Zingale
6	132	Intel's 80186: A 16-Bit Computer on a Chip	Simington
7	154	The Intel 8087 Numerics Processor Extension	Levine
8	176	Super Graphics Hardware from NEC	Fleming
9	190	NAPLPS: A New Standard for Text and Graphics, Part 3: Advanced Features	Schmitt
10	210	Virtual Memory for Microcomputers	Lemmons
11	242	BYTE West Coast: Hard Choices for Software Houses	Swank
12	260	The Enhanced VIC-20, Part 3: Interfacing an MX-80 Printer	Lemmons
13	290	Two Ways to Use CP/M-80 on the IBM PC	Alexander
14	304	Building a Hard-Disk Interface for an S-100 Bus System, Part 2: Hardware	Pournelle
15	324	User's Column: Terminal Solutions, Manual Madness, BASIC Bits, and Info Helpers	Spitzer
16	360	Build This Memory, Part 2: Constructing the Memory Card	McCormack, Gleaves
17	385	Modula-2	McDermott
18	398	The Design of an Advanced Logic Simulator	Williams
19	442	Information Hiding: A Brief Example	

Compaq Leads Off

BYTE readers voted Mark Dahmke first-place winner in the January BOMB contest for his product description of "The Compaq Computer," a portable and affordable alternative to the IBM Personal Computer. He will receive the \$100 prize. Second place goes to John Smith for his article, "Public Key Cryptography." He will get the \$50 kitty. Gregg Williams holds third place for his report from London on "Micro-computing, British Style."

Reader Service

Inquiry No.	Page No.	Inquiry No.	Page No.	Inquiry No.	Page No.	Inquiry No.	Page No.
118	1st NATIONAL COMP. 211	90	COMPUADD 500	419	FROBCO 148	265	MICRO BUSN.WORLD 371
469	1 SUPER WAREHOUSE 437	91	COMPUPRO/GODBOUT 240, 241	174	G-H COMPUTER SYS. 502	268	MICRO MANAGEMENT SYS. 307
1	800 SOFTWARE 205	*	COMPUPRO/GODBOUT 452, 453	175	GARDEN OF EDEN COMP. 504	269	MICRO MART 420
2	A.S.T.RESEARCH 42, 43	92	COMPUSERVE 52	176	GENERAL SOFTWARE INC. 264	270	MICRO MIDWEST 512
4	AB COMPUTERS 499	340	COMPUSHACK 358, 359	177	GENIE COMP.CORP. 368, 369	271	MICRO MINT 384
5	ABACUS DATA INC. 29	343	COMPUSHACK 365	178	GENSTAR REI SALES CO. 76	272	MICRO MINT 420
8	ACOUSTIC RESEARCH 504	93	COMPUTER APPARATUS 511	179	GENSTAR REI SALES CO. 512	261	MICRO MINT 429
6	ACTIVE ELECTRONICS 439	94	COMPUTER CHANNEL 451	180	GIFFORD COMP. SYS. 269	272	MICRO MYSTIQUE 512
11	ADDMASTER CORP. 510	95	COMPUTER DISCOUNT PROD. 501	180	G&G ENGINEERING 269	273	MICRO PRO. INT'L. 294, 295
12	ADV.COMP.PROD. 526, 527	96	COMPUTER EXCHANGE 200, 201	181	GILTRONIX INC. 514	276	MICRO SCI 67
143	ADV.LOGIC SYSTEMS 137	97	COMPUTER EXCHANGE 200, 201	182	GOULD, INC. 195	277	MICRO SOLUTIONS 510
14	ADV.SYS.CONCEPTS 514	98	COMPUTER EXCHANGE 200, 201	183	GTEK INC. 328	278	MICRO WEST 247
16	ADVANCED DATA TECH. 506	99	COMPUTER INNOVATIONS 20	184	HANDWELL CORP. 498	279	MICRO WORKS, THE 172
17	AFTERTHOUGHT ENG. 512	460	COMPUTER LEARNING TREE 338	185	HAYES MICROCOMP.PROD. 191	280	MICROCOMP.BUSN.IND. 208, 209
*	ALF PRODUCTS, INC. 419	101	COMPUTER MAIL ORDER 382, 383	186	HEALTH COMPANY 105	281	MICRODYNAMICS 514
18	ALL ELECTRONICS CORP. 502	102	COMPUTER PERIPH. INC. 157	*	HEWLETT-PACKARD 263	282	MICROHOUSE 10, 11
19	ALPHA BYTE COMP.PROD. 50, 51	103	COMPUTER PUBLISHING CO. 218	*	HEWLETT-PACKARD 456	283	MICROPERIPH.CORP.THE 498
20	ALPHA BYTE COMP.PROD. 266	15	COMPUTER PLUS 476	*	HOBB-Y-TRONIX INC. 505	284	MICROPROCESSORS UNLTD. 496
21	ALTOS COMP.SYS. 127	104	COMPUTER SPCLTIES. 219	187	HUMAN DESIGNED SYSTEMS 135	*	MICROSOFT 75
22	AMER.SMALL BUSN.COMP. 474	105	COMPUTER WAREHOUSE 379	188	HUMAN SOFT 163	*	MICROSOFT 177
23	AMER.SQUARE COMP. 173	107	COMPUTERLINE INT'L-A 252, 253	189	I X O 129	*	MICROSOFT 297
24	AMPERSAND INC. 474	107	COMPUTERLINE INT'L-B 409	192	I/O TECHNOLOGY 325	*	MICROSOFT 336, 337
25	ANCIE LABS 332	108	COMPUTERS & MORE 498	193	IBM CORP. 232, 233	285	MICROSTUF, INC. 121
26	APPARAT INC. 257	110	COMPUTERS WHOLESALE 444	194	IDE CORPORATION 152, 153	286	MICROTECH EXPORTS 204
27	APPLE COMPUTER INC. CII. 1	111	COMPUTERWARE 111	195	IMS INTERNATIONAL 239	287	MICROWARE 500
29	APPLEWARE, INC. 498	112	COMPUVIEW PROD.INC. 49	196	INCOMM 475	289	MITSUBA 160
*	APPLIED CREATIVE TECH.INC. 18	113	COMSILK 510	197	INFO. REDUCTION RESEARCH 340	245	MKS 508
465	ARBA 464	114	CONCORD COMP.PROD. 495	*	INFOCOM,INC. 322, 323	370	MODERN SOFTWARE SYS. 412
30	ARBUSUTUS TOTALSOFT INC. 443	115	CONCURRENT CORP. 128	479	INFOPRO SYSTEMS 309	290	MORROW DESIGNS 180, 181
31	ARK MICROSYSTEMS 477	116	CONDOR COMP.CORP. 440, 441	200	INMAC 465	291	MORROW DESIGNS 265
32	ARTEL ART & ELECTRONICS 97	*	CONNECTICUT MICRO COMP. 192	213	INNOVATIVE COMM. 496	292	MOUNTAIN VIEW PRESS 435
33	ARTIFICIAL INT'L.RESRCH. 500	117	CONSOLINK 34	201	INNOVATIVE SOFTWARE 103	293	MTI SYSTEMS CORP. 418
34	ASHTON-TATE 119	120	COST PLUS COMP. 512	202	INSIGHT ENTERPRISES 502	294	MULTITECH ELECTRONICS INC. 199
485	ASHTON-TATE 207	121	CPU SHOP, THE 513	203	INSTITUTE-SCFT.ANALYSIS 498	295	MUSYS 282
35	ASHTON-TATE 221	122	CREATIVITY UNLTD. 506	204	INT'L.MICRO SYS. 425	296	NEBS 144
36	ASHTON-TATE 312, 313	123	CROMEMCO 2	205	INT'L.NORTH STAR 506	297	NEC HOME ELECTR.USA 215
37	ASPEN SFTW.CO. 92	124	CSCS 510	206	INTEGRAL DATA SYS. 333	298	NEC HOME ELECTR.USA 217
38	ATARI 68, 69	76	CSX CORP-FAMILY LINES SYS. 62	207	INTEGRAL QUALITY 106	299	NEC HOME ELECTR.USA 305
39	ATLANTIC CABINET CORP. 512	125	CUESTA SYSTEMS 443	208	INTEGRAND 254	300	NEC INFORMATION SYS. 17
40	ATLANTIS COMP.SERV. 504	126	CUSTOM COMP.TECH. 330	210	INTERACTIVE MICROWRE. 481	*	NETRONICS 516
41	ATSUKO COMPUTING INT'L. 496	*	CYBERNETICS INC. 73	211	INTERACTIVE STRUCT. 122	301	NETWORK CONSULTING CORP. 74
42	AUSTIN DATA MANAGEMENT 439	127	D/PUNCH CO. 235	212	INTERACTIVE STRUCT. 143	303	NEWTech CO. LTD. 416
42	AUTOCONTROL INC. 496	463	DAISY SYSTEMS 151	214	INTERDATA SYSTEMS INC. 498	304	NORTH HILLS CORP. 504
43	AUTOMATED EQUIPMNT. 301	128	DAMAN 506	215	INTERTEC DATA SYS. 9	305	NORTH HILLS CORP. 412
44	AVOCET 413	129	DATA EXCHANGE 443	216	INTEX SYSTEMS 339	306	NOVATION 94, 95
45	B&B ELECTR. 514	209	DATA MAIL 459	217	IPEX INT'L. 496	307	NOVELL DATA SYS. 81
46	B&B ELECTR. 510	130	DATA SOURCE SYS.CORP. 327	218	IRONSIDES COMP. CORP. 343	*	NRI SCHOOLS ELECTR.DIV. 353
*	BARGAIN BOARDS 496	132	DATA TRANSLATION INC. 347	219	J.C.SYSTEMS 32	309	O'HANLON COMP.SYS. 403
47	BASF SYSTEMS 77	133	DATASOUTH COMP.CORP. 37	474	JADE COMP.PROD. 517	310	ORANGE MICRO 140
48	BAUSCH & LOMB INSTR.SYS. 83	134	DATASOUTH COMP.CORP. 248	475	JADE COMP.PROD. 518, 519	311	ORANGE MICRO 141
49	BAUSCH & LOMB INSTR.SYS. 83	135	DATABASE SYSTEMS 508	221	JAMECO ELECTR. 522, 523	314	ORION INSTRUMENTS 514
50	BAY TECHNICAL ASSOC. 146	136	DENNISON KYBE CORP. 249	222	JDR MICRODEVICES 536, 537	315	ORTHO CODE GROUP 346
51	BELL, JOHN ENGR. 510	137	DHD INC. 156	223	JDR MICRODEVICES 538, 539	316	ORYX SOFTWARE 267
52	BHRT 147	138	DIGISOFT 161	224	JDR MICRODEVICES 540	*	OSBORNE COMPUTERS 31
53	BHRT 288	139	DIGITAL DIMENSIONS 354	*	JRT SYSTEMS 344, 345	*	OWENS ASSOC. 84
54	BI-COMM SYSTEM 451	140	DIGITAL EQUIPMNT.CORP. 130, 131	462	KADAK PRODUCTS, LTD. 355	319	PACIFIC EXCHANGES 406
55	BISON PROD INC. 245	141	DIGITAL MARKETING 6	226	LABORATORY MICROSYS. 502	319	PACIFIC EXCHANGES 500
56	BISON PROD INC. 245	142	DIGITAL PRESS 300	227	LANIER BUSN.PROD. 422, 423	319	PACIFIC EXCHANGES 502
57	BISON PROD INC. 245	143	DIGITAL RESEARCH 39	228	LANIER DICTATING SYSTEMS 167	319	PACIFIC EXCHANGES 506
58	BISON PROD INC. 245	144	DIGITAL RESEARCH 137	229	LEADING EDGE PROD. CIII	319	PACIFIC EXCHANGES 508
59	BISON PROD INC. 245	144	DIGITAL RESEARCH 279	231	LIBERTY COMP. SALES 317	319	PACIFIC EXCHANGES 510
61	BOTTOM LINE, THE 283	*	DIGITAL RESEARCH COMP. 503	232	LIGO RESEARCH INC. 231	319	PACIFIC EXCHANGES 514
62	BUSINESS MANAGER 401	DIP INC. 515	DISCOUNT SOFTWARE 187	234	LINK FLIGHT SIMULATION 445	326	PALOMAR COMP.EQUIP. 374, 375
64	BUSINESS SOLUTIONS 404	*	DMA 299	235	LOCKHEED DIALOG 107	327	PAN AMERICAN ELEC.INC. 328
*	BYTE BACK ISSUES 426	*	DOKAY COMP.PROD.INC. 524, 525	498	LOGIC PROGRAMMING ASSOC.	328	PERCOM DATA 7
*	BYTE BOOK CLUB 289	149	DOW JONES INFO.SERV. 63	236	LOGICAL DEVICES 482	480	PERSCI 309
65	BYTE PUBL. INC. 478	150	DRIVER-HARRIS SYSTEMS, INC. 443	237	LOGICAL MICROCOMPUTER 155	481	PERSCI 420
66	BYTEK COMP. SYS. 481	151	DUAL SYS.CONTROL CORP. 246	238	LOMAS DATA PRODUCTS 275	330	PERSONAL SYS.TECHN. 99
67	BYTEWRITER 30	152	DYSAN CORP. 287	488	LOTUS DEVELOPMENT 396, 397	331	PETRO-Lewis FUNDS INC. 251
68	C.S.D.INC. 502	152	DYSAN CORP. 311	239	LYBEN COMP.SYS. 496	332	PH ASSOCIATES 482
69	CAB-TEK, INC. 340	*	E. ARTHUR BROWN CO. 504	240	LYCO COMPUTER 261	333	PHASER 193
70	CALIF. DATA CORP. 500	230	EASTERN ENTERPRISES 315	241	MACROTECH COMP.PROD. 473	334	PICKLES & TROUT 222
*	CALIF. DIGITAL 520, 521	153	EZ ASSOC. 406	242	MACROTECH INT'L. 281	335	PION INC. 142
*	CALIF.MICRO.COMP. 462	154	ECOSOFT 439	243	MAI SORBUS SERVICE 341	336	PRACTICAL PERIPH. 26, 27
71	CDEX CORP. 93	155	EDGE MICROSYSTEMS 500	244	MAILCOMP INC. 291	337	PRAGMATIC DESIGN 82
72	CDR SYSTEMS 500	157	EEM 149	246	MANNESMANN TALLY 223	338	PRINCETON GRAPHIC SYS. 123
73	CENTENNIAL SOFTWARE 330	461	E.F. JOHNSON 224	247	MANX SOFTWARE 89	470	PRINTER STORE, THE 352
72	CENTRE COMP.CONSTNTS. 506	158	ELEK-TEK 334	248	MARCEY, INC. 430, 431	471	PRIORITY ONE 528, 529
74	CHECK-MATE 473	159	ELLIS COMPUTING 373	249	MARK OF THE UNICORN 331	472	PRIORITY ONE 530, 531
75	CHECKS-TO-GO 235	160	EMC DISTRIBUTING 443	250	MARYMAC INDUSTRIES 469	473	PRIORITY ONE 532, 533
77	CHIPS & DALE 496	161	EMERGING TECH.CONSLT. 184	251	MASON COMPUTERS 226	344	PROGRAMMERS SFTW. EX. 280
78	CHRISLIN INDUSTRIES 285	*	EMPIRICAL RESRCH.GRP. 114	252	MAXTEK 156	345	PROGRAMMING INT'L. 454, 455
466	CMC INT'L. 417	156	EMS 226	106	MBI 5	346	PROTECTO ENTERPR. 88
476	CMC INT'L. 468	163	ENERCOMP 136	252	MC NEILL 416	347	PROTECTO ENTERPR. 214
79	COGIMATE 502	164	ENGINEERING SPECIALTIES 412	253	MC NEILL 416	348	PROTECTO ENTERPR. 508
80	COLONIAL DATA SERV. 86	165	EPSON AMERICA 108, 109	254	MC NEILL 416	349	PROTOCOL 64
81	COLUMBIA DATA PROD. 19	166	EPSON AMERICA 410, 411	255	MC/N INC. 506	350	PROTOCOL 184
82	COLUMBIA NATIONAL 508	168	EXPOTEK 150	257	MEDIA DISTRIBUTING 164	351	PROTOCOL 296
83	COMMUNICAL, INC. 395	169	EXTENDED PROCESSING 512	258	MEDISOFT 506	352	PROTOSYS 349
84	COMMUNICATIONS ELECTR. 507	170	FACIT DATAROYAL 407	259	MEDISOFT 508	487	PRYOR COMP. SUPPLIES 348
85	COMP.COMPNTS.UNLTD. 509	*	FAMOUS PROGRAMMERS' SCHOOL 433	260	MEMORY MERCHANT 23	353	PURCHASING AGENT, THE 118
86	COMPAQ COMPUTER CORP. 25	171	FORMULA INT'L. 427	464	METAMORPHIC SYS.INC. 183	354	QANTEX DIV. 255
87	COMPONENTS EXPRESS 206	172	FOX & GELLER INC. 237	262	METHOD SYSTEMS 508	355	QT/COMPATIBLE 351
89	COMPUADD 500	173	FRANKLIN COMP.CORP. 71	263	MFJ ENTERPRISES INC. 356	356	QUADRAM CORP. 78, 79
				264	MICRO AGE COMP.STORE 326	357	QUADRAM CORP. 272, 273
						358	QUARK ENGINEERING 65
						450	QUBIE DISTRIBUTING 115
						359	QUESTIONNAIRE SERV.CO. 508
						362	R.R.SOFTWARE 149
						363	RACAL VADIC 185
						364	RACET COMPUTES LTD. 262
						365	RADIO SHACK CIV
						477	RANDOM HOUSE 451
						312	RED BARON COMP.PROD. 188, 189
						367	RED GATE PUBL.CO. 125
						368	ROCKY MT.MICRO INC. 203

Reader Service

Inquiry No.	Page No.	Inquiry No.	Page No.	Inquiry No.	Page No.	Inquiry No.	Page No.
369	RON SAN ELECTRONICS 504	388	SONY VIDEO PRODUCTS 447	406	TELECON SYSTEMS 8	431	VISUAL TECH, INC. 145
371	RTL PROGRAMMING AIDS 504	389	STARBUCK DATA CO. 414	407	TELETEK 13	432	VLM COMPUTER ELECTR. 506
486	RUTISHAUSER DATA AG 318	*	STEMMOS LTD. 256	408	TERMINALS TERRIFIC 298	433	VOTRAX 415
372	S C DIGITAL 448	391	STREET ELECTR. CORP. 80	409	TEXAS COMP. SYS. 216	435	WADSWORTH ELECT. PUBL. 357
373	S&W COMPUTER SUPPLY 502	392	STRUCTURED DESIGN 514	*	TEXAS INSTRUMENTS 168, 169	*	WAREHOUSE SOFTWARE 378
374	S-100 INC. 405	393	STRUCTURED DESIGN 510	410	TEXAS INSTRUMENTS 91	437	WARNER BOOKS 342
375	SAGE COMP. TECH. 33	394	SUNNY INT'L. 495	411	THOUGHTWARE INC. 165	438	WASHINGTON COMP. SERV. 178
376	SATURN SYSTEMS 225	478	SUNTRONICS 309	412	THUNDERHAWK CORP. 293	439	WASHINGTON COMP. SERV. 483
*	SCOTTSDALE SYSTEMS 229	395	SUNTRONICS 497	415	TOTAL ACCESS 243	440	WEST STAR MICRO 162
377	SEARS ELECTRONICS INC. 498	396	SUPERSOFT 133	*	TRANS WORLD AIRLINES 250	*	WESTICO INC. 277
467	SHERATON HOTELS	397	SUPERSOFT 197	417	TRANSTAR 87	442	WESTINGHOUSE/LIGHTING DIV 377
	WORLDWIDE 329	398	SYSTEMED 512	418	TRANSTAR 399	443	WHITESMITHS LTD 14
378	SIERRA DATA SCIENCES 35	399	SYSTEMS STRATEGIES 380	420	TRIOLOG 302	444	WHOLESALE SUPPLIERS 443
*	SINCLAIR RESEARCH 227	400	TALLGRASS TECH. 47	421	TRIOLOG 303	445	WILD HARE COMP. SYS. 213
380	SLR 504	401	TARBELL ELECTR. 280	468	TRISTAR DATA SYS. 128	446	WIN/MILL RESEARCH INC. 500
381	SLUDER 380	402	TATUM LABS 502	422	TSI MARKETING 236	447	WINCHENDON GRP., THE 514
482	SNAVE SYSTEMS 420	341	TAVA CORP 361	423	TSK ELECTR. CORP. 85	448	WINTEK CORP. 510
382	SOFTTECH MICROSYS 117	342	TAVA CORP 363	424	U.S. MICRO SALES 534, 535	449	WINTERHALTER & ASSOC. 462
383	SOFTWARE ARTS 158, 159	403	TAYCO BUSINESS FORMS 498	425	U.S. ROBOTICS 22	451	X COMP 271
385	SOFTWARE BANC 381	413	TDI 148	426	U.S. EXCHANGE 512	452	XEDEX CORP. 90
386	SOFTWARE TECHNIQUE 504	404	TECH-DATA CORP. 406	427	UNIFIED SOFTWARE SYS. 514	453	XEDEX CORP. 331
167	SOFTWARE TOOLWORKS 476	*	TECHNICAL SYS. CONSULTNS. 259	428	USI INT'L. 101	456	XEROX PRINTING SYS. 367
387	SOLID STATE SALES 244	405	TECMAR INC. 15	429	VIDEX 21	454	YANG ELECTRONIC 508
	SONICS MICRO SYS. 335	*	TEKTRONIX INC. 45	430	VISTA COMPUTER CO 16		

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2 22 42 62 82	102 122 142 162 182	202 222 242 262 282	302 322 342 362 382	402 422 442 462 482	502 522 542 562 582	602 622 642 662 682
3 23 43 63 83	103 123 143 163 183	203 223 243 263 283	303 323 343 363 383	403 423 443 463 483	503 523 543 563 583	603 623 643 663 683
4 24 44 64 84	104 124 144 164 184	204 224 244 264 284	304 324 344 364 384	404 424 444 464 484	504 524 544 564 584	604 624 644 664 684
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6 26 46 66 86	106 126 146 166 186	206 226 246 266 286	306 326 346 366 386	406 426 446 466 486	506 526 546 566 586	606 626 646 666 686
7 27 47 67 87	107 127 147 167 187	207 227 247 267 287	307 327 347 367 387	407 427 447 467 487	507 527 547 567 587	607 627 647 667 687
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