the small systems journal
A McGRAW-HILL PUBLICATION

DOUBL

THE FORTH LANGUAGE
When we introduced the "S" system last year we knew that we were ahead of the industry. We didn’t realize just how far.

WE KNEW THE NEEDS—
When we began designing the S/09 computer, we knew that the normal eight-bit microprocessor system was not adequate for any but the smallest, single user business applications. What was worse there was little that could be done to expand the capabilities of the system if the customer needed it. There is nothing much worse to a business customer than a "dead end" system.

MEMORY IS THE KEY—
Obviously a business system should be able to operate with multiple terminals if needed. It should also be able to do a variety of jobs; not just data processing, but also word processing and computer aided instruction. With a system limited to 64K bytes of memory addresses such a system is just not practical. The amount of user memory available to each terminal is too small for useful work.

HOW DO YOU GET IT—
The common solution to this problem is called bank switching. This process is similar to a selector switch that turns on the bank of memory that you want to work with. This, however, has a few problems. It is inefficient, therefore expensive, plus being slow. It is also extremely clumsy when data must be exchanged between two different programs. Besides with all this you still cannot use more than 64K of memory for any one program. So what is the alternative?

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The alternative is an address bus with more than the normal 16 bits found on eight-bit microprocessors. By using 20 address bits you can, for instance, address up to a million memory locations directly. This way you have access to any part of memory at any time without any intermediate processes. Program interaction is now no problem at all.

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ON THE COVER

This month's cover by Robert Tinney shows a rocket-like needle threading its way through granite cubes labeled: DOUBLE, DUPLICATE, and +. The threaded path of the needle is a representation of the process used in FORTH and other threaded languages to create a new word (here, DOUBLE) with previously defined words (here, DUPLICATE and +)

Other aspects of this fascinating language are described in the editorial, "Threads of a FORTH Tapestry," and in the theme articles for this issue.

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Threads of a FORTH Tapestry

Editor's Note: This month's editorial is by BYTE Editor Gregg Williams. Gregg was responsible for the preparation of this month's special section devoted to the FORTH language. Carl Helmers returns next month with an editorial... CM

What do a portable heart monitor, the new Craig Language Translator, a peach-sorting machine, and a movie called Battle Beyond the Stars have in common? The answer is FORTH, a not-so-new language as comfortable in industrial machinery as it is in a personal computer. In fact, it was originally used by its inventor, Charles H Moore, to control the telescope and equipment at the Kitt Peak Observatory.

Although I have known about FORTH for about a year, it was only during the preparation of this issue that I began to actively keep my ears open for mention of this unusual language. I have uncovered a lot of information (and some experience) about FORTH and its variations. The language is so unusual that no single line of thought could give you a picture of what the language is like. Instead, the following sections represent several threads from the rich tapestry called FORTH.

FORTH in the Real World

No language I know of is as comfortable in real-world situations as FORTH. Here are some examples of the breadth of applications that have been created using FORTH:

- Elicon Inc of Brea, California, is using FORTH software to drive the same kind of computer-controlled cameras that were used to film the sophisticated space-battle scenes in Star Wars. New World Productions of Venice, California, is using this camera system to film the spaceship sequences in the motion picture Battle Beyond the Stars. In a related development, Magicam Inc (which devised a number of the special effects for the recent movie Star Trek) is in the process of converting control of its master-slave camera pair from an analog computer to a digital computer running FORTH software. In the Magicam process, the master camera follows actors on a special blue stage while the computer guides the slave camera across a detailed model. Later, the two images are optically combined, producing the effect of the actors actually being in the landscape depicted on the model.

- Allen Test Products of Kalamazoo, Michigan, has developed an ignition analyzer for use in service stations and automobile repair shops that analyzes the behavior of automobile ignition systems and displays both diagnostic and corrective information. Formerly, the voltage waveform from a spark plug was displayed on an oscilloscope, after which a mechanic would attempt repairs based on his interpretation of the waveforms.

- Atari Inc is using FORTH in two of its divisions and is rumored to be contemplating other uses for the language. In its Coin-Operated Division,
"For reliable data storage, you can't beat Shugart's Minifloppy."™ Raymond Schlitzer, Owner—Computerland, San Francisco

"I sell systems my customers can depend on. That's why most of the personal and small business computer systems sold here feature Minifloppy disk drives. I know from experience I can rely on the Minifloppy."

Since 1976 Shugart's Minifloppy has been used by more small computer system manufacturers than any other drive. In fact, more than half-a-million Minifloppys have been installed. The Minifloppy looks small—but it stores a lot of data. 250 kilobytes on one side, or up to 500 kilobytes in the double-sided model. That's about 50 pages of printed information on a single-sided Minidiskette, and twice that on the double-sided version. You'll have plenty of storage capacity for your programs, letters, forms, or ledger entries. And you find your data fast, too, because the Minifloppy is a random access device that eliminates the need to search for your data serially as you must with a tape cassette unit.

No matter what problem you're solving with your computer system, you can rely on Shugart's Minifloppy for data storage. We're known as the Headstrong company for good reason. We're Headstrong about reliability, quality, and value. Ask your dealer. He knows us.

Rely on the Headstrong Company.

TM—Minifloppy is a trademark of Shugart Associates.
which develops and markets the stand-alone games found in pinball arcades and restaurants, a 6502-based development system employs FORTH software to debug and test arcade circuit boards. In addition, Atari has developed its own custom version of the language, called game-FORTH, that is awaiting its first use to replace machine code as the language used to create arcade games. Someday soon, you may play a coin-operated game without knowing that you are actually running a FORTH program.

In the Consumer Group of Atari, a version of FORTH that has been extended to allow manipulation of the video screen and game peripherals has been developed for the Atari 800 computer. Although no definite plans have been made, Atari may market it as an option for the Atari 800, or, like the Coin-Operated Division, use it in "transparent" mode to implement games and other programs.

- FORTH is used in a portable 1802-based computer that aids in the treatment of patients with infrequent heart flutter. The device, small enough to be worn comfortably by the patient during his or her daily activities, constantly updates a "snapshot" of the patient's heart activity every 7 seconds. In addition to recording this information in real time, the device analyzes the data for evidence of a heart murmur. When a murmur is detected, the device stores the data containing the evidence and signals the patient to return with the device to the doctor's office for analysis and diagnosis.
- In another medical application, FORTH is the sole language used in a computer at the Cedar-Sinai Medical Center in Los Angeles, California. Using FORTH, a Digital Equipment Corporation PDP-11/60 simultaneously performs, among others, the following tasks: manages 32 remote terminals; stores patient information from an optical reader into a large data base; runs a statistical package that analyzes the patient data base in search of trends in the physical makeup, treatment, and results of similar patients; and analyzes blood samples and heart behavior in real time while a patient is exercising on a treadmill machine. Spencer SooHoo, in the pulmonary medicine section, is also developing a portable 6800-based FORTH system to be used for monitoring intensive-care patients.
- A stripped-down version of FORTH was used to create the handheld Craig M100 Language Translator under time, size, and other design constraints. This same language also runs the software inside the translator unit. In a related product, a hand-held ASCII terminal manufactured by MSI Data Corporation of Costa Mesa, California, also uses FORTH internally.
- In what must be the most interesting FORTH application I have encountered, a central California fruit farming cooperative uses an 8080-based machine running FORTH to adaptively sort and grade peaches. Infrared sensors send information to the computer on the coloring and quality of pitted peach halves that pass the sensors on a conveyor belt. After analyzing this data, the FORTH program causes flippers to knock the peach halves into appropriately graded bins—extra fancy, fancy, etc. In addition, the program keeps track of the percentage of peaches in each bin and changes its selection criteria to maintain a certain fixed ratio among the various grades of peaches.
- Last but not least, FORTH is used in several aerospace applications. A FORTH-like language called IPS (running on an 1802-based system) is orbiting Earth in an amateur radio satellite called the OSCAR Phase III. Avco Inc is using another 1802-based system (again, for the small size and power consumption of the 1802 microprocessor) to monitor temperature and take care of ground-to-satellite and satellite-to-ground telemetry in a military satellite.

Who Should Try FORTH?

FORTH is an easy language: a high school student, Arnold Schaeffer, wrote an arcade-type game called BREAKFORTH. (See "Breakforth into FORTH," by A Richard Miller and Judy Miller, on page 150.)

FORTH is a difficult language: it easily beats APL as a "write-only language"; you can write a program in the language, but you can't easily read what you've written.

Given these two valid extremes, your initial reaction might be, "This doesn't make sense." True, learning
At Intersystems, “dump” is an instruction. Not a way of life.
(Or, when you’re ready for IEEE S-100, will your computer be ready for you?)

We’re about to be gadflies again. While everyone’s been busy trying to convince you that large buses housed in strong metal boxes will guarantee versatility and ward off obsolescence, we’ve been busy with something better. Solving the real problem with the first line of computer products built from the ground up to conform to the new IEEE S-100 Bus Standard. Offering you extra versatility in 8-bit applications today. And a full 16 bits tomorrow.

We call our new line Series II™. And even if you don’t need the full 24-bit address for up to 16 megabytes (!) of memory right now, there’s something to think about. Because of all the performance, flexibility and economy they offer. Whether you’re looking at a new mainframe, expanding your present one or upgrading your system with an eye to the future. (Series II boards are compatible with most existing S-100 systems and all IEEE S-100 Standard cards as other manufacturers get around to building them.)

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The best part is that all this heady stuff is available now! In our advanced processor—a full IEEE Bus Master featuring Memory Map™ addressing to a full megabyte. Our fast, flexible 16K Static RAM and 64K Dynamic RAM boards. An incredibly versatile and economical 2-serial, 4-parallel Multiple I/O board. 8-bit A/D-D/A converter. Our Double-Density High-Speed Disk Controller. And what is undoubtedly the most flexible front panel in the business. Everything you need for a complete IEEE S-100 system. Available separately, or all together in our new DPS-1 Mainframe!

Whatever your needs, why dump your money into obsolete products labelled “IEEE timing compatible” or other words people use to make up for a lack of product. See the future now, at your Intersystems dealer or call/write for our new catalog. We’ll tell you all about Series II and the new IEEE S-100 Bus we helped pioneer. Because it doesn’t make sense to buy yesterday’s products when tomorrow’s are already here.
FORTH takes some time; it's somewhat like learning a foreign language. So far, my experiences with FORTH remind me of my attempts at learning a smattering of Russian; both languages are so different from any I've seen before—French or Spanish, BASIC or FORTRAN—that I have to mentally shift gears to work in the new language.

You should give FORTH a try if you are excited by what you see here. Especially important in this respect are the articles, "What is FORTH? A Tutorial Introduction," by John James, and "A FORTH Glossary," pages 100 and 186, respectively. Your best bet is to get to a computer that can run a version of FORTH; or, better yet, get someone who knows the language to demonstrate it to you.

My first experience with FORTH was at the Fourth West Coast Computer Faire in May 1979. A member of the FORTH Interest Group was demonstrating the language using an Apple II and an Advent television screen. First, he defined a word called COUNT, like this:

```
: COUNT 0 DO 1. LOOP ;
```

Then he said `{ 6 COUNT }` (note: the braces are not part of the expression; see the accompanying text box), the computer replied with `{ 0 1 2 3 4 5 OK }`. I was instantly hooked on learning more about FORTH. What he had done closely paralleled the iota function in APL, and anything that even resembled APL was going to get my full attention.

If you are at all dissatisfied with the capabilities of your current computer, or if you feel that there should be more to computers than BASIC and assembly language, you should try FORTH. Once you get accustomed to its peculiar syntax, you can make it do nearly anything you want it to. In fact, you can even make it have features it did not previously have. Assembly language is like this to some extent, but FORTH is a higher-level language with the same abilities—only magnified. FORTH is what I call a "homebrew" language; its enthusiasts carry with themselves the same look-how-this-works enthusiasm as do most hardware hackers who build their own hardware. If we ever have a homebrew software issue, FORTH will certainly be included.

FORTH is the ultimate software hacker's language because, like a bag of components before a hardware hacker, you can do anything you want to with it. It can be argued that assembly language is the ultimate programming language; strictly speaking, this is true, but it takes so much more time to craft a piece of software in assembly language that it is practically ruled out in most cases.

However, this total freedom carries with it complete responsibility. Since, for example, the FORTH program you write is free to use an array subscript that is out of bounds, you must be responsible enough to either (a) put in error-checking routines (you can take them out later), or (b) build your program up from small tested modules to assure that your program will never execute an improper subscript. If you would rather have the language system do this kind of work for you, stick to BASIC or whatever you're running now.
Why not kill two birds with one stone?

If you have an Apple* and you want to interface it with parallel and serial devices, we have a board for you that will do both. It's the AIO™

Serial Interface.
The RS-232 standard assures maximum compatibility with a variety of serial devices. For example, with the AIO you can connect your Apple* to a video terminal to get 80 characters per line instead of 40, a modem to use time-sharing services, or a printer for hard copy. The serial interface is software programmable, features three handshaking lines, and includes a rotary switch to select from 7 standard baud rates. On-board firmware provides a powerful driver routine so you won’t need to write any software to utilize the interface.

Parallel Interface.
This interface can be used to connect your Apple* to a variety of parallel printers. The programmable I/O ports have enough lines to handle two printers simultaneously with handshaking control. The user manual includes a software listing for controlling parallel printers or, if you prefer, a parallel driver routine is available in firmware as an option. And printing is only one application for this general purpose parallel interface.

Two boards in one.
The AIO is the only board on the market that can interface the Apple to both serial and parallel devices. It can even do both at the same time. That's the kind of innovative design and solid value that's been going into SSM products since the beginning of personal computing.

The AIO comes complete with serial PROM's, serial and parallel cables, and complete documentation including software listings. See the AIO at your local computer store or contact us for more information.

SSM
2190 Paragon Drive
San Jose, California 95131
(408) 946-7400

Maybe we can save you a call.

Many people have called with the same questions about the AIO. We'll answer those and a few more here.

Q: Does the AIO have hardware handshaking?
A: Yes. The serial port accommodates 3 types—RTS, CTS, and DCD. The parallel port handles ACK, ACK, BSY, STB, and STB.

Q: What equipment can be used with the AIO?
A: A partial list of devices that have actually been tested with the AIO includes: IDS 440 Paper Tiger, Centronics 779, Qume Sprint 5, NEC Spinwriter, Comprint, Heathkit HM14, IDS 125, IDS 225, Hazelilne 1500, Lear Siegler ADM-3, DTC 300, AJ 841.

Q: Does the AIO work with Pascal?
A: Yes. The current AIO serial firmware works great with Pascal. If you want to run the parallel port, or both the serial and parallel ports with Pascal, order our "Pascal Patch disk".

Q: What kind of firmware option is available for the parallel interface?
A: Two PROM's that the user installs on the AIO card in place of the Serial Firmware PROM's provide: Variable margins, Variable page length, Variable indentations, and Auto-line feed on carriage return.

Q: How do I interface my new printer to my Apple using my AIO card?
A: Interconnection diagrams for many popular printers and other devices are contained in the AIO Manual. If your printer is not mentioned, please contact SSM's Technical Support Dept. and they will help you with the proper connections.

Q: I want to use my Apple as a dumb terminal with a modem on a timesharing service like The Source. Can I do that with the AIO?
A: Yes. A "Dumb Terminal Routine" is listed in the AIO Manual. It provides for full and half duplex, and also checks for presence of a carrier.

Q: What length cables are provided?
A: For the serial port, a 12 inch ribbon cable with a DB-25 socket on the user end is supplied. For the parallel port, a 72 inch ribbon cable with an unterminated user end is provided. Other cables are available on special volume orders.

The AIO is just one of several boards for the Apple that SSM will be introducing over the next year. We are also receptive to developing products to meet special OEM requirements. So please contact us if you have a need and there is nothing available to meet it.

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With Apple, Edison could’ve written a program to determine why some filaments burned longer than others.

With Apple, Edison had the first movie camera... and Apple has the DOS Tool Kit that takes you into the colorful world of animation.

With Apple, Edison could’ve written a program to determine why some filaments burned longer than others.

With Apple, Edison could’ve written a program to determine why some filaments burned longer than others.
Isaac Newton explained it over 300 years ago. Introductory physics students learn it less than three months into their first course. Yet now it seems to be treated as an argument over words, rather than principles, in BYTE's Letters column. I speak of the description of circular motion under the influence of gravity, and in particular of Delmer Hinrichs' recent contribution "Marsport Forces Resurface" (January 1980 BYTE, pages 16 and 17).

In the situation described, there is only one force acting: gravity, given by $GMm/r^2$. The other relation Hinrichs presents does not show how to calculate another kind of force, but is simply a statement of Newton's second law of motion, namely, if any net force acts on a body, an accelerated motion will be observed. For circular motion, the acceleration is equal to $v^2/r$, and the force giving rise to such motion, from whatever physical source, is called a centripetal force; i.e., a force toward the center of the circle, which is quite the opposite of Mr Hinrichs' "centrifugal" force (of which there is none in the situation under discussion). The physics here is thus simply to note that the gravitational force acts centripetally, and thus can be equated to $m$ times the acceleration, or $ma$.

It is unfortunate that many people have not yet realized that programming, once one is past the initial hurdles, is no longer a self-sufficient discipline, but must be viewed as a tool within the context of some other discipline in order to acquire real value. If the discipline is economics, for example, the programmer must be a reasonably accomplished economist if one is to trust his results; if the discipline is physics, then the physics must be understood thoroughly, and not just pulled out of some handbook; and so on...

5 Leslie Blatt
Professor of Physics
The Ohio State University
Van de Graaff Accelerator Laboratory
1302 Klinear Rd
Columbus OH 43212

More Marsport Commentary
In Delmer Hinrichs' second letter in the January 1980 BYTE, he continues to miss the point about the nature of forces in circular motion. (See "Marsport, Here I Come," April 1979 BYTE, page 84.) As he points out, the National Aeronautics and Space Administration (NASA) explains circular orbits in terms of centripetal force and gravitational force, while Mr Hinrichs says, "The attraction of gravity is exactly balanced by the centrifugal force at all times." This is not just a matter of "slightly different" terminology. As can be confirmed with a dictionary, a centripetal force is one directed toward the center of motion, but a centrifugal force is one directed away from the center of motion. Thus the terminology of Mr Hinrichs is in fact opposite that of NASA.

Perhaps the confusion results from the use of two names, centripetal and gravitational, which suggests the existence of two forces. However, gravita-
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An additional explanation for this central issue; i.e., directed toward the center (of Mars in this case). In other words, for circular orbits the gravitational force and the centripetal force are one and the same and cannot balance one another.

You might then wonder why two names and two formulas are used for the same force. The answer is that the two different formulas come from two separate types of analysis, one independent of motion, the other requiring motion. The formula for gravitational force, \( F_g = \frac{GMm}{r^2} \), comes from measurements of forces between two masses. The two masses might be orbiting each other, in contact, on a collision course, or moving apart. The gravitational-force formula works the same in all of these cases. On the other hand, the formula for centripetal force, \( F_c = \frac{mv^2}{r} \), comes from measurements of forces needed to keep a single mass moving in a circular path. These forces can be of any type. Examples include tension in a string, friction between a car's tires and the road surface, electricity, magnetism, and gravity. The centripetal force equation works the same in all of these cases. Notice that both of these formulas apply to circular orbits and can be set equal because the centripetal force is supplied by gravity.

As a high school physics teacher with a Master's degree in physics, I have discussed this subject with over a dozen physicists and hundreds of students. All of the physicists and most of the students would agree with what I have written here.

Robert Reiland
RR 1
Portersville PA 16051

A Message About the Reminder

My article in the January 1980 BYTE "A Computer-Generated Reminder Message" (page 160) has prompted several people to contact me, raising various questions related to the article.

The data conversion routines caused the most comment. They require a BASIC processor which maintains at least seven full decimal digits of precision; many do not. To determine if a given BASIC maintains seven digits of precision, enter "PRINT 9999999". If "9999999" is printed, the BASIC maintains sufficient precision. References for further study of data-processing algorithms may be found in the following articles:


Robertson, "Remark on Algorithm 396," Collected Algorithms from CACM.

Stone, "Tableless Date Conversion," Algorithm 199, CACM, volume 6, August, 1963.

The only known error in the January article appears on page 172. The reference to line 9500 should be deleted, since the line was deleted from the program listing.

Another area of questions concerned the conversion of the program to other disk BASICs. I have been asked about TSC BASIC, North Star BASIC, and other versions. The usual two areas of concern are the required seven digits of precision and disk input/output (I/O) methods. Without reference to specific implementations, Microsoft-like BASICS should prove the easiest to convert.

Other implementations which do not use FIELD statements are also convertible, though with some increase in difficulty.

Edgar M Pass
Computer Systems Consultants Inc
1454 Latta Ln NW
Conyers GA 30207

Here's a Good Book on Curve Fitting

In response to F R Ruckdeschel's appeal for a good, balanced reference book on curve fitting (Letters, March 1980 BYTE, page 161), I heartily recommend Applied Linear Statistical Models by John Neter and William Wasserman (Richard Irwin & Sons, 1974). This book features a unified approach to both simple and multiple cases of linear and polynomial regression techniques, and through the use of indicator variables, it also offers a regression approach to basic and multifactor analysis of variance.

It is a good book for both beginners and statisticians alike, since it starts out at an introductory level, introduces matrix theory early, and goes on to show how matrix operations (operations on two-dimensional arrays, which most computer languages can handle) can be applied to a large variety of statistical analyses.

After I had struggled for years in the seemingly muddy area of statistics, this book has been instrumental for me in
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**Beware of Handshakes**

If any BYTE readers are thinking about installing a dot-matrix printer in their microcomputer system, I have a friendly warning to pass on: pay close attention to your manufacturer's recommendations, or know the risk you're taking if you ignore them.

For example, North Star Computers, Inc recommends that owners connect the Anadex DP-8000 to the parallel interface of its Horizon computer. But comparing printer specifications, I chose to save a few bucks by building a Heath H-14 line printer for the Horizon's serial interface. I saved some money: the printer kit cost $625 plus shipping, plus an additional $82.98 at the Heathkit Electronic
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Figure 1.

Pass the Pi

Emory Sprenkle remarked in his letter (February 1980 BYTE, page 16) that 1/113 is a good rational approximation of π, and it is easily remembered. In fact, 355/113 is the best rational fraction approximation to π having no more than three digits in the numerator.

I was reminded of the following problem which appeared a few years ago in American Mathematical Monthly:

What is the smallest number of perfect 1-ohm resistors needed to create a network with an equivalent resistance of π ohms, ± 10⁻ⁿ ohms?

This problem leads one to discover how positive rational fractions may be presented as continued fractions. The solution shown in figure 1 includes three resistors in series with a network consisting of sixteen series-connected resistors in parallel with seven parallel-connected resistors, making twenty-six in all.

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I receive many personal-computer club newsletters. Some of the larger clubs around the country have put me on their mailing lists to keep me informed of what's going on in their area. One I recently received was significant because it demonstrated the tremendous advancements in personal computing in a very subtle way.

It was not the content of this newsletter that was important. It contained the usual new business, old business, and other information. The significant point was the preparation of the document itself.

According to an editorial, this publication has an editor/publisher and four columnists spread across the state. Each columnist prepares his textual material on his own personal computer, using a word-processing program. He then telephones the editor's computer and down-loads the text to it. The editor, using his computer, combines the four individual columns, along with his work, and lays out the complete newsletter. Finally, the editor telephones the print shop and transmits the entire newsletter for typesetting and printing.

The significant point is that all the communication is between computers and is conducted over the telephone lines.

Transmitting and receiving data using the telephone is not a difficult task if you have the correct equipment. Virtually any microcomputer can be configured for this activity. To communicate properly, the system must be a serial terminal or emulate one and be attached to the phone lines through a modem.

A "terminal" describes any equipment with hardware and software designed to facilitate serial data communication with prescribed data rates and protocol. My June 1980 article on the COMM-80 was such a hardware package. (See "I/O Expansion for the TRS-80" June 1980 BYTE, pages 42 thru 62.) With the COMM-80 attached and using the communication software provided, the TRS-80 computer emulates a terminal. Any other computer system calling itself a "terminal" and using the same data rates and protocol would be able to communicate with it. This includes all users of The Source and MicroNet timesharing services.

A modem is the device that allows the computer to be connected to a telephone.

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Photo 2: Comparison of two generations of modems. At right is an early model made by Anderson-Jacobson, shown with the covers open. The old modem uses discrete semiconductor components and toroidal inductors. On the left is an example of a current model of modem: a Novation Cat acoustic-coupled modem, which is popular with home-computer hobbyists.

Photo 3: First of a series of photos (3 thru 9) showing how you can easily construct an acoustic-coupler pickup. My design for the pickup uses such "exotic" materials as a hot-water pipe foam insulation, a pair of 2-inch, 8-ohm dynamic speakers, a foam-backed dinner placemat, rubber cement, and adhesive tape.

Step 1 of the process (shown here) is to cut a wedge-shaped piece from the insulating foam. The foam I used had an inside diameter of 1½ inches with a ½-inch wall, giving an outside diameter of about 2½ inches. The high side of the wedge should have a height of about 1 inch, the low side about ¾ inch.

Next, cut and trim a rectangular piece of foam measuring ¾ by ¾ by 3½ inches. This is used to help fit the speaker snugly into the hole in the wedge-shaped piece previously cut.

Solder the electrical connections to the speaker before proceeding to apply rubber cement to the rectangular foam piece and wrap it around the voice coil of the speaker. Hold it in place until the cement sets.

are not unlike those associated with the cassette data-storage system on a personal computer. Like the telephone, the cassette recorder is incompatible with digital data and has a very narrow bandwidth (a few thousand hertz). Since all personal computers accommodate cassette data storage, there is obviously a reasonable solution.

Rather than using digital voltage levels, as in a direct-wired communication link, audio-frequency tones are recorded instead. In most systems, one tone of a given frequency signifies a logic 0 and a tone of a different frequency signifies a logic 1. When we change or shift the tones to correspond with the logic input, we are performing frequency-shift-keyed (FSK) modulation. When we play back the tape into the computer, a demodulator distinguishes the tones and separates them back into 1s and 0s.

How Does a Modem Work?

Terminal-to-terminal communication is more complex than a simple cassette system even though it employs similar techniques. Transmission over the two-wire phone system from one terminal, called the originating terminal, to another, called the answering terminal, uses FSK tones. The major distinction is that terminals, unlike cassette recorders, can operate in full-duplex mode and communicate in both directions over the same pair of wires. Rather than using a single pair of tones, which would be confusing if both terminals tried to transmit at the same time, a modem uses two sets of tones.

One set of tones (1070 Hz and 1270 Hz) is used by the originating terminal and another (2025 Hz and 2225 Hz) is used by the answering terminal. If your computer were connected to a timesharing computer, your computer would be the originating system and all your data would be sent with FSK tones of 1070 Hz and 1270 Hz for logic 0 and 1, respectively. The timesharing computer would answer you with 2025 Hz (logic 0) and 2225 Hz (logic 1) FSK data.

Almost universally, if you are dialing up a large computer network, you are the originating terminal. An originate-only modem, which is all

Text continued on page 28
INTRODUCING
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The trouble with video terminals today is that most of the low-cost models just don’t have the performance to handle your tough applications. And the few that do are usually not compatible with your existing system. But now, Intertec has resolved this age old dilemma with the introduction of its new Emulator Video Terminal.

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*Quantity one - Dealer inquiries invited.
Figure 1a: Origin-\-ate-only demodulator section of the modem circuit, shown as a schematic diagram. This circuit features automatic muting and LED indication of carrier detection and will operate at data rates from 0 to 300 bps. The demodulator section is more complex than the modulator (shown in figure 1b) and consists of a preamplifier, a bandpass filter, and the phase-locked-loop demodulator.

Capacitors marked with asterisks (*) must be Mylar or polystyrene types. If RS-232C compatibility is not needed, the LM741 operational (op) amplifier shown as IC7 can be omitted from the circuit. If a crystal microphone is used, instead of the voice-coil speaker, the op amplifier IC1 might be unnecessary.

Components were chosen to operate from power supplies of +12 V and -12 V. The circuit can be made to work for supplies within the range of ±5 V to ±18 V; however, the resistor network associated with IC7 may have to be changed.
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NorthWord is the central building block for all the North Star application software to follow. Packages now being tested include other accounting and professional application packages. For more information or a demonstration, contact your local North Star dealer.

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Figure 1b: Modulator section of the modem circuit in schematic form. The tone frequency for a mark (1270 Hz) is set up by choosing the proper values for capacitor C2 and adjusting the 20 k-ohm potentiometer. When transistor Q2 gates capacitor C1 in parallel with C2, the oscillator frequency changes to 1070 Hz.

Capacitor C1 (0.0037 µF) may be formed from a parallel combination of two components, a 0.0015 µF and a 0.0022 µF part. For use in the answer mode, the proper value for capacitor C1 is 0.001 µF, and the value for C2 is 0.01 µF.

If RS-232C communication is not a necessity, transistor Q3 may be omitted from the circuit.

Text continued from page 24:

you need in this instance, has a 1070/1270 Hz modulator and a 2025/2225 Hz demodulator. On standard dial-up telephone lines the acceptable speed limit is 300 bits per second (bps). An answer modem is necessary when someone else calls you and chooses the originate frequencies for himself. In the answer mode, the modulator uses 2025/2225 Hz and the demodulator uses 1070/1270 Hz.

The choice is arbitrary: either modem can use originate mode or answer mode so long as they don’t both use the same mode. Owning an originate-only modem is not a handicap as long as someone trying to communicate with you can set his modem to the answer mode to accommodate you.

The modem attaches to the serial input/output (I/O) port on the computer. Most serial ports use the RS-232C protocol, and most commercial modems also use RS-232C. While there are various handshaking requirements listed in the complete RS-232 specification, for the most part handshaking is ignored in simple full-duplex modem applications. Usually the only signals required for operation, beyond the data itself, are Carrier Detect and Data Set Ready.

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national timesharing network or phone any of a hundred computer-information services on your personal computer is a significant milestone. When connected to these systems, you go beyond the hardware limits of the personal computer and instantly add large-computer capabilities. Figure 1 is the schematic diagram of a 0-to-300 bps originate modem which meets all the requirements for communicating with these systems. The prototype is shown in photo 1, mounted under the top cover of the COMM-80 serial/parallel interface.

There are two kinds of modems: direct-connect and acoustic-coupled. The former type requires attachment to the telephone wires through a data-coupler transformer. The latter type, the use of which has fewer legal strings attached, employs an acoustic coupler. This is nothing more than a speaker and microphone that sit under the mouthpiece and earpiece of the telephone handset. The speaker transmits the modem's output tones into the telephone, and the microphone listens for the other terminal's response.

Modems vary in complexity. Fifteen years ago they were very expensive and contained many discrete, precision components, including many toroidal inductors for the filter circuits. Photo 2 shows, on the right, an old Anderson-Jacobson modem. Newer technology is shown on the left: the Novation Cat, which is probably the most popular acoustic modem around. The reduction in size is accomplished through integrated-circuit technology.

Figure 2 is a block diagram of the modem circuit in figure 1. The design I am presenting takes advantage of advanced technology and uses only six integrated circuits for the complete modem. Two additional RS-232-converter devices can be added if RS-232 interfacing is required.

The modem is divided into two sections: modulator and demodulator. It also features carrier detection and automatic muting. A light emitting diode (LED) lights to signify that the answering modem is on the line and connected when the 2025 Hz tone (the "carrier") is detected on the line. A signal generated upon detection of the carrier automatically enables the modulator output (of the 1070 Hz tone) in response. Without this feature, the 1070 Hz tone would be blaring out of the speaker continuously.

The modulator section of figure 1b is not very difficult to understand. Tone decoder IC5 (an NE567 device)
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Circle 18 on Inquiry card.
Figure 3: The multiple-feedback, second-order bandpass filter: schematic diagram, response curve, and parameter-value calculation for given center-of-passband frequency.

is configured as a very stable current-controlled triangular-wave oscillator. The space frequency (1270 Hz) is determined by the setting of the 20 k-ohm 10-turn potentiometer and capacitor C2. In response to a logic 1 input (inverted from logic 0 by IC4c) transistor Q2 gates capacitor C1 in parallel with C2. The oscillator frequency will now be 1070 Hz. This 567 oscillator, while very stable, has a high-impedance output. One section of the CD4011 NAND gate (IC4d) is used as a high-impedance linear amplifier to match the output of IC5 to the 50 k-ohm impedance input of IC6, the LM386 amplifier. Also connected to pin 13 of the CD4011 is the carrier-detect signal, which mutes the tone output when no 2025 Hz carrier is being received.

The demodulator section of figure 1a is more complicated and accounts for the major expense in a modem. In an acoustic demodulator there are three basic sections: preamplifier, bandpass filter, and demodulator. Either a crystal microphone or a standard 8-ohm speaker (the latter of which is really about the same thing as a dynamic microphone) can be used with this circuit.

The output of the speaker/mike is amplified by IC1, an LM741. You may not need the gain provided by this circuit (22X) if you’re using a crystal mike. In that case you should eliminate IC1 and the 10 k-ohm and 220 k-ohm resistors, and feed the microphone output directly to the 6.2 k-ohm resistor leading to IC2. In either case, the signals acquired by the mike are sent through a sharp bandpass filter which passes only signals between 2000 Hz and 2250 Hz.

We use an MC1458 operational amplifier (IC2) to construct a multiple-feedback, second-order bandpass filter. IC2 is configured as two such elements, cascaded to improve response. The mathematical calculations behind component selection in this type of filter are outlined in figure 3. The objective is to pro-

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bandwidth</td>
<td>( B = \frac{2}{R_3 C} )</td>
</tr>
<tr>
<td>Gain</td>
<td>( G = -\frac{R_3}{2R_1} )</td>
</tr>
<tr>
<td>Q factor</td>
<td>( Q = \frac{f_0}{B} )</td>
</tr>
<tr>
<td>Center freq.</td>
<td>( \frac{w_0^2}{2} = \frac{1}{R_3 C^2 (1/R_1 + 1/R_2)} )</td>
</tr>
</tbody>
</table>

For: \( R_1 = 6.2\, \Omega \), \( R_2 = 810\, \Omega \), \( R_3 = 120\, \Omega \), \( C = 0.01\, \mu F \)

Calculated parameters:

- \( B = 265 \, \text{Hz} \)
- \( G = -9.7 \)
- \( Q = 8 \)
- \( f_0 = 2117 \, \text{Hz} \)

For an answer modem with \( f_0 = 1170 \, \text{Hz} \) use:

- \( R_1 = 11\, \Omega \)
- \( R_2 = 910\, \Omega \)
- \( R_3 = 220\, \Omega \)
- \( C = 0.001\, \mu F \)
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Figure 4: Block diagram of the XR2211 phase-locked loop component, which is IC3 in figure 1a. Appropriate component values for the two modem modes are shown.

The output of the filter is sent to IC3, which is an XR2211 monolithic phase-locked loop (PLL) especially designed for FSK data communication by Exar Integrated Systems. Figure 4 presents a block diagram of this device with pertinent external component selection.

A phase-locked loop is basically an electronic servo loop consisting of a phase detector, a low-pass filter, and a voltage-controlled oscillator (VCO). Its function is to synchronize its own oscillator to the incoming signal. If the incoming signal changes, the phase-detector output changes correspondingly to adjust the VCO to track the signal. In the XR2211, if the signal amplitude at the locked frequency is above a minimal value, the FSK comparator signifies this condition with a binary 1 output. The XR2211 can accommodate analog input signals between 2 mV and 3 V.

As shown in figure 1, the components are chosen for originate frequencies, and the XR2211 is powered by +12 V. (The specification says anything between +4.5 V and +20 V is acceptable, but +5 V is marginal in my experience.)

Alignment is simply a case of adjusting the 5 k-ohm potentiometer (R4). With a 2225 Hz signal applied to the microphone input, adjust R4 until pin 7 of IC3 goes low. Changing the input frequency to 2025 Hz
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should make this pin go high.

In addition to the FSK output on pin 7, there is a lock-detect output on pin 5, used to denote carrier detection. It is connected to one section of the CD4011. This circuit is a 1-second-on/2-second-off delayed-trigger monostable multivibrator (one-shot). Either tone (considered the carrier in this case) has to be present for at least 1 second to trigger the circuit into operation, allow data to flow from the modem to the terminal, and turn on the modulator amplifier.

IC7 and Q3 are added for RS-232C interfacing. If RS-232C communication is not a requirement, then these parts can be eliminated. Using the CD4011 (IC4b), the circuit can directly drive one low-power Schottky (LS) transistor-transistor logic (TTL) input load. A CD4049 inverting buffer or CD4050 buffer can be added to drive more input loads if necessary.

**Construction Hints**

We are dealing with high impedances and critical capacitances in this modem circuit. Layout should be compact, and Mylar or polystyrene capacitors should be used where indicated. Shielded cable should be used between the microphone and the modem board to reduce electrical-noise interference.

The acoustic coupler can be salvaged from an old modem, such as the Anderson-Jacobson unit.
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(bought on the surplus market for $20.00), purchased from the source I listed, or you can make one from readily available materials which cost virtually nothing.

Photos 3 thru 9 illustrate the construction of an acoustic coupler. Both the transmitter and receiver use a 2-inch Radio Shack 8-ohm speaker and such "exotic" materials as foam pipe insulation, a plastic placemat, needlepoint canvas, and rubber cement.

When you are through building the coupler, connect it to the modem circuit and dial your favorite timesharing system. When the telephone connection has been made and you hear the tone, place the handset into the coupler. The carrier-detect LED should light, and you'll be in business.

If you succeed in building the modem and use it to call The Source, send me a message describing your effort. My user-identification number is TCE317.

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Readers who wish to obtain the modem may order the following:

- a complete kit of integrated circuits and components as shown in figures 1a and 1b, a printed-circuit board, and directions for assembly—$39.95
- two commercially made rubber cushions designed to fit 2-inch speakers, for use in acoustic couplers and two 2-inch speakers—$12.95
- this modem is available combined with the COMM-80 serial/parallel interface (June Circuit Cellar) and called the "chatter box." Assembled and tested with software—$259.95

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Since the man calling is John Morell, the owner, he knows he can type in a special access code. He types in 999 on the Touch Tone phone. The computer on the other end of the line recognizes this sequence.

"Business status," the metallic voice answers. "Zones 1 thru 8 secure—no intruders. Zones 1 thru 8 report no fire alarms. Do you wish messages?"

Mr Morell types in 9, which stands for yes.

"You had three calls. Mr Morse called at 6:04 PM. Ms Morell called at 7:40 PM. Unidentified caller, phone 555-1501, called at 7:51 PM. Do you wish controls?"

Mr Morell types in another yes.

"Operation?" the computer asks. Mr Morell presses the buttons for the digits 0 and 2.

"Office lights on. Time to turn off?" the computer asks. Mr Morell presses the buttons 1, 0, 4, and 5, instructing the computer to turn the lights off at 10:45 that night.

"Another command?" Mr Morell types in a 6, which stands for no.

"Thank you. Good night," the computer voice says, then hangs up.

Is this another computer user's fantasy? (After all, we know that computers cannot do useful things like start coffee in the morning or water the lawn.) No, the above scene is entirely possible. In fact, I have seen a scaled-down demonstration similar to the above during a recent trip to Ohio Scientific to see its new CA-15 universal telephone interface (UTI).

**Description**

The CA-15 universal telephone interface (shown in photo 1) is a one-board peripheral device that will fit in any Model C8P, C2-8P, C2-OEM, or C3-series Ohio Scientific computer. The internal organization of the

---

Touch Tone is a registered trademark of the Bell Telephone System for its dual-tone, multiple-frequency signaling system.

---

Photo 1: The CA-15 universal telephone interface board, shown with its optional Votrax voice synthesis module.

Photo 2: Rear panel of an Ohio Scientific C8P computer, showing connections from the CA-15 universal telephone interface to outside components. The board connects to a CBT-type data coupler through the DB-15 connector (the small gold-colored connector in the center of the back panel). Other connections are made through the six phono jacks in the upper right-hand corner of the back panel. The jacks, listed in row order from left to right, are: cassette-recorder on/off control, phone-line monitor output, Votrax output (if used), cassette-player on/off control, cassette-player input, and auxiliary input.
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Circle 25 on inquiry card.
The CA-15 interface can:

- Initiate either Touch Tone or rotary pulse dialing of telephone numbers of any length.
- Use Touch Tone dialing to transmit numeric and control data.
- Sense a phone line ringing (on an incoming call) or a busy signal (on an outgoing call).
- Answer incoming calls and disconnect outgoing calls.
- Act as a 300 bits per second (bps) originate-answer modem.
- Play a prerecorded message from an external cassette player onto the phone line.
- Record a voice message onto an external cassette recorder.
- Place audio information (e.g., computer-generated music from a digital-to-analog converter) on the phone line from an auxiliary input device.
- Optionally, speak using a computer-controlled Votrax speech synthesizer.

The CA-15 interfaces to the outside world via seven output jacks, as shown in photo 2. The board connects to a dedicated (i.e., not used for any other purposes) telephone line through a CBT-type data coupler, which can be purchased from Ohio Scientific or rented from the telephone company. The data coupler is necessary to make a reliable, safe, and legal connection between a computer and the telephone line.

The universal telephone-interface board connects to the external data coupler through a DB-15 connector (the small gold connector in the center of the CBP rear panel shown in photo 2). The remaining six connections are made through the two rows of three jacks each in the upper right-hand corner of the computer's backplane. The jacks, listed in row order from left to right, are: cassette-recorder on/off control, phone-line-monitor output, Votrax output (if used), cassette-player on/off control, cassette-player input, and auxiliary input.

In keeping with Ohio Scientific's "hardware-first" orientation, the interface is controlled through examining and writing to (PEEKing and POKEing, in BASIC) certain memory locations. For example, to dial the three digits 6, 0, 3 (after initializing the interface board), we execute the BASIC instructions:

\[
\begin{align*}
\text{POKE} & \ 63494,189 \\
\text{POKE} & \ 63494,215 \\
\text{POKE} & \ 63494,190 \\
\end{align*}
\]

The documentation supplied with the CA-15 universal telephone interface includes complete instructions that detail manipulation of the interface through reading and writing the appropriate memory locations.

**Commentary**

Coupled to the security and home-control options available in the Ohio Scientific line of computers, the CA-15 universal telephone interface is the link that extends the influence of a computer beyond its immediate environment. This extended environment includes any point within reach of the existing telephone network. With the Ohio Scientific AC-12P wireless remote-control option, the CA-15 interface can control home appliances.
Imagine the new world that would unfold before you if you had a powerful, portable, completely integrated computer system at your personal disposal. And at an affordable price. That's exactly what Hewlett-Packard has just created.

THE HP-85: A PERSONAL COMPUTER FOR PROFESSIONALS.
At the lab, on your desk or in your study this 20-pound, self-contained system provides professional computing power when and where you need it. That means no more waiting for data to be remotely processed and returned.

A COMPLETE COMPUTER SYSTEM IN ONE SMALL PACKAGE:
You get all this in the HP-85:
Interactive graphics under keyboard control.
16K RAM Memory standard.
Standard typewriter keyboard with separate numeric key pad and eight user-definable special function keys.
High resolution CRT display with powerful editing capability.
Built-in thermal printer produces a hard copy of the display on command.
Built-in tape cartridge drive.
Each cartridge provides 217K bytes of storage capacity.
Operating system and BASIC language, permanently stored in ROM.

A SOPHISTICATED COMPUTER AT YOUR FINGERTIPS.
Hewlett-Packard has combined these sophisticated capabilities with advanced design to give you a system that is easy to use yet uncompromised in its power.

A key to this achievement is Hewlett-Packard's choice of BASIC for the HP-85's language. The HP-85 has more than 150 commands and statements to let you solve your problems swiftly and easily.

In addition, sixteen graphic commands have been added to the HP-85's extended BASIC to give you easy control of its amazingly versatile graphic capabilities.

DESIGNED FOR TODAY AND TOMORROW.
Whether you're in science, engineering, industry or business, the HP-85 you need today can easily be expanded or customized to meet your needs tomorrow.

You can double RAM capacity to 32K or expand ROM firmware to 80K with optional modules that plug right into the HP-85.
from any Touch Tone telephone. (A dial-type telephone can also be used if the person called has an external device that generates the standard Touch Tones.)

With the AC-17P home-security option, the CA-15 interface allows you to remotely determine whether intrusion, fire, or car alarms have been activated. And, with a sufficiently sophisticated BASIC program running, you can interconnect and control the security and wireless-control options from any telephone.

Other applications that come readily to mind are a sophisticated telephone-answering service (such as the scenario at the beginning of this review) and a standalone terminal, which can be used to call up computer bulletin boards, time-sharing services, and other remote devices.

The CA-15 universal telephone interface requires three power-supply voltages (+5 V, +12 V, and -9 V), while the popular model C4P computer (and its predecessor, the C2-4P) supply only +5 V. Other difficulties include the large number of input and output lines the interface requires and the limited number of slots in the C4P and C2-4P. Because of these problems, the interface cannot be used with the above two machines. However, I was told that an area of the CA-15 board has been left blank (see the bottom center of the interface board in photo 1) for a voltage-doubler circuit that would make its use feasible in the C4P and C2-4P. C4P or C2-4P owners interested in this option should express their interest to Eric Davis at Ohio Scientific, 1333 S Chillicothe Rd, Aurora OH 44202.

The CA-15 universal telephone interface is available through Ohio Scientific dealers for $499, or $799 with the Votrax voice module added. A Federal Communications Commission (FCC) approved CBT-type telephone line isolator is available for $199. Finally, a modified disk BASIC called Security BASIC is available for disk-based Ohio Scientific machines only. It is a modified Microsoft 9-digit-precision BASIC with extensions for the wireless remote-control, home-security, and telephone-interface options; these software extensions replace some of the PEEKs and POKEs otherwise used for device control with BASIC-like mnemonic commands. The Security-BASIC language system is available for $99.
The MODEL 800 MST is certainly pleasing to look at, but its true beauty lies beneath the surface. A glimpse at its features reveals why it is rapidly becoming the most sought after printer in the world.

- Four standard interfaces:
  - RS-232 (15 baud rates)
  - Centronics compatible parallel
  - IEEE-488
  - 20mA current loop
- Six line densities: 64, 72, 80, 96, 120, 132
- 100 CPS at all six densities
- Unidirectional or bidirectional printing
- Sixteen horizontal and ten vertical tabs
- Elongated characters in all six densities
- 1920 character buffer
- Uses either perforated or roll paper
- Fully adjustable tractors to 9½"
- Auto self-test

- Up to 10 character fonts
  - Standard 96 character ASCII
  - User defined character font
  - Provision for up to eight additional fonts
- Dot resolution graphics in six densities
- Variable line spacing control from 0 to 64 dots in half-dot increments
- Auto form-feed for any form length at any line spacing
- Heavy-duty all aluminum chassis
- 110vac or 220vac, 50/60Hz.
- 100 million character printhead
- Measures only 15" wide, 3" high, and 11" deep
- Weighs only 15 lbs.

but maybe its most attractive feature is the price . . . . $699.00.

A NEW MASTERPIECE IN PRINTERS
Mark Dahmke, 1515 Superior St, Apt 15, Lincoln NE 68521

The Heath H-89 is Heath Company's latest in their rapidly expanding line of desk-top computers. The H-89 has a number of unique hardware features, and the same excellent software support and documentation as the original H-8 8080-based system.

Heath Company is promoting the H-89 as the all-in-one computer, which it most certainly is. It is based on the Zilog Z80 microprocessor, which makes it upward-compatible with all H-8 8080 software. Not only is the computer based on the Z80, but the video display terminal and keyboard subsystem also contains a Z80.

The processor board Z80 runs at 2.048 MHz — slightly faster than an 8080 at 2 MHz, but not at the 4 MHz maximum possible with a Z80. Up to 48 K bytes of main memory may be plugged into sockets directly on the processor board, as well as up to six expansion cards on twenty-five pin connectors. The processor board also has single-step and full interrupt logic, a serial RS-232 port that connects to the terminal board, and sockets for three 2708 EPROMs (erasable programmable read-only memories).

The terminal board consists of a Z80, a 6845 video controller chip, two read-only memories, two 2112-2 programmable memory components, an S740 keyboard encoder circuit, and an 8250 UART (universal asynchronous receiver/transmitter) for RS-232 communications. The terminal has a 12-inch video screen that displays twenty-four lines of eighty 5-by-7 dot-matrix characters. The twenty-fifth line is accessible under software control for special applications. Lowercase descenders and thirty-three 8-by-10 dot graphics characters are also provided.

A full keyboard with repeat key (this repeats any key pressed), eight user-definable function keys (see table 1), and a separate numeric keypad are standard on the H-89.

The special function keys generally send out a series of characters such as ESC H for cursor home, ESC E for erase screen, and so on. Although Heath has its own set of escape functions, the terminal may be placed in the ANSI (American National Standards Institute) mode for a standardized set of the same functions. The numeric keypad actually has three possible modes: the unshifted numeric mode (normal), the keypad shifted mode, and the alternate keypad mode. Table 2 shows the keycodes for each mode. A complete list of escape sequences is shown in table 3.

The ESC r X sequence allows the user to set the data rate from 110 to 9600 bits per second. For example, ESC r C sets the data rate to 300 bits per second.

Another nice feature is the special twenty-fifth line of the screen. This line is separate from the other twenty-four and will not scroll with the rest of the screen. The line may be enabled by sending ESC x 1 from either the computer or the keyboard. After enabling the twenty-fifth line, the cursor must be positioned somewhere in the line before writing characters using the direct cursor addressing sequence: ESC Y (line number) (column number) where the line and column numbers are sent as two ASCII characters after the ESC Y. In this case, the line number is 25 + 31 (31 must be added to the actual line and column number values) which is equal to 56 or "8" in ASCII codes. The column number (1 to 80) may range from 32 (i.e. 1 + 31) to 111. To position the cursor...
MEMORY EXPANSION FOR TRS-80*
All you have to remember is to plug it in

Memory expansion. It's a field packed with intriguing theories. For instance, it has been suggested that the memory areas of the human brain are transferable from one body to another, like transplanted kidneys. In man or machine, a larger memory is always a welcome acquisition.

If you are interested in expanding your TRS-80 memory without shelling out dollars for a full blown expansion interface, we have just the solution.

Introducing the MT-32. Our new, brilliantly designed Printer/Memory expansion module for the TRS-80. This unit will add 16K or 32K of dynamic RAM to your basic 16K machine. The module also contains circuitry to drive Microtek's MT-80P dot matrix printer, or any other Centronics-compatible printer.

No hardware modification to your TRS-80 is required. Just plug into your bus connector and you are ready to go.

All Microtek products are covered by a one year warranty.

Four configurations are available:

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without RAM in kit form</td>
<td>MT-32K @ $79.50</td>
</tr>
<tr>
<td>Without RAM assembled and tested</td>
<td>MT-32A @ $99.50</td>
</tr>
<tr>
<td>With 16K RAM assembled and tested</td>
<td>MT-32B @ $159.50</td>
</tr>
<tr>
<td>With 32K RAM assembled and tested</td>
<td>MT-32C @ $199.50</td>
</tr>
</tbody>
</table>

Available from Microtek or your nearest computer dealer.

MICROTEK INC.
9514 Chesapeake Drive
San Diego, CA 92123
Tel. (714) 278-0633
TWX 910-335-1269

*TRS-80 is a Registered Trademark of Tandy Corp.
in column 1 of line 25, the following sequence would be entered via the keyboard or sent from the computer: ESC "Y" "8" ". If the sequence is sent from the keyboard, it is necessary to look up the character equivalents for each value (as above), but if the terminal is driven from a program in BASIC, the process is much simpler:

```
PRINT CHR$(27); "Y" ; CHR$(56); CHR$(32);
```

Note that the CHR$(27) causes the ASCII "ESCAPE" code to be sent; 56 and 32 are the line and column numbers, added to 31. The CHR$ function converts the decimal code number into the corresponding character.

### MTR-88 Monitor Program

The H-89 comes with a monitor program in programmable read-only memory that allows the user to operate at machine level or use the system without disk drives (or tape, for that matter). The MTR-88 cassette I/O functions are compatible with the cassette entry points in the PAM-8 front-panel monitor of the H-8, so software written for the H-8 will execute correctly on the H-89.

The monitor supports the following commands:

- **Boot** Load HDOS from disk.
- **Dump** Dump a program to cassette tape.
- **Go** Execute a program at the given address.
- **Load** Load a program from cassette tape.
- **Program Counter** Set the program counter address (prior to entering the Go command).
- **Substitute** Inspect or change memory locations.

The load and dump commands are set up to work with the H-88-5 cassette interface board. MTR-88 also maintains a tick counter in memory. The counter is a 2-byte field at memory addresses 040.033 and 040.034 (in split octal notation) that is incremented by 1 every 2 ms as long as interrupts are enabled. It is possible to assign interrupt vectors for special applications (as with all Heath software) by changing the addresses in the bottom 64 bytes of memory.

### HDOS Disk Operating System

HDOS (Heath Disk Operating System) is a comprehensive disk-management package. HDOS allows the user to create, manipulate, and display the contents of disk files and the disk directory. Other commands allow the user to display disk statistics (i.e., usage, remaining space, errors) and to set device options such as console/printer data rate, whether or not a back-space cursor function is available on the terminal in use, uppercase or upper/lowercase mode, tabs, console width, and so on. HDOS provides "device drivers," special subroutines which perform all necessary initialization and housekeeping functions for each peripheral interface — console, line printer, alternate console, and so on. The device drivers may be called by the user's program, saving the user the effort of writing device interface routines.
Plug the new Microsoft Z-80 SoftCard into your Apple II™ and start using all of the system and application software written for Z-80 based computers. Software that you could never use before on your Apple II.

The SoftCard actually contains a Z-80 processor and lets you switch between the Apple's 6502 and the Z-80 with simple commands, so you can use software written for either processor.

**Starting with Two Software Standards.** Versatile CP/M, the most widely used microcomputer operating system ever, is included on diskette in the SoftCard package, ready to run on your Apple II.

You get Microsoft's 5.0 BASIC too, the most powerful version to date of our famous BASIC interpreter. PRINT USING, 16-digit precision, CALL, and CHAIN and COMMON are just some of the major BASIC features you'll add. Applesoft's graphics extensions are still included.

**More Power Down the Line.** You can get even more programming power and versatility by adding Microsoft's FORTRAN, COBOL, BASIC Compiler and Assembly Language Development System. All are available separately to run with the SoftCard system.

And the whole host of CP/M-based business, scientific and educational applications can be easily transferred to your Apple with SoftCard.

The Microsoft Z-80 SoftCard is compatible with most every Apple product from the Apple II to the Apple II Plus, Language Card and peripherals. Independent peripherals for the Apple are supported as well. The SoftCard package requires a system with 48K and a disk drive.

Line up a SoftCard demonstration at your Microsoft Consumer Products dealer today. They'll be glad to show you how the Z-80 SoftCard and your Apple computer combine to form a system that can't be beat for either practicality or pure pleasure by any personal computer available today. Or give us a call, 206/454-1315, for more information.

But act quickly. At the low price of $349 for SoftCard, CP/M, Microsoft BASIC and complete documentation, you may have to stand in line to get one!

Apple II is a trademark of Apple Computer, Inc.
*CP/M is a registered trademark of Digital Research.
All devices on the H-89 have been assigned device names. Table 4 lists all devices. For example, to list a file on the printer, the command

\[
\text{COPY LP: = SYO: FNAME.EXT }
\]

is used, where LP: is the destination, and FNAME.EXT is the disk file on device SYO: to be listed.

**Table 3: H-89 escape sequences.**

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESC H</td>
<td>Cursor home</td>
</tr>
<tr>
<td>ESC C</td>
<td>Cursor forward (right)</td>
</tr>
<tr>
<td>ESC D</td>
<td>Cursor backward (left)</td>
</tr>
<tr>
<td>ESC B</td>
<td>Cursor down</td>
</tr>
<tr>
<td>ESC A</td>
<td>Cursor up</td>
</tr>
<tr>
<td>ESC I</td>
<td>Reverse index</td>
</tr>
<tr>
<td>ESC n</td>
<td>Cursor position report</td>
</tr>
<tr>
<td>ESC j</td>
<td>Save cursor position</td>
</tr>
<tr>
<td>ESC k</td>
<td>Set cursor to previously saved position</td>
</tr>
<tr>
<td>ESC Y</td>
<td>Direct cursor addressing</td>
</tr>
<tr>
<td>ESC E</td>
<td>Clear display (also shift erase)</td>
</tr>
<tr>
<td>ESC b</td>
<td>Erase beginning of display</td>
</tr>
<tr>
<td>ESC J</td>
<td>Erase to end of page</td>
</tr>
<tr>
<td>ESC I</td>
<td>Erase entire line</td>
</tr>
<tr>
<td>ESC o</td>
<td>Erase beginning of line</td>
</tr>
<tr>
<td>ESC K</td>
<td>Erase to end of line</td>
</tr>
<tr>
<td>ESC L</td>
<td>Insert line</td>
</tr>
<tr>
<td>ESC M</td>
<td>Delete line</td>
</tr>
<tr>
<td>ESC N</td>
<td>Delete character</td>
</tr>
<tr>
<td>ESC @</td>
<td>Enter insert character mode</td>
</tr>
<tr>
<td>ESC 0</td>
<td>Exit insert character mode</td>
</tr>
<tr>
<td>ESC z</td>
<td>Reset to power-up configuration</td>
</tr>
<tr>
<td>ESC r Bn</td>
<td>Modify data rate (Bn is a character to select data rates from 110 to 9600 bps.)</td>
</tr>
</tbody>
</table>
| ESC x Ps | Set mode: (select Ps from:)  
1 = Enable twenty-fifth line  
2 = No key click  
3 = Hold screen mode  
4 = Block cursor  
5 = Cursor off  
6 = Keypad shifted  
7 = Alternate keypad mode  
8 = Auto line feed on receipt of carriage return  
9 = Auto carriage return on receipt of line feed |
| ESC y Ps | Reset mode(s): (same as set modes listed above) |
| ESC < | Enter ANSI escape-sequence mode |
| ESC [ | Enter hold screen mode |
| ESC \ | Exit hold screen mode |
| ESC p | Enter reverse video mode |
| ESC q | Exit reverse video mode |
| ESC F | Enter graphics mode |
| ESC G | Exit graphics mode |
| ESC l | Enter keypad shifted mode |
| ESC u | Exit keypad shifted mode |
| ESC = | Enter alternate keypad mode |
| ESC > | Exit alternate keypad mode |
| ESC / | Keyboard disabled |
| ESC V | Keyboard enabled |
| ESC w | Wrap around at end of line |
| ESC d | Discard at end of line |
| ESC Z | Identity as DEC VT52 terminal |
| ESC } | Transmit twenty-fifth line |
| ESC # | Transmit page |

**Table 4: H-89 device assignments in HDOS.**

<table>
<thead>
<tr>
<th>Device</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYO:</td>
<td>System disk drive #0</td>
</tr>
<tr>
<td>SY1:</td>
<td>System disk drive #1 (optional)</td>
</tr>
<tr>
<td>TT:</td>
<td>Console device</td>
</tr>
<tr>
<td>AT:</td>
<td>Alternate terminal (optional)</td>
</tr>
<tr>
<td>LP:</td>
<td>Line printer</td>
</tr>
<tr>
<td>ND:</td>
<td>Null device (This eats up characters sent to it.)</td>
</tr>
</tbody>
</table>

The H-89, Heath’s all-in-one computer, has a number of unique hardware features and the same excellent software support and documentation as the original H-8 system.

The two directory-oriented devices are SYO: and SY1:.

On these devices (i.e., disks), the directory keeps track of what files exist and where they are. Each file can have an eight-character name with a three-character extension. The extension is useful when keeping track of a number of related files. For example:

- **MYPROG.ASM**
- **MYPROG.LST**
- **MYPROG.ABS**

Here the .ASM indicates that the first file is the assembler source of MYPROG entered via the text editor. The .LST file is the listing output of the assembler, and .ABS is the object code resulting from the assembler run.

**HDOS Utilities**

HDOS also comes with a number of useful utility programs:

- **PIP** (peripheral interchange program)  
  A generalized disk-file maintenance program.

- **ONECOPY**  
  A program that allows the user with only one disk drive to copy files from one disk to another.

- **SET**  
  A very useful program that allows the user to redefine device driver configurations. Table 5 lists all options of the SET command.

- **STAT**  
  Displays system performance, number of disk errors, etc.

- **FLAGS**  
  Sets disk-file flags to write-protect a file, to suppress normal listing and copying of a file, and (optionally) to lock the file against further flag changes.

**DBUG**

The Heath console debug program allows the user to enter and debug machine-language programs from the console. DBUG will perform the following functions:

- Display and alter contents of any memory location.
- Display and alter contents of any 8080 processor register.
- Single step through a program.
- Execute a program.
- Set breakpoints in a program.
- Load or dump user programs to or from a device (e.g., tape or disk).

Note that DBUG supports only the 8080 register set, not the extra registers in the Z80. Also, DBUG does not have a disassembler feature.
Once in a great while someone comes along with a simple improvement for an already great product. Take our SuperBrain, for example. Really a simple concept. A high-powered, low cost microcomputer packaged in an attractive desk top cabinet. So how do you improve on that?

**WE DID IT...**

It wasn’t enough that our SuperBrain had such standard features as twin double density 5 ¼” drives with over 300,000 bytes of disk storage. A full 32K of dynamic RAM - expandable to 64K in seconds. A CP/M Disk Operating System which assures compatibility to literally hundreds of application packages presently available. A crisp, 12” non-glare screen with a full 24 line by 80 column display. A full ASCII keyboard with a separate keypad and individual cursor control keys. Twin RS232C serial ports for fast and easy connection to a modem and/or a printer. And, dual 280 processors which operate at 4 MHZ to insure lightning-fast program execution. No, it wasn’t enough. So we made it better.

**ANNOUNCING SUPERBRAIN QD...**

Our new QD model has all of the features of our phenomenally popular SuperBrain with the addition of double-sided disk drives and an extra 32K of dynamic RAM. So, for only a modest increase in price, you can order your next SuperBrain with more than twice the disk and memory storage capability. But, best of all, the new QD model has the same tough, rugged construction and exceptional quality that made our SuperBrain such a success.

**HOW DID WE DO IT?**

The secret of SuperBrain QD’s incredible disk storage lies within our new double-density double-sided disk drives. A total of nearly 720,000 bytes of data are formatted on two specially designed 5 ¼” drives. And that’s more than enough to get you started with most serious small business applications. And SuperBrain QD’s standard 64K of dynamic RAM will handle even the most complicated programming tasks.

Of course, if you’re into megabytes instead of kilobytes, you may think neither SuperBrain is right for you. Not so! Intertec offers 20-96 megabytes of hard-disk storage which connects in seconds to either the SuperBrain or SuperBrain QD. So, your original investment is always protected. As you grow. No matter how much your needs expand.

**BUT IS IT RELIABLE?**

Our best salesmen are our present users. Not only have SuperBrain users been impressed with the inherent reliability of the system, they tell us that no other microcomputer system available today offers such a unique modular design concept. Just about the only tool required to easily maintain the system is a common screwdriver. And Intertec’s total commitment to product service and customer support, with service outlets in most major cities, insures your original investment will be a valuable one for many years to come.

**THE DECISION IS YOURS.**

Whether your next SuperBrain is a regular model or our QD version, you will have the satisfaction of knowing you purchased what is becoming one of the world’s most popular microcomputer systems. And regardless of which model you choose, you’ll probably never outgrow it because you can keep expanding it.

So, call or write us today for more information. Intertec systems are distributed worldwide and may be available in your area now.

Circle 31 on Inquiry card.

2300 Broad River Rd. Columbia, SC 29210
(803) 796-9100 TWX: 610-666-2115
The Text Editor
The Heath Text Editor is used to enter and edit assembly and BASIC programs, as well as to create and edit reports, letters, and manuscripts.

EDIT uses all available memory in the system as a text buffer. When the buffer is full, all or part of it may be transferred to a disk file. This allows the user to work on files in size up to the limit that will fit on disk. EDIT has a very unusual command format:

\(<-range> <verb> <qualifier string> <option> <parameters>\)

Range defines the buffer lines the command is to operate on. Characters to indicate certain lines are as follows:

1
$ + - 'string' 'string'

Defines the first line of the buffer.
 Defines the last line of the buffer.
 Followed by a decimal number, refers to the \(n\)th line past the current line pointer.
 Followed by a decimal number, refers to the \(n\)th line preceding the current line pointer.
 The first line in the buffer which contains the 'string' after the current line.
 The first line in the buffer which contains the 'string' preceding the current line pointer.

Multiple line ranges can be specified by using two of the above range expressions in sequence with a comma between them. A blank preceding a verb will cause the command to operate on the entire buffer. An equals sign reuses the range of the last command.

The verb specifies the action to be taken by the editor. Examples are: Print, Replace, Delete, Read, Write, Use, Search, Bye, and so on.

The qualifier string is a further restraint on the range expression and is optional. For example, it is possible to operate on only those lines that contain a phrase or string of characters. If the phrase is entered in single quotes in the qualifier string field, only those lines containing the specified string will be affected.

The option field determines if the current line is to be displayed before it has been modified, after it has been modified, or both. Use of this field is optional.

The parameter field is a special field used to direct disk I/O actions of the editor.

This is the most difficult editor I have ever tried to work with. Even after carefully reading the manual and spending a great deal of time learning how to use it, it is incredibly frustrating. The range and other fields are unconventional and require some getting used to. When writing programs in BASIC, it is far easier to use the line entry and edit commands in the BASIC interpreter. Trying to write assembler programs with this editor is nearly impossible.

Considering all the excellent software and hardware documentation and support of the H-89, and the powerful intelligent terminal features for full-screen editing, it...
Suddenly, S-100 microcomputer systems can easily handle 100 million bytes. Because Morrow Designs™ now offers the first 26 megabyte hard disk memory for S-100 systems—the DISCUS M26™ Hard Disk System.

It has 26 megabytes of useable memory (29 megabytes unformatted). And it's expandable to 104 megabytes.

The DISCUS M26™ system is delivered complete—a 26 megabyte hard disk drive, controller, cables and operating system—for just $4995. Up to three additional drives can be added, $4495 apiece.

The DISCUS M26™ system features the Shugart SA4008 Winchester-type sealed media hard disk drive, in a handsome metal cabinet with fan and power supply.

The single-board S-100 controller incorporates intelligence to supervise all data transfers, communicating with the CPU via three I/O ports (command, status, and data). The controller has the ability to generate interrupts at the completion of each command to increase system throughput. There is a 512 byte sector buffer on-board. And each sector can be individually write-protected for data base security.

The operating system furnished with DISCUS M26™ systems is the widely accepted CP/M® 2.0.

See the biggest, most cost-efficient memory ever introduced for S-100 systems, now at your local computer shop. If unavailable locally, write Morrow Designs™, 5221 Central Avenue, Richmond, CA 94804. Or call (415) 524-2101, weekdays 10-5 Pacific Time.

*CP/M is a trademark of Digital Research.


SET VER  prints the version number of the SET program.
SET HELP  gives information on the SET command.
SET TT: HELP  gives information on the SET command for a particular device; TT: in this case.

SET TT:

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOBKS</td>
<td>uses the back-slash character for errors.</td>
</tr>
<tr>
<td>BK5</td>
<td>allows back-spacing to correct typing errors.</td>
</tr>
<tr>
<td>BKM</td>
<td>causes back-space (control-H) to be treated as a delete.</td>
</tr>
<tr>
<td>NOBKM</td>
<td>lets HDOS receive the back-space character.</td>
</tr>
<tr>
<td>MUL</td>
<td>maps lowercase input to uppercase.</td>
</tr>
<tr>
<td>NOMLI</td>
<td>allows lowercase output from HDOS.</td>
</tr>
<tr>
<td>NOTAB</td>
<td>HDOS expands TAB (control-H).</td>
</tr>
<tr>
<td>TAB</td>
<td>sets terminal expand TABs (faster).</td>
</tr>
<tr>
<td>2SB</td>
<td>uses 2 stop bits (universal).</td>
</tr>
<tr>
<td>1SB</td>
<td>uses 1 stop bit (normal).</td>
</tr>
<tr>
<td>WIDTH n</td>
<td>sets console width to n characters, 80 is default.</td>
</tr>
<tr>
<td>FILL c n</td>
<td>sets c as a character that needs n fill characters following it; for slow hardcopy terminals.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SET LP:</th>
</tr>
</thead>
<tbody>
<tr>
<td>GLPI</td>
</tr>
<tr>
<td>BLP1</td>
</tr>
<tr>
<td>PAGE n</td>
</tr>
<tr>
<td>PORT n</td>
</tr>
<tr>
<td>WIDTH m,n</td>
</tr>
<tr>
<td>BAUD n</td>
</tr>
<tr>
<td>SET AT:</td>
</tr>
<tr>
<td>SET SY:</td>
</tr>
<tr>
<td>STEP n</td>
</tr>
</tbody>
</table>

| REPAIR "fname" | replaces "fname" with current program, if it exists; works like SAVE if the file doesn't exist. |
| CNTRL iexp1,iexp2 | CNTRL 0 sets a GOSUB to line iexp2 when a CTL-B is typed. |
|                  | CNTRL 1 sets iexp2 digits before exponential format is used. |
|                  | CNTRL 2 controls the H-B front panel. |
|                  | CNTRL 3 sets the width of a print zone to iexp2 columns. |
| FREEZE "fname"  | saves BASIC interpreter, current program, and data values on the file "fname". |
| UNFREEZE "fname"| reloads the file saved with a FREEZE command. |
| LOCK             | protects the program by preventing execution of BUILD, BYE, CHAIN, UNFREEZE, DELETE, RUN, SCRATCH, and CLEAR commands. |
| UNLOCK           | reverses a LOCK command. |
| UNSAVE "fname"   | deletes the file "fname" from disk. |

Table 5: SET command options.

Table 6: Extended Benton Harbor BASIC commands not found in other versions of BASIC.

The Assembler

The Heath Assembler is a very straightforward, absolute 8080 assembler (not 280) with most of the standard assembler directives (ie: DB, DS, DW, END, EQU, ORG, SET, TITLE). The XTEXT directive is used to include whole disk files of assembler text into a program. This is convenient if there are some standard symbols or memory addresses that are to be incorporated into every assembler program, such as HDOS definitions. Also, useful subroutines may be included in this way. This feature may be used as a macro-instruction library facility, because the assembler does not allow macro-

Printers

<table>
<thead>
<tr>
<th>Printers</th>
<th>Wholesale</th>
<th>Printers</th>
</tr>
</thead>
<tbody>
<tr>
<td>IDS PAPER TIGER</td>
<td>$950.00</td>
<td></td>
</tr>
<tr>
<td>OLIVETTI PR 240</td>
<td>$950.00</td>
<td>$2.25/ea</td>
</tr>
<tr>
<td>CENTRONICS 704</td>
<td>1900.00</td>
<td>28.50/6</td>
</tr>
<tr>
<td>NEC SPINWRITER (RO) Serial</td>
<td>2900.00</td>
<td></td>
</tr>
<tr>
<td>SIEMENS INK JET</td>
<td>3700.00</td>
<td></td>
</tr>
<tr>
<td>(Call for Parallel prices)</td>
<td>3500.00</td>
<td></td>
</tr>
<tr>
<td>SPECIALS:</td>
<td>$150.00</td>
<td>$185.00</td>
</tr>
<tr>
<td>CENTRONICS 779 Uppercase/Lowercase</td>
<td>$3700.00</td>
<td>$27.50/10</td>
</tr>
<tr>
<td>CAT MODEM Orig &amp; Answer RS232C</td>
<td>$165.00</td>
<td>8&quot; $28.50/10</td>
</tr>
<tr>
<td>MEMOREX Soft Sector</td>
<td>5&quot; $27.50/10</td>
<td></td>
</tr>
<tr>
<td>DISK HEAD CLEANING KIT</td>
<td>$24.00</td>
<td>$24.00</td>
</tr>
<tr>
<td>5&quot; or 8&quot;</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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---

### Microsoft BASIC

Microsoft BASIC is widely used and is very standardized. I will not spend time describing its features.

The Heath implementation of Microsoft BASIC does have one significant fault; when a program is loaded from disk, the disk read head is raised and lowered for each and every sector of the file. This produces an annoying banging sound that seems to go on forever. It is also bad for the drive mechanism and will contribute to the wear and tear of the unit.

**Conclusions**

The H-89 has flexibility and does not require the user to understand anything about the hardware to take full advantage of all the features. One important point remains: after all the HDOS operating system utilities are put on a single 5-inch floppy disk, there is very little room for any large user programs. To make the system really useful, a second disk drive is a necessity. If the H-89 were to be used in a business with a really large data base, the data would be a tight fit even with two drives.
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The Hard-Disk Explosion
High-Powered Mass Storage for Your Personal Computer

Tom Manuel
1208 Apollo Way, Suite 502
Sunnyvale CA 94086

High-performance, high-quality, and large-capacity hard-disk drives are now a low-cost reality for your personal-computer system. Most hard disks use Winchester media, head technology, and other modern techniques to achieve high density and high performance in a small space. One side effect is low power consumption. Some of the drives suitable for personal computers use the older 14-inch standard diameter platters. Many new drives use one of two new small sizes—200 mm (7.87 inch) or 210 mm (8.27 inch) diameter—and one new drive uses 130 mm (5.12 inch) platters. Even so, their data capacities are significantly larger than floppy-disk drives of the same approximate size.

The latest disk drives can be divided into two general categories:

- low-cost, relatively low-performance drives that will eventually replace floppy-disk drives, especially where multiple drives would normally be necessary to obtain enough storage. For example, instead of adding more floppy drives to increase the storage capacity of a system, one set of dual floppy-disk drives might be replaced with an 8-inch hard-disk drive that fits in the same space. This improves the storage capacity and system performance dramatically. These low-end disk products will compete on a cost-per-drive basis.

- high-capacity, top-performance drives that must compete on a cost-per-byte basis. The 8-inch or smaller versions will likely (at least at first) be more costly per byte than the 14-inch models. However, their advantages of small size, light weight, low noise, and low power requirements make them very attractive for desktop and personal computers as well as small business systems.

The Winchester disk-drive technology developed by IBM provided expensive, large-capacity, high-performance, and low cost-per-byte disk subsystems (ie: the IBM 3350 and 3370 disk-drive systems) for large, expensive computer systems. This technology and development in other areas of disk-drive performance are now being applied to the development of products suitable for smaller systems. The tremendous growth of microcomputers has created a de-
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mand for small, compact disk drives. The industry has responded and is beginning to produce them. A Winchester disk drive for your personal computer is now, or soon will be, a possibility. However, it may still cost you five to ten times the price of your processor to get a complete small hard-disk subsystem with drive, controller, interface, power supply, and packaging.

What Is Winchester Technology?
Three disk technologies have evolved, all pioneered by IBM. Other manufacturers have refined the designs. These technologies are usually referred to by the model numbers of the original IBM product employing the technology: "2314" technology (in the 1960s), "3330" technology (late 1960s, early 1970s), and "Winchester" technology (1973).

Disk storage, being a special type of add-on memory, can directly affect a computer system’s performance, throughput, and reliability. Because of this crucial role, the principal design objectives for disks are large capacity, fast access time, absolute reliability, and low cost.

Each of the three advances has brought a significant increase in storage density. One way to increase density is to reduce the flying height of the heads over the disk surface. Each reduction in height allows an increase in tpi (tracks per inch) and bpi (bits per inch) (see figure 1). Advances in head design and positioning mechanisms have also contributed to increases in tpi and bpi.

Head flying heights have evolved as shown in table 1.

Just prior to 1973, disk-drive technology approached some limits. The flying height had been reduced to 31 microinches. Without further reduction, significant improvement in data density was difficult. At lower flying heights, a single smoke particle, whose diameter may be up to ten times the distance between the head and disk surface, can damage the disk and data. Therefore, cleaner conditions were required. Also, the disk platters and magnetic surfaces were inadequate for large increases in track and bit densities.

The 3340 Winchester disk drive, introduced by IBM in 1973, was the first breakthrough. Storage Technology Corporation announced a similar disk drive around the same time: the STC 8800 superdisk.

Winchester Characteristics
Winchester disk drives have the following characteristics:

- sealed disk, head, and positioning assemblies
- new trimaran head design—two outriggers supporting a narrower inner hull containing the read/write head (see photo 2)
- thinner magnetic coating: 44 microinches versus 185 microinches in the 2314 disk drive
- lubricated disk surfaces
- heads resting on disk surface when drive is stopped—they take off and fly low when motion starts (normal take-off and landing are done on an area reserved for that purpose)
- light loading force (10 g) and lighter heads.

These characteristics permit many performance improvements: very low flying heights (19 to 20 microinches), improved reliability, and a dramatic reduction in head crashes are possible because of the clean environment, new head and loading designs, and lubrication. Data densities are increased because of lower flying height and thinner platter coating. The higher densities improve throughput performance directly. More bits per inch allow more data to pass under the heads per unit time. More tracks per inch mean that track-to-track access times are shorter. The lighter heads and head mounts have less inertia and can be positioned faster. Throughput performance can be improved by increasing the rotational speed, up to a point—the aerodynamic characteristics of the flying head put some constraints on the rotational speed. The reliability of the Winchester drives surpassed that of any moving-head disk drive that was previously available.

Improvements and refinements have continued from many manufacturers. The costs of many of the most expensive elements in a disk (the motor, head actuator, and control electronics) are relatively independent of the capacity of the disk platters. It is, therefore, cost-effective to increase the density of the platters and the number of platters. The incentive has been to add capacity by any conceivable means, and trends have been toward more platters per spindle and greater bpi and tpi densities (data density has gone from about 1000 bpi on early 2314s to over 8600 bpi on some of the recent disks, and tpi density has gone from 200 tpi on 2314s to over 600 tpi on new products). Cost effectiveness has also been enhanced by reducing the access time and increasing the data flow; the economic payoff is increased throughput and efficiency of the total
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The new Industrial Micro Systems Model 16 Hard Disk Subsystem is a "fixed-removable" high speed, bulk storage device providing from 32 megabytes (32 million characters) to 96 megabytes of on-line storage for the Industrial Micro Systems 8000 or Series 5000 microcomputer systems. The Model 16 includes a credenza enclosure that provides a quiet, strong and attractive package for office or industrial applications where large memory is required. The Model 16 also includes a fully buffered DMA S-100 bus controller for fast and easy interfacing.

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system. In applications where disk storage is a key element, the processor is often disk-I/O-bound. Program execution speed depends on disk speed. Every increase in throughput will improve the total performance.

Other improvements in throughput performance in disk subsystems have come from RPS (rotational position sensing), which frees the disk controller and I/O (input/output) channel for other work during seek time (head actuator movement) and during part of the rotational delay time. Improvements have also included new automatic error detection, correction, and recovery capabilities built into disk controllers.

Voice-coil actuators, described in the next section, are common on high-performance disk drives. There are both linear and rotary voice-coil positioners. Rotary voice coils typically take up less space, require less power, and generate less heat than linear voice coils. Stepper motors with band actuators are usually used in lower-performance, lower-cost disk drives. Many of the new small drives use brushless DC (direct current) motors with direct drive on the platters. Designed as part of the spindles, these motors are compact (about 1 inch high), maintain speed more accurately, use less power, and require simpler power supplies than AC (alternating current) motors with belt drives. In many drives, each recording surface is split into inner and outer bands with a head for each band, reducing the average access time by one-half, because twice the amount of data can be read or written without moving the heads.

Comparing the New Hard Disks to Floppy-Disk Drives

The current trends toward multi-terminal systems, real-time transaction-oriented systems, small business systems, and more powerful personal computers for a great variety of applications have created a demand for more on-line data storage. Floppy-disk drives and tape cassettes often do not have the required performance (access times, throughput, etc), reliability, or capacities. Thus, the need for secondary storage is being filled by new, inexpensive, high-performance, highly reliable small-disk drives with capacities, speeds, and reliability close to the very expensive drives. These new drives are physically much smaller and more reliable than 14-inch cartridge or disk-pack drives. They are aimed initially at a gap between floppy drives and 14-inch drives (eg: Winchester, 5440 cartridges and 3330 type packs). They are designed for use on small business systems, distributed-processing systems, word-processing systems, and advanced personal computer systems.

The new drives offer a lower cost per unit than 14-inch drives, and lower cost per byte than floppy-disk drives. They provide the advantages in capacity and performance of hard disks in a package the same size as an

---

Photo 4: BASF Systems' 6170 Series 8-inch, fixed hard-disk drive, available in 8- and 24-megabyte versions. (Photo courtesy of BASF.)

Photo 5: Priam 14-inch (at left) and 8-inch Winchester hard-disk drives. (Photo courtesy of Priam.)

Photo 6: Kennedy Series 7000 8-inch hard-disk drive. (Photo courtesy of Kennedy Company.)
UniFLEX is the first full capability multi-user operating system available for microprocessors. Designed for the 6809 and 68000, it offers its users a very friendly computing environment. After a user 'logs-in' with his user name and password, any of the system programs may be run at will. One user may run the text editor while another runs BASIC and still another runs the C compiler. Each user operates in his own system environment, unaware of other user activity. The total number of users is only restricted by the resources and efficiency of the hardware in use.

The design of UniFLEX, with its hierarchical file system and device independent I/O, allows the creation of a variety of complex support programs. There is currently a wide variety of software available and under development. Included in this list is a Text Processing System for word processing functions, BASIC interpreter and precompiler for general programming and educational use, native C and Pascal compilers for more advanced programming, sort/merge for business applications, and a variety of debug packages. The standard system includes a text editor, assembler, and about forty utility programs. UniFLEX for 6809 is sold with a single CPU license and one years maintenance for $450.00. Additional yearly maintenance is available for $100.00. OEM licenses are also available.

UniFLEX is offered for the advanced microprocessor systems. FLEX, the industry standard for 6800 and 6809 systems, is offered for smaller, single user systems. A full line of FLEX support software and OEM licenses are also available.

UniFLEX is a true multi-tasking operating system. Not only may several users run different programs, but one user may run several programs at a time. For example, a compilation of one file could be initiated while simultaneously making changes to another file using the text editor. New tasks are generated in the system by the 'fork' operation. Tasks may be run in the background or 'locked' in main memory to assist critical response times. Inter-task communication is also supported through the 'pipe' mechanism.
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Figure 1: Detail of hard-disk surface, illustrating the ideas of tpi and bpi.

<table>
<thead>
<tr>
<th>Head flying height (in microinches)</th>
<th>2314</th>
<th>3330</th>
<th>Winchester</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 to 120</td>
<td>19 to 20</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Evolution of head flying heights in hard-disk drives.

<table>
<thead>
<tr>
<th>Floppy-Disk Drives</th>
<th>Hard-Disk Drives, Cartridges and Disk Packs</th>
</tr>
</thead>
<tbody>
<tr>
<td>8-inch, 5-inch</td>
<td>14-inch, 8-inch, and 5-inch</td>
</tr>
<tr>
<td>Capacity 100 K bytes to 1 megabyte</td>
<td>2 megabytes to 300+ megabytes</td>
</tr>
<tr>
<td>Average Access Time 0.1 to 1 second</td>
<td>25 to 70 ms</td>
</tr>
<tr>
<td>Rotational Speed 300 rpm</td>
<td>2400 to 4700 rpm</td>
</tr>
<tr>
<td>Reliability and Useful Life Relative to Floppy-Disk Drives</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>2+</td>
</tr>
</tbody>
</table>

Table 2: Technical comparisons between floppy-disk drives and hard-disk drives, cartridges, and disk packs.

The availability of low-cost-performance hard disks has long been awaited by the small system marketplace. The wait is all but over. This summer a score of products are scheduled to be available, at least in sample or evaluation quantities.

Though many of the new small disk products are advertised as fitting the same 4.6 by 8.5-inch opening as the standard floppy-disk drive (Shugart Technology's 5-inch Micro Winchester fits a 5-inch floppy-drive opening, see photo 3), a floppy-disk drive cannot literally be pulled out and replaced by the hard drive. To begin with, the packages contain different electronics. Most of the drives...
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GRAPHICS DIVISION OF Bausch & Lomb

*U.S. suggested retail prices only.
**DMP 2, 3 and 4 UL listed.
DMP 5, 6 and 7 UL listing pending.
Table 3: Specifications and characteristics of low-end, 5-inch and 8-inch hard-disk drives.

<table>
<thead>
<tr>
<th>Model</th>
<th>Memorex Corporation</th>
<th>New World Computer Co Inc</th>
<th>Shugart Associates</th>
<th>Shugart Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Santa Clara CA</td>
<td>Costa Mesa CA</td>
<td>Sunnyvale CA</td>
<td>Scotts Valley CA</td>
</tr>
<tr>
<td>Model</td>
<td>101</td>
<td>211</td>
<td>SA1002/SA1004</td>
<td>ST506</td>
</tr>
<tr>
<td>Capacity</td>
<td>17.72</td>
<td>2.1</td>
<td>5.33/10.67</td>
<td>6.38</td>
</tr>
<tr>
<td>Platter Size</td>
<td>200 (7.87)</td>
<td>8 inch</td>
<td>200 (7.87)</td>
<td>130 (5.12)</td>
</tr>
<tr>
<td>Number of Platters</td>
<td>2</td>
<td>1</td>
<td>1 or 2</td>
<td>2</td>
</tr>
<tr>
<td>Average Access Time</td>
<td>70 ms</td>
<td>18.825 ms</td>
<td>70 ms</td>
<td>170 ms</td>
</tr>
<tr>
<td>Maximum Data Transfer Rate</td>
<td>—</td>
<td>756</td>
<td>543</td>
<td>625</td>
</tr>
<tr>
<td>Average Latency</td>
<td>10.1 ms</td>
<td>8.825 ms</td>
<td>9.6 ms</td>
<td>8.3 ms</td>
</tr>
<tr>
<td>Rotational Speed</td>
<td>2964 rpm</td>
<td>3600 rpm</td>
<td>3125 rpm</td>
<td>3600 rpm</td>
</tr>
<tr>
<td>Motor Type</td>
<td>DC</td>
<td>—</td>
<td>AC brushless DC</td>
<td></td>
</tr>
<tr>
<td>Spindle Drive</td>
<td>direct drive</td>
<td>belt drive</td>
<td>direct drive</td>
<td></td>
</tr>
<tr>
<td>Actuator Type</td>
<td>high speed band</td>
<td>simplified band</td>
<td>band</td>
<td></td>
</tr>
<tr>
<td>Positioning Mechanism</td>
<td>open loop stepper motor</td>
<td>stepper motor</td>
<td>stepper motor</td>
<td>open loop stepper motor</td>
</tr>
<tr>
<td>Density bpi</td>
<td>6100</td>
<td>8000</td>
<td>6270</td>
<td>7690</td>
</tr>
<tr>
<td>Density tpi</td>
<td>195</td>
<td>100</td>
<td>172</td>
<td>254</td>
</tr>
<tr>
<td>Physical Size (inches)</td>
<td>4.38 by 8.55 by 14</td>
<td>2 by 9.5 by 9.5</td>
<td>4.62 by 8.55 by 14.25</td>
<td>3.25 by 5.75 by 8</td>
</tr>
<tr>
<td>Weight (pounds)</td>
<td>10</td>
<td>8</td>
<td>17</td>
<td>3.5</td>
</tr>
<tr>
<td>Single Quantity Price</td>
<td>—</td>
<td>$4,500</td>
<td>$1,600/$1,980</td>
<td>$1,500</td>
</tr>
<tr>
<td>OEM Discount Price</td>
<td>$1,200'</td>
<td>$1,250</td>
<td>$1,140/$1,400</td>
<td>$925</td>
</tr>
<tr>
<td>Cost Per Thousand Bytes (OEM Discount)</td>
<td>$1.103</td>
<td>$3.595</td>
<td>$2.14/1.31</td>
<td>$1.145</td>
</tr>
<tr>
<td>Comments</td>
<td>Includes a data separator</td>
<td>20 heads, 8 tracks per head. Low-end only in capacity, not in performance.</td>
<td>First micro Winchester Drive. Fits 5-inch floppy space</td>
<td></td>
</tr>
</tbody>
</table>

have the basic drive electronics, signal amplifiers, read/write electronics, and motor and servo control circuitry integrated into the package. Some have room to add optional, separately priced controllers to do error-checking and correction, data formatting, and interfacing to the computers.

Stepper-motor actuators are a technique borrowed from floppy drives for use in hard-disk drives. This idea allowed lower prices for Winchester-technology units such as the 14-inch Shugart SA4000 and Century Data Systems Marksman, but at a cost of greater access time and reduced storage capacities when compared with voice-coil actuator-based units.

A voice-coil actuator is a cylindrical, permanent magnet with a hole machined from pole to pole. A coil rides on bearings within the magnet and moves back and forth. The read/write positioning mechanism with electromagnetic heads is attached to the coil. A voice-coil actuator is positioned by servo-control with servo tracks written on one platter's surface at the factory.

Voice-coil actuators allow increases in data-storage capacity because their accuracy in small movements allows high tpi densities. Since the distance between tracks is smaller, access time is reduced. Also, voice-coil actuators do not impose the additional penalty of settling time.

One disadvantage of a voice-coil actuator is the magnetic field produced by the coil: the coil's magnetic field must not get too close to the disk platters or it could erase them. Efficient design can keep the magnetic field intensity at a safe level near the recording surfaces. Table 2 gives a partial technical comparison between floppy-disk drives and hard disks.

**Future Technological Progress**

Some of the more recent developments in heads (such as thin film heads) and disks (thin-film-plated disks) mean that data densities will probably advance from the presently attainable 8 to 10 megabytes per 8-inch surface to 50 or more megabytes per surface as track densities of 1000 tpi and bit densities of 10,000 bpi are achieved. A small, relatively inexpensive disk drive could then store 100 megabytes or more of data with an additional 100 megabytes added for nominal cost. Thin-film
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technology may be the next breakthrough in mass-storage techniques. Secondary storage and storage backup are currently being supplied by a wide variety of devices, including:

- cassette tapes
- 8-inch floppy-disk drives
- 5-inch floppy-disk drives
- reel-to-reel magnetic tapes
- cartridge magnetic tapes
- cartridge-disk drives
- disk-pack drives
- fixed storage Winchester drives
- combinations: fixed Winchester/cartridge-disk drive or fixed Winchester magnetic-tape cartridge
- streaming-tape drives
- bubble memories
- nonvolatile semiconductor programmable memory
- videocassette recorders
- video disks

The last three or four types are more for the future than now. Bubble memories and nonvolatile integrated circuits will have the great advantage of no moving parts and the potential convenience of plug-in modules; but they are still quite expensive. At least one interface and controller for American and European standard VCRs (videocassette recorders) is available to provide removable backup for high-capacity disks on small systems (the Corvus Mirror, manufactured by Corvus Systems Inc, San Jose, California). It stores up to 100 megabytes on one videocassette and has a transfer rate of 15 K bytes/second. Video disks have the potential to offer extremely high data-storage capacity and fast access rates (up to 1250 megabytes per 12-inch disk, equal to approximately four times the contents of the Encyclopaedia Britannica).

**Small vs Large Hard-Disk Drives**

Hard-disk drives for small systems fall roughly into two size categories: up to 12 megabytes and over 12 megabytes; and two performance categories: slow, with stepping-motor positioning, and fast, with voice-coil positioning. Those with stepping-motor positioning have average access times of 70 ms and capacities of under 12 megabytes. The drives with fast voice-coil positioning have average access times ranging from 25 ms to 50 ms, with models that fall into both size categories. The less expensive units are aimed at replacing floppy-disk drives directly. Examples of this type of product are the Memorex 101, the Shugart Associates SA-1000 series, and the Shugart Technology ST 506. The high end is led by IBM with the Piccolo drive, which is integrated into the System 34, and is an add-on peripheral for the Series 1. It features a rotary voice coil, 17 ms average access time, and up to 64.5 megabytes of storage capacity. Other contenders in this category offer high performance in a wide range of sizes (eg: the BASF Systems 6170 Series, IMI (International Memories, Inc) 7700 Series, Kennedy Company 7000 Series, Microcomputer Systems MSC-8000, Micropolis Corporation Micro Disk 1200 Series, Pertec Computer Corporation D-8000, and Priam Diskos 2050/3450).

The disk capacity and the performance you need depend on your particular application, which in turn has a significant impact on the cost of a system. Small-system applications, as...
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in BASIC

"This is easy...

100 MOVE R,0
110 FOR T=0 TO 360 STEP 25
120 DRAW R*COS(T), R*SIN(T)
130 NEXT T

"Oops, didn't quite meet...

... but that's easy to fix."

100 MOVE R,0
110 FOR T=0 TO 360 STEP 25
120 DRAW R*COS(T), R*SIN(T)
130 NEXT T

"Oh, now it closes... in fact, it overlaps."

Programming by trial and error

in Pascal

"The simplest circle drawn with line segments is a regular polygon..."

procedure Circle(X, Y, Radius: real);
const Sides = 16; Pi = 3.14159265;
var N : integer; Theta : real;
begin
  Move(X+Radius,Y);
  for N := 1 to Sides do begin
    Theta := 2*Pi*(N/Sides);
    Draw(Radius*cos(Theta) + X,
         Radius*sin(Theta) + Y);
  end;
end;

Programming by design

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mentioned before, can be placed in two major classes: single-user, single task and multi-user, multi-task.

- Single-user, single-task systems are usually stand-alone workstations, intelligent terminals, or personal computers. Their chief use of magnetic storage, in general, is for program storage and data storage. The amount of storage required is often less than 10 megabytes. Because the speed need only match one human operator’s response time, there is no benefit to be derived from disks with extremely fast access times. An average access time of 70 ms is usually sufficient in such applications. This class of application is cost-per-unit-oriented, since the storage device is dedicated to one user. It is price-oriented, and performance is not a vital factor. The low-end, small hard-disk drives fill this need splendidly.

- Multi-user, multi-task systems require that more than one, sometimes many, users have access to a common data base.

They typically require from 30 to 100 megabytes of magnetic storage, usually on one spindle. Some require less storage and some will require multiple spindles. The cost per byte of storage is a more important consideration than the cost per drive unit, because the basic device cost is spread over many users.

Multi-user, multi-task systems require an average access time of 50 ms or less because multiple users must contend for the common storage device. The main purpose of these applications is usually not to share the processing power, but rather to share the data. These systems are often “disk-bound” rather than “computer-bound.” Disk performance becomes a critical factor in system performance. Even when the disk capacity required might be relatively small (8 to 10 megabytes), the fast performance of the high end mini-disks will be required.

With their faster access times, higher capacities, greater reliability and OEM (original equipment manufacturer) quantity prices ranging from $1000 to $5000 (some may soon drop below $1000), both classes of the new hard-disk drives should be attractive to personal-computer systems builders who want additional capacity and performance, but not the traditional 14-inch disk size and price per unit. Some complete packages of drives, controllers, interfaces, and power supplies are available for about $5000. Even though they cost five to ten times as much as the processor, these units are still cheaper per drive than 14-inch drives. They are also applicable where more capacity and performance than a floppy disk can supply are needed, but the space or the cost of a 14-inch disk drive is prohibitive.

Tables 3, 4, and 5 list some of the current disk-drive products for small systems. The reliability and maintainability of these products are essentially high and are consistent across the board. (See table 6.)

Controllers and Interfaces

One of the problems with the new 8-inch hard-disk drives is the variety of interface systems to choose from. Such variety is inevitable at this stage because of the many personal computers already on the market, and the diversity of interface requirements. In the absence of a comprehensive interface standard, many of the drive suppliers have designed their own. A similar situation has developed in the audio industry. Consider the many types of noncompatible audio recording standards including: the LP (long-playing) record, 45 rpm records, open reel tapes, cassettes, and eight-track cartridges. This kind of variety at the outset of new products is not necessarily bad—there is much freedom for innovation.

In August of 1979 an ANSI (American National Standards Institute) Subcommittee (number X3T9.3) began to standardize an interface for 8-inch hard disks. If a standard interface is widely accepted by the industry, users may soon be able to interface drives from several vendors.

Types of Interfaces

There are two main categories of disk-drive interfaces, device level and host level. The main characteristics for the device level are:

- serial data transfer
- formatting/de-formatting external to drive

Text continued on page 138
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Listing 1 is a C program that duplicates itself. When the program is run it produces (on the standard output) a file containing an exact copy of its own source code. This program runs under the UNIX operating system and uses the American Standard Code for Information Interchange (ASCII) character set. If the program is compiled on a system using a different character set, the octal values of “q” and “n” must be changed to the numbers representing that system’s codes for the quote and newline (or linefeed) characters, respectively.

Why We Wrote a Self-Reproducing Program
A while back, Pascal News contained a listing of a Pascal program called PRINTME that performs this feat. (See reference.) The Pascal listing took 46 lines of code. We are currently writing a large system in the C language. We considered the Pascal program to be an unstated challenge, and in response we wrote a C version of the PRINTME program that works pretty much the same way as the Pascal version. This version is shown in listing 2.

This version is more elegant than the Pascal version and is 12 lines shorter. It takes a total of decimal 1313 bytes to store the source code. Then, one of us who once had done a lot of LISP programming wrote a LISP function that evaluates to itself. This function takes exactly 279 bytes of memory in which to store the print image of the code. The LISP function is shown in listing 3.

A week or so after the LISP function had been written, we were all discussing the similarities of LISP and C. From this discussion, we developed the C program of listing 1. It works like the LISP function and takes 126 bytes in the source code file.

For purists, though, a still shorter C version can be written. The C compiler, like a LISP compiler, sees all programs as a stream of bytes, and linefeed characters are parsed as spaces. Thus a C program could be written all on one line. The program in listing 4 is written on a single line in order to remove the necessity of printing linefeeds in the internal print.

Note that the octal ASCII values for the quote and linefeed characters have been replaced by decimal values (gaining one byte per number) and that all linefeeds except the last have been removed. Our C compiler seems to require at least one linefeed at the end of the file. The source code for this program is only 101 bytes long!
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Listing 1: Four-line C program which duplicates itself without any user input. If a non-ASCII character set is used on your system, the values of "q" and "n" must be changed to the values representing that system's quote and newline (linefeed) characters.

```c
main() { char q='42', n='12';
    *a=newmain();
    for (p=text; *p; p++)
        if (*p = quote) putchar(escape);
        else
            putchar (*p);
    printf ("\%c\%c", quote, newline);
}
```

Listing 2: Original self-duplicating C program.

```c
char *text[] = {
    "char text [] > [", 
    "main () { char newline = 012, quote = 042, escape = 0134, *p; 
        printf (\"%s,c\%c, text, newline); 
        for (pp = text; *pp; pp++) [ 
            printf (\"%s,c\%c, *p; *p++; [ 
                if (*p = quote) putchar (escape); 
                putchar (*p); 
            ];
        }
        printf (\"%c, c\%c, quote, newline); 
    }
}
```

Listing 3: Self-duplicating LISP function which inspired the C program in listing 1.

```lisp
(PRINTME (LAMBDA NIL (PROG (A B)
    (SETO A (QUOTE (PRINTME (LAMBDA NIL (PROG (A B)
        (SETOQ A (QUOTE Foo)))
        (SETO B (COPY A))
        (RPLACI (CDADDR (CADDAR (CDDADR B))) A)
        (RETURN B))))))
    (SETO B (COPY A))
    (RPLACA (CDADDR (CADDAR (CDDADR B))) A)
    (RETURN B))))
```

Listing 4: Final one-line, self-duplicating C program. This program is written on a single line to remove the necessity for code to generate linefeeds. However, the program is too long to display here without breaking the line. The program shown is to be written and compiled as a single line of source code.

```c
main() (char g=34,n=10,*a="main() !char q=34,n =10, 
    *a=%c%cs%c; printf(a,q,a,q,n);%c; printf(a,q,a,q,n);)
```

Reference
Pascal News, Pascal Users' Group, number 12, June 1978. (Pascal Users' Group, c/o Andy Mickel, University Computer Center: 227 EX, 208 SE Union St, University of Minnesota, Minneapolis MN 55455.)
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The Evolution of FORTH, an Unusual Language

Charles H. Moore
FORTH Inc
2309 Pacific Coast Hwy
Hermosa Beach CA 90254

Introduction
When I invented FORTH about 10 years ago, my goal was simply to make myself a more productive programmer. When I first worked with computers at MIT and Stanford in the early 1960s, I figured that in 40 years a very good programmer could write forty programs. And I wanted to write more programs than that. There were things out in the world to be done, and I wanted a tool to help me do them. As I worked on programs that ranged from satellite orbits to chromatography to business systems, I developed FORTH in line with my overall goal. For several years now, I have been able to work at ten times my original rate.

As I began thinking of rather drastic improvements to programs, I think I was arrogant. I wanted to do things my way. I was not convinced that I should not be permitted to, and I was a bit hard to get along with. The arrogance was necessary because I felt insecure. I was promoting ideas that everyone said were wrong, and there were many more of them than me. And it took a lot of arrogance to persist in the face of massive disinterest.

FORTH is a polarizing concept. There are people who love it and people who hate it. It's just like religion and politics. If you want to start an argument, say, "Boy, FORTH's really a great language."

This is partly because FORTH is an amplifier. A good programmer can do a fantastic job with FORTH; a bad programmer can do a disastrous job. I have seen very bad FORTH code and have been unable to explain to the author exactly why it was bad. There are some visible characteristics of good FORTH, such as very short definitions (many of them). Bad FORTH often takes the form of one definition per block—big, long, and dense. It is quite apparent, but difficult to explain, why or how a FORTH program is bad.

BASIC and FORTRAN are less sensitive to the quality of the programmer. I was a good FORTRAN programmer; I thought that I was doing the best job possible with FORTRAN, but it was not much better than what everybody else was doing. In this sense, FORTH is an elitist language.

On the other hand, I think that FORTH is a language that a grade school child can learn to use quite effectively, if it is presented in bite-size pieces with the proper motivation.

FORTH is the first language that has come up from the grass roots. It is the first language that has been honed against the rock of experience before being standardized. I hesitate to say it is perfect; I will say that if you take anything away from FORTH, it is not FORTH any longer—the basic components are all essential to the viability of the language.

History
What might be called the prehistory of the FORTH language goes back much further than 10 years. The first element of FORTH to exist was the text interpreter, shown in listing 1. This early version, programmed in ALGOL at the Stanford Linear Accelerator Center in the early 1960s, was part of a program called TRANSPORT, which designed electron-beam transport systems. Besides the text interpreter, this printout also shows an early version of the dictionary. The influence of LISP is evident in the indivisible entity (which in FORTH is called a word) named ATOM. As the interpreter reads a word from a punched card, it executes the associated routine, as for DRIFT in this example. The style resembles that of modern FORTH: there is no limit on the length of a word, as you can see by the length of the word SOLENOID, but only the...
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first characters are significant and words are separated by spaces.

Other very early concepts have either changed in form or have evolved dramatically. In listing 2, the word that has become { } (colon) in modern FORTH is called DEFINE, while END has become { ; } (semicolon). This listing also shows stack operators being defined. As an example of a concept that has evolved, consider the dictionary being sealed by the word SEAL and broken by the word BREAK. Such sealing and breaking has since been replaced by the idea of vocabularies.

Listing 1: An early version of the FORTH text interpreter (written in ALGOL).

```
IF ATOM = "DRIFT" THEN DRIFT
ELSE IF ATOM = "QUAD" THEN QUAD
ELSE IF ATOM = "BEND" THEN BEND
ELSE IF ATOM = "FACE" THEN FACE(-1)
ELSE IF ATOM = "ROTATE" THEN ROTATE
ELSE IF ATOM = "FACE " THEN FACE(-1)
ELSE IF ATOM = "SEX" THEN SEX
ELSE IF ATOM = "ACC" THEN ACC
ELSE IF ATOM = "SOLENO" THEN SOLENO
ELSE IF ATOM = "MATRIX" THEN BEGIN IF NOT FITTING THEN BEGIN
REAL A;
WRITE1(3,0,0,CORESISK); LINE(-8+42*(ORDER-1));
FOR I = 1 STEP 1 UNTIL 6 DO BEGIN
FOR K = 1 STEP 1 UNTIL 6 DO WRITE(2,8,R1,1,K) * UNIT(K) / UNIT(I),2);
LINE(1) END;
IF ORDER = 2 THEN FOR C = 1 STEP 1 UNTIL 6 DO BEGIN
```

Listing 2: An early version of the FORTH words { ; } (called DEFINE here) and { ; } (called END here).

```
" - "OPEN DEFINE MINUS + END
SEAL "<" "OPEN DEFINE - < END BREAK
" NOT "OPEN DEFINE MINUS I + END
" > "OPEN DEFINE < END
" AND "OPEN DEFINE x END
" OR "OPEN DEFINE NOT + NOT END
" T " "REAL DECLARE
" = "OPEN DEFINE T - DUP T < T > OR NOT END
" # "OPEN DEFINE = NOT END
" # "OPEN DEFINE > NOT END
" # "OPEN DEFINE < NOT END
"DUMP "OPEN DEFINE NAME 10 "ALPHA WRITE; 3 10 "REAL WRITE 0 LINE END
```

Listing 3: Another prototype of the FORTH text editor, again in ALGOL. In this listing, the word ATOM (the predecessor of the basic unit in FORTH, the word) has been replaced by the word W.

```
120 CYCLE; FILL OUTPUT WITH BUFFER[1],BUFFER[2];
1 WHILE WORD NEQ "END" DO
2 IF W = GM1 THEN REPLY("OK ")
3 ELSE IF NUMERIC THEN L = MIN(W,1,EOF)
4 ELSE IF W = "+ " THEN L = MIN(L,W,EOF)
5 ELSE IF W = "- " THEN L = MAX(L,W,0)
6 ELSE IF W = "T " THEN BEGIN
7 IF WORD = GM1 THEN W = 1; W = MIN(L+W,1,EOF);
8 FOR L = 1 STEP 1 UNTIL W DO BEGIN
9 POSITION; TYPE END; L = L-1 END
130 ELSE IF W = "R " THEN BEGIN
1 POSITION; REPLACE END
2 ELSE IF W = "A " THEN BEGIN
3 L = EOF; EOF = EOF + 1; REPLACE END
4 ELSE IF W = "I " THEN BEGIN
5 IF NOT RECOPY THEN BEGIN
6 RECOPY = TRUE; REWIND(CARD) END;
7 POSITION; IF W = "I " THEN BEGIN
8 PLACE; REPLACE END
9 ELSE BEGIN EMPTY = TRUE; IF WORD NEQ GM1 THEN BEGIN
140 L = MIN(L+W,1,EOF); SPACE(CARD,L; L = L+1; L = L+1)
```

Listing 4 shows another prototype in ALGOL, this time of a FORTH text editor. Here ATOM has become W and I am looking up plus, minus, and the commands T, R, A, and I, to edit a deck program.

Another method of implementing a dictionary is shown in listing 4. I am looking up the words in a conditional statement and setting NEXT, the key routine of modern FORTH’s address interpreter, to the index.

Listing 5 shows an early implementation of a stack. Since it is written in BALGOL, which allows assignment statements inside other statements, I could replace STACK[] with [J+1] in order to push items onto the stack. I did this so that I could manipulate parameters that were interpreted from the card deck as arguments to the routines. When I wanted, for instance, to convert angular measure from one unit to another, this added the ability to use arithmetic operators.

From Stanford I moved to the East Coast, where I programmed on a free-lance basis for several years. Some of you probably remember that, in the 1960s, a programmer at a typical computer center needed to learn about nineteen languages in order to function adequately: JCL (Job Control Language); languages to control utilities and facilities, such as the linking loader; assembly language and the assembler’s control language; plus several high-level languages and the methods for controlling their compilers.

Listing 6 shows two of these languages, a PL/I program and the JCL necessary to run it. Note the obvious difference in syntaxes. FORTH developed in response to such conditions. In terms of modern FORTH, the importance of this example lies in the use of NEXT as a procedure that goes off to get the next word and do something with it.

Listing 7 shows a version of FORTH coded for the IBM System/360 with the routines PUSH and POP, which executed in about 15 µs. They include stack limit checking, which doubled the cost and was one of the things that led me to believe that execution-time stack checking is not desirable. This was coded in a macroassembler that did not have stack operations, which led to the deck full of statements like L19
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Listing 4: An early version of the FORTH dictionary.

```
8 PROCEDURE RELEVANCE; BEGIN REAL T,KO;
9 J:=0; I:=-1; WHILE WORD NEQ "END" DO
100 IF W="=" THEN NEXT:=3
1 ELSE IF W="GT" THEN NEXT:=4
2 ELSE IF W="LT" THEN NEXT:=5
3 ELSE IF W="NOT" THEN NEXT:=6
4 ELSE IF W="AND" THEN NEXT:=7
5 ELSE IF W="OR" THEN NEXT:=8
6 ELSE IF W="+" THEN NEXT:=9
7 ELSE IF W="-" THEN NEXT:=10
8 ELSE IF W="*" THEN NEXT:=11
9 ELSE IF W="/" THEN NEXT:=12
190 ELSE IF KO:=SEARCH(W) GEQ 0 THEN BEGIN
200 I:=1; NEXT:=K:=KO END
2 ELSE BEGIN
210 NEXT:=2;
3 IF BASE(I)=" "THEN NEXT:=WORDS[I]
4 ELSE NEXT:=W END;
6 NEXT:=0 END;
```

Listing 5: An early implementation of the FORTH stack, written in BALGOL.

```
7 BOOLEAN PROCEDURE RELEVANT; BEGIN
8 I:=I:=-1; STACK[I]:=1; DO CASE NEXT OF BEGIN
9
210 STACK[I]:=I:=1:=I:=1:=CONTENT;
1 STACK[I]:=I:=1:=I:=NEXT;
2 STACK[I]:=I:=1:=1:=REAL(STACK[I]=STACK[I]+1);
3 STACK[I]:=I:=1:=1:=REAL(STACK[I] GTR STACK[I]+1);
4 STACK[I]:=I:=1:=1:=REAL(STACK[I] LSS STACK[I]+1);
5 STACK[I]:=I:=1:=1:=REAL(NOT BOOLEAN(STACK[I]));
6 STACK[I]:=I:=1:=1:=REAL(BOOLEAN(STACK[I]) AND BOOLEAN(STACK[I]+1));
7 STACK[I]:=I:=1:=1:=REAL(BOOLEAN(STACK[I]) OR BOOLEAN(STACK[I]+1));
8 STACK[I]:=I:=1:=1:=STACK[I]+STACK[I]+1;
9 STACK[I]:=I:=1:=1:=STACK[I]-STACK[I]+1;
220 STACK[I]:=I:=1:=STACK[I]xSTACK[I]+1;
1 STACK[I]:=I:=1:=STACK[I]+STACK[I]+1;
2 END UN TIL I LSS O;
3 RELEVANT:=BOOLEAN(STACK[0]) END;
```

DC AL2("-L18"), which gave me a link
from L19 to the previous label. It worked but it was not pleasant.

Listing 8 shows a similar routine, this time coded in COBOL. I am setting up a table of identified words that will be interpreted from an input stream. Since COBOL does not allow parameters for subroutines, it is awkward to do anything meaningful.

New Concepts

About this time, I began to think of defining a word that would define other words; and at that time, this idea was staggering. For example, `{ ; CODE } was a very esoteric word. I explained it to people, but I could not express the potential I thought it had.

It took time to find out exactly what `{ ; CODE } should do (it specified the code to be executed for a previously defined word). I do not have the records, but I think the initial code for `{ ; CODE } was three or four lines long; to simplify that code was one of the driving forces behind the address interpreter—to make it possible to code `{ ; CODE } cleanly. This had implications as to what registers should be available.

The fact that W should be saved in a register for defining words led to indirect, rather than direct, threaded code. That was the most complicated concept I had coded in this evolving program—probably deserving of a patent in its own right.

A little bit later, it seemed that there ought to be an analog of `{ ; CODE } that specified the code to be interpreted when you executed a word. It seemed the natural balance, but when the idea first arose, I did not have the foggiest notion of what to do or what the implementation should be. The first definition of this analog, called `{ ; : } (semicolon-colon), required three or four lines of code. It had to do what `{ ; CODE } did, and then more.

Out of that came the distinction between compile-time action and
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execute-time action. It was convenient for words to be coded to act this way, but it was expensive. It required not only the address of the code to be executed, but the address of the code to be interpreted, as well as the parameter to be supplied to the code being interpreted so you could do something useful.

Late in the 1960s I went to work for Mohasco Industries, where I put something strongly resembling FORTH on a Burroughs 5500, cross-compiled to the 5500 from an IBM FIND (a dictionary search routine) coded for the 5500. Notice the word SCRAMBLE, a colon definition making a hashed search. Apparently I had eight threads to the dictionary here, a concept we added back to FORTH when we developed polyFORTH last year.

FORTH and the IBM 1130

At Mohasco I also worked directly on an IBM 1130 interfaced with an IBM 2250 graphics display. The 1130 was a very important computer; it had the first hard disk drive, as well as a 13-line typewriter (as backup for the disk), and a console typewriter. The 1130 let the programmer, for the first time, totally control the computer interactively.

FORTH first appeared as an entity on that 1130. It was called F-O-R-T-H, a five-letter abbreviation of FORTH, standing for fourth-generation computer language. That was the day, you may remember, of third-generation computers and I was going to leapfrog. But because FORTH ran on the 1130 (which permitted only five-character identifiers), the name was shortened.

What came out of the 1130 was a cross-assembler that assembled the instructions, which were then to be executed by the 2250. I think the 2250 had its own memory, and these things had to be programmed carefully. What I accomplished was that the 1130 in FORTAN in 32 K bytes could draw pictures on the 2250, fairly slowly; and FORTH, in 8 K bytes, could draw three-dimensional moving pictures on the 2250—but it could do that only if every cycle was accounted for and if the utmost was squeezed out. That is why FORTAN had to go—I required an assembler and could not do an impressive enough job with FORTAN.

But high-level or colon definitions were not yet compiled—the compiler came much later. The text was stored in the body of the definition, and the text interpreter reinterpreted the text in order to discover what it was to do. This contradicts the efficiency of the language, but I had big words that put up pictures and I did not have to interpret too much. The cleverness was limited to squeezing out extraneous blanks as a compression medium. I am told that this is the way that BASIC acts today in many instances.

This machine had a disk drive, and I am almost certain that the word BLOCK existed in order to access
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records off the disk. I do remember that I had to use the FORTRAN I/O (input/output) package and that it would not put the blocks where I wanted them; it put the blocks where it wanted them, and I had to pick them up and move them into my buffers.

At Mohasco I also implemented FORTH on a Univac 1108, interfacing it with their COBOL compiler. Listing 11 displays a set of record descriptions in a Dun and Bradstreet reference file (for looking up bad debts). The layout shows named fields followed by the number of bytes allocated.

The Mohasco programs mark the transition point between something that could be called FORTH and something that could not. All the essential features except the compiler were present by 1968.

The First Modern FORTHs

The first modern FORTH was coded in FORTRAN. Shortly thereafter it was recoded in assembler. Much later it was coded in FORTH. It took a long time before I thought that FORTH was complete enough to code itself. The first thing to be added was the return stack. That was an important development: the recognition that there had to be exactly two stacks, no more, no less.

The next thing to be added was even more important—the full-fledged dictionary, that is, the dictionary in the form of a linked list. Up until then, flags had been set or computed GO TOs had been executed to provide some mechanism for associating a subroutine with a word. The replacement of all that by a code file containing the address of the routine made an incredibly fast way of implementing a word once it was identified.

The first use of modern FORTH occurred when it was written for a Honeywell H316 at the NRAO (National Radio Astronomy Observatory). In 1971 I was hired by George Conant to write a radio-telescope data-acquisition program: that led to the next step, the compiler. This meant the recognition that, rather than reinterpret a string of text, words could be compiled and an average of 5 characters per word could be replaced by 2 bytes per word. This gave a compression factor of 2 or 3, not drastic but appreciable. But execution speed would be much faster. Again I asked myself, as I had done when I first began modifying programs: if it was that easy, why hadn’t anyone else done it? It took me a long time to convince myself that you could compile anything and everything.

Interrupts came around this time. It was important to utilize the interrupt capability of the computer, but it had not been done by me before that—I did not know anything about interrupts. I/O, however, was not yet interrupt-driven. Interrupts were available for the application if it wanted them—FORTH did not bother.

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a couple of years later when we developed an improved version of the system for NRAO's telescope at Kitt Peak. This computer was a PDP-11; the multiprogrammer had four tasks. Input was still not interrupt-driven, which was unfortunate.

**The Second FORTH Programmer**

Ten years ago there was one FORTH programmer, me. The second FORTH programmer, Elizabeth Rather, came along in 1971. That is quite a quantum jump, from one to two; the next step was four (the next two came out of Kitt Peak National Observatory); the growth can be traced from there to the several thousand today.

The first FORTH user was Ned Conklin, head of the NRAO station at Kitt Peak, Arizona. NRAO runs a millimeter-wave radio telescope that is in great demand by observers, in part because it is responsible over the last 10 years for discovering half of the interstellar molecules that are known to exist. FORTH is still running on that telescope at Kitt Peak and on a lot of other telescopes.

Given interest from other astronomers, a few believers split off from NRAO in 1973 and formed FORTH Inc. We were deluged by requests for FORTH systems from astronomers and went into business to try to exploit that market. It would still be our principal line of business today except that there are so few new telescopes in the world that you cannot support a company on that market.

We developed miniFORTH™ (FORTH on minicomputers) with the idea of having a programming tool. An important implementation of the tool came when we put an LSI-11 and FORTH into a suitcase. I think I became the first computer-aided programmer—computer-aided in that I had my computer and took it around with me. I talked to my computer, my computer talked to your computer, and we could communicate much more efficiently than I could communicate directly with your computer before it could run FORTH. Using this tool, we have put FORTH on many computers.

We added the feature of interrupt-driven I/O when FORTH Inc produced its first multiterminal system. It did not speed things up particularly from the user's point of view, but it did prevent any loss of characters when several people were typing at the same time. You did not have to look quickly to get the character before the next one came along. They were all buffered and waiting for you, which is an important distinction for multiprogrammed systems.

Data-base management came along at this time. It has been extensively changed, just as FORTH has. But fundamentally, nothing has changed. The concept of files, records, fields, and relational pointers that polyFORTH™ offers dates back from 1974 or so—years and years ago. Listing 12 shows a recent application of the FORTH Inc data-base management system.

With microFORTH™ in 1976 came the first version of our current target compilers. They are very complex things, much more so than I expected them to be. At about the same time, we worked out the current implementation of DOES>.

This new form of {; : } does not require the address of the code to be interpreted. Since that is supplied by a different mechanism, the parameter can occupy the parameter field as it is supposed to. You can "tick" it and change its value, which is nice. [The FORTH word { ; } (called "tick" above) places the address of the word that follows it onto the stack....GW] But we save 2 bytes for every DOES> word, 2 bytes for very common words—and for 3 years, we did...
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not realize that we had missed the optimum by so much.

I know no way of speeding this process from initial thought to development, except to let a certain amount of time pass. We could sit, we did sit and debate this thing endlessly, and we missed the obvious.

I think that completes the capabilities that I think of as FORTH today. You see how they dribbled in—at no point did I sit down to design a programming language. I solved the problems as they arose. When demands for improved performance came along, I would sit and worry and come up with a way of providing improved performance.

polyFORTH is a condensation of everything that we at FORTH Inc have learned in the last 10 years of developing FORTH. I think it is a very good package. I foresee no fundamental changes in the design of the language except for accommodation to FORTH standards, which are becoming increasingly important.

Implementations of FORTH

I would like to review the implementations of FORTH of which I am aware. It is actually a tour through the history of computers and it is fascinating that this could all have happened in 10 years.

FORTH has been programmed in FORTRAN, ALGOL, PL/I, COBOL, assembler, and FORTH; and I am sure some of you can come up with other languages with the same history. My list is strictly personal.

FORTH has been implemented on the Burroughs 5500; the IBM 1130; the Univac 1108; the Honeywell 316; the IBM 360; the Data General Nova; the HP 2100 (not by me but by Paul Scott at Kitt Peak); the PDP-10 and PDP-11 (by Marty Ewing at the California Institute of Technology); the PDP-11 (by FORTH Inc); the Varian 620; the Mod-Comp II; the GA SPC-16; the CDC-6400 (by Kitt Peak); the PDP-8; the IV-Phase; the Computer Automation LSI-4; the RCA 1802; the Honeywell Level 6; the IBM Series 1; the Interdata; the 6800; the 8080; the 8086; the TI-9900; and soon the 68000, the Z8000, the 6809, and a Child Inc computer. Some independent groups have 6502s, ILLIAC, and others running FORTH. I raise the question—is it the case that FORTH has been put on every computer that exists?

Some people think FORTH ought to be machine independent, but that premise is wrong. The equivalence is FORTH—each machine requires meticulous attention to its individual characteristics. You must use all the hardware capabilities of each machine and must then work to force it into the mold specified by FORTH's virtual machine.

For example, we put a subset of FORTH on an SMS-300 microcomputer. It had only eight instructions. The internal characteristics of every machine can and must be exploited. You do not need any particular number of registers or stacks or anything. All can be simulated, but if you neglect the abilities of the machine, you can end up a factor of 2 down in performance from where you might otherwise be.

FORTH-in-Hardware Computers

The first FORTH computer I know of was built at Jodrell Bank in England around 1973. It is a redesign of an English Ferranti computer that went out of production. The observatory at Jodrell Bank was going to build their own bit-slice version; they discovered FORTH about the same time, modified the instruction set to accommodate FORTH, and built what I am told is a very fast FORTH computer. I have never seen it, but have talked to its competent designer, John Davies, who is one of the early FORTH enthusiasts.

In 1973, before Dean Sanderson came to FORTH Inc to develop microFORTH, he had a FORTH computer at a company called General Logic. It qualifies as a FORTH computer because it has a FORTH instruction. And there is a story there. Dean showed me his instruction set, and there was this funny instruction that I could not see any reason for—I figured it was some kind of no-op or catchall or something; it had the weirdest properties, and it could not possibly be useful. It was NEXT. It was a one-instruction NEXT which was beautiful. And it was a very simple modification (this was a bit-slice computer) to the instruction set—a few wires here and there—and that is the first time I saw a FORTH computer, if you will. I call it a FORTH computer because it had the ability to change itself from an ordinary computer into a FORTH computer.

I think that hardware today is in the same shape as software was 20 years ago. No offense, but it is time that the hardware people learned something about software. There is an order or two of magnitude improvement in performance possible with existing technology. We do not need picosecond computers to make really substantial improvements in execution speed. Faced with that realization, there is no point in trying to optimize the software any further until we have taken the first crack at the hardware. The hardware redesign has to be as complete as the software redesign was. The standard microprocessors did not have FORTH in mind. Those minicomputers that can be microprogrammed cannot be microprogrammed well enough to even be worth doing. The improvements available are much greater than you can achieve by these half measures.

I have built a small FORTH computer. The design changes as fast as the chips can be plugged into the board. But it is not difficult to do. Here are the characteristics of a FORTH computer:

- It does not need a lot of memory (16 K bytes is about right—half programmable read-only memory, half user programmable memory, maybe).
- It does not need a lot of I/O ports; in fact, it does not need any I/O ports except for the application requirements.
- A serial line and interface to a disk drive are useful but not required.

We have put FORTH on an 8080-based machine with a virtual disk in memory, enough memory to hold eight blocks. The system is quite viable and has no particular problem with system crashes. Bubble
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memories are coming. A FORTH computer does not need much mass storage; 100 K bytes are adequate, and 250 K bytes are plenty. The fact that FORTH can exist quite happily on a machine that is very small by contemporary standards should be exploited.

Organizations

Finally, I would like to run through the history of the organizations that have been involved with FORTH. They have formed another thread of the tapestry. It began with Mohasco, of course, followed by NRAO and Kitt Peak National Observatory; then came FORTH Inc.

The next step was probably DECUS (Digital Equipment Computer Users' Group). Marty Ewing gave his PDP-11 FORTH system to DECUS. FORTH Inc was not sure whether free FORTHS floating around was a good idea at the time. But it turned out that a lot of people were exposed to FORTH who otherwise would not have been.

Cybek came along and provided an entry into the business-systems market. Art Gravina, the president of Cybek, is the person who designed

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Conclusion

The tendency seems to be for people to organize themselves in groups. Some of these groups are companies, others are associations. It looks like FORTH is going to be a communal activity in that sense—that it will grow from the work of unstructured clusterings of like-minded people. The suggestion is that this whole world of FORTH is going to be quite disorganized, uncentralized, and uncontrollable. It's not bad, perhaps it's good.

My view of the future is more unsettled today than it has been for years; promising, confusing, perplexing. The implications are perhaps as staggering now as they were 20 years ago. The promise of realization is much higher. My original goal was to write more than forty programs in my life. I think I have increased my throughput by a factor of 10. I do not think that that throughput is program-language limited any longer. So I have accomplished what I set out to do: I have a tool that is very effective in my hands. It seems it is very effective in others' hands as well. I am happy and proud that this is true.
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Actual Photograph of WordPro on CBM Model 8032

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All four versions of WordPro are written in 6502 machine code.

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WordPro was developed by Steve Punter of Pro-Micro Software Ltd., and is marketed exclusively by Professional Software Inc.

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Components of FORTH

FORTH is characterized by five major elements: dictionary, stack, interpreters, assembler, and virtual memory. Although not one of these is unique to FORTH, their interaction in FORTH produces a synergistic effect that creates a programming system of unexpected power and flexibility.

- Dictionary: The resident FORTH system is organized into a dictionary that occupies almost all of program memory. The dictionary is a threaded list of variable-length items, each of which defines a word of the vocabulary. The actual content of each definition depends on the type of word: noun, verb, etc. The dictionary is extensible, growing toward high memory. In a multiterminal system, terminal tasks may have private dictionaries that are connected in a hierarchical tree structure.

- Stack: Two push-down stacks (last-in, first-out, or LIFO, lists) are maintained for each multiprogrammed task in the system. These provide the primary communication between routines as well as an efficient mechanism for controlling logical flow. A stack normally contains items one computer word long, which may be addresses, numbers, or other objects. Stacks, which are of indefinite size, grow toward low memory.

- Interpreters: FORTH is fundamentally an interpretive system, meaning that program execution is controlled by data items rather than by machine code. It is a common assumption that interpreters are severely wasteful of processor time; this is avoided in FORTH by maintaining two levels of interpretation.

The first of these is the text interpreter, also known as the outer interpreter. It works in a conventional manner, parsing text strings that come from terminals or mass storage and looking up each word in the dictionary. When a word is found in the dictionary, it is executed (unless the task is in compile mode) by invoking the address interpreter.

The address interpreter (also known as the inner interpreter) interprets strings of absolute memory addresses by executing the definition pointed to by each. Most dictionary definitions contain addresses of previously defined words that are to be executed by this interpreter. This level of interpretation requires no dictionary search since these words have already been compiled by the text interpreter, which generated the absolute addresses.

The address interpreter has several important properties. First, it is fast. Indeed, on some computers it executes only one instruction for each word, in addition to the code implied by the word itself. Second, it interprets compact definitions. Each word referenced in a definition compiles a single memory location. Finally, the definitions are machine independent because the definition of one word in terms of others does not depend upon the computer that interprets the definitions.

- Assembler: FORTH includes a resident assembler, which allows the programmer to define words that will cause specified machine instructions to be executed. This type of definition is necessary to perform device-dependent input and output operations, to implement elementary operations, and to do highly time-critical processing.

- Virtual memory: The final key element of FORTH is its blocks: fixed-length segments of disk space that may contain program text or data. A number of buffers are provided in memory; blocks are read into them automatically when referenced. If a block is modified in memory, it is automatically replaced on disk. Explicit read and write operations, therefore, are not required; programmers may presume that program text or data is in memory whenever it is referenced.

The above paragraphs present a concise overview of FORTH as a language; the following paragraphs describe features of a FORTH Inc product, polyFORTH®-GW

The standard polyFORTH system utilities include the following:

Text editor: Facilitates editing program source text, both by line and by character.

Source listings: Prints program source listings and indexes.

Disk copy: Provides for disk-to-disk copying of data file and program source files for backup purposes.

Disk diagnostic: Produces a simple, read-only disk diagnostic that may be run at any time without disturbing other users. (More extensive hardware diagnostics are optional.)

Each polyFORTH system also contains a Target Compiler™ capability; this allows the user to develop, for run-time applications only, a computer system that does not require the entire operating system. Since FORTH is an interpretive language, an interpreter must always be present; but the target compilation process creates the minimum dictionary necessary, thus allowing a program to be run with a minimum of memory overhead. Typically, this overhead is less than 1000 bytes.

Full data-base management support is available in an optional Extended File Management package. Included within its structure are the essential features of the CODASYL standard along with the characteristic speed, compactness, and flexibility of the FORTH language. Facilities include commands for file definition and formatting and for table and record descriptions, as well as several file-accessing techniques, operators for accessing individual fields by name and fields within specified files, and such utility functions as a report generator and an optional key-sort routine.

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Prices Increasing: Both Texas Instruments (TI) and Atari recently announced price increases for their personal computer systems. Radio Shack, Commodore, and Apple are holding the line, at least for the present.

Atari increased the price of its Model 400 from $550 to $630 and the Model 800 from $1000 to $1080. The company attributed the increase to rising component costs, particularly components that incorporate precious metals.

TI, on the other hand, has subtly unbundled the 99/4 system. Previously, a purchaser bought the keyboard/processor console and a 13-inch color video monitor for $1150. Now he can buy the console for $950 and the monitor for $450, a total of $1400. Or, he can buy the console and an RF (radio-frequency) modulator ($75) and hook it up to a standard color television set. This combination costs $1025, which is only $125 less than the old complete system price.

Although Radio Shack, Commodore, and Apple have not raised the prices of their basic systems, certain peripheral devices and add-ons have increased in price. Furthermore, when the Federal Communications Commission (FCC) RF-radiation standards go into effect on January 1, 1981, there may be significant price increases.

Most personal-computer marketing experts agree that for personal computing to become a true mass market, prices must decrease, not increase. The experts are therefore disturbed over what they feel will be a real damper to personal-computing sales.

Software Piracy: Over the years, software vendors have complained many times about hobbyists copying software from one another instead of buying it. One supplier even has gone so far as to offer a $10,000 reward for information leading to the conviction of anyone found copying its software. I am not aware that this plan has had any positive results. It has, however, raised the ire of many hobbyists, and there may have been a negative effect on this particular supplier's software sales, because he sells cassette software mostly to hobbyists.

Although copying by hobbyists remains a problem for software vendors, a much greater problem has developed: software piracy for commercial purposes, by pirate vendors who are marketing copies in much the same way as audio- and video-cassette pirates do.

For example, Nestar Systems of Palo Alto, California, has charged that its read-only-memory-based "Basic Programmer's Toolkit" (for the Commodore PET) is being distributed in Europe in both cassette and floppy-disk format. The pirating distributor is alleged to have changed the code (relocating it into user memory) and to have changed the copyright notice. Nestar is taking action in this case.

This type of software piracy will have a more serious financial impact on the software vendor than hobbyist copying. Here, the vendor is actually losing dealer sales, since many dealers are purchasing the software from the pirate at a much lower cost—and probably marking it up more—then if the dealer purchased it from the legitimate vendor. In most instances, end users are not aware that they have purchased a pirated copy until they try to get software support from the rightful vendor.

Tektronix Sets Up Handicapped Person's Hot Line: Physically handicapped persons, or people wanting information on special electronic equipment for coping with physical impairments, can get answers to questions by calling the Tektronix Special Interest Group on Computers and the Physically Handicapped in Beaverton, Oregon, at (503) 357-4354.

Intel Releases Data on 32-Bit Microprocessor: Intel, the recognized leader in microprocessor development, has "leaked" advanced information on three new forthcoming 16- and 32-bit microprocessors. Intel is now playing the game of trying to scoop its competition by announcing products long before they will be available in production. This will, no doubt, have an impact on sales of the Zilog Z8000 and Motorola MC68000, as purchasers may now wait for a more powerful product.

The 32-bit microprocessor will be known as the iAPX-432, and will be a 3-chip set with a brand-new architecture and instruction set. Intel claims that it will provide the power of a medium-scale IBM 370 system. It will directly execute Ada code. Ada is an upward extension of Pascal, and it is the language designed for and to be used by the US Department of Defense. It is interesting to note that at this time there is no Ada compiler up and running.

The two new 16-bit microprocessors are essentially 8086s with integrated functions and higher speed to improve performance. They are intended for multiprogram and multiuser systems.

Intel promises that all three new microprocessors will be available in 1981, with the 32-bit microprocessor becoming available first.

Xerox Opened Computer Stores: The Xerox Corporation recently opened retail stores in Dallas, Texas, and Denver, Colorado. Apparently these are the first links in a chain of retail computer stores across the country. The store is selling Xerox 510 small-business computers, Apple II com-
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Various other software programs are also available.
puter, Centronics printers, Hewlett-Packard calculators, and ADT security systems. Xerox plans to open at least 200 such outlets in at least 50 cities within 2 years.

Apple Foundation Awards Grants To Schools: The Apple Education Foundation, chartered by Apple Inc, has awarded $120,000 worth of equipment to schools and individuals to expand the use of microcomputers in education. The foundation plans to donate another $250,000 worth of equipment to support programs at all educational levels. Current recipients include Iowa State University; Bowditch Middle School in Foster City, California; North Texas State University; Educational Services Management Corporation in Raleigh, North Carolina; Children's Hospital in Philadelphia; the National Science Foundation; Dr Robert N Noyce, vice president of Intel Corporation; and others.

Other participating contributors include the Bell & Howell Company, Heuristics Inc, and Integral Data Systems Inc.

For more information, contact the Apple Education Foundation, 20605 Lazaneo Dr, Cupertino CA 95014.

5 1/4-Inch Mini-Winchester Disk Introduced: Shugart Technology of Scotts Valley, California (not to be confused with Shugart Associates) has introduced a 5 1/4-inch Winchester-type hard-disk drive with a 6.38-megabyte formatted capacity. It is the same size and uses the same power-supply voltages as a standard 5 1/4-inch floppy-disk drive. [See Tom Manuel's article, "The Hard Disk Explosion," on page 35 of this issue for more details...CM]

Lobo Drives, Goleta, California, plans to make available a low-cost controller which interfaces the 5 1/4-inch hard-disk drive and floppy-disk drives to several personal-computer systems. These products should become available in 1981.

Random News Bits: Votrax (Division of Federal Screw Works, 300 Stephenson Hwy, Troy MI 48084) has announced a new voice synthesizer with an unlimited vocabulary in seven languages and controllable inflection. The Model VSB, built on a single-printed-circuit card, is intended to interface with terminals, electronic typewriters, word processors, and other equipment. The unit is controlled by 8-bit input commands that select phonemes and inflection. Original equipment manufacturer price is $280... A national FORTH language group is in operation. They publish a newsletter, distribute software, and conduct meetings. For information contact: Jim Flounoy, 17370 Hawkins Ln, Morgan Hill CA 95037... Radio Shack has released a software package for its TRS-80 Model I which enables users to originate Mailgram messages. Users must have an Eastern Union (WU) Electronic Mail account, and if so, users are billed monthly by WU for messages sent... Matsushita Electric, Osaka, Japan, has introduced a single-component voice synthesizer that generates either 10 seconds of high-quality speech or up to 30 seconds of low-quality speech. The integrated circuit uses only 28 pins and operates from +5 V. The device will probably be used in consumer appliances, cars, etc... National Semiconductor, Santa Clara, California, has introduced a microprocessor that includes a read-only memory-resident BASIC interpreter and 64 bytes of user memory. The single-chip computer keeps getting closer and closer to reality... Compuserve, the company that provides the MicroNet information utility, has been negotiating with H & R Block about a corporate merger, with intent to become a subsidiary of the income-tax firm.

Random Rumors: A semiconductor manufacturer will soon introduce two integrated circuits that together will interlace for requirements for the S-100 bus, thereby reducing the number of components required by S-100 master and slave boards. The two devices will provide all the necessary bus buffering, control signals, and address decoding and will meet IEEE S-100 specifications... Hewlett-Packard (HP) is rumored to be working on a hand-held calculator that is programmable in BASIC (maybe they should call it a computer). Rumor is that they, and several others, will introduce such units by year end. A few have already been introduced in Japan... Texas Instruments (TI), which has been working on a disk-drive system of its own, is now negotiating with a number of outside suppliers for 8-inch Winchester-type hard-disk drives to be included in a new small-business/word-processor system to be introduced next year. TI, however, is still pursuing in-house designs. TI is also negotiating with several tape-drive suppliers for a backup storage system... The rumor is that Tandon Magnetics, Chatsworth, California, is about to announce a 2-megabyte quad-density 5-inch floppy-disk drive with a $375 original equipment manufacturer price tag... Look for Integral Microsystems in the S-100 extension?...CH

Microminis and Micromaxis: Two new words have been coined to describe the new microprocessors. If an 8-bit processor is called a "micro," then a 16-bit microprocessor must be a "micromaxi." That is the conclusion of many in the industry, particularly since many of these new 16-bit microminis will be competing head-on with applications that were previously the exclusive domain of the 16-bit minicomputers.

It therefore follows that the 32-bit microprocessors, which are expected within three years, should be called "micromaxis," since they will most likely compete for applications previously handled by large mainframe computers. At least that is what many industry watchers think.

Well now...my question is: what do we call a 4-bit microprocessor? Is it a "minimicro"?

MAIL: I receive a large number of letters each month as a result of this column. If you wish a response, please include a stamped, self-addressed envelope.

Sol Libes Amateur Computer Group of New Jersey (ACG-NJ) 1778 Roxbury Rd Scotch Plains NJ 07076

Too Good To Be True? A rumor recently heard at BYTE says that a major manufacturer will shortly introduce a 5-inch floppy-disk drive with a tenfold increase in density. This sounds too good to be true. Will standard media support such an extension?...CH

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This selected list of FORTH vendors is meant to be an overview only. For complete details contact the vendors. Many of the products, listed as fig-FORTH versions, are implementations of the FORTH Interest Group software customized for a given machine and available in machine-readable (as opposed to printed) form.

When purchasing a version of FORTH, check to see what source the version is based upon. All good versions of FORTH are based on either the FORTH Inc or the FORTH Interest Group versions. Some existing implementations use nonstandard shortcuts that limit the usability of the product; these should be avoided.

Literature on FORTH is scarce, so be prepared to puzzle through cryptic documentation. Miller Microcomputer Services offers a wide selection of books on FORTH (the only selection we know of). Particularly suitable are microFORTH Primer (supplied with the purchase of MMSFORTH) and Using FORTH, both written by FORTH Inc.

STOIC is a FORTH-like language available from the CP/M Users’ Group and is listed because of its low price. N/A refers to information unavailable at the time this table was compiled.

GW and CHF

## Selected FORTH Vendors

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Product Name(s)</th>
<th>Machine Requirements</th>
<th>Format</th>
<th>Cost</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acropolis Software</td>
<td>A-FORTH (based on fig-FORTH)</td>
<td>Any machine running Micropolis disks and MDOS operating system</td>
<td>Floppy disk</td>
<td>$150</td>
<td>Includes 8085 assembler, double-precision fixed-point math, enhanced disk access, other features.</td>
</tr>
<tr>
<td>Cap'n Software</td>
<td>fig-FORTH</td>
<td>Apple II with disk</td>
<td>5-inch floppy disk</td>
<td>$140</td>
<td>FORTH hot line available for questions. Extra packages (Apple high-resolution graphics, floating point) available at extra cost.</td>
</tr>
<tr>
<td>CP/M Users Group</td>
<td>STOIC (not FORTH, but a FORTH variant)</td>
<td>Any CP/M machine</td>
<td>8-inch floppy disk</td>
<td>$20</td>
<td>See editorial for further details.</td>
</tr>
<tr>
<td>FORTH Inc</td>
<td>FORTH, polyFORTH, microFORTH, picoFORTH</td>
<td>Versions for various machines: 8080, 6800, 8000, 1802, 8086, 6600, 1802, 6900; also handles versions for minicomputers and mainframes</td>
<td>Various with machine.</td>
<td>$2500 up</td>
<td>These are the inventors of the language; they supply custom packages and extensive support; picoFORTH (for 8300 or 1802) can be directly upgraded to polyFORTH.</td>
</tr>
<tr>
<td>FORTH Interest Group</td>
<td>fig-FORTH</td>
<td>Various machines with 16 K bytes or more: 8080, 8020, 6800, 6080, 1802, LSI-11; also handles versions for minicomputers and mainframes</td>
<td>Printed listings; must be customized by user.</td>
<td>$20</td>
<td>$20 includes installation manual and assembly language source for one processor (8080, etc.) requires some work by user to install; quality product at a low price.</td>
</tr>
<tr>
<td>FORTH Power</td>
<td>fig-FORTH</td>
<td>Heath WH-89 or 6800 EXORciser</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Fortbight Enterprises</td>
<td>fig-FORTH</td>
<td>CP/M machine, 16 K bytes</td>
<td>8-inch CP/M floppy disk</td>
<td>$30</td>
<td>Includes all source code.</td>
</tr>
<tr>
<td>John James</td>
<td>fig-FORTH</td>
<td>PDP-11, all models; stand-alone or running under RT-11 or RSX-11M: 24 K bytes or more</td>
<td>8-inch floppy disk</td>
<td>$140</td>
<td>Package includes all documentation and source code; also offers a book of FORTH reprints.</td>
</tr>
<tr>
<td>M&amp;B Design</td>
<td>polyFORTh-CP/M</td>
<td>8080 CP/M system</td>
<td>8-inch CP/M floppy disk</td>
<td>$4000</td>
<td>Multitasking version of FORTH running on CP/M system with 32 K bytes or more; includes utility programs and interface to CP/M system uses CP/M 10 drivers only.</td>
</tr>
<tr>
<td>Miller Microcomputer Services</td>
<td>MMSFORTH (based on FORTH Inc microFORTH)</td>
<td>TRS-80 Model I, with Level II BASIC: 16 K bytes or more</td>
<td>Cassette or 5-inch floppy disk</td>
<td>$59.95, cassette</td>
<td>Offers support of product, consultation, newsletter, additional FORTH products, and a wide selection of FORTH books.</td>
</tr>
<tr>
<td>The Stackworks</td>
<td>SLS (FORTH under a different name)</td>
<td>Any CP/M machine, 8080 or Z80</td>
<td>8-inch CP/M floppy disk</td>
<td>$150 (noncommercial use), $1500 (commercial use)</td>
<td>This language is essentially an implementation of the 1977 FORTH Standard; SLS includes a debug package and packages that allow the generation of condensed, stand-alone programs as either CP/M, COM files, or as programs to be placed in read-only memory.</td>
</tr>
<tr>
<td>Telnet Microsystems</td>
<td>fig-FORTH</td>
<td>Minimum 12 K bytes (20 K better for FLEX 9.0): 6809 SW/FPC FLEX 9.0</td>
<td>5-inch floppy disk</td>
<td>$39.95</td>
<td>Offers telephone support of product.</td>
</tr>
</tbody>
</table>
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What Is FORTH?
A Tutorial Introduction

John S James
POB 348
Berkeley CA 94701

FORTH is a programming language with a small but fast-growing and enthusiastic user community. Though easy to learn at a terminal, it is difficult to explain abstractly because it is so different from other languages. Even advocates do not agree why it is good or how it should be used.

FORTH was developed for control applications (using a computer to run other machinery), data bases, and general business. It is least useful for big number-crunching jobs (eg: writing a matrix inversion routine), although it can link to subroutine packages written in other languages to incorporate such functions. Unlike Pascal, FORTH gives the user complete access to the machine and does not try to guard the programmer against mistakes. But its modularity and other forms of error control allow production of remarkably bug-free application programs—perhaps more than any other language in common use. The compiler uses much less memory than Pascal does, and its programs run about equally fast. FORTH is much more interactive than most conventional implementations of Pascal. FORTH is available on most common personal computers (eg: Apple, TRS-80) and all major microprocessors (eg: 8080, 6800, 6809, 6502, PACE, LSI-11, and 9900). An international FORTH Standards Team exists, and standard systems are virtually identical among all different machines.

This article will describe what it is like to program in FORTH. A group of annotated terminal sessions, shown in listings 1 thru 10, will provide more details on the language itself.

The Philosophy of FORTH

FORTH reduces the cost of a subroutine to very little, and the whole language is built on functions that are like subroutine calls. The programmer keeps defining new words (new functions) from old ones until, finally, one of them is the whole job. Most programmers keep each definition short, usually one to three lines not counting comments. The definitions are compiled as entered and are immediately ready to run.

Because FORTH definitions are short, all possible execution paths of the definition can be tested easily. Since most functions work exactly the same when executed as commands from the terminal or when used as components in further definitions, they can be tested immediately from the terminal. And the functions are so general that there is no sharp distinction between program and data.

Since programmers define their own operations, special application libraries of FORTH words can be developed. The new routines are generally part of the language, so they do not need any special calling sequences, and they are immediately ready to run. Even the original words supplied with the system (there are about one hundred of them), can be redefined if desired, adapting the language for special circumstances. Also, programmers can create their own data types or operation types (eg: their own kinds of arrays or other data structures, or new classes of operations). This flexibility allows unprecedented "customization" of a language to the requirements of a particular installation or application. The finished programs are easily modifiable when requirements change because they are composed of pretested building blocks specially designed for that kind of program.

Stack and Postfix Notation

A smaller convenience of FORTH is that you do not have to do much coding when you start a new program. As soon as the system comes up, all your previous work is ready to go, just as if it were originally part of the language.

A feature that some people do not like is FORTH's use of a stack (explained below) and its postfix notation (also called reverse Polish...
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<thead>
<tr>
<th>Capacities</th>
<th>2MHz Prices</th>
<th>4MHz Prices</th>
</tr>
</thead>
<tbody>
<tr>
<td>16K</td>
<td>$249</td>
<td>$259</td>
</tr>
<tr>
<td>32K</td>
<td>$375</td>
<td>$395</td>
</tr>
<tr>
<td>48K</td>
<td>$500</td>
<td>$530</td>
</tr>
<tr>
<td>64K</td>
<td>$625</td>
<td>$665</td>
</tr>
</tbody>
</table>

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Central Data
Most FORTH operations communicate only through a stack.

In postfix notation (a system used on most Hewlett-Packard calculators), arithmetic formulas are written with the operations after their arguments, not between them. For example, "2+3" becomes \{ 2 3 + \} in FORTH or other postfix systems; "((4+5)*(6+7))" becomes \{ 4 5 + 6 7 + * \}. (See explanation below.) No parentheses are needed in postfix.

Some programmers do not like postfix, and they ask, "Why doesn't someone write an algebraic-to-postfix translator for FORTH? That would be easy to do." The reason is that postfix has benefits far more important than the compiler-writer's convenience. It greatly simplifies linkage to subroutines. With postfix, you do not need any CALL statement or argument list, or any formal parameters in the subroutine. While arithmetic-formula operations (add, subtract, etc.) must take either one or two arguments and return exactly one result, postfix functions can have any number of arguments or results.

In FORTH, most operations communicate only through a stack. The stack, perhaps the most important data structure in programming, is used in almost all languages, but most languages hide it from the user. In FORTH, the user controls the stack directly.

A stack is a pile of numbers where the last ones put in are the first ones taken out; that is, you can only remove the number that is on top of the stack. It is like a stack of trays in a restaurant; trays are conveniently added and removed only at the top. (Unfortunately, computer-science texts do not agree on terminology, and a few call the top of the stack "the bottom.")

To see how a stack works in computation, consider the expression \{ 2 3 + \} above. In FORTH, numbers are compiled as operations which place their values onto the stack. So when the 2 is executed, it is placed on top of the stack, which then looks as follows:

```
   2
   --
   --
```

where the dashes represent whatever data may have been on the stack before. Then after the 3 has been encountered, the stack becomes:

```
   3
   2
   --
   --
```

Then the + is executed. The 1-character word + takes two arguments from the stack (destroying them), performs the addition, and leaves the result on the stack. So the stack finally is:

```
   5
   --
   --
```

The reader can verify that when the formula \{ 4 5 + 6 7 + * \} is executed, the stack goes through the sequence shown in figure 1.

Now we can see why FORTH is not the best language for big number-crunching jobs. Numbers to be operated on must be moved to the stack in addition to whatever operations are to be carried out, and this extra movement slows FORTH down for this kind of computation. Once on the stack, however, arithmetic is fast (for example, single instruction execution for addition on some 16-bit machines, more for 8-bit machines). Also, FORTH can link the useful instructions of one routine and those of another in as little as one or two instruction executions (depending on machine architecture). This makes FORTH programs much faster than BASIC, usually ten times faster or more (assuming an interactive BASIC, that is—FORTH is always interactive). But a good FORTRAN compiler's code may do number-crunching several times faster still.

Characteristics of FORTH Code

FORTH is a structured language (as is Pascal) in that it has no GOTO or statement labels in the language. Discussion of structured programming is outside the scope of this article, but its importance for program correctness and maintainability is recognized.

FORTH object code (ie: a compiled program) is extremely compact, even more so than machine language. The reason is that no matter how much work an operation performs, each invocation of it takes the same space in the object program—two bytes. The bigger the program, the greater the memory advantage, since the hierarchical structure of programs allows increasingly powerful and application-targeted operations to be built up. But FORTH has a relatively large run-time memory overhead, so small programs can take less total space in other languages.

[The reason that a FORTH call can be shorter than a normal machine-language subroutine call (usually three bytes) is that a FORTH program is interpreted by a FORTH interpreter (also part of the FORTH language) in much the same way that a BASIC program is interpreted by a BASIC interpreter. The "relatively large run-time memory overhead" mentioned above is the FORTH interpreter plus a core of FORTH words defined in machine language. When a FORTH program is very large, it saves enough memory in FORTH calls to make up for run-time memory overhead.... GW]

The complete FORTH system (itself largely written in FORTH) takes about 7 K bytes, and this whole system including the compiler is com-
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grams are sufficient hardware for an application program. Therefore, 16 K bytes and a floppy disk for storing source programs are sufficient hardware for an excellent FORTH system (compare this with the memory requirements of Pascal, 48 K bytes or more). When compactness is especially important, as when programs are burned into read-only memory and embedded in machinery, FORTH's compiler, terminal handler, and operation names—anything not needed to run—can be stripped out of the application program, leaving a runtime package of about 800 bytes, instead of the usual 7 K bytes.

FORTH programming is reentrant; this means that different users can share the same copy of a program in memory while running at the same time. FORTH easily handles multitasking, including multiple terminals used for program development. (At present, however, most of the low-cost systems on the market are still single-user.) FORTH is recursive, meaning that routines can invoke themselves.

Suppose you want to link your high-level-language program to a machine-language subroutine (eg: you may be controlling a high-speed device and need the full speed of the computer to keep up). Many languages make this linkage difficult or impossible. In FORTH, however, it is very convenient. You can type in or load from disk a machine-language routine, using a FORTH assembler, and the new routine can be executed immediately. Listing 9 shows examples for PDP-11 and for 8080.

The word CODE invokes the FORTH assembler and begins the definition of a machine-language routine. Mnemonic instructions and address-mode symbols are understood by this assembler, and the whole power of FORTH is available for address arithmetic at assembly time. FORTH assemblers use postfix notation, so op codes come after their addresses, not before as in conventional assemblers.

The machine-language code is generated as the definition is being entered. The completed operation works just like any other FORTH word, so the user does not need to use any special calling sequence, or even need to know which operations are defined in code and which are not. (In fact, about fifty FORTH words are written in machine language—all other words in FORTH are ultimately defined in terms of these fifty words.)

The FORTH assembler allows structured conditionals and loops at the machine-code level; it can also assemble unstructured code if desired. Users can define their own macro-instructions, use custom-made data types, etc.

In other words, the FORTH assembler allows structured programming even in machine code, and it links the resulting machine-language subroutines into the system immediately. No separate assembly and linking-loader passes are needed, and the associated file management overhead is avoided.

Some More Advantages

FORTH programs are highly transportable between different computers. Any assembly-language routines used by the program must be rewritten, but most applications do not need any assembly, and very few need more than a handful of short, critical routines. When FORTH systems have been designed for compatibility, large applications can be moved among very different
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machines, with little or no change. For example, it can be practical to down-load program development from a PDP-11 to a TRS-80 or an Apple II. It is even possible to write the software for a product before a hardware commitment is final.

Another advantage is that FORTH is a self-contained operating system. The 7 K bytes include terminal and disk handlers and a rudimentary file system. No other software is needed anywhere in the computer. Yet, if a monitor in read-only memory is available, FORTH can use it; and FORTH can run as a task under some other operating system (eg: CP/M) when that is wanted. FORTH can link together otherwise incompatible pieces of systems: software in read-only memory, operating systems, subroutine packages, and hardware. It provides a user interface that enables subroutine packages normally used by batch (ie: noninteractive) programs, mostly on older, larger computers, to be used interactively.

FORTH puts you in charge of your computer. You can understand everything happening in your software or in any desired parts of it, and you can change it. This means no more "black box" systems that only the manufacturer's specialists can understand, no more dependence on someone else for upgrades, fixes, or documentation, and no more question of who is responsible if software does not work. The whole system is written in FORTH, right down to the bits—your application programs, the compiler, the operating system, the I/O drivers, etc. You do not have to learn some other language or be a systems specialist to modify it.

Disadvantages

Few FORTH systems used today have floating-point arithmetic. This is not a fault of the language; rather, it reflects its history in microcomputer control applications, where integer arithmetic is often needed for speed. Now there is more pressure for floating point, and it is becoming available.

A more fundamental limitation of FORTH is that it is not a typed language (unlike Pascal). For example, if an integer operation is performed on a floating-point quantity, no message is printed either at compile time or at run time to warn of this error. (However, the user can add type checking and other error-preventing operations into any FORTH word.)

It may seem that unreliable code would result from the untyped nature of FORTH, but, in fact, FORTH code is remarkably solid and bug-free. The modularity and excellent testing environment aid error control; and type mismatches are less dangerous than most other mistakes because they are easy to detect.

Another criticism of FORTH is its lack of a directory file structure. Again, this is historical and is not a characteristic of the language, which can be developed to use any kind of files.

The traditional FORTH file system is primitive, but in practice it has worked very well. The entire disk (or disks) is a single virtual array of blocks numbered from 1, with the block size standardized at 1024 bytes regardless of physical disk sector size. The blocks (called screens because they can be displayed as sixteen 64-character lines on a terminal) are automatically buffered so that they are physically read and written only when necessary. A LOAD command will read a given screen and treat the information exactly as if it had been typed in a terminal session, thereby compiling source code or executing commands (depending on the contents of the screen). The LOAD instruction can be executed within a screen; in this way, a single LOAD command can control the compilation of large source programs.

This disk-based file system allows any part of the disk to be read or written with a single access. Load screens or data areas can be saved by name, and portions of the disk can be protected by redefining the names of a few input and output operations so that they check before writing and/or reading.

The disadvantage of this system is that there is no directory; when a new disk is inserted, the user or the program must know the block numbers for load screens and data files. Also, FORTH source programs are traditionally stored without tabs or truncation of blank lines, making whitespace (ie: unused area on a line) and
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FORTH uses punctuation in some of its words, which makes representing them in text a difficult problem. For example, one FORTH word is ("), which could be taken to mean one of several character combinations. (For your information, the word has three characters and is made from a left parenthesis followed by a double quote mark and a right parenthesis.)

To decrease the chance of confusion while trying not to clutter text unnecessarily, we will sparingly use braces, { }, to isolate the character string within a FORTH word or phrase. (For example, the above word would be written {"} { }.). Braces will be used only under the following situations:

- when the material being quoted is a phrase of FORTH words (eg: { 26 LOAD } or { 3 5 + })
- with the FORTH words { }, (period), { . } (comma), { i } (colon), { ; } (semicolon), { } (question mark), { ' } (exclamation point), { " } (single quote mark), and { " } (double quote mark)
- with any word using the above punctuation marks (eg: { $ } or { . } )

All other FORTH words will be set apart by a space on either side of the word. So, in this and other FORTH articles in this issue, braces will always signal a FORTH word or phrase. The braces are not part of the word or phrase, and FORTH words will never use braces within the body of a figure or listing...GW

On the Necessity of Using Camera-Ready Copy

Examination of listings 1 thru 10 will reveal a variety of typesfaces used. This variety is present because each listing was created by the printer of the system producing the listing. Such listings are called camera-ready copy, which means that we can reproduce them in BYTE without inadvertently adding the errors that creep in with the retyping of a listing. Contributors to BYTE and onComputing are strongly encouraged to submit camera-ready listings made with a fresh ribbon, since this helps us to improve the accuracy of the article.

64KB RAM MEMORIES

<table>
<thead>
<tr>
<th>Product</th>
<th>Price</th>
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<tr>
<td>LSI-11</td>
<td>$750.00</td>
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<td>S-100</td>
<td>$750.00</td>
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<tr>
<td>CI-1103</td>
<td>$750.00</td>
</tr>
<tr>
<td>Cl-6800</td>
<td>$750.00</td>
</tr>
</tbody>
</table>

Cl-6800-2 64K x 9
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Listing 1: FORTH as a calculator. FORTH is easy to approach because it can be used as a calculator. Here, the programmer has not defined any new operation but has used addition, multiplication, and print (the dot means print). These are three of about one hundred operations that are available when FORTH first comes up. Programming consists of defining new operations which can be custom designed for a particular task or a particular industry.

FORTH uses postfix (also called RPN or reverse Polish notation) arithmetic, which is best known from its use in Hewlett-Packard calculators. In postfix notation, the operations are written after their arguments, not between them. The text of this article shows how postfix notation works, using a data structure called the stack, and it explains the formulas in this example.

Postfix notation, which does not use parentheses, is more general than ordinary arithmetic notation. Its biggest advantage is that it greatly simplifies the writing and calling of subroutines.

In these examples, underlining indicates what the user has typed on the terminal. FORTH does not process the line until you type a carriage return. The OK prompt means that the system has completed its work and is ready for new input from the user.

Listing 2: Changing number bases. FORTH can work in different number bases and can change any time, so it serves as an octal/hexadecimal/binary/decimal calculator within the limits of 16-bit numbers (or 32 bits for double precision). The FORTH word HEX converts FORTH into a hexadecimal machine, and all numbers are printed in hexadecimal...

Listing 2 continued on page 112
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Listing 2 continued:

hexadecimal until some other operation changes the base again. FORTH always begins a session in decimal radix.

The operations DECIMAL and HEX are built into the system; OCTAL, BINARY, and TRINARY (base 3) are not. So when OCTAL was first used, the error message \{ OCTAL ? \} indicated an undefined word; that is, the system did not recognize the word OCTAL. In the next line, the user defined OCTAL (line 6). This example illustrates FORTH's extensibility; users can extend the language to include new operators.

Incidentally, the second error message \{ 12885 ? \} in line 12 resulted because the system was in binary (from the line above), and, in binary, numbers must contain only the digits 0 and 1, so 12885 was not recognized as a number. It was treated as a word, and, because there was no operation named 12885, the error message was generated.

OCTAL and the other number-base operations work by giving a new value to BASE, a variable used by the system. Defining new operations is more fully explained in listing 3. The \{ 1 \} operation (store) is explained later.

Number bases only affect input and output. All internal computation is in binary, so there is no speed penalty for using nondecimal numeric bases.

Listing 3: Defining new operations. Here, a new operation CUBE is created. CUBE replaces whatever number is on top of the stack with the cube of that number. The statements within the parentheses are comments.

The colon \{ CUBE \} begins a FORTH word definition; the word following it is the name being defined. Semicolon, \{ ; \}, ends the definition.

The new word CUBE will first execute DUP, which duplicates the number on top of the stack, making a second copy. The second DUP leaves three copies. The first \* causes the top two copies to be replaced by the square of the number; the next \* computes the cube, and then all three copies of the original number are gone, leaving the cube of the number on top of the stack.

This colon definition shows one of several ways to create new words in FORTH. Most words that appear inside the definition are compiled and not executed immediately.

All words and numbers in FORTH are separated by one or more blanks (and/or carriage returns). FORTH operation names can be up to thirty-one characters long and can consist of letters, numbers, or any other characters. For example, an operation name could be a number, or it could be nonprinting characters only. In practice such names are rarely used, but they illustrate the flexibility that is available.

Listing 3 continued on page 114
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Listing 3 continued:

This listing shows CUBE being executed from the terminal. It can also be used as a component in further definitions. A fundamental property of FORTH is that operations defined by users are indistinguishable from those which were originally part of the system.

```
: CUBE ( N -> N; CUBE A NUMBER)
  DUB DUN I NOW THERE ARE THREE COPIES
  ; OK
5 CUBE - 125 OK
-28 CUBE -21952 OK
HEX 17 CUBE BINARY ; DECIMAL 10111110000111 OK
```

Listing 4: Conditional branching. The IF ... THEN is for conditional execution. IF takes one argument off of the stack; this argument is interpreted as a boolean or truth value, with 0 meaning false and any nonzero value meaning true. If true, any statements between the IF and THEN are executed. In either case, execution continues after the THEN, which terminates the conditional. There is also an optional ELSE clause that is executed only if the argument is false. (See figure 2.)

Here, the true-clause contains only one word, MINUS, but it could contain almost any FORTH statements, including other conditionals and loops nested to any practical depth. These statements run fast because they are compiled into a form of object program called threaded code.

Incidentally, the FORTH word 0< returns a boolean value indicating whether its argument (the number on top of the stack) is less than zero. The DUP is necessary because 0< follows the FORTH convention that operations should destroy their arguments on the stack. MINUS reverses the sign of its argument (the top stack number).

Items in parentheses are comments. The comment "N -> N" in the first line is to show that this operation takes one number off of the stack and returns one number to it. Perhaps the most important information to put in the comments accompanying each new operation is what arguments it takes off of the stack and what results it returns to the stack.

```
: ABSOLUTE-VALUE ( N -> N; ABSOLUTE VALUE)
  DUP OK ( GET BOOLEAN, TRUE IF NEGATIVE)
  IF MINUS THEN ( NEGATE THE NUMBER IF TRUE)
  OK
10 ABSOLUTE-VALUE 10 OK
5 ABSOLUTE-VALUE 5 OK
```

Listing 5: The DO ... LOOP, a structured loop with a counting index. DO takes two arguments from the stack, the initial value of the index (on top) and the final value plus 1. (See figure 3.) These indices are written in reverse order from most other languages, making the loop terminating value (which is more often passed as an argument) more accessible on the stack.

CR simply performs a carriage return. In this example, the index values are literals (10 and 0), but they can also come from variables or from computations of any complexity; anything that gets the indices onto the stack is legitimate.

This listing also shows a timing benchmark; the word TIME-TEST does 30,000 empty loops. On an Apple II running FORTH, TIME-TEST executes in less then 4 seconds. In Apple Integer BASIC (which is a fast BASIC), 30,000 empty loops take 40 seconds.

```
: CUBES ( N -> PRINT A TABLE OF CUBES OF 0-9)
  10 D (INDICES OF LOOP)
  DO (START LOOP)
  IF I CUBE (PRINT A NUMBER AND ITS CUBE)
  LOOP (END OF LOOP)
  OK

: CUBES
  0 0
  1 1
  7 8
  3 27
  4 64
  5 125
  2 8
  6 216
  7 343
  8 512
  9 729 OK

: TIME-TEST 30000 0 DO LOOP ; OK
: TIME-TEST OK
```

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Listing 6: The BEGIN ... UNTIL loop. This loop takes one argument, a truth value, usually computed within the loop, at the end. If it is false (0), control branches to the corresponding BEGIN; if the value is true (nonzero), the loop ends, and control transfers to the next word in the program. (See figure 4.)

Note that the test of the value on top of the stack occurs at the end of the body of the loop; this guarantees that the body of the loop will be executed at least once.

The word = removes the top two numbers from the stack and returns a truth value of 1 if they are equal, 0 otherwise. In this example, the index stays on the stack and is duplicated before each use. The DROP at the end throws away the top stack value; this prevents the used index from cluttering the stack.

The warning message "1OCUBES ISN'T UNIQUE" notifies us that the same name has already been defined. The only penalty for reusing a name is that the former definition becomes inaccessible for the rest of the program. Therefore, you do not have to remember a list of reserved words in FORTH; if you do not know about a name or have forgotten about it, you probably were not planning to use it anyway. But, in case of a mistake, the bad definition can be deleted with a FORGET operation, or the source code can be changed on disk.

[Some versions of FORTH use BEGIN ... END instead of BEGIN ... UNTIL ... GW]

Listing 7: The BEGIN ... WHILE ... REPEAT loop. This looping structure tests the value on top of the stack at the beginning of the loop; because of this, this loop can execute 0 times. REPEAT causes an unconditional branch back to BEGIN, and WHILE branches out of the loop (just beyond REPEAT) if the truth-value which it finds on top of the stack is false (ie: 0); see figure 5.

All of these looping and conditional branching structures can be nested within each other to any practical depth. Any mismatching can be detected at compile time. Most FORTH systems allow these structures only inside colon definitions; they cannot be executed directly from the terminal.

[Some versions of FORTH use: BEGIN ... IF ... WHILE or WHILE ... PERFORM ... PEND instead of BEGIN ... WHILE ... REPEAT .... GW]
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Figure 3: An explanation of the DO ... LOOP construct. As shown in figure 3a, the top number on the stack is taken to be the lower limit of the loop variable, I, and the next-to-top number on the stack is the upper limit of the loop variable + 1. The body of the loop is shaded, and the loop variable is incremented and tested after the body of the loop is executed. Figure 3b gives the equivalent construct in conventional flowchart notation.

Figure 4: An explanation of the BEGIN ... UNTIL construct. As shown in figure 4a, the body of the loop (shaded) is repeated only if the value on top of the stack when the word UNTIL is reached is false. Figure 4b gives the equivalent construct in conventional flowchart notation.
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CP/M® is a registered trade name of Digital Research. FAMOS™ is a trade name of MVT Micro Computer Systems. HARDTAPE™ is a trade name of Konan Corporation.
Listing 8: An example of FORTH looping. A practical use of FORTH's structured looping is this terminal output handler. This example is for a PDP-11; for an example for other computers would be similar. Address 177564 (octal) is the output status register of the console terminal; bit 7 of this address is set when the device is ready to receive a character. The ASCII code for the output character can then be placed in address 177566 (the data buffer register).

The FORTH word @ (pronounced fetch) does the work of PEEK in BASIC; it treats the number on top of the stack as an address and replaces it with the contents of that address word. AND does a "bitwise" boolean AND operation. So { 177564 @ 200 AND } indicates true (nonzero) only if bit 7 of the status register is set. Until then, the BEGIN ... UNTIL loop does a waiting loop ending on the above condition. When the device is ready, the argument that was given to TERMINAL-OUT (an ASCII character to be written) is still on top of the stack; { } (pronounced store) stores the word that is second on the stack into the address that is on top of the stack; so { 177566 ! } transmits the character to the terminal data buffer register, from which it will be written onto the terminal by the hardware of the PDP-11 system.

The FORTH word ASCII-TEST was written to test the TERMINAL-OUT word. It transmits ASCII values for all of the printable character set.

Listing 9 shows the same device handler, only written in machine-language code with a FORTH assembler.

```
Listing 9 continued on page 122
```
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- TEX (Text Formatter)—$75.
- DESPOOL™ (Background Print Utility)—$50.

All are supplied on a diskette, with operating manual.
Listing 9 continued:

Collectively, { ] } and CODE are called defining words because they are used to create new FORTH words. There are several other such functions in FORTH, and users can also define their own types of defining words, creating new data types or operation types; see listing 10.

```
CODE TERMINAL-OUT-2 ( CHAR -> , TERMINAL OUTPUT HANDLER: POP-2 ) OK
BEGIN
  177564 200 @ BIT; NE UNLIL; ( WAIT TILL PORT READY ) OK
  $1> 177566 MOV, ( POP FORTH STACK INTO DATA REGISTER ) OK
  NEXT; ( A 2-INSTRUCTION MACRO TO CONTINUE FORTH EXECUTION ) OK
  C1; ( GET OUT OF THE FORTH ASSEMBLER ) OK
DECIMAL OK
  ASCII-TEST-2 (-), PRINT ASCII CHARACTER SET
  #74 40 ( ASCII BLANK THROUGH 1*74 )
  DO 1 TERMINAL-OUT-2 LOOP ( OUTPUT THE CHARACTERS ) OK

Listing 10: User-defined data types. Because this example is longer, it was not typed in directly like the others, but was stored on disk with an editor (the editor session is not shown here). This example is contained in two disk screens, each of which is a virtual block of 1024 bytes (see text). The commands \{ 59 LIST \} and \{ 59 LIST \} print these screens. The line numbers (0 thru 15) are not part of the program and are used only by the editor.

This example creates table-lookup sine and cosine routines for integer-degree arguments. The results are accurate enough for most graphics applications, making this situation an example of the versatility of FORTH, even without floating-point routines.

The definition of TABLE creates a new data type. When TABLE is executed, it creates a new table of numbers taken from the stack; the number on top of the stack tells how many items there are in the table. Source code is supplied on standard 8" diskette.

FPP on CP/M diskette...

用户定义的数据类型。因为这个示例更长，所以没有直接输入，而是存储在磁盘上与编辑器一起使用。这个示例包含在两个磁盘屏幕上，每个屏幕都是一个虚拟块，大小为1024字节（见文本）。命令{ 59 LIST }和{ 59 LIST }打印这些屏幕。行号（0到15）不是程序的一部分，而是用于编辑器。

这个示例创建了用于整数度数的表格查找正弦和余弦函数。结果足够准确以用于大多数图形应用程序，这是FORTH的灵活性的一个例子，即使没有浮点运算。

TABLE的定义创建了一个新数据类型。当TABLE执行时，它创建了一个新的从堆栈中取数的表；堆栈顶部的数表示表中有多少项。源代码附在标准8"磁盘上。

FPP在CP/M磁盘上...

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• ASCII Character Set:

<table>
<thead>
<tr>
<th>ASCII Character Code</th>
<th>Character</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>Space</td>
</tr>
<tr>
<td>0001</td>
<td>Command</td>
</tr>
<tr>
<td>0002</td>
<td>Control</td>
</tr>
<tr>
<td>0003</td>
<td>ESC</td>
</tr>
<tr>
<td>0004</td>
<td>Enter</td>
</tr>
<tr>
<td>0005</td>
<td>Del</td>
</tr>
<tr>
<td>0006</td>
<td>Backspace</td>
</tr>
<tr>
<td>0007</td>
<td>TAB</td>
</tr>
<tr>
<td>0008</td>
<td>LF</td>
</tr>
<tr>
<td>0009</td>
<td>CR</td>
</tr>
<tr>
<td>0010</td>
<td>VT</td>
</tr>
<tr>
<td>0011</td>
<td>FF</td>
</tr>
<tr>
<td>0012</td>
<td>Home</td>
</tr>
<tr>
<td>0013</td>
<td>End</td>
</tr>
<tr>
<td>0014</td>
<td>PgUp</td>
</tr>
<tr>
<td>0015</td>
<td>PgDn</td>
</tr>
<tr>
<td>0016</td>
<td>Ins</td>
</tr>
<tr>
<td>0017</td>
<td>Del</td>
</tr>
<tr>
<td>0018</td>
<td>Home</td>
</tr>
<tr>
<td>0019</td>
<td>End</td>
</tr>
<tr>
<td>0020</td>
<td>PgUp</td>
</tr>
<tr>
<td>0021</td>
<td>PgDn</td>
</tr>
<tr>
<td>0022</td>
<td>NumLock</td>
</tr>
<tr>
<td>0023</td>
<td>CapsLock</td>
</tr>
<tr>
<td>0024</td>
<td>ScrollLock</td>
</tr>
<tr>
<td>0025</td>
<td>NumPad</td>
</tr>
<tr>
<td>0026</td>
<td>Insert</td>
</tr>
<tr>
<td>0027</td>
<td>Delete</td>
</tr>
<tr>
<td>0028</td>
<td>PAUSE</td>
</tr>
</tbody>
</table>

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SERIES OF STATEMENTS
THAT LEAVE A TRUTH
VALUE, N, ON TOP OF STACK

BEGIN
A
B
WHILE
D
E
REPEAT
F

N IS TESTED HERE;
IF N=0, JUMP TO FIRST
WORD AFTER "REPEAT"

BODY OF LOOP:
EXECUTED IF AND ONLY
IF N # 0

BY THIS POINT,
THE TRUTH VALUE,
N, IS ON TOP OF
STACK

Figure 5: An explanation of the
BEGIN ... WHILE ... REPEAT construct.
As shown in figure 5a, the FORTH words
between BEGIN and WHILE perform
operations that leave a truth value, N, on
top of the stack. The value of N deter­
mines whether the body of the loop (the
words between WHILE and REPEAT) is
performed or not. The loop repeats until
N evaluates to false (N=0). Figure 5b
gives the equivalent construct in conven­
tional flowchart notation.

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You should also look at FORTH if you have limited computer or financial resources. FORTH is a big language in a small package, and you can buy a version of FORTH for as little as $20. (See "Selected FORTH Vendors," on page 98.) Unlike most new languages that gobble up more and more of the 64 K bytes allotted to an 8-bit microcomputer (some won't comfortably fit in 64 K bytes), there is plenty of room for very large FORTH programs even in a 16 K machine. FORTH takes up only about 8 K bytes, and this can be pared down; in an industrial application that will run only one program, the FORTH interpreter can be made as small as 800 bytes. Also, FORTH can be run on cassette-based systems due to its small size; although this is still more inconvenient than running FORTH on a disk system, most languages that use a disk are impractical or impossible on cassette-only systems.

Finally, you may want to consider FORTH for applications where speed is of the utmost importance. Since portions (or all) of a FORTH program can be written in the assembly language of the host computer, FORTH programs can be written that compare favorably in speed with machine-language programs. And, again, productivity is higher using FORTH than it is with machine language.

What Is a Threaded Language?
Imagine a language that starts with a few fundamental subroutines written in the machine language of the host computer; eg: routines to put a character to the display device, to get a character from the keyboard, to multiply two fixed-point numbers. Then imagine that the only way to combine these subroutines is to string them together (with embedded data bytes) as a series of subroutine calls; eg: a routine to get a signed digit number from the keyboard is written as a controlled series of calls to the subroutine that gets a character. Then these routines are called by other routines that perform even bigger tasks. For example, a routine to sum a series of signed numbers entered from the keyboard is written as series of subroutine calls that includes the one mentioned just above. The final pro-

### Special Notation Used in This Issue
Because FORTH is such an unusual language (it uses punctuation marks by themselves and within words), a pair of braces, 

```
{ }  
```

is sometimes used to set apart FORTH words from the rest of the text. Braces are used under the following conditions:

- When the material being quoted is a series of FORTH words; eg: 

```
{ 26 LOAD } ;  
```

- When the FORTH word is or contains any of the following punctuation marks: period, comma, colon, question mark, exclamation point, single quote mark, or double quote mark. Two examples are 

```
( ... )  
```

In addition, spaces are always used to separate FORTH words from other words or punctuation—even when this means doing something like "... the words BEGIN, WHILE, and REPEAT are all..." (spaces between FORTH words and the commas that follow them). There are two reasons for doing this: first, for clarity; and second, to emphasize that the FORTH word in question does not include the punctuation that follows. Some FORTH words do contain punctuation (eg: 

```
{ IF }  
```
)
but such words will always be enclosed in braces (except within program listings).

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FORTH: Pro and Con

Pros: I have already mentioned most of the advantages of FORTH. The language is:

- Compact;
- Fast, although this is due to its implementation in threaded code, not its inherent qualities;
- Structured: it has the major constructs of structured programming and, in fact, does not have any kind of goto statement, thus forcing it to be structured;
- Extensible;
- Highly portable.

These last two features deserve further description. The extensibility of FORTH is probably its most important feature. Never before in a high-level language has it been so easy to add new features, new data types, and new operators to a language. Unlike other languages, these new words (everything in FORTH is called a word) have the same priority and receive the same treatment as words defined in the standard FORTH vocabulary. For example, you can define a word 10+ that will add ten to any number it is given; or, in fact, you can even redefine the addition operator +. You can also define entirely new families of words in FORTH. This advanced topic is ably discussed in what I believe is the only written treatment of the subject anywhere in FORTH literature by Kim Harris in his article, "FORTH Extensibility," on page 164.

Most FORTH programs can be transferred from, say, a mainframe computer to a microcomputer without modification; therefore, FORTH is highly portable. Most of the FORTH words supplied in a given system have been defined to do the same operation regardless of the computer used. Although the vocabulary of words varies from supplier to supplier, most FORTH programs will run with minor or no modifications. A standard set of words, called FORTH-79, collectively developed by many of the major suppliers and users of FORTH, will help in this situation.

Cons: Here are some of the disadvantages of FORTH:

- FORTH code is hard to read. This is probably the most common complaint against the language. As a new user, I can say that you slowly get used to the odd syntax of the language. The stack architecture (see below) of the language contributes to the novice's initial disorientation, but this feeling is usually blamed on the unreadability of the language. In addition, the stack architecture encourages the storage of working values on the stack rather than in variables with names. Variable names, if chosen properly, give vital clues to the workings of a program; this scarcity of variable names makes most FORTH programs less readable. Adequate indentation and comments can help a FORTH program, but programmers of FORTH, like programmers of all other languages, often omit these aids to comprehension.

- The stack architecture of FORTH offers disadvantages as well as advantages. Remember the odd feeling you got the first time you used a Hewlett-Packard calculator and had to punch in "5 ENTER 3 + " instead of the more understandable "5 + 3 = " . FORTH uses the same reverse Polish notation (abbreviated RPN), where the objects being entered come before the operators that work on them. Not only does this take some getting used to (it takes even longer before you can fluently "think in FORTH"), it also encourages a scarcity of named variables, as mentioned above. In addition, stack-manipulating words like SWAP, DUP (for duplicating the top entry on the stack), ROT (for rotating the top three items on the stack), and others muddle the FORTH program and make it hard to tell just what variable is being operated on. This uncertainty is particularly evident during debugging; most of your time is spent finding out why what you thought was on the stack isn't there.

- FORTH encourages programming "tricks" in place of plain, easier to read programming. Although the examples to support this statement have already been mentioned, I think the statement as a generality is true. We must remember that, especially since lack of memory is usually not a problem in FORTH, FORTH programmers should name appropriate variables and, in general, worry less about fitting a program on one screen (a basic unit of FORTH program-
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ming) and more about making it readable.

However, drawing a comparison to APL, any language that compresses a lot of program into a small number of lines suffers from readability problems. Broad, powerful algorithms often represent complex processes; when they are described in a terse notation, they look like programming tricks. In this case, the only remedy is to use a lot of comments. The lack of such comments is solely the fault of the programmer, not of the computer language.

- FORTH lacks many of the programming constructs we are used to—strings, arrays, floating-point numbers—but that's not the whole story. Many applications, for example, can get by without floating-point numbers: look at the number of programs written in Integer BASIC for TRS-80. With a maximum absolute numeric value of 32,767, normal FORTH can handle many problems by simply assuming a decimal point. In addition, all versions of FORTH can add all these features and more, simply by defining new words. For example, MMSFORTH, a version of FORTH for the TRS-80 by Miller Microcomputer Services, has over ten screens (each screen is 16 lines of source code) that implement their version of words for double-precision math, arrays, strings, random numbers, and TRS-80 graphics. You compile a series of screens, thus adding to the size of your resident FORTH interpreter, only if you need these features. So you can have all these programming constructs and tools, but only if you write them yourself or get somebody else to write them for you.

Friends of FORTH

Almost everyone who is working in FORTH professionally is doing good work, but a few people or groups of people deserve special mention. Foremost in this group is Charles H Moore and, through him, the company FORTH Inc. Moore developed the language over a long period of time (see his article "The Evolution of FORTH, An Unusual Language," on page 76) and promoted it through the company FORTH Inc. Elizabeth Rather, who contributed significantly to the development of the language and who is vice-president at FORTH Inc, should also be mentioned in this context.

Then there is the FORTH Interest Group (PO Box 1105, San Carlos CA 94070), without whose efforts low-cost versions of FORTH would not be available. Although many people in the group have contributed to its working, names that must be mentioned are Bill Ragsdale (coordinator), Dave Boulton, Kim Harris, John James, and George Maverick. Over the past two years, this group has collectively raised its membership from a few dozen people in northern California to over a thousand members worldwide. In the process, they have also publicized FORTH at numerous conventions and have distributed public-domain versions of FORTH (called fig-FORTH) for all the major microprocessors; ie: 8080, 6800, 6502, 9900, PACE, and LSI-11. Although they supply only listings and documentation, versions customized for various popular microcomputers are available inexpensively. In addition, they are working on standardizing certain extensions to FORTH (floating-point numbers, arrays, etc.), and they publish a very professional-looking bimonthly magazine called FORTH Dimensions. The group has monthly meetings at the Liberty House Department Store in Hayward, California, on (what else?) the fourth Saturday of each month. Membership in the FORTH Interest Group (which includes a subscription to its magazine) is $12 per year, $15 overseas.

A final group that must be mentioned is Miller Microcomputer Services of Natick, Massachusetts, which sells and supports a version of FORTH, called MMSFORTH, and other related FORTH products for the Radio Shack TRS-80 Model I. Not only do they provide a fine version of FORTH with arrays, strings, graphics, and other extensions, they are the only microcomputer-FORTH vendor that supports its product with both information and new vocabularies of FORTH words. (For example, they have a set of FORTH words that add 6- and 15-digit floating-point arithmetic, complex numbers, and a full Z80 assembler, all for $29.95.) They also publish an MMSFORTH Newsletter that always has some
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GET INTO THE TIME MACHINE.

DIGITAL PATHWAYS
Miller, along with free-lance pro-

grammer Tom Dowling, who wrote MMSFORTH for the TRS-80.

In addition, the major vendors of FORTH should be commended for the way they have worked and are working together to help standardize the language. The people mentioned above, along with the European FORTH Users' Group (EFUG), have met as the International FORTH Standards Team to work out a standard set of FORTH words (with standard behavior) that can be used to increase the already high portability of FORTH programs. Once the proposed FORTH-79 standard is approved by this standards team, FORTH Inc, the FORTH Interest Group, and Miller Microcomputer Services have indicated that they will bring out new FORTH versions conforming to this standard.

Variants of FORTH

A few other FORTH-like languages should be mentioned here. URTH (University of Rochester TThreaded language) is simply FORTH by another name. I am told that CONVERS, an experimental language that was offered by the Digital Group, is a FORTH-like language.

STOIC is a language that is different from FORTH primarily in some small syntax rules, although its enthusiasts claim it is more powerful than FORTH. From reading the documentation, I have found that STOIC interacts differently and has more sophisticated disk access than FORTH. CP/M Users Group (1651 Third Ave, New York NY 10028) distributes STOIC on two 8-inch single-density CP/M floppy disks; the cost is $20, which includes postage, documentation (on CP/M DOC files), and group membership fees. STOIC was developed by Roger G Mark and Stephen K Burns in the Biomedical Engineering Center for Clinical Instrumentation, funded by the Harvard-MIT Program in Health Sciences and Technology in Cambridge, Massachusetts.

Also, I am very excited about a book nearing publication: Threaded Interpretive Languages by Ron Loeliger. This book, to be published soon by BYTE Books, delves deeper into the practical aspects of designing and implementing a threaded language than any book I have seen. Not only does it demonstrate exactly how the machine code must work, it also details the specific implementation of Z80 (which looks like FORTH under another name) in Z80 assembly language. The book promises to be the definitive work on how threaded languages perform.

Final Notes

As we received more and more FORTH articles, I realized that we would soon have too many for this special August issue. I immediately scheduled for subsequent nontheme issues those extra articles we could not use at this time, a process known as “holding down the FORTH.” In any case, we have several FORTH articles that will appear in upcoming issues of BYTE. These include an article on recursion in FORTH by George Flammer, a tutorial on string-manipulating FORTH words by John Cassady, a history of the FORTH Standards Team by Bill Ragsdale, and a detailed discussion of the different kinds of threaded codes by Terry Ritter and Gregory Walker.

We hope you will enjoy looking at the FORTH tapestry presented in this issue.

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<td>11T</td>
<td>4963 29A/64A</td>
<td>7710/7720</td>
</tr>
<tr>
<td>Unformatted Capacity (millions of bytes)</td>
<td>8/24</td>
<td>11</td>
<td>29/64</td>
<td>29A/64</td>
</tr>
<tr>
<td>Platter Size</td>
<td>210mm (8.27 inch)</td>
<td>200mm (7.87 inch)</td>
<td>210mm (8.27 inch)</td>
<td>200mm (7.87 inch)</td>
</tr>
<tr>
<td>Number of Platters</td>
<td>1 or 2</td>
<td>2</td>
<td>3 or 6</td>
<td>2</td>
</tr>
<tr>
<td>Average Access Time</td>
<td>42 ms</td>
<td>50 ms</td>
<td>27 ms</td>
<td>50 ms</td>
</tr>
<tr>
<td>Maximum Data Transfer Rate (K bytes per second)</td>
<td>800</td>
<td>648</td>
<td>1030</td>
<td>648</td>
</tr>
<tr>
<td>Average Latency</td>
<td>8.3 ms</td>
<td>8.3 ms</td>
<td>9.7 ms</td>
<td>8.3 ms</td>
</tr>
<tr>
<td>Rotational Speed</td>
<td>3600 rpm</td>
<td>3600 rpm</td>
<td>approx. 3100 rpm</td>
<td>3600 rpm</td>
</tr>
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<td>Motor Type</td>
<td>brushless DC</td>
<td>brushless DC</td>
<td>—</td>
<td>brushless DC</td>
</tr>
<tr>
<td>Spindle Drive</td>
<td>direct drive</td>
<td>direct drive</td>
<td>—</td>
<td>direct drive</td>
</tr>
<tr>
<td>Actuator Type</td>
<td>linear voice coil</td>
<td>linear voice coil</td>
<td>rotary voice coil</td>
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<tr>
<td>Positioning Mechanism</td>
<td>servo</td>
<td>servo</td>
<td>servo</td>
<td>servo</td>
</tr>
<tr>
<td>Density bpi</td>
<td>6542</td>
<td>5868</td>
<td>8530</td>
<td>5868/6000</td>
</tr>
<tr>
<td>Density tpi</td>
<td>500</td>
<td>300</td>
<td>450</td>
<td>300</td>
</tr>
<tr>
<td>Physical Size</td>
<td>4.59 by 8.99 by 16</td>
<td>5.5 by 8.57 by 19.25</td>
<td>—</td>
<td>5.5 by 8.57 by 19.25</td>
</tr>
<tr>
<td>Weight (pounds)</td>
<td>20</td>
<td>22</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>Single Quantity Price</td>
<td>—/$3,100</td>
<td>$5,350$</td>
<td>approx. $9,300/$10,700</td>
<td>$2,990/$3,590</td>
</tr>
<tr>
<td>OEM Discount Price</td>
<td>Competitive OEM discounts available</td>
<td>—</td>
<td>—</td>
<td>$1,900/$2,290 (100)</td>
</tr>
<tr>
<td>Cost Per Thousand Bytes</td>
<td>—/—</td>
<td>—</td>
<td>—</td>
<td>—/—</td>
</tr>
<tr>
<td>Comments</td>
<td>Available with integrated SMD interface @ $3,500 and integrated controller with host bus interface for $3,900; all prices quoted are for 24 megabyte Model 6172. 1. Includes disk bus interface. 2. Complete subsystem</td>
<td>Up to 4 drives per subsystem. Add-on drives @ $2,990. Uses IMI 7710 drive. 3. Integrated into System/34. Add-on peripheral for Series 1.</td>
<td>Optional integrated controller available @ $500 (quantity 1); $325 (quantity 100). Power supply @ $250</td>
<td></td>
</tr>
</tbody>
</table>

**Text continued from page 70:**

- **SMD**
- **Floppy-disk-like**

The **ANSI interface**, as far as it is currently defined, will use a single 50-conductor flat cable. Up to four drives can be connected in a daisy-chain configuration. Differential drivers and receivers will be used only for block and data signals for read and write functions. All other lines will use standard TTL (transistor-transistor logic) signals. Control commands and status information will be transferred over an 8-bit-wide bidirectional bus. The bus control lines use an asynchronous handshake mechanism, allowing simple adaptation of the bus speed to any microprocessor. Data is transferred in serial NRZ (nonreturn-to-zero) format separated from the clock signal.

In the **ANSI-like interface**, most of the current device-level interfaces are more or less similar to the ANSI interface. Common to all are an 8-bit parallel control bus and serial NRZ data transfer.

**SMD (storage module drive) interface** is a industry standard for 14-inch drives and is being adapted for 14-inch drives by ANSl. It has also been implemented for 8-inch drives. The SMD interface uses differential drivers and receivers for all signals. (They give excellent performance as regards high speed, long cable lengths, and high noise immunity.) The drives are connected through...
one daisy-chain cable for control and one radial cable for read/write and additional control. Control information is transferred on a 10-bit-wide unidirectional synchronous bus. Data is transferred in serial NRZ format.

The SMD interface allows very high transfer rates and long cable lengths. Because SMD uses differential drivers and receivers for all signals, it is somewhat more costly than other interfaces using TTL circuits. Because of the 10-bit synchronous bus structure, SMD is not easy to interface to current 8-bit processors. The main advantage of SMD for 8-inch drives is that it is a standard, and controllers are readily available for easy integration into existing or currently supplied systems.

Having a floppy-disk-like interface for 8-inch hard disks allows the combination of floppy-disk drives and hard-disk drives in one system. Because of the differences in transfer rates and other parameters, floppy- and hard-disk drives are not fully interface-compatible. Hard-disk users must add a radial cable for differential read/write signals in addition to the normally used daisy-chain cable. By adding 15% to 20% more circuitry, a hard-disk controller can be designed to also control floppy-disk drives. However, a floppy-disk controller cannot handle a Winchester-type hard-disk drive.

In comparing floppy-disk-like interfaces with other device-level interfaces, there are three major differences. First, with floppy-disk-like interfaces there is no control bus because commands and status signals are transferred on discrete lines. Second, positioning control is achieved with step and direction signals as opposed to the transfer of a parallel-cylinder address with other interfaces. Third, data is transferred in the raw format as recorded on the disk. This implies that synchronization, separation (or generation) of clock and data, and generation and detection of sector and address marks must all be performed externally to the drive. The floppy-disk-like concept minimizes drive electronics, but puts the burden of developing and producing the balance of the required electronics on the user.

Table 4: Specifications and characteristics of high-end, 8-inch hard-disk drives.
Threaded languages (such as FORTH) are an exciting new class of languages. They are compact and fast, giving the speed of assembly language with the programming ease of BASIC, and combine features found in no other programming languages. An increasing number of people are using them, but few know much about how they work. Is a threaded language interpreted or compiled? How much memory overhead does it require? Just what is an "inner interpreter"? Threaded Interpretive Languages, by R. G. Loeliger, concentrates on the development of an interactive, extensible language with specific routines for the ZILOG Z80 microprocessor. With the core interpreter, assembler, and data type defining words covered in the text, it is possible to design and implement programs for almost any application imaginable. Since the language itself is highly segmented into very short routines, it is easy to design equivalent routines for different processors and produce an equivalent threaded interpretive language for other development systems. If you are interested in learning how to write better FORTH programs or you want to design your own powerful, but low-cost, threaded language specific to your needs, this book is for you.
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Introduction to Personal Computing, noon, Nov. 1.

Computer-Assisted Mathematics Courses, Dr. Frank Scalise, Queensborough Community College, 1 pm, Nov. 1.

Artificial Intelligence Update, Prof. Peter Kugel, Boston College, 1 pm, Nov. 1.

Compiling and Retrieving Personal Medical Data with a Microcomputer, Derek Estlander, MD, St. Luke's Hospital, 2 pm, Nov. 1.


High Volume Data Handling: Intro. to File Processing, Prof. Peter Kugel, Boston College, 3 pm, Nov. 1.

Connecting the Computer to the Outside World, Prof. James Gips, Boston College, 3 pm, Nov. 1.

Educational Applications in the Home, David Ahl, Creative Computing Magazine, 4 pm, Nov. 1.

Household Applications - Some of Them New, Dr. Dennis M. McGuire, 4 pm, Nov. 1.

(Additional lectures to be announced)

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Circle 95 on Inquiry card.
<table>
<thead>
<tr>
<th>Model</th>
<th>Century Data Systems Anaheim CA</th>
<th>Century Data Systems Anaheim CA</th>
<th>Fujitsu America Inc Santa Clara CA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unformatted Capacity</td>
<td>Marksman M-10/M-20/M-30</td>
<td>Hunter H-32/H-64/H-96</td>
<td>M2292/M2283/M2294</td>
</tr>
<tr>
<td>Platter Size (inches)</td>
<td>14</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Number of Platters</td>
<td>1, 2, or 4</td>
<td>2, 3, or 4</td>
<td></td>
</tr>
<tr>
<td>Average Access Time</td>
<td>60 ms(^1)</td>
<td>30 ms</td>
<td>27 ms</td>
</tr>
<tr>
<td>Maximum Data Transfer Rate (K bytes per second)</td>
<td>960</td>
<td>1209</td>
<td>1012</td>
</tr>
<tr>
<td>Average Latency</td>
<td>12.5 ms</td>
<td>8.3 ms</td>
<td>10.12 ms</td>
</tr>
<tr>
<td>Rotational Speed</td>
<td>2400 rpm</td>
<td>3600 rpm</td>
<td>3000 rpm</td>
</tr>
<tr>
<td>Motor Type</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Spindle Drive</td>
<td>—</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Acuator Type</td>
<td>band</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Positioning Mechanism</td>
<td>stepper motor</td>
<td>servo</td>
<td>servo</td>
</tr>
<tr>
<td>Density bpi</td>
<td>—</td>
<td>—</td>
<td>6475</td>
</tr>
<tr>
<td>Density tpi</td>
<td>—</td>
<td>—</td>
<td>668</td>
</tr>
<tr>
<td>Physical Size (inches)</td>
<td>8 by 16.5 by 21.5</td>
<td>10.5 by 17.5 by 30</td>
<td>10.3 by 18.9 by 26.6</td>
</tr>
<tr>
<td>Weight (pounds)</td>
<td>45</td>
<td>175</td>
<td>100</td>
</tr>
<tr>
<td>Single Quantity Price</td>
<td>—</td>
<td>—</td>
<td>$4,350/$5,200/$5,500</td>
</tr>
<tr>
<td>OEM Discount Price</td>
<td>—</td>
<td>—</td>
<td>$3,450/$4,300/$4,600 (quantity 100)</td>
</tr>
<tr>
<td>Cost Per Thousand Bytes (OEM Discount)</td>
<td>—</td>
<td>—</td>
<td>$0.052/$0.033/$0.028</td>
</tr>
<tr>
<td>Comments</td>
<td>Winchester Technology</td>
<td>16.7 megabytes of removable storage on each model (5440 Type)</td>
<td>Optional 655 K byte fixed head storage for $700</td>
</tr>
</tbody>
</table>

\(^1\) includes settling time

Host-Level Interface

A typical implementation for host-level interface is the BASF 6170 series drive with integral formatter/controller. The BASF host bus interface uses a single daisy-chain cable that can connect one or more units to the host adapter. Transfer of data, command, and status information is done across one common 8-bit-wide bidirectional asynchronous bus. The eight bus lines, as well as additional lines for bus control and interrupt generation, all use standard TTL drivers and receivers. Using a host-level interface is the easiest and fastest way to interface an 8-inch Winchester drive to a given host system.

How Intelligent Should a Controller Be?

With the decreasing cost of microprocessors and memories, the trend is toward the use of intelligent subsystems to handle all I/O-related functions, rather than tying up the processor.

These subsystems can communicate with the main system through a high-level command language (e.g., one that is file-oriented as opposed to hardware-oriented). Functions such as automatic backup, automatic error recovery, power-on bootstrap loading, etc., can be completely controlled locally in the subsystem, thus taking the burden off the main processor and improving the system's performance.

Further improvement can be gained by adding hardware and software for such things as double-buffering for data transfer, overlapped operation in a multiple drive configuration, and RPS (rotational-positioning sensing) for access optimization.

There is a limit to the transparency of the disk system to the operating system. If a disk with higher packing density is substituted, the number of sectors on each track or the number of tracks per surface will likely be different. This information must be communicated to the operating system. (With luck, this is a small parameter change in the I/O driver of a well-designed, modular operating system). But, however easy or difficult it is to change, it must be done to take full advantage of the new higher-capacity drive.

The Question of Backup for Fixed Disks

The usefulness of removable media on fixed-disk-based systems arises from three needs:

- system backup for crash/fault recovery
- program and data-base dissemination
- archival storage of information

The excellent reliability record of Winchester-technology disks is caus-
taking some system builders and users to take a fresh look at backup requirements for data storage. They are concluding that, for some applications, it is no longer necessary to include removable media for backup protection in systems design.

Error-correcting capabilities of system software and intelligent controllers help to eliminate the need for backup in some cases. However, there will probably always be applications—perhaps the majority—in which backup cannot be eliminated. Many systems require removable media for program and data-base dissemination and/or archival storage in addition to any backup considerations. Therefore, it seems that there will be a continuing need for removable-media storage peripherals on some fixed-disk-based systems.

According to many small-system designers and users, system backup is needed regardless of the hardware reliability of the fixed-storage subsystem. System crashes or failures can be caused by software bugs and human error as well as by hardware faults. Until the new wave of small Winchester disks came on the scene beginning about a year and a half ago, the small-systems hard-disk market was being served primarily by products based on IBM 5440-type removable-cartridge disk technology. Most of these products have the unique characteristic of having 50% of their spindle capacity removable—in other words, they have built-in backup. But the major drawbacks to their use in small systems are relatively low performance (70 ms average access time); relatively high cost per byte; large physical size; and high maintenance costs that get higher as field engineering labor costs grow. Even with the introduction of cost-effective, small, reliable Winchester-type products, these 5440-based products still have a place in some small systems. After all, the backup problem is solved, whereas no generally accepted backup method has yet emerged for the “mini Winnies” to make most customers feel comfortable. It is a problem yet to be solved.

Several approaches are being tried for backup. There are floppy disks, tape cassettes, tape cartridges, reel-to-reel tape drives, and, in at least one case, videocassettes.

The ideal characteristics of a backup device are:

- The cost of the modular removable medium should be low (less than $20).
- The cost of the transport device should be low.
- The data-transfer rate should be similar to the transfer rate of the disk.
- A single removable module should hold more, or at least as

<table>
<thead>
<tr>
<th>Fujitsu America Inc</th>
<th>Kennedy Co</th>
<th>Priam</th>
<th>Shugart Associates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Santa Clara CA</td>
<td>Altadena CA</td>
<td>San Jose CA</td>
<td>Sunnyvale CA</td>
</tr>
<tr>
<td>M2201/M2211</td>
<td>5300</td>
<td>3350/6650/15450</td>
<td>SA4000</td>
</tr>
<tr>
<td>50/83</td>
<td>14/42/70</td>
<td>33/66/154</td>
<td>14.5/29</td>
</tr>
<tr>
<td>14</td>
<td>14</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>2 or 3</td>
<td>1, 2, or 3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>30 ms</td>
<td>70 ms</td>
<td>50 ms</td>
<td>87 ms</td>
</tr>
<tr>
<td>819</td>
<td>—</td>
<td>1030</td>
<td>—</td>
</tr>
<tr>
<td>12.5 ms</td>
<td>10 ms</td>
<td>9.7 ms</td>
<td>—</td>
</tr>
<tr>
<td>2400 rpm</td>
<td>3000 rpm</td>
<td>approx. 3100 rpm</td>
<td>—</td>
</tr>
<tr>
<td>—</td>
<td>—</td>
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<td>6000</td>
<td>6370</td>
<td>5534</td>
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<tr>
<td>370</td>
<td>300</td>
<td>480/960/172</td>
<td>172</td>
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<td>10.3 by 19 by 30.2</td>
<td>7 by 19 by 22</td>
<td>6.8 by 16.6 by 20</td>
<td>—</td>
</tr>
<tr>
<td>150</td>
<td>75</td>
<td>33</td>
<td>—</td>
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<td>$5,400/$7,200</td>
<td>$3,200/$3,700/$4,200</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>$3.900/$4.990 (quantity 100)</td>
<td>$2.560/$2.960/$3.360 (quantity 100)</td>
<td>$1,800/—/—</td>
<td>—</td>
</tr>
<tr>
<td>$.078/$.080</td>
<td>$.183/$.07/$.048</td>
<td>$.055/—/—</td>
<td>—</td>
</tr>
</tbody>
</table>

Table 5: Specifications and characteristics of 14-inch, hard-disk drives.
### Error Rates

<table>
<thead>
<tr>
<th>Error Type</th>
<th>Recoverable</th>
<th>Unrecoverable</th>
<th>Seek Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 in 10^9 bits</td>
<td>1 in 10^13 bits</td>
<td>1 in 10^7 seeks</td>
</tr>
</tbody>
</table>

### Maintainability

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preventive Maintenance</td>
<td>None</td>
</tr>
<tr>
<td>(MTBF) Mean Time Between Failures (sealed modules)</td>
<td>25,000 hours</td>
</tr>
<tr>
<td>(MTBF) Mean Time Between Failures (product)</td>
<td>8000 to 10,000* POH (power-on hours)</td>
</tr>
<tr>
<td>Component Life</td>
<td>5 years</td>
</tr>
</tbody>
</table>

* Exception: Kennedy 7000 Series, 1500 hours

**Table 6: Reliability data for hard-disk drives.**

---

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- Model S-00125 with two double density drives, 32K Static RAM: $2,765
- Model S-00125 as above but with 8" drives: $4,185
- Other configurations available.

**TELETYPE**

- Model 4320 AAK: $1,185
- Model 4330 punch/reader, 10 or 30 CPS: $1,210
- 8 level, 1" tape: $2,595
- Limited supply of Model 45 available.

**IBM**

- 3101 CRT Model 10: $1,195
- Model 20: $1,395
- Selectric-like, detached keyboard: $2,265
- Dot matrix, Maintenance contract from IBM only: $2,545

**TELEVIDEO SMART CRTs**

- 912 B and C: $780
- 920 B and C: $850

**IMS MEMORY**

- 16 K static: $285
- 32 K static: $585
- 64 K Dynamic with parity: $950

**TEI MAINFRAMES, S-100**

- 12 slot: $500
- 22 slot: $670

**TARBELL**

- Double density controller: $420

**DEC LA 35/36 Upgrade**

- Increases baud rate to 1200. Microprocessor controlled. Many features include TOP, tabs and margin control.

**HAZELTINE 1500**

- $885
- 1510: $980
- 1520: $1,210

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---

much, data as the fixed disk, preferably an integer multiple of the disk capacity (i.e., a 100-megabyte videocassette to back up a 20-megabyte disk).

With the relatively unsophisticated operating-system software present in many small systems today (though this is rapidly changing), the backup strategy is usually to write the entire contents of the disk to a removable backup medium on a daily basis. This procedure results in a significant loss in system availability (while dumping or restoring) unless the backup device has a fast transfer rate and a large capacity.

Perhaps the most appropriate backup for a small Winchester is a device that can be included in the same package, sharing the same spindle drive mechanism and/or some of the same electronics. For the low end this may be a floppy disk; for the high end it can be a cartridge tape drive or a streaming reel-to-reel tape drive. But, except for the very low end where system cost is a prime consideration, a small-capacity, slow floppy disk is not an ideal backup for a large, fast, fixed disk. Streaming tape drives may be good backup devices for high-performance, high-capacity hard disks, but they are too expensive for most personal computer systems. Nevertheless, some streaming tape drives are becoming available. Kennedy Company of Monrovia, California, is delivering (60 to 90 days) its Model 6809 Data Streamer. It is a microprocessor-controlled reel-to-reel (10.5-inch reels) tape transport with formatter for reading, writing, and controlling the 9-track, 100 ips (inches per
Century plus fixed-disk capacity ranging from 16.7-megabyte 5440-type cartridge, 14-inch Marksman model (Winchester technology) with capacities from 10 to 30 megabytes, and the Hunter model with a removable 16.7-megabyte 5440-type cartridge, plus fixed-disk capacity ranging from 16.7 to 83.9 megabytes. Century Data Systems is a long-time manufacturer of computer peripherals. Corvus Systems Inc, San Jose, California, is offering a complete hard-disk subsystem based on the IMI 7710 10-megabyte 8-inch disk. It includes the Z80-based Corvus intelligent disk controller with comprehensive diagnostics and interfaces for TRS-80, Apple II, S-100-bus, and LSI-11 computers. As mentioned above, Corvus also markets a 100-megabyte removable backup in the form of an interface to a standard videocassette recorder using the microprocessor and interface bus of the Corvus disk subsystem. IMI was the first manufacturer to deliver a high-performance 8-inch Winchester drive.

Memorex Corporation of Santa Clara, California, is introducing its first in a planned family of 8-inch hard-disk products, the Model 101. It offers low cost per megabyte, low weight (10 pounds), low power requirements (56 W), and high reliability. With 11.7 megabytes and 70 ms access time, it is a good example of a product in the low-end segment of the small hard-disk-drive market. Memorex has been manufacturing disk drives since 1967 and has been a major supplier of magnetic media since the company was formed in 1961. The MSC-8000 from Microcomputer Systems Corporation of Sunnyvale, California, is an 8-inch disk drive with built-in removable backup in the form of an 80-mega-

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byte half-inch tape drive on the same motor spindle. Micropolis Corporation, of Chatsworth, California, is offering the largest capacity (now available) 8-inch Winchester disk, the Model 1203-I, with 45 megabytes on five surfaces. The density is high (8626 bpi, 478 tpi), the access time fast (42 ms), and the price reasonable. It is another good example of a high-capacity, high-performance 8-inch disk in the high-end segment. New World Computer Company Inc, of Costa Mesa, California, is making an unconventional, miniature hard disk, the Mikro-Disc 211. It is a cross between a high-performance, one-head-per-track disk and a cost-effective moving head mini-Winchester drive. It is small, light (8 pounds), and very fast (18.625 ms access time). It has relatively low capacity (2.1 megabytes) but makes up for it in performance, price (less than $1000 in large OQM quantities), size (9½ inch by 9½ inch), weight, and power requirements (less than 50 W). In the words of company president, Phil Haines, "It's a little screamer." The Mikro-Disc 211 is a versatile storage system suitable for a variety of uses: it can efficiently augment or replace floppy-disk drives, supplement other larger and slower mass-storage devices by acting as a high-speed cache memory, improve system response time by providing fast-access key-directory storage, and be the primary file device in small systems. It has an assembly with twenty proprietary low-cost heads that write and read data onto 0.008-inch-wide tracks. The head assembly is moved only seven 0.10-inch steps (eight positions) across the disk. Each step is accomplished in 5 ms, precisely and accurately, by a low-cost open-loop stepper motor.

The Model 3450 from Priam, San Jose, California, is another example in the high-end segment, along with BASF and Micropolis. It has 34 megabytes on five surfaces, fast transfer rate (1.02 megabytes per second), and high density (6370 bpi, 480 tpi). It is a state-of-the-art product at a reasonable price. The Shugart Associates SA1000-series drives are another example of the low-end segment along with the Memorex 101 with 5-and 11-megabyte models.

Shugart Technology of Scotts Valley, California (a new company not connected with Shugart Associates or Xerox) has just announced its Model ST506 5-inch 6-megabyte Winchester disk drive. It is the size of a 5-inch floppy drive and weighs only 3.5 pounds — 6 megabytes of reliable Winchester disk storage in the palm of your hand for $925 (OEM quantity 500)! In the popular parlance, this is a hot little product for the small computer system. Evaluation units are scheduled to be available this month and production quantities by next month.

The latest in disk drives for small systems are these 8-inch and 5-inch wonders. The hard disks are upon us, and they're taking personal computing forward by a giant step.■
DYNACOMP

Quality software for: PET Apple II Plus TRS-80 (Level II) North Star

All software is supplied with complete documentation which includes clear explanations and examples. Each program will run with standard terminals (32 characters or wider) and within 16K program memory space. Except where noted, all software is available on PET cassette, North Star diskette (North Star BASIC), TRS-80 cassette (Level II) and Apple cassette (AppleSoft BASIC). These programs are also available on PAPER TAPE (Microsoft BASIC).

BRIDGE 2.0

Price: $17.95 postpaid

An all-inclusive version of this most popular of card games. This program both BIDS and PLAYS either contract or duplicate bridge. Depending on the contract, your computer opponent will either play the offense OR defense. If you bid too high the computer will double your contract! BRIDGE 2.0 provides challenging entertainment for advanced players and is an excellent learning tool for the bridge novice.

HEARTS 1.5

Price: $14.95 postpaid

An exciting and entertaining computer version of this popular card game. Hearts is a trick-oriented game in which the purpose is not to take any hearts or the queen of spades. Play against two computer opponents who are armed with hard-to-please playing strategies.

FLIGHT SIMULATOR

(as described in SIMULATION, Volume II)

Price: $17.95 postpaid

A realistic and extensive mathematical simulation of take-off, flight and landing. The program utilizes aerodynamic equations and the characteristics of a real-size airfoil. You can practice instrument approaches and navigation using radials and compass headings. The more advanced flyer can also perform loops, half-rolls and similar aerobatic maneuvers.

SIMULATION, Volume II (BYTE Publications): $6.00

VALDEZ

Price: $14.95 postpaid

A simulation of supertanker navigation in the Prince William Sound and Valdez Narrows. The program uses an extensive 256K×256 element radar map and employs physical models of ship response and tidal patterns. Chart your own course through ship and iceberg traffic. Any standard terminal may be used for display.

CHESS MASTER

Price: $19.95 postpaid (available for North Star and TRS-80 only)

This complete and very powerful program provides five levels of play, It includes casting, en passant captures, and the promotion of pawns. Additionally, the board may be preset before the start of play, permitting the examination of "book" plays. To maximize execution speed, the program is written in assembly language (SOFTWARE SPECIALISTS of California). Full graphics are employed in the TRS-80 version, and two widths of alphanumeric display are provided to accommodate North Star users.

FOURIER ANALYZER

Price: $14.95 postpaid

Use this program to examine the frequency spectrums of limited duration signals. The program features automatic scaling and plotting of the input data and results. Practical applications include the analysis of complicated patterns in such fields as electronics, communications and business.

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This easy-to-use program now includes full alphabetic and word/sentence sorting as well as file merging. Entries can be retrieved by user-defined code, client name or Zip Code. The printout format allows the use of standard size address labels. Each diskette can store more than 1000 entries (single density; over 2000 with double density systems!)

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This is the classic Star Trek simulation, but with several new features. For example, the Klingons now shoot at the Enterprise without warning while also attacking starbases in other quadrants. The Klingons also attack both light and heavy cruisers and move when shot at! The situation is hectic when the Enterprise is besieged by three heavy cruisers and a starbase S.O.S. is received! The Klingons get even!

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Editor’s Note

We are particularly pleased to include this article by Dick and Jill Miller in this FORTH theme issue. One of the problems with past BYTE language issues has been the lack of concrete examples of the language being showcased—namely, a full, nontrivial program that does something useful or fun and, at the same time, shows an example of the language at its best.

The program BREAKFORTH, written for the MMSFORTH language running on the Radio Shack TRS-80, does show the language FORTH at its best. This real-time video game, which is a version of the arcade-type game that requires the user to chip away at a “brick wall” by directing a bouncing ball at it with a paddle, is what Dick Miller calls “electronic flypaper”—a game so addictive that it keeps people trapped at their TRS-80, unable to stop playing.

In addition to being playable (quite a testament to the speed of FORTH, especially if you have ever seen the same game written in TRS-80 BASIC), the game also gives an example of how a good FORTH program is put together, as well as how it can be more readable when properly written out with adequate indentation and comments.

Another departure from previous language issues is the availability of the language FORTH at reasonable cost on a wide range of microcomputers (see chart of FORTH sources, elsewhere in this issue). Miller Microcomputer Services (MMS) supplies one of the most complete and well-supported versions of FORTH available, along with a newsletter and other FORTH products available at reasonable prices. (For example, MMS sells a FORTH software package that adds floating-point arithmetic (both single- and double-precision), complex arithmetic, and a full Z80 assembler, all on floppy disk for $29.95.)

This article was produced with the help of two other people not yet mentioned. The first is Tom Dowling, who wrote the MMSFORTH language for the TRS-80 and who does a large portion of the FORTH programming for MMS. The second person is Arnold Schaeffer, who wrote the BREAKFORTH program as his first FORTH program. If this achievement were not impressive enough, then I should add that Arnold is a high school student. This is proof that FORTH can be learned by anyone with sufficient enthusiasm for the language.

Analyzing the BREAKFORTH program is a great way to learn about FORTH and how to program in it. The program can be typed in as is on a TR5-80 using MMSFORTH’s full-screen editor and virtual memory, but I suggest that you first read John James article in this issue, “What Is FORTH? A Tutorial Introduction,” before seriously studying the BREAKFORTH program.

One final note on alteration: this program is meant to work on a TRS-80 Model I running MMSFORTH. Users of other FORTH systems having a graphic display of 48 by 128 resolution or better can probably get the program running by rewriting some words unfamiliar to their system. Some information designed to help in this conversion effort has been supplied in this article...GW

BREAKFORTH Into FORTH!

A Richard Miller and Jill Miller
Miller Microcomputer Services
61 Lake Shore Rd
Natick MA 01760

About the Authors

A Richard (Dick) and Jill Miller founded Miller Microcomputer Services in 1977 as a consulting firm specializing in support for the Radio Shack TRS-80. After continued dissatisfaction with other languages available for the TRS-80 (FORTRAN, COBOL, Pascal, PILOT, BASIC), they settled on FORTH as a language that combines the seemingly incompatible traits of language complexity, high operating speed, and low memory overhead. They released their first version of MMSFORTH (version 1.5) in June 1979, and have been improving disk and cassette versions of the system ever since. MMSFORTH resembles the FORTH Inc version of the language called microFORTH, and was written independently with permission from that company.

Editor's Note

150 August 1980 © BYTE Publications Inc

Introduction to BREAKFORTH

This BREAKFORTH program was created by Arnold Schaeffer. The program, which was purchased by MMS, has received minor modifications and is now included with the purchase of MMSFORTH version 1.9 (on a different range of blocks from those shown here, blocks 69 thru 74). We think it is a classic game as is, and fully expect individuals to modify it in accord with their game preferences—for their individual use.

The BREAKFORTH program is a straightforward one, although it is not a trivial one. It combines many of the techniques of FORTH and can be followed easily with a little time and study. Figure 1 shows a typical BREAKFORTH video display, with an operator-controlled game paddle at the bottom, a bouncing ball, and a barrier to be knocked out one brick at a time by successive bounces until all the bricks have been cleared away. Each removed brick scores one point or more depending on its level, and there is a surprise bonus for a completely cleared barrier. Ball speed and number of balls are selectable, but be warned that, as you bounce your way up to the higher layers, the ball speed increases! You might want to start with short games using five balls and...
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a ball speed of seven. Fifty balls and a speed of four will present a challenge for high scorers.

BREAKFORTH offers some other features, too. As you and your friends try for better scores, a BEST score is kept to challenge your present effort. In addition, the paddle adds backspin in certain cases that we will leave you to discover.

To add sound, plug an external speaker into the EAR jack of your cassette tape recorder, attach the middle cable from the keyboard unit (not the motor remote cable) to the AUX jack of the tape recorder, and open the tape compartment door. While depressing the write-protect detector switch at the left side of the back of this compartment, simultaneously press the Record and Play keys. This procedure allows the cassette tape recorder to be used as an amplifier. The BREAKFORTH program manipulates the cassette port (normally used for writing a program to tape), causing a sound to be amplified by the recorder and played on the speaker.

Like other brands of electronic flypaper, BREAKFORTH may keep you glued to the keyboard. If you have to leave but do not want to give up the game, press shift-@ to pause the game. Pressing any other key will cause the game to resume where you left off. To start a new game in midstream while keeping the BEST score, press the Break key, type in the word BREAKFORTH, and press the Enter (Return) key.

BREAKFORTH is developed in the FORTH manner, with top-down design and bottom-up programming.

The First Block

Let us take a detailed look at block 50 in listing 1. Lines 0 thru 2 are all comment lines, as are any words surrounded by parentheses. Notice that because FORTH words are set off by spaces on either side, the “begin comment” word, ( ( ) , must be separated from the first word of the comment by at least one space. (Because of the way ( ( ) is defined, the closing parenthesis need not be separated from the last word of the comment by a space.)

Most definitions in FORTH begin with a colon ( ( : ) ) and end with a semicolon ( { ; } ), where the first word after the colon is the word being defined. In line 3, the first word defined is TASK. Since the only word following TASK is the closing semicolon, we can conclude that the word TASK does not do much. However, it does serve as a "bookmark," marking the beginning of the words and variables that are specific to this application (game). We will come back to TASK later, at the end of block 55.

Line 3 also causes two other blocks on the MMSFORTH system disk to be loaded into memory. Block 32, when loaded, adds several special-purpose words having to do with random numbers: RANDOMIZE and RND. Block 33, when loaded, adds several words that have to do with graphics: DCLR, DSET, { D? }, ECLR, ESET, and { E? }. (The last three are the same as TRS-80 BASIC words RESET, SET, and POINT, and the variables beginning with D are the same, but referencing double-width characters.)

Lines 4 thru 6 initialize seven double-byte variables and two single-byte (CVARIABLE) variables. In FORTH, unless specified, all variables, constants, and stack entries are 16 bits (2 bytes) long. See table 1 for the meaning of these variables.

Line 7 defines a new word, LINE, using a colon to begin the definition and a semicolon to end it. Several spaces (usually three) are placed be-
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- THE REAL USEFULNESS OF THE 16 BIT MICROPROCESSORS WILL BE DETERMINED BY THE SOFTWARE.
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- SIXTY-FOUR KILOBYTES OF ADDRESSABLE RAM. THE MAXIMUM FOR 8 BIT SYSTEMS, IS NOT ADEQUATE FOR MANY BUSINESS OR SCIENTIFIC APPLICATIONS.
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Figure 2: A hierarchical diagram of the BREAKFORTH program. Each box contains a word used within the BREAKFORTH program and is used by the word(s) in the box(es) above it. See table 1 for a definition of each word.

tween the word being defined and the first word of the definition; this adds to the clarity of the definition. PTC (for "put cursor") places the cursor at a given point on the screen, much like the PRINT@ instruction in TRS-80 BASIC. It expects two numbers on the stack, the row (second-to-top) and the column (on top) giving the desired position for the cursor. (For example, \( [8 \ 32 \ \text{PTC} ] \) puts the cursor near the center of the screen, 8 rows from the top and 32 characters from the left edge of the screen.)

However, our new word LINE expects only one number on the stack because the first thing it does when it is called is to put a zero on top of the stack. So the words \( [0 \ \text{PTC} ] \) put the cursor at the beginning of a given line (that is, at position \((x,0)\), where \(x\) is the number on top of the stack when LINE is called).

The FORTH word ECHO (EMIT in some other versions of FORTH) is like the PRINT CHR$ function in BASIC—it outputs the corresponding ASCII character for the number. In this case, \( [30 \ \text{ECHO} ] \) outputs a clear-to-the-end-of-the-line signal on the TRS-80. (By the way, the 30 is the decimal number thirty; although you can change to hexadecimal with the word HEX or to any other numeric base, MMSFORTH assumes decimal numbers unless told otherwise.)

Now we are finally able to say what the word LINE does: the phrase \( [x \ \text{LINE} ] \) clears line \(x\) and leaves the cursor at row \(x\), column 0. \( [0 \ \text{PTC} ] \) puts the cursor at the beginning of the line, and \( [30 \ \text{ECHO} ] \) clears the line with a special character (ASCII decimal 30) and leaves the cursor where it is.

The final word described in block 50, INIT, begins in line 8. Its definition is longer than most words, but its function is not at all mysterious once you know a few FORTH words. CLS clears the video screen (as in TRS-80 BASIC), \( [0 \ \text{LINE} ] \) clears line zero, and \( ["\"] \) in some FORTHs causes the character string until the next quote mark to be printed, just as PRINT " STRING " does in BASIC. The word \#IN causes a single-

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Listing 1: The BREAKFORTH program. These six blocks, when loaded into an MMSFORTH system, cause the BREAKFORTH program to compile, execute, and, once finished, erase itself from the system. Tape-based users should omit the last three words in the last block. This program does require that the MMSFORTH words for random numbers (block 32 on the MMSFORTH system disk or cassette) and for TRS-80 graphics (block 33) be available to the FORTH system. If these blocks have already been loaded, delete the two LOAD commands in block 50, line 3. Also, the sequence [A MVI 255] in lines 10 and 11 of block 51 is the notation FORTH uses for the 8080 assembly-language statement MVI A,255. [To speed up paddle response, you can replace the 3 in block 55, line 8 with a higher value. Personally, I enjoy playing the game at speed level 1, with a 12 replacing the 3....GW]

BLOCK : 50

0 ( BREAKFORTH/MMSFORTH, BY ARNOLD SCHAEFFER, PART 1 OF 6 )
1 ( COPYRIGHT 1980 BY MILLER MICROCOMPUTER SERVICES )
2 ( W/SOUND - USE THE LEFT AND RIGHT ARROWS TO MOVE THE PADDLE )
3 : TASK ; 32 LOAD ( RANDOM &"S' ) 33 LOAD ( GRAPHICS ) RANDOMIZE
4 0 VARIABLE SPEED 0 VARIABLE SPVAR 0 VARIABLE SCORE
5 0 VARIABLE XPOS 0 VARIABLE YPOS 2 VARIABLE PPOS
6 1 VARIABLE YDIR 1 VARIABLE XDIR 0 VARIABLE BEST
7 : LINE 0 PTC 30 ECHO
8 : INIT CLS 0 LINE " SPEED ( 1 - 10, 1 IS FASTEST )"
9 #2N 1 MAX 10 MIN 10 U* SPEED C1
10 0 LINE " NUMBER OF BALLS DESIRED" #2N
11 CLS 64 0 DO 3 I DSET 4 I DSET LOOP
12 48 3 DO I 0 DSET I 63 DSET I 1 DSET I 62 DSET LOOP
13 191 15616 320 FILL 0 SCORE I
14 0 LINE " BREAKFORTH IN MMSFORTH SCORE: 0 BEST:"
15 BEST ? 0 54 PTC " BALL: "

BLOCK : 51

0 ( BREAKFORTH/MMSFORTH, BY ARNOLD SCHAEFFER, PART 2 OF 6 )
1 2 : PCLR 32 PPOS @ 16320 + 8 PILL ;
3 : PSET 176 PPOS @ 16320 + 8 PILL ;
4 5 : PADDLE
6 14400 C@ 32 IF PCLR -1 PPOS @ + 2 MAX PPOS PSET THEN
7 14400 C@ 64 IF PCLR 1 PPOS @ + 54 MIN PPOS PSET THEN
8 9
10 CODE 1CASSOUT 1 A MVI 255 OUT NEXT ( THESE 3 LINES )
11 CODE 2CASSOUT 2 A MVI 255 OUT NEXT ( PRODUCE THE SOUND. )
12 : BOP 10 0 DO 1CASSOUT 2CASSOUT LOOP ;
13
14
15

BLOCK : 52

0 ( BREAKFORTH/MMSFORTH, BY ARNOLD SCHAEFFER, PART 3 OF 6 )
1 2 : XCHK
3 XPOS @ 2 IF XDIR @ MINUS XDIR 1 2 XPOS : BOP THEN
4 XPOS @ 61 IF XDIR @ MINUS XDIR 1 61 XPOS : BOP THEN
5 6
7 : YCHK
8 YPOS @ 5 IF YDIR 1 5 YPOS @ 1 SPVAR C1 BOP THEN
9 YPOS @ 23 IF SPVAR C@ 4 MIN SPVAR C THEN
10 YPOS @ 19 IF SPVAR C@ 3 MIN SPVAR C THEN
11 YPOS @ 15 IF SPVAR C@ 2 MIN SPVAR C THEN
12
13
14
15

BLOCK : 53

0 ( BREAKFORTH/MMSFORTH, BY ARNOLD SCHAEFFER, PART 4 OF 6 )

Listing 1 continued on page 158
REUSE INVOICE/ CUSTOMER NUMBERS TO DATE DATA BY DATE AHO PERCENT

FORLOOKINGPLFOR

SELECTIVELY GENERATE STATEMENTS PAYROLL PAYABLES (I .E., MORTGAGES)

COMPARE!

RECEIPT OF PAYMENTS BY CUSTOMER “DOUBLY PASSWORD PROTECTED EXPENSE ACCOUNTS ,”

ACCOUNTING FOR SHIPPING

GENERATES “ QUOTATION ” SUBSTANTIAL

up TO

ACCEPTS CREDIT BALANCES INCOME AHO BALANCE SHEET REPORTS BY DOLLAR AMOUNT,

MERCHANDISE RETURNS WITH COMPREHENSIVE STUB “EASY ENTRY -

PARTS RECEIVED REPORT keeping techniques and practices by

PRINTED ON STATEMENTS AHO YEAR TO DATE TOTALS • ACCOUNTING FOR CONTINUING

PERPETUAL INVENTORY • FOR EASY UPDATING • HANDLES 250 ACCOUNT NUMBERS - "-

POINT OF SALES AS REQUIRED YEAR

MAINTAIN INS

GAIN T

Method”). “KSAM” Instantly sorts the files and gives less than 2 second access into any file while maintaining the file in sequence.

OPEN ITEM RECEIVABLES

glasses includes a firmware board containing special programming for file maintenance called KSAM (for “Keyed Sequential Access

designed for the small businessman. FMS fills the businessman’s needs with a speed comparable to many of the larger systems. FMS

Financial Management System (FMS) was originally designed and created on

APPLE) & APPLE)( PLUS are registered trademarks of Apple Computer, Inc.

Unlike~

the

market

there was not

the

need to make compromi,

... to enable system <op•tion .

ADAPTATION

4

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The 2nd Generation...

It’s all that it’s

Cracked up to be.
precision number to be entered from the keyboard and placed on top of the stack. The phrase \( \text{1 MAX} \) causes the number to be replaced by 1 if the number just entered is smaller. Similarly, the phrase \( \text{10 MIN} \) limits the number on the top of the stack to a maximum value of 10. \( \text{10 U*} \) multiplies the number by 10 (\( \text{U*} \) is an unsigned single-precision multiply), and \( \text{SPEED C!} \) stores the value from the top of the stack in the single-byte variable \( \text{SPEED} \).

Each of the above phrases contains a number and an operation. Since each operation requires two numbers on the stack, the number entered by \#IN is the first number, with the second number always being supplied by the first word of the phrase.

Using the same words as listed above, line 10 again clears line 0, prompts for the number of balls to be used in the game, putting that number on top of the stack with the word \#IN.

Line 11 clears the video screen again and sets up the back (top) wall of the BREAKFORTH “court” using a do-loop and double-width graphics. In FORTH, the parameters of the loop go on the stack before the loop is called, so \( \text{64 0 DO} \) begins the loop, and the word LOOP ends it. The loop will be executed sixty-four times, and the word I puts on top of the stack the current value of the loop (0, 1, 2, 3, ..., 63); note that I does not take on the limit value of 64. The phrase \( \text{I 3 I DSET} \) sets a double-width character at row 3, column I; similarly, \( \text{I 4 I DSET} \) sets the double-width character on the next row below the first.

Similarly, line 11 sets the right and left walls of the BREAKFORTH court, columns 0 and 64 for the right wall.

The phrase \( \text{191 15616 320 FILL} \) in line 13 creates the initial wall of bricks by using character code decimal 191 (a whited-out character cell) to fill an area of memory (the video display area of the TRS-80) starting at location 15616 and filling for a total of 320 bytes.

The phrase \( \text{0 SCORE !} \), also in line 13, shows us how we store a value (0) in a variable (SCORE) by using the store operator \( [ ] \). Two points should be mentioned here. First, executing a variable name (like SCORE) causes the address of the variable, not its value, to be pushed onto the top of the stack. Second, the store operator \( [ ] \) requires the value to be the second-to-top item in the stack and the address of the variable receiving the new value to be the top item in the stack.

The words in line 14 print a message on the same line, setting the score to zero but leaving the cursor just after the colon that ends the message. In line 15, the phrase \( \text{BEST !} \) causes the value of BEST to be displayed on the screen, and the rest of line 15 completes the message that is shown on line 0 of the screen. Finally, the semicolon on line 15 ends the definition of INIT begun on line 8.

**The Middle Blocks**

Whew, that was a lot of explaining! Now you see why FORTH is not very easy for beginners to read—you are packing a lot of work into a small space, using an ever-more-specialized
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Since that first breakthrough product, Don Tarbell has expanded his list of useful, dependable components...components to meet your needs of today, and keep you prepared for tomorrow.

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*CP/M® & MP/M® are products of Digital Research Corp.
Figure 3: A flowchart for the BREAKFORTH program (given in listing 1, block 55). The number above each box is the line number within block 55 that performs the action of the box. Many calculations in FORTH are done on the stack and do not acquire variable names. Because of this, an asterisk in a variable or procedure name (eg: X*, 3PADDLE*) denotes that the name was given only in this flowchart to add clarity.

When the ten-to-twenty times speed increase of FORTH over BASIC is not enough (or when we want to do things that cannot be done with existing FORTH words), we can redefine some FORTH words in the assembly language of the computer.
(in the case of the TRS-80, 8080 or Z80 assembly language). When we want a FORTH word (program) to run faster, usually a short assembly-language definition of the word that gets used the most will speed things up sufficiently. Lines 10 and 11 of block 51 are the only two words used in BREAKFORTH that are defined in 8080 assembly language.

(MMSFORTH comes with a compact 8080 assembler built in, like many Z80-based FORTHs. A full Z80 assembler also is available from MMS at a modest price.)

Inspection of lines 10 and 11 of block 51 shows that assembly-language definitions begin with the word CODE (instead of [:]) and end with the word NEXT (instead of [:]). Here, FORTH's 8080 assembler is used to define a new type of word to output to a port. Both 1CASSOUT and 2CASSOUT drive the cassette recorder port (I/O port 255 on the TRS-80), and the word BOP executes both these words in a do-loop ten times to create a short square-wave sound on the external speaker.

The definition of PCHK ("paddle check" of ball location) in block 53 uses two more constructs. There are two if constructs, the inner one beginning in line 6 and ending in line 10, the outer beginning in line 5 and ending in line 11. (Notice that only the inner loop uses the optional else clause, as in line 9.) The second construct is a numeric case construct, NCASE ; as shown in line 7. When NCASE is executed, it expects the number on top of the stack to be one of the numbers listed between NCASE and the double quote marks (here, zero thru seven). The value found causes the execution of the corresponding FORTH action word in the series of apparent numbers between the double quote mark and the word CASEND. (Numbers are words but are not in FORTH's dictionary—when they are "executed," they are pushed on top of the stack.) MMSFORTH case statements require their action words to be words in the FORTH dictionary and not numeric literals, so in block 53, line 2, 2 and -2 are defined as constants (FORTH words). 1 and -1 are already defined as constants by standard FORTH. Taking \[ 2 \text{ CONSTANT } 2 \] as an example, the first 2 is the value of the constant, while the second 2 is the name of the constant; we might have used the word TWO in its place.) In our program, \[ 0 \text{ NCASE } \] causes the word -2 to be executed. \[ 1 \text{ NCASE } \], \[ 2 \text{ NCASE } \], \[ 3 \text{ NCASE } \] cause -1 to be pushed on top of the stack, and so on. Only one of the words is executed; execution then continues with the first word after CASEND. MMSFORTH also has an alphanumeric case statement that branches on the value of a single character. Each may be thought of as a compact, structured, many-branched alternative to a nested series of if statements.

The Last Block

Block 55, the last block used to
<table>
<thead>
<tr>
<th>Word Name</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPEED</td>
<td>CVARIABLE contains speed of play.</td>
</tr>
<tr>
<td>SPVAR</td>
<td>CVARIABLE contains speed multiplier, depends on height ball reaches.</td>
</tr>
<tr>
<td>SCORE</td>
<td>VARIABLE contains current score.</td>
</tr>
<tr>
<td>XPOS</td>
<td>VARIABLE contains current ball X position (range, 2 thru 61).</td>
</tr>
<tr>
<td>YPOS</td>
<td>VARIABLE contains current ball Y position (range, 5 thru 47).</td>
</tr>
<tr>
<td>POS</td>
<td>VARIABLE contains current paddle position (range, 2 thru 54).</td>
</tr>
<tr>
<td>XDIR</td>
<td>VARIABLE contains current ball X increment (possible values: -2, -1, 1, 2).</td>
</tr>
<tr>
<td>YDIR</td>
<td>VARIABLE contains current ball Y increment (possible values: -1, 1).</td>
</tr>
<tr>
<td>LINE</td>
<td>Expects n on top of stack; moves cursor to line n, clears line.</td>
</tr>
<tr>
<td>INIT</td>
<td>Asks questions and draws display.</td>
</tr>
<tr>
<td>PCLR</td>
<td>Clears paddle.</td>
</tr>
<tr>
<td>PSET</td>
<td>Draws paddle.</td>
</tr>
<tr>
<td>PADDLE</td>
<td>Checks for right- or left-arrow key being pressed and moves paddle appropriately.</td>
</tr>
<tr>
<td>TACCOUT</td>
<td>8080-code procedure for sound.</td>
</tr>
<tr>
<td>2CASSOUT</td>
<td>8080-code procedure for sound.</td>
</tr>
<tr>
<td>BOP</td>
<td>Makes one bounce noise.</td>
</tr>
<tr>
<td>XCHK</td>
<td>Checks if ball hit either side wall, modifies XDIR and XPOS if necessary.</td>
</tr>
<tr>
<td>YCHK</td>
<td>Checks if ball hit top wall and modifies YDIR and YPOS if necessary; also sets speed multiplier.</td>
</tr>
<tr>
<td>PCHK</td>
<td>Checks if ball at paddle level; if so, did it hit paddle or is it out of play? Leaves F on top of stack; F = 0 if ball still in play, else 1.</td>
</tr>
<tr>
<td>CLR</td>
<td>Clears brick, modifies score and YDIR.</td>
</tr>
<tr>
<td>BALL</td>
<td>Increments ball position and checks for wall, paddle, or brick hits. Leaves F on top of stack; F = 0 if ball still in play, else 1.</td>
</tr>
<tr>
<td>BALL</td>
<td>Clears old ball position, calls BALL, and draws new ball; see BALL for value left on top of stack.</td>
</tr>
<tr>
<td>GAMECHK</td>
<td>Checks if all bricks cleared and draws new barrier if so.</td>
</tr>
<tr>
<td>DELAY</td>
<td>Causes a given time delay between ball moves.</td>
</tr>
<tr>
<td>BREAKFORTH</td>
<td>Main game loop.</td>
</tr>
</tbody>
</table>

Table 1: Table of variable names and FORTH words used in the BREAKFORTH program. Note that all variables leave their address on the stack, that LINE removes one entry from the stack before executing, and that PCHK, BALL, and BALL add one entry to the stack after executing.

define the word BREAKFORTH, defines one last word (DELAY, in line 1), then puts all the words defined so far together to define the word (which is also the program) BREAKFORTH. This is a good demonstration of how FORTH is meant to work: first you define specialized words that are helpful in solving problems of a given class or application, then you use them to write the specific program needed.

**WHY CAN'T MICROPOLIS DO THINGS LIKE EVERYONE ELSE?**
The building words, if chosen and defined properly, can be used to help write other programs in the same class.

The word BREAKFORTH is defined in lines 2 thru 14. A flowchart for the program is given in figure 3; the number to the left of each box gives the line number within block 55 which the box is associated with.

Line 15, the last line of block 55, is interesting in that it triggers all the work done so far. The word BREAKFORTH causes the definition of the word to be executed. Once the game is finished, the next words, \{ FORGET TASK \}, are executed; these cause the word TASK (remember block 50?) and every word defined after it to be erased from the vocabulary of the language. This is done to free up the computer once we are finished playing BREAKFORTH. You can omit these words if you wish, but the disk program is recalled into memory so easily (with the phrase \{ 50 6 LOADS \}) that most people prefer to keep the FORTH dictionary as uncluttered as possible. The last word, DIR, causes the standard disk MMSFORTH directory to be displayed on the screen. (The last three words should be deleted if you are running the cassette version of MMSFORTH.)

**Summary**

It takes some work to understand your first FORTH program. But this work is only the flip side of the same coin that makes FORTH such a powerful language—where else can you easily write such a large and speedy program in such a small space? (The only other candidate language I can think of is APL, which is also known for its compactness and unreadability to the uninitiated... GW) But, of course, your second FORTH program is easier than your first, and so on. Better yet, your second program may be 90% written by your first, thanks to FORTH's structured and modular design.

We hope you have enjoyed this introduction to FORTH. We can assure you that it has just scratched the surface of FORTH, which performs equally well in process control projects and business applications. FORTH improves our programming skills while improving our computer's effective speed, memory capacity, and instruction set. It is a most satisfying language.

---

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FORTH Extensibility
Or How to Write a Compiler in 25 Words or Less

Kim Harris
1055 Oregon Ave
Palo Alto CA 94303

A computer language should help users solve problems. Languages bridge the gap between the primitive operations the computer can perform (add, fetch from memory, etc.), and the tasks a user needs (invert a matrix, search a file, etc.). When the operations of an application are well matched to those of a language, the solution can be simplified and developed in less time; in addition, the resulting program becomes more readable.

Because all applications have various needs, it is impossible for a nonextensible computer language to satisfy all needs equally well. Although languages have been produced which attempt to include all possible operations, structures, and facilities, these have not been satisfactory.

FORTH's approach is to provide a few techniques that allow a user to quickly add the special operations his particular application requires. The remainder of this article will describe some of these techniques and give examples that add arrays (with and without subscript range checking), virtual arrays, and a case selection control structure.

Extending the Language
The ability to add language facilities and compiler structures is called extensibility. FORTH is extensible on three levels of increasing power:

- using existing compilers
- creating new compilers
- creating new operating systems

This article focuses on the second level and demonstrates the construction and use of specialized compilers. The specialized compilers are usually simple (definable in a few source lines), but permit entire new classes of language or compiler facilities to be added to a FORTH system.

The compilation of any computer language is diagrammed in figure 1. Compilation is the process of converting a source language program into a form that a computer can use.

FORTH uses multiple compilers to implement different compiler functions. For example, compiling a data structure declaration (eg: an array) is distinctly different from compiling an executable statement. FORTH uses separate compilers for these two activities. Such compilers are many times simpler than the compilers for most popular languages (eg: BASIC, Pascal, COBOL); however, a collection of FORTH compilers can perform all the functions of the other languages' compilers (when these functions are adapted to a FORTH-like environment).

FORTH uses the English word "word" to mean an executable procedure, not a piece of memory. In this article, "word" will be used in the FORTH sense, and storage sizes will be specified in terms of 8-bit bytes.

User-Defined Words
The input language to the FORTH compilers is a sequence of FORTH source language word-names separated by spaces. (Unlike other languages, a space in FORTH is very important.) The output is one dictionary definition for each new word (procedure) compiled. The compilation process is controlled by special FORTH procedures called defining words. A source definition, which is a series of FORTH words including defining words, specifies a procedure that can be compiled by executing (typing in) the sequence. The result of compilation is a functionally equivalent program in a different, object language.

Editor's Note
In this article, Kim Harris uses the syntax of FORTH-79, which is different from that of existing FORTH implementations, for his examples. FORTH-79 is a standard set of FORTH words that, if used to build all other FORTH words needed for a given application, insures the complete portability of a given program between different versions of FORTH. Members from FORTH Inc, the FORTH Interest Group, the European FORTH Users Group, and MMS worked together to define FORTH-79. I have noted the differences between the text and existing FORTH implementations (in particular, fig-FORTH and MMSFORTH) where known....GW
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dictionary definition, which is a block of FORTH-interpretable instructions. All compiled FORTH words are kept in this dictionary, which is usually located in the computer's memory.

User-defined words are treated the same as system-supplied words. If some new words are defined which behave like operators (e.g., triple-precision versions of the FORTH words +, −, *, /, etc), then the language has been truly extended to include these operators. Subsequent words may use these new words as system-supplied operators.

Examples of standard, system-supplied defining words are { : } (colon), which starts the compilation of subroutine-like procedures, and VARIABLE, which compiles a named memory location for the variable's value.

A source definition consists of a defining word followed by the name of the word being defined and then by other FORTH words and numbers. Figure 2 illustrates the source definitions and the corresponding dictionary definitions for two new words named 2* and %INTEREST. (FORTH word-names may be made of any nonblank characters.) The word 2* simulates a multiplication by 2 by adding a value to itself.

The defining word { : } compiles the words that follow it in a definition, which is then added to the dictionary. Each FORTH dictionary definition consists of two parts: a head and a body. The head contains system-internal information including a name field and a code field. (A link, which points from a definition to a previous definition, is part of the head but will be ignored in this article.) The name field contains the name of the word. The code field contains a pointer to the instructions that will be executed when the word is executed.

For definitions compiled by { : }, the code field points to a procedure that begins the execution of the words referenced in the definition. The body of this kind of definition, called the parameter field, is a series of addresses that point in order to each FORTH word in the definition. The addresses of these referenced words are placed in the parameter field by the { : } compiler, and the definition is ended by the FORTH word { ; } (semicolon). The execution of the word EXIT (compiled at the reference to { ; }) ends the execution of the word.

Some Examples

The word 2* will leave a result that is twice the value of its input. (See figure 2a.) Examples in this article will underline the input typed by the user and will end in an unseen carriage return; the computer's response follows. The following line shows the use of the word 2*:

3 2* . 6 OK

Any subsequently compiled word may call the word 2* as if it were any other FORTH word. When called, 2* performs its function and then returns. This is analogous to the execution of a subroutine call in other languages.

A word is called by simply using its name, as in the following source definition for 4*:

: 4* 2* 2* ;

The defining word { : } has been used to compile another definition into the dictionary. Using 4* will cause 2* to be called and executed twice. Here is an example of the use of the word 4*:

3 4* . 12 OK

The second word defined in figure 2 uses the defining word VARIABLE to compile a dictionary definition that contains data. The source word-name %INTEREST is compiled into a new dictionary definition containing a

![Figure 2: Examples of extending the FORTH language. The first source line adds a new operator named 2* (see figure 2a); the second source line adds a new operand named %INTEREST (see figure 2b).](image)
Using standard FORTH defining words to add new operations (programs).

II. Creating new user-defined defining words that, in turn, create new classes of words.

III. Creating new FORTH-like systems through metaFORTH.

Table 1: Levels of extensibility in FORTH. Level I refers to the act of defining ordinary words in FORTH using standard defining words. Level II refers to the creation of new defining words that are then used to create a family of ordinary FORTH words. Level III refers to the act of altering and re-compiling FORTH itself (sometimes called metaFORTH) to create significantly different variant FORTH-like systems. Higher levels imply greater capability and flexibility.

2-byte area where the value of the variable will always be stored. (The use of the word-name %INTEREST, either inside or outside a definition, will cause the address of this variable’s value to be returned, not the value of the variable.)

The dictionary definition for %INTEREST contains the variable’s name, a pointer to the instructions executed when %INTEREST is executed, and a 2-byte data area. The code fields of all words defined by VARIABLE point to a procedure which returns the address of the data area of the variable when the variable’s name is referenced. All FORTH words, even data words, have some code that is executable.

The two defining words of this figure are actually different compilers. The defining word { : } compiles procedure definitions, while the defining word VARIABLE compiles data definitions. All user-added operators and operands can be used exactly like the system-supplied ones. Even new control structures can be added to the FORTH compiler by the user.

Levels of Extensibility in FORTH

As shown in table 1, there are three levels of extensibility supported by FORTH. The two words defined in figure 2 are examples of extensibility level I, the most commonly used level. It comprises the “ordinary” act of programming in FORTH. Although it is very useful, this level is the most restrictive and the least powerful of the three.

The process of writing and using new defining words is the second level of extensibility. Level II, which is more powerful than level I, allows a new “family” of words to be added to the language or compiler. This is done by creating a special word, called a defining word, that will be used to create FORTH words in the same family. The user specifies via the defining word how the compilation of a new family member (itself an ordinary FORTH word) is to be performed and what the result will be. Also the user specifies what a member of the family will do when it is executed.

Level III, the highest level of extensibility, is called metaFORTH. It uses the entire FORTH system to compile a collection of source definitions (including both lower levels) in order to produce a clone or a mutation of FORTH.
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(Please don't be misled by my use of the word "compiler.") I have been asked, "Can you write a compiler in FORTH that will compile BASIC, Pascal, COBOL...?" The answer is not easy. Defining words can compile application-oriented languages, but those languages should be FORTH-like in nature. Ordinarily, the language being compiled satisfies the syntax of FORTH—words separated by spaces. The compilation will result in FORTH-interpretable instructions that will add to its dictionary of word definitions.

In keeping with the FORTH philosophy of keeping all definitions small, defining-word definitions are also small. This results in compilers (defining words) that are simple and specialized, although the range of complexity of these compilers can vary greatly. A simple defining word such as VARIABLE may accept only one source word and produce a single, simple definition in the dictionary. A more complex defining word such as { : } may take several source words and produces a more complex definition.

The remainder of this article concentrates on level II, defining new families of words. The scope and usefulness of new defining words are discussed using functional descriptions and examples. New defining words can be created which can later compile application-oriented languages.

Creating Families of Words

The technique of creating new defining words permits

---

**Figure 3:** The order of events governing defining words. The first event creates a word that will define a new family of words; this family currently has no members. The second event uses this new family-defining word to create a new family member, a named FORTH word. The third event occurs when any named FORTH word belonging to this family is used.

---

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a user to later create a family of FORTH words that can have any number of members. Each member shares some family traits but can also have individual characteristics. The family members are all the words that have been compiled by a defining word. Their common traits are specified by the defining word. However, each word in the family has individual characteristics that are assigned when added to the family.

For example, the defining word VARIABLE defines a family with individual members, each of which has a different name and value, but all share the same execution trait: specifically, the use of the name of any variable returns the address of its value.

It is important to understand that there are three time-ordered events related to defining words. These are listed in figure 3. These events will be explained using an example.

The compilation of the new words in figure 2 is a sequence 2 event (ie: using a defining word to compile another word). When the defining word VARIABLE is executed, as in:

```
VARIABLE %INTEREST
```

the source word %INTEREST is compiled.

Storing a value into the variable is a sequence 3 event.

The following words store a 5 into the variable.

```
5 %INTEREST
```

Since VARIABLE is system-supplied, the sequence 1 event (the compilation of VARIABLE) occurred when the FORTH system was generated.

<**<BUILDS and DOES>**>

To illustrate a simple sequence 1 event, a definition of VARIABLE is presented.

```
: VARIABLE <BUILDS 2 ALLOT DOES>
```

The defining word { : } (colon) is used to compile the source definition of VARIABLE. To the word { : }, VARIABLE is an ordinary definition (level 1), and its definition is a sequence 2 event for { : }. VARIABLE is a defining word because the special words <BUILDS and DOES> are used. (The < and > characters are part of the names of the words; they are used like parentheses to indicate that <BUILDS comes before DOES>.)

As illustrated in figure 4, a defining word specifies both the compile-time behavior (sequence 2) and the execution-time behavior (sequence 3) of all words compiled by this defining word. The sequence 2 behavior is specified by <BUILDS and any following words up to DOES>. The sequence 3 behavior is specified by DOES and any following words up to { ; }. The English meaning of <BUILDS is "compiles" and the meaning of DOES is "executes."

Figure 5 demonstrates what occurs when VARIABLE is executed. The end result of the execution of VARIABLE is that a new dictionary definition is created for the word %INTEREST. The following describes each step in the compilation of %INTEREST:

1. The execution of VARIABLE causes <BUILDS to be executed. <BUILDS reads the next word-name after the word VARIABLE from the input text stream. (In this example, the next word-name is %INTEREST.)
2. <BUILDS then adds the head of a new definition to the end of the dictionary. Within this head, the name field contains the member's word-name.

```
5 %INTEREST
```
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( %INTEREST ), and the code field contains a pointer to the instructions that will be executed when %INTEREST is executed (during sequence 3).

3. The two words { 2 ALLOT } are executed next. These will reserve 2 bytes of dictionary space for the value of the variable. This space is in the parameter field of the dictionary definition.

4. Finally, DOES> terminates the compilation of %INTEREST and links the code field of %INTEREST to the execution-time part of VARIABLE.

When %INTEREST is executed (sequence 3), DOES> is executed, followed by the FORTH words between DOES> and the end of the definition. (In this example, there are no words following DOES> ; the word EXIT is a routine left by the end-of-definition word { ; }.) DOES> returns the memory address of the parameter field within the dictionary definition of %INTEREST. Since the parameter field of a word defined by VARIABLE contains only the value of that word, execution of the word %INTEREST returns the address of its value, which is then pushed onto the parameter stack. (That is, in fact, the execution-time behavior of a FORTH variable.)

Figure 6 shows an example of the execution of %INTEREST.

The above definition and usage of the word VARIABLE are valid for existing FORTHS. However, the definition of VARIABLE supplied with most FORTHS requires the initial value of the variable before the word VARIABLE (e.g. { 5 VARIABLE %INTEREST }). This definition of VARIABLE is:

\{ : VARIABLE <BUILDS , DOES> ; \}

...GW

...GW

The previous example demonstrated the following principles:

- Sequence 1: the definition of a defining word specifies both the compile-time behavior and execution-time behavior of all words belonging to the family of the defining word (i.e. all words created using the defining word).

- Sequence 2: the execution of a defining word causes the compilation of the word-name(s) that follow. This creates a new dictionary

\[ (\text{SEQUENCE } 3) \]

5 pushed onto the stack

5 executes (DOES > ) within [ VARIABLE ].

This pushes the address of the value onto the stack.

Stores the value 5 into the address returned by [ %INTEREST ]

Figure 6: The execution of a family member word. The value 5 is stored in the variable %INTEREST.

---

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<td>525</td>
<td>32K</td>
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<td>480</td>
<td>400</td>
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```
STRING when the string variable BEANS is defined.
```

To show how defining words can create data structures, a one-dimensional array of 8-bit values will be created. A defining word named STRING will be constructed. After STRING has been compiled, any number of strings may be created. Each can have a different name and size. Before the definition for STRING is shown, an example will first be described to show how STRING will be used.

To create a string 5 bytes long with the name BEANS, the following words are used:

```
BEANS C@ DEFINED
```

would fetch character number 3 from BEANS. This is a sequence 3 event because it is a normal use of a word defined by STRING. The subscript preceded BEANS because FORTH prefers to pass data values on a stack.

The definition of STRING can now be written as shown in listing 1. This definition is similar to that of VARIABLE.

```
DEFINITION of STRING can now be written as
```

```
SEQUENCE 3: the execution of a member word
```

```
DEFINING the execution of the execution-time words within the defining word that creates the member word.
```

```
To illustrate the versatility of defining words, examples of new defining words follow. These examples present the creation of new data structures, control structures, and software tools.

Creating a String-Handling Defining Word

```
FUNCTION?$</BUILDS
```

This is a sequence 2 event that will create a dictionary definition for BEANS; this definition will contain 5 bytes of data space for the value of the string.

To fetch or store a character in BEANS, a subscript will be passed to BEANS. BEANS will return the address of the subscripted byte. For example, the words

```
3 BEANS C@
```

Listing 1: A user-defined defining word. The word STRING, once defined, can be used to define new FORTH words with unique properties.

```
SEQUENCE 1: STRING <BUILDS ALLOT DOES> +
```
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When STRING is executed (sequence 2), it builds a dictionary definition for BEANS, which is allotted 5 bytes of data space. When BEANS is executed (sequence 3), it does the addition of the subscript on top of the stack to the address of the first character within BEANS.

The following examples show how BEANS could be used in a FORTH program. The word STUFF-BEANS will store the American Standard Code for Information Interchange (ASCII) characters A thru E in the string variable BEANS. (See listing 2a.) The word SPILL-BEANS will print the characters in BEANS on the user's terminal. (See listing 2b.) Using these words would produce the results shown in listing 2c.

In a similar way, multidimensional-array defining words may be defined; the size of each element can be any number of bytes.

Since the execution-time function of all family members is specified only once in the definition of the family's defining word, programming time is reduced, memory space is saved, and readability is improved. By changing the definition of the defining word and recompiling the FORTH words using it, the capabilities of every member word are changed. This can be done so that the use of all member words in a user's program is the same.

To illustrate the power of this technique, several variations on STRING will be presented.

Variations on the Defining Word STRING

The original version of STRING did not initialize the contents of the array when it created member arrays. The following version will store blanks in a string when it is created (at sequence 2). It is convenient to first define a word which allocates and blanks dictionary space. The definition of BLANK&ALLOT is a sequence 2 event. (See listing 3a.)

Next, we create a new version of STRING that is the same as the original, except that BLANK&ALLOT is substituted for ALLOT. (See listing 3b.) (The redefinition of STRING is a sequence 1 event.) This version is used exactly like the original, but initialized strings are created automatically.

Another variation of STRING checks if a subscript exceeds the string size when member strings are executed (at sequence 3). If the subscript is less than the string size, the result is the same as before; but, if the subscript is negative or greater than the string size, an error message

Listing 2: Using a FORTH word created by a user-defined defining word. The 5-character string variable BEANS was previously defined with the FORTH statement { 5 STRING BEANS }. Now the word BEANS can be used like any other word in FORTH. In listing 2a, the five characters of BEANS are filled with the letters A thru E. In listing 2b, the characters are printed out. Listing 2c gives the results of executing the words defined in listings 2a and 2b. (The underline denotes user input followed by a carriage return; the computer output, not underlined, follows.)

: STUFF-BEANS 5 0 DO ( for all of 'BEANS' )
   165 + ( add 65 decimal to )
   I BEANS CI ( store character in the )
   ( 'T' byte of 'BEANS' )
   LOOP

:SPILL-BEANS 5 0 DO ( for all of 'BEANS' )
   I BEANS C@
   ( fetch the 'T' character )
   EMIT ( print it )
   LOOP SPACE ( print an extra space )

(c)
STUFF-BEANS OK
SPILL-BEANS ABCDE OK
Listing 3: A more sophisticated definition of STRING. The word BLANK&ALLOC (shown in listing 3a) allocates space for and assigns blanks to a newly defined string. The new definition of STRING (shown in listing 3b) uses BLANK&ALLOC to blank out a string when it is created.

: BLANK&ALLOC
HERE
(a) OVER BLANK
ALLOC
( get the address of the )
( store blanks in the string )
( allocate space for the array )

: STRING <BUILDS BLANK&ALLOC ( used at sequence 2 )
(b) DOES> +
( used at sequence 3 )

Listing 4: Another definition of STRING. This definition stores the size of the string variable when the variable is created and checks for a correct subscript when a character within the string variable is referenced.

: STRING ( used at sequence 2: )
<BUILDS DUP , 
ALLOC ( used at sequence 3: )
DOES> 2DUP ,
@ U< IF
( store string size )
( member's parameter field )
( duplicate both the subscript )
( & parameter field address )
( if the subscript is less )
( then the string size )
( add subscript to address )
( sleep over the string size )
( stored in the first 2 bytes )
( otherwise the subscript )
( is too large or negative )
. " RANGE ERROR" ( print error message )
OVER . @ ,
( print string size and )
( and bad subscript )
2+ @ ,
( leave address of first byte, )
( a "safe" address )

is produced and the illegal subscript is printed. The string size must be stored in the dictionary definition of member strings when they are compiled (at sequence 2) so that the range check can be made when they are executed (at sequence 3).

A new definition of STRING (a sequence 1 event) that does the subscript checking defined previously is given in listing 4.

The range check slows the execution of every reference to a member string, but such checking may be useful during program development. Since this version and the original version defining STRING are used exactly the same, it is possible to compile this definition of STRING while debugging (then compile all references to it or its member strings). After the program has been debugged, the original version can be compiled (followed by the compilation of all references to it or its members), and the program will run faster.

The next version of STRING allows very large strings to be created and used.
Virtual Strings in FORTH

If the maximum string size exceeds the amount of programmable memory in the computer, the only solution is to rewrite your program using virtual memory management. This means that data stored on disk or tape is considered part of the memory of the computer, and that all operations working on these data take care of reading and writing data between main memory and the magnetic storage device.

Using virtual memory management, a program can operate on a string array that is larger than main memory; pieces of the string can be read into memory and written back to disk or tape when required. And, although this technique will slow the execution rate of a program using it, it may be the only way to get a problem solved—and better a slow solution than none at all.

(It is more common to need to manipulate large arrays of numbers rather than strings. Still, the same technique described here can be applied to numeric or any other kind of array.)

With most traditional languages, it would be necessary to rewrite the user program so that all array references would call some function that could perform the disk read operations. Execution time could be decreased if frequently referenced array elements were kept in memory as much as possible. Therefore, it would help if our virtual-memory-array program could keep track of what data is in memory as the program executes.

To show the difficulty of implementing this technique in traditional languages, a FORTRAN example will be used. In standard FORTRAN, the statement:

```
ARRAY(5,7,2) = AR1(1,2) + AR2(10,20,30)
```

is equivalent to the FORTH words:

```
1 2 AR1 @ 10 20 30 AR2 @ +
```

In either FORTRAN or FORTH, if the arrays could not fit into memory and were instead on disk, the array references would have to be changed so that some additional procedures read and wrote selected pieces of data between disk and memory. But in FORTRAN, the entire source program would have to be changed. (In FORTH, the body of the program would remain the same; only the appropriate defining word would be changed.)

The following might be the simplest modification possible in standard FORTRAN to do the previous statement using virtual memory management of the arrays:

```
 TEMP = FETCH2(AR1(1,1), 1, 2) + FETCH3(AR2(1,1, 1), 10, 20, 30)
 CALL STORE3(ARRAY(1,1,1), 5, 7, 2, TEMP)
```

The functions FETCH2 and FETCH3 are user-written procedures to read the referenced array elements. The subroutine STORE3 is a user-written procedure to write a given value into an assigned array element. If a large program using many normal array references had to be changed to use FETCH and STORE calls, a lot of work would be required.

FORTH's separation of control between defining words and their members permits the necessary changes to be made in the definition of the defining word; in this

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way, the program that uses the arrays does not have to be changed.

Furthermore, FORTH's virtual memory facility for disk reading and writing automatically keeps track of what data has been read into memory and tries to keep frequently referenced sections in memory.

Figure 8 illustrates how the array will be read in blocks of 1024 bytes into memory buffers. The new definition for the defining word STRING is given in listing 5.

Adding New Control Structures with Defining Words

The next example illustrates the use of defining words to add control structures to the FORTH compiler. FORTH supplies \{ IF ... ELSE ... THEN \} compiler structures and also loop structures like \{ DO ... LOOP \}, \{ BEGIN ... UNTIL \}, and \{ BEGIN ... WHILE ... REPEAT \} loops.

In this example, we will create a case (choose one of \( n \) alternatives) selection mechanism. A case number will designate one of several words to be executed. Figure 9 presents how a case statement selects one of several procedures for execution. No matter which one is chosen, execution continues with one common procedure that follows the case structure.

The new defining word will be named \{ CASE: \} and can be used similarly to \{ : \}, as the following

Listing 5: Another definition of STRING. This definition creates a virtual string array that stores the string on disk and reads it into main memory when necessary. With this definition of STRING, it is possible to manipulate a string that is larger than main memory without changing the program that uses the long string. The disk operations are transparent—that is, the programmer does not know he is using the disk except for response time.

```
: STRING
  ( used at sequence 2 )
  <BUILDS NEXT-BLOCK# ( get the next available )
    ( disk block # )
    ,
    ( store it in the member 's )
    ( parameter field )
    DISK-ALLOC ( reserve disk space for )
    ( the array )
  DOES> @ ( get start-block )
    ( start-block H )
    SWAP ( subscript on top, )
    ( start-block beneath )
    1024 MOD ( divide subscript by )
    ( H bytes in a disk block; )
    ( the quotient is the block )
    ( index within the array; )
    ( the remainder is the byte )
    ROT + ( add start-block # to the )
    ( block index )
    BLOCK ( call the FORTH virtual )
    ( disk manager to read the )
    ( referenced block; )
    ( if it is already in memory )
    + ( no read is performed )
    ( add the byte index to the )
    ( memory address of the )
    ( reference address is )
    ( byte specified by the )
    ( subscript before BEANS )
```
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---

**BYTE August 1980 181**
example shows. (In this implementation of the case construct, the selection of a case causes the execution of one FORTH word. Since there is no restriction as to the internal complexity of a given word, the selection of one case

Listing 6: Example of a new user-defined programming construct. In listing 6a, we define the words we want to execute when the numbers 0, 1, and 2 are on top of the parameter stack. In listing 6b, the user-defined defining word { CASE: } defines the word ANIMAL, which will execute OPET, 1PET, or 2PET, depending on the value on top of the parameter stack. Listing 6c illustrates what happens when the case-word ANIMAL is executed. See listing 7 for the definition of { CASE: }

(a) : OPET ." AARDVARK " ; (print the quoted string)
: 1PET ." BEAVER " ; (when executed)
: 2PET ." COUGAR " ;

(b) (sequence 2) CASE: ANIMAL OPET 1PET 2PET ;

(c) (sequence 3)
0 ANIMAL AARDVARK OK
1 ANIMAL BEAVER OK
2 ANIMAL COUGAR OK

Listing 7: Definition of the defining word { CASE: } in FORTH-79. This word allows the user to create case-words that execute one of several FORTH words depending on the value on top of the parameter stack.

: CASE:
  ( used at sequence 2 )
  <BUILDS
   ( begin ' : ' compilation)
  | (used at sequence 3)
  DOES>
   SWAP 2+ (convert case number to )
   + @ (a byte index)
   EXECUTE (fetch the address of the )
   (indexed case word)
   (execute the selected word)

Case word execution can cause any combination of conditional, loop, or case structures to be executed.)

In our example, let us first define three words, 0PET, 1PET, and 2PET, that are to be executed when the value on top of the stack is 0, 1, or 2, respectively. This is done in listing 6a. Then we use the { CASE: } defining word (which we will look at later) to define the word ANIMAL (listing 6b). Now that ANIMAL and the case words it uses are defined, calling ANIMAL with the appropriate value on the stack executes the proper case word (listing 6c). For example, pushing a 2 onto the stack and calling ANIMAL causes word 2PET to be executed; this causes the English word COUGAR to be printed.

Since { CASE: } is a defining word, ANIMAL is a member of the { CASE: } family. The definition of ANIMAL consists of a list of addresses for the case words associated with ANIMAL.

The definition of { CASE: } is a sequence 1 event. Listing 7 shows the definition of { CASE: } in FORTH-79. [Listings 8a and 8b show the same definition for fig-FORTH and MMSFORTH, respectively...GW]

Figure 10 shows how the word ANIMAL is built using { CASE: }. The { : } compiler is used to compile the words following ANIMAL. When ANIMAL is

Figure 9: The function of a case control structure. The case number selects one of several procedures for execution, then continues along a single exit path.

Figure 10: The creation of a case control word. The execution of { CASE: } causes a definition for ANIMAL to be appended to the dictionary. The 'word uses the { : } compiler to compile the addresses of the case words following ANIMAL.
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Listing 8: Definition of the defining word \{ CASE: \} in fig-FORTH (listing 8a) and in MMSFORTH (listing 8b).

\{( CASE: as implemented in fig-FORTH) \}
: CASE: <BUILDS SMUDGE >
  DOES > SWAP 2*
  + @
  EXECUTE
  ;

\{( CASE: as implemented in MMSFORTH) \}
: CASE: ( new word ) replaces SMUDGE 
  );
  ) STATE Cl 21144 ;
  : CASE <BUILDS >
  DOES > SWAP 2*
  + @ 2+
  EXECUTE
  ;

Listing 9: Definition of a defining word that acts as a programming tool. The word LOADED-BY allows the user to execute (or load) a screen by name rather than by number. For example, if you define \{ 125 LOADED-BY ACCOUNTING \}, executing the word ACCOUNTING will have the same effect as executing the phrase \{ 125 LOAD \}.

\{( sequence 1 \} : LOADED-BY <BUILDS , (store screen #)
  (in members def.)
  DOES > @ (fetch screen #)
  LOAD (load it)

Defining Words as Programming Tools

The final example applies defining words to the creation of software tools. Such tools are conveniences for the user. Good tools can increase a programmer's productivity, reduce errors, and improve program readability. Defining words can be used to add powerful tools to the FORTH language and operating system.

In FORTH, the word LOAD will compile source definitions from the disk starting at a specified screen number. A screen is a block of disk space where source text can be stored using an editor. Additional screens may be loaded if the initial screen contains more LOAD commands.

Application programs and utility programs begin on various screen numbers determined by the user. The defining word LOADED-BY allows words to be defined which will LOAD a screen without calling it by number.

For example, assume a business application starts on screen 125. Then the defining word LOADED-BY can be used to define a word that will load screen 125 when the member word is executed. When we define:

\{ 125 LOADED-BY ACCOUNTING \}

screen 125 will be loaded when the single word ACCOUNTING is executed. (If LOADED-BY looks strange, think of it as a FORTH word like VARIABLE.)

The definition of LOADED-BY is given in listing 9. This definition is similar to the definition of the word CONSTANT except that, rather than returning the value stored in the definition of the member word, LOADED-BY uses that value to provide a parameter to the word LOAD.

Summary

FORTH exploits its own extensibility to support a user's need for a variety of language facilities and compiler structures.

A defining word controls the compilation and execution of all words compiled by it. New defining words that define a new family of capabilities may be constructed. Subsequently, any number of individual members can be added to the family.

The source definitions of most defining words are short and simple. Proper use of defining words in a software development project reduces program development time, improves program readability, and makes program modification and maintenance easier.

Defining words are applicable to data structures, control structures used by the FORTH compiler, and software tools. The ability to create new kinds of defining words (which are, in their own way, small compilers) is a unique feature of FORTH and is one of the most powerful programming tools in the language.
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This glossary is a compilation of most of the FORTH words used in the listings and figures of all the FORTH articles in this issue. It does not include all the standard words in FORTH (there are quite a few), nor does it include user-defined words required by each article. The pronunciations of some words are given in parentheses. Wherever possible, an example is given showing the use of the defined word. The words “before” and “after” show the stack before and after the word is executed. In these representations of the stack, the top of the stack is the rightmost number, and the words influenced by the defined word are depicted in boldface.

The columns marked “uses” and “leaves” show how the execution of a FORTH word affects the top entries of the stack. FORTH words remove the stack entries they use and sometimes leave one or more entries on the stack. Therefore, the number under “uses” and “leaves” should equal the number of entries in boldface in the “before” and “after” stacks. Asterisks in both columns mean that the numbers are not given for multiword constructs for the purpose of clarity.

Multiword constructs, like the following example:

```forth
{ IF ... ELSE ... THEN }
```

are enclosed in braces with the keywords separated by ellipses that represent zero or more FORTH words. Also, these constructs are listed only under the first word of the construct. In general, all the words in this table are sorted by ascending ASCII value — for example, the word * (ASCII hexadecimal 2A) is listed before the word + (ASCII hexadecimal 2B).

This glossary assumes that the output device used by the FORTH system is a video terminal. When any definition refers to the video display or display, it actually refers to whatever output device or devices are currently enabled.

## FORTH Glossary

<table>
<thead>
<tr>
<th>Word</th>
<th>Uses</th>
<th>Leaves</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>{ ! } (store)</code></td>
<td>2</td>
<td>0</td>
<td>Sees top-of-stack as address of a 2-byte variable and stores second-on-stack in this variable; for example, suppose that address 20000 points to a 2-byte variable; then: before: 9 9 -1150 20000 after: 9 9 ((-1150 is stored in a 1-byte variable.))</td>
</tr>
<tr>
<td>`{ &quot; }</td>
<td>0</td>
<td>0</td>
<td>{ &quot; HI THERE!&quot; }, when executed, prints HI THERE! on the video display.</td>
</tr>
<tr>
<td>`{ ' } (tic)</td>
<td>0</td>
<td>1</td>
<td>Puts onto top-of-stack the address of the word that follows it.</td>
</tr>
<tr>
<td>`{ ( }</td>
<td>0</td>
<td>0</td>
<td>{ ( THIS IS A COMMENT) ), if included in a definition, will not be compiled; ({}) requires a { ) to end the comment.</td>
</tr>
<tr>
<td>*</td>
<td>2</td>
<td>1</td>
<td>Multiplication; example: before: 9 9 3 5 after: 9 9 15 The word * multiplies 5 and 3, leaving 15.</td>
</tr>
<tr>
<td>+</td>
<td>2</td>
<td>1</td>
<td>Addition; example: before: 9 9 3 5 after: 9 9 8 The word + adds 5 and 3, leaving 8.</td>
</tr>
<tr>
<td>{, }</td>
<td>1</td>
<td>0</td>
<td>Embeds the number on the top of the stack into a dictionary definition, incrementing the dictionary pointer.</td>
</tr>
<tr>
<td>-</td>
<td>2</td>
<td>1</td>
<td>Subtraction; example: before: 9 9 3 5 after: 9 9 -2 The word - subtracts 5 from 3, leaving -2.</td>
</tr>
<tr>
<td>{. }</td>
<td>1</td>
<td>0</td>
<td>Displays the number on the top of the stack; example: before: 9 9 3 5 after: 9 9 3 ((5 is printed on screen.))</td>
</tr>
</tbody>
</table>
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I had heard everyone speak about Hayden software. How it was the finest available. "I would be so pleased," said I, "if we could discuss some of their programs."

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("#03403, TRS-80 Level II; #03404, Apple II; each $89.95; #04403, Apple II Disk Version; #05408, TRS-80 Disk Version; each $54.95")

I then looked around, and spotted a new program. I lifted the cassette, examined it critically, and then began to speak. "This DATA MANAGER looks to be as fine a specimen as that SARGON II. It stores up to 96,000 alphanumeric characters on just one floppy disk. And one third of this information may be recovered from Random Access Memory at a time. This means, that on just eleven diskettes one can store and retrieve up to 1,000,000 characters. It is, in my judgment, a clever program to have around."

("#04909, Apple II Disk, $49.95")

"Extraordinary. Here's another program for the Apple II. They call it APPLESOFT UTILITY PROGRAMS. It contains 9 subroutines, among them 3 statement formatters: REM, PRINT, and POKE writers. You can calculate the decimal address of your machine language programs, get an exact byte and line count, renumber the program in any increment, and much more. I wonder what other fine programs are to be had from Hayden?"

("#05504, Apple II, $29.95")

Holmes leaned back, still puffing at his black pipe. "Wait a minute," said he. "Here's something."

"What is it?" said I.

"It's APPLE ASSEMBLY LANGUAGE DEVELOPMENT SYSTEM. It features a cursor-based editor, global and local labels, and disk-based macros which allow you to incorporate subroutines into any program. And, one can write and modify machine language programs quickly and easily. It is indeed quite remarkable."

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"Quite. But let us not forget BLACKJACK MASTER, what. Unlike other blackjack programs that emphasize graphics and harmless fun, this is a serious game. Imagine being able to perform complex simulations and evaluations of any playing and betting strategies that are entered into the microcomputer. And, it will tutor one in how to play these strategies! Good gracious, there's also a $250.00 BLACKJACK Challenge!"

("#05503, TRS-80 Level II, $19.95; #05508, TRS-80 Disk Version, $24.95")

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Division; example:
before: 9 9 13 2
after: 9 9 6
The word / divides 13 by 2, leaving 6. (Remainder is lost.)

If top-of-stack is <0, it is replaced with a 1 (true); if top-of-stack is ≥ 0, it is replaced with a 0 (false); example:
before: 9 9 3 5
after: 9 9 3 0

Adds 1 to top-of-stack; example:
before: 9 9 3 5
after: 9 9 3 6

{ ... } begins the definition of a word; { } ends the definition; example:
{ : 3* 3 * ; } defines the word 3*.

If the two top items on the stack are exactly equal, both of them are removed and replaced with a single 1 (true); if not, both are replaced with a single 0 (false); example:
before: 9 9 3 5
after: 9 9 0

If the second item on the stack is less than the top item on the stack, both of them are removed and replaced with a single 1 (true); if not, both of them are replaced with a single 0 (false); example:
before: 9 9 3 5
after: 9 9 1

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\begin{itemize}
  \item \texttt{<BUILDS \ldots DOES> \ldots} Used to define new defining words; see "FORTH Extensibility" article, figure 4.
  \item \texttt{> 2 1} Similar to entry for \texttt{<}; example:
    \begin{itemize}
      \item \texttt{before: 9 9 3 5} \texttt{after: 9 9 0} (3 is not less than 5.)
    \end{itemize}
  \item \texttt{?} 1 0 Sees top-of-stack as address for 2-byte variable; displays value of that variable; using the example for \texttt{?} , then:
    \begin{itemize}
      \item \texttt{before: 9 9 20000} \texttt{after: 9 9} (-1150, contents of 20000, prints on screen.)
    \end{itemize}
  \item \texttt{@ (fetch)} 1 1 Sees top-of-stack as address for 2-byte variable and replaces it with value of that variable; using the example in \texttt{?} :
    \begin{itemize}
      \item \texttt{before: 9 9 20000} \texttt{after: 9 9 -1150} (-1150 is contents of 2-byte variable at 20000.)
    \end{itemize}
  \item \texttt{ALLOT} 1 0 Sees top-of-stack as number of bytes to be reserved (and filled in later) during the definition of a word.
  \item \texttt{AND 2 1} Does an AND operation on the corresponding bits of the top two stack entries (both 16-bit numbers); example:
    \begin{itemize}
      \item \texttt{before: 9 9 3 5} \texttt{after: 9 9 1} (3 AND 5, in binary, is 1.)
    \end{itemize}
  \item \texttt{BASE} 0 1 \texttt{BASE} is a 1-byte variable that contains the number base being used; for example, \texttt{2 BASE} \texttt{C!} causes all subsequent input and output to be in binary (base 2); execution of this word causes the address of this 1-byte variable to be placed on top-of-stack.
\end{itemize}
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Judging by the letters we've received from buyers of Computer Bismarck, home computer historical wargaming is a great mind-stretching recreation to uncramp the old synapses after a few hours of trying to cram 54K of code into 48K of memory. But before you read any further, let us warn you that our new game, Computer Ambush, is more gut-wrenching than mind-stretching.

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{ BEGIN ... UNTIL }  
  Looping construct that tests at the end of the loop; see “What Is FORTH?” article, figure 4.

{ BEGIN ... WHILE ... REPEAT }  
  Looping construct that tests at the beginning of the loop; see “What Is FORTH?” article, figure 5; other forms are { BEGIN ... PERFORM ... PEND } and { BEGIN ... IF ... WHILE }.

{ C; }  
  Sometimes used to end a machine-code word definition; most versions use NEXT.

{ Cl }  
  Similar to { I } except that only low byte of second-to-top is stored in 1-byte variable pointed to by top-of-stack; for example, suppose that address 21000 points to a 1-byte variable; then:

before: 9 9 103 21000  
after: 9 9 (103 is stored in 1-byte variable.)

Note that the maximum value that can be stored in 1 byte is 127.

C@  
  Same as the word @, only for 1-byte variable; using the example of { Cl } , then:

before: 9 9 21000  
after: 9 9 103 (103 is contents of 1-byte variable at 21000.)

{ CODE ... NEXT }  
  Defining words, used like { : } and { ; }, used when defining a new word using assembly language only.

CONSTANT 1  
  Creates a constant that has the value of top-of-stack; for example, before executing the phrase { CONSTANT CON } , the stack looks like:

9 9 25140
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After the phrase has been executed, the stack looks like:

```
9 9
```

and the word `CON`, when executed, will place 25140 on the top of the stack.

<table>
<thead>
<tr>
<th>CR</th>
<th>0 0</th>
<th>Causes the cursor to jump to the beginning of the next line of the display.</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>{ DO ... LOOP }</code></td>
<td>2 0</td>
<td>Looping construct that specifies a beginning and an ending-value-plus-one; see “What Is FORTH?” article, figure 3.</td>
</tr>
<tr>
<td>DROP</td>
<td>1 0</td>
<td>Drops top entry from stack; example:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>before: 9 9 3 5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>after: 9 9 3</td>
</tr>
<tr>
<td>DUP</td>
<td>1 2</td>
<td>Duplicates item on top-of-stack; example:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>before: 9 9 3 5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>after: 9 9 3 5 5</td>
</tr>
<tr>
<td>ECHO</td>
<td>1 0</td>
<td>Isolates the low-order byte of the 2-byte entry on top of the stack and writes it to the video display; example:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>before: 9 9 32</td>
</tr>
<tr>
<td></td>
<td></td>
<td>after: 9 9 (A space, ASCII decimal 32, is printed.)</td>
</tr>
<tr>
<td>FILL</td>
<td>3 0</td>
<td>Fills an area of memory with a given value; for example,</td>
</tr>
<tr>
<td></td>
<td></td>
<td><code>{ 255 3000 100 FILL }</code> fills memory locations from 3000 thru 3099 (100 bytes) with the value 255.</td>
</tr>
<tr>
<td>FORGET</td>
<td>0 0</td>
<td>Causes system to delete all definitions including and after the word following FORGET; for example, <code>{ FORGET BASEPGM }</code> causes the system to delete BASEPGM and all FORTH words, variables, and constants defined after it.</td>
</tr>
</tbody>
</table>

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**H** 0 1 2-byte variable containing address of the top of the dictionary; execution of this word causes the address of the variable H (not its value, which equals the address of the top of the dictionary) to be placed on top of the stack.

**HERE** 0 1 Places the address of the next byte to be used in the dictionary (the value of H) on top of the stack.

**I** 0 1 When executed within a { DO ... LOOP }, the word I pushes onto the top of the stack the value of the index counter; for example, { 10 0 DO I . LOOP } prints the numbers from 0 thru 9.

**{ IF ... ELSE ... THEN }** 1 0 Conditional execution of words depending on value of top-of-stack. If nonzero, execute words between IF and ELSE . If zero, execute words between ELSE and THEN ; for example, { IF " NUMBER ON TOP IS NONZERO" ELSE " NUMBER ON TOP IS ZERO" THEN } prints the appropriate message depending on the value on top of the stack.

**KEY** 0 1 Gets a single character from the keyboard; for example, if the stack before we press the space bar is:

```
9 9 3 5
```

Then, after we press the space bar (ASCII value decimal 32), the stack is:

```
9 9 3 5 32
```

**MAX** 2 1 Compares the two top entries on the stack and leaves only the larger; example:

before: 9 9 3 5  
after: 9 9 5

**MIN** 2 1 Compares the two top entries on the stack and leaves only the smaller; example:

before: 9 9 3 5  
after: 9 9 3

**MINUS** 1 1 Changes the sign of the entry on top of the stack; example:

before: 9 9 3 5  
after: 9 9 3 -5

**OVER** 2 3 Copies the second-to-top entry onto the top of the stack; example:

before: 9 9 3 5  
after: 9 9 3 5 3

**PAD** 0 1 PAD is a 2-byte variable that points to the beginning of a 64-byte area for temporary storage of character strings; execution of this word causes the address of this 2-byte variable to be placed on top of the stack.

**SWAP** 2 2 Exchanges the two top entries on the stack; example:

before: 9 9 3 5  
after: 9 9 5 3

**U** 2 1 The lower 8 bits of the two top entries on the stack are isolated and multiplied together, leaving their unsigned 16-bit product; example:

before: 9 9 3 5  
after: 9 9 15

Each factor will effectively be 255 or less, giving a product that will not overflow in 16 bits.

**VARIABLE** 1 0 Creates a variable that has the value of top-of-stack; example, before executing the phrase { VARIABLE VAR }, the stack looks like:

```
9 9 -14017
```

After the phrase has been executed, the stack looks like:

```
9 9
```

and the word VAR, when executed, will place the address of the variable on the stack. (The 2-byte number stored at that address will contain the value -14017.) Unlike a constant, the value of a variable can be changed using { 1 } (store).

{ 1 }  *  * Resumes compilation of a colon definition.
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Khachiyan's Algorithm, Part 1: A New Solution to Linear Programming Problems

G C Berresford, A M Rockett, and J C Stevenson
Dept of Mathematics
C W Post Center, Long Island University
Greenvale NY 11548

Editor's Note:
This two-part article presents some of the most difficult mathematics we have ever published in BYTE, but we believe that the attention given to the Khachiyan algorithm of late warrants a complete and rigorous treatment here. Part 2 will contain a linear programming example and a TRS-80 BASIC program designed to illustrate the algorithm....CM

Khachiyan's Vector Notation
The vector notation used in Khachiyan's paper is different from that used by most Western mathematicians, so a word of explanation is in order. A system of linear equations (or, as in equation (1.1), linear inequalities) can be expressed in the form:

\[Ax=b\]

where \(x\) is a column vector of the variables \(x_1\) thru \(x_n\), \(b\) is a column vector of the coefficients \(b_1\) thru \(b_m\) (one for each of the \(m\) equations in the system), and \(A\) is an \(m\)-by-\(n\) matrix (\(m\) rows, \(n\) columns), where each row of the matrix \(A\) contains the coefficient for the corresponding equation. Khachiyan's notation expresses everything in terms of column vectors. In particular, \(a_i\) is a column vector containing the coefficients of the \(i\)th equation. But since the coefficient vector must be a row vector in order to be multiplied by the column vector \(x\), we follow Khachiyan's notation and denote the corresponding row vector as \(a_i^t\) where the superscript \(t\) denotes the transposition of column vector \(a_i\)....GW

The three-column headline "A Soviet Discovery Rocks World of Mathematics" was spread across the bottom of the front page of the New York Times for Wednesday, November 7, 1979. In the following weeks, subsequent articles were heralded as “Shazam! A Shortcut for Computers” and “Mathematician Is Obscure No More.” Overnight, Leonid Khachiyan became famous as the author of a revolutionary discovery in the field of linear programming.

What has Khachiyan accomplished? All of the articles in the press are based on second- or third-hand reports and interpretations. [In fact, the first New York Times article incorrectly heralded the discovery as a solution to the still-unsolved “traveling salesman” problem....GW] Lynn Steen's article in Science News, "Linear Programming: Solid New Algorithm," (October 6, 1979) and Gina Bari Kolata's article in Science, "Mathematicians Amazed by Russian's Discovery," (November 2, 1979) discuss the basic problem of linear programming and then report on a paper by Peter Gacs and Laszlo Lovasz that discusses Khachiyan's algorithm. The Gacs and Lovasz paper opens with the statement "we have ignored his [Khachiyan's] considerations which concern the precision of real computations..." and then proceeds to describe a modification of Khachiyan's algorithm, although the differences between the two procedures are never made explicit.

The notation used in this article, although explained in the text, deserves some attention. In particular, the distinction between boldface and italics is an important one. An italicized variable refers to a scalar quantity (eg: \(x=3\)). A variable in boldface refers to a column vector or a matrix. For example, in the equation \(Ax=b\), \(A\) is a matrix and \(x\) and \(b\) are column vectors.

Also, although this article is based on a paper written by Khachiyan, his discovery was not made without the benefit of previous work by other men. Khachiyan's paper is based on earlier work by A Yu Levin, N Z Shor, D B Judin, and A Z Nemirovsky....GW
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TYPE
TIME_OF_DAY = RECORD
  HOURS  : 0..24;
  MINUTES : 0..59;
  SECONDS : 0..59;
END;
VAR
  NOW: TIME_OF_DAY;
  SAMPLE: INTEGER;
PROCEDURE INCREMENT_TIME_OF_DAY;
BEGIN
  INCREMENTS NOW BY ONE SECOND;
END;
PROCEDURE GET SAMPLE; (TALK TO AID CONVERTER)
BEGIN
  SAMPLE: = INPUT [$38]; (GET 1/0 PORT DATA)
  OUTPUT ($FA) = SHA [SAMPLE, 3]; (USE SHIFT RIGHT)
  WHILE TESTBIT [INPUT ($SC), 2] <> TRUE DO: (WAIT)
  INLINE ['MVI A, $3E'] SIM 'MOV A, B'; (STORAGE)
END;
PROCEDURE INTERRUPT [RTC_VECTOR] RTC_ISR;
BEGIN
  INTERRUPT SERVICE ROUTINE
  GET SAMPLE (* EVERY SECOND *)
  INCREMENT_TIME_OF_DAY
END;
BEGIN
  NOW.SECONDS: = 0;
  NOW.MINUTES: = 0;
  NOW.HOURS: = 0;
  INLINE ['MVI A, /B3E /SIM ($DB5)'; (START CLOCK)
  GET SAMPLE; (TAKE FIRST SAMPLE)
  WHILE NOW.HOURS <> 3 DO: (SAMPLE FOR 3 HOURS)
END; (AT END RETURN TO OPERATING SYSTEM)
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This article will present a summary of and a commentary on Khachiyan's original paper. A graphic example of how the algorithm works is shown in figure 3. We will show how Khachiyan's method handles linear programming problems and discuss some possible improvements in the computer application of Khachiyan's proposals. We will then turn to the practical question: Is Khachiyan's algorithm capable of immediate computer application? Although our conclusion is a qualified "no," we will discuss a BASIC program (in Part 2 of this article) for the TRS-80 that can be used to gain an appreciation of Khachiyan's achievement.

Khachiyan's Paper

Our discussion of Khachiyan's paper is based on B Seckler's translation of the paper into English. We would like to thank Professor Seckler for making this translation for us. We use Khachiyan's notations in this discussion so that what he did and how he described it will be clear.

Consider the regions of the plane \( \mathbb{R}^2 \) shown in figure 1. The region in figure 1a is the intersection of the four half-planes \( x_1 \geq 1, x_1 = s_2, x_2 \geq 1, \) and \( x_2 = s_2. \) These inequalities may be rewritten in the form:

\[
\begin{align*}
-x_1 + 0x_2 & \leq -1 \\
x_1 + 0x_2 & \leq 2 \\
0x_1 - x_2 & \leq -1 \\
0x_1 + x_2 & \leq 2
\end{align*}
\] (1.1)

Since there are points in the plane that satisfy all four inequalities at once, this system of linear inequalities is said to be consistent.

In figure 1b, the shaded region on the lower left-hand side is defined by \( x_1 = s_1 \) and \( x_2 = s_1, \) while the shaded region on the upper right-hand side is given by \( x_1 \geq 2 \) and \( x_2 \geq 2. \) If we combine these inequalities into one system:

\[
\begin{align*}
x_1 + 0x_2 & \leq s_1 \\
0x_1 + x_2 & \leq s_1 \\
-x_1 + 0x_2 & \leq -2 \\
0x_1 - x_2 & \leq -2
\end{align*}
\] (1.2)

we notice that there is no point in the plane that satisfies all four inequalities at once. Such a system of linear inequalities is said to be inconsistent.

We shall use the letters \( a, b, \ldots \) to denote column vectors and \( a^t \) to denote the transposition of the column vector into a row vector. (See text box.) We will write \( \mathbb{R}^n \) for the usual \( n \)-dimensional Euclidean space. [Readers unfamiliar with vectors and matrices will find descriptions in many engineering mathematics texts. Advanced Engineering Mathematics by E Kreyszig, Wiley, 1967, 2nd ed., is particularly good... CM]

Using the above notation, we may let \( x' = (x_1, x_2), a_1 = (-1, 0), a_2 = (1, 0), a_3 = (0, -1), \) and \( a_4 = (0,1). \) Then (1.1) may be rewritten in the form:

\[
a_i^t x \leq b_i \quad (\text{for } i = 1, 2, 3, 4)
\]

where \( b_1 = -1, b_2 = 2, b_3 = -1, \) and \( b_4 = 2. \)

As we see from figure 1, such a system of linear inequalities may or may not be consistent. We will consider only inequalities in which all coefficients are integers. This is no loss of generality, since numbers in a computer can be expressed only to a fixed number of decimal places. By multiplying each inequality through by an appropriate power of ten, we may express each inequality in integers alone.

Thus we are led to the following problem. Given a system of linear inequalities:

\[
a_i^t x \leq b_i \quad (\text{for } i = 1, \ldots, m)
\] (2)

with integral coefficients, is the system consistent or inconsistent?

Advantages of Khachiyan's Algorithm

Khachiyan's algorithm is a procedure for deciding whether the system given in (2) is consistent. In addition, if the system is consistent, it finds the coordinates of a point satisfying all of the inequalities, or it at least determines them within a small margin of error. Furthermore—and this is the "revolutionary" aspect—the method gives at the start a maximum number of steps (each step...
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requiring a fixed number of mathematical operations) that will be required to solve the problem. This maximum number of steps increases as the number of variables in the problem increases. With Khachiyan's method, however, the maximum number of steps grows far more slowly than with any other known method, as will be described shortly.

For a system given by (2), let:

$$L = \left\lceil \sum_{i=1}^{m} \sum_{j=1}^{n} \log_2(|a_{ij}| + 1) + \sum_{i=1}^{m} \log_2(|b_i| + 1) + \log_{2}nm \right\rceil + 1 \quad (3)$$

where \(\lceil x \rceil\) denotes the greatest integer less than \(x\). This quantity gives a measure of the size of the system (2) of inequalities and an estimate of the number of binary symbols (0 and 1) needed to pose the system for Turing machine solution.

The execution of the algorithm involves \(N = 16Ln^2\) iterations. The values computed at each step are required to be accurate to \(2^{-37}\). Notice that as the system of inequalities is made more and more complicated, the number of steps in the algorithm increases as a polynomial in \(n\). This means that the problem of determining the consistency of a system of linear inequalities belongs to the class of problems that are solvable in polynomial time on deterministic Turing machines. But from a practical viewpoint, it must be noted that the precision required also increases tremendously with the size of the problem.

The phrase "solvable in polynomial time" means that the time (or amount of computation) necessary to solve the problem is always less than a certain computable amount. The amount is computed by evaluating a function of \(n\), the number of variables in the problem; and when the problem is solvable in polynomial time, the function uses only powers of the function (eg: time \(t = K_n^n\) for Khachiyan's algorithm, for some very large value of \(K\) and some constant value \(p\)). This is an advantage when solving a linear programming problem because existing methods solve the problem in exponential time (a function that uses the term \(e^n\)), and, for a sufficiently large value of \(n\), a solution in exponential time will take much

longer than a solution in polynomial time. To date, the extremely high computation time has made computer solution of very large linear programming problems impossible. The significance of Khachiyan's algorithm being computable in polynomial time is that, on the surface, it opens the possibility of computer solution of these problems....[GW]

Details of the Algorithm

The steps of the algorithm involve four quantities: a vector \(x_i\) in \(R^n\) representing the estimate of a solution at the conclusion of the \(k\)th iteration; an \(n\)-by-\(n\) matrix, \(Q_k\), representing the dimensions of an ellipsoid containing the solutions of the system; the current discrepancy \(\theta_k(x_k)\) which measures how far the current estimate \(x_k\) is from being a solution; and the discrepancy of record, \(\theta_\text{rec}\), which keeps track of the best estimate of a solution found so far by being equal to the smallest \(\theta\) value encountered within its first \(k\) values.

The principle of the algorithm is like the traditional method of catching fish in a net: casting the net over such a large region that some of what is wanted must be inside, then gradually decreasing the volume of the net. When the volume is sufficiently reduced, it becomes obvious whether or not anything has been caught.

At the initial step, \(k = 0\), we set:

\[
\begin{align*}
    x_0 &= 0 \\
    Q_0 &= 2^n \times I_n \\
    \theta_0 &= \theta(x_0) = \max_i (b_i) \\
    \theta_\text{rec} &= \theta_0(x_0)
\end{align*}
\]

(where \(I_n\) is the \(n\)-by-\(n\) identity matrix)

The execution of the algorithm at the \(k\)th step begins by finding the current discrepancy

\[
\theta_k(x_k) = \max_i (a_{ij} \cdot x_k - b_i)
\]

and recording the value of \(i\) (labeled \(i(k)\)) of the equation giving this maximum value. \(\theta_k\) measures the discrepancy of the current \(x_k\) from being a solution of (2), while \(i(k)\) specifies the index of the inequality that is the worst offender. The discrepancy of record, \(\theta_\text{rec}\), is defined as the minimum of \(\theta_k\) and \(\theta_{\text{rec}}(x_k)\).
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The algorithm then shifts the center of the ellipsoid net in the "direction" of \(i(k)\) and shrinks the ellipsoid to close in on the desired solution. (See figure 3 and the following geometric interpretation of the algorithm in the text.) This is accomplished by setting:

\[
\begin{align*}
x_{k+1} &= x_k + \frac{1}{n+1} \frac{Q_k \cdot F_k}{|F_k|} \\
Q_{k+1} &= 2^{1/(8n^2)} \times Q_k \cdot \text{Ort}(F_k) \cdot \Lambda_n
\end{align*}
\]

where:
- \(F_k = -Q_k \cdot a_{i(k)}\)
- \(|F_k|\) is the norm (or magnitude) of the column vector \(F_k\)
- \(\text{Ort}(F_k)\) is an orthogonal \(n\)-by-\(n\) matrix (constructed by the Gram-Schmidt process) with the first column equal to \(F_k\) (remember that, because of its orthogonality, \(\text{Ort}(F_k)\) is a distance-preserving linear transformation)
- \(\Lambda_n\) is the \(n\)-by-\(n\) diagonal matrix with diagonal entries \((n/(n+1)), (n/\sqrt{n^2-1}), \ldots, (n/\sqrt{n^2-1})\)

It is possible to show by induction that the sizes of the quantities in (5) obey the following constraints:

\[
|Q_k| \leq 2 \frac{1}{\sqrt{n}}
\]

where the norm of matrix \(Q_k\) (\(|Q_k|\)) is the square root of the sum of the squares of its entries. It is important to note that the point \(x_k\) generated by this algorithm may jump around in a rather random and sometimes extravagant manner, and that it is only the steady contraction of the region (which has a volume equal to \(\det(Q_k)\)) that ensures that a solution will ultimately be found.

If \(\theta_k(x_k)\) becomes zero or negative at any step, then \(x_k\) is a solution of the system (2), and the algorithm is terminated. If the algorithm runs through all \(N = 16L_n^2\) steps, the discrepancy \(\Theta_{N+1}\) is calculated and the process ends.

**Geometry of the Algorithm**

Geometrically, each solution \(x\) for the system (2) of inequalities can be considered as a point in \(n\)-dimensional space, and the aggregate of all such solution points forms a certain volume, the solution set. In Khachiyan's algorithm, each matrix \(Q_k\) specifies an ellipse \(E_k\) centered at the point \(x_k\) according to \(E_k = \{y: y = x_k + Q_k z, |z| \leq 1\}\). A less formal description of \(E_k\) is as follows: the \(n\)-dimensional ellipse \(E_k\) is the set of points (or column vectors) \(y\) that are formed by adding the column vector \(Q_k z\) to the current estimate \(x_k\), where \(z\) is an arbitrary \(n\)-dimensional column vector with a length (magnitude) of 1 or less...GW

The initial choice of \(x_0\) and \(Q_0\) specifies a sphere of radius \(2^L\) centered at the origin. It can be shown that this sphere contains at least a certain minimum volume of solution points, if any exist. The ellipses then change position and shrink, but they always contain at least the prescribed minimum volume of solutions. Khachiyan's observation is that, once the ellipse has shrunk to that...
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Figure 3: A graphic example of Khachiyan's algorithm. The Khachiyan algorithm (described here for a two-dimensional problem) begins with a circle centered at the origin with a radius of a given size such that the circle is guaranteed to contain the solution points, if they exist. Successive iterations of Khachiyan's algorithm produce ellipses of smaller area that still contain the solution points. Here, the initial circle $E_0$ is shown in figure 3a. Ellipse $E_1$ is then computed from $E_0$, as shown in figure 3b, and ellipse $E_2$ is computed from $E_1$, as shown in figure 3c. In the last two figures, the current ellipse is shown in black, and the previous ellipse is shown in gray. The shaded area in all three figures describes the inequalities' solution set.

Minimum volume (and it does so within $16L_n^2$ steps), it can contain only solutions. Thus, either the center $x_0$ is a solution (making the discrepancy $\leq 0$), or there were no solutions in the first place, and the system is inconsistent.

To see graphically how the ellipses evolve, we will consider the following simple system of linear inequalities:

$$-x_1 + 0x_2 \leq -1$$
$$0x_1 - x_2 \leq -1$$

graphed in figure 2. These are, in fact, the first and third inequalities of system (1.1).

To make the diagrams clearer, we do not take $L = 7$, as equation (3) would dictate, but $L = 2$, which we will later show (in Part 2) is permissible. This makes $x_0 = 0$ and $Q_0 = \text{diag}(4,4)$ (a 2-by-2 matrix with 4 in the main diagonal elements, 0 elsewhere). The initial ellipse $E_0$ is shown in figure 3a.
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Khachiyan's algorithm is an approximation of the following geometric construction of the next ellipse \( E_{i+1} \) with center \( x_{i+1} \), from the known ellipse \( E_i \) with center \( x_i \). Since this construction does not give the exact results of the formulas in (5), we will denote the results of our construction by \( E'_i \) and \( x'_i \).

The ellipse \( E'_i \) is determined from \( E_0 \) and \( x_0 \) (see figure 3b) as follows:

- Draw a chord through \( x_0 \) parallel to the boundary of the inequality most severely violated (indicated previously as having subscript \( i(k) \)). This chord cuts the ellipse \( E_i \) at two points, \( p_1 \) and \( p_2 \). The solution set of the inequality \( i(k) \) will lie on one side, the "solution side," of the chord. (The solution side of the hyperplane can be determined by examination.)
- The new ellipse \( E'_i \) passes through \( p_1 \) and \( p_2 \), has its center on the solution side of the chord, and is tangent to the old ellipse \( E_i \) at the point \( T \).
- Of the infinite family of ellipses satisfying the above conditions, choose the one with the smallest volume. \( x'_i \) is the center of this new ellipse \( E'_i \).

The ellipses \( E_i \) and \( E'_i \) (determined similarly from \( E_i \)) are shown in figures 3b and 3c, each with its predecessor drawn in gray. Note that the ellipses are shrinking, the three having approximate areas of fifty, forty, and thirty-two square units respectively. The algorithm ended with ellipse \( E_i \), since its center \( x'_i \) is in the solution set.

It is important to notice that, while the requirements of tangency and minimal volume in our construction are aesthetically pleasing, they are impossible to achieve in practice. Remember that Khachiyan is concerned with a calculation procedure having only a limited degree of accuracy. If any of the numbers encountered in the execution of the algorithm could not be exactly represented in the computer, the cumulative effect of the resulting rounding errors could be fatal, particularly in the detection of the inconsistency of a system of inequalities. The paper of Gacs and Lovasz, mentioned previously as ignoring questions of computational precision, presents a modification of the algorithm that computes the tangent ellipses of minimal volume. Thus the Gacs-Lovasz formulas cannot be expected to be successful in any actual computation.

Khachiyan overcomes this difficulty by choosing his ellipses slightly larger than necessary so that, even with his limited accuracy, he can assure that the region he wants is contained in them. The trick here is that if the ellipses are made too large, they will not shrink down on the solutions fast enough. Khachiyan's formulas in (5) for the ellipses achieve the proper balance between the problem of accuracy and the need for a rapidly shrinking series of ellipses.

If you carry out the calculations for the example of figure 2, you will find that, while \( E_i \) passes through the points \((0, 0')\) and \((4, 0')\), Khachiyan's ellipse \( E'_i \) passes through \((0, 4.12')\) and \((4.06, 0')\).

Part 2 of this article will discuss a fundamental shortcoming of Khachiyan's algorithm and will include a program in BASIC for the TRS-80.
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Construction of a Fourth-Generation Video Terminal, Part 1

Theron Wierenga
POB 2007
Holland MI 49423

The construction of this fourth-generation video terminal is a project that began as a detour from the plans for building a 16-bit microcomputer. I have had a long-standing interest in building an advanced-design video terminal that would have a scrolling feature and a large 2000-character display. It was my desire to have the terminal utilize one of the new programmable video-display-controller integrated circuits, and be a stand-alone unit with its own microprocessor that would not steal cycles from or otherwise load down the host computer. The number of additional parts that are needed to add the microprocessor is quite minimal and, in turn, the microprocessor reduces additional interfacing that would be otherwise needed. The circuitry of this terminal, when wire-wrapped on a single board, could fill one slot in the motherboard of the planned 16-bit microcomputer, or could be used with any other host computer as a stand-alone unit.

Upon receiving a copy of Intel Corporation's Peripheral Design Handbook (April 1978 edition), I found a set of plans for just such a terminal. The article is entitled "CRT Terminal Design Using the Intel 8275 and 8279." This circuit and its associated software were the basis for my design. This month, in Part 1, I'll describe the construction up to the point where you can get the 8085 microprocessor operating. Next month, in Part 2, I shall tell about the procedures for assembling the keyboard and video circuitry, putting the control software into operation, and checking out the system. Readers planning to build this terminal should obtain a copy of the Peripheral Design Handbook, as well as the MCS-85 Users Manual, which describes the operation of the 8085 microprocessor. Included in the fifty-seven-page article are detailed design theory, system specifications, system hardware and software design, an explanation of software subroutines, and the original design schematics and data sheets on the Intel peripheral circuits that are utilized in the design. The Intel handbooks are available from Intel Corporation, Literature Department, 3065 Bowers Ave, Santa Clara CA 95051.

Terminal Features

Here are some of the features of this video terminal:

Display format: eighty characters per display row, twenty-five display rows.

Character format: 5-by-7 character contained within a 7-by-10 matrix, first and tenth lines blanked, first and seventh columns blanked, ninth line cursor position, blinking underline cursor.


Control characters:
- Line feed (control-])
- Carriage return (control-M)
- Back space (control-H)

Escape sequences:
- Cursor up (ESC, A)
- Cursor down (ESC, B)
- Cursor right (ESC, C)
- Cursor left (ESC, D)
- Clear screen (ESC, E)
- Home (ESC, H)
- Erase to end of screen (ESC, J)
- Erase line (ESC, K)

Characters transmitted: sixty-four
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"The Seven Bridges of Königsberg" shown mounted in a standard 12"x16" frame. Frame not included.
ASCII uppercase alphanumeric characters, ASCII control character set, ASCII escape sequence set.

Program memory: 2 K bytes, 2716 erasable programmable read-only memory.

Display/buffer/stack memory: 2 K bytes, 2114 static programmable memory.

Data rates: 300, 600, 1200, 2400, 4800 bits per second (bps).

Interface to host computer: 20 mA current loop.

Scrolling capability: Scroll-up feature implemented with 8257 direct-memory-access controller.

The author of the Intel article used an 8080A-based single-board computer, the Intel SDK-80, and an SBC-905 prototype board for the additional circuitry needed. I wanted everything to fit on a single board and to run off a single 5 V power supply, so extensive changes were made in my design. The schematic diagram appears in figure 1. The completed unit retains all of the original features plus one or two more.

Hardware Changes

The following are the major hardware changes that were made in my design:

- An 8085 microprocessor was substituted for the 8080A device. Although the parts count is about the same, the 8085 system needs only a single 5 V power supply. The 8085 microprocessor needs an additional 8212 latch for the lower address lines and a 74LS257 multiplexer to produce the control bus. The interfacing to the 8257 direct-memory-access controller is somewhat involved; a detailed schematic of this is provided in the Peripheral Design Handbook on pages 1 thru 82.

- The additional 8216 buffer from MEMR and MEMW is unnecessary. These signals can be taken directly from the 74LS257.

- A single 74LS138 decoder was used for enabling the peripheral circuitry (i.e., the 8251, 8257, 8275, and 8279 devices).

- A 5 V type, 2513 character-generator read-only memory was substituted for the 2708. This saves programming the sixty-four 5-by-7 matrices into a 2708-type programmable read-only memory.

- The MD (mode) lines on the two 8212s that buffer the 2114 memory integrated circuits are tied to ground instead of +5 V. This is an error in the Intel schematic.

- Interrupt lines for the 8251 and 8275 are not connected into the 8085. The TRAP interrupt is pulled down to ground through a dual-in-line pin (DIP) switch. Opening this switch pulls up the TRAP interrupt, vectoring the 8085 microprocessor to a small system monitor.

- Video and sync signals were added together through the use of a 7401 open-collector NAND package and a single transistor to form a composite-video output.

Photo 1: The complete video terminal circuitry constructed on a wire-wrap board. The component side is shown.

Photo 2: The bottom or wired side of the video terminal board.
Programming Techniques is a series of collected articles concerned with the art and science of computer programming. The first volume in the Programming Techniques series is entitled Program Design. The purpose of the book is to provide the personal computer user with the techniques needed to design efficient, effective, maintainable programs.

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Figure 1: Schematic diagram of the video terminal circuit. The Intel 8275 video-display controller is in the center of the figure.
Text continued from page 212:
- With a system clock of 6.144 MHz, data rates of 300, 600, 1200, 2400, and 4800 bps were generated with a 7490 and 7493 counter. Data-rate selection is through five positions of an eight-position DIP switch.
- A current-loop interface was used, since only a 5 V supply was available. There is also provision for direct access to the universal asynchronous receiver/transmitter (UART) pins.
- An 8131 comparator was substituted for the 74LS138 used for 2716 decoding.
- Decoding was done somewhat differently for the programmable memory, although the addresses still extend from hexadecimal 8000 to 87FF. These addresses make compatibility with the 8257 direct-memory-access controller easy.
- Details are given as to how the keyboard is connected to the system. This is missing in the original article. An inexpensive unencoded keyboard (available from Jameco Electronics) was mounted using a printed-circuit board as well as some wire-wrap connections.
- The video monitor that I used is a 12-inch Motorola unit that takes a composite-video input signal. It was obtained as surplus in used condition. Whatever brand or size is used, it should have a bandwidth of 12 MHz.

Software Changes
A number of changes were made in the software as supplied in the Intel articles. Several minor changes have no direct effect on the program execution, but rather just shorten the code. The major changes are as follows:
- The interrupt vectors at the top of the program were removed. A single vector for the TRAP interrupt was left in. When the TRAP switch is opened, the 8085 microprocessor will transfer control to a small system monitor that can be used for debugging.
- A polling system is used in place of the interrupt system to check the states of three of the peripheral systems. First, the system checks to see if a character has been received by the 8212; second, if the 8275 has requested that the 8257 be reinitialized; and third, if the 8279 has a character to be transmitted from the keyboard. A data rate of 4800 bps is still possible using this polling system.
- The table for character lookup for the keyboard has been changed completely. This was done to comply with the way that I had wired the scan matrix for the unencoded keyboard. A few additional ASCII codes were added that can be transmitted from the video terminal. These codes were for keys on the Jameco keyboard.
- The initialization of the 8251 and 8279 was changed. The values used should work for most systems.
- The 8257 was initialized to Mode 0 because of the change to a standard 2513 character generator.
- A system monitor was added at the bottom of the program which has five commands. The use of the monitor is covered in Part 2 of this article.

Photo 3: The sixty-three-key Jameco keyboard mounted on its printed-circuit board and installed on support blocks.

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The port numbers for the peripheral circuits have been changed. These values are set at the beginning of the video-control software.

Construction

The order in which the sections of this video terminal are built is very important. It is most unusual to put together a project as complex as this without having some sort of problems. Following the order as it is given here will help with some debugging, and hopefully make things go more easily. Do not try to assemble everything and then give it the smoke test.

I chose to connect the electronic parts by wire-wrapping. With the hundreds of connections necessary, it is almost impossible to not make a few wiring errors the first time around. Wire-wrapping allows you to add or change connections easily if it is necessary. Wire-wrap also allows for a very compact design, which helps to cut down the electrical noise in the system. You should have available an oscilloscope, frequency counter, a general-purpose volt-ohm milliammeter, a wire-wrap gun, 30-gauge wire strippers, and a quantity of 30-gauge wire (as well as the usual pliers, screwdrivers, soldering iron, etc).

A large Vector wire-wrap board (#4350) was used for the circuit, but several other general-purpose wire-wrap boards could also be used. Some individuals may choose one of the S-100 type boards, which would work just as well. Use one that has power and ground planes on it. This makes it easy to distribute the power supply lines to integrated circuits, and provides a good method for installing noise capacitors.

Glue the integrated-circuit wire-wrap sockets in place with an epoxy-type glue that comes in two components and must be mixed before use. After mixing the adhesive, wait until it starts to thicken considerably before applying it to the sockets. If the integrated-circuit sockets that you use do not have a few small holes in the bottom of the plastic body, make two or three holes with a 1/16-inch drill. This will give the glue something to which it can adhere. Do not use any of the "super glue" types of instant-bonding adhesive, as these are very thin and can bleed into the integrated-circuit socket, plugging up the pin holes and cementing the contacts together. An illustration of the parts layout is shown in figure 3.

Following my own particular order, I first make all connections to the power-supply pins on the integrated circuits. These connections are given in table 1. Connect 5 V to the power-supply bus and check out the voltage at the proper pins of each integrated-circuit socket before installing the integrated circuits themselves. When you do apply power to the circuit, have an ammeter connected to your power supply. High current readings are a quick indication of serious problems. The entire circuit when completed should draw about 1.6 A at 5 V. The usual precautions against static electricity when handling metal-oxide semiconductors (MOS) should be observed for the memory circuits, as
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well as all of the 8000-series Intel circuits.

Next, make a photocopy of the entire schematic diagram. As you begin to wrap connections, use a red pen to trace each connection made on the schematic. This simple method eliminates the need for a wiring table, but establishes a complete bookkeeping system that indicates which connections are installed or incomplete.

It is helpful to use as many different colors of wire as possible. The address bus can be done in one color, the data bus in another, power-supply lines can be red for +5 V and black for ground, and so forth. This is a great help when you have to trace down wires to check connections. Take the time to cut each wire to the exact length needed. Do not make wires any longer than necessary.

Route wires neatly in between the wire-wrap sockets, and try to keep wires free from bundles of wires. A neat board is much easier to troubleshoot than the "rat's nest" variety.

The few resistors and capacitors that are needed can be mounted on one 16-pin and one 24-pin header plug. The 22.68 MHz crystal and 2N3710 transistor can also be mounted on the 24-pin header plug. The 6.144 MHz crystal with its two 20 pf capacitors is mounted next to the 8085 with Vector T-49 Klipwrap pins.

Getting the 8085 Microprocessor Operating

The first integrated circuits to install are the 8085 (IC1), 8212 (IC2), low address latch for the 8085, 74LS257 (IC28), 8213 (IC35), 7216 (IC34), 8251 (IC7), 74LS138 (IC18, peripheral decoder), 7490 (IC16), 7493 (IC17), the eight-position DIP switch, and IC11 (the 7400 NAND package that contains a gate to buffer the clock output of the 8085). All of the connections should be made to these devices.

Program the 2716 read-only memory with the 22-byte checkout program that is given in listing 1. Temporarily ground the HOLD input to the 8085 (pin 39) and three of the inputs that are normally driven by the AEN output (pin 9) of the 8257. These inputs are at pin 4 of IC18 (the 74LS138 peripheral decoder), pins 1 of IC2 (the 8212 latch that holds the low address lines from the 8085), and IC28 of the 74LS257.

After you reset the 8085 microprocessor, the simple test program should send out continuous ASCII "U" characters from the 8251 transmitter data output (pin 19). With the 300 bps switch closed, pin 19 of the 8251 should produce a square wave at 150 Hz, which is 300 bps. The IOW line (pin 12 of the 74LS257) should show 30 Hz on a frequency counter. The negative pulses on IOW are very narrow and may not show up on an inexpensive oscilloscope. If you have these signals present, your 8085 microprocessor and its associated circuitry are working correctly.

Do not go beyond this point in construction until your 8085 microprocessor is functioning correctly. If you have problems, check the following items. Make sure that the clock output of the 8085 is 3.072 MHz, and that this signal is getting to

Text continued on page 224
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Listing 1: A test program for the 8085 microprocessor section of the video terminal. This should be programmed into the 2716 read-only memory. When the checkout terminal is connected using the temporary interface shown in figure 2 and the 8085 is reset, this program should cause the ASCII character "U" to be printed continuously on the checkout terminal.

```
LIST PROGRAM 1 FOR TRS-80

0001 CNTCH EQU 1
0000 CNTR EQU 0

INITIALIZING R251

0000 1370 MVI A, 079H
0002 B301 OUT CNR 11
0004 1327 MVI A, 027H
0006 B301 OUT CNR 11

SEND CONTINUOUS U'S FROM R251

0008 BR01 LOOP: TN CNTCH INPUU STATUS
000A EA01 LOOP: JZ LOOP
000C 180B000 MVI A, 055H
000F 1355 MVI A, 055H
0011 B300 OUT CNR 11
0013 13300000 MVI A, 0080H

NO PROGRAM ERRORS
1 B080 MACRO ASSEMBLER, VER 2.0 ERRORS = 0 PAGE 2

SYMBOL TABLE

01
A 0007 8 0000 0 0001 CNTCH 0001
H 0004 1 0005 1 MPP 0000 1

1C CRT7800

Figure 2: Schematic diagram of the temporary interface for connecting the checkout terminal to the new terminal for debugging.

Circle 165 on Inquiry card.
Circle 166 on inquiry card.

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06 = ENTER/UPDATE INVENTORY

07 = ENTER/UPDATE ORDERS

08 = ENTER/UPDATE BANKS

09 = EXAMINE/MONITOR SALES LEDGER

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14 = PRINT SUPPLIER STATEMENTS

15 = PRINT AGENT STATEMENTS

16 = PRINT TAX STATEMENTS

17 = PRINT WEEK/MONTH SALES

18 = PRINT WEEK/MONTH PURCHASES

19 = PRINT YEAR AUDIT

20 = PRINT PROFIT/Loss ACCOUNT

21 = UPDATE END MONTH FILES MAINTENANCE

22 = PRINT CASH FLOW FORECAST

23 = ENTER/UPDATE PAYROLL (NOT YET AVAILABLE)

24 = RETURN TO BASIC

**WHICH ONE? (ENTER 1-24)**

01 SUB. MENU EXAMPLE: 01 = EXAMINE; 02 = INSERT; 03 = AMEND; 04 = DELETE

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Circle 168 on inquiry card.
Text continued from page 220:

pin 20 of the 8251. Check the TxC and RxC inputs of the 8251 (pins 9 and 25). The frequency on these inputs should be sixty-four times the desired data rate (ie: for 300 bps it should be 19,200 Hz). If this frequency is not correct, check the connections on the 7490 and 7493, as well as the data rate switch. The ALE line (pin 30 on the 8085) should have a frequency of about 650.8 kHz on it. There should be no activity on the MEMW line (pin 9 of the 74LS257). The IOR line (pin 7 of the 74LS257) should have a frequency of about 92.2 kHz. The frequencies listed above should all be read with a frequency counter that uses a full 1-second count period, since the pulses on many of these lines do not have a constant duty cycle. Erroneous readings can result from count periods shorter than one second.

Until next month's BYTE arrives, you will have plenty of time to check the construction of this portion of the circuit. Then, in Part 2, we can proceed with the rest of the project.

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**Another Club in Florida**

The Level II Club is an organization where TRS-80 owners can exchange software. The group has a large program library and will soon offer an ads section and programming contests. There are no membership fees. For more information, write Level II Club, 3713 Bay-to-Bay Blvd., Tampa, FL 33609.

**FORTH Interest Group**

The FORTH Interest Group meets on the fourth Saturday of each month in the Special Events Room of Liberty House Department Store, Southland Shopping Center, Highway 17 at Winton Ave., Hayward, California. The group also publishes a newsletter, FORTH Dimensions. Editorial material is always welcome. A subscription to FORTH Dimensions is free when you join the FORTH Interest Group for $12 per year in the US, or $15 overseas. Contact the group by writing, FORTH Interest Group, POB 1105, San Carlos CA 94070.

**International Apple Core**

The International Apple Core (IAC) is a nonprofit independent organization that will act as the parent organization for local Apple computer groups. Membership is not open to individuals, although they may subscribe to the IAC's quarterly publication. The organization will offer information on hardware, software, application notes, and programming tips to member groups. The IAC will also make its library accessible to member groups. More information, Apple user groups can contact the International Apple Core, POB 976, Daly City CA 94017.

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**A Computer Group in Amarillo**

The High Plains TRS-80 Users Group of Amarillo, Texas, meets the second and fourth Tuesdays of every month at the downtown branch of the Amarillo Public Library on 413 E 4th St., from 7 to 9 PM. The annual dues are $15. For information, write High Plains TRS-80 Users Group, POB 30545, Amarillo TX 79120.

**TBUG-80 in Florida**

This group in Tampa Bay, Florida, supports the use of the TRS-80 for games and business applications. Tutorial sessions at the meetings cover everything from the proper operation of the hardware to disk-based programming techniques. The club's newsletter contains program notes, reviews of products for the TRS-80, and letters of Rational Data Systems' (RDS) Pascal to competitive products, and a section on matters of programming style. Free subscriptions to RDS's Pascal Newsletter and a product brochure are available by writing or calling Rational Data Systems, 245 W 55th St., New York NY 10019, (212) 757-0011.
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computer-aided instruction library for the Apple and is
receiving donations from throughout the world. Con-
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Heights CA 95610.

Computer Society in Washington

The Whidbey Island Computer Society (WICS) is
dedicated to promoting education and fellowship in
the realm of home computing. The only require-
ment for membership is an interest in the field of
microcomputing. The group currently has an AIM-65,
Apple II, Heathkit H8, TRS-80, Exidy Sorcerer, and
a Z80 homebrew system.

WICS meets monthly on the
second and fourth Saturday.
For further information,
contact Dee Minter, 1616
Larch Dr, Oak Harbor WA
98277, (206) 675-7964.

Gosub-TRS-80 Users Group

Gosub TRS-80 Users Group was formed to pro-
vide TRS-80 users with a
place to exchange ideas, in-
formation, and other
computer-related material.

The group meets on the
third Sunday of each month
in the computer room at the
Camar Corporation, 186
Prescott St, Worcester,
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Membership dues are $6 per
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BYTE's Bits

First National Conference on Artificial
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Stanford University in
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being sponsored by the newly
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Association for Artificial
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The topics will cover
robotics, cognitive modelling,
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more. Many artificial in-
telligence research groups
and manufacturers will be
demonstrating AI and other
computer hardware and
software. A tutorial pro-
gram on August 18 will ex-
amine the current artificial
intelligence research in this
country. The AAAI is a
group whose purpose is to
study and disseminate infor-
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SEPTEMBER 1980

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The Thirteenth International Symposium and Exhibition on Minicomputer and Microcomputer Applications, MIMI'80, Montreal, Canada. This symposium will cover communications, signal processing, data acquisition, control, robotics, education, hardware, languages, networks, and other topics. It is being held in conjunction with the first IASTED International Symposium and Exhibition on Office Automation. For more information, contact Professor M H Hamza, Dept of Electrical Engineering, University of Calgary, Calgary, Alberta, T2N 1N4 Canada.

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Wescon/80, Anaheim Convention Center, Anaheim CA. This year's show will include a large exhibition and a variety of talks covering communications, computers, microprocessors, consumer electronics, energy, office automation, semiconductor technology, and more. Contact Wescon, 999 N Sepulveda Blvd, El Segundo CA 90245, (213) 772-2965.

September 16 thru October 16
Eastern European Electronics Catalog Exhibit. Exhibits will focus on production tools and machines, test instrumentation, electronic components and hardware, computers for production, chemicals, and other materials. Symposia will cover electronic manufacturing techniques and progressive production computer technology. The host cities will be: Warsaw, Poland; Bucharest, Romania; Sofia, Bulgaria; Budapest, Hungary; and Prague, Czechoslovakia.

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September 17-19
ACM Small/Personal Computer Conference, Rickey's Hyatt House, Palo Alto CA. This symposium will blend contributed papers with panel and informal discussions. Included will be hardware and software topics involving theory, design, construction, marketing, and applications. Discussions will cover microcomputer applications in business, industry, education, and the home. Details are available from Conference Chairman, Philippe Lehot, PLA, 976 Longridge Rd, Oakland CA 94610.

September 18-21
Mid-Atlantic Business and Home-Computer Show, DC Armory/Starplex, Washington DC. This is an end-user exposition featuring small- and medium-sized business systems, scientific and engineering computers, microcomputers, and electronics. Contact Northeast Expositions Inc, POB 678, Brookline Village MA 02147, (617) 524-0000.

September 22-25
Software INFO, Hyatt Regency, Chicago IL. This is the first national conference and exhibition on packaged software held in the US. For more information, or to reserve exhibition space, call or write Software INFO, Suite 545, 222 W Adams St, Chicago IL 60606, (312) 263-3131.

September 24-27
The Tenth Annual Conference of the Society for Computer Medicine, San Diego Hilton, San Diego CA. This conference has been planned for physicians, attorneys, administrators, computer professionals, comptrollers, engineers, nurses, and anyone interested in the use of computers for patient care. Sessions on medical subjects, technical subjects, and contributed papers on new research in computer medicine will be offered. For information, contact Society for Computer Medicine, 1901 N Ft Myer Dr, Suite 602, Arlington VA 22209, (703) 529-0098.

September 25-28
Mid-Atlantic Personal and Business Computer Show, Philadelphia Civic Center, Philadelphia PA. General admission for adults is $5. This show is being produced by National Computer Shows, POB 678, Brookline Village MA 02147, (617) 524-0000.

September 26-27
Classroom Applications of Computers in Grades K Thru 12, Independence High School, San Jose CA. A visit to "Silicon Valley," tutorials, workshops, and exhibits will highlight this conference. The emphasis will be to inform teachers about the possible uses of computers in all areas of education. Contact Computer-Using Educators, c/o W Don McKell, Independence High School, 1776 Educational Park Dr, San Jose CA 95133.

September 27-28
New Jersey Personal Computer Show and Flea Market -80, Holiday Inn (North) Convention Center, Newark NJ. This show will feature an indoor commercial exhibit and sales area, an outdoor flea market with room for 500 sellers, and systems; and more. Details from Compcon '80 Fall, POB 639, Silver Spring MD 20901.
forums for all popular hobby computing systems. This show is primarily for hobbyists and small-business owners. The admission price is $4 in advance and $5 at the door. Contact NJPCS, Kenmore Corp., 9 James Ave, Kendall Park NJ 08824, (201) 297-6918 after 7 PM.

September 29-October 4
The Eighth International Conference on Computational Linguistics, Tokyo, Japan. This conference will provide a forum for a variety of computational linguistics topics including theories, methods, and applications of computational linguistics; models of natural language processing; applications of natural language processing; hardware and software supports for language data processing; and more. For information, contact Professor David G. Hays, Twin Willows, 5048 Lakeside Rd, Hamburg NY 14075.

OCTOBER 1980
October 6-8
APL Users Meeting, Toronto, Canada. This conference is aimed at APL users as well as those considering the future use of APL in their systems. Speakers will present papers that discuss the practical use of APL, managing APL resources, teaching APL, and APL programming techniques. The registration fee for $180 (Canadian currency) includes a copy of the proceedings. For further information, contact Professor Rosanne Will, I P Sharp Associates Ltd, 145 King St W, Toronto Ontario MSH 1J8, Canada.

October 6-9 and 14-17
The Eighth World Computer Congress, Tokyo, Japan, and Melbourne, Australia. Computer architecture and hardware, software, database and information systems, computer networks and communication, information processing and education, and computers in everyday life are some of the topics that will be discussed at this conference. There will also be a large exhibition of hardware and software at the conferences. Contact the US Committee for IFIP Congress '80, c/o The Bowery Savings Bank, 110 E 42nd St, New York NY 10017.

October 8-10
Circulation Computer Systems Symposium, Chicago Marriott Hotel, Chicago IL. More than 425 newspaper publishers, general managers, circulation directors, controllers, and data-processing managers are expected to attend. Workshop sessions will be held for participants who already have or are considering automated circulation systems. For more information, contact American Newspaper Publishers Association, The Newspaper Center, POB 17407, Dulles Airport, Washington DC 20041, (703) 620-9500.

October 26-29
International Data Processing Conference and Business Exposition, Philadelphia Sheraton Hotel, Philadelphia PA. This conference is being sponsored by the Data Processing Management Association. Contact Conference Coordinator, DPMA International Headquarters, 505 Busse Hwy, Park Ridge IL 60068, (312) 825-8124.

In order to gain optimal coverage of your organization's computer conferences, seminars, workshops, courses, etc., notice should reach our office at least three months in advance of the date of the event. Entries should be sent to: Event Queue, BYTE Publications, 70 Main St, Peterborough NH 03458. Each month we publish the current contents of the queue for the month of the cover date and the two following calendar months. Thus, a given event may appear as many as three times in this section if it is sent to us far enough in advance.

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Liquid-Crystal Displays

Dear Steve,

I recently examined a Milton Bradley Microvision miniature video game, which features a 1-5-inch-square liquid-crystal display (LCD) consisting of 16 rows of 16 square blocks. I want to build a circuit to drive this display unit. How difficult would it be to modify the circuit you presented for use with an 8-by-16 array of light-emitting diodes (LEDs)?

(See "Self-Refreshing LED Graphics Display," by Steve Ciarcia, October 1979 BYTE, pages 58 thru 69.)

The LCD display unit could provide useful capability to a single-board microcomputer.

I have also considered developing a programmable game cartridge for the Microvision console. The console contains two 9 V battery cells, a voltage regulator, a potentiometer "paddle control," a piezoelectric beeper, a 4-by-3 printed-circuit keypad, the LCD unit, and a 40-pin dual-inline-package integrated circuit that appears to be the display driver. The Blockbuster game cartridge that comes with the console contains a 28-pin integrated circuit, a window for the display, and labeled cutouts for four control keys, along with passive components. Communication between the cartridge and the console is via a 24-pin connector.

I don’t expect you to design circuits for me; if you did that for everyone who writes, you would not have enough time for your own work. However, you could do me a real favor by identifying two integrated circuits in the Microvision game: The first has 40 pins and is marked “SCUS0488, H 7920.” The second has 28 pins and is marked “TMS1100NL, MP 3450A, DBU7932.”

I hope you will keep up the good work.

Daniel Q Dye Jr

A lot of people are interested in using the LCD unit you mention. However, LEDs (light-emitting diodes) and LCDs have very different principles of operation. An LED becomes a source of light when you pass an electric current through it, consuming a fair amount of power. LCDs, on the other hand, act as voltage-controlled reflectors of light. When an AC voltage (not DC) is applied to a liquid-crystal display, the liquid changes from transparent to opaque, consuming relatively little power. Because of this, the design approach in my LED project does not work for LCDs. But don’t despair: I

Continued on page 238
What TECO* does for minis, TED will do for your micro.

Like TECO*, TED is a character-oriented editor that gives you everything you'd expect. Plus, you get many things you wouldn't expect.

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MAPPER I adapts the TRS-80 to run the vast library of CP/M software as well as the TRS-80 software. All Lifeboat Software may be ordered for the MAPPER I. All MAPPER I CP/M software is compatible with the CP/M for the Model II. With MAPPER II and 8" drives, the Model I becomes disk compatible with the Model II.

Standard features include lower case support, serial and parallel printer drivers, and an addressable cursor. MAPPER I is supplied with complete utilities including a memory test, a disk test, a copy program, and a proprietary program for converting TRS-DOS files to CP/M files. $199.

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See reviews in July 80 and August 80 BYTE By Jerry Pournelle.
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I have written a tutorial article on LCDs to be presented in the October Ciarcia's Circuit Cellar.

Concerning the components in the Microvision: the 28-pin device is a Texas Instruments TMS1000-series 4-bit microprocessor, that uses CMOS (complementary metal-oxide semiconductor) technology. The program for the Blockbuster game (or other game) is contained within it in a read-only memory. The 40-pin part is a custom multiplexed display-driver circuit for the LCD unit. The display driver is driven through the I/O (input/output) lines of the microprocessor. I hope I've helped.

Steve

The Very Busy Box

Dear Steve,

In all of your articles (which I read avidly) I have not seen any projects directed towards the Heath H8 computer system. I constructed my H8 hoping to learn about computer hardware, but instead found myself only following instructions. I find it very difficult to apply your projects to my system. It would be of great benefit if, in one of your articles, you would include information on interfacing your "house controller" (see "Computerize a Home," January 1980 BYTE, page 28) to the H8.

Bearing in mind that we H8 owners are basically hardware-oriented, I believe that we would be more likely to construct a project than someone who purchased a system completely assembled. Please consider the H8 in future articles; I am sure that the reception will be well worth the effort.

Ted Benglen

Most computers are equal where interfacing is concerned. If you look closely at the bus signals on your H8 you will notice a striking similarity between their names and the names of

ports, the signals are often easily accessible and compatible among systems.

Steve

A Bit of Music

Dear Steve,

As a composer/performer, I found your article "Sound

Figure 1

Continued from page 234:

The BSR interface (trademarked "Busy Box") requires an I/OWR* strobe (the *indicates a negative-true signal), address lines A0 thru A7, data lines D0 thru D7, and power. All address and data bus lines on the H8 use inverted logic levels, so the circuit of figure 1 is necessary to make the system compatible with the TRS-80 attachment shown in the article.

I generally try to list signal inputs so that experimenters will not be discouraged by a title that says "TRS-80" or "Apple." For simple input and output

ports, the signals are often easily accessible and compatible among systems.

Steve

Dear Steve,

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The potential of computer-controlled music generation inspired me to purchase a Commodore PET, but the tones generated by my rudimentary system are not exactly musical.

I would appreciate any improvements and suggestions you might have. The limiting factor in my case, and I am sure this is true for others, is lack of proficiency with the instrument.

Jack Hobson

My talents are geared more toward building the instrument than making music on it. If you are reasonably adept at building circuitry there is a way to run the General Instrument AY-3-8910 Programmable Complex Sound Generator from the parallel user port (I2) of the PET. The clocking of the integrated circuit is not critical, only the sequence of events, but the circuit does require 11 bits of information.
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The circuit of figure 2 here uses only 74LS95 4-bit parallel-access shift registers. IC1, IC2, and IC3 are paralleled to form a 12-bit shift register, and IC4, IC5, and IC6 make up a 12-bit latch. By setting the appropriate logic level on bit 7 of the user port, the information will be loaded into the 12-bit register when a high/low/high transition occurs on bit 1. When 12 bits have been loaded, a low/high/low transition on bit 0 can be used to latch the binary value and stabilize the information while more is loaded.

The fast action of the shift and store operations should be fairly transparent to the AY-3-8910, which should operate as described in the article.

Steve

A Bit More Music

Dear Steve,

I read with interest your article on the AY-3-8910, and I am presently building the interface for my Southwest Technical Products 6800 system. Do you intend to publish any software for the 6800-based processors that will drive the circuit?

Arnold Pung

The AY-3-8910 is made by General Instrument on Long Island (600 W John St, Hicksville NY 11802). They

Figure 3

Power to the Computer

Dear Steve,

I would like to suggest a possible future subject: backup power for microcomputers. I am very interested in home control and security, but the more responsibility and power I give my system, the more strongly I feel that it should have an uninterruptible power source (UPS).

Stanly W Pozeisky

Thank you for your suggestion. I have also been considering uninterruptible power supplies. I have a 26 K-byte Z80 computer running 24 hours a day, and an UPS is a requirement. Unfortunately, when we start talking about running the computer and disk drives, we start talking about quite a bit of power. This could conceivably require several hundred watts, so a system similar to those used in commercial installations might be in order. (See figure 3.)

This system uses battery backup, with a large inverter to supply normal AC during an outage. Designing power inverters is an art itself, and considerable care must be taken so as not to run afoul of the FCC radiofrequency interference (RFI) standards. While I mull this over, you might want to obtain a copy of the February 1980 issue of Digital Design for a good article on the subject.

Steve

Control Your Life!

Now have full computer control of up to 256 lights, appliances and even wall switches without special wiring. The SciTronics REMOTE CONTROLLER permits direct control of the inexpensive BSR remote line-carrier switches sold by Sears, Radio Shack and many others.

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Circle 200 on inquiry card.
The electric Pencil II

The Electric Pencil is a Character-Oriented Word Processing System. This means that text is entered as a continuous string of characters and is rendered as such. This allows the user to add or delete text at any point without any restriction. Since lines are not destroyed, the user can add or delete text at any point, much like a typewriter. This makes text entry much easier and more efficient.

The Electric Pencil II is designed for industrial and laboratory use. It is a hybrid chip, operating at 25 kHz, and has 12-bit resolution, ± the LSB accuracy. It is compatible with an ASCII level 1 (IBM system) and Level II models of the TRS-80. This means that it can be used with most of the popular software packages available for the TRS-80.

### Features

- **Camera Conversion**: Instantaneous image capture and display of images. The electric Pencil II allows you to enter and exit the camera mode quickly and easily.
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- **Text Searching**: Quick text searching. The electric Pencil II allows you to quickly search for text in the document.
- **Text Printing**: Easy text printing. The electric Pencil II allows you to easily print the document.

The electric Pencil II is available for the TRS-80 Model I and II. It is a hybrid chip, operating at 25 kHz, and has 12-bit resolution, ± the LSB accuracy. It is compatible with an ASCII level 1 (IBM system) and Level II models of the TRS-80.

In summary, the Electric Pencil II is a powerful and versatile word processing system that allows you to enter and edit text quickly and easily. It is a valuable tool for anyone who needs to work with text on a daily basis.
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System requirements are 32K CP/M. CP/M is a registered trademark of Digital Research
PERIPHERALS

Printer Uses Plastic and Metallized Daisy Wheels Interchangeably

A series of serial impact printers that produce typewriter-quality output for word processing, data processing, and communications applications has been announced by Diablo Systems Inc, 24500 Industrial Blvd, Hayward CA 94545, (415) 786-5207. The Model 630 daisy-wheel printers use plastic and metallized print wheels interchangeably, with print speeds from 32 to 40 cps (characters per second) depending on the type of print wheel, type style, and text. Model 630 printers accept all Diablo and Xerox plastic and metal print wheels. Friction and pin-feed platens and other paper-handling options are offered. The 630 series supports the RS-232C/V.24 interface for communications applications, and a microprocessor interface that permits direct attachment of the printers to a variety of small office and data processing systems. The price is $860 in original equipment manufacturer's (OEM) quantities of 500. Circle 490 on inquiry card.

Removable Disk Cartridges for CDC and Ampex Drives

The 4420 is a removable disk cartridge for use on Control Data's cartridge module drive (CMD) 9448 series and equivalent disk drives. The product is available for storing up to 16 megabytes of data. The disk cartridge uses one surface to record data and one surface to function as a dedicated servo reference. Density is 248 tracks per inch, with 823 tracks per surface. The cartridge is available with factory formatting. For information, contact Nashua Corporation, 4 Franklin St, Nashua NH 03061. Circle 491 on inquiry card.

Two Printers from Facit

Facit Inc, 66 Field Point Rd, Greenwich CT 06830, has developed two printers, the 4520 and the 4542. The 4520 is a bidirectional printer with a speed of 100 cps (characters per second) and a noise level of less than 60 dB. The 4520 is microprocessor-controlled, with a 100% duty cycle. The printer utilizes a 9-by-9 dot matrix, while accommodating paper-roll or fanfold forms. A serial or parallel interface is included. The unit price is under $1000. The 4542 provides the full graphic capability and control of Facit's 9-by-9 matrix. It features two-color printout, gray scale, and proportionate spacing. All European versions, Katakana, APL, and Libris character sets are available. The 4542 lists for under $4000. Circle 493 on inquiry card.

Modem Eliminator

International Data Sciences Inc, 7 Wellington Rd, Lincoln RI 02865, (401) 333-6300, has introduced the Model 6100 modem eliminator. The unit allows interconnection of data-terminal equipment without modems. It can be used in asynchronous or synchronous modes, and with terminals configured for half- or full-duplex operation. The BDS modem eliminator also eliminates the need for two back-to-back modems operating within a short distance. Features include internal strap selections for primary and secondary RTS/CTS delays, ring memory functions, and clock source. Data-terminal equipment can be located up to 50 feet from the modem eliminator, allowing a maximum separation of 100 feet. Its DTE interface conforms to EIA RS-232C and CCITT V.24 standards. The Model 6100 is priced at $360. Circle 494 on inquiry card.

An RS-232 Card Reader

The Model 121-4 card reader is capable of reading any common punched or marked card and includes serial RS-232 or card image output (with Hollerith-to-ASCII conversion if necessary), parallel 20 mA current-loop output, self-clocking on both marked and 80-column punched cards, or operation with printed strobe marks on either side of the card. The 121-4 may be set for card feed-through at 6 ips (inches per second), or automatic return of cards to the front after reading. This card reader also has a self-test feature which enables the user to check sensor accuracy. The Model 121-4 operates on either 50 or 60 cps (characters per second) and sells for approximately $520 in original equipment manufacturer's quantities. For more information, contact HEI Inc, Jonathan Industrial Center, Chaska MN 55318, (612) 448-3510. Circle 492 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 judgement the information might be of interest to the personal computing experimenters and homeworkers 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.
A Printer from Mauro

Mauro Engineering, Rt 1, Box 133, Mt Shasta CA 96067, (916) 926-4406, has introduced the MP-250 PROAC pen plotter. It uses standard paper sizes and plots at speeds of up to 2.5 inches per second with 0.005-inch resolution. The standard machine uses one parallel output port and comes with full-vector driver software for 8080, 6502, and 6800 microprocessors. Interfaces are available for the TRS-80, Apple, and serial data ports. The MP-250 can be used for graphics, schematics, music composition, architectural drawings, and other applications involving plotting. The MP-250 costs $650.
Circle 497 on inquiry card.

EPROM Programmer with RS-232 Interface

This erasable programmable read-only memory (EPROM) programmer, Model EP-2A-87, with RS-232 and 20 mA loop interfaces, has been introduced by Optimal Technology Inc, Blue Wood 127, Earlysville VA 22936, (804) 973-5482. The programmer includes a 2 K- or 4 K-byte buffer which can be loaded or read by another computer in the on-line mode. Data rates are 110 and 1200 bps (bits per second). In the off-line mode, a keyboard enables the operator to program, verify, and check if the EPROM is erased, and load the buffer from the EPROM. EPROMs may be copied in the off-line mode by first loading the buffer from the programming socket. A built-in self-test includes provisions for checking the buffer and whether the EPROM will enter the high-impedance state. Priced at $600 with a 4 K-byte buffer, personality modules are $16 to $35 for programming various EPROMs on the market.
Circle 499 on inquiry card.

6502-Based Single-Board Computer

Compas Microsystems, 224 S E 16th St, Ames IA 50010, (515) 232-8187, has announced CSB 2, a stand-alone module based on the 6502 microprocessor. The board is compatible with the Rockwell System 65 bus standard. EXORcisor-based cards may be used with CSB 2 with minor modifications. CSB 2 includes a 6502 microprocessor, 2 K bytes of static programmable memory, four sockets for Intel 2716 or 2764 erasable programmable read-only memory (EPROM) integrated circuits, one VIA (6522), one PIA (6520), and one ACIA (6551). CSB 2 provides 30 input/output (I/O) lines, ten buffered output lines, two interval timers, input latching on peripheral ports, an RS-232 port with data speeds from 110 to 19,200 bps (bits per second), and up to 32 K bytes of EPROM space. CSB 2 is priced at $395 and the manual is available for $4.
Circle 500 on inquiry card.
What's New?

MISCELLANEOUS

Nuts & Volts

Nuts & Volts is a new publication serving amateur radio and computer enthusiasts. It is devoted exclusively to classified and display advertising for new and used equipment. Items are categorized for easy reference, and there are sections for business opportunities and wanted items as well. Classified ads are $0.10 per word with a $2 minimum charge. Typesetting and art services are available for display advertisers. Nuts & Volts is available monthly for a one-time charge of $5 from Nuts & Volts POB 1111, Placentia CA 92670.

Circle 538 on inquiry card.

Reset Extender for TRS-80

The Reset Extender is an aid for TRS-80 owners who have trouble accessing the Reset button in the back of the keyboard. Most TRS-80 owners use a pencil to hit the Reset button. With little effort, the Extender attaches to the hood and simplifies reset tremendously. The Reset Extender is available from Emmanuel B Garcia Jr & Associates, 203 N Wabash, Rm 2102, Chicago IL 60601, (312) 782-9750, for $3.99.

Circle 501 on inquiry card.

Microprocessor-Controlled Floppy-Disk Drive and Controller

The System 2000/10 is a microprocessor-controlled floppy-disk drive and controller that plugs into the Teletype Model 43, the Texas Instruments Silent 700, and similar typewriter terminals. The System 2000/10 can operate as a stand-alone word processor, or as an on-line, storage, edit, and forward unit. In the on-line mode, the data rate is capable of reaching 9600 bps (bits per second). In the on-line mode, it can be invisible to the host computer. The system can also be used with ADM-3A, Teletype 912, and similar video displays. A software package includes global search and global replace commands. Options include extra programmable memory up to 64 K bytes, a printer port, Telex interface, BASIC and IBM 3740 compatibility. The price for the System 2000/10 is $1595. Contact Terminal Data Corporation, 11878 Coakley Cir, Rockville MD 20852, (301) 881-7655.

Circle 502 on inquiry card.

Commercial Calculators from Texas Instruments

Texas Instruments has announced a family of heavy-duty commercial calculators incorporating the Seiko 350 mechanical printer. Ranging in price from $160 to $205, the TI-5213, -5215, -5217, and -5219, have been designed for operator comfort and reliability. Each model features two-key rollover and 10-level keyboard buffering. The printer delivers 2.8 lines per second using standard 5.8 cm (2.25 inch) paper and prints up to twelve digits plus commas, decimal point, and two-column audit trail. Other features common to all four models include multiplication and division by a constant, automatic computation of percentage calculations, independent add register, grand total register, grand total on/off switch, decimal selector, automatic rounding, and item count. Inquiries should be addressed to Texas Instruments Inc, POB 10508, M/S 5889, Lubbock TX 79408.

Circle 504 on Inquiry card.

Serial Communications and Control on a Single Card

Vantage Data Products has developed a single-card computer for use in communications and control applications. The Z80-based card is used with serial input/output (I/O), parallel I/O, programmable memory, and erasable programmable read-only memory (EPROM). Serial communications are asynchronous RS-232 and programmable to all standard data rates up to 5600 bps (bits per second). Modern-control functions are also included. Power requirements are +5 V and +12 V. Negative voltage for RS-232 communication is generated on the card. Options include a software-monitor program on EPROM for operation of the computer with a terminal, and single power-supply options. The suggested retail price is $195. Contact Vantage Data Products, 550 W 200 South, Suite 8, Provo UT 84601, (801) 377-6687.

Circle 505 on Inquiry card.
Floppy-Disk Drive Power Supplies

Powertec Inc, 20550 Nordhoff St, Chatsworth CA 91311, (213) 882-0004, has introduced the FD series of floppy-disk, dual-output power supplies. The FD101 delivers main channel outputs of +5 V at 0.75 A and secondary channel outputs of +12 V at 1.8 V. The FD101 offers flexible strap-selectable inputs of 103-127/206-254 VAC, single phase 47 to 440 Hz. Standard features include overvoltage, overload, short circuit and reverse voltage protections, no turn-on or turn-off overshoot, and a one-year warranty. The supplies provide line regulation of ±0.5% for a ±10% input line change, and static loads of 50 to 100%. Load regulation for the units is ±0.5% on all outputs for a 0 to 100% load change, 5 mV peak-to-peak maximum ripple, 0.03°C temperature stability over full operating ranges and 0.3% drift for a 24-hour period. Transient response is less than 50 ms for a 50% load change. Contact the company for prices and availability.

Bidirectional Totalizer

The DigiTec Model 8222 bidirectional totalizer is used for counting functions in industrial processes or product-test systems where up-down counting is required. All up-down counting functions, with count direction control, are user-programmable. Operating modes include totalizing two inputs by adding and/or subtracting one from the other based on phase relationship or logic input. Software response ensures that every pulse is added or subtracted even during simultaneous occurrence. The Model 8222 is available with either a 5- or 7-digit LED (light-emitting diode) display. Both models offer polarity and overflow indication. The unit is 4.8 by 38 by 19 cm (1.89 by 6.6 by 6.86 inches), and the cost is $415 for the 5-digit model and $467 for the 7-digit model. Address inquiries to United Systems Corporation, 918 Woodley Rd, Dayton OH 45403, (313) 254-6251.

A Talking Voltmeter

This talking voltmeter allows users to keep their eyes on the probes and avoid shocks, short circuits, and blown integrated circuits. It is also an aid for the visually handicapped. The dual microprocessor-based system provides voltage readings that are automatically announced via an internal 3-inch speaker every 7 seconds, or upon operator command. A slave processor selects the speech elements that are required by the measurement, while the main processor controls the system timing and signal processing. The instrument is powered by a rechargeable nicad battery pack. It weighs 1.1 kg (2.5 lbs) and measures 6.2 by 25.5 by 23 cm (2.5 by 10 by 9 inches). An earphone jack is provided for work in noisy environments. Options include an LCD (liquid-crystal display), current and resistance measurement circuits, and a serial interface for recording the digital output on audio cassette recorders. Foreign languages are also available. The price is $395. For details, contact the Franklin Institute Research Laboratory Inc, The Benjamin Franklin Pky, Philadelphia PA 19103, (215) 448-1340.

The Connection

The Connection is a modem designed for TRS-80 Models I and II. It eliminates acoustic coupling, so line sensitivity is increased and transmission errors are reduced. The RS-232 port provides the means to simultaneously run a printer or input data from a keyboard. It features a data rate of 300 bits per second (bps), single and duplex mode, direct connection of wires between telephone and computer, software, and instructions. For further details on The Connection, contact The micro-Peripheral Corporation, POB 529, Mercer Island WA 98040.

Circle 506 on inquiry card.
What's New?

MISCELLANEOUS

Winter 1980 Catalog from Inmac

Twenty-four new computer supply and accessory products are featured in Inmac's Winter 1980 catalog. The new offerings include preformatted floppy disks, thirteen Clear Signal microcomputer cables, sound enclosures designed to keep noise in and dust out, floppy-disk hanging file folders, and mini-data-cartridge binder leaves. For a free subscription to the full-color catalog, call or write Inmac, Dept BPR, 2465 Augustine Dr, Santa Clara CA 95051, (408) 727-1970.

Computer Products from Electronic Systems

A catalog featuring systems by Apple, Radio Shack, Atari, Compucolor, and other companies is available from Electronic Systems, POB 21638, San Jose CA 95151, (408) 448-0800. Electronic Systems also sells products for S-100 bus systems, tools, software, terminals, and many other items. The catalog includes prices and order forms.

Vector Offers Electronic Packaging Catalog

Vector Electronic Company's catalog has complete details on the company's electronic-packaging products, tools, and kits. Emphasis is placed on microcomputer-interface boards for all conventional buses, a variety of card cages and cabinets, breadboarding components, plus numerous sockets and terminals. Price lists are included along with the names and the addresses of Vector's distributors. Contact Vector Electronic Company, 12460 Gladstone Ave, Sylmar CA 91342, (213) 365-9661.

SDI Graphics Interface

The Cromemco SDI is a high-resolution graphics interface designed for use in Cromemco computer systems. The SDI displays color or black-and-white images with up to 756-by-484 point resolution. It features color map selection, dual page windowing function, automatic area fill mode, and NTSC broadcast compatibility. The SDI consists of two circuit boards that plug directly into the S-100 bus of any Cromemco microcomputer system. Each pixel of the display may be mapped from one nybble or from one bit of the display memory. Twelve or 48 bytes of memory may be used for the display memory, allowing four basic modes of operation. In bit-mapped mode any two of these colors may be displayed in a single picture. For black-and-white nybble-mapped mode there can be 16 shades of grey. A bit-mapped black-and-white picture yields only a black-and-white display. The three outputs of the device can display three different pictures to three different selections, dual page windowing function, and NTSC broadcast compatibility. The SDI can be synchronized to external television equipment through the use of an external composite RS-170 sync signal, a composite video signal, or external horizontal and vertical sync signals. The SDI graphics interface is available for $595 from Cromemco Inc, 280 Bernardo Ave, Mountain View CA 94043, (415) 964-7400.

The Hayden 1980 Computer Science Catalog

This publication contains the complete selection of Hayden titles on everything about computers from introductory information to advanced technology. It is available from Hayden Book Company Inc, 50 Essex St, Rochelle Park NJ 07662, (201) 843-0550.

The Hobby-Blox System

Hobby-Blox is a breadboard system that allows the user to customize the board to fit projects. The system includes plug-in tie points, interchangeable modules, color-keyed and cross-indexed modules. There are two starter packs; one for discrete component projects, the other for integrated circuits projects. The system includes 14 modules that can be purchased individually, most with a suggested retail price below $3. The modular packs include a tray, terminal strips, distribution strips, discrete strips, bus strips, display strips, LED (light-emitting diodes) strips, vertical tray, speaker panel, control panel, blank panel, battery holder, binding post strips, and tray extender clips. The two starter packs are priced under $7. For information, contact A P Products Inc, 1359 W Jackson St, Painesville OH 44077.

Circle 510 on Inquiry card.

Circle 513 on Inquiry card.

Circle 511 on Inquiry card.

Circle 514 on Inquiry card.

Circle 515 on Inquiry card.

Circle 512 on Inquiry card.
The Z-88 Processor Card

The Z-88 offers 16-bit processing power to S-100 bus users. The card combines a Z80A and an 8088 microprocessor to allow access to all currently available 8080 software without the need to translate into 8086 machine language. The 8088 is fully software compatible with the 8086, so all 16-bit software, such as Microsoft 8086 BASIC, will run on the Z-88. The Z-88 features an 8-bit data bus that uses existing products without modification; direct memory address of 16 megabytes; selectable IEEE Preliminary Standard or Altair/Imai S-100 bus; no wait states with 450-ns memory access; vectored or noninterrupting modes that transfer control between processors; a 1 K-byte phantom read-only memory (ROM) which initializes the microprocessor; and an 8-level TTL (transistor-transistor logic) priority-vector interrupt. The cost to build a Z-88 is around $450. For more information, contact the designers at Programmers Publishing Company, POB 2571, Kalamazoo MI 49003, (616) 344-9323.

Circle 516 on Inquiry card.

Intel MDS-Compatible 10-Megabyte Storage Unit

Advant Corporation, 696 Trimble Rd, San Jose CA 95131, (408) 946-9300, has introduced a 10-megabyte Winchester hard-disk data storage unit. Interfacing with all Intel MDS models, the MicroSupport Model 105 data storage unit utilizes Shugart 8-inch Winchester hard disks. The MicroSupport 105 features built-in error correction, a microprocessor-based controller, and a power supply. For more information, contact the Advant Corporation.

Circle 518 on Inquiry card.

Books from MIT Press

Systems theory, computer sciences, artificial intelligence, programming languages, information, communication, and control are the topics covered by a variety of books published by the MIT Press. The new catalog also contains series and classified listings. For a copy of Computer Science, Engineering, contact the MIT Press, 28 Carleton St, Cambridge MA 02142.

Circle 519 on Inquiry card.

Software for the Atari 800

Atari 800 software is now available through Sebree's Computing. Atari's 3-Dimensional Graphics Package, for $29.95, will run on 8 K- or 16 K-byte machines. It features multiple-color control, selectable resolution, line clipping and pushing, telephoto and wide-angle views, four program listings, and a manual. Using one of the four programs, the user can input any scene, rotate it and view it from any location in three-dimensional space or even from inside of it. Wumpus Adventure is a mixture of two popular games that has color graphics and sound effects. The user can control arrow direction and action during the battles. The program is designed for the 16 K-byte unit and costs $14.95. Contact Sebree's Computing, 456 Granite Ave, Monrovia CA 91016, (213) 359-8092.

Circle 520 on Inquiry card.
**SOFTWARE**

**Suprdump for the TRS-80**
Definitive Micro Systems, 20 Glenwood Cres, St. Alberta, Alberta T5N 1X5, Canada, have announced Suprdump, a disk dump/modify utility for the TRS-80 Model I. Suprdump is designed to expedite the debugging of programs utilizing disk files. It can also create disk-file test data. The utility will dump a specified disk sector onto the video screen in a hexadecimal plus ASCII (American Standard Code for Information Interchange) format. Modification of the information on disk is accomplished by typing over the displayed data. Suprdump is supplied on a floppy disk for $29.95.

Circle 521 on Inquiry card.

**The Magic Wand**
The Magic Wand is a word-processing program that provides underscoring, boldface, superscripting, and subscripting in any combination and even all at once. Boldface can vary in intensity and underline can be broken or solid. The program provides justification, discretionary hyphens, and other processing capabilities. It can also create form letters from a mailing list, assist in writing standard letters, perform variable line spacing, print with true proportional spacing, print headers and footers on each page, automatic pagination, and more. It is written for the TRS-80 Model I and requires CP/M. The price is $350 from Pickles & Trout, POB 1206, Goleta CA 93017, (805) 967-9553.

Circle 522 on Inquiry card.

**Attach an Apple to a Malibu**
The Malibu/Apple Input/Output (I/O) card serves as an interface between the Apple II and the Malibu Model 165 printer. The Malibu card uses the Apple's microprocessor to provide bidirectional printing, changeable type fonts, high-resolution graphics printout, and other functions. The card is compatible with Integer BASIC, AppleSoft, Apple Pascal, as well as Appewriter and EasyWriter. The Malibu card uses a technique whereby it substitutes its software for the Apple's during printing. After the printing is completed, control is passed back to the Apple software. For further information, contact Malibu Design Group Inc, 211109 Nordhoff St, Chatsworth CA 91311.

Circle 523 on Inquiry card.

**6800 C Compiler**
Wintek has introduced a C compiler for the 6800 microprocessor. The compiler includes the features described in the book *The C Programming Language* by Kernighan and Ritchie (Prentice-Hall). C is a structured-programming language for operating systems and numerical, text-processing, data-base programs, and other general applications. Characters, numbers, and addresses can be combined and efficiently moved about with the 6800 arithmetic and logical operations. Consequently, C is very efficient in the amount of 6800 code generated. C provides pointers and the ability to do arithmetic. Any function can be called recursively and its variables declared in a block-structured fashion. Variables may be internal, external, or global. Functions of a C program can be compiled separately. The C compiler is intended to run under the Wizrd multitasking disk operating system on the Sprint 68 microcomputer. The cost for C is $495. The cost for the Sprint 68 with 48 K bytes of programmable memory, dual 8-inch floppy-disk drives, and Wizrd is $3995. Contact Wintek Corporation, 1801 South St, Lafayette IN 47904, (317) 742-8428.

Circle 524 on Inquiry card.

**polyFORTH**
polyFORTH is an operating system for microprocessor-development systems and minicomputers. polyFORTH provides the compiler, interpreters, assembler, character editor, virtual memory, and multitasking capability within its 8 K bytes of memory. Application programs can be coded combining high-level with low-level languages. Program-development time is cut down because the interactive programming environment allows rapid testing and debugging. Memory requirements for complex applications are reduced to as little as half that of assembler programs and to about 10% that of other high-level languages. Run speed is controlled by the programmer. Time-critical routines can run at full machine speed. All versions of polyFORTH are compatible with a minimal number of machine-dependent features. The language features 16-bit arithmetic on all systems, as well as 32-bit capacity. For $2500, users receive polyFORTH on a floppy disk, a set of programmable read-only memory (PROM) integrated circuits containing the precompiled system, two manuals, and access to a hot line service and newsletter. Contact FORTH Inc, 2309 Pacific Coast Hwy, Hermosa Beach CA 90254, (213) 372-8493.

Circle 527 on Inquiry card.

**Software for the HP-85: The Pro-Organizer**
The Pro-Organizer is for applications ranging from a daily appointment organizer to an index box for maintaining name and address lists, to a data bank for the professional, executive, engineer, or scientist. The program is designed for the 16 K-byte HP-85 computer and is supplied on cartridge. It is completely automatic from power turn-on. Any data-management requirements may be custom formatted. Data may be edited easily. Additional cartridges may be used to build up a library. The suggested retail price is $95. For details, contact Scelbi Publications, 20 Huribut St, Elmwood CT 06110, (203) 522-3515.

Circle 525 on Inquiry card.

**Apple FORTH 1.7**
With this FORTH Interest Group-compatible system, Apple users can define operations and enter them as components of the language. Machine-language subroutines can be entered directly from the keyboard, where they are assembled immediately and ready to run or test. Apple FORTH 1.7 includes a screen editor that can be customized. It has facilities to manufacture turnkey disks which boot directly into user applications. FORTH is its own operating system and debugger, including compile-time checks. Programs run faster than Integer BASIC, and object code is very compact. This language is compatible with the FORTH International Standard, so programs can be run on 8080- and PDP-11-based systems. A 48 K-byte Apple II or Apple II Plus with one or two disk drives is required. The price is $140, including a manual, from Cap'n Software, POB 575, San Francisco CA 94101, (415) 848-6913.

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10 Megabyte Hard Disk

$3,495*

5440-12 Top Load Drive
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COMPUTER COMPONENTS

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What's New?

SOFTWARE

SBC-FORTH on EPROM

This implementation of FORTH can run in many of Intel's and National's line of SBC-80 microprocessor cards. It runs stand-alone and requires no additional memory, input/output (I/O) devices, or disks to operate. Standard features include a resident compiler, an 8080/8085 assembler, screen editor, and adaptive disk I/O. The disk I/O allows a combination of four single-density drives or four double-density drives with two additional single-density units for a total capacity of 2500 screens. The system price is $500 including the manual. Contact Zendex Corporation, 6398 Dougherty Rd, Dublin CA 94566, (415) 829-1284.

Circle 526 on Inquiry card.

FLEX for Custom Hardware

A new version of the FLEX disk operating system is available for users of custom or nonstandard 6800 and 6809 systems. Developed by Technical Systems Consultants Inc, POB 2770, 1208 Kent Ave, West Lafayette IN 47906, (317) 463-2502, it is fully compatible with most versions of FLEX. FLEX supports features such as dynamic file space allocation, random and sequential file accessing, user startup facility, user environment control, English-language error messages, and over twenty commands for normal disk operations. This version contains a manual describing how to write disk and terminal input/output (I/O) routines to adapt FLEX to most any hardware. The only major system requirement is a soft- sectored floppy disk drive that uses 256 bytes per sector. When the adaptation is complete, the user's system will be capable of running any standard FLEX software. The $150 price includes the FLEX disk with editor and assembler, and a set of manuals.

Circle 529 on Inquiry card.

The Datahandler

The Datahandler is a data-base management system running in MMSFORTH on the TRS-80 Model I with at least 32 K bytes of programmable memory and one floppy-disk drive. Users can specify up to ten data fields appropriate to each particular job. Standard and special report formats can be output to the screen and the printer. The Datahandler includes mailing list checking-account programs with custom report commands and sample data files. It can sort a typical 100-record file in 5 seconds, and lookups take less than 1 second. An indexed-key structure incorporates string and value selection mechanisms including normal-compare and values inside or outside a range. One feature allows the program area of the Datahandler disk to be software write-protected, while the data file area is left open. Regularly used system configurations may be recompiled for 5-second loading times. Additions to the Datahandler will be a report-generator module and a large-data-files module. The Datahandler costs $59.90 including the PIMS Manual. It also requires the MMSFORTH system disk which provides its language and operating system, which costs $79.95 including an introductory manual. Contact Miller Microcomputer Services, 61 Lake Shore Rd, Natick MA 01760, (617) 653-6136.

Circle 530 on Inquiry card.

SL5—A Software-Development Tool

SL5 is a software-development tool for small systems. It is an interactive programming system with an integral compiler, interpreter, assembler, disk operating system, and library of procedures. SL5 is based on the recommendations of the 1977 FORTH Standards Committee. Since SL5 is written in SL5, it adapts to most computer operating systems. A host-executable code kernel, a source-code kernel, and a system-generation program are provided. The system-generation program regenerates the kernel from the source or generates compact stand-alone read-only memory (ROM) object modules. An SL5 development system requires less than 32 K bytes of memory. Most applications programs require less than 8 K bytes. SL5 reads and writes standard CP/M files. Versions are available for both the 8080 and Z80. The Z80 system uses the additional registers and instructions of the Z80, and contains an assembler with Z80 mnemonics. The single-system price of $150 includes complete source code and a manual. Original equipment manufacturer (OEM) and resale licenses are available. For more information, contact The Stackworks, POB 1596, 321 E Kirkwood Ave, Bloomington IN 47402, (812) 336-1600.

Circle 531 on Inquiry card.

Word Processor and 8810 System from PolyMorphic

Wordmaster II is a menu-driven word processor. The program enables users to create, edit, format, and print documents. It is designed for PolyMorphic Systems 8810 or 8813 computers. The program can print with two-color ribbons, print in boldface, print superscripts, subscripts, and multiple-line headers and footers. Repetitive spelling, phrase, or numerical errors can be easily changed. The System 8810 with Wordmaster II is available for under $9000, including the NEC Spinwriter or comparable printer. Contact PolyMorphic Systems, 460 Ward Dr, Santa Barbara CA 93111.

Circle 532 on Inquiry card.
Matrox Computer Systems

MACS-10

The MACS-10 microcomputer system combines Multibus-based hardware with the CP/M 2.0 disk operating system. The system is configured around the Z80A microprocessor and includes 48 K bytes of programmable memory and sockets for 8 K bytes of ROM (read-only memory) and EPROM (erasable programmable read-only memory). A 2 K-byte monitor, a dual 8-inch double-density floppy-disk drive, a disk controller, and interfaces for a video terminal and line printer are also included. Other peripherals can be connected through additional ports at the rear of the chassis. The microprocessor and floppy-disk controller cards occupy two slots in the card cage, leaving five slots for systems expansion. If more slots are needed, up to three card cages can be stacked together for a maximum of nineteen free card slots. Optional hardware includes a 128 K-byte programmable-memory card, and an alphanumeric and graphic video-display controllers. The price for the MACS-10 system is $5990. Details are available from Matrox Electronic Systems Ltd, 5800 Andover Ave, T M R, Quebec H4T 1H4, Canada, (514) 735-1182.

CSSN Inc has announced its System 1000 family of microcomputers. This modular, bus-oriented line of systems is organized around the IEEE (Institute of Electrical and Electronic Engineers) S-100 standard bus. The S/1000 includes a 4 MHz Z80A microprocessor, 64 K bytes of programmable memory, an 8-inch Winchester hard disk, a 13.4-megabyte cartridge-tape data backup, a variety of I/O (input/output) devices and other peripherals, and expansion capability to 16-bit processors. It is available in different configurations of operating systems and peripherals, and retails between $15,000 and $20,000. The S/1000 hard-disk cartridge backup combination can store 24 megabytes. Operating systems for the series includes CP/M 2.0, MP/M, OASIS, and CSSN PDCS, a superset of CP/M 1.4. Languages such as BASIC, COBOL, FORTRAN, C, and Pascal, can be run on the systems. For further information, contact CSSN Inc, 120 Boylston St, 4th Fl, Boston MA 02116, (617) 482-2343.

AmZ800 Single-Board Computer

The Am96/4116 MonoBoard Computer uses the 16-bit processing power of the 4 MHz AmZ800 microprocessor. Auxiliary support for the AmZ800 includes 32 K bytes of programmable memory, 8 K bytes of PROM (programmable read-only memory) sockets, two serial and three parallel I/O (input/output) ports, and five programmable counter/timers. The two RS-232 serial ports transmit data from 50 to 9600 bps (bits per second). The parallel I/O ports break down into twenty-four lines or three 8-bit ports that can be programmed for input, output, or bidirectional operation. The computer can accept multiple interrupt channels from twenty-three independent sources in non-maskable, vectored, and nonvectored modes of operation. Eight interrupt channels are handled by a programmable interrupt controller which allocates priorities, determines modes of operation and supports direct vectoring. The Am9513 System Timing Controller incorporates five independent 16-bit counters that can count up or down in binary or BCD (binary-coded decimal) at rates up to 7 MHz. The price for the Am96/4116 is $2145. Contact Advanced Micro Computers, 3340 Scott Blvd, Santa Clara CA 95051, (408) 988-7777.

CSSN Inc has announced its System 800 from IPDI

The System 800 can be expanded from 64 K bytes to 2.04 megabytes of programmable memory and from 11.2 to 31.2 megabytes of disk storage on four drives. The system allows a combination of floppy and hard disks, as well as tape cartridge backup in the same system enclosure. IPDI’s video-graphics card produces a display of up to 3000 characters of over 256 user-definable characters and symbols on a 15-inch monitor. The video-display system features sixteen levels of gray or full color and is capable of driving over thirty-two displays. For more information, contact IPDI, 2584 Wyandotte, Mountain View CA 94043, (415) 969-6086.

A Z8000 Board from Quasar Data Products

This 16-bit Z8000 S-100 board conforms to the proposed IEEE (Institute of Electrical and Electronic Engineers) standards. The system can read and write 8-bit, 16-bit or mixed 8- and 16-bit memories. The module also incorporates on-board, single-step circuitry hardware. The clock rate is 4 MHz. An 8080/8080 emulator enables users to employ most of the software that has been developed for the 8080/8080 processors. The system also has provisions to plug an 8-bit microprocessor card in the same bus as the Z8000 module, allowing software to be developed on an 8-bit system and then transferred to and executed by the Z8000. Available software includes a cross assembler, text editor, word processing software, and a business package. The QDP-8100 is available from Quasar Data Products, 25151 Mitchell Dr, North Olmsted OH 44070, (216) 779-9387, for $6395.
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THE COMPLETE PC BOARD HOUSE
EVERYTHING FOR THE S-100 BUS

* FPB-1 FRONT PANEL BOARD FOR 8080A AND Z80
  SYSTEMS IMSAI COMPATIBLE.
  PCBD  $54.95  KIT $165.00

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* CPU-1 8080A PROCESSOR BOARD WITH VECTOR
  INTERRUPT.
  PCBD  $31.95  KIT $124.95

* I0B-1 I/O BOARD, ONE SERIAL, TWO PARALLEL
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  PCBD  $31.95

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Can be used with or without the expansion bus
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Diskettes
Includes 2 game paddles, interface, software, speakers, power supply, full documentation including: schematics, theory of operation, and user guide; plus 2 games on cassette (Ping and Pong Starship Wars). $39.95

S-100 INTERFACE
AN S-100 bus Adapter—Motherboard for the TRS-80. Kit Part No. HUB121 DXK $29.95. Assembled Part No. HUB121A $37.95

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- Serial RS232C/20 mA I/O Floppy controller Disk control Data acquisition Parallel I/O Serial I/O Plug into GPA's Motherboard. GPA's quality design includes 6-44 pin edge connectors +5V, -5V, +12V, -12V external power supply required Active termination. The Motherboard, Part No. GPA80, is only $149.95.

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FOR THE GPA80
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ELECTRONIC SYSTEMS
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Circle 217 on inquiry card.
HEX ENCODED KEYBOARD
Four onboard LEDs indicate the HEX code generated for each key depression. The board requires a power supply voltage of ±5 volts. Board only $15.00 Part No. HEX-3, with parts $49.50 Part No. HEX-3A, 44 pin DIP connector $4.00 Part No. 44P.

ASCII TO CORRESPONDENCE CODE CONVERTER
This bidirectional board is a direct replacement for the board inside the Trendata 1000 terminal. The board connects to the computer via a 32-pin DIP connector and provides RS-232 serial in and out. Sold only as an assembled and tested board for $249.95 Part No. TLA-1000.

ASCII KEYBOARD
53 Keys, popular ASCII-33 format • Rugged G-10 P.C. Board, Through-Molded encoding • Two-Key Rollover • Data and Strobe compatible • Upper Case Lockout • Data and Strobe selectable • Custom Keys • George Risk Model 753. Requires +5,-12 volts. $59.95 Kit.

ASCII KEYBOARD
TTL & DTL compatible • Full 87 key array • Full 128 character ASCII output • Positive logic with outputs resting low • Data Strobe • Five user-definable spare keys • Standard 22 pin dual card edge connector • Requires +5VDC, 395 mA. Assembled & Tested.

Cherry Pro Part No. P70-05AG, $119.95.

T.V. INTERFACE
• Converts video to AM modulated RF, Channels 2 or 3. So powerful, almost no tuning is required. On board regulated power supply makes this extremely stable. Rated very highly in Doctor Dobbs Journal. Recommended by Apple. Power required is 12 volts AC/DC, or +5 volts DC. Board only $76.00 Part No. 107, with parts $13.00 Part No. 107A.

MODERN
• Type 103 • Full height • 300 baud • RS-232 compatible • CW synchronous • CW asynchronous • 44 pin DIP connector • Requires +5 volts DC Board only $76.00 Part No. 108, with parts $59.95 Part No. 108A.

UART & Baud RATE GENERATOR
• Stand alone TTY • 32 char./line, 15 lines, modifications for 64 char./line included • Parallel ASCII TTY Input • Video output • RS-232 and DCE compatible • Data and Strobe selected • Up/Down selection • 1 K on board memory • Parallel ASCII and EDS • Scroll up, down, left, right, home, EOL.

• 64 character/line included • Stand alone TTY • 44 pin L156J connector • Requires +5VDC, 395 mA. Assembled & Tested.

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44 BUS MOTHER BOARD
Has provisions for ten 44 pin (L156J) connectors, spaced 3/4 of an inch apart. Pin 20 is connected to X, and pin 22 is connected to 2 for power and ground. All others are connected in parallel. This board also has provisions for bypass capacitors. Board cost $16.00 Part No. 106. Connectors $3.00 each Part No. 44WP.

SOLID STATE SWITCH
Your computer can control power (120VAC) to your printer, power (120VAC) to your power supply, and other 120VAC appliances up to 700 watts. Board requires ±15VDC, ±5VDC, ±12VDC, ±24VDC, ±30VDC, ±50VDC, ±100VDC, ±150VDC, ±200VDC, ±300VDC, ±400VDC, ±500VDC, ±600VDC, ±700VDC.

SUPER MODERN
Originate: RS-232-20mA, 20mA compatible, Full duplex, and half duplex, direct connect, on-board power supply, compatible. Board only $9.95 Part No. 7901A, with parts $14.95 Part No. 7901A.

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This board has 8 triacs capable of switching 110 volt 6 amp loads (600 watts per channel) or a total of 880 watts. Board only $15.00 Part No. 210A, with parts $119.95 Part No. 210A

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Baud rate is continuously adjustable from 0 to 30,000. Plugs into any peripheral connector at low current drain. RS-232 input and output. On board switch selectable 5 to 8 data bits, 1 or 2 stop bits, parity or no parity either odd or even. Jumper selectable address. SOFTWARE/ INPUT and Output routine from monitor or BASIC to teletype or other serial printer. Program for using an Apple II for a video or an intelligent terminal. Also can output in correspondence code to interface with some electrics. Also watches DTR. Board only $15.00 Part No. 2, with parts $42.00 Part No. 2A, assembled $62.00 Part No. 2C

APPLE II# PARALLEL INTERFACE

There are Inputs that can be driven from TTL logic or any 5 volt logic. The circuit board can be plugged into any of the 8 sockets for your Apple II. It has a 16 pin socket for standard dip ribbon cable connection. Board only $15.00 Part No. 120, with parts $39.95 Part No. 120A

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- Power on jump and reset jump option for “turnkey” systems and use or 1680, or 1620.
- Program says software in 2706 EPROM.
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MBS-121 A & T ......................................... $89.95
MBS-181 Bare board .................................... $19.95
MBS-181 Kit ........................................... $39.95
MBS-181 A & T ......................................... $139.95

Mainframes

MAINFRAME - Cal Comp Sys
12 slot S-100 mainframe with 20 amp power supply
ENC-112105 Kit ....................................... $309.95
ENC-112106 A ......................................... $549.95

DISK MAINFRAME - NNC
Dual 9" drive cabinet w/ 8 slot motherboard
ENS-112520 with 20 amp p.s. .......................... $699.95

Video Monitors

VIDEO 100 - Leedex
12" B&W monitor with 12 MHz bandwidth
VDM-801210 .......................................... $139.95

VIDEO 100-80 - Leedex
81 x 24 version of Video 100 with metal cabinet
VDM-801250 .......................................... $179.95

B & W MONITOR - Sanyo
High quality, high resolution video monitors
VDM-700901 9" monitor ................................ $209.95
VDM-701801 15" monitor ................................ $279.95

13" COLOR MONITOR - Zenith
The high color you've been promising yourself
VDC-201301 .......................................... $449.00

Disk Drives

JADE DISK PACKAGE
Double-D controller kit, two 8" double density disk drives, cabinet, power supply, & cables
Special package price ................................ $1295.00

DUAL 8" DRIVES - Lobo
A pair of double density Shugarts in a cabinet
MSF-12800R 2 single sided ................................ $995.00
MSF-125202 2 double sided .............................. $1425.00

DISKETTES - Jade
Hug benefit prices on magnificent media
8" single sided, single density, box of 10
MMD-511010 Soft sector ................................ $27.95
MMD-511103 15 sector ................................ $27.95
8" double sided, single density, box of 10
MMD-522010 Soft sector ................................ $39.95
MMD-522103 15 sector ................................ $39.95
8" single sided, single density, box of 10
MMD-811010 Soft sector ................................ $33.95
8" single sided, double density, box of 10
MMD-812010 Soft sector ................................ $65.95
8" double sided, double density, box of 10
MMD-822010 Soft sector ................................ $57.95

FLOPPY SAVERS - Tri-Star
Protect your valuable software from spindle damage
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MMA-208 5" kit ......................................... $15.95

 SOFTWARE

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Lacie & most powerful release of CP/M
SFC-5250000D Manual set ................................ $249.95
SFC-5250000M 5¼" disk & manual .................. $149.95
SFC-5250000F 8" disk & manual ....................... $149.95

MP/M - Digital Research
Multi-user operating system for Z80 computers
SFC-5250000P 8" disk & manual .................... $295.00

PASCAL/MT - MetaTech
A powerful language for CP/M systems
SFC-7830101P F 8" disk & manual .................. $99.95

SDOS - SD Systems
DISC, CLASSIC 240 assembler/relinter
SFX-5500100D Manual set ................................ $249.95
SFX-5500100M 5¼" disk & manual .................. $149.95
SFX-5500100F 8" disk & manual ....................... $149.95

WORDSTAR - MicroPro Intl
The finest word-processing package for CP/M
SFC-13800100F 8" disk & manual .................. $395.00

VISICALC - Personal Software
Visible business accounting calculator for Apple
SFA-2410105M 5¼" disk & manual .................. $145.00

SINGLE DRIVE COPY - Apple
Make backup disks with a single disk II
SFA-5115010M 5¼" disk & manual .................. $195.00

SUPER-TEXT - Muse
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SFC-1380005M 5¼" disk & manual .................. $99.95

Modems

NOVATION CAT
300 bps, auto answer originate acoustic modem
IOM-5200A Special sale price ........................ $149.00

EPROM ERASER - L.S. Engineering
UV eraser for up to 48 EPROMs
XME-3200 A & T ....................................... $39.95

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The 460 uses a dot-matrix character formation technique in which the placement of the dots overlaps both horizontally and vertically to achieve a correspondingly higher quality printing. The printer's wire-based print head uses staggered needle rows to create the vertically overlapping dots. The print head is driven by microprocessor control by a stepper motor driven mechanism with logic-seeking look ahead capability. Standard "Two-K Byte" buffer allows the printer to accept the entire content of a 1220-character CRT screen. Weight 27 lbs. suggested list price $1,095. Calif. Digital price $1,076

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These used data terminals were carefully selected for clear menu, necessary controls, and ease of readout. Pre-owned units have been fully tested and reconditioned to give you the best value for your money. Each system includes a hard case, power supply, and all manuals. Both units will be reconditioned and used for on the road working conditions. Original retail $1,395.

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Circle 221 on inquiry card.
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Hobby Wire Wrap Starter Package

BW2630 WW Tool ........ $19.95
BT30 #30 Bit .............. 3.95
BC1 Batteries & Charger 14.95
*Kit #1 Wire Kit ........ 9.95

Regular Price .... $46.80

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*Kit #1 Contains 900 pcs. of precut wire in asst. sizes.
Choose from Red, Blue, White, Black, Green, Orange, Violet, Yellow, or assortment.

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BT30I #30 Bit & Sleeve .. 29.50
BC1 Batteries & Charger 14.95
*Kit #3 Wire Kit ......... 32.95

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$119.95

*Kit #2 Contains 4000 pcs. of precut wire in asst. sizes.
Choose from Red, Blue, White, Black, Green, Orange, Violet, Yellow or assortment.

BIG DEAL
IC Sockets by the Tube

RN HIGH RELIABILITY eliminates trouble. "Sidewipe" contacts make 100% greater surface contact with the wide, flat sides of your IC leads for positive electrical connection.

ORDERING INFORMATION
- Orders under $25 include $2 handling
- All prepaid orders shipped UPS Ppd.
- Visa, MC & COD's charged Ppd.
- All prices good through cover date
- Most orders shipped next day

<table>
<thead>
<tr>
<th>WIRE WRAP SOCKETS</th>
<th>Size Quantity/Tube Price</th>
<th>Price/Tube</th>
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<tr>
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<tr>
<td>40 10</td>
<td>1.60</td>
<td>$18.00</td>
</tr>
</tbody>
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Above prices include gold up to $800/oz.

SOLDER TAIL
Low Profile Tin
Closed Entry
Design

1¢/pin
(over 5 tubes)

3/4¢/pin
(over 100 tubes)

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Qume Datatrak 8

Double sided floppy with NO HEADACHES. Although many think this an impossibility, seeing is believing, and this drive is really something! Shugart compatible, fully optioned, reliable, and rapidly becoming the standard in double-sided diskdom.

$599, Two/$549.

Siemens FDD 100-8D

Single sided 8" floppy drive, the latest & greatest revision. Features double density plus much more. An extremely reliable drive $439 2/$409

Hard sector option kit... $9.95

Date separator option kit... $9.95

The following 5¼" mini-flip floppies share most features with their 8" cousins, so without further ado...

Siemens FDD 100-5D,.............. $279,

Qume Datatrak 5 (double sided).... 399,

BASF Mini mini,................. 279,

SA 400,......................... 299

All the above mini-flip floppies are fully SA400 compatible.

Manuals for all drives are $10, refundable against future purchase of drives. Also, all 8" drives can be ordered with 220 v/50 hz for worldwide use.

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TELEVIDE 912C ........... $699

TELEVIDE 920C ........... 799

Features typewriter keyboard, microprocessor controls, Upper/lower case, adjustable baud rates (75-9600 baud), special function keys, much much more.

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used 12" Sylvania monitors. Composite video, 12 MHz, 120 VAC. with new P-39 or P-4 tube, $79, used tube $59, OEM style (without case), subtract $12. U-fx model, 10/$300.

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Set of 8, 16K, for Apple, TRS-80, Eddy, Heath & more. 200 Hz, prime parts, at the unheard of $49.8.

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Incredible!! — Two 8" Shugart compatible single sided floppy disk drives (double density), CP-206 power supply, in handsome color coordinated cabinet, with full cabling, connectors, and documentation, plus one box diskettes!! All for an unprecedented $1295. Up to one MBY of storage.

with Qume Datatrak 8" double-sided drive $1695

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Cable kits for 8" drives with 10' 50 cond, flat cable, power cable, and all connectors. Assembled if desired. One drive 27.50, two 33.95, three 38.95 for mini floppies (34 cond): one 24,95, two, 29.95

CP-206 Power-one power supply, Powers two drives more than adequately, top quality, 2.5A/24V, 2.5A/5V, 5A/5V,................ $99.

mini-flip floppies........... $79

Media

8" ....$39.99 SS/DD

8" ....$49.00 SS/DD

5½" ....$65.00 SS/DD

5½" ....$69.00 SS/DD

5½" ....$34.95 SS

5½" ....$59.00 SS

Verbatim, Memorex, Scotch, or equivalent name brand

Special Introductory Offer!!!

Webash 8" diskettes $29.00 SS

$39.00 DS

Price is cheap, but they run like champs!!!

Diskette head cleaning kit for 5½" or 8" $28.75 includes everything for 1 drive for 1 year. Alignment Diskette for Floppy Drives .............. $39.00

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Rackmount Mainframe MT-200. This gorgeous beast is so appealing that it can easily function also as stand-alone mainframe. Very modern styling with fully actively terminated S-100 bus.

With two 8" single-sided disk drives, ... $1899.

With two 8" double sided disk drives in place of single-sided variety, ................ $2499.

Desktop Mainframe MT-100. Contemporary styling, a handsome cabinet coated with durable epoxy finish colors (blue, beige, off-white & silver). Easy to fit into an office environment. The proper way to start your system.

Above plus two 8" single sided disk drives ............... $1599.

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$25 min. order. Calif. residents add 6% sales tax. Orders under $75, add 5% shipping and handling, over $75 add 2.5%. All pricing subject to change without notice.
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**Keyboard Special 2!!**

- **CHERRY "PRO" Keyboard**
  - Streamlined Custom Enclosure
  - BOTH only $152.00
- **paper basket**
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  - Arabic & Hebrew, Multilingual Data Entry
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- **Print feed platen**
- **165**
- **power supply**
- **349**
- **combination special**
- **1699**
- **cases**
- **S-100 interface card**
- **140**

**Qume Printers**

- **Sprint 3/45**
  - (requires self assembly)
  - $1499
- **power supply**
- **349**
- **combination special**
- **1699**
- **cases**
- **S-100 interface card**
- **140**

**Disk Subsystem**

**Matchmaker Technology**

- **TURNKEY DISK SUBSYSTEMS**
- **APPLE**
  - Single density disk controller
  - Expanded Apple DDS
- **TRS-80**
  - Single or double density, Expansion interface necessary
  - Space for 48K dynamic RAM on controller card
- **SORCERER**
  - Full RS-232 Interface, One-S100 slot for memory expansion, Single or double density

**Software available for above disk add-ons**

- **TRS-80 & Sorcerer operate on all CP/M compatible software**

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- **Hiplot Plotter**
  - $875.00
- **HID-440 Paper tiger**
  - $999.00
- **SO Ex prosperum II**
  - $529.00
- **Imali 65K dynamic RAM III**
  - $529.00
- **DC Hayes Microcommod 100**
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**Phone**: 415-553-1816

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  - **BASIC**
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    - Microsoft "BASIC 80" 350.00
  - **FORTRAN**
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    - Whitesmith's "C" 600.00
  - **PL/1**
    - Digital Research's PL/1 500.00
  - **PASCAL**
    - M.T. Compiler 250.00
- **Z-80 Optimized** (Under OS-1 or CP/M)
  - **COBOL**
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    - LSI-11/PDP-11* Under RT-11 or RSTS
    - COBOL - ANSI '74 Introducing:
      - RJ-11 Compiler 1750.00

**Applications in COBOL '74**

- Available in R-M COBOL, COBOL 80 and RJ-11 (Source Included)

**Operating Systems**

- **Z-80 Optimized**
  - OS-1™
  - A breakthrough in microcomputer software from Electrolabs! UNIX®-like OS with virtual I/O, bank-select memory control to 16 MBytes and optional memory protection! Totally compatible with all CP/M programs. You will be amazed at the difference. Excellent brochure available. Includes editor, linker-loader, debugger, and one year update. 249.00

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- **8080, 8085 & Z-80**
  - CP/M Version 2.2 150.00
  - Manuals only 35.00
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  - Manuals only 35.00

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Software Supplies Media Storage Equipment Publications

- Upon Request
- Circle 283 on inquiry card.

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**Important Note:** Please specify complete system hardware and software configuration with each order.
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The Supermarket for TRS-80* Add-on Components (and other computers, too)

The VISTA V-80 Disk Drive System
- 23% more storage capacity than TRS-80
- 120 day warranty
- 40 track patch at NO CHARGE

- Single drive system $395.00
- Two drive system $770.00
- Four drive system $1480.00
- Two drive cable $29.95
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The VISTA V-80 Expansion Module
- Provides double density modification to your current Radio Shack interface (lets you format diskettes in either single or double density).
- Increases storage capacity up to 204K bytes (on single 40 track drive).
- Includes all hardware and software. $239.00

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- Provides one, two or three drives.
- Adds up to 1.5 million bytes of on-line storage.
- 120 day warranty
- Does everything Radio Shack's expansion system will do...for less!

- $1000.00 Single drive Expansion System
- $1550.00 Two drive Expansion System
- $2100.00 Three drive Expansion System
- $525.00 Additional drives alone

The TRS-80 Printers
- Centronics 730...$945.00
- 7x7 dot matrix...
- Provides one, two or three drives.
- Adds up to 1.5 million bytes of on-line storage.
- 120 day warranty
- Does everything Radio Shack's expansion system will do...for less!

- $1000.00 Single drive Printer...
- $745.00 Expansion System
- $1550.00 Two drive Expansion System
- $2100.00 Three drive Expansion System
- $27.50 each Cables

Other Products
1. VISTA Verbatim diskettes (hard or soft sector) Certified MPI B51
   40 track.. $38.95
2. 16K RPM upgrade kits, guaranteed for 120 days
   PRIME PRODUCT
   $74.50
3. PRODOS
   $110.00
4. LNW expansion bare board
   $66.95
5. H.C. Pennington book, VISTA CP/M and Other Mysteries
   $18.95
6. DDT Disco-Tech disk drive timer
   $19.95
7. Cryptext (An Encryption Module)
   $299.00

Add On Drives
- MPI B51 40 Track, Double Density-204K
  $275.00
- MPI B52 Dual Head, Double Density-408K
  $375.00
- Siemens FDD100-5-40 Track Double Density 204K
  $275.00
- Siemens FDD100-5 Floppy, records both sides
  $290.00
- Siemens FDD100-8 8" Single Sided Drive
  $448.00

The VISTA V-200 for Exidy
- Completely packaged system, tested and ready to plug in, includes:
  power supply, two 40 track drives, case, controller, all cabling and
  total CP/M documentation.
- Storage capacity from 400K to 1.2 meg.
- System software-VISTA CP/M Disk Operating System and BASIC-E Compiler
  recorded on 5-1/4" diskettes.
- Price: Starting as low as $1199.00

CALL TOLL-FREE 800-854-8017

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The VISTA Computer Company 1401 Borchard Street • Santa Ana, California 92705 • 714/953-0523

*TRS-80 is a registered trademark of Radio Shack

Circle 224 on inquiry card.
**THE STAR MODEM**

**from Livermore**

The STAR modem from Livermore represents a significant breakthrough in the development of acoustic modems. The small, lightweight case houses a high-performance modem that competes with the highest quality standard-sized couplers available. Yet, because of its cost effective design, the STAR has become the price-performance leader in the industry.

**CIRCUITRY**

The switchable, four-section bandpass filter provides the user with excellent out-of-band rejection to assure accurate processing of the received carrier, even at signal levels of less than -47 dBm. Further, the proven soft limiter and phase lock loop discriminator yields data that is essentially jitter free.

**FEATURE**

**FITS GTE HANDSETS!**

The oscillator is built using highly stable, state-variable circuitry that delivers a nearly harmonic free, phase coherent sine wave to the telephone network, assuring compatibility with all other 103 type modems. Because of the pureness of the sine wave, the STAR modem exceeds even the stringent harmonic requirements of all CCITT countries.

**CARRIER DETECT**

To assure accurate teleprocessing connections, the carrier detect circuitry prevents the modem from attempting to operate when excessive noise would produce errors or cause marginal operation. The circuitry also has a special amplitude sensor that prevents chatter when the received signal fades.

**STANDARD FEATURES**

- 50 Characters/second
- Characters/silver
- 10 characters/sinch
- 3-way paper handling system
- 7 x 7 dot matrix
- 96 character ASCII
- microprocessor electronics
- unidirectional print at 300 baud
- high speed return approximately 10 ips
- 21 lpm with 80 columns printed
- 56 lpm with 20 columns printed
- 80 character buffer
- 6 line vertical
- Centronics Colors and logo

**FORMS HANDLING**

Roll Paper: 8.5 in. x 5.5 in. with 1 in. core maximum dimension 3.5 in. wide with 36 in. core minimum dimension. Fanfold 9 in. x 22 in. wide, pin to pin 2.5 in. on 24 tcm wide overall. Up to 13 ply paper with 2 carbons (total thickness not to exceed 0.12 inches). Cut Sheet: Maximum width 8.5 inches.

**RIBBON SYSTEM**

Continuous ribbon 916" (14mm) wide, 20 yards (18 meters) long.

**OPERATOR CONTROLS**

Power on/off, Reset Switch allows disabling of printer without dropping AC.

**DATA INPUT**

7 or 8 bit ASCII parallel. TTL levels with strobe, Acknowledge pulse indicates that data was received.

**PHYSICAL DIMENSIONS**

Width: less than 10 lbs/Wide: 14.5 inches/Depth: 10.0 inches/Height: 4.8 inches/31 inches Dimensions exclusive of roller paper holder.

**FOR MORE INFORMATION SEE OUR 52 PAGE AD IN JANUARY BYTE OR SEND $1.00 FOR PAGE CATALOG**

**OUR CORNER**

THE MARKET PRICE $139.00

**STARS & STRIPES SPECIAL**

LIST PRICE $199.00

OUR CORNER THE MARKET PRICE $139.00

**EXCLUSIVE ACOUSTIC CHAMBERS**

The exclusive triple seal of Livermore’s new flat mounted cups locks the handset into the acoustic chamber yielding superior acoustic isolation and mechanical cushioning. Designed to adapt to most common handsets used throughout the world, the STAR offers the utmost in flexibility and transmission reliability.

**SELF TEST**

The self test feature on the STAR allows the user to verify total operation of the acoustic modem by using the terminal in the full duplex mode. No need for remote assistance in diagnosing terminal or modem problems.

Utilizing the experience gained from building high quality couplers for over twelve years, Livermore has designed a coupler superior to any in its class for cost efficiency in industrial, commercial, business or home situations. You can see why we call it the STAR!

**SPECIFICATIONS**

* Data Rate. 10 to 300 baud.
* Compatibility. Bell 103 and 113; CCITT.
* Transmit Frequencies. Original - 1070 Hz/Space, 1270 Hz/Mark; Answer - 2025 Hz/Space, 2225 Hz/Mark.
* Receive Frequencies. Original - 2025 Hz/Space, 2225 Hz/Mark; Answer - 1070 Hz/Space, 1270 Hz/Mark.
* Frequency Stability. ± 0.3 percent.
* Receiver Sensitivity. - 50 dBm ON, - 53 dBm OFF.
* Transmit Level. - 15 dBm.
* Modulation. Frequency shift keying (FSK).
* Carrier Detect Delay. 1.2 seconds ON; 120 msec OFF.
* EIA Terminal Interface. Compatible with RS 232 specifications.
* Teletype Interface. 20 milliamperes current loop.
* Optional Interfaces. IEEE 488; TTL; TTY 43.

**INTERNATIONAL (CCITT) frequencies available.**

Switches: Original/Off/Answer; Full Duplex/Test/Half Duplex.

Indicators: Transmit Data, Receive Data, Carrier Ready, Test.

**ENTERPRISE**

Ambient operating temperature 5° to 50° C. Relative humidity 10 to 90 percent (non-condensing).

Power. Supplied by 24 VAC/150 MA UL/CSA listed transformer. Input 115 VAC, 2.5 watts. (A 220 VAC, 50 Hz adapter is available upon request.)

**Dimensions**

Weight. 1.75 lbs (2.2 lbs. shipping weight including AC adapter.)

**Warranty.** Two years on parts and labor, excluding AC in which case it’s manufacturer’s warranty.

**CENTRONICS**

**730 Dot Matrix Printer**

LIST PRICE $795.00

SALE PRICE $695.00

**STANDARD FEATURES**

- 50 Characters/second
- Characters/sinch
- 10 characters/sinch
- 3-way paper handling system
- 7 x 7 dot matrix
- 96 character ASCII
- microprocessor electronics
- unidirectional print at 500 baud
- high speed return approximately 10 ips
- 21 lpm with 80 columns printed
- 56 lpm with 20 columns printed
- 80 character buffer
- 6 line vertical
- Centronics Colors and logo

**FORMS HANDLING**

Roll Paper: 8.5 in. x 5.5 in. with 1 in. core maximum dimension 3.5 in. wide with 36 in. core minimum dimension. Fanfold 9 in. x 22 in. wide, pin to pin 2.5 in. on 24 tcm wide overall. Up to 13 ply paper with 2 carbons (total thickness not to exceed 0.12 inches). Cut Sheet: Maximum width 8.5 inches.

**RIBBON SYSTEM**

Continuous ribbon 916" (14mm) wide, 20 yards (18 meters) long, Mobius Loop allows printing on carbonless paper on alternate passes.

**OPERATOR CONTROLS**

Power on/off, Reset Switch allows disabling of printer without dropping AC.

**DATA INPUT**

7 or 8 bit ASCII parallel. TTL levels with strobe, Acknowledge pulse indicates that data was received.

**PHYSICAL DIMENSIONS**

Weight: less than 10 lbs/Wide: 14.5 inches/Depth: 11.0 inches/Height: 4.8 inches/31 inches Dimensions exclusive of roller paper holder.

**FOR MORE INFORMATION SEE OUR 52 PAGE AD IN JANUARY BYTE OR SEND $1.00 FOR PAGE CATALOG**

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Circle 228 on inquiry card.
**TRIS-80/APPLE MEMORY EXPANSION KITS**

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<tr>
<td>4116's RAMs</td>
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<tr>
<td>16Kx1 200/250ns</td>
<td>$198.00</td>
<td>$159.00</td>
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<td>$189.00</td>
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<tr>
<td>64Kx1 200/250ns</td>
<td>$529.00</td>
<td>$469.00</td>
<td>$679.00</td>
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**EXPANDABLE + DYNAMIC MEMORY**

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**MEMORY HEADQUARTERS**

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<tr>
<td>2716 16K 5 Volt only EPROM</td>
<td>$129.00</td>
<td>$109.00</td>
<td>$169.00</td>
<td>$149.00</td>
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<tr>
<td>2708 8K 450ns EPROM</td>
<td>$219.00</td>
<td>$189.00</td>
<td>$279.00</td>
<td>$249.00</td>
</tr>
<tr>
<td>2714-3L 1Kx4 300ns Low Power</td>
<td>$219.00</td>
<td>$189.00</td>
<td>$279.00</td>
<td>$249.00</td>
</tr>
<tr>
<td>256-7L 4Kx1 300ns Low Power</td>
<td>$259.00</td>
<td>$229.00</td>
<td>$319.00</td>
<td>$299.00</td>
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<tr>
<td>2702-AL 2 LP 250ns in Lots of 20</td>
<td>$239.00</td>
<td>$219.00</td>
<td>$329.00</td>
<td>$309.00</td>
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**SPECIAL PURCHASES**

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<tr>
<td>5 Volt 3 Amp w/OPV Input 110/220 Open Frame</td>
<td>$19.95</td>
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<tr>
<td>Magnifier with 79 fluorescent tube List $94.95</td>
<td>$49.95</td>
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<tr>
<td>Magnifier with 79 fluorescent tube List $94.95</td>
<td>$49.95</td>
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**LOBO 8" DISK DRIVE CABINET**

New from Lobo, a dual Cabinet with power supply, and internal data cable hook-up.
- Cabinet accepts 2 801R, 800R, FD120, or FD200 style disk drives.
- Power Supply for 2 drives.
- Assembled, tested and guaranteed by Lobo Drives.
- Shipping Weight: 30 lbs.

**SDS-EXPANDORAM I KIT**

- 4Kx1 300ns Low Power 81
- 2K EPROM (2708-2716, 2732) useable on any 80 CPU
- 100/400ns, 100µA, 100µA

**SDS-EXPANDORAM II KIT**

- 2K EPROM (2708-2716, 2732) useable on any 80 CPU
- 100/400ns, 100µA, 100µA

**SDS-EXPANDORAM III KIT**

- 4Kx1 300ns Low Power 81
- 2K EPROM (2708-2716, 2732) useable on any 80 CPU
- 100/400ns, 100µA, 100µA

**SDS-EXPANDORAM IV KIT**

- 4Kx1 300ns Low Power 81
- 2K EPROM (2708-2716, 2732) useable on any 80 CPU
- 100/400ns, 100µA, 100µA

**Hitachi V302**

30MHz DUAL TRACE OSCILLOSCOPE

**LEDF**

- TV sync-separator circuit
- High-sensitivity 10V/dv
- Sweeptime magnifier (10 times)
- 2-zero input (intensity modulation)
- Signal delay line
- X-Y operation

**CEDERONIC**

- Complete with 2 probes: CH1, CH2, DUAL, ADD, DIFF.
- Vertical Deflection Motors
- 1V2 Dual Trace

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When you purchase any SD SYSTEMS Computer Board, either kit or A&T from PRIORITY 1 ELECTRONICS, you will receive a COUPON FOR A $25.00 CASH REBATE direct from the Manufacturer, SD SYSTEMS. Combine the Rebate with our already low prices, and you can hardly afford to pass up this special offer.

For more information, see last month's issue of Byte, or our catalog.

Compare our Sale Prices, and then don't forget your Rebate!

**PRIORITY ONE ELECTRONICS**

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**PRIORITY ONE ELECTRONICS**

Circle 229 on inquiry card.
**PRIORITY ONE ELECTRONICS**

**MEET THE ECONORAM FAMILY.......... all ECONORAMS from COMPUKIT include:**

- Fully static memory used throughout to promote reliable operation and facilitate direct memory access, (DMA)
- 4 MHz with 285 - 5 MHz with 8085
- Buffered tri-state outputs and buffered inputs.
- All lines buffered; address and data lines buffered to 1 low power Schottky TTL load, all other lines buffered to 1 high power Schottky TTL load.
- Onboard regulation.
- DIP switch address selection and de-selection (no wire jumpers).
- Low power Schottky support ICs.
- S-100 boards have WRITE strobe selection: allows use of memory with or without front panel.

Most ECONORAMs come in 3 forms: UNKIT (UKT) - means that all sockets, disc capacitors are already soldered in place for easy assembly, fully assembled & tested (A&T), or qualified under the Certified System Component (CSC) high-reliability program (200 hour burn-in, guaranteed 4MHz operation over full temperature range, serial numbered, immediate replacement in event of failure with 1 year of invoice date),

<table>
<thead>
<tr>
<th>Model</th>
<th>Type</th>
<th>Price</th>
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<tbody>
<tr>
<td>GBT - ECONORAM II A&amp;T</td>
<td>$189.00</td>
<td>$169.00</td>
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<tr>
<td>GBT - ECONORAM II UKT</td>
<td>$169.00</td>
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<tr>
<td>GBT - ECONORAM IV A&amp;T</td>
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<td>GBT - ECONORAM IV UKT</td>
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<tr>
<td>GBT - ECONORAM II A&amp;T</td>
<td>$209.00</td>
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<tr>
<td>GBT - ECONORAM II UKT</td>
<td>$219.00</td>
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**NEW! 32K X 8 ECONORAM X**

Static storage for the S-100 bus.

Static storage for the S-100 bus. Guaranteed 4 MHz operation. Configured as two 8K and one 16K block, all independently addressable, selectable & enableable. Suitable for use in phantom systems. Extra select/deselect qualifiers for systems using more than 64K of memory make this board the ideal building block for large memory systems. Maybe you can't believe the low pricing - but you can count on the ECONORAM performance! Also available populated to 16K. Shipping Weight 2 lbs.

<table>
<thead>
<tr>
<th>Model</th>
<th>Type</th>
<th>Price</th>
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<tbody>
<tr>
<td>GBT - ECONORAM X 16K A&amp;T</td>
<td>$329.00</td>
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<td>GBT - ECONORAM X 16K UKT</td>
<td>$309.00</td>
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<tr>
<td>GBT - ECONORAM X 24K A&amp;T</td>
<td>$479.00</td>
<td>$449.00</td>
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<tr>
<td>GBT - ECONORAM X 24K UKT</td>
<td>$459.00</td>
<td>$439.00</td>
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<tr>
<td>GBT - ECONORAM X 32K A&amp;T</td>
<td>$599.00</td>
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<tr>
<td>GBT - ECONORAM X 32K UKT</td>
<td>$579.00</td>
<td>$539.00</td>
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**ECONORAM XIII-32**

32K BANK SELECT/S-100 compatible. 4 MHz guaranteed operation (S-70 C). Features two 16K blocks independently addressable on 16K boundaries. Two independent banks - individual phantom - 256 ports DIP switch selectable each block may be deselected with a single switch. Effect for use in Alpha Micro Systems. Maximizes & others. Uses 4K & 1 low power STATIC RAM. Current consumption guaranteed 350mA max. Shipping Weight 2 lbs.

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<td>GBT - ECONORAM XIII-32 A&amp;T</td>
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<tr>
<td>GBT - ECONORAM XIII-32 UKT</td>
<td>$329.00</td>
<td>$309.00</td>
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</table>

**ECONORAM XIV**

16K x 8 for S-100. Addressable on any 4K boundary. Direct addressing on up to 24 address lines. Fully meets IEEE S-100 bus specs. Low power, hi speed static memory. Operates up to 5MHz with newest 6805/6806/6808 CPUs. Can be used with 8080, 286, 6808, 6808, 8908, 89000, etc.

<table>
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<tr>
<th>Model</th>
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<tr>
<td>GBT - ECONORAM XIV A&amp;T</td>
<td>$349.00</td>
<td>$299.00</td>
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**INTERFACER II**

The new Interfacer II I/O board incorporates one channel of serial I/O with all of the features of the Interfacer dual RS232 serial board, plus 3 full duplex Parallel ports. The serial section includes all the features you've come to expect - a hardware UART, on-board crystal controlled Baud rate generator, hardware/software programmability, RS232 handshaking lines with real RS232 drivers, current loop & TTL drivers, full interrupts and more! The parallel section utilizes LS11 TTL octal latches for latched input & output data with 24mA drive current, attention, enable & strobe bits for each parallel port. Each with selectable polarity, interrupts for each input port, separate 25 pin connectors with power for each channel and a status port for interrupt mask and port status. All in all - an incredibly flexible and easy to use board.

<table>
<thead>
<tr>
<th>Model</th>
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<tr>
<td>GBT - INTERFACER II A&amp;T</td>
<td>$199.00</td>
<td>$189.00</td>
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<tr>
<td>GBT - INTERFACER II UKT</td>
<td>$199.00</td>
<td>$189.00</td>
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**ECONORAM 2708**

Has provisions for wait states for 4MHz operations. Configured as four 4K blocks - each independently addressable and disableable. Power-on jump. Does NOT include 2708s. Includes all support chips, sockets, regulators, heat sinks, etc. Sold in UNKIT form only. Shipping Weight 2 lbs.

<table>
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<tr>
<th>Model</th>
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<tr>
<td>GBT - ECONORAM 2708 UKT</td>
<td>$65.00</td>
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Circle 229 on inquiry card.

**CK022 S-100 INTERFACER**

Our new I/O board gives you unparalleled flexibility and operating convenience. We include such features as:

- 2 independently addressable serial ports (dip switch selectable addresses)
- Real LS hardware UARTs for maximum CPU housekeeping
- RS232C current loop (20mA), TTL signals (20mA) inputs
- Precision, crystal-controlled Baud rates up to 9600 baud (dip switch selectable) on each channel
- Transmit/receive interface on each channel, jumperable to any required interrupt line
- Industry standard RS232 level converters with five RS232 handshaking lines per port (typically included in I/O circuits)
- Optically isolated current loop with provisions for both on-board & off-board current sources
- UART parameters, interrupt enablers & RS232 handshaking lines are software programmable with on-board software selectable standard interface settings for maximum flexibility
- Port connectors made directly to ribbon cable & DB25 connectors in standard pinouts
- RS232 lines will conform to either master or slave configurations

Board gives full feature operation with both 7 & 4 8 systems

Low power consumption: -16V @ 450mA, -16V @ 150mA, -16V @ 70mA max

Software interface required for board operation, although board parameters may be altered by software

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<tr>
<td>GBT - INTERFACER I A&amp;T</td>
<td>$199.00</td>
<td>$189.00</td>
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<tr>
<td>GBT - INTERFACER I UKT</td>
<td>$249.00</td>
<td>$219.00</td>
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**SEND $1.00 FOR 52 PAGE CATALOG**

**ECONORAM SPECTRUM**

32K BANK SELECT/S-100 compatible. 4MHz guaranteed operation (S-70.C). Features two 16K blocks independently addressable on 16K boundaries. Two independent banks - individual phantom - 256 ports DIP switch selectable each block may be deselected with a single switch. Effect for use in Alpha Micro Systems. Maximizes & others. Uses 4K & 1 low power STATIC RAM. Current consumption guaranteed 350mA max. Shipping Weight 2 lbs.

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<td>GBT - SPECTRUM Color kit</td>
<td>$299.00</td>
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<td>GBT - SPECTRUM 2K kit</td>
<td>$299.00</td>
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S-100 VOICE

The ARTICULATOR board allows you to record, store, and playback any vocabulary on your S-100 computer. Input speech is digitized by the ARTICULATOR and sent to the computer via an on-board port for storage at 1K to 2K bytes/sec. This data is then sent back from the computer to the ARTICULATOR for very high quality playback. On-board VOX switching minimizes memory storage requirements.

PRICE — $319 A&T
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Circle 230 on Inquiry card.
Circle 231 on Inquiry card.
Circle 232 on Inquiry card.
Circle 233 on Inquiry card.
Circle 234 on Inquiry card.
Circle 235 on Inquiry card.
Circle 236 on Inquiry card.
Circle 237 on Inquiry card.
**Z-80 CPU**
Two serial ports, three parallel ports. 1/4 MHz, on board Prom Monitor Phantoms. (Less cable and Monitor).
A & T $325.00

**DOUBLE/SINGLE DISK CONTROLLER**
Two stage phase lock loop circuitry for greatest reliability. Data transfer at maximum rate. Transparent density selection. 8" or 5" operation 2 or 4 MHZ (Some restrictions on DMA).
DMA — $425.00
STD. — $385.00

**16K, 32K STATIC RAM**
Worlds most reliable memory, responds to extended address lines A16, A17, cool running, fast.
16K-$395.00 32K-$650.00

**TELEVIDEO 912**
80 x 24-Lower case descenders. Teletype or typewriter keyboard 110/220 VAC 60 to 19.2K Baud Hex entry pad. Similar to SOROC but better looking with NO FAN NOISE.
8" CDC $675.00
8" Remax $645.00

**FLOPPYS**
5" Shugart ... $550.00
5" Siemens ... $525.00
5" Siemens ... $500.00
(Duble Sided)
8" CDC across $675.00
8" Remax $645.00

**DYSAN Quality**
Designed for MP/M® software of Digital Research. 6 users serial port, three 8 bit parallel ports for hard disk. Timer and vectored interrupt.

**SOFTWARE/CABLES/PROMS**
CP/M 2.2 ....... $150.00
MP/M ....... $350.00
2708 Monitor ... $25.00
2716 Monitor ... $40.00
Disk 50 Pin ... $22.00
RS-322 ....... $15.00
CPU to Back ... $32.00
Disk DC ....... $4.50
Disk AC ....... $2.50
Winchester ....... $50.00

**WINCHESTER/SHUGART**
Basic dynamic board tested to run at 4 MHZ with our Z-80 board. A116 chips at 200 nanosecond speed in- sures most reliable data storage. Double density and DMA compatible.
32K-$600.00 48K-$640.00
64K-$750.00

**WINCHESTER/CENTURY DATA SYSTEM**
State of the art development. Parity generation and error detection. Compatible with 16 bit CPU designs. 16K bank, select software control, 4 MHZ Z-80, 8086, Cromenco, Alpha Micro compatible.
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64K-$850.00

**WINCHESTER/FLOPPYS SOFTWARE/DYSAN Quality**
COMING SOON

**WINCHESTER/FLOPPYS INTERFACE**
COMING SOON

**WINCHESTER/SHUGART 5A 1000**
5 megs now expandable to 10, works alongside floppy disk drive for expanded storage. Use with controller below.
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20 megs expandable to 40—Marksman series, plugs into our CPU parallel port or MP/M board drive, cabinet, power supply, 2.0 Bios.
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**S-100 MAINFRAME**
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- **30A of +8V**
- **6A of ±16V**
- Disc Power Supply
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  - 50 or 60 Cycle Operation
- Connectors Supplied For Up To 4 Drives
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**S-100 MODULE**
- **INCLUDES S-100 MODULE SHOWN AT RIGHT.**
- **$849.00**

**S-100 MODULE**
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New Lennox, IL 60451
TELEPHONE: (815) 485-9072

TELEX: 681-367 DELTMAR HTBH
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2114-L300 5.95 20 @ 5.45 10 @ 5.10
2114-2L450 21.00 15 @ 19.00 100 @ 16.45
4116-200 MB RAM 10 @ 8 @ 25 @ 2
6550 RAM (PET 8K) 127.00
2112 90
S-100 Wire Wrap 28 15 @ 2.65
S-100 Solder Tail 23 35 @ 2.15

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High output, low noise. 5 screw housing, labels.
C-10 10/$65.00 25/$150.00
C-20 20/$10.65 50/$24.50 100/$57.00
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SCOTCH 8" Disks $10/$31.00
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Diskette Storage Pages $10/$3.95
Disk Library Cases $8—2.95 5—2.15
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PT-1 PHOTO BOARD. Over 2500 holes 4" regulations. All S-100 bus functions labeled, gold fingers. $25.95
PCBD $25.95
PT-2 PHOTO BOARD. Similar to PT-1 except set up to use onboard connector sockets. PCBD $25.95
CCS MAIN FRAME. Kit (S-100) $339.95
APPLE EXTENDER. $22.95
APPLE IEEE INSTRUMENTATION INTERFACE KIT 7490.Kit $275.00
ARITHMETIC PROCESSOR FOR APPLE 781A. Kit $350.00
APPLE ASYNCHRONOUS SERIAL INTERFACE KIT 771A. Kit $88.95
APPLE SYNCHRONOUS SERIAL INTERFACE KIT 7712A. Kit $88.95
ALL OTHER CCS PRODUCTS AVAILABLE

PB-1 2708 & 2716 Programming Board with provisions for 4K or 8K EPROM. No external supplies required. Textile socket kits. $119.95
CB-1A 6000 Processor Board. 2K of PROM 256 BYTE RAM power on reset Vector Jump Parallel port with status. Kit $29.95 PCBD $37.85
PB-3 2x 65 VIDEO BOARD. Graphics included. 2 MHz $294.95 4 MHz $329.95
CB-1A 2 Parallel I/O ports with full handshaking. $200 ma current loop. Two parallel I/O ports. Kit $130.00 PCBD $27.95
CB-1B 64x 16 video board, upper and lower case Greek characters and parallel video with software, S-100. Kit $125.00 PCBD $27.95
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### POWER TRANSFORMERS (WITH MOUNTING BRACKETS)

<table>
<thead>
<tr>
<th>NO.</th>
<th>KIT NO.</th>
<th>PRI. WINDING</th>
<th>TAPS</th>
<th>SECONDARY WINDING OUTPUTS</th>
<th>SIZE</th>
<th>UNIT PRICE</th>
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<tr>
<td>T1</td>
<td>1</td>
<td>0V, 110V, 120V</td>
<td>2x7.5A</td>
<td>2x2.5A</td>
<td>3/4&quot;x3/4&quot;x3/4&quot;</td>
<td>21.95</td>
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<td>T2</td>
<td>2</td>
<td>0V, 110V, 120V</td>
<td>2x12.5A</td>
<td>2x3.5A</td>
<td>3/4&quot;x4/4&quot;x3/4&quot;</td>
<td>27.95</td>
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<td>T3</td>
<td>3</td>
<td>0V, 110V, 120V</td>
<td>2x9A</td>
<td>2x2.5A</td>
<td>3/4&quot;x4/4&quot;x3/4&quot;</td>
<td>29.95</td>
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<tr>
<td>T4</td>
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<td>0V, 110V, 120V</td>
<td>2x4A</td>
<td>2x2.5A</td>
<td>3/4&quot;x3/4&quot;x3/4&quot;</td>
<td>22.95</td>
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<table>
<thead>
<tr>
<th>ITEM USED FOR</th>
<th>@+8 Vdc</th>
<th>@-8 Vdc</th>
<th>@+16 Vdc</th>
<th>@-16 Vdc</th>
<th>@+28 Vdc</th>
<th>SIZE W X D X H</th>
<th>UNIT PRICE</th>
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<tr>
<td>KIT 1</td>
<td>15 CARDS SOURCE</td>
<td>15A</td>
<td>2.5A</td>
<td>2.5A</td>
<td>12&quot;x8&quot;x4&quot;/6&quot;</td>
<td>51.95</td>
<td></td>
</tr>
<tr>
<td>KIT 2</td>
<td>SYSTEM SOURCE</td>
<td>25A</td>
<td>3A</td>
<td>3A</td>
<td>12&quot;x8&quot;x4&quot;/6&quot;</td>
<td>56.95</td>
<td></td>
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<tr>
<td>KIT 3</td>
<td>DISC SYSTEM</td>
<td>1A</td>
<td>2A</td>
<td>2A</td>
<td>5A</td>
<td>10&quot;x8&quot;x4&quot;/6&quot;</td>
<td>49.95</td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th>PART DESCRIPTION</th>
<th># OF PIECES</th>
<th>1 Pcs.</th>
<th>10 Pcs.</th>
<th>25 Pcs.</th>
<th>50 Pcs.</th>
<th>100 Pcs.</th>
<th>500 Pcs.</th>
<th>1000 Pcs.</th>
<th>10,000 Pcs.</th>
<th>25,000 Pcs.</th>
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<tbody>
<tr>
<td>GRAND TAMAS RACK</td>
<td>400/606</td>
<td>0.99</td>
<td>0.58</td>
<td>0.35</td>
<td>0.25</td>
<td>0.20</td>
<td>0.15</td>
<td>0.10</td>
<td>0.09</td>
<td>0.08</td>
</tr>
<tr>
<td>BRAND BULLEIN II</td>
<td>400/606</td>
<td>0.99</td>
<td>0.58</td>
<td>0.35</td>
<td>0.25</td>
<td>0.20</td>
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<td>0.10</td>
<td>0.09</td>
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<tr>
<td>128856 50/100 Solder Edge</td>
<td>1.40</td>
<td>0.99</td>
<td>0.58</td>
<td>0.35</td>
<td>0.25</td>
<td>0.20</td>
<td>0.15</td>
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<tr>
<td>126670 50/100 I/F Weld</td>
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<td>0.35</td>
<td>0.25</td>
<td>0.20</td>
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<tr>
<td>126875 50/100 I/F Weld</td>
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<td>0.25</td>
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<td>0.09</td>
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<tr>
<td>126950 50/100 I/F Therm</td>
<td>1.40</td>
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<td>OTHER ...</td>
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<tr>
<td>12305 22/44 SE On Ear</td>
<td>1.40</td>
<td>0.99</td>
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### O' TYPE SUBMINIATURE CONNECTORS

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<td>1200 pcs.</td>
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<td>2 pc. Black Hood</td>
<td>1200 pcs.</td>
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<th>Model</th>
<th>Tracks</th>
<th>Size</th>
<th>Price</th>
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8" DRIVES

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<td>CCI-800</td>
<td>77</td>
<td>1/2 Meg</td>
<td>$895.00</td>
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Double Density, Kit
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26 megabytes of formatted storage
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Please note that it may take three or four months for an ad to appear in the magazine.

FOR SALE: New Gluton Rustrack inkless strip-chart recorder with paper roll. Also, Graphic Sciences DEX 570 and DEX 1 graphical communications systems. They send photos and legal documents over phones, self-contained. R. Qualis, College Inn Apts, Box 238, Durantsville OH 74701, (405) 824-6505 after 5.


FOR SALE: TRS-80 quick printer and/or line printer and 763-7249.


FOR SALE: Altair 8800A, 16 K, Maca Alpha I, Alpha II, SIO, Act I terminal, 8 K, and Extended BASIC. $4000 takes all, or will separate. D. Olsten, 313 Meadow Ln, Hastings Mi 49058, (810) 845-8254.


FOR SALE: 48 K Apple II with manuals, paddles, and software on cassette. Software includes the S-C Assembly Assembler II, an implementation of the FORTH language, and the Apple Invaders game. $1100 or best offer. Will ship via UPS. Tim Tillson, 312 Arbor Dr, Fort Collins CO 80525, (303) 223-7364.


FOR SALE: Dynamic programmable memory circuits. National MS3580P-05S (2107) 4 K x 1. These parts are available due to project cancellations. They are new and guaranteed to meet specifications. Have 200; will sell all or part at $1.75 each. Doryn Johnson, 12A Triads, Logan UT 84321, (801) 752-9378.


FOR SALE: 8800 Altair 5-100 mainframe; 8660, SSM video V8-16 graphics board; $35, two Godbout 8 K Eroromar memory boards; $95 each, Altair 800CR cassette-interface board; $55. Documentation included with each item. Robert Faulkner, 607 Bryan Ct, Altamonte Springs FL 32701. (305) 830-4387 after 7 PM.


FOR SALE: Processor Technology 64KRA-1 (64 k by 8) memory board for 5100 computers with 2 MHz clock such as SOL-20, IMSAI 8000 and 8085, and Altair. Has three different bank select options; includes manual with updates. $575. John Edwards, 40th 13th St 1545, Oakland CA 94612, (415) 462-3394.

FOR SALE: Ohio Scientific Challenger II-BP cassette-based system with 20 K bytes static memory, 540 video board, 542 polled keyboard, two full parallel ports, C64 Assembler/Editor, some game tapes, and two binders of documentation and notes. This is a plain but reliable computer with a heavy power supply. Cost about $1250 new; will sell for $650 or best offer. Greg Williams, (803) 588-3044 the Monday thru Thursday.

FOR SALE: Ohio Scientific printed-circuit boards, documentation, backplane, and cabinet for $600 or $602 Challenger system. Original cost $3200, will sell for $200. Included are: #400 processor and output/input (#32) board, #400 A K programmable memory boards, #430 cassette and D/A board, #440 Video Graphics board, #450 8 K read-only memory and I/O board, and #480 backplane board. Paul Manos, 39743 Lincoln Rd, Bay Village OH 44140, (216) 331-3501 evenings.

FOR SALE: Memorex hard-copy terminal with digital cassette. 60 characters per second. Includes all manuals. Needs some work. $500. Michael C Lewis, 1602 Shepherd Dr, Duarte CA 91010.

WANTED: Clock generator circuit for TMS9900 microprocessor (as used in Tim9904 or 74LS332). Please contact me if you can sell me one or know of a source for one. I am also interested in corresponding with other 900 users. Andy Hall, 4124-55th St, Des Moines IA 50310, (515) 278-2459.

FOR SALE: Space 6800 computer, 12 K memory, video board, cassette/modem interface board. Best offer over $300; original cost $1000. David Moore, 1518 Jefferson, Quincy IL 62301, (217) 228-1792.


WANTED: Printer (and/or Micromodem II, Disk II without controller) for Apple II. Will trade (or sell) Acousmat X direct-drive electrostatic speaker system and Kenwood KT8300 FM/AM tuner. Also, Applesoft read-only-memory card without Autostart read-only-memory for sale; make offer. Charles White, 1712F Newport Cir, Santa Ana CA 92705, (714) 787-9665 days, (714) 751-1262 evenings and weekends.

FOR SALE: BYTE from first issue up to current. All original publications in excellent condition. No marks, scribes, or underlines. Give issues you want and offer. C Tseng, 67-05 Austin St, Forest Hills NY 11375.

FOR SALE: Three 16 K dynamic 5100 memory boards ($75 each); minicomputer system PDP-8I, 4 K memory, four cartridge drives; ASRS3; 100 cps printer; and RS-232 interface. Cost of entire system, $750. Kelton Kelley, 149 Ramallet Road, Santa Barbara CA 93108, (805) 999-1539.


FOR SALE: Memorex 651 floppy-disk drive (new), thirty blank disks, Ken Welles floppy-controller board; all for $350, 3706B $3 each, 5204S $4 each, 1702A $3 each, 4116S $5 each. Paper-tape reader: $10. Gordon Wilson, 819 San Lucas Ave, Mtn View CA 94043.


WANTED: Processor Technology VDM-1 board, working or not, and ALS-B Information. Richard Miller, POB 6337, Jacksonville FL 32205.

WANTED: Heathkit ET-4000 microprocessor trainer only in kit or assembled; all Radio Shack Tandy 75-50 Level II with 16 K, integral keyboard, power supply, video monitor, and cassette recorder. All in good condition. Roland Dumont, 731 Jacques Berthiseune, Ste-Foy Quebec, G1V 3T2 Canada.

FOR SALE: Chalco high-speed paper-tape reader; 5, 6, or 8 level tape (ASCII or Barocode), 620 cpm, self-contained power supply, simple interface, industrial quality, excellent condition, complete with documentation. New: $755. Asking $500. Fred Goldberg, 2892 Cheviot Rd, E Brunswick NJ 08816, (609) 754-2180 days.

WANTED: Schematics (service documentation) for VOGUE Instrument Co line printer. Please call Steve Gardner, Birmingham AL 35209, (205) 942-6567.

FOR SALE: New 4P video display monitor. $30. Purchased from Electrolab; never used. Will ship UPS COD. Frank Sneade, RT 1 Box 60A, Rawlings VA 23876, (804) 949-7535.

FOR SALE: SIM-1 microcomputer with Microsoft BASIC (read-only memory), 4 K monitor, 1 K programmable memory, and power supply. All manuals and documentation supplied. Will ship UPS for $220. Robert Dixon, RT 1 Box 239-A, Lynde TN 38472, (815) 363-7489.

May BOMB Results
Floppy Disks
BYTE readers output their interest in Steve Clarcia's "I/O Expansion for the Radio Shack TRS-80" (page 22) by expanding Steve's rank with another first place. John Hoeppner also interfaced well with readers, receiving a second place for his floppy-disk-controller article (page 72). First place for May was 1.84 standard deviations above the mean, while second was 1.09, closely followed by Gregory J Walker ("Error Checking and Correcting for your Computer," page 250) in third place and Emory Cook ("The Cassette Lives On," page 12) in fourth place.

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D) The Datatech Intimus 007 shredder works for Scotland Yard, for government authorities, for important corporations, banks and embassies. The cutting capacity is 12 to 14 sheets at one pass. Cross cut is 1/35 x 3/8. It has a 2 H.P. motor and runs off of 220/380 V 3 phase.

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E) The Intimus 306 is designed for trouble free operation and has a switch for forward and reverse rotation. It has 2 motors with terminal overload. Housing consists of coated steel, mounted on rubber cushions for noiseless shredding. The 306 can sit on a table or a stand. Cutting width is 1/2 or 1/4" and has two 150 watt 110 V 60 cycle, 1 phase motors.

Wt. 95 lbs.  
Sale Price $1189.00

F) The Intimus Simplex is designed for security without problems in the office. One push of the button renders confidential information into five illegible paper strips 1/8" thin. The simplex has a wide opening in the middle for throw away of cans, etc. Even a paper clip is simply cut into pieces. The cutting capacity is 8 to 10 sheets at one time. It has a 1/5 H.P. motor and runs off of 110 volts.

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G) Our catalog consists of more information on equipment in this ad. Other models are available plus a complete line of calculators and typewriters by Adler, Lathem time recorders, several varieties of safes, and our deintegrator that destroys paper, aluminum, film and carbon to a complete loss of identity.

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Terms: Check or money order U.S. funds only. Prepaid orders add 3% S/H, COD's add 5% S/H (U.S. only). California residents add 6% sales tax. Prices subject to change without notice. Sale ends Sept. 15, 1980.

Circle 309 on inquiry card.
C8P DF $2,895
Ohio Scientific's top of the line personal computer, the C8P DF. This system incorporates the most advanced technology now available in standard configurations and add-on options. The C8P DF has full capabilities as a personal computer, a small business computer, a home monitoring security system and an advanced process controller.

Personal Computer Features
The C8P DF features ultra-fast program execution. The standard model is twice as fast as other personal computers such as the Apple II and PET. The computer system is available with a GT option which nearly doubles the speed again, making it comparable to high end mini-computer systems. High speed execution makes elaborate video animation possible as well as other I/O functions which until now, have not been possible. The C8P DF features Ohio Scientific’s 32 x 64 character display with graphics and gaming elements for an effective resolution of 256 x 512 points and up to 16 colors. Other features for personal use include a programmable tone generator from 200 to 20KHz and an 8 bit companding digital to analog converter for music and voice output, 2-8 axis joystick interfaces, and 2-10 key pad interfaces. Hundreds of personal applications, games and educational software packages are currently available for use with the C8P DF.

Business Applications
The C8P DF utilizes full size 8" floppy disks and is compatible with Ohio Scientific’s advanced small business operating system, OS-65U and two types of information management systems, OS-MDM and OS-DMS.

The computer system comes standard with a high-speed printer interface and a modern interface. It features a full 53-key ASCII keyboard as well as 2048 character display with upper and lower case for business and word processing applications.

Home Control
The C8P DF has the most advanced home monitoring and control capabilities ever offered in a computer system. It incorporates a real time clock and a unique FOREGROUND/BACKGROUND operating system which allows the computer to function with normal BASIC programs at the same time it is monitoring external devices. The C8P DF comes standard with an AC remote control interface which allows it to control a wide range of AC appliances and lights remotely without wiring and an interface for home security systems which monitors fire, intrusion, car theft, water levels and freezer temperature, all without messy wiring. In addition, the C8P DF can accept Ohio Scientific’s Votrax voice I/O board and/or Ohio Scientific’s new universal telephone interface (UTI). The telephone interface connects the computer to any touch-tone or rotary dial telephone line. The computer system is able to answer calls, initiate calls and communicate via touch-tone signals, voice output or 300 baud modem signals. It can accept and decode touch-tone signals, 300 baud modem signals and record incoming voice messages. These features collectively give the C8P DF capabilities to monitor and control home functions with almost human-like capabilities.

Process Controller
The C8P DF incorporates a real time clock, FOREGROUND/BACKGROUND operation and 16 parallel I/O lines. Additionally a universal accessory BUS connector is accessible at the back of the computer to plug in additional 48 lines of parallel I/O and/or a complete analog signal I/O board with A/D and D/A and multiplexers.

Clearly, the C8P DF beats all existing small computers in conventional specifications plus it has capabilities far beyond any other computer system on the market today. The C8P DF is an 8-slot mainframe class computer with 32K static RAM, dual 8" floppies, and several open slots for expansion.

C8P $950
Or get started with a C8P with cassette interface, 8K BASIC-in-ROM which includes most of the features of the C8P DF except the real time clock, 16 parallel I/O lines, home security interface and accessory BUS. It comes with 8K static RAM and Ohio Scientific’s ultra-fast 8K BASIC-in-ROM. It can be expanded to a C8P DF later. Base price $950. Virtually all the programs available on disk are also available for the C8P cassette system on audio cassette.

Computers come with keyboards and floppies where specified. Other equipment shown is optional.

For literature and the name of your local dealer, CALL 1-800-321-6850 TOLL FREE.

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Aurora, OH 44202 • (216) 831-5600

Circle 310 on inquiry card.