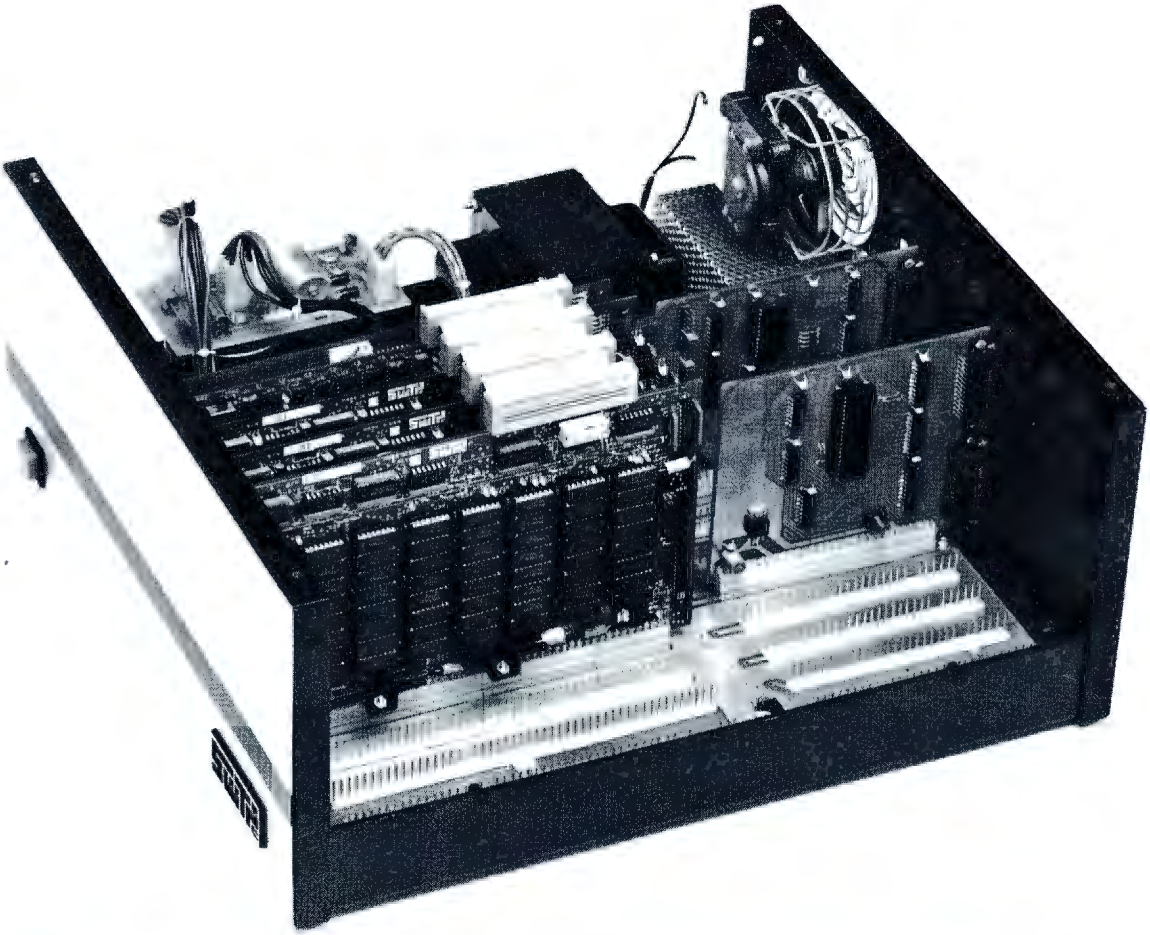
NOVEMBER 1979 Volume 4, Number 11 $2.50 in USA/$2.95 in Canada

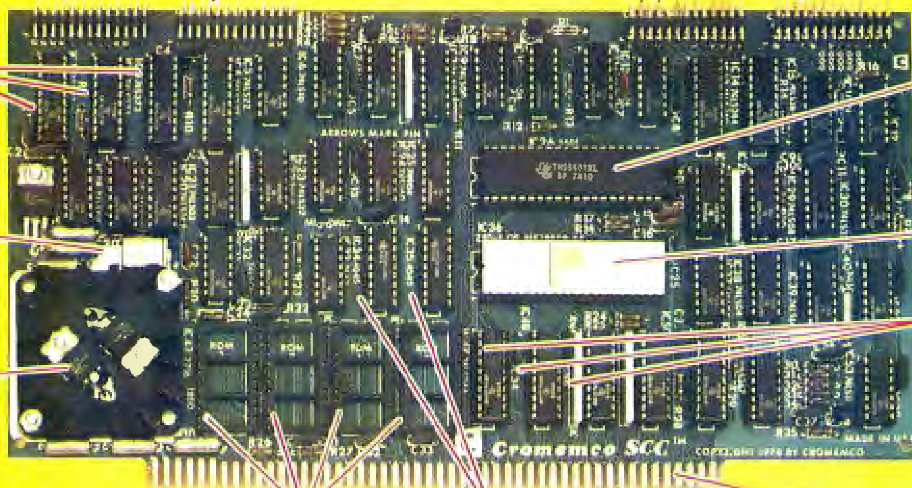
BYTE®

the small systems journal

A McGRAW-HILL PUBLICATION

FUN AND GAMES





The single card computer with the features that help you in real life

COMPLETE COMPUTER

In this advanced card you get a professional quality computer that meets today's engineering needs. And it's one that's complete. It lets you be up and running fast. All you need is a power supply and your ROM software.

The computer itself is super. Fast 4 MHz operation. Capacity for 8K bytes of ROM (uses 2716 PROMs which **can be programmed by our new 32K** BYTESAVER® PROM card). There's also 1K of on-board static RAM. Further, you get straightforward interfacing through an RS-232 serial interface with ultra-fast speed of up to 76,800 baud — software programmable.

Other features include 24 bits of bidirectional parallel I/O and five onboard programmable timers.

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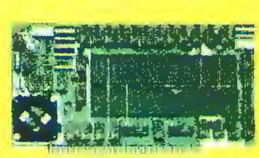
Card Cage



32K BYTESAVER PROM card

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Another convenience that makes the Model SCC computer easy to use is our Z-80 monitor and 3K Control BASIC (in two ROMs). With this optional software you're ready to go. The monitor gives you 12 commands. The BASIC, with 36 commands/functions, will directly access I/O ports and memory locations — and call machine language subroutines.

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- **Word Processing System**
- **Data Base Management**

with more coming all the time.

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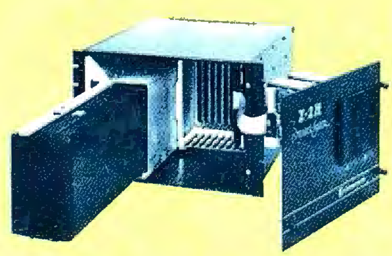
With all its features the new Z-2H, including its hard disk drive, is still housed in just one small cabinet.



Hard disk drive at lower left can be interchanged just by sliding out and disconnecting plug. Seven free card slots are available. Z-2H includes printer interface card.

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Tomorrow's computers now

Circle 80 on inquiry card.

In The Queue

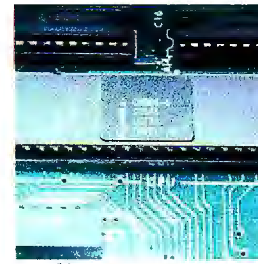
BYTE November 1979
Volume 4, Number 11

Foreground

Background

Nucleus

Cover Art: **The Magic of Computers** *by Robert Tinney*



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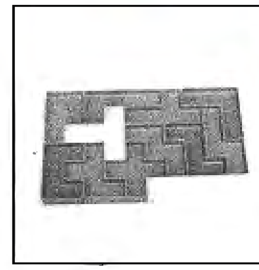

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TEAM FILE ? 75-BOSTON

ID HITTERS     BATS HITS
 0 YASTREMSKI     1 .232
 1 DOYLE          1 .296
 2 BURLESON       0 .234
 3 PETROCELLI     0 .217
 4 EVANS          0 .246
 5 LYNN           1 .297
 6 RICE           0 .290
 7 FISK           0 .300
 8 COOPER         1 .293
 9 CARBO          1 .204
10 GRIGGIN        0 .226
11 BENIQUEZ       0 .262
12 MILLER         1 .163
13 HEISE          0 .208
14 MONTGOMERY     0 .221
15 BLACKWELL      2 .172
16 CONEGLIARO     0 .108

ID PITCHERS     R-L HITS
 0 WISE           0 .253
 1 TIANT          0 .250
 2 LEE            1 .259
 3 MORET          1 .218
 4 CLEVELAND      0 .249
 5 WILLOUGHBL     0 .237
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In This BYTE

About the Cover

The theme for this issue is "Fun and Games", using the personal computer to implement dynamic interactive forms of enjoyment not otherwise possible. In the cover by Robert Tinney, entitled "The Magic of Computers", we find the essence of an ancient shell game applied with a desk top computer as the missing pea.

One of the quickest ways to gain experience with a processor is to actually program and interface to it. **The Intel 8086** 16-bit processor is now available for evaluation as the SDK-86 single board computer. Steve Ciarcia evaluates the SDK-86 board.
Page 14

The solution of games such as Soma Cubes and polyominoes presents the computer programmer with a nontrivial problem. Although the method of solution may seem quite straightforward, the actual implementation may use up excessive amounts of memory or time. This was one problem facing Douglas Macdonald and Yekta Gürsel when they started **Solving Soma Cube and Polyomino Puzzles Using a Microcomputer.** Their final program is capable of solving many problems of this sort in reasonable lengths of time on an 8 K byte machine.
Page 26

Peter B Maggs takes readers behind the scenes to show how a programmer can design a board-game program using minimax theory, a technqiue used to maximize one's chances of winning a game. Read **Programming Strategies in the Game of Reversi,** a tutorial article with broad applicability in the field of computer games.
Page 66

Implementing the data structures needed to simulate a chess game is a task that the average programmer is quite capable of performing. However, developing an effective method of defining the respective priorities for all the possible moves is a cumbersome task whose solution has eluded many programmers. W D Maurer illustrates the use of the game-tree diagram in a method called **Alpha-Beta Pruning,** a technique that offers a possible solution to this problem.
Page 84

Owners of Commodore PETs often wish to have hard-copy printouts of data appearing on their machine's video displays. P K Govind gives advice on how to obtain hard copy in **Interfacing the PET to a Line Printer.**
Page 98

Escape all your earthly restrictions and go into orbit with **A Spacecraft Simulator.** Gary Sivak has put together a BASIC program to put your celestial flight skills to the test.
Page 104

One type of popular computer-game activity is the simulation of sports events. If you have ever wondered if the best baseball team of today could beat the best team of some long-past season, you may now be able to get at least a theoretical answer. Joseph J Roehrig developed a system that uses real statistical data to simulate the play of baseball games, and he now shares it with us in **The National Micropastime.**
Page 113

Using stacks can help to simplify otherwise very complex programming problems. In **Stack It Up,** Charlton H Allen demonstrates a simple procedure for evaluating mathematical expressions that employ stack control.
Page 140

Have your recent endeavors with your personal computer been all work and no play? Tony Estep discusses some of the basic principles involved in **Writing Animated Computer Games.** The software was written for the SOL-20, but with minor modifications will run on any VDM-based 8080 computer.
Page 152

Even if you own a minimum computer system, you can still do interesting things with it. Charles A Kapps gives **Five Useful Programs for the SC/MP** which are suitable for minimum systems. The routines can be converted to other systems, such as the COSMAC VIP and KIM.
Page 172

Do you need a simple device to show logic signals compared to the system clock? Frank DeCaro can help you to **Build a Simple Digital Oscilloscope.**
Page 222

Where most people are particular about the computer they buy, they don't think twice about the most frequently used component of a system: the keyboard. **The Cherry PRO Keyboard** is Dan S Parker's choice and he tells us why.
Page 232

Editorial

Is Pseudoscience Done by Computer Pseudo-Computer-Science?

by Carl Helmers

One of my main tasks each month is reading all the manuscripts which are sent to BYTE by authors, who are often our readers. The number of well-prepared manuscripts which come our way is fantastic, and for obvious reasons of space we can only accept so many in a given interval of time. Thus, when an unsolicited article is received, we look for a certain uniqueness of idea and appropriateness for our readers. The article content of BYTE magazine is approximately 90% the result of unsolicited articles. Of course, exceptions occur, for example, the 6809 series by Joel Boney and Terry Ritter (which required a bit of encouragement in advance of its writing), or several of the articles on LISP in our August 1979 issue, which were solicited explicitly by guest editor John Allen.

Thus, a magazine like BYTE has proven to be a self-generating forum, as the readers interact with authors and, as they write about their own particular experiences or pet concepts, even become authors.

This month our featured theme for the issue is loosely entitled "Fun and Games," ie, how computers can be used in various forms to implement mental recreations. We describe how to use computers to simulate mythical worlds and situations and to examine logically defined games and their states. All these topics and more fit under this general category of fun and games.

Readers who examine our table of contents, however, will find that not one of our recent articles has been devoted to the subject of "biorhythms," this in spite of the immense popularity of biorhythm programs at every convention or computer demonstration and a virtual flood of prospective article submissions on this topic. Far be it from me to belittle the concept of having harmless fun with computers by creating fantasy trips and games. Just because one can program a computation does not make that computation a valid representation or model of the real world — witness the fun and humor we get out of fantasy games. Humor is in large measure due to a gentle (or not so gentle) bending of reality in a specific and limited context.

But some biorhythm writers start out by pontificating the veritable truth of a hypothesis and its implications, and fail to make the point that it is all a fantasy simulation. Most people writing about the biorhythm algorithm assume that it corresponds to a proven, well-documented and scientifically valid field of endeavor.

I am reminded of the epistemology of a former associate of mine, who shall remain anonymous. His epistemology essentially boiled down to "if it is printed on paper it must be true . . . ." Much has been printed about the alleged validity of the biorhythm mythology; there is an entire branch of the special-purpose computer industry devoted to cranking out biorhythm calculators. And biorhythm programs do indeed appear in much of the sales promotional literature of personal computing. But that does not make the results a science any more than the prevalence of adventure-style games in tomorrow's computers makes any statement about the real world, other than mankind's characteristic love of fantasy. A corollary of the "if it's printed" epistemology is the statement "if it is represented in a programmed calculation, it must be true . . . ."

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"When I was shopping around for my system, the guys in the computer stores demonstrated all the unique features of the minifloppy. I've got to admit that at first I didn't really understand all the technical details. But now that I use the system every day, I really appreciate the minifloppy's fast random access and data transfer. I like the reliability, too.

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As commonly stated, the biorhythm hypothesis has two major assertions. The first is that there exists a fixed point in time, namely the date of birth, when each individual's biological clock starts ticking. The second is that there are three well-defined periods which start in phase at that reference point and have an integer relationship to one another. The particular integers are unimportant. Then, by doing a Fourier summation with unit amplitudes on the three periodic waveforms, we come up with the time domain evaluation of one's state for any given date after birth. Much graphic display programming can be done to make the results of this meaningless calculation look beautiful on a color terminal.

The holes in this hypothesis are obvious. First, why are integer ratios used? After all, nature seems to abhor integers in physical constants, especially so in complicated systematic entities such as biological organisms. At the level of physical constants and ratios of physical constants, there is only one experimental near-integer of any prominence: the reciprocal fine structure constant (137.0360) — and even its "integerness" has become less significant of late as the limits of physical precision of measurement have improved.

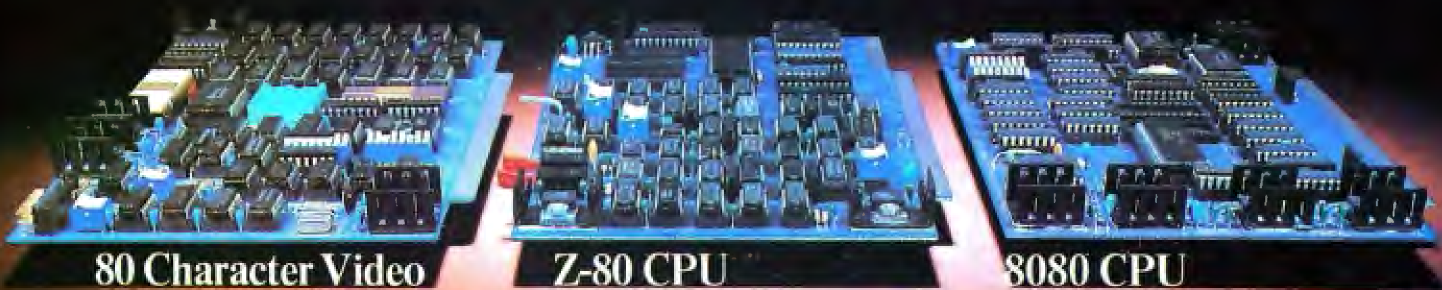
Then, in a fallacy shared with astrology, biorhythm calculations assume that the date of birth somehow determines the whole of one's life. In view of even recent knowledge of biological organisms, why not use the date of conception? Replies the "biorhythmaticianologist," "Oh, but we don't know that precisely! So let's use something we know instead!" Thus, if there were any validity to a lifelong cycle, the hypothesis would start off by picking a random phase point which is the date of birth relative to the whole lifetime of the organism. But living systems do not fit ad hoc assumptions. It is true that we observe periodicities in life, even in our own personal lives. But, in order to study such rhythms, the spirit of the natural science investigator must be invoked, obviously aided by the tools of calculation which are now so widely available.

A detailed scientific dissection of biorhythms can be found in William Bainbridge's article "Biorhythms: Evaluating a Pseudoscience," in *The Skeptical Enquirer*, published by the Committee for the Scientific Investigation of Claims of the Paranormal. Editor Kendrick Frazier and the editorial board (which includes such luminaries as Martin Gardner and Philip J Klass) are fighting a valiant fight against the doctrines of pseudoscience in today's world. The magazine is published four times a year. Subscriptions are $10 a year and are available from the Executive Editor, *The Skeptical Enquirer*, POB 5 Amherst Br, Buffalo NY 14226.

Thus, the dearth of biorhythm calculation articles in BYTE will continue. But, on quite a different plane, there is ample room for appropriate articles on personal information analysis — possibly with some attention to the idea of biological rhythms, which forms the basis for the genuine science of chronobiology. Here we make the hypothesis that there are obvious rhythms of some variables of daily life which go up and down.

To explore this hypothesis, we begin to take data on our daily personal lives using an appropriate measurement. This could be a single bit of information such as "today was a good day" or "today, on the balance, was not so good." Or it could be a series of integer evalua-

New from SSM.



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With 80 characters per line our VB3 is the perfect video interface for word processing. It produces a standard 80x24 display of upper and lower case characters or as much as 80x51 for a full page of text. The matrix for graphic display goes up to 160x204. And with optional EPROM, as many as 256 user programmed characters or symbols can be produced.

VB3 is memory mapped for rapid screen updating. But it occupies memory only when activated. So one or more VB3s can be located at the same address with a full 65K of memory still available to the user.

It generates both U.S. and European TV rates and meets the new IEEE S-100 standard. Other features include keyboard input, black on white or white on black, one level of grey, underline, strike thru, blinking char., blank-out char., and programmable cursor. Software includes a CP/M compatible driver and a powerful terminal simulator.

VB3 is available in several configurations. Retail prices start at $375 kit, $440 assembled.

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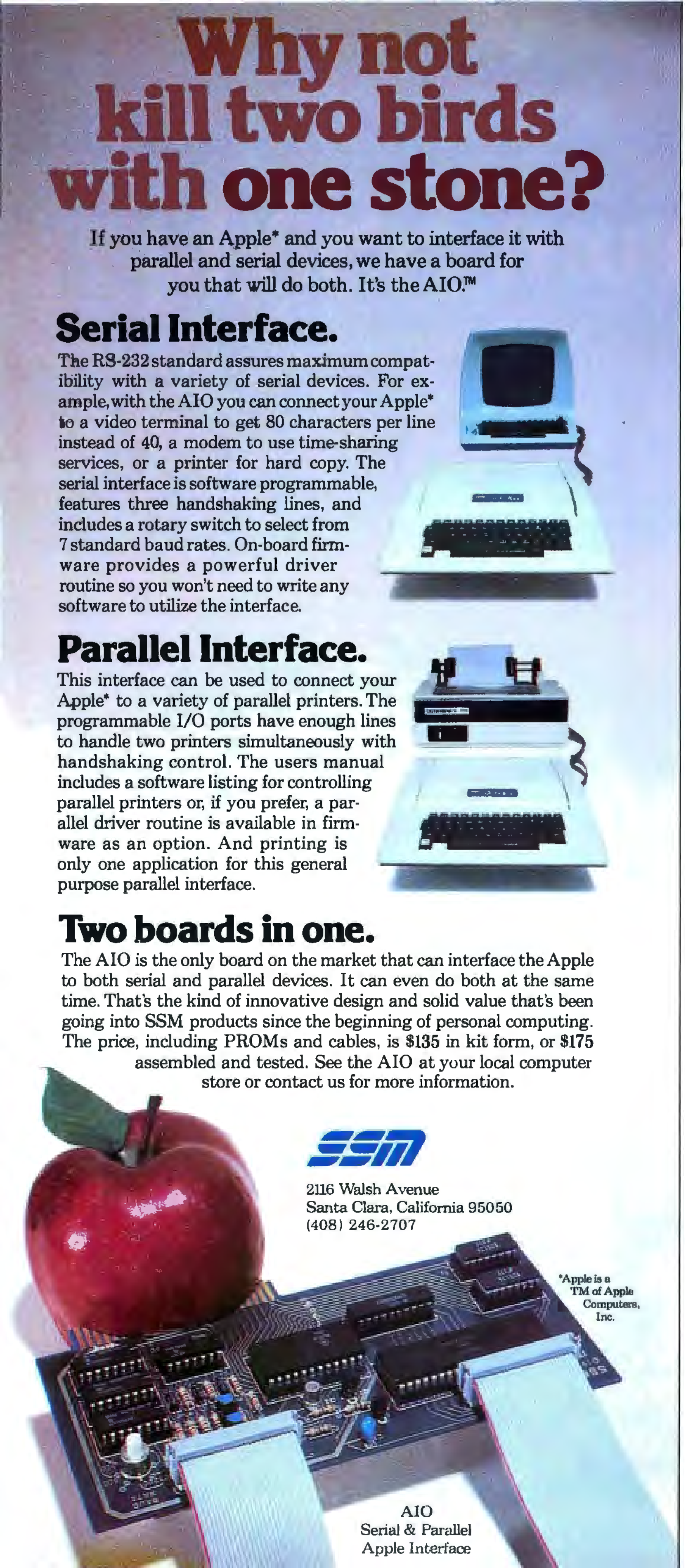

To explore this hypothesis, we begin to take data on our daily personal lives using an appropriate measurement. This could be a single bit of information such as "today was a good day" or "today, on the balance, was not so good." Or it could be a series of integer evaluations of the form "on a scale of 1 to 10, today rated 8." The important idea here is to begin taking measurements. When a real sequence of data has been built up over several hundred days, we can begin to check the hypothesis for validity by using a Fourier analysis of the data to isolate periodic effects. Due to the sampling time of once per day, no periods could possibly be present shorter than two days, and the longest periodicity component would be half the number of days in the sample. But the result would be a calculated spectrum for this "how I feel" variable. Then, one could check this continuing curve for function for predictability. Besides the Fourier decomposition approach, other methods of analysis are of course possible. Any of the commonly used methods for stock market "prediction" could certainly be applied.

But the result of this "biological rhythm" exercise would be very specific and only applicable to the individual who makes the measurements. There would be no reason to assume that any period found in this data would be the same length as the period for any other person. I do not know what the results would be, but the method of checking the hypothesis is present, and the means of doing such an experiment are within the grasp of every reader who owns a personal computer and who can find access to a Fourier analysis program — such as the Fast Fourier Transform. (See BYTE December 1978 and February 1979 for articles on the Fast Fourier Transform technique.)

So, to answer the question raised by this editorial, I would conclude with several points. First, pseudoscience is pseudoscience. Second, pseudoscience done by computer is still pseudoscience, for the tools of implementation hardly affect the imprecision of thought used in ignoring reality.

Finally, what makes the pseudoscience a pseudoscience is its element of pious fraud, an attempt to ignore contrary data and purport that its premises describe and predict reality. When we remove any intention of purporting that the given hypothesis is anything other than a fantasy, then the pseudoscience classification goes away and we can enjoy it as a game or fantasy.

Thus, pseudoscience done by computer is most definitely not pseudo-computer-science, for even a biorhythm program can be correctly implemented from its premises! And, with the caveat of not purporting a false scientific validity to our fantasies, we can have lots of fun correctly implementing quasi-computer science fantasies and games which make absurd premises. ■

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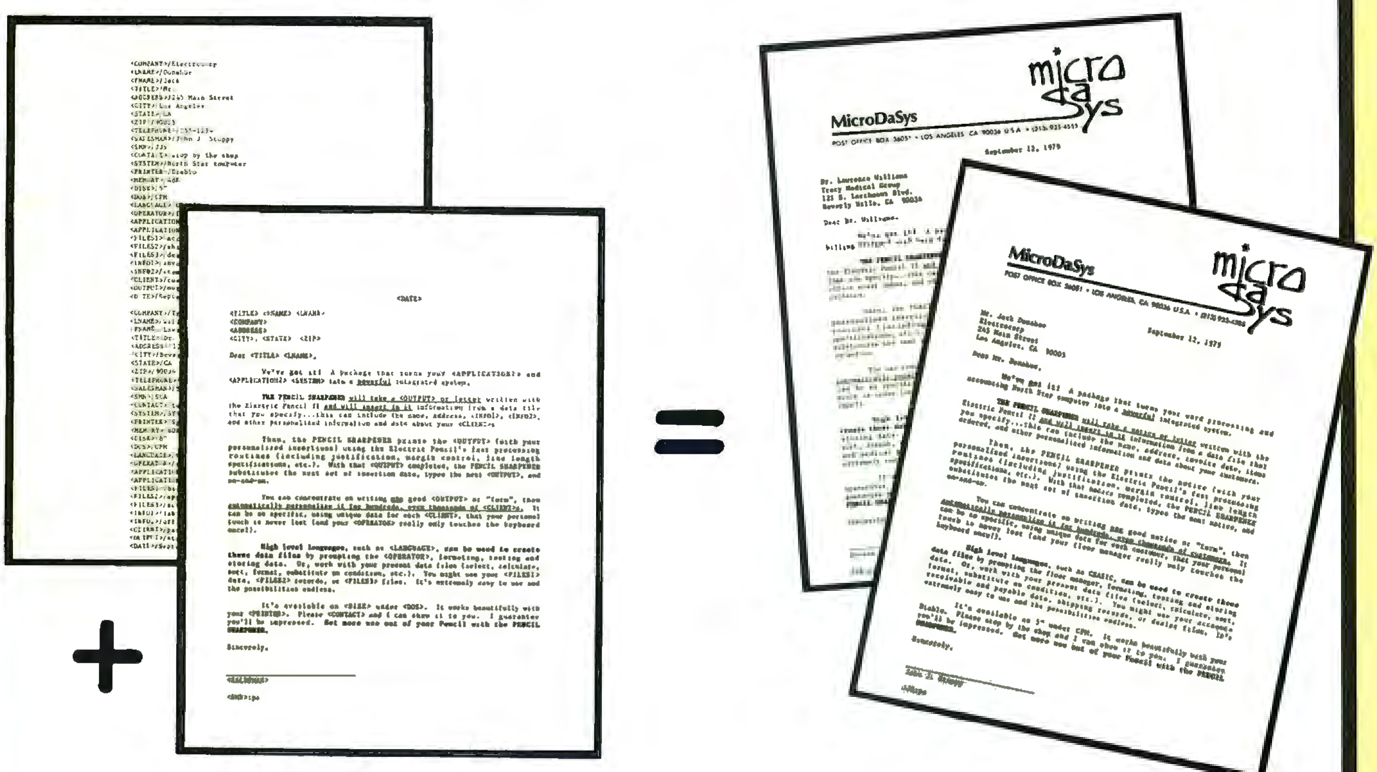

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Letters

Mind Over Matter Expansion

I found your article "Mind Over Matter" (June 1979 BYTE, page 149) very interesting. When all the components arrive, I hope to have an operational muscle monitor. A friend of mine has a great deal of enthusiasm for brain wave monitors, and, although I do not quite see the magic he sees in them, the idea is intriguing.

My difficulty with building the brain wave monitor is that my knowledge of electronics has never gotten past the reading the Heathkit-instructions-stage. You mentioned changing the 100 K ohm resistor on IC2 to 1 M ohm for brain wave amplification, which is OK; however, then you said that bandpass filters must be added, and you have lost me.

I know it would be a time-consuming project, but I thought that I would try and trouble you for a circuit and parts list at the Heathkit-level for brain wave monitor expansion. I assume that, along with input to an oscilloscope (Heathkit, naturally), the analog output could be used as input to my Cromemco D+7A I/O board?

Frank Gizinski
2060 St Clair St
Racine WI 53402

Author Ciarcia Replies:

I hope you will have an operational muscle monitor by the time you read this. I regret, however, that I cannot comply with your request. Heathkit and the Muppets both have something in common: because the original is done so well and anything equivalent could only be accomplished with a similar effort, there are no copies. Except through the effort of a complete article on the subject, I hesitate to do only half the job by sketching out a few filter circuits which ultimately demand a great deal of technical ability.

In addition to yours, many letters have requested expansion information. In actuality, the required circuitry would constitute a low-frequency spectrum analyzer. I will look into the design, and use it either as an article specifically on expansion of the "Mind over Matter" introduction, or as an additional supplement with one of my regular monthly offerings. I am aware of the obvious interest in expansion, and I do try to present circuits that can be readily constructed.

Finally, the biofeedback interface can be readily used with the Cromemco A/D board, if the analog output from the monitor is scaled down to 0 to 2.56 V. This can be done with a 500 K ohm potentiometer serving essentially as a volume control. Analysis of the acquired data is another subject entirely.

Perhaps your strength is really software, and you will achieve success better by this method. The ultimate goal is to analyze the low-frequency spectrum. This can be done either through hardware or software.

A Rejoycing LISPer

Had James Joyce been a computer scientist, he would have created LISP.

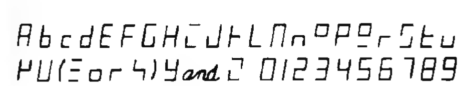
Martin D Sandman
10720 Cariuto Ct
San Diego CA 92124

Move Segmenting

I was gratified to see some evidence ("A Digital Alphanumeric Display," April 1979 BYTE, page 218) that someone is beginning to realize that 7 segments can portray alphanumerics, but noted that Daniel Chester's 7-segment set is confusing in these respects:

A "G" could be a "9,"
a "Q" could be a "9,"
an "S" could be a "5,"
and a "Z" could be a "2."

The following is a set which I devised two years ago:



You will note that none of these characters are ambiguous. Furthermore, they do not conflict with Mr Chester's set of special characters.

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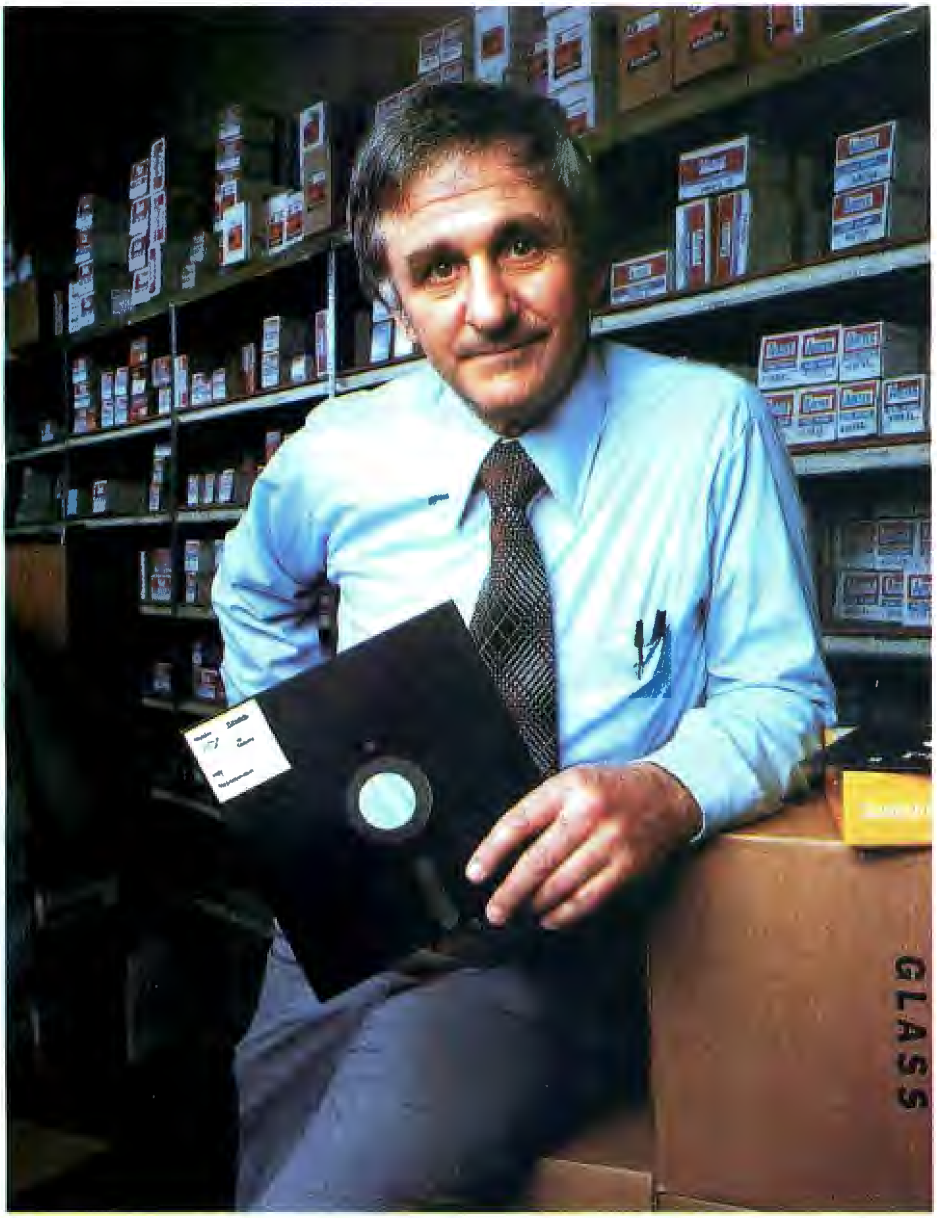

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The Intel 8086

Steve Ciarcia
POB 582
Glastonbury CT 06033

There has been a lot of talk about 16-bit microprocessors lately. You are probably interested in how they work and how they differ from present 8-bit microprocessors. This may seem more important to someone designing systems for a living rather than to the casual computer experimenter; but ultimately personal computing will be affected.

The majority of systems currently available use 8-bit processors primarily because few cost-effective 16-bit processors were available when these systems were designed. As new personal computers are conceived, the designers will have more 16-bit microprocessors to choose from, and in my opinion, the latter will win out.

Software development is much more expensive than hardware development. It is much cheaper to write one line of code executing a hardware multiply instruction than to write an algorithm to do the same function on a processor devoid of this direct capability. Reduced cost of development should be reflected in lower retail cost. There are always exceptions to the rule, but once amortized and in volume production, the 16-bit microprocessor should prove to be the logical choice for medium to high-level applications.

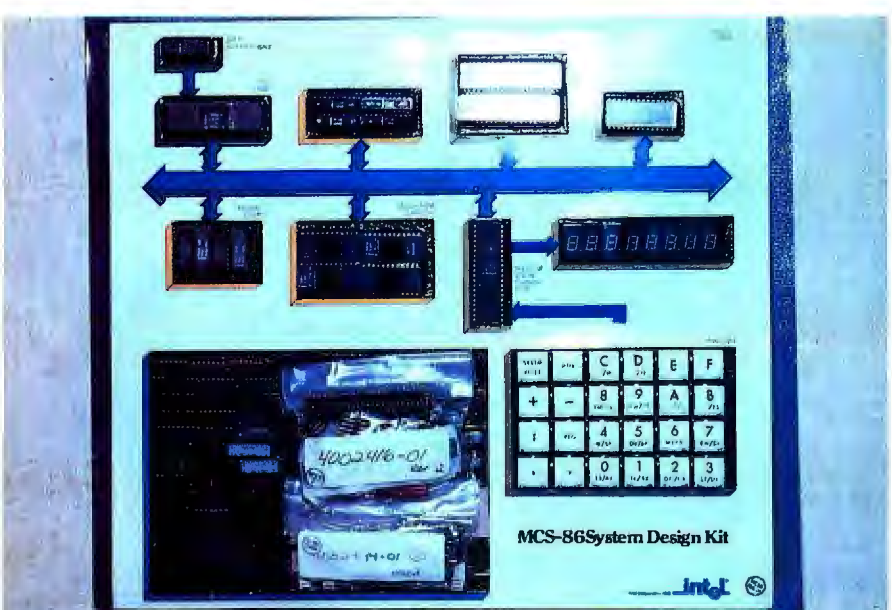

Photo 1: *SDK-86 system as delivered from factory.*

The Intel 8086

It isn't necessary to wait any longer if you have a burning desire to learn about 16-bit microprocessors. The latest one available and in volume production is the Intel 8086. The 8086 is a 16-bit microprocessor which is upward-compatible from the 8-bit 8080/8085 series processors. The 8086 contains a set of powerful, new 16-bit instructions. This enables a system designer familiar with 8080 devices to start coding immediately and gradually gain expertise in using the additional 16-bit instructions. It is important to realize that when I refer to compatible instructions I mean functional compatibility. A program written for an 8080 would have different object code than an 8086. This is only a slight inconvenience considering that this former 8080 program should run about ten times faster on an 8086. The evolutionary step between the 8086 and 8080 is far greater than that between the 8080 and 8008.

The apparent goal of Intel designers was to extend existing 8080 features symmetrically and add a wide range of new processing capabilities. The added features include 16-bit multiply and divide, interruptible byte-string operations, 1 M byte direct addressing, and enhanced

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bit manipulation. Arithmetic operations are accomplished in American Standard Code for Information Interchange (ASCII) or binary-coded decimal with a one-instruction hardware conversion.

In addition to the capability of handling data in bits, bytes, words, or blocks, the 8086 incorporates many features formerly found only in minicomputer architecture. It also supports such operations as reentrant code, position-independent code, and dynamically relocatable programs.

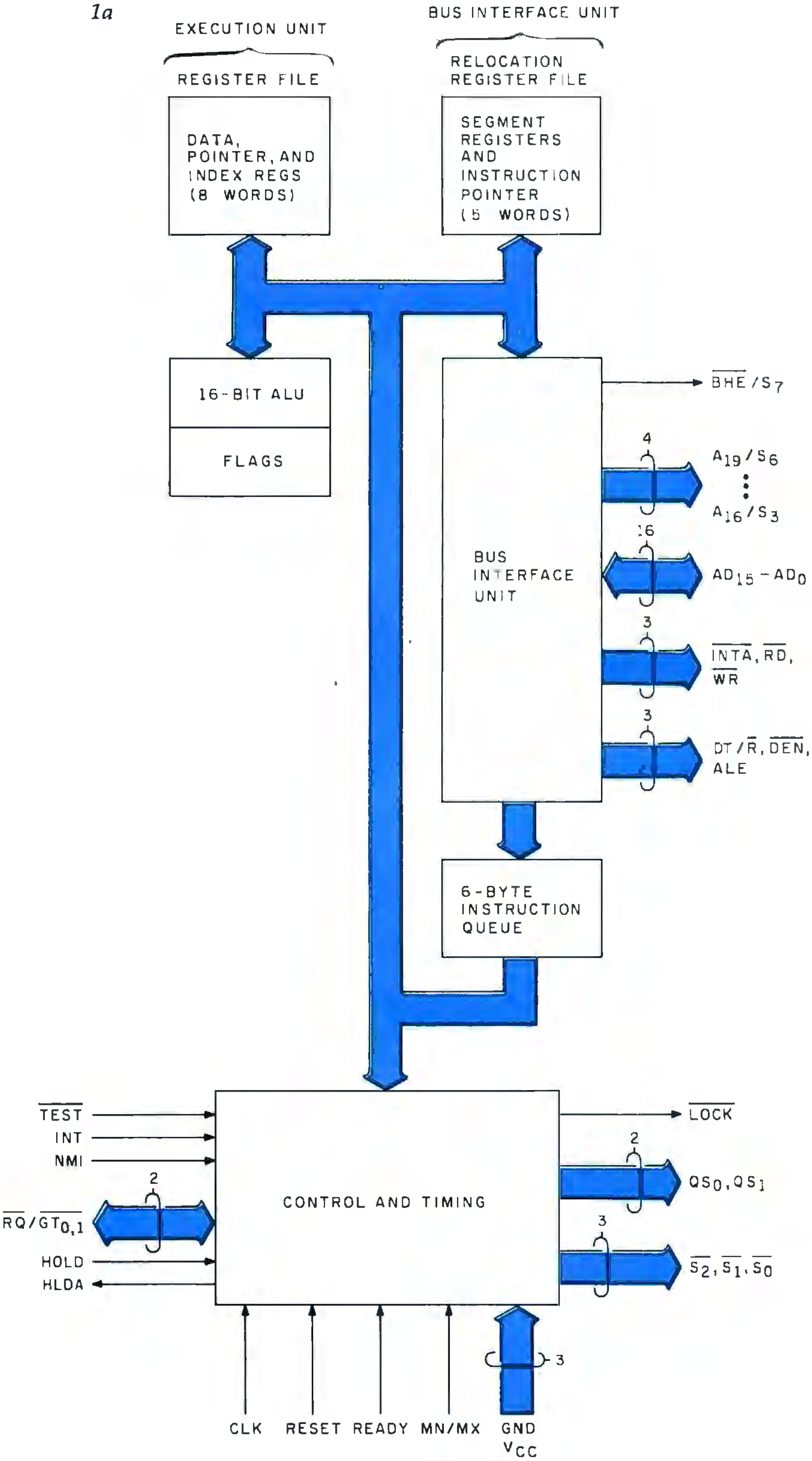
The 8086 is fabricated with a newly developed, high-speed metal-oxide semiconductor (H-MOS) process which is considerably faster than standard MOS. Running up to 8 MHz, the 29,000-transistor 8086 is the fastest single-chip central processor currently available. Unlike the 8080/8085 processor's registers, the 8086's registers can process 16-bit as well as 8-bit data.

Figure 1a shows an internal block diagram of the 8086. The 16-bit arithmetic/logic instructions are handled within the general register files. This section contains four 16-bit general data registers, two 16-bit base pointer registers, and two 16-bit index registers. Figure 1b illustrates an 8086 register model for comparison to the 8080.

The four data registers, addressable also in 8-bit partitions, are primarily from the original 8080. There are twice as many general-purpose registers as there are on 8-bit processors.

The relocation register file is the other unique 8086 enhancement. This group is referred to as the segment register file, and extends direct addressing capability to a full megabyte of memory. This file has four address pointers which contain program relocation values for up to four 64 K byte program segments. In addition, a fifth pointer serves as an I/O (in-

1a



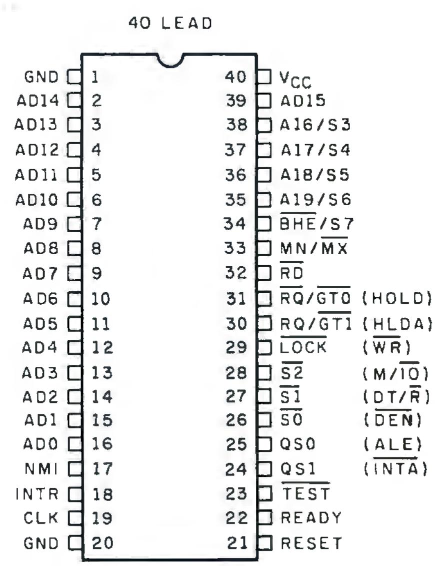
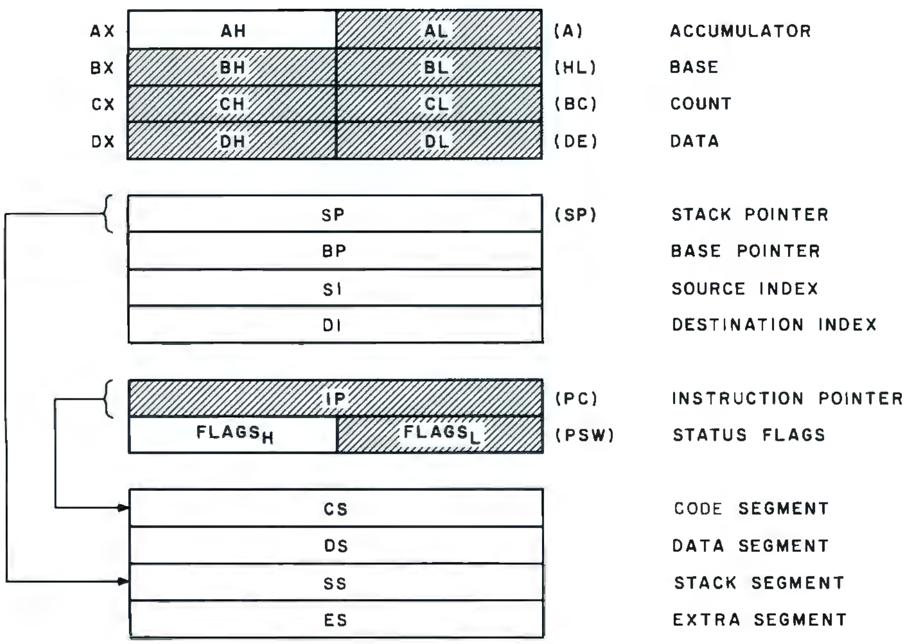


Figure 1: *An internal block diagram and pinout specifications of the Intel 8086 (figure 1a). Figure 1b shows the 8086 register model illustrating the differences between the 8086 and the 8080. Figure courtesy Intel Corp.*

1b 8086 REGISTER MODEL; (8080 REGISTERS SHADED)



put/output) control providing address space for a full 65,536 I/O ports.

Logically the 8086 operates more like larger computers than like a classical microprocessor. This is accomplished through independently controlled bus interface and execution units (figure 2). The major contribution is to speed processing by overlapping instruction fetch and execution. Up to six bytes of instruction are placed in a queue before execution. As each instruction is processed, the following instructions move up one position and a new instruction is fetched and placed in the queue. This simultaneous fetch and execute capability induces more efficient use of the memory bus. It is possible for two single-byte 8086 instructions to be executed within the time for one memory cycle. The result is improved performance, given the same bus bandwidth and memory speed as other systems.

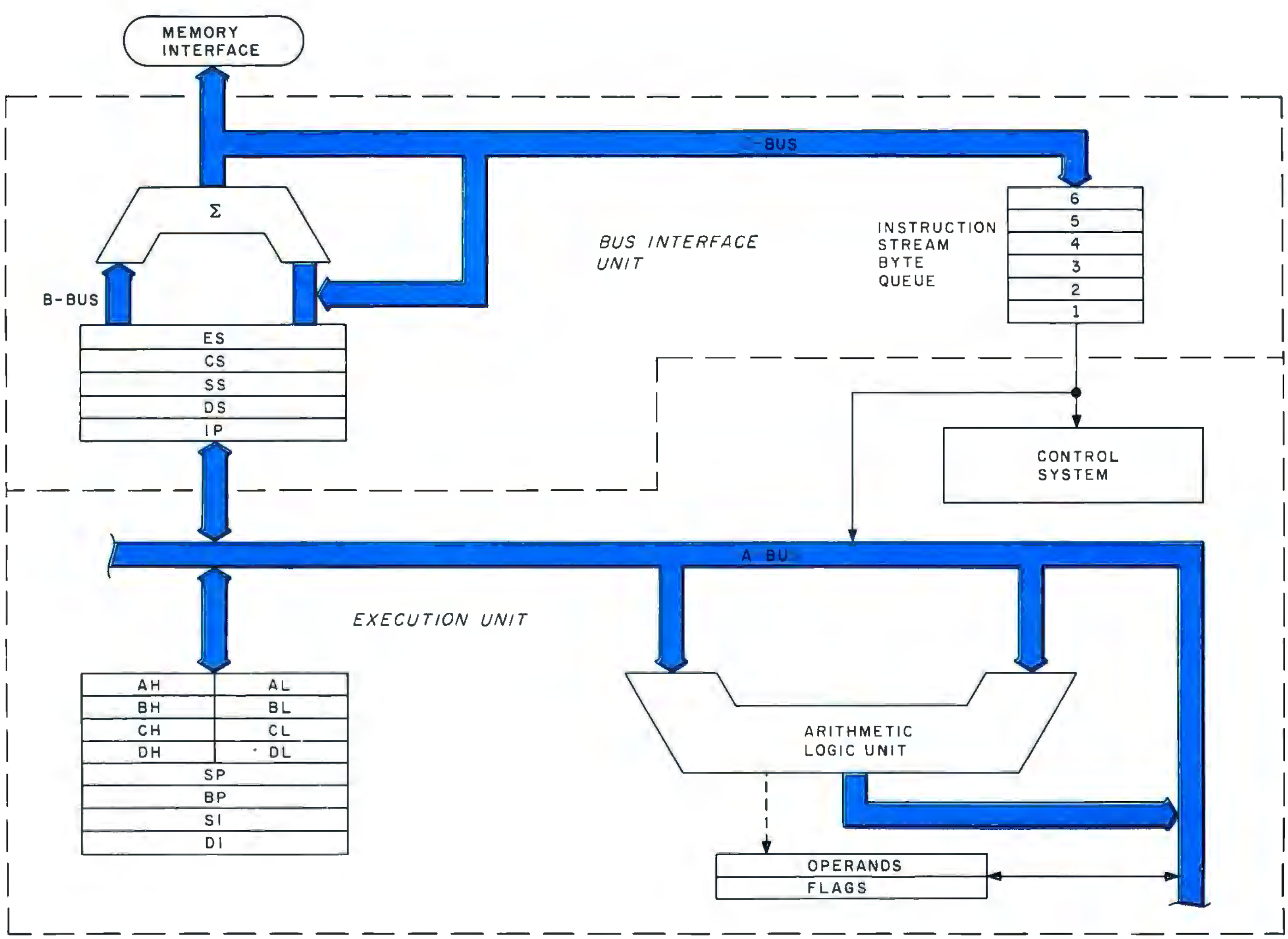


Figure 2: *Functional block diagram of internal data paths of the 8086. Figure courtesy Intel Corp.*

Table 1: *Summary of specifications for the SDK-86 board.*

Central Processor

Processor: 8086
Clock Frequency: 2.5 MHz or 5 MHz (jumper selectable)
Instruction Cycle Time: 800 ns (5 MHz)

Memory Type

Read-Only Memory: 8 K bytes
Programmable Memory: 2 K bytes (expandable to 4 K bytes)
(2 bytes equal one 16-bit word)

Memory Addressing

Read-Only Memory: FE000 thru FFFFF
Programmable Memory: 0 thru 7FF (0-FFF with 4 K bytes)

Input/Output (I/O)

Parallel: 48 lines (two 8255As)
Serial: RS232 or current loop (8251A)
Data Transfer: Rate selectable from 110 to 4800 bps
Display: On-board, 8-digit, light-emitting diode (LED) readout

Interface Signals

Processor Bus: All signals transistor-transistor logic (TTL) compatible
Parallel I/O: All signals TTL compatible
Serial I/O: 20 mA current loop or RS232

Interrupts

External: Maskable and nonmaskable; Interrupt vector 2 reserved for nonmaskable interrupt (NMI)
Internal: Interrupt vectors 1 (single-step) and 3 (breakpoint) reserved by monitor

Direct Memory Access

Hold Request: Jumper selectable, TTL compatible input

Software

System Monitors: Preprogrammed 2316 or 2716 read-only memories
Addresses: FE000 thru FFFFF
Monitor I/O: Keypad and Serial (teletypewriter or video display)

Power Requirements

V_{CC}: +5 V (±5%), 3.5 A
V_{TTY}: −12 V (±10%), 0.3 A (required if teletypewriter (TTY) or video display terminal connected to serial interface port)

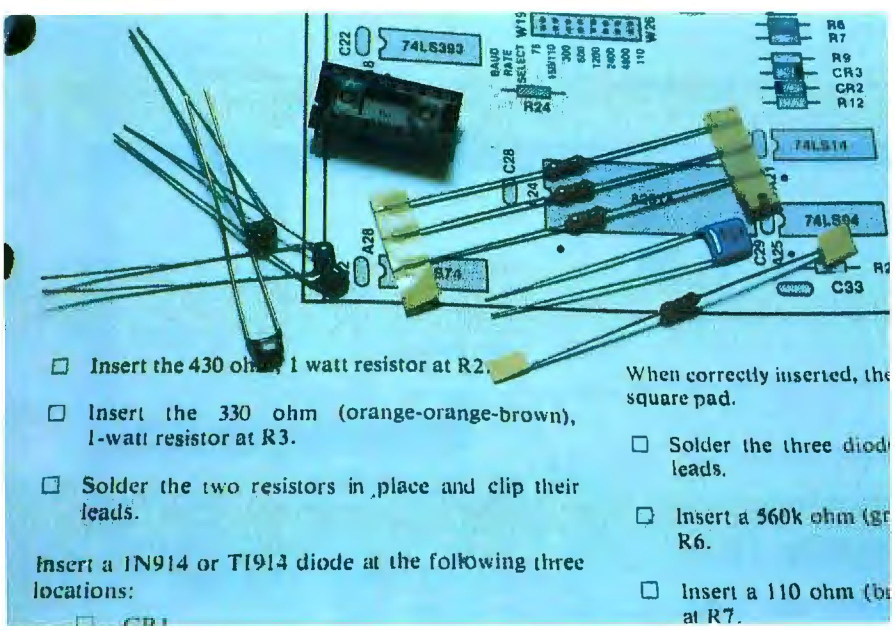


Photo 2: *Typical page from the construction manual. Each instruction step is clearly explained and each component is accurately identified.*

The Intel SDK-86

Perhaps this brief introduction has sparked your curiosity and you wish to know more about the 8086. Of course, the best method of learning is to use one. Since at this writing the 8086 is still so new that it is not incorporated into any general-use personal computer, we are left to our own resources and construction abilities. Fortunately Intel realizes that the success of any new product depends on evaluation by as many potential users as possible. For this reason the System Design Kit (SDK) series of products were conceived.

The SDK-86, shown prior to assembly in photo 1, is a single-board, 8086-based computer. Intel's pricing policies make the purchase of the SDK-86 kit far more attractive than a single 8086 chip. It results, in the name of advertising, in one of the better computer offerings on the market. At $780 the SDK-86 fits within most budgets. It is a complete computer including processor, programmable memory, read-only memory, I/O (input/output), and display. Table 1 is a more explicit listing of specifications and figure 3 is a detailed block diagram.

The SDK-86 is very easy to assemble. As shown in photo 2, it comes packaged so that all components are easily recognizable, even for a novice. Documentation includes an Assembly Manual, User's Manual, User's Guide, and Monitor listings (see photo 3). The assembly procedures are written at such a level that even a person having limited technical knowledge may assemble the kit. The assembly manual progresses from basic solder techniques and component identification to step-by-step assembly and checkout. The only microcomputer assembly literature I have read which was as easily understandable as this comes from the Heathkit people.

All major components are socketed, but to be on the safe side it is a wise idea to purchase additional integrated-circuit sockets. This will allow all integrated circuits to be removed in case troubleshooting is necessary. The fully constructed com-

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puter is shown in photo 4. Checkout, after determining that there are no obvious errors, is simply a matter of applying power and pressing the system reset button.

When the SDK-86 is reset, the 8086 executes the instruction at hexadecimal location FFFF0. The instruction at this location is an intersegment direct jump to the beginning of the monitor program that resides in read-only memory, hexadecimal locations FF000 to FFFFF. The monitor is comprised of two programs resident in programmable read-only memory; one for use with the on-board keypad, and the other a serial monitor that supports a video display or teletypewriter connected to the Electronics Industries Association (EIA) serial interface connector. This latter communication mode is preferable if the SDK-86 is to be used efficiently for software development. Even though the system is constructed to vector to the keyboard monitor on power up, simply interchanging the two sets of programmable read-only memory will allow the unit to start up immediately in the serial mode.

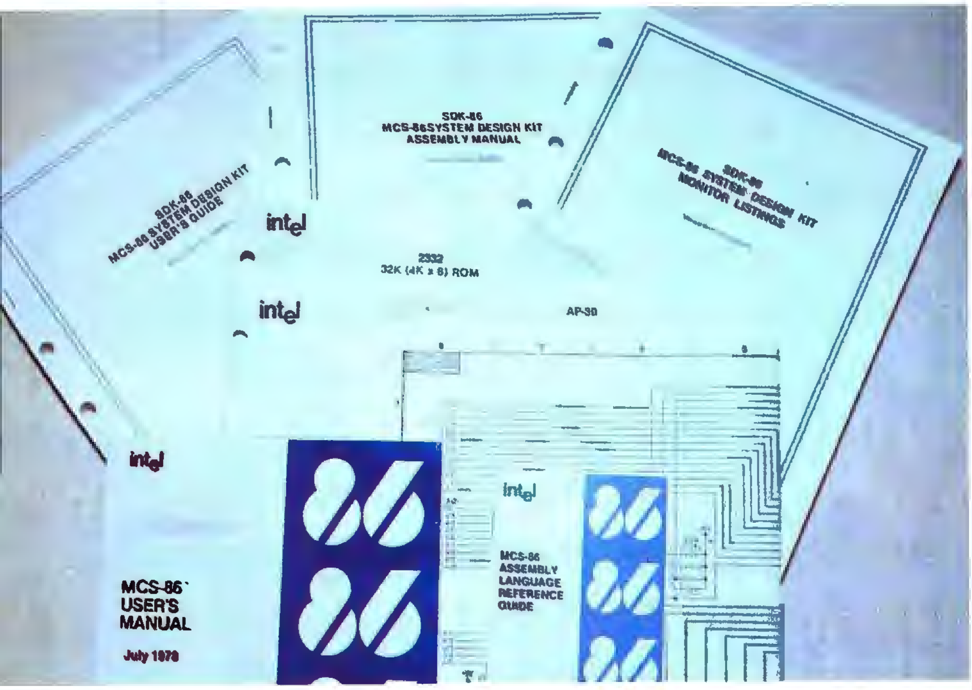

Photo 3: *The SDK-86 board comes complete with well-written documentation manuals for assembly and use.*

The SDK-86 Monitor

Both monitors share similar command capability. The keyboard monitor is optimized for the 8-digit, light-emitting-diode (LED) display while the serial monitor is obviously for a video display or teletypewriter. The only dissimilarity is that the latter has the additional ability to read or write to a paper-tape punch, or with the addition of a Frequency-Shift-Keying (FSK) modulator/demodulator, cassette storage. Table 2 lists the serial monitor I/O commands.

Of particular importance are the single-step and go commands. Single step allows a program to be executed one instruction at a time, while the go command allows the user to specify a breakpoint which returns control to the monitor while preserving the machine's status. This allows a program to be run in segments facilitating checkout.

While the monitor does provide some powerful routines, the PL/M listings provided in the documentation do not directly give the addresses of the individual routines. Enough effort is required to extract this information, that rewriting particular routines in user memory is a worthwhile consideration.

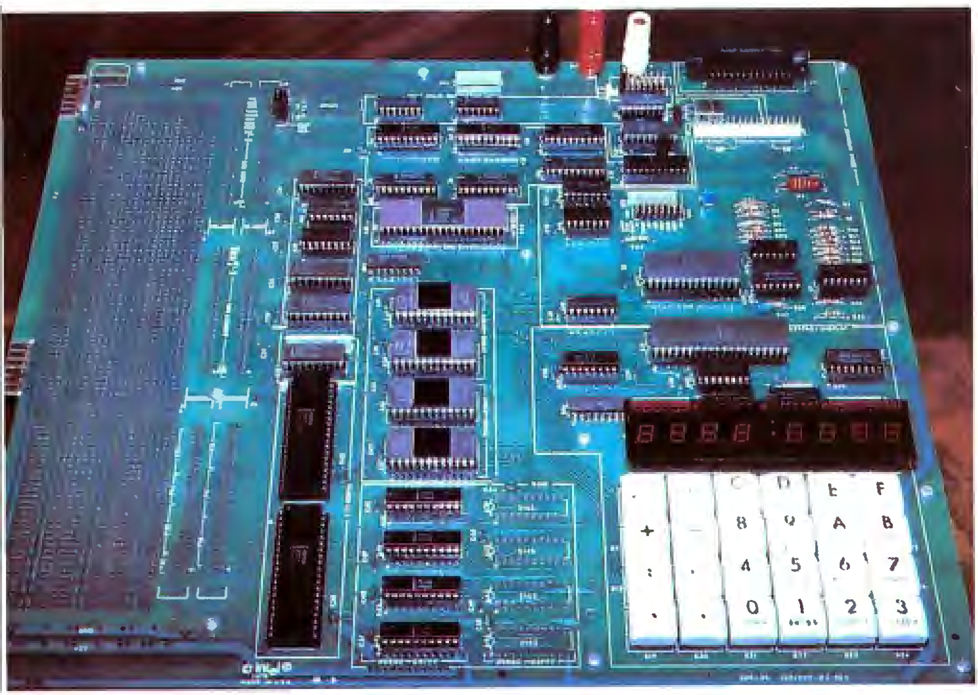

Photo 4: *Assembled SDK-86 board. Note the prototyping area on the left-hand side.*

Text continued on page 24

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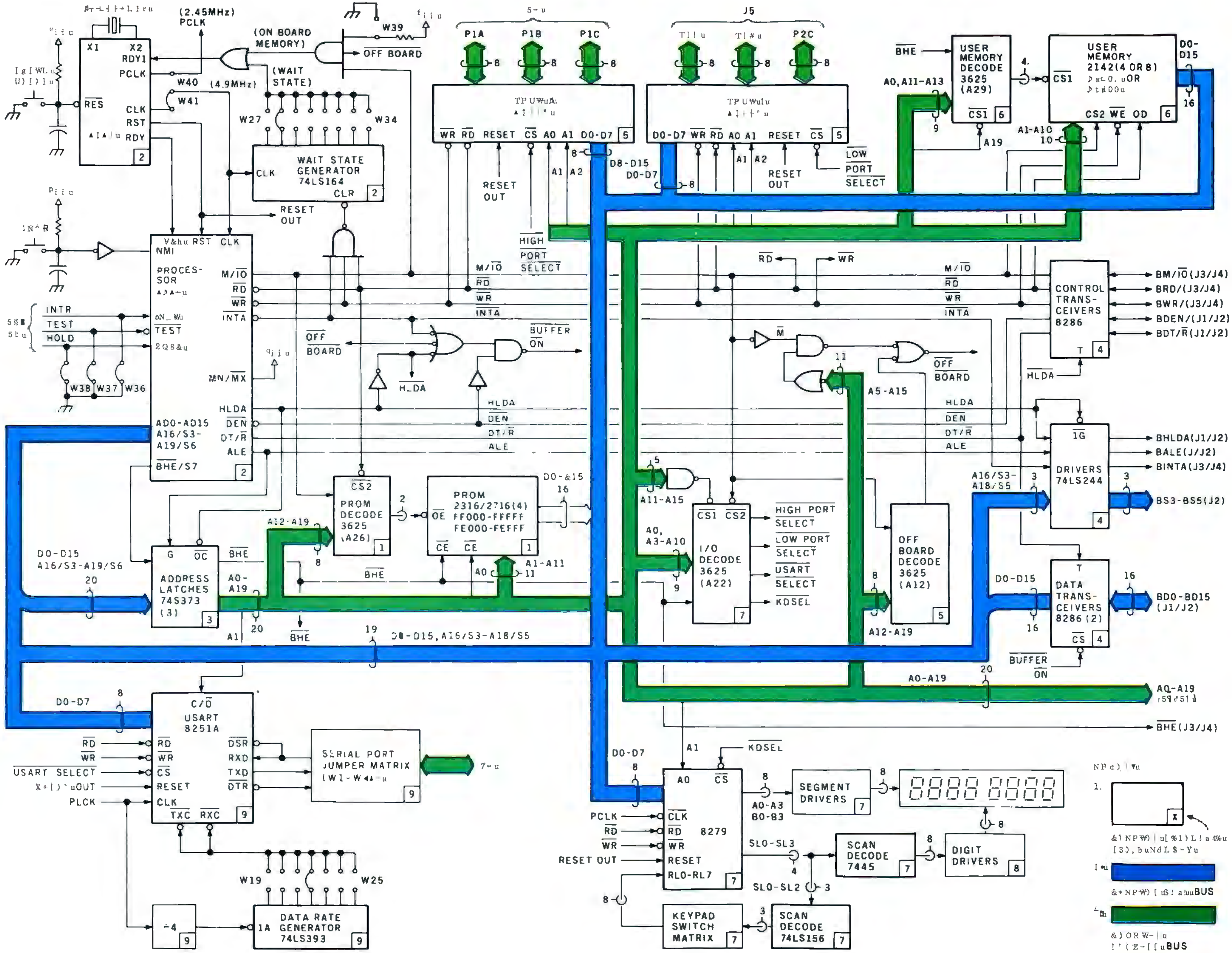

Figure 3: *A detailed block diagram of the SDK-86 evaluation board. Figure courtesy Intel Corp.*

Text continued:

In Conclusion

If you have an interest in 16-bit microprocessors, perhaps the best place to start is with the SDK-86. The 8086 is a quantum leap forward for microprocessors and the SDK-86 is a cost-effective method of evaluation, complete with all the hardware of a basic computer system. It must be cautioned that a first-time user, unaccustomed even to 8-bit microprocessors, may find the learning process somewhat complicated. The SDK-86, while packaged and assembled in a Heathkit fashion, is an industrial training device and not aimed specifically at the personal computing market. Beyond the minimal checkout procedures and brief description of the monitor commands, there are no sample programs which can be immediately entered and executed. This unit must be thought of as a rather sophisticated trainer. The mechanism is provided in the form of the board, but the actual course of education is completely in the hands of the user. ■

Table 2: *The commands which are available for use with the serial monitor.*

Command	Monitor Command Summary FUNCTION/SYNTAX
S (Substitute Memory)	Displays/modifies memory locations S[W]<addr>,[[<new contents>],]*<cr>
X (Examine/Modify Register)	Displays/modifies 8086 registers X[<reg>][[<new contents>],]*<cr>
D (Display Memory)	Moves block of memory data D[W]<start addr>[,<end addr>]<cr>
M (Move)	Moves block of memory data M<start addr>,<end addr>,<destination addr><cr>
I (Port Input)	Accepts and displays data at input port I[W]<port addr>,[,]*<cr>
O (Port Output)	Outputs data to output port O[W]<port addr>,<data>[,<data>]*<cr>
G (Go)	Transfers 8086 control from monitor to user program G[<start addr>][,<breakpoint addr>]<cr>
N (Single Step)	Executes single user program instruction N[<start addr>],[[<start addr>],]*<cr>
R (Read Hexadecimal File)	Reads hexadecimal object file from tape into memory R[<bias number>]<cr>
W (Write Hexadecimal File)	Outputs block of memory data to paper tape punch W[X]<start addr>,<end addr>[,<exec addr>]<cr>

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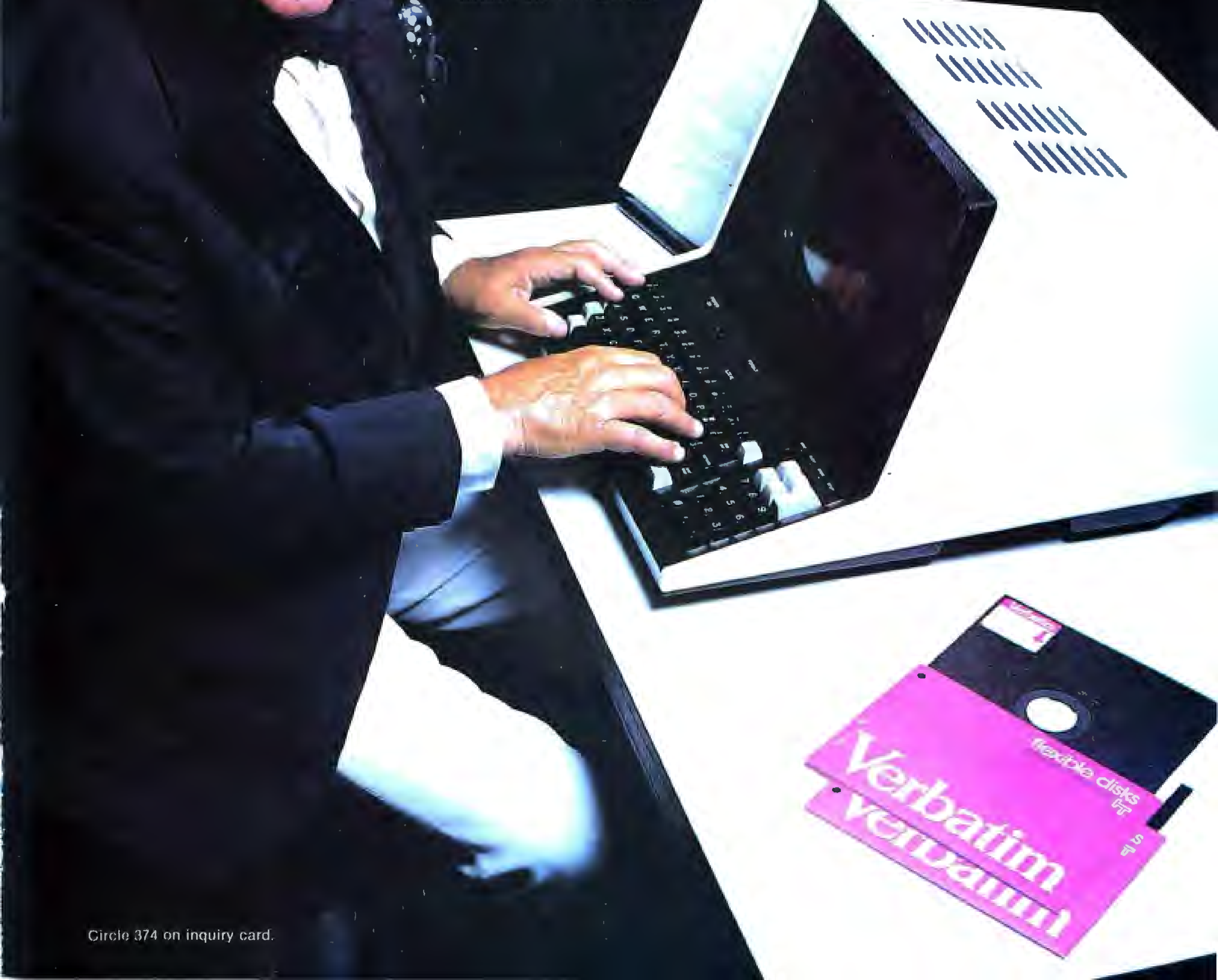

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Solving Soma Cube and Polyomino Puzzles Using a Microcomputer

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Yekta Gürsel
130-33
Theoretical Astrophysics
California Institute of Technology
Pasadena CA 91125

The genesis of this article was an inexpensive puzzle consisting of twelve plastic pieces which are supposed to be fitted into a rectangular cardboard box. Despite assurances by experts (see bibliography, Martin Gardner) that there are 2339 separate and distinct ways of solving the puzzle, a year's work by a veritable platoon of people (mainly Yekta) produced only slightly more than 150 solutions.

Introduction

Polyomino puzzles and Soma Cubes are examples of a class of problems which are particularly suited to solution on a small computer. The amount of data needed in each case is relatively small, but the amount of calculation needed to do an exhaustive search for solutions is staggering.

For a set of Pentominoes, for instance, you need only encode the shapes of the twelve pieces and provide an array of sixty spaces into which you try to fit them. For a Soma Cube there are only seven pieces, which fit into an array of twenty-seven spaces. In both cases, all of the necessary data will easily fit into 2 K bytes of memory. However, the number of individual situations that would have to be considered in an unoptimized exhaustive search would be 3.2×10^{16} for the Pentomino puzzle and 4.7×10^{11} for the Soma Cube.

In this article, we will present a 6502 assembly language program which will solve a wide variety of puzzles of the sort where a given region, either two or three dimensional, must be filled with a given set of pieces. The program has been written in a general manner so that the shape of the region can be easily changed and certain pieces can be specified as fixed, in order to take advantage of symmetry. The number and shape of the pieces themselves can also be easily changed.

Due to a clever search method, the program given here actually considers many fewer cases than the unoptimized search mentioned above. Using a Commodore PET with a clock frequency of 1 MHz, most of the problems for which we have generated a complete set of solutions have taken from a few minutes to a few hours to run. The longest running problem we have considered, that of Pentominoes in a 10 by 6 rectangle, took slightly less than two days to generate all of the 2339 solutions.

If the program is run in BASIC, which we actually tried, this problem takes more than two months. The large difference in running speeds is due to the fact that BASIC on the PET is an interpreted language, each line of which must be decoded every time it is executed. This should serve as a caveat to anyone intending to write a BASIC interpreter version of this program.

The search algorithm used in the program is extremely general, as is illustrated by the fact that there are only three places in the assembly code where a check is made to see if the region under consideration is two or three dimensional. Thus the user should find it easy to modify the program to consider more complicated or exotic problems, such as those involving oddly shaped pieces or more than three dimensions.

The program given here is written in the symbolic assembly language of the 6502 microprocessor, but users of other microprocessors should be able to adapt the fundamental algorithm to their own machines without much trouble. The accompanying BASIC routines are written in Commodore's version of BASIC (a Microsoft product), but they should also be easily adaptable to other machines. Since "safe" memory locations vary from machine to machine, users should be aware of the quirks of their own particular computer when they choose the addresses for the variables in the program.

Polyominoes

Polyominoes are planar objects consisting of a number of squares connected at their edges (see figure 1). The simplest such object is a monomino, which is just a single square. Next is the domino, consisting of two squares joined at a side, which has the shape of the familiar game pieces.

Acknowledgment

The authors would like to thank Mark Zimmermann for teaching them assembly language, and for allowing generous amounts of computer time to write and debug the program.

Both monominoes and dominoes have only one possible shape. Trominoes consist of three squares and there are two possible shapes, as shown. Similarly, there are five different tetrominoes, twelve different Pentominoes (photo 1), thirty-five different hexominoes, and so on. Interestingly, the formula for the number of n-ominoes as a function of n is not known.

The type of puzzle that we considered was the problem of using a given set of polyominoes to *tile*, or fill in, a region with a given boundary. For instance, the twelve Pentominoes can be used to tile a 20 by 3 rectangle (there are only two different ways of doing this), a 10 by 6 rectangle (2339 ways), a 15 by 4 rectangle (368 ways), or a 12 by 5 rectangle (1010 ways).

We do not even have to be restricted to rectangular shapes: we can give the computer some arbitrary region consisting of sixty squares, and ask it to find all the solutions or a subset of the solutions. One of the more interesting of the Pentomino problems is the case of an 8 by 8 chessboard with the four center squares filled in and not used (65 solutions).

A variety of problems can be developed using the various polyominoes, but the ones to which computer solution is most applicable seem to be those involving Pentominoes. The smaller polyominoes, especially monominoes and dominoes, are so few in number and simple in shape that any puzzle involving them is trivial and can be easily solved without a computer. On the other hand, for hexominoes and higher orders of polyominoes, the number of objects in a complete set is so great that an exhaustive search is impractical, even on a large computer. For this reason, the only examples that we have actually run on the computer have been Pentomino puzzles, although the program is general enough to consider other polyominoes.

In order to make a tractable problem using hexominoes or other higher-order polyominoes, a reasonably sized subset of the complete set of pieces should be chosen. For instance, one could try to tile a sixty square region using ten of the thirty-five hexominoes, or a seventy-two square region using twelve of the hexominoes.

Soma Cubes

The Soma Cube (trademark of Parker Brothers Inc, Salem MA) is a puzzle invented by Piet Hein, consisting of seven pieces which can be fitted together into a 3 by 3 by 3 cube (and other more exotic shapes). Each of the pieces consists of a number of cubes joined together at their faces. Six of the pieces are composed of four cubes, and the seventh piece is composed of three cubes, as shown in photo 2. Note that piece 2 is just a three-dimensional version of the second tromino in figure 1, and that pieces 5, 6, and 7 are three-dimensional versions of three of the tetrominoes.

There are 240 different ways of constructing a cube out of these pieces. If rotations and reflections of the cube itself and of individual pieces within the cube are treated as different solutions, this number is increased by a factor of 4608 to make a total of 1,105,920 solutions.

As with polyominoes, we can generalize the problem by using more than one set of pieces, or by trying to fill a noncubical region. The program can be easily adapted to consider these situations.

Encoding

In order to make the problem understandable to the computer, we represent the box into which we are trying to fit the pieces as an array in memory. Each of the pieces is assigned a number. An empty square in the box is represented by a zero in the appropriate array cell, and squares which are filled by piece number K are represented by the actual number K in the corresponding array cells. For convenience, the entire array is surrounded by a boundary of cells into which we put the number -1. This speeds up the search since the machine does not have to make a distinction between cells which are filled and cells which are off the edge of the board.

As an example, consider the Pentomino problem for the 10 by 6 rectangle. The pieces would be assigned numbers between one and twelve, and the array plus boundary would have dimensions of 12 by 8. The number -1 is also put into any square which is off-limits. Thus, an 8 by 8 square with the center four squares off-limits would be represented in memory by a 10 by 10 array

Figure 1: *Polyominoes are planar objects consisting of a number of squares connected at their edges.*

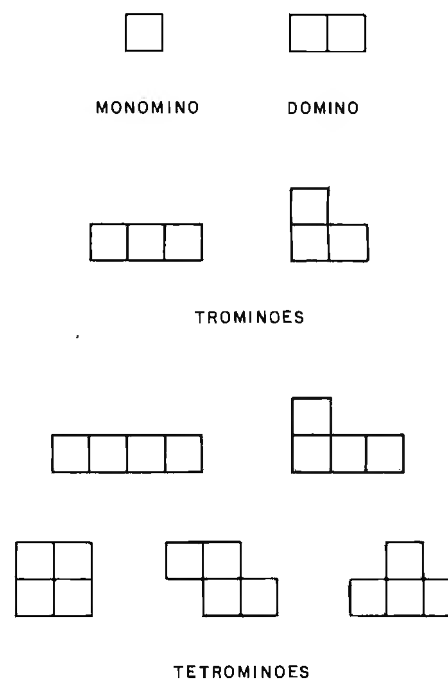


Photo 1: *The twelve different Pentominoes, showing their assigned number and letter designations. Pentominoes is a registered trademark of Solomon W Golomb.*

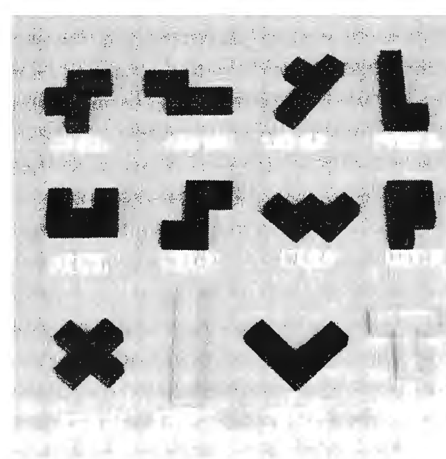
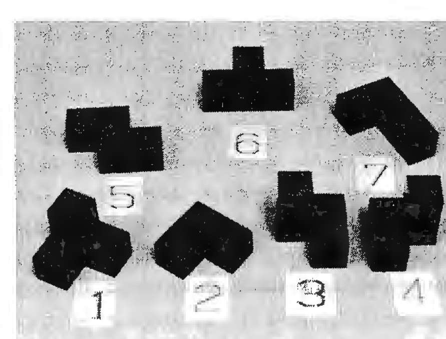


Photo 2: *The seven Soma Cube pieces with their assigned numbers.*



Solomon W Golomb originally introduced the terminology and many of the problems associated with polyominoes.

with −1s around the boundary and in the four center squares.

Unfortunately, things are not quite this simple, since we cannot specify a two-dimensional array in assembly language, and must therefore store it as a linear array in memory. The mechanics of how we encode and decode the coordinates of a particular square will be explained later.

The numbering of the pieces is somewhat arbitrary, but it is convenient to put the most symmetric pieces first. This makes it easy to have the computer fix one of the pieces on the board in order to take advantage of symmetry. Again using the Pentominoes as an example, the X Pentomino should always be assigned the number 1, since it has the fewest orientations of any of the pieces (ie: only one). If you look at a 10 by 6 board, it is easy to convince yourself that any solution can be rotated or reflected to get the X in the lower left-hand quarter of the board. Thus, a simple way to keep from generating rotations and reflections of already known solutions is to constrain the X to the lower left-hand quarter of the board. Furthermore, it is easy to see that only seven different positions of the X in this corner can possibly lead to solutions; so successive consideration of these seven cases is the quickest way to generate all of the 2339 solutions. For these reasons, the program allows the user to specify any number of pieces as fixed.

The numbering of the Pentominoes and the Soma Cube pieces shown in photos 1 and 2 will be used in the program. Also shown in photo 1 are mnemonic letters assigned to each of the twelve Pentominoes. These letters are used in printing out the solutions to make the output easy to read. For the Soma Cube we used the numbers one thru seven for the printout symbols, but you can easily change these to any symbols you choose.

The option of fixing pieces also allows the user to specify part of the solution. For instance, if you want to know whether or not a solution exists when a certain number of the pieces are fixed, enter the positions of these pieces from the keyboard, and the computer will hold them fixed and fiddle around with the remaining pieces. The parts of the program which initialize the positions of the pieces and print out the solutions have been written in BASIC because they are not time-critical. These will be easy for the user to change.

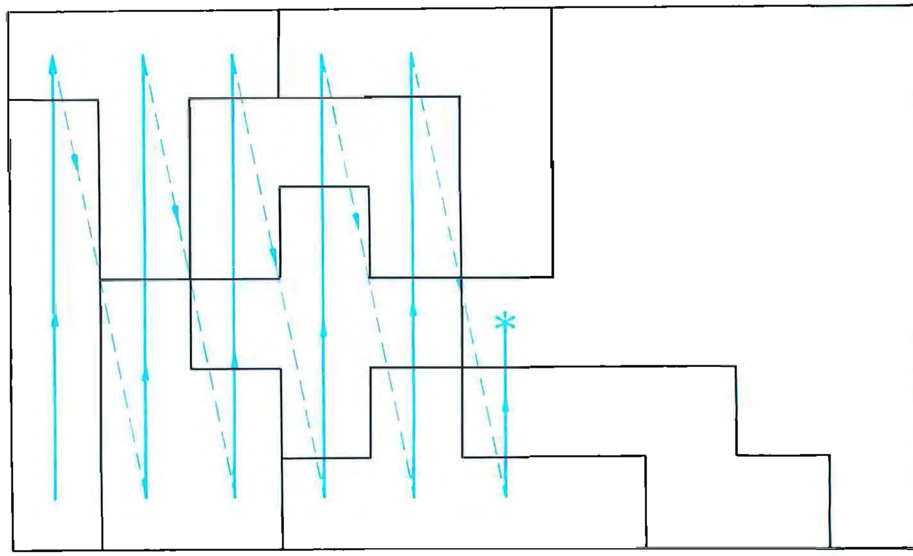


Figure 2: *The scan procedure starts in the lower left-hand corner of the defined area and proceeds up the first column. When the top of the column is reached, the scan returns to the bottom of the second column, which is scanned from bottom to top. This procedure is repeated until an empty square is encountered. This empty square is then the base square. If no empty squares are found, the problem has been solved.*

Algorithm

The program has to order the solutions so that it knows what solutions have already been found and what possibilities are yet to be tried. The program does this by considering the permutations of the piece numbers in ascending order. The meaning of *ascending order* is best illustrated by considering a simple example. If we have three pieces, numbered 1, 2, and 3, then the permutations in ascending order are:

(123), (132), (213),
(231), (312), (321)

That is, considering the permutations as three-digit numbers, these three-digit numbers are in ascending order. The generalization of this example to higher numbers of pieces is self-evident.

The total number of permutations of N pieces is given by the product of all of the numbers between 1 and N, which is denoted by N! (read N-factorial):

$$N! = N \times (N-1) \times (N-2) \times \ldots \times 3 \times 2 \times 1$$

Thus for the twelve Pentominoes, we have 12! = 479, 001, 600 permutations to consider! This is not, however, cause for despair; an efficient search procedure will reduce the possibilities to a small fraction of this number.

In order to make the search procedure clear, we will describe it for the special case of the 10 by 6 Pentomino puzzle. It will be obvious how the method can be generally applied to other cases.

The board is arranged with the long dimension placed horizontally and the short dimension placed vertically. The program applies a scan procedure which starts in the lower left-hand corner and scans up the first column, then goes to the bottom of the second column and scans up this column, and so on, for the third through tenth columns. The first empty square which it runs across in this search is called the *base square* (see figure 2).

The search procedure is summarized in the flowchart in figure 3. Just before the BASIC initialization routine is finished, it performs the search

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described above and finds the first base square. If the user has not specified any pieces as fixed, this is just the lower left-hand corner square. If fixed pieces were specified, it need not be this square (figure 2). The computer has in mind a particular permutation of the twelve pieces which was specified by the user. The program chooses the appropriate piece and looks up its orientations in a table. If the first orientation that it tries does not fit, it goes on to the second, and keeps trying until one of two things happens:

- It finds an orientation which fits, in which case it puts the piece in the box and then scans as described above for the next base square. It then tests this new base square to see whether or not it is isolated (ie: whether or not it is completely surrounded by four filled squares). If the base square is isolated, it cannot serve as the new base square, so the program jumps to the isolated square routine which will be described later. If the new base square is not isolated, the program picks the next piece in the permutation and goes back to the beginning to look up the orientations of this new piece.
- None of the orientations fit, in which case the program takes out the last piece it put in and tests that piece to determine if it has any orientations which have not yet been considered. If there are additional orientations, the program jumps back to the beginning to try these. If all orientations have been considered, the program removes the preceding piece and tests that piece for any more orientations. Pieces are removed in this manner until either a piece is found which has more orientations, in which case the program branches back to the beginning to consider them; or the program reaches the nucleus of pieces which the user specified as fixed. When this happens, the next

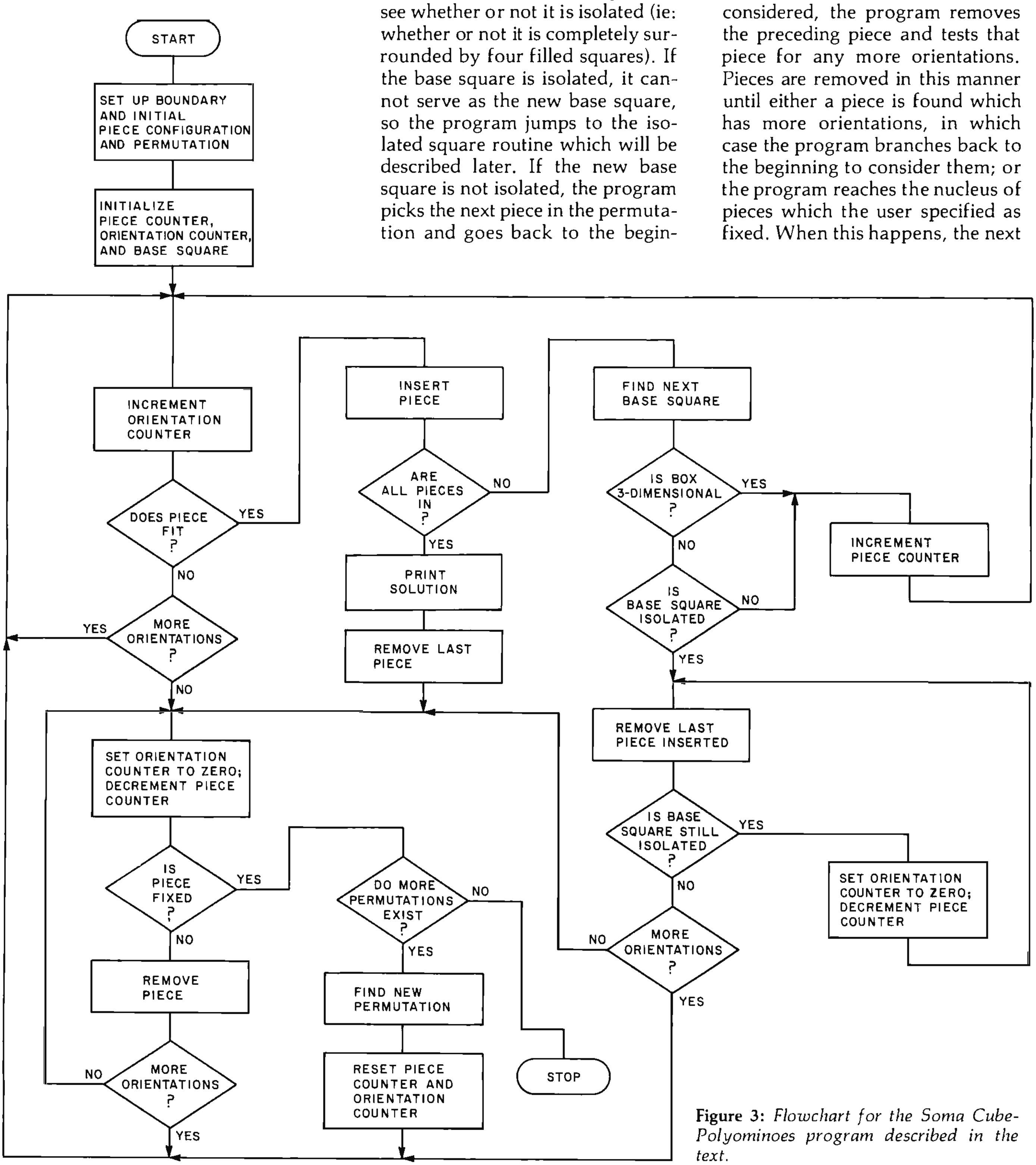

Figure 3: *Flowchart for the Soma Cube-Polyominoes program described in the text.*

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permutation in the ascending sequence described above is generated and tested. If there are no permutations left, execution stops.

Immediately after any piece is placed, the program checks to see if the board is full. If the board is filled, control is transferred back to BASIC to print out the solution.

Two refinements have been added to the above bare-bones routine, which together result in a considerable savings of time:

The *isolated square* routine mentioned above saves time by immediately recognizing and rejecting isolated base squares. Otherwise, the machine would have to make many tests before rejecting an obviously invalid base square. The routine works by successively removing pieces until the square under consideration is no longer isolated. This routine results in a savings of time only in the two-dimensional case: in three dimensions, it is no more efficient than the basic search described above. This is mainly due to the fact that an isolated square seldom occurs in the three-dimensional case because of the large number of cubes (six) which must be filled to isolate a given cube. For this reason, the isolated square routine is bypassed when the program is used to run the Soma Cube.

The other refinement allows the machine to avoid considering permutations of the pieces which are certain to lead to no solutions. For instance, if the machine never succeeded in fitting more than five pieces into the box in a particular permutation, it will do no good for the permutation routine to interchange the eleventh and twelfth pieces: no progress will be made until the position of the sixth piece is changed. The program takes account of this, and the result is that while the permutations are still done in the ascending order previously described, a large fraction are simply skipped since they cannot lead to solutions.

The method of scanning for the base square in the two-dimensional case is implemented in two loops: the Y-scan loop nested inside the X-scan loop. The scan method for the three-dimensional case is similarly defined by three nested loops: the Z-scan loop is nested inside the Y-scan loop, which is in turn nested inside the X-scan loop.

Orientation Table

We should explain the meaning of the phrase which was used above when we said that the computer "looks up" the orientations of the pieces. This phrase means exactly what it says: the machine looks up the orientation from a table in memory which has been entered by the user.

But why can't the computer figure the orientations itself? The answer is, of course, that it could. However this would increase the running time of the program by a factor of ten to one hundred. The orientation checker is the most often-used routine in the program, and it is important to have it run as quickly as possible.

The user does not actually have to enter the entire table. Listing 1 is a BASIC program which automatically generates the orientation table in memory. In using this program, the user need enter only one orientation for each piece. The computer automatically generates and encodes the rest of the orientations. This can result in a considerable savings in time and frustration, since a polyomino can have as many as eight orientations, and a Soma Cube piece can have as many as twenty-four orientations.

Although this BASIC program makes it possible to use the program without understanding how the orientation table works, it is worthwhile for anyone who intends to use this program to learn how the table is set up, since it is fundamental to the operation for the entire program.

In a BASIC routine, the table would be a four-dimensional array B(K, J, M, I). In the assembly language routine, the table is one-dimensional, but we will explain the mechanics of this shortly. At the moment, an explanation of the four-dimensional array will be more helpful.

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Listing 1: *BASIC program to generate the orientation tables for polyominoes and Soma Cube. The computer generates all possible orientations after the first orientation has been entered.*

```
1 REM COPYRIGHT 1979 ORIENTATION TABLE GENERATOR
10 INPUT"NUMBER OF DIMENSIONS";D:Q=8:IF D=3 THEN Q=24
20 INPUT"NUMBER OF PIECES";P:INPUT"NUMBER OF SQUARES PER
   PIECE";S
30 PRINT"ENTER R0:FIRST ADDRESS OF ARRAY OF LENGTH";P:INPUT R0
40 PRINT"ENTER B0:FIRST ADDRESS OF ARRAY OF LENGTH";(S-1)*Q*P*D
   :INPUT B0
50 DIM X(20),Y(20),Z(20):T=0:M=P*Q*(S-1):FOR I=R0 TO R0+P
   :POKE I,0:NEXT I
60 FOR I=B0 TO B0+(S-1)*P*Q*D:POKE I,0:NEXT I
70 REM ENTER X,Y,Z COORDINATES OF EACH SQUARE OF EACH PIECE
80 FOR K=1 TO P
90 FOR I=1 TO S:X(I)=0:Y(I)=0:Z(I)=0:NEXT I
100 PRINT"PIECE #";K:FOR I=1 TO S:PRINT"  SQUARE #";I
    :INPUT"   ENTER X";X(I)
110 INPUT"   ENTER Y";Y(I):IF D=3 THEN INPUT"   ENTER Z";Z(I)
120 NEXT I:PRINT" STANDBY ......"
130 REM TRANSLATE PIECE SO THAT BASE SQUARE IS AT ORIGIN
140 A=0:B=0:C=0:E=0:F=0
150 U=100:FOR I=1 TO S:IF X(I)<U THEN U=X(I)
160 NEXT I:FOR I=1 TO S:X(I)=X(I)-U:NEXT I
170 U=100:FOR I=1 TO S:IF Y(I)<U AND X(I)=0 THEN U=Y(I)
180 NEXT I:FOR I=1 TO S:Y(I)=Y(I)-U:NEXT I:IF D=2 GOTO 220
190 U=100:FOR I=1 TO S:IF Z(I)<U AND X(I)=0 AND Y(I)=0 THEN
    U=Z(I)
200 NEXT I:FOR I=1 TO S:Z(I)=Z(I)-U:NEXT I
210 REM ORDER SQUARES ACCORDING TO THEIR DISTANCE FROM THE BASE
    SQUARE
220 FOR I=1 TO S=1:FOR J=I+1 TO S
    :G=X(I)*X(I)+Y(I)*Y(I)+Z(I)*Z(I)
230 H=X(J)*X(J)+Y(J)*Y(J)+Z(J)*Z(J):IF G<H GOTO 270
240 IF G=H AND (X(I)<X(J) OR (X(I)=X(J) AND Y(I)<Y(J))) GOTO 270
250 IF G=H AND X(I)=X(J) AND Y(I)=Y(J) AND Z(I)<Z(J) GOTO 270
260 W=X(I):X(I)=X(J):X(J)=W:W=Y(I):Y(I)=Y(J):Y(J)=W:W=Z(I)
    :Z(I)=Z(J):Z(J)=W
270 NEXT J:NEXT I:IF A=0 GOTO 380
280 REM COMPARE ORIENTATION TO THOSE ALREADY OBTAINED
290 FOR I=1 TO A:FOR J=1 TO S-1:U=B0+J-1+(S-1)*(Q*(K-1)+I-1)
300 V=Y(J+1):IF V<0 THEN V=V+256
310 IF X(J+1)<>PEEK(U) OR V<>PEEK(U+M) GOTO 360
320 IF D<>3 GOTO 350
330 W=Z(J+1):IF W<0 THEN W=W+256
340 IF W<>PEEK(U+2*M) GOTO 360
350 NEXT J:GOTO 440
360 NEXT I
370 REM PUT ENTRIES IN TABLE
380 J=0:A=A+1:FOR I=2 TO S:J=J+1:U=B0+J-1+(S-1)*(Q*(K-1)+A-1)
390 V=Y(I):IF V<0 THEN V=V+256
400 W=Z(I):IF W<0 THEN W=W+256
410 POKE U,X(I):POKE U+M,V:IF D=3 THEN POKE U+2*M,W
420 NEXT I
430 REM ROTATE TO NEW ORIENTATION
440 B=B+1:IF B=4 THEN B=0:GOTO 460
450 FOR I=1 TO S:W=X(I):X(I)=Y(I):Y(I)=-W:NEXT I:GOTO 150
460 C=C+1:IF C<>2 GOTO 520
470 C=0:IF D=2 GOTO 530
480 E=E+1:IF E>1 GOTO 500
490 FOR I=1 TO S:W=Z(I):Z(I)=X(I):X(I)=-W:NEXT I:GOTO 150
500 F=F+1:IF F>1 GOTO 540
510 FOR I=1 TO S:W=Y(I):Y(I)=Z(I):Z(I)=-W:NEXT I:GOTO 150
520 FOR I=1 TO S:X(I)=-X(I):Z(I)=-Z(I):NEXT I:GOTO 150
530 REM PRINT NUMBER OF ORIENTATIONS AND PUT IT IN ARRAY R
540 PRINT A,"ORIENTATIONS":POKE R0+K,A:IF T=1 GOTO 570
550 NEXT K
560 REM GO BACK AND CORRECT MISTAKES
570 T=1:INPUT"ENTER I.D. NUMBER OF A PIECE YOU NEED TO
    CORRECT(0 IF NONE)";K
580 IF K<>0 GOTO 90
590 PRINT" *****  DONE  *****"
600 PRINT"RECORD ARRAYS R AND B ON TAPE TO SAVE":END
```

The first index, K, is the assigned number of the piece whose orientations are being considered. Thus, for the case of Pentominoes, K ranges from one to twelve, and for the Soma Cube pieces it ranges from one to seven.

The second index, J, labels the individual squares or cubes that make up the piece under consideration. The positions of these squares will be defined in the table by their Cartesian coordinates relative to the base square, which is taken at the origin, ie: at (0,0) in the two-dimensional case, and at (0,0,0) in the three-dimensional case. Since the coordinates of the base square are fixed in this way, we need only tabulate the positions of the other squares relative to it. Thus, for Pentominoes, J ranges from one to four (not five), and for the Soma Cube it ranges from one to three (not four).

The ordering of the J values assigned to the various squares is determined by their distance from the base square. It is important that the squares nearest the base square have the lowest values of J because of the method we use to define the boundary of the box (ie: putting -1s around it). Unless the J values are in ascending order with increasing distance from the base square, there is a chance that the program might try to access a memory location which is not a part of the box. The BASIC table-generating program automatically takes care of this ordering.

The third index, M, labels which Cartesian coordinate is referred to by a given table entry. $M=1$ refers to an X-coordinate, $M=2$ refers to a Y-coordinate, and $M=3$ refers to a Z-coordinate. For any polyominoes M can be either one or two, and for the Soma Cube M can be one, two, or three.

The fourth index, I, labels which orientation is being described. The number assigned to a given orientation has no significance except for labelling purposes. The range of I is given by the maximum number of orientations of the pieces under consideration, which is eight for all polyominoes, and twenty-four for the Soma Cube pieces.

To sum up this information with an example, the table element B (1, 2, 3, 4) gives the Z-coordinate of square number 2 in the fourth orientation of

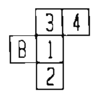
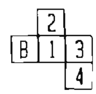
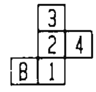
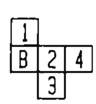
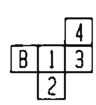
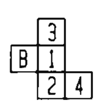
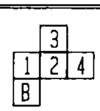
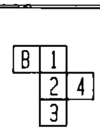
K=9	I \ J	1	2	3	4	M
	1	1	1	1	2	1
		0	-1	1	1	2
	2	1	1	2	2	1
		0	1	0	-1	2
	3	1	1	1	2	1
		0	1	2	1	2
	4	0	1	1	2	1
		1	0	-1	0	2
	5	1	1	2	2	1
		0	-1	0	1	2
	6	1	1	1	2	1
		0	-1	1	-1	2
	7	0	1	1	2	1
		1	1	2	1	2
	8	1	1	1	2	1
		0	-1	-2	-1	2

Table 1: *Orientation table entries for example of Pentomino 9. In the diagrams, the base square is labeled B and the other squares are labeled by their J values. The base square is always the lowest square in the leftmost column of the figure, and the table gives the coordinates of the other squares with respect to it.*

piece number 1. Table 1 clarifies this by showing all of the orientations of Pentomino number 9 and the table entries which go with each figure.

The main program *looks up* values in the orientation table by calling a subroutine called LOOKUP. This subroutine is called many times during each loop of the main program and is therefore the most time-critical portion of the program.

In the program given here, a certain amount of speed has been sacrificed for the sake of generality. If the user is interested only in a particular problem, the subroutine can be specifically rewritten for this problem, and the running time may be cut considerably. For instance, the first program that we wrote considered only the Pentomino problem for a 10 by 6 box, and ran almost twice as fast as the general routine given in this article. Clearly, however, it is most desirable to start with a completely general program like the one given here.

Definition of Variables

As mentioned before, any arrays of more than one dimension must be stored as linear arrays in memory.

The array A, representing the playing region, is two-dimensional when we are considering polyominoes and three-dimensional when we are considering Soma Cubes. In both cases the linearized array is arranged in memory so that the scan procedure described above goes through the linear array in ascending order. For instance, the Soma Cube array is stored with the Z index varying fastest and the X index varying slowest:

A(1,1,1), A(1,1,2), . . ., A(1,1,5),
A(1,2,1), A(1,2,2), . . .,
A(1,2,5) . . . ., A(5,5,1),
A(5,5,2), . . . A(5,5,5)

(Remember that we put a boundary of −1s around the box, so the dimensions of the array are 5 by 5 by 5 rather than 3 by 3 by 3.) The dimensions of array A vary depending on the problem being considered, but a reserved memory space of about 300 bytes is sufficient for most reasonably sized problems. Array A begins at an address denoted by A0 in the BASIC and assembly listings, and is indexed by the value stored in variable L.

In the linearization of the orientation table, the elements B(K, J, M,I) are stored with the index J varying fastest, I varying next fastest, K next, and finally M, varying slowest. More specifically, if we define the following quantities:

P: number of pieces,
S: number of squares or cubes per piece,
Q: maximum number of orientations for any one piece (eight for polyominoes and twenty-four for Soma Cube pieces),
D: number of dimensions (two for polyominoes, three for Soma Cube),
B0: beginning address of orientation table,

then the location in memory of the element B(K,J,M,I) is given by B0 + J − 1 + (S − 1) × { Q × [P ×(M−1)+K−1]+I−1}, and the number of elements in the table is given by (S−1)×Q×P×D. In assigning array space, the user should provide enough space for this table. Note that in the symbolic assembly program, the letters P,S,Q,D,I,J,K are used to denote the addresses of these quantities rather than the quantities themselves. Henceforth we will

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Listing 2: *BASIC driver and printout routine for Soma Cube — Polyominoes program. The "blackout" in line 1070 indicates use of the PET Shift-& graphics character.*

```
1 REM POKE 135,20 TO PROTECT MACHINE CODE FROM BASIC INTERPRETER
2 REM B$ HOLDS PRINTOUT SYMBOLS FOR PIECES
3 B$="XIVTUSWPRZYL"
10 REM COPRIGHT 1979 SOMA-POLYOMINO DRIVER PROGRAM
11 INPUT" ENTER NUMBER OF DIMENSIONS";D
12 POKE 31,D
13 INPUT" ENTER THE NUMBER OF PIECES";P
14 POKE 27,P
15 INPUT"NUMBER OF SQUARES PER PIECE";S
16 POKE 25,S
17 PRINT"ENTER DIMENSIONS OF THE BOX":INPUT"WX";WX:INPUT"WY";WY
18 WZ=-1:IF D=3 THEN INPUT"WZ";WZ
19 WX=WX+2:WY=WY+2:WZ=WZ+2:POKE 28,WX:POKE 29,WY:POKE 30,WZ
20 REM ASSIGN VALUES TO A0,R0,B0,C1,C2,E0 AGGREEING WITH
   ASSEMBLY PROGRAM
21 A0=6300:R0=6580:B0=6600:C1=6200:C2=6220:E0=6240
30 REM A$ HOLDS EACH SOLUTION FOR PRINTOUT
40 REM ARRAYS R AND B ARE PRODUCED BY TAB. GEN. PROGRAM AND
   LOADED FROM TAPE
50 POKE 26,S-1:POKE 32,P-1
60 Q=8:IF D=3 THEN Q=24
70 POKE 33,Q:SPACE=Q*P*(S-1):I=INT(SPACE/256):J=SPACE-256*I
   :POKE 36,J:POKE 37,I
80 INDEX=B0-1-(S-1)*(Q+1):I=INT(INDEX/256):J=INDEX-256*I
   :POKE 38,J:POKE 39,I
90 FOR I=A0 TO A0+WX*WY*WZ-1:POKE I,0:NEXT I
100 FOR I=C2 TO C2+P:POKE I,0:NEXT I
110 REM PLACE BOUNDARY OF (-1)'S AROUND BOX
120 J=(WX-1)*WY*WZ:K=(WY-1)*WZ:M=WY*WZ
130 FOR I=A0 TO A0+M-1:POKE I,255:POKE I+J,255:NEXT I
    :FOR L=1 TO WZ
140 FOR I=A0+M+L-1 TO A0+J+L-M-1 STEP M:POKE I,255:POKE I+K,255
    :NEXT I:NEXT L
150 IF D=3 THEN FOR I=A0+M+WZ TO A0+J-2*WZ STEP WZ:POKE I,255
160 POKE I+WZ-1,255:NEXT I
170 PRINT"ENTER COORDINATES OF OFF=LIMITS SQUARES."
    :PRINT"WHEN DONE ENTER 999 FOR X"
180 INPUT" X";X:IF X=999 GOTO 210
190 INPUT" Y";Y:Z=0:IF D=3 THEN INPUT" Z";Z
200 POKE A0+WZ*(WY*X+Y)+Z,255:PRINT:GOTO 180
210 PRINT:PRINT"ENTER INITIAL PERMUTATION OF PIECES":PRINT
220 FOR I=1 TO P:INPUT X:POKE C1+I,X:NEXT I
230 INPUT"ENTER NUMBER OF PIECES FIXED";Z
240 POKE 15,Z:POKE 0,Z+1:POKE 14,Z+1:IF Z=0 GOTO 300
250 REM PUT IN FIXED PIECES, IF ANY
260 FOR I=1 TO Z:PRINT:PRINT"ENTER COORDS. OF EACH SQUARE OF
     PIECE";PEEK(C1+I)
270 FOR J=1 TO S:PRINT"SQUARE";J:INPUT"  X";X:INPUT"  Y";Y:Z=0
    :IF D=3 THEN INPUT"  Z";Z
280 PE=PEEK(C1+I):POKE A0+WZ*(WY*X+Y)+Z,PE:NEXT J:NEXT I
290 REM INITIALIZE BASE SQUARE
300 FOR I=1 TO WX*WY*WZ-1:IF PEEK(A0+I)=0 THEN POKE 11,I
    :GOTO 320
310 NEXT I
320 POKE 18,1
330 SYS(5120)
999 C=0
1000 REM PRINT A SOLUTION
1010 IF PEEK(18)=0 THEN PRINT:PRINT"  DONE !!!!!":END
1020 C=C+1:PRINT:PRINT"SOLUTION #";C:PRINT
1030 Z=0:A$="":FOR Y=WY-2 TO 1 STEP -1
     :IF D=3 THEN FOR Z=1 TO WZ-2
1040 FOR X=1 TO WX-2:A=PEEK(A0+WZ*(WY*X+Y)+Z
1050 IF X=1 AND Z<>0 AND Z<>WZ-2 THEN A$=A$+" "
1060 IF A=0 THEN A$=A$+"0":GOTO 1090
1070 IF A=255 THEN A$=A$+"blackout":GOTO 1090
1080 A$=A$+MID$(B$,A,1)
1090 NEXT X:IF D=3 THEN NEXT Z
1100 NEXT Y
1110 U=WX-2:IF D=3 THEN U=(WX-1)*(WZ-2)+1
1120 FOR I=1 TO WY-2:PRINT MID$(A$,U*(I-1)+1,U):NEXT I
1130 REM TYPING "S" WILL CAUSE EXECUTION TO STOP ON NEXT RETURN
     TO BASIC
1140 GET YG$:IF YG$="S" THEN PRINT:PRINT"  STOP":END
1150 SYS(5759)
1160 GOTO 1010
```

use (P) with parentheses to denote the contents of memory location P, etc.

Other symbolic addresses appearing in the program include:

N: address containing 1 plus the number of pieces currently in the box,
Z: address containing the number of pieces specified as fixed by the user,
T: address containing the maximum number of pieces fitted into the box during the current permutation,
WX, WY, WZ: addresses containing the width of the box in the X, Y, and Z directions respectively (including the boundaries of −1s). For two-dimensional problems, WZ is set equal to 1,
C1: first address of an array containing the piece numbers in the order given by the current permutation, (P) is the length of this array,
C2: first address of an array containing the orientation numbers of the pieces in the order corresponding to that in the table beginning at C1, (P) is length,
R0: first address of an array, the N-th element of which is the number of possible orientations of piece number N. This table is automatically generated by the BASIC program which generates the orientation table B, (P) is length,
E0: first address of an array, the N-th element of which gives the position of the base square of piece number N, (P) is length.

The user should choose absolute addresses for the arrays so that they do not overlap; note that the array at B0 is particularly long. Since the arrays at R0 and B0 are both generated by the BASIC orientation-table routine, it simplifies matters if R0 is about 30 bytes in front of B0 so that the two arrays can be recorded on tape as a single file.

Although the assembly language part of the program (listing 3) is completely symbolic and therefore relocatable, the BASIC driver routine in listing 2, which contains the initialization and printout routines, must refer to the *absolute* addresses of some of the variables. Table 2 is a list of the absolute hexadecimal addresses used in running the program on a Commodore Pet with 8 K bytes of memory. In relocating the program, the user should be careful to make the addresses referred to by the two routines consistent. Listing 4 (see

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Table 2: *Absolute hexadecimal addresses used in running the Soma Cube — Polyominoes program on an 8 K byte Commodore Pet. This table includes the addresses of all symbolic variables used in listing 3.*

Variable or Location Name	Location (Hexadecimal)	Variable or Location Name	Location (Hexadecimal)
N	0	REMOVE	14CD
I	1	SAVE	14ED
K	2	LOOP3	1508
J	A	JUMP1	1524
L	B	ISOSQ	1527
U	D	LOOP4	1547
T	E	LEAVE	159C
Z	F	JUMP2	15A8
SAFE	10	REPEAT	15AB
V	11	PERMUTE	15C2
FLAG	12	ILOOP	15CC
BXLO	13	JLOOP	15D7
BXHI	24	MAX	15F4
BYLO	25	SWITCH	1612
BYHI	26	ZEROC2	162B
BZLO	27	ORDER	1643
BZHI	28	NEXTJ	164A
S	29	NEXTU	1651
SM1	2A	NOSWTCH	166C
P	2B	LSTPCE	167F
WX	2C	TAKEOUT	168F
WY	2D	LOOKUP	16BC
WZ	3E	TOP	16CD
D	3F	MULT1	16D7
PM1	20	STEP1	16DE
Q	21	STORE1	16E5
OLDK	22	MULT2	16EB
OLDI	23	STORE2	16F8
SPACELO	24	MIDDLE	1721
SPACEHI	25	MULT3	1729
INDEXLO	26	STEP3	1730
INDEXHI	27	ADD	1737
TEMP	28	DIM3	174F
START	1400	MULT4	1753
LOOP1	1413	STEP4	175A
TEST	1428	END	1761
INSERT	1437	C1	1838
LOOP2	143B	C2	184C
NXTBASE	146D	E0	1860
INCX	146F	A0	189C
ISOTEST	148C	R0	19B4
REPLACE	14B4	B0	19C8
JSTART	14C8		

Listing 3: *Symbolic 6502 assembly code listing for Soma Cube — Polyominoes program. The nonrelative variables addressed are given in table 2. Listing 4 is a hexadecimal dump of the program for people who do not have an assembler available.*

```
START:  LDX N
        INC C2,X    ;increment orientation counter
        LDA C2,X
        STA I       ;(I)=orientation number
        LDA C1,X
        STA K       ;(K)=piece number
        LDY #1
        STY J
LOOP1:  JSR LOOKUP  ;check if orientation (I) of
        LDA A0,X     piece (K) will fit into box
        BNE TEST    ;if no, check for other orientations
        INC J
        LDA SM1
        CMP J
        BCS LOOP1
        JMP INSERT  ;if yes, insert it
 TEST:  LDX K       ;check if piece (K) has any
        LDA I        more orientations
        CMP R0,X
        BCC START   ;if yes, go check them out
        JMP REMOVE  ;if no, remove previous piece
INSERT: LDY #1
        STY J
```

Listing 3 continued on page 42

page 52) is a hexadecimal object code dump of the main assembler routine of listing 3.

Using the Program

The assembly language program (listing 3), the BASIC driver routine (listing 2), and the table-generating routine (listing 1) should each be recorded on tape in separate files.

Once a specific problem has been chosen, the table-generating program should be loaded and run. As input, this program requires the number of dimensions (D), the number of pieces (P), the number of squares or cubes per piece (S), and the array addresses R0 and B0, defined above. The computer then asks for the X and Y (and Z if (D)=3) coordinates of each square of each piece. When entering these, the chosen location of the origin of coordinates is not important. For instance, the second tromino in figure 1 could be entered in either of these two ways:

(X,Y)=(1,0)		(X,Y)=(4,2)
(0,0)	or:	(3,2)
(0,1)		(3,3)

After the data for each piece has been entered, the computer pauses, prints out the total number of different orientations of that piece, and then asks for the data on the next piece. After all of the pieces have been entered, the program asks if any were entered incorrectly, and gives the user an opportunity to go back and correct any mistakes. Once the program stops, the arrays beginning at R0 and B0 should be recorded on tape. They can be recorded as one file if R0 and B0 were chosen close together as suggested.

There is one slight difficulty. In running the Soma Cube, the program will ask for the positions of four cubes for each of the seven pieces, even though one piece, the second, is made up of only three cubes. This problem can be sidestepped by simply entering one of the cubes of this piece twice. A slight redundancy during running will result, but the increased generality in the problems that can be run will more than compensate.

Once the orientation table has been generated and saved, the assembly language module and the BASIC driver routine should be loaded into memory along with the table. In the

Text continued on page 48

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Listing 3 continued:

```
LOOP2:  JSR LOOKUP  ;insert piece (K) by putting the
        LDA K        number (K) into the appropriate
        STA A0,X     squares of the box
        INC J
        LDA SM1
        CMP J
        BCS LOOP2
        LDX L
        LDA K
        STA A0,X
        TAX
        LDA L
        STA E0,X    ;save base square of piece (K)
        LDA P       ;if all of the pieces are in the box,
        CMP N        return to BASIC to print solution
        BNE NXTBASE ;otherwise, find next base square
        RTS
NXTBASE: LDX L      ;scan for next base square
   INCX: INX
        LDA A0,X
        BEQ ISOTEST
        JMP INCX
ISOTEST: STX J      ;put new base square in location J
        LDA D
        CMP #3
        BEQ REPLACE ;if (D)=3, skip isolated square test
        TXA         ;test if new base square is isolated
        CLC
        ADC #1
        TAX
        LDA A0,X
        BEQ REPLACE
        TXA
        CLC
        ADC WY
        TAX
        DEX
        LDA A0,X
        BEQ REPLACE ;if it is not, go to REPLACE
        JMP ISOSQ   ;if it is, go to isolated square routine
REPLACE: LDA J
        STA L       ;set new base square
        INC N       ;increment piece counter
        LDA T       ;(T)=greatest number of pieces
        CMP N        successfully fitted into box in
        BCS JSTART   current permutation
        LDA N
        STA T
 JSTART: JMP START  ;return to START
 REMOVE: LDX N      ;remove last piece inserted
        LDA #0
        STA C2,X    ;set orientation number to zero
        DEX         ;decrement piece counter
        STX N
        LDA C1,X
        STA K
        LDA C2,X
        STA I
        LDA Z       ;check if new piece is fixed
        CMP N
        BCC SAVE    ;if no, take it out
        JMP PERMUTE ;if yes, go to next permutation of pieces
   SAVE: LDY K      ;recover base square of the
        LDX E0,Y     piece to be taken out
        STX L
        LDA #0
        STA A0,X
        LDY #1
        STY J
  LOOP3: JSR LOOKUP ;take out piece by putting zeroes
        LDA #0       in each square it occupies
        STA A0,X
        INC J
        LDA SM1
        CMP J
        BCS LOOP3
        LDX K       ;check if piece has any more orientations
        LDA I
```

```
         CMP RO,X
         BCS JUMP1     ;if no, remove a further piece
         JMP START     ;if yes, go check them out
JUMP1:   JMP REMOVE
ISOSQ:   LDY K         ;recover base square of piece to be taken
         LDX EO,Y       out to cure isolation of new base square
         STX L
         LDA #0
         STA AO,X
         LDA J
         STA SAFE      ;store base square in safe place
         LDY #1
         STY J
LOOP4:   JSR LOOKUP    ;remove last piece inserted
         LDA #0
         STA AO,X
         INC J
         LDA SM1
         CMP J
         BCS LOOP4
         LDA SAFE      ;recover base square
         STA J
         CLC           ;test if it is still isolated by checking
         ADC #1         if each of the four squares around it is
         TAX            filled
         LDA AO,X
         BEQ LEAVE
         DEX
         DEX
         LDA AO,X
         BEQ LEAVE
         TXA
         SEC
         SBC WY
         TAX
         INX
         LDA AO,X
         BEQ LEAVE
         TXA
         CLC
         ADC WY
         ADC WY
         TAX
         LDA AO,X      ;if it is not still isolated,
         BEQ LEAVE      prepare to return to normal routine
         JMP REPEAT    ;if it is, repeat isolated square routine
LEAVE:   LDX K         ;check if piece (K) has any
         LDA I          more orientations
         CMP RO,X
         BCS JUMP2     ;if no, remove previous piece
         JMP START     ;if yes, go check them out
JUMP2:   JMP REMOVE
REPEAT:  LDX N
         LDA #0
         STA C2,X      ;set orientation number to zero
         DEX           ;decrement piece counter
         STX N
         LDA C1,X      ;set new values of (K) and (I)
         STA K
         LDA C2,X
         STA I
         JMP ISOSQ     ;repeat isolated square routine
PERMUTB: LDA T         ;find new permutation, making sure that
         STA I          the repermutation goes at least as far
         CMP P          back as the (T)-th piece of the old
         BNE ILOOP      permutation
         DEC I
ILOOP:   LDA #127      ;the nested I and J loops pick two elements
         STA U          of the permutation to be interchanged.
         LDA I          These are: the last element of the
         CLC            permutation which has a larger element
         ADC #1         following it, and the smallest element
         STA J          following this element which is greater
JLOOP:   LDX I          than it
         LDY J
         LDA C1,Y
         CMP C1,X
         BCC MAX
```

Listing 3 continued on page 46

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Listing 3 continued:

```
          LDA U
          CMP C1,Y
          BCC MAX
          STY V
          LDA C1,Y
          STA U
MAX:      INC J
          LDA P
          CMP J
          BCS JLOOP
          LDA U
          CMP #127
          BNE SWITCH
          DEC I
          LDA Z
          CMP I
          BCC ILOOP
          LDA #0          ;if such elements cannot be found, clear
          STA FLAG         FLAG and return to BASIC to stop
          RTS
SWITCH:   INC N           ;interchange elements found by
          LDA N            I and J loops
          STA T
          LDX I
          LDA C1,X
          LDY V
          STA C1,Y
          LDA U
          STA C1,X
          LDA N
          STA J
ZEROC2:   LDA #0          ;reinitialize orientation numbers
          LDX J
          STA C2,X
          INC J
          LDA P
          CMP J
          BCS ZEROC2
          LDA PM1         ;if repermutation only interchanged last
          CMP I            two pieces, return to START
          BNE ORDER
          JMP START
ORDER:    LDA I           ;otherwise, reorder new permutation
          CLC              into ascending order
          ADC #1
          STA J
NEXTJ:    LDA J
          CLC
          ADC #1
          STA U
NEXTU:    LDX J
          LDY U
          LDA C1,X
          CMP C1,Y
          BCC NOSWTCH
          STA V
          LDA C1,Y
          STA C1,X
          LDA V
          STA C1,Y
NOSWTCH:  INC U
          LDA P
          CMP U
          BCS NEXTU
          INC J
          LDA PM1
          CMP J
          BCS NEXTJ
          JMP START       ;return to START
LSTPCE:   LDX K           ;BASIC returns control to here after
          LDA E0,X         printing a solution so that the (P)-th
          STA L            piece can be taken out
          LDA #1
          STA J
TAKEOUT:  JSR LOOKUP
          LDA #0
          STA A0,X
          INC J
```

Listing 3 continued on page 48

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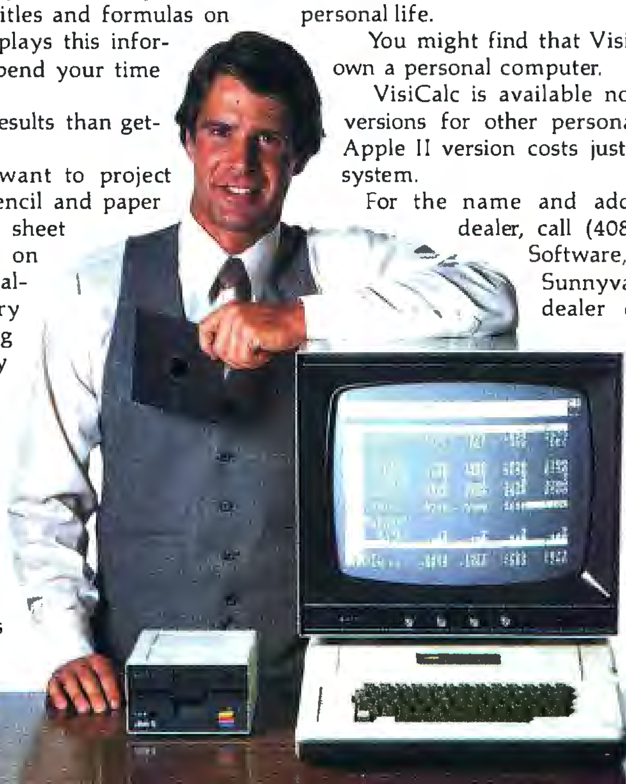

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Listing 3 continued:

```
          LDA SM1
          CMP J
          BCS TAKEOUT
          LDX L
          LDA #0
          STA A0,X
          JMP REMOVE
LOOKUP:   LDY J          ;put square number in Y register
          LDA I          ;if (I) and (K) are the same as in the
          CMP OLDI        previous call to LOOKUP, go to MIDDLE,
          BNE TOP         otherwise to TOP
          LDA K
          CMP OLDK
          BNE TOP
          JMP MIDDLE
TOP:      LDA Q
          STA BXLO
          LDA #0
          STA BXHI
          LDX #8
MULT1:    ASL BXLO       ;one byte multiplication
          BCC STEP1       routine figures (Q)*(K)
          CLC
          ADC K
STEP1:    DEX
          BEQ STORE1
          ASL A
          JMP MULT1
STORE1:   ADC I          ;add (I) to it
          STA BXLO       ;store result in BXLO
          LDX SM1
MULT2:    DEX            ;multiply this by (S)-1 and store the
          BEQ STORE2      two-byte result in BXLO and BXHI
          ADC BXLO
          BCC MULT2
          INC BXHI
          CLC
          JMP MULT2
STORE2:   ADC INDEXLO ;add the two-byte quantity (INDEX) to (BX)
          STA BXLO
          LDA BXHI
          ADC INDEXHI
          STA BXHI
          LDA SPACELO ;add the two-byte quantity (SPACE) to (BX)
          ADC BXLO       to get (BY)
          STA BYLO
          LDA SPACEHI
          ADC BXHI
          STA BYHI
          LDA D          ;if (D)≠3, go to MIDDLE
          CMP #3
          BNE MIDDLE
          CLC
          LDA SPACELO ;add the two-byte quantity (SPACE) to (BY)
          ADC BYLO       to get (BZ)
          STA BZLO
          LDA SPACEHI
          ADC BYHI
          STA BZHI
MIDDLE:   LDA (BXLO),Y   ;load X coordinate of square
          STA TEMP
          LDA #0
          LDX #8
MULT3:    ASL TEMP       ;multiply it by (WY)
          BCC STEP3
          CLC
          ADC WY
STEP3:    DEX
          BEQ ADD
          ASL A
          JMP MULT3
ADD:      CLC
          ADC (BYLO),Y   ;add Y coordinate of square
          STA TEMP       ;store result in TEMP
          LDX D          ;if (D)=3, go to DIM3
          CPX #3
          BEQ DIM3
          CLC
```

Listing 3 continued on page 50

Text continued:

case of the Commodore PET, the BASIC driver should be loaded last. Before it is loaded, the page number on which the assembly routine starts should be placed into location 135 decimal, using the POKE statement. This insures that the arrays defined by BASIC will not interfere with the assembly routine or the table.

Before running, the user should check lines 3 and 21 of the BASIC driver routine, to determine whether or not they are correct for the problem under consideration. When run, the driver routine asks the user for input with prompts that are fairly self-explanatory. However, a few specific hints may be helpful.

Although the program will work no matter how the box is oriented, it will run fastest if the dimensions WX, WY, and WZ are chosen to be in descending order (ie: WX>WY>WZ), due to the mechanics of the search procedure. Failure to do this may lengthen the running time by a factor of ten or more.

When entering the off-limits squares, and also the coordinates of any fixed squares, the coordinates are defined for polyominoes so that the lower left-hand corner of the box (excluding boundary) has the coordinates (1,1); and for Soma Cubes the corner with the lowest coordinate values has coordinates (1,1,1).

In entering the initial permutation of pieces, the order in which the machine goes through the permutations should be kept in mind. Thus, entering the piece numbers in ascending order: 1,2,3,. . . .,P will result in an exhaustive search, whereas any other initial permutation will cause only a subset of the complete set of permutations to be considered.

Any pieces which are to be specified as fixed should be put at the beginning of the initial permutation. For example, to find all of the solutions with pieces 2 and 4 fixed in particular locations, the initial permutation array should have 2 and 4 at the beginning, and the rest of the numbers in ascending order, (ie: 2, 4, 1, 3, 5, 6, 7, . . ., P). The number of fixed pieces should then be entered as two, after which the computer will ask for the coordinates of each square of pieces 2 and 4.

The program does not check to see if the coordinates entered by the user for a fixed piece correspond to a legal

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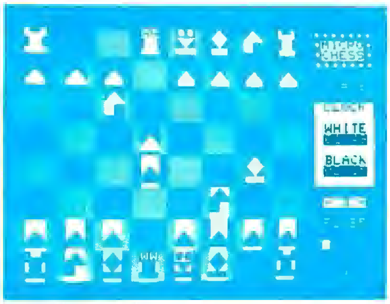

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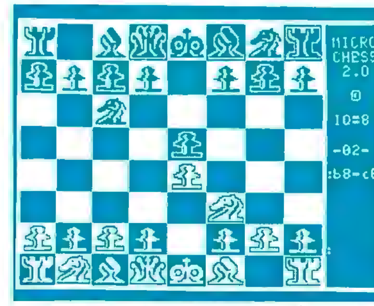

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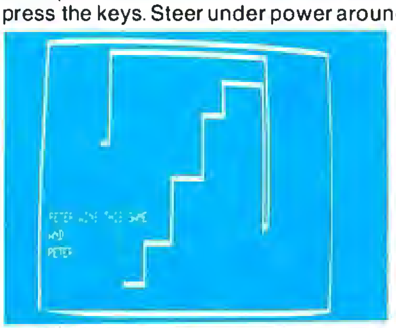

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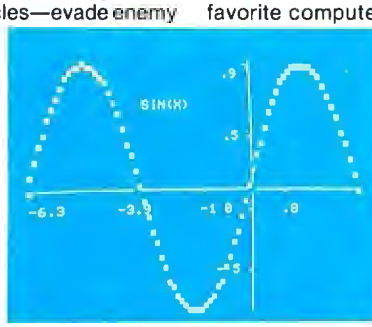

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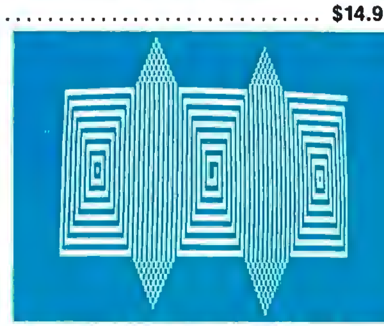

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Circle 302 on inquiry card.

Listing 3 continued:

```
        ADC L       ;otherwise, add base square index
        TAX         ;transfer result to X register
        LDA K       ;store old (K) and (I) values
        STA OLDK
        LDA I
        STA OLDI
        RTS         ;return to main routine
 DIM3:  LDA #0
        LDX #8
MULT4:  ASL TEMP    ;multiply (TEMP) by (WZ)
        BCC STEP4
        CLC
        ADC WZ
STEP4:  DEX
        BEQ END
        ASL A
        JMP MULT4
  END:  ADC L           ;add base square index
        ADC (BZLO),Y    ;add Z coordinate of square
        TAX             ;transfer result to X register
        LDA K           ;store old (K) and (I) values
        STA OLDK
        LDA I
        STA OLDI
        RTS             ;return to main routine
```

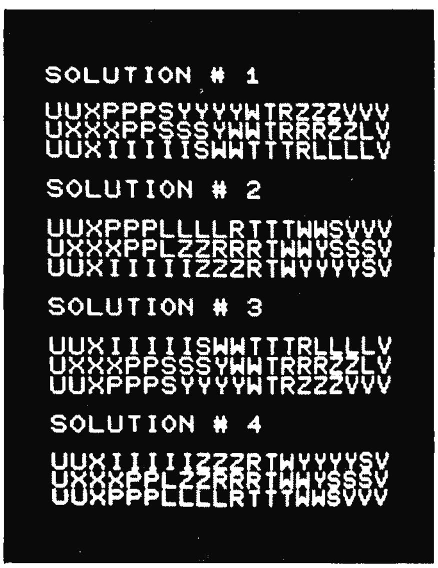

Photo 3: *All of the solutions for Pentominoes in a 20 by 3 box. Solutions three and four are mirror images of solutions one and two, so there are only two fundamentally different solutions.*

orientation of that piece, so care should be taken to insure that all of these numbers are entered correctly.

To stop the program in mid-run, the S key may be pressed at any time. This will cause execution to stop on the next return to the BASIC printout routine.

Photo 3 is a typical output of the Soma Cube — Polyominoes problem solver. The solutions are for Pentominoes in a 20 by 3 box.

Conclusion

As general as this program is, it by no means exhausts the possibilities inherent in problems such as these.

In addition to squares, it is possible to tile the plane with other figures such as triangles and hexagons. It should not be hard to modify the program to consider figures made out of these shapes. At a more abstract level, since the assembly language routine depends so little on the dimensionality of the pieces under consideration, the user could extend it to consider analogous problems in four or more spatial dimensions. Hard as these might be to visualize, the computations involved are not fundamentally different from those encountered in two and three-dimensional problems.

Another possibility is to assign colors to the various pieces and look for interesting properties of the resulting solutions. For example, the plastic Pentomino puzzle which provided the inspiration for this article had the following piece colors:

X,P,Y	:	Red
I,T	:	Yellow
V,U,S,	:	Blue
W,R,Z,L	:	Green

There is one and *only* one 10 by 6 solution using this set which is a true four-coloring (ie: a solution in which no two pieces of the same color touch each other). Can you find it?

These are only suggestions. The capabilities of the program and the uses to which it can be put depend ultimately on the interests and ingenuity of the user.

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Listing 4: *Hexadecimal object code dump for the Soma Cube — Polyominoes program given in listing 3.*

```
 HEX DUMP OF

    **************************
    * SOMA/POLYOMINO SOLVER *
    **************************

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    ***************
    * CHEEP PRINT *
    ***************

               0  1  2  3  4  5  6  7
.:   1400 A6 00 BE 4C 18 BD 4C 18
.:   1408 85 01 BD 38 18 85 02 A0
.:   1410 01 84 0A 20 BC 16 BD 9C
.:   1418 18 D0 0D E6 0A A5 1A C5
.:   1420 0A B0 F0 4C 37 14 EA EA
.:   1428 A6 02 A5 01 DD B4 19 90
.:   1430 CF 4C CD 14 EA EA EA A0
.:   1438 01 84 0A 20 BC 16 A5 02
.:   1440 9D 9C 18 E6 0A A5 1A C5
.:   1448 0A B0 F0 A6 0B EA EA EA
.:   1450 EA EA EA A5 02 9D 9C 18
.:   1458 A6 02 A5 0B 9D 60 18 EA
.:   1460 EA EA EA EA A5 1B C5 00
.:   1468 D0 03 60 EA EA A6 0B E8
.:   1470 BD 9C 18 F0 17 4C 6F 14
.:   1478 EA EA EA EA EA EA EA EA
.:   1480 EA EA EA EA EA EA EA EA
.:   1488 EA EA EA EA 86 0A A5 1F
.:   1490 C9 03 F0 20 8A EA EA EA
.:   1498 EA EA EA 18 69 01 AA BD
.:   14A0 9C 18 F0 10 EA EA 8A 18
.:   14A8 65 10 AA CA BD 9C 18 F0
.:   14B0 03 4C 27 15 A5 0A 85 0B
.:   14B8 EA EA EA EA E6 00 A5 0E
.:   14C0 C5 00 B0 04 A5 00 85 0E
.:   14C8 4C 00 14 EA EA A6 00 A9
.:   14D0 00 9D 4C 18 CA 86 00 BD
.:   14D8 38 18 85 02 BD 4C 18 85
.:   14E0 01 A5 0F EA EA EA C5 00
.:   14E8 90 03 4C C2 15 A4 02 EA
.:   14F0 EA EA EA EA BE 60 18 86
.:   14F8 0B EA EA EA EA EA EA A9
.:   1500 00 9D 9C 18 A0 01 84 0A
.:   1508 20 BC 16 A9 00 9D 9C 18
.:   1510 E6 0A A5 1A C5 0A B0 F0
.:   1518 A6 02 A5 01 DD B4 19 B0
.:   1520 03 4C 00 14 4C CD 14 A4
.:   1528 02 EA EA EA EA EA BE 60
.:   1530 18 86 0B EA EA EA EA EA
.:   1538 EA A9 00 9D 9C 18 EA A5
.:   1540 0A 85 10 A0 01 84 0A 20
.:   1548 BC 16 A9 00 9D 9C 18 E6
.:   1550 0A A5 1A C5 0A B0 F0 A5
.:   1558 10 85 0A EA EA EA EA EA
.:   1560 18 69 01 EA EA AA BD 9C
.:   1568 18 F0 31 CA CA EA EA EA
.:   1570 EA EA EA EA EA EA EA EA
.:   1578 EA EA EA EA EA BD 9C 18
.:   1580 F0 1A 8A 38 E5 1D AA E8
.:   1588 BD 9C 18 F0 0F 8A 18 65
.:   1590 1D 65 1D AA BD 9C 18 F0
.:   1598 03 4C AB 15 A6 02 A5 01
.:   15A0 DD B4 19 B0 03 4C 00 14
.:   15A8 4C CD 14 A6 00 A9 00 9D
.:   15B0 4C 18 CA 86 00 BD 38 18
.:   15B8 85 02 BD 4C 18 85 01 4C
.:   15C0 27 15 A5 0E 85 01 C5 1B
.:   15C8 D0 02 C6 01 A9 7F 85 0D
.:   15D0 A5 01 18 69 01 85 0A A6
.:   15D8 01 A4 0A B9 38 18 DD 38
.:   15E0 18 90 11 A5 0D D9 38 18
.:   15E8 90 0A 84 11 B9 38 18 85
.:   15F0 0D EA EA EA E6 0A A5 1B
.:   15F8 C5 0A B0 DB A5 0D C9 7F
.:   1600 D0 10 C6 01 A5 0F EA EA
.:   1608 EA C5 01 D0 BF A9 00 85
.:   1610 12 60 E6 00 A5 00 85 0E
.:   1618 A6 01 BD 38 18 A4 11 99
.:   1620 38 18 A5 0D 9D 38 18 A5
.:   1628 00 85 0A A9 00 A6 0A 9D
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.:   1638 B0 F1 A5 20 C5 01 D0 03
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.:   1648 85 0A A5 0A 18 69 01 85
.:   1650 0D A6 0A A4 0D BD 38 18
.:   1658 D9 38 18 90 0F 85 11 B9
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.:   1668 38 18 EA EA E6 0D A5 1B
.:   1670 C5 0D B0 DD E6 0A A5 20
.:   1678 C5 0A B0 CE 4C 00 14 A6
.:   1680 02 BD 60 18 85 0B EA EA
.:   1688 EA EA EA A9 01 85 0A 20
.:   1690 BC 16 A9 00 9D 9C 18 E6
.:   1698 0A A5 1A C5 0A B0 F0 A6
.:   16A0 0B EA EA EA EA EA EA A9
.:   16A8 00 9D 9C 18 4C CD 14 EA
.:   16B0 EA EA EA EA EA EA EA EA
.:   16B8 EA EA EA EA A4 0A A5 01
.:   16C0 C5 23 D0 09 A5 02 C5 22
.:   16C8 D0 03 4C 21 17 A5 21 85
.:   16D0 13 A9 00 85 14 A2 08 06
.:   16D8 13 90 03 18 65 02 CA F0
.:   16E0 04 0A 4C D7 16 65 01 85
.:   16E8 13 A6 1A CA F0 0A 65 13
.:   16F0 90 F9 E6 14 18 4C EB 16
.:   16F8 65 26 85 13 A5 14 65 27
.:   1700 85 14 A5 24 65 13 85 15
.:   1708 A5 25 65 14 85 16 A5 1F
.:   1710 C9 03 D0 0D 18 A5 24 65
.:   1718 15 85 17 A5 25 65 16 85
.:   1720 18 B1 13 85 28 A9 00 A2
.:   1728 08 06 28 90 03 18 65 1D
.:   1730 CA F0 04 0A 4C 29 17 18
.:   1738 71 15 85 28 A6 1F E0 03
.:   1740 F0 0D 18 65 0B AA A5 02
.:   1748 85 22 A5 01 85 23 60 A9
.:   1750 00 A2 08 06 28 90 03 18
.:   1758 65 1E CA F0 04 0A 4C 53
.:   1760 17 65 0B 71 17 AA A5 02
.:   1768 85 22 A5 01 85 23 60 20
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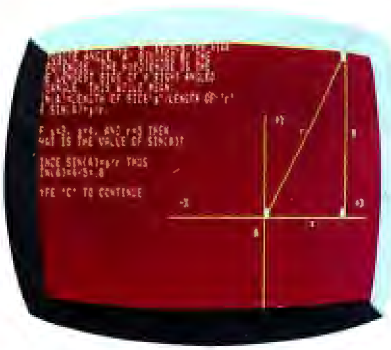

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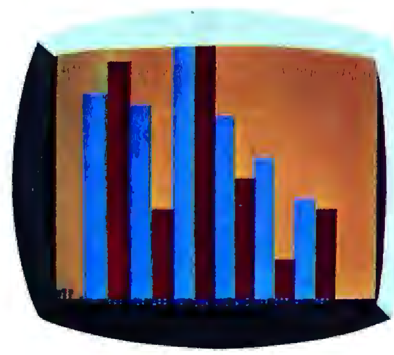

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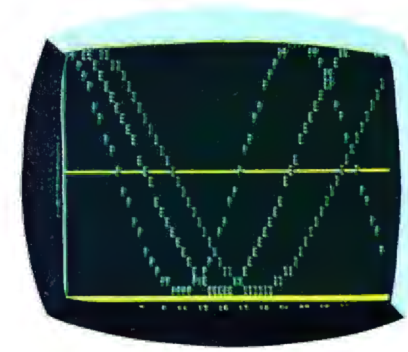

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BASIC Game: GOBANG

John Allwork, 21 Brook Rd, Heaton Chapel,
Stockport, ENGLAND

GOBANG is, as far as I can tell, a traditional game of the Orient. It is a large game of tic-tac-toe (noughts and crosses), played on a 19 by 19 inch board. The object of the game is to get 5 adjacent markers in a row horizontally, vertically or diagonally.

The program in listing 1 is written in BASIC; the only deviation from standard BASIC being that of the IF...THEN IF... rather than the less flexible IF...GOTO. The BASIC I used is a version of the MicroBASIC supplied by SwTPC, and the program was run on an EXORciser system. The program and BASIC interpreter fit into 8 K bytes of memory, if the remark statements are omitted. Alternatively, the size of arrays T and M can be reduced, but reducing them too much inhibits the game. A 9 by 9 board appears to be the smallest size possible for a reasonable game. (Listing 2 shows a sample output of the 19 by 19 board.)

Listing 1: *BASIC listing of the GOBANG game.*

```
0001  REM      GOBANG
0002  REM      M IS ARRAY HOLDING BEST MOVE
0003  REM      T IS BOARD, S IS PRIORITY OF THAT POSITION
0004  DIM      M[19,19],T[27,27],S[81]
0005  REM      SET UP PRIORITIES—SEE TABLE 1
0006  FOR      I=1 TO 81
0010        LET S[I]=0
0015  NEXT I
0019  LET      S[20]=1
0020  LET      S[10]=40
0021  LET      S[12]=30
0022  LET      S[13]=47
0023  LET      S[27]=15
0024  LET      S[28]=20
0025  LET      S[29]=10
0026  LET      S[30]=40
0027  LET      S[31]=50
0028  LET      S[32]=30
0029  LET      S[24]=1
0030  LET      S[36]=39
0031  LET      S[37]=65
0032  LET      S[38]=40
0033  LET      S[39]=70
0034  LET      S[40]=100
0035  LET      S[41]=60
0036  LET      S[42]=30
0037  LET      S[43]=30
0038  LET      S[44]=30
0040  LET      S[62]=41
0041  LET      S[72]=31
0042  LET      S[73]=11
0043  LET      S[74]=41
0044  LET      S[78]=51
0045  LET      S[80]=90
0046  LET      S[26]=21
0047  LET      S[79]=40
0048  LET      S[60]=21
0049  LET      S[61]=11
0050  REM      CLEAR BOARD AND BEST MOVE ARRAYS
0051  FOR      I=1 TO 27
0055        FOR J=1 TO 27
0060           IF I<19 THEN IF J<19 THEN LET M[I, J]=0
0065           REM MAKE FIRST MOVE
0070        NEXT J
0075  NEXT I
0076  LET      C=-1
0085  LET      W=14
0086  LET      N=14
0087  LET      O=14
0090  LET      X=14
0091  GOTO 0300
0095  GOSUB 0800
0096  REM REQUEST MOVE AND CHECK FOR VALIDITY
0097  INPUT Z,Y
0099  LET      Y=Y+4
0100  LET      Z=Z+4
0101  IF Y>23 THEN GOTO 0097
0102  IF Z>23 THEN GOTO 0097
0103  IF Y<5 THEN GOTO 0097
0104  IF Z<5 THEN GOTO 0097
0106  IF T[Y,Z]>0 THEN GOTO 0097
0110  LET      T[Y,Z]=2
0115  LET      I=Y
0120  LET      J=Z
0125  REM STUDY LAST TWO MOVES
0127  GOSUB 1000
0128  IF C< > -1 THEN GOTO 0310
0129  REM      IF C=0 COMPUTER HAS LOST
0130  LET      I=W
0131  LET      J=X
0141  GOSUB 1000
0145  REM SCAN BOARD FOR BEST MOVE
0150  REM NOTE LIMITS TO SPEED UP PROGRAM
0160  LET      Q=-1
0161  FOR      I=N-1 TO O+1
0162        FOR J = 5 TO 23
0200           IF T[I,J]>0 THEN GOTO 0220
0201           LET A=M[I-4, J-4]
0205           IF A<Q THEN GOTO 0220
0210           LET W=I
0215           LET X=J
0216           LET Q=A
0220        NEXT J
0225  NEXT I
```

Listing 1 continued on page 58

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Listing 1 continued:

```
0299   PRINT "MY MOVE";X-4;",";W-4
0300   LET T[W,X]=1
0301   IF M[W-4,X-4]<100 THEN GOTO 0095
0307   PRINT "I WIN"
0310   IF C=0 THEN PRINT "YOU WIN"
0330   GOTO 0050
0799   REM SUBROUTINE TO DISPLAY BOARD
0800   PRINT "      1 2 3 4 5 6 7 8 910111213141516171819"
0805   FOR I=5 TO 23
0810          IF I-4<10 THEN PRINT I-4;" ";
0811          IF I-4>9 THEN PRINT I-4;
0815          FOR J=5 TO 23
0820             IF [I,J]=0 THEN PRINT " :";
0825             IF T[I,J]=1 THEN PRINT " X";
0830             IF T[I,J]=2 THEN PRINT " O";
0835          NEXT J
0840          PRINT " "
0845   NEXT I
0850   RETURN
0990   REM SUBROUTINE TO CALCULATE BEST MOVE
0991   REM SCAN THRU MOVE AT I,J
0992   REM FOR FIVE SQUARES EITHER SIDE OF MOVE
0993   REM IN EIGHT DIRECTIONS,
       AND UPDATE BEST MOVE ARRAY
1000   LET       K=1
1001   LET       L=-1
1002   IF I<N THEN IF I>5 THEN LET N=I
1003   IF I>O THEN IF I<23 THEN LET O=I
1004   REM UPDATE SCAN LIMITS
1005   LET       U=I
1006   LET       V=J
1007   REM I,J IS MOVE TO CHECK,D IS LOOP COUNT
1008   REM K,L ARE X AND Y DIRECTIONS THRU MOVE
1010   LET D=0
1011   LET D=D+1
1013   LET P=81
1020   REM CHECK STILL ON BOARD
1026   IF U>23 THEN GOTO 1090
1027   IF V>23 THEN GOTO 1090
1028   IF U<5 THEN GOTO 1090
1029   IF V<5 THEN GOTO 1090
1030   LET E=U-4
1031   LET G=V-4
1032   LET A=M[E,G]
1033   LET Q=T[U+K,V+L]
1034   REM CALCULATE PRIORITY OF POSITION
1035   LET R=T[U-K,V-L]*27+T[U-2*K, V-2*L]*9
1036   LET R=R+T[U-3*K,V-3*L]*3+T[U-4*K,V-4*L]
1037   LET B=Q*27+T[U+2*K,V+2*L]*9+T[U+3*K,V+3*L]*3
1038   IF R=80 THEN IF T[U,V]=2 THEN LET C=0
1039   IF T[U,V]<>0 THEN GOTO 1075
1040   REM S(R) IS PRIORITY; THE FOLLOWING ARE EXCEPTIONS
1041   REM SEE TABLE 2
1042   IF R<14 THEN IF R>11 THEN IF Q=1 THEN LET P=37
1044   IF R>71 THEN IF B>53 THEN IF B<63 THEN LET P=80
1046   IF R>71 THEN IF B>71 THEN LET P=80
1048   IF R>53 THEN IF R<63 THEN IF Q=2 THEN LET P=72
1050   IF P=72 THEN IF R=60 THEN LET P=31
1052   IF Q<>2 THEN GOTO 1058
1053   IF R=78 THEN LET P=80
1054   IF R=79 THEN LET P=80
1056   IF R=41 THEN LET R=81
1058   IF R<42 THEN IF R>35 THEN IF Q=1 THEN LET P=41
1059   IF R<33 THEN IF R>29 THEN IF Q=1 THEN LET P=41
1060   IF R>53 THEN IF R<63 THEN IF B>71 THEN LET P=80
1061   IF R>38 THEN IF R<42 THEN IF Q=1 THEN LET R=40
1062   IF R>35 THEN IF R<45 THEN IF B>35 THEN
       IF B<45 THEN LET R=40
1063   IF R>27 THEN IF R<54 THEN IF B>38 THEN
       IF B<42 THEN LET R=40
1064   IF R=79 THEN IF A=51 THEN LET M[E,G]=41
1065   IF R=0 THEN LET R=81
1066   IF S[P]>S[R] THEN LET R=P
1067   IF S[R]-S[R]/10*10=1 THEN IF A-A/10*10=1 THEN
       IF S[R]<41 THEN LET R=74
1068   IF S[R]-S[R]/10*10=9 THEN IF A-A/10*10=9 THEN
       IF S[R]<65 THEN LET R=37
1069   REM UPDATE BEST MOVE ARRAY
1070   IF S[R]>M[E,G] THEN LET M[E,G]=S[R]
1075   IF D>4 THEN GOTO 1090
1081   LET U=U+K
1082   LET V=V+L
1085   GOTO 1011
1089   REM CHANGE DIRECTION
1090   IF K=0 THEN IF L=-1 THEN RETURN
1095   IF K=-1 THEN IF L=-1 THEN LET K=0
1100   IF K=-1 THEN IF L=0 THEN LET L=-1
1105   IF K=-1 THEN IF L=1  THEN LET L=0
1110   IF K=0 THEN IF L=1 THEN LET K=-1
1115   IF K=1  THEN IF L=1 THEN LET K=0
1120   IF K=1 THEN IF L=0 THEN LET L=1
1125   IF K=1 THEN IF L=-1 THEN LET L=0
1130   GOTO 1005
```

Listing 2: *Sample output of the 19 by 19 board.*

```
     1 2 3 4 5 6 7 8 910111213141516171819
 1   : : : : : : : : : : : : : : : : : : :
 2   : : : : : : : : : : : : : : : : : : :
 3   : : : : : : : : : : : : : : : : : : :
 4   : : : : : : : : : : : : : : : : : : :
 5   : : : : : : : : : : : : : : : : : : :
 6   : : : : : : : : : : : : : : : : : : :
 7   : : : : : : : : : : : : : : : : : : :
 8   : : : : : : : : : : : : : : : : : : :
 9   : : : : : : : : : : : : : : : : : : :
 10  : : : : : : : : : X : : : : : : : : :
 11  : : : : : : : : : : : : : : : : : : :
 12  : : : : : : : : : : : : : : : : : : :
 13  : : : : : : : : : : : : : : : : : : :
 14  : : : : : : : : : : : : : : : : : : :
 15  : : : : : : : : : : : : : : : : : : :
 16  : : : : : : : : : : : : : : : : : : :
 17  : : : : : : : : : : : : : : : : : : :
 18  : : : : : : : : : : : : : : : : : : :
 19  : : : : : : : : : : : : : : : : : : :
?9,9
MY MOVE 10, 11
     1 2 3 4 5 6 7 8 910111213141516171819
 1   : : : : : : : : : : : : : : : : : : :
 2   : : : : : : : : : : : : : : : : : : :
 3   : : : : : : : : : : : : : : : : : : :
 4   : : : : : : : : : : : : : : : : : : :
 5   : : : : : : : : : : : : : : : : : : :
 6   : : : : : : : : : : : : : : : : : : :
 7   : : : : : : : : : : : : : : : : : : :
 8   : : : : : : : : : : : : : : : : : : :
 9   : : : : : : : : O : : : : : : : : : :
 10  : : : : : : : : : X : : : : : : : : :
 11  : : : : : : : : : X : : : : : : : : :
 12  : : : : : : : : : : : : : : : : : : :
 13  : : : : : : : : : : : : : : : : : : :
 14  : : : : : : : : : : : : : : : : : : :
 15  : : : : : : : : : : : : : : : : : : :
 16  : : : : : : : : : : : : : : : : : : :
 17  : : : : : : : : : : : : : : : : : : :
 18  : : : : : : : : : : : : : : : : : : :
 19  : : : : : : : : : : : : : : : : : : :
?10,9
MY MOVE 11, 9
     1 2 3 4 5 6 7 8 910111213141516171819
 1   : : : : : : : : : : : : : : : : : : :
 2   : : : : : : : : : : : : : : : : : : :
 3   : : : : : : : : : : : : : : : : : : :
 4   : : : : : : : : : : : : : : : : : : :
 5   : : : : : : : : : : : : : : : : : : :
 6   : : : : : : : : : : : : : : : : : : :
 7   : : : : : : : : : : : : : : : : : : :
 8   : : : : : : : : : : : : : : : : : : :
 9   : : : : : : : : O O X : : : : : : : :
 10  : : : : : : : : : X : : : : : : : : :
 11  : : : : : : : : : X : : : : : : : : :
 12  : : : : : : : : : : : : : : : : : : :
 13  : : : : : : : : : : : : : : : : : : :
 14  : : : : : : : : : : : : : : : : : : :
 15  : : : : : : : : : : : : : : : : : : :
 16  : : : : : : : : : : : : : : : : : : :
 17  : : : : : : : : : : : : : : : : : : :
 18  : : : : : : : : : : : : : : : : : : :
 19  : : : : : : : : : : : : : : : : : : :
```

```
?9,10
7,6
MY MOVE 11, 10
     1 2 3 4 5 6 7 8 910111213141516171819
 1   : : : : : : : : : : : : : : : : : : :
 2   : : : : : : : : : : : : : : : : : : :
 3   : : : : : : : : : : : : : : : : : : :
 4   : : : : : : : : : : : O : : : : : : :
 5   : : : : : : : : : : : X : : : : : : :
 6   : : : : : : O : : : : X : : : : : : :
 7   : : : : : : : O X O O X O : : : : : :
 8   : : : : : : : X O O X X : : : : : : :
 9   : : : : : X O O O O X O : : : : : : :
 10  : : : : : : X O O X X : O : : : : : :
 11  : : : : : : X O X X X X O : : : : : :
 12  : : : : : : X O : : : : : : : : : : :
 13  : : : : : : : X : : : : : : : : : : :
 14  : : : : : : : X : : : : : : : : : : :
 15  : : : : : : : : : : : : : : : : : : :
 16  : : : : : : : : : : : : : : : : : : :
 17  : : : : : : : : : : : : : : : : : : :
 18  : : : : : : : : : : : : : : : : : : :
 19  : : : : : : : : : : : : : : : : : : :
?6,5
YOU WIN
```

I hope I have eradicated most of the bugs, but some may still exist (as with all programs); for example, I do not check to see if the board is full, because I have never encountered this situation with a 19 by 19 board.

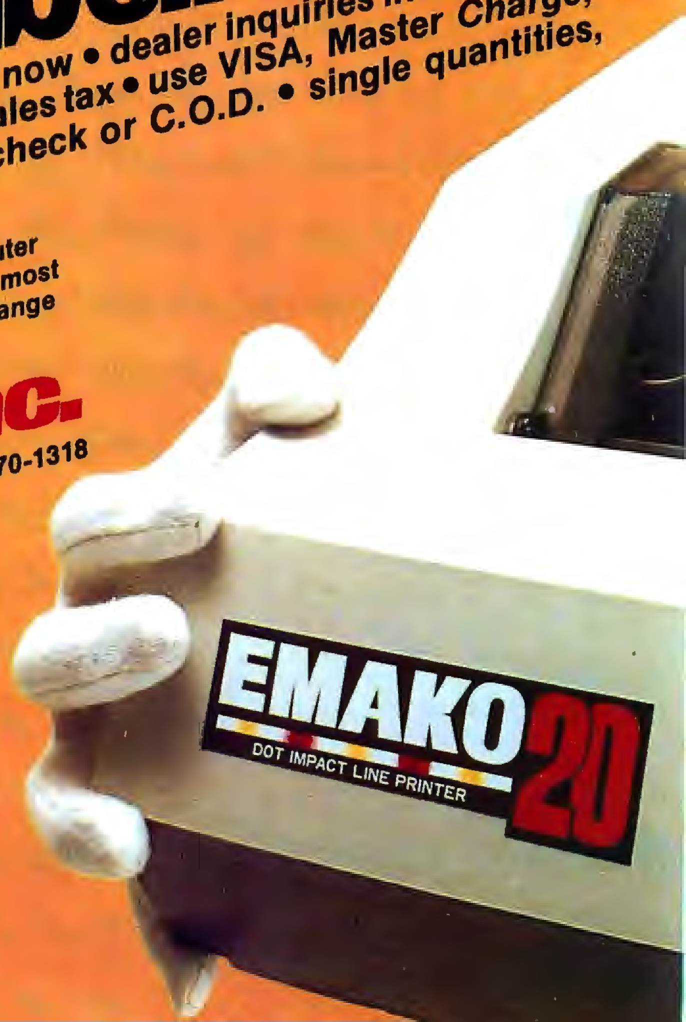

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Table 2: *Some exceptions encountered by the computer that necessitate redefining its strategy.*

LINE NUMBER	PATTERN	PRIORITY
1Ø42	X♦-XX	65
1Ø44	-O♦OO	9Ø
1Ø46	OO♦OO	9Ø
1Ø48	O♦O-	31
1Ø5Ø	O♦O-O-	5Ø
1Ø53	O♦OOO-	9Ø
1Ø54	O♦OOOX	9Ø
1Ø56	O♦XXXO	Ø
1Ø58	X♦XX-	6Ø
1Ø58	X♦XXX	6Ø
1Ø59	X♦X-X	6Ø
1Ø6Ø	OO♦O-	9Ø
1Ø61	X♦XXX	1ØØ
1Ø62	XX♦XX	1ØØ
1Ø63	XXX♦X	1ØØ
1Ø64	REDUCES PRIORITY OF -OOO- TO 41 IF BLOCKED AT ONE END	
1Ø67	INCREASES PRIORITY OF INTERSECTING ROWS OF O'S	
1Ø68	INCREASES PRIORITY OF INTERSECTING ROWS OF X'S	

Table 1: *A lookup table that defines the computer's strategy.*

Ø	♦----	Ø	27	♦X---	15	54	♦O---	Ø
1	♦---X	Ø	28	♦X--X	2Ø	55	♦O--X	Ø
2	♦---O	Ø	29	♦X--O	1Ø	56	♦O--O	Ø
3	♦--X-	Ø	3Ø	♦X-X-	4Ø	57	♦O-X-	Ø
4	♦--XX	Ø	31	♦X-XX	5Ø	58	♦O-XX	Ø
5	♦--XO	Ø	32	♦X-XO	3Ø	59	♦O-XO	Ø
6	♦--O-	Ø	33	♦X-O-	Ø	6Ø	♦O-O-	21
7	♦--OX	Ø	34	♦X-OX	Ø	61	♦O-OX	11
8	♦--OO	Ø	35	♦X-OO	Ø	62	♦O-OO	41
9	♦-X--	Ø	36	♦XX--	39	63	♦OX--	Ø
1Ø	♦-X-X	4Ø	37	♦XX-X	65	64	♦OX-X	Ø
11	♦-X-O	Ø	38	♦XX-O	4Ø	65	♦OX-O	Ø
12	♦-XX-	3Ø	39	♦XXX-	7Ø	66	♦OXX-	Ø
13	♦-XXX	47	4Ø	♦XXXX	1ØØ	67	♦OXXX	Ø
14	♦-XXO	Ø	41	♦XXXO	6Ø	68	♦OXXO	Ø
15	♦-XO-	Ø	42	♦XXO-	3Ø	69	♦OXO-	Ø
16	♦-XOX	Ø	43	♦XXOX	3Ø	7Ø	♦OXOX	Ø
17	♦-XOO	Ø	44	♦XXOO	3Ø	71	♦OXOO	Ø
18	♦-O--	Ø	45	♦XO--	Ø	72	♦OO--	31
19	♦-O-X	Ø	46	♦XO-X	Ø	73	♦OO-X	11
2Ø	♦-O-O	1	47	♦XO-O	Ø	74	♦OO-O	41
21	♦-OX-	Ø	48	♦XOX-	Ø	75	♦OOX-	Ø
22	♦-OXX	Ø	49	♦XOXX	Ø	76	♦OOXX	Ø
23	♦-OXO	Ø	5Ø	♦XOXO	Ø	77	♦OOXO	Ø
24	♦-OO-	1	51	♦XOO-	Ø	78	♦OOO-	51
25	♦-OOX	Ø	52	♦XOOX	Ø	79	♦OOOX	Ø
26	♦-OOO	21	53	♦XOOO	Ø	8Ø	♦OOOO	9Ø

The program relies on a lookup table (entry S, table 1) and some exception conditions (table 2) to determine the priority of move of the square in question. The last 2 moves (by nought and cross) are scrutinized, scanning through these squares for 4 squares either side of the move in all 8 directions. The priority is calculated and updated if greater than previously calculated. Finally the board is scanned for the highest priority and the move made in this square.

The computer always goes first, and is X, although this can easily be modified. On the EXORciser, it takes about 40 seconds to think of the best move, compared with 10 seconds on a NOVA 2 using the same program and a BASIC interpreter, so do not worry if there is not an immediate response.

The program plays a very good game, occasionally almost beating the author, and has beaten several people who have played. Changing the strategies radically alters the way the computer plays, and the strategies in table 1 and exceptions in table 2 are the best I have found so far, but try changing S(12) to 29, and S(13) to 49. I would be interested to hear from anybody who finds better strategies. ■

Shape Table Conversion for the Apple II

Dave Partyka, 1707 N Nantuckett Dr, Lorain OH 44053

If you own an Apple II with high-resolution graphics, I'm sure you have tried using the shape table. If you are like me, you converted the points to their hexadecimal values, ran the shape subroutine, and got a completely different shape from what you wanted. After two or three tries and a lot of time, you finally got the shape the way you wanted it.

There has to be a better way, and there is. The program in listing 1 performs the plot conversion to hexadecimal and puts the values in the table starting at the decimal location you specify. After using this program, you will find it very easy to build shape tables. Instead of drawing arrows, you can use just the points.

This program follows the rules of the *Apple II Reference Guide:* a double move up or 00 will end the program and put a 0 at the end of the table. The value of the moves are the same as in the *Reference Guide*:

0 = Move up
1 = Move right
2 = Move down
3 = Move left
4 = Plot and move up
5 = Plot and move right
6 = Plot and move down
7 = Plot and move left

The program does not require that the user press the return key while entering the plot values. You can try this program using the example given in the *Apple II Reference Guide* on page 53. Assign the correct values to the shape vectors at the top of the page and the hexadecimal values given will be in your table. Remember that this program requires a decimal location, while the shape subroutine requires the hexadecimal value. ■

Listing 1: Shape table program for the Apple II.

```
10 INPUT "STARTING DECIMAL LOCATION",L
20 N=N+1 : PRINT "PLOT "; N ; "-";
30 Z= PEEK(-16384) : IF Z<176 OR Z>183 THEN 30 :
            POKE -16368,0 : Z=Z-176 : PRINT Z :
            IF N#1 THEN RETURN
40 E=1 : IF Z=0 THEN D=1 : A=Z : GOSUB 20
50 IF Z#0 THEN 60 : IF D=1 THEN 90 : E=0 : GOTO 70
60 D=0 : IF Z=2 OR Z=4 OR Z=6 THEN 70 :
            Z=Z-1 : A=A+8
70 B=Z/2 : GOSUB 20 : IF Z#1 AND Z#2 AND Z#3
            THEN 80 : B=Z*4+B : E=1 : GOSUB 20
80 B=B*16+A : POKE L,B : L=L+1 : IF E#0 THEN 40 :
            A=0 : D=1 : E=1 : GOTO 50
90 PRINT "END OF TABLE" : POKE L,0 : END
```

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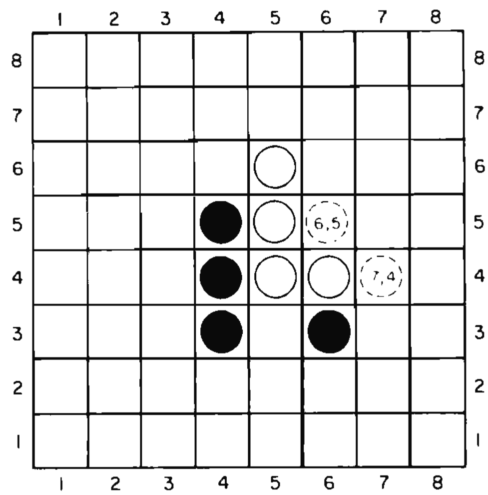

Programming Strategies in the Game of Reversi

Figure 1: Typical position in the game of Reversi. The game is played with counters having two different colors, one on each side. A player's turn consists of placing a counter (with the player's color face up) on the board so that it traps one or more enemy pieces between it and another friendly piece in a straight line. The trapped enemy pieces are then reversed in color. Thus, a play by Black to square (6,5), with the horizontal coordinate given first, would allow Black to turn over White's pieces at (6,4), (5,4) and (5,5). A play by Black to square (7,4) would allow Black to turn over White's pieces at (6,4) and (5,4). Play ends when neither player can make a legal move. The player with the greater number of counters showing wins the game.

Peter B Maggs
2011 Silver Ct E
Urbana IL 61801

Board games such as checkers or chess can be fun and challenging to play, and programs that play these games can be fun and challenging to write. This article covers some of the decisions I made and methods I used in the programming of a board game called Reversi. It examines in turn the choice of a game, the programming language, the data structure and the details of the program structure.

Choosing a Game

There are both legal and practical considerations in choosing a game to program. Since I earn a living teaching law, and program as a hobby, I will start with the legal aspects. Many games present no legal problems. For instance, chess and checkers are in the public domain and anyone is free to write programs for them, but copyrighted games could pose serious legal problems. While writing a program to play a copyrighted game solely for your own amusement at home would probably fall within the fair use exception to the copyright law, any attempt to distribute, publish or sell the program could be made only with the permission or tolerance of the copyright and trademark owner. There is a third category of game wherein the game itself is in the public domain, but playing equipment is sold under a trademark. Thus, while no one has any rights to three-dimensional tic-tac-toe, the manufacturer who sells sets for playing three-dimensional tic-tac-toe under a trademark has the right to prevent you from distributing a computer game with the same name. So, you are free to program and even sell three-dimensional tic-tac-toe, but you will have to make up your own name for it.

There are also practical problems in

choosing a game. The game you select should not only be free of serious legal complications, it should also be complex enough to be challenging, yet simple enough to be implemented with the hardware and software at your disposal (taking account of your own programming ability and free time). If you are clever enough, you can choose an extremely complex game like chess or Go. If you are a novice programmer with only a small programmable calculator, you might want to begin with something simple like tic-tac-toe.

Since my own equipment (A SOL-20 computer with 16 K of programmable memory, video monitor, Teletype, two cassette drives, BASIC and assembler languages) and my own programming ability both fall somewhere between the two extremes, I sought a moderately difficult game to program.

The game I selected is called "Reversi." According to the *Oxford English Dictionary,* Reversi was first mentioned in print in the 1880s and its rules were first published in the 1890s; thus the game has long been in the public domain. It is now enjoying a revival because of the marketing of a board and set of playing pieces for the game by Gabriel Industries under that firm's trademark, "Othello," and the publication of a well written book on the game. (See "Othello, a New Ancient Game," October 1977 BYTE, page 60, and the bibliography at the end of this article.)

The rules of the game are simple, but play can be quite complicated. The game is played on an 8 by 8 square board like a standard chess or checkerboard. The players start with a supply of 64 playing pieces, each shaped like a checker piece, but black on one side and white or red on the other. Players take alternate turns. If a player has no legal play, he or she loses his turn. When neither player has a legal play, the game ends.

A play consists of placing a piece on an unoccupied square on the board with the player's color up. Each of the first two plays by each player must be made to one of the four center squares. Thereafter, each player may place a piece on any unoccupied square that will result in the formation of an unbroken line (horizontal, vertical, or diagonal) of pieces, with one of his own pieces on each end and one or more of his opponent's pieces in the middle. The opponent's pieces in the middle are then turned over (see figure 1). At the end of the game, the player with the most pieces showing his color wins.

Strategy for the game can be complex — only the most basic ideas are covered in the 200 page book by Hasegawa mentioned in the bibliography. However, the various writers on the game do agree on some basic points: Corner squares are very valuable because they can never be taken; squares next to corners are dangerous because they can make it possible for one's opponent to take corners. Edge squares are usually valuable because they can be used to force turnovers of large numbers of opponent's pieces in middle squares. Control of strategic squares in the middle of the game is more important than having a substantial material advantage at that time.

Programming Language

After I chose the game, the next step was to choose a programming language for the game. I really had only two choices because of the limitations of my own software library — BASIC or assembler. I chose BASIC because I can program much more easily in BASIC and because BASIC programs are more generally transferable to other computers than are assembler language programs, which will work with only one type of processor. With transferability in mind I made considerable efforts to avoid the use of the fancy special features available in the BASIC interpreters I have, since their use would make transfer a nightmare. Now that I have finished the programming, I am still happy with my choice, though I am now tempted to convert a few of the critical subroutines (which I will discuss later) into assembler language. This conversion would make the program run faster or to allow it to make a deeper analysis of its plays while running at the same speed.

Data Structure

Before starting programming I had to choose a suitable data structure. Following methods used in one of the leading computer chess programs (see the article by Gillogly in the bibliography), I decided to represent the standard 8 by 8 chessboard as being surrounded by a border of out-of-bounds squares, thus making a 10 by 10 board. For computer purposes, this augmented board could most naturally be represented as a 10 by 10 array dimensioned by the BASIC statement DIM B(10,10). However, because many BASIC interpreters for microcomputers allow only one-dimensional arrays, and because use of a one-dimensional array simplified my program in various ways, I decided instead to represent the board by a single array of 100 elements: DIM B(100). (See figures 2 and 3.) Another array, DIM E(100), was

Text continued on page 70

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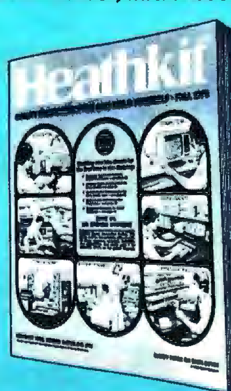

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Figure 2: Integer numbers used to identify Reversi squares. These numbers correspond to the elements of one-dimensional 100 element BASIC arrays used by the author in his program to store a given Reversi board pattern.

91	92	93	94	95	96	97	98	99	100
81	82	83	84	85	86	87	88	89	90
71	72	73	74	75	76	77	78	79	80
61	62	63	64	65	66	67	68	69	70
51	52	53	54	55	56	57	58	59	60
41	42	43	44	45	46	47	48	49	50
31	32	33	34	35	36	37	38	39	40
21	22	23	24	25	26	27	28	29	30
11	12	13	14	15	16	17	18	19	20
1	2	3	4	5	6	7	8	9	10

Figure 3: Initial board position. These values are stored in the one-dimensional 100 element matrix B (see listing 1). They enable the program to tell where the four center squares and out-of-bounds squares are located. (The first four moves of the game must be made to the four center squares.)

3	3	3	3	3	3	3	3	3	3
3	0	0	0	0	0	0	0	0	3
3	0	0	0	0	0	0	0	0	3
3	0	0	0	0	0	0	0	0	3
3	0	0	0	2	2	0	0	0	3
3	0	0	0	2	2	0	0	0	3
3	0	0	0	0	0	0	0	0	3
3	0	0	0	0	0	0	0	0	3
3	0	0	0	0	0	0	0	0	3
3	3	3	3	3	3	3	3	3	3

0	0	0	0	0	0	0	0	0	0
0	64	-30	10	5	5	10	-30	64	0
0	-30	-40	2	2	2	2	-40	64	0
0	10	2	5	1	1	5	2	-30	0
0	5	2	1	1	1	1	2	5	0
0	5	2	1	1	1	1	2	5	0
0	10	2	5	1	1	5	2	10	0
0	-30	-40	2	2	2	2	-40	-30	0
0	64	-30	10	5	5	10	-30	64	0
0	0	0	0	0	0	0	0	0	0

Figure 4: Initial strategic values of the board squares stored in the E matrix (see listing 1), used by the program to evaluate it using a minimax strategy. The higher the value, the more desirable the square.

Text continued:

declared for storage of the strategic value of each square (see figure 4). Two more 100 element arrays were declared for use in saving different versions of the board while the computer was considering possible plays.

This rather lavish use of storage was made possible by the fact that I was using a 5 K BASIC package in a 16 K memory. If memory were at a premium, it would have been necessary to use a much more complex board representation which could pack each square into a few bits (see the article by Yost in the bibliography) and perhaps necessary to develop a method for storing changes in board positions without storing whole boards. However, if you have the storage you might as well use it.

Several simple techniques could be used to adapt my program for users with less memory space. If a BASIC with strings is available, board squares can be stored in 1 byte string variables rather than in multibyte numerical variables. Alternatively, several board squares could be stored in one numerical variable, using the 1's position for the first square, the 10's position for the second square, etc. If the BASIC package has POKE and PEEK instructions, still another possibility is to store each square as 1 byte in memory with a POKE instruction and retrieve each square as needed with an appropriate PEEK instruction.

Program Structure

Having chosen the data structure, I next had to choose a program structure. Just as I chose a simple data structure so that it would be easily adaptable to many types of games, I selected what I hoped would be a very adaptable program structure. In designing the program structure, I drew upon

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the rich body of published descriptions of chess playing programs on the theory that a program structure capable of supporting a chess game should be adequate for most simpler board games. (See the computer chess material listed in the bibliography.)

The program structure consists of the following parts which will be analyzed in turn: the main game control routine and subroutines for initialization; board display; move input; legal move checking; legal move generating; computer move selection; and board evaluation. The following discussion will consider each of these, since each typifies a routine needed for almost any board program.

First I'll discuss the main game control procedure. This procedure must first call the subroutine that gives initial values to the board squares and to the board evaluation array. Then it must display the board on the video screen or print it on the Teletype and ask Black to make the first move. It must call the appropriate subroutine to check each move made for legality, and must terminate the game and declare the score if there are no legal moves. If the user wants the computer to make a play, it must call the subroutine that selects a move for the computer.

The board initialization routine is the simplest: Since the board is empty at the start of the game, it is filled with zeroes, except for the four center squares that must be covered in the first four moves. The out-of-bounds squares are filled with threes (see figure 3). If this were a game such as checkers, which starts with pieces on the board, they would have to be indicated by assigning appropriate initial values for the occupied squares. The strategic value of each square (high for corner squares, low for center squares, negative for next to corner squares, etc) is also entered by the initialization subroutine into the evaluation array (see figure 4).

Next comes the board display routine. Here a simple Teletype oriented printout of the 8 by 8 board was chosen. It would have been more elegant and little more trouble to use POKE commands to directly alter squares on a board displayed on the video monitor, and to represent the pieces with good-looking symbols from my character generator, but I decided to forego these luxury features in the interests of program portability. I also made an effort to limit each display frame to 15 lines so it would not disappear off the top of a 16 line video display monitor.

Before a player is asked to move, the computer must see if that player has any legal moves. This is done by a subroutine that checks for the existence of a legal move. It first searches for an empty square; if it finds one, it checks to see if there is an adjacent square occupied by an opponent. The flattening of the two-dimensional board into one dimension causes adjacent squares to be in positions that are +1, +11, +10, +9, −1, −11, −10, or −9 squares away from the square in question (see figure 2). These adjacent squares are checked in turn. If a square is found that is occupied by an opponent, the search continues in the same direction as long as more opponent's pieces are found. When the first square that does not have an opponent's piece is found, it is examined. If it contains one of the player's pieces, the move is legal; if it is empty or out-of-bounds, the move is illegal. This search process is continued until a legal move is found, or it is established that there is no legal move. Modifications of this search routine will work for games anywhere in the range between tic-tac-toe and chess, inclusively.

The next routine used is the input routine. I decided to ask the user to input two numbers, giving the x and y coordinates of the square to which the player wishes to move. I avoided alphabetic input since I wanted the program to work for BASIC without string variables. I also provided that the input of the coordinates (0, 0) would be a signal that the user wants the computer to make the next move. Both approaches can be used for almost any board game.

Once a play is entered, the next step is to see if it is legal. If so, the computer must make the play and change the color of any pieces turned over by the play. If it is not legal, the computer must ask the player to try another play. The routine used to check and execute the move is very similar to that mentioned earlier for checking the legality of moves. However, unlike the legal move routine, the routine cannot stop after finding that a play allows turnovers in one direction, but must continue to make all turnovers in all directions the player is entitled to.

Some moves may affect the strategic value of board squares. For instance if a piece is placed in a corner, the squares next to that corner no longer are dangerous, so their values in the evaluation array must be changed from highly negative values to slightly positive. This is the only change in evaluation values made during the running of the present program. Undoubtedly it could be improved by introducing a number of other changes reflecting particular board configurations and the possibility that a square might have different values for

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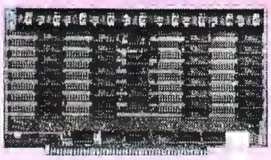

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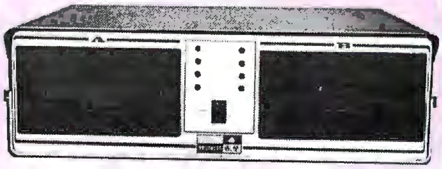

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Black and White in some circumstances. Chess playing programs often have entirely separate evaluation routines for beginning, middle and end game positions.

Finally come the most complicated and interesting subroutines, those for choosing a move for the computer. These use an approach suggested by Shannon in his classic article, an approach later refined by numerous other researchers (see the bibliography). This is the minimax algorithm. Assume that the computer is to make a play for White. It generates all legal moves for White (using the legal move checking procedure discussed above). As each legal move is generated, the computer considers all possible replies by Black. An evaluation routine is called to calculate the strategic value to Black of the board position after Black has played. The minimax strategy calls for the computer to select that legal play for White that *minimizes* the *maximum* value of the response Black can make.

For instance, suppose White has two legal plays, and that for the first play Black may make reply A with value to Black of 80, or reply B with value 90. For White's other possible move, Black may make reply C with value to Black of 100, or reply D with value 50 (see figure 5). Using the minimax strategy, White will choose the first move. This ensures that even if Black makes his best reply, he cannot achieve a board position worth more than 90 evaluation points.

This procedure can be extended to any depth. However, the number of moves to be evaluated, and consequently the computer time needed, rises at an astronomical rate. In the middle game in chess, each side may have 50 legal moves. This means that the complexity of search is of the order of 50^n, where n represents the depth of the search. This is a very large number even for a relatively shallow search, which may explain why world championship computer chess matches are usually won by very large and fast computers. In Reversi there is an average of approximately 8 possible legal plays per turn. This means that for a search of depth 2 (ie: to consider all possible moves by White and all possible replies by Black) 64 final board positions would have to be evaluated. A search of depth 4 would require 2796 evaluations.

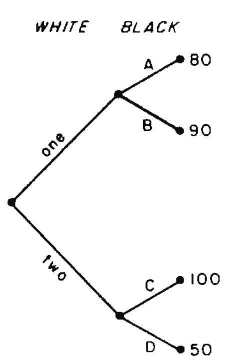

Figure 5: Minimax strategy tree, showing alpha-beta pruning. Minimax is a game theory strategy in which the object is to minimize the value of the opponent's maximum response. In this illustration, White has two moves to choose from: move one enables Black to counter with moves having strategic values of 80 or 90 (the higher the number, the better). Move two, on the other hand, enables Black to respond with moves having values of 50 or 100. Move one is the preferable move for White, since it minimizes Black's maximum response to 90, rather than 100. It is not necessary for the computer, playing the role of White, to analyze the move two branch any further, since it has already been eliminated by the minimax strategy. That branch can therefore be pruned to save computing time.

Computer chess programmers have adopted a number of tricks to speed up the search process. Many of these tricks are adaptable to other types of board games; one of them is used here. This is what artificial intelligence specialists call alpha-beta pruning. A simple example may be given. Consider again the situation mentioned above, in which White has two legal plays. For play one, Black may make play A with value 90 or play B with value 80. For play two, Black may make play C with value 100 or play D with value 50 (see figure 5). Suppose the computer evaluates play one first. It discovers that the best that Black can do if White makes play one is to achieve a 90 point position. Now the computer starts to evaluate White's play two. It finds that Black has reply C which gives it a 100 point position. It need consider no further replies to play two, since it already knows enough to realize that play two is inferior to play one under the minimax approach, ie: Black has at least one reply to play two which is better for Black and hence worse for White than any of Black's replies to play one.

Another important method used for speeding the operation of chess programs, but not yet incorporated in my Reversi program, is that of saving particularly good moves (or particularly harmful replies by an opponent) and trying them in other situations. Thus Black may have a reply that is extremely damaging for almost any move White makes, plus a number of weaker replies. It pays to check Black's most powerful replies to previously checked White moves first, since a good reply to one move is often a good reply to other moves.

A sure way to speed up evaluations substantially and allow a deeper search is to use a compiled rather than interpreted language or to rewrite the program (or at least the move selection strategy) in assembler language. Again it is instructive to note that most championship chess programs are written in assembler language to obtain an extra edge in the depth of search possible under the time limits enforced in chess tournaments.

Once a game program is up and working, the most interesting point for further effort is to try to improve the program's strategy. It certainly helps to be a good player of the game, or at least to have read some background material on the theory of play. One ingenious method sometimes

Listing 1: BASIC program for playing the game of Reversi.

```
1      REM **** REVERSI ****
2      REM ALL REMARKS MAY BE OMITTED TO SAVE MEMORY
50     REM VARIABLES
55     REM A(100) — FOR SAVING BOARD
60     REM B(100) — BOARD
62     REM C(100) — FOR SAVING BOARD
63     REM D(8) — DISTANCE TO NEXT SQUARE IN 8 DIRECTIONS
64     REM E(100) — VALUE OF BOARD SQUARES
65     REM F — VALUE OF OPPONENT'S BEST REPLY TO
66     REM COMPUTER'S BEST PLAY
67     REM G — VALUE OF OPPONENT'S BEST REPLY TO
68     REM COMPUTER'S CURRENT PLAY
69     REM H — VALUE OF OPPONENT'S CURRENT REPLY
70     REM I — NOT USED
71     REM J, K, L — COUNTERS
74     REM M — PLAY
75     REM N — COUNTER
76     REM O — NOT USED
77     REM P — PLAYER, BLACK=—1, WHITE=1
78     REM Q — TOTAL MOVES
79     REM R, S — NOT USED
80     REM T — LOGICAL VALUE, TRUE=1, FALSE=0
81     REM U — COUNTER
82     REM V, W — TO SAVE PLAY
84     REM Z — COUNTER
105    DIM A(100)
110    DIM B(100)
112    DIM C(100)
113    DIM D(8)
114    DIM E(100)
115    REM RANDOMIZE
118    REM IF YOUR COMPUTER HAS A RANDOMIZE COMMAND, SUBSTITUTE
119    REM IT FOR LINE 115 AND OMIT LINES 118 THROUGH 150
123    PRINT "TYPE A NUMBER BETWEEN 100 AND 1000":
125    INPUT N
130    IF N<100 THEN 123
135    IF N>1000 THEN 123
137    PRINT "RANDOMIZING"
140    FOR J=1 TO N
145        LET Z=RND(0)
150    NEXT J
171    LET D(1)=1
172    LET D(2)=11
173    LET D(3)=10
174    LET D(4)=9
175    LET D(5)=—1
176    LET D(6)=—11
177    LET D(7)=—10
178    LET D(8)=—9
182    REM INITIALIZE
185    GOSUB 9000
190    REM DISPLAY BOARD
200    GOSUB 8000
205    IF Q<5 THEN 295
210    REM CHECK FOR LEGAL PLAY
215    GOSUB 1300
220    IF T=1 THEN 295
225    LET T3=T3+1
226    IF T3<2 THEN 254
228    PRINT "THE GAME IS OVER"
229    LET N=0
230    LET J=0
231    FOR Z=12 TO 89
232        IF B(Z)=—1 THEN 239
234        IF B(Z) <> 1 THEN 244
235        LET J=J+1
237        GOTO 244
239        LET N=N+1
244    NEXT Z
245    PRINT "BLACK HAS ";N;", WHITE HAS ";J;" PIECES"
248    PRINT "DO YOU WANT TO PLAY AGAIN (0=NO, 1=YES)";
250    INPUT T
251    RESTORE
252    IF T=1 THEN 185
253    GOTO 9998
254    PRINT
255    IF P=1 THEN 260
256    PRINT "BLACK HAS NO PLAY, LOSES TURN"
258    GOTO 950
260    PRINT "WHITE HAS NO PLAY, LOSES TURN"
270    GOTO 950
295    GOSUB 1100
380    IF M<> 1 THEN 500
390    IF Q>4 THEN 430
395    REM COMPUTER PLAYS
400    REM FIRST 4 PLAYS
402    LET M=45
403    IF B(M)=2 THEN 540
404    LET M=M+1
405    GOTO 403
430    GOSUB 3000
450    REM CHECK PLAY
500    IF M<1 THEN 800
510    IF M>100 THEN 800
520    IF Q>4 THEN 600
530    IF B(M) <>2 THEN 800
540    LET B(M)=P
550    GOTO 830
600    GOSUB 1400
640    IF T<>0 THEN 950
800    PRINT "ILLEGAL PLAY"
820    GOTO 200
830    LET Q=Q+1
950    LET P=—P
```

Listing 1 continued on page 78

used in order to find better parameters for evaluation routines is to select a variety of values for use in these routines and to have the program run a tournament against itself using the different values. The winning values are then incorporated in the revised and improved program.

I hope this description and the listing of the Reversi program will inspire readers to make their own game playing programs. The books about board games mentioned in the bibliography list over 700 games, so there are plenty of games waiting to be programmed.

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Listing 1, continued:

```
955   IF E(M) <>64 THEN 200
960   GOSUB 5000
970   GOTO 200
1099  REM * GET A PLAY *
1100  PRINT
1101  PRINT "IF YOU WANT THE COMPUTER TO PLAY, ENTER 0,0"
1115  IF P=1 THEN 1140
1120  PRINT "BLACK";
1130  GOTO 1145
1140  PRINT "WHITE";
1145  PRINT "'S TURN, ENTER X,Y";
1150  INPUT X,Y
1160  LET M=X+1+10*Y
1170  RETURN
1299  REM * CHECK FOR LEGAL PLAY *
1300  LET T=1
1301  PRINT "CHECKING";
1302  LET M=1
1310  IF U<4 THEN 1318
1316  LET U=0
1317  PRINT ".";
1318  LET U=U+1
1320  IF B(M) <>0 THEN 1390
1330  LET N=1
1340  LET J=D(N)
1350  IF B(M+J) <>-P THEN 1385
1370  LET K=M+J+J
1380  IF B(K)=3 THEN 1385
1381  IF B(K)=0 THEN 1385
1382  IF B(K)=P THEN 1394
1383  LET K=K+J
1384  GOTO 1380
1385  LET N=N+1
1386  IF N<9 THEN 1340
1390  LET M=M+1
1391  IF M<90 THEN 1310
1392  LET T=0
1394  RETURN
1399  REM * MAKE A PLAY *
1400  LET T=0
1410  IF B(M)=0 THEN 1430
1420  RETURN
1430  LET N=1
1440  LET J=D(N)
1444  IF B(M+J) <>-P THEN 1700
1470  LET K=M+J+J
1480  IF B(K)=3 THEN 1700
1490  IF B(K)=0 THEN 1700
1500  IF B(K)=P THEN 1530
1510  LET K=K+J
1515  GOTO 1480
1530  LET T=1
1531  LET L=M
1532  IF L=K THEN 1700
1533  LET B(L)=P
1534  LET L=L+J
1535  GOTO 1532
1700  LET N=N+1
1705  IF N<9 THEN 1440
1710  RETURN
2999  REM CHECK COMPUTER'S PLAYS *
3000  PRINT "THINKING";
3680  LET F=9999
3690  FOR Z=12 TO 89
3700       LET C(Z)=B(Z)
3710  NEXT Z
3750  LET M=12
3752  IF U<4 THEN 3759
3753  LET U=0
3755  PRINT ".";
3759  LET U=U+1
3770  GOSUB 1400
3780  IF T=0 THEN 3860
3790  GOSUB 3900
3800  IF H>F THEN 3840
3802  IF H<F THEN 3810
3803  REM CHOOSE RANDOM OF EQUAL PLAYS
3804  LET Z=RND(0)
3806  IF Z>0.7 THEN 3840
3810  LET F=H
3815  REM FOUND BETTER MOVE
3820  LET W=V
3840  FOR Z=12 TO 89
3850       LET B(Z)=C(Z)
3855  NEXT Z
3860  LET M=M+1
3865  IF M<90 THEN 3752
3870  LET M=W
3875  PRINT
3880  RETURN
3899  REM * CHECK OPPONENT'S REPLIES *
3900  LET H=-99999
3920  FOR Z=12 TO 89
3925      LET A(Z)=B(Z)
3930  NEXT Z
3935  LET P=-P
3940  LET V=M
3950  LET M=12
3970  GOSUB 1400
3980  IF T=0 THEN 4080
3990  GOSUB 4130
4000  IF G<F THEN 4030
4014  REM FORGET THIS PLAY
4016  LET H=G
4020  GOTO 4100
4030  IF G<H THEN 4050
4035  REM FOUND MORE HARMFUL REPLY
4040  LET H=G
4050  FOR Z=12 TO 89
4060      LET B(Z)=A(Z)
4070  NEXT Z
4080  LET M=M+1
4090  IF M<90 THEN 3970
4100  LET M=V
4105  LET P=-P
4110  RETURN
4129  REM * EVALUATE *
4130  LET G=0
4140  LET Z=12
4150  IF B(Z)=P THEN 4190
4160  IF B(Z)=0 THEN 4300
4170  LET G=G-E(Z)
4180  GOTO 4300
4190  LET G=G+E(Z)
4195  REM FORGET THIS PLAY
4200  IF G>F THEN 4500
4300  LET Z=Z+1
4400  IF Z<90 THEN 4150
4500  RETURN
4999  REM ADJUST CORNER VALUES
5000  IF M<>12 THEN 5100
5010  LET E(13)=5
5020  LET E(22)=5
5030  LET E(23)=5
5100  IF M<>19 THEN 5200
5110  LET E(18)=5
5120  LET E(28)=5
5130  LET E(29)=5
5200  IF M<>82 THEN 5300
5210  LET E(72)=5
5220  LET E(73)=5
5230  LET E(83)=5
5300  IF M<>89 THEN 5400
5310  LET E(77)=5
5320  LET E(78)=5
5330  LET E(88)=5
5400  RETURN
7999  REM DISPLAY THE BOARD
8000  PRINT "     1   2   3   4   5   6   7   8"
8200  FOR Y=8 TO 1 STEP -1
8300     PRINT Y;"   ";
8400     FOR X=1 TO 8
8500         IF B(X+1+Y*10)=1 THEN 8700
8550         IF B(X+1+Y*10)=-1 THEN 8900
8600         PRINT " - ";
8650         GOTO 8990
8700         PRINT " W ";
8800         GOTO 8990
8900         PRINT " B ";
8990     NEXT X
8995     PRINT Y
8996  NEXT Y
8997  PRINT "     1   2   3   4   5   6   7   8"
8998  RETURN
8999  REM * INITIALIZE *
9000  FOR N=11 TO 90
9050     READ E(N)
9060  NEXT N
9066  FOR N=1 TO 100
9068     LET B(N)=0
9070  NEXT N
9074  FOR N=1 TO 10
```

```
9076        LET B(N)=3
9078        LET B(90+N)=3
9080        LET B(10*N-9)=3
9082        LET B(10*N)=3
9085     NEXT N
9087     LET B(45)=2
9088     LET B(46)=2
9089     LET B(55)=2
9090     LET B(56)=2
9172     LET U=5
9186     LET Q=1
9190     LET P=-1
9191     RETURN
9220     DATA 0, 64, -30, 10, 5, 5, 10, -30, 64, 0
9222     DATA 0, -30, -40, 2, 2, 2, 2, -40, -30, 0
9224     DATA 0, 10, 2, 5, 1, 1, 5, 2, 10, 0
9226     DATA 0, 5, 2, 1, 1, 1, 1, 2, 5, 0
9228     DATA 0, 5, 2, 1, 1, 1, 1, 2, 5, 0
9230     DATA 0, 10, 2, 5, 1, 1, 5, 2, 10, 0
9234     DATA 0, -30, -40, 2, 2, 2, 2, -40, -30, 0
9236     DATA 0, 64, -30, 10, 5, 5, 10, -30, 64, 0
9998     STOP
9999     END
```

Listing 2: Sample output of the program in listing 1.

```
IF YOU WANT THE COMPUTER TO PLAY,
ENTER 0, 0
BLACK'S TURN, ENTER X, Y
?3,4

     1   2   3   4   5   6   7   8
8  -   -   -   -   -   -   -   -   -   8
7  -   -   -   -   -   -   -   -   -   7
6  -   -   -   -   -   -   -   -   -   6
5  -   -   -   W   B   -   -   -   5
4  -   -   B   B   B   -   -   -   4
3  -   -   -   -   -   -   -   -   -   3
2  -   -   -   -   -   -   -   -   -   2
1  -   -   -   -   -   -   -   -   -   1
     1   2   3   4   5   6   7   8
```

■

BYTE News . . . .

HOME BUS STANDARD BEING DEVELOPED: Stanford Research Institute, Menlo Park California, and the Home Bus Standard Association, Washington DC, are conducting a feasibility study to develop a home bus standard. It will allow home electronic appliances to interact with one another over regular home wiring.

TI MICROCOMPUTER PICTURE IN TRANSITION: Although Texas Instruments finally introduced its 99/4 personal computer system in June, it is expected to be an interim product. TI failed to get FCC approval for the original version and also ran into processor production difficulties which forced the introduction of a high-priced personal computer system ($1150). TI is still pursuing a rule change request with the FCC and the development of its 9985 stripped down version of its 9940 16-bit processor. TI hopes to then introduce a personal computer system for under $500 which connects to a standard color-television receiver.

TI has also expanded its small business computer (99/7) marketing efforts. The 99/7, which starts at $5000, will be marketed by Moore Business Forms, through over 750 sales offices as well as through computer stores and TI's own retail outlets.

AT&T TESTING HOME INFORMATION SYTSTEMS: American Telephone and Telegraph Co has undertaken customer acceptance tests of several home information systems similar to the Viewdata system. Among the systems AT&T will test are the Knight-Ridder system (reported in the August BYTE News), a system developed by McDonnell Douglas, and a Bell Labs developed system.

The Knight-Ridder system test will take two years and involve 150 to 200 families in Miami, Florida. The system will transmit news, sports results, weather,and public information. The McDonnell Douglas system will be tested in Kansas City, Michigan, and New York. It will allow users to call a special number, key a special code on a push button phone, and receive the requested information in audible form. No details are as yet available on the Bell system.

HEATH ACQUIRED BY ZENITH: Heath Co, a leader in the consumer electronic kit business, was sold by Schlumberger Ltd to Zenith Radio Corp for $64.5 million. In 1977 Heath introduced two personal computer kit systems, the H-8 which is based on the 8080 processor, and the H-11 which is based on the Digital Equipment Corp (DEC) LSI-11. Heath entered into a three-year contract with DEC. Heath also entered the adult-education market. Heath sales for the last several years have declined at a 3 to 5% rate.

Zenith, a manufacturer of radio and television receivers, has been diversifying. They have been making video monitors for terminals and cable-television converters. Immediately after the acquisition was completed, Heath announced an aggressive marketing program to sell assembled computer systems through a network of distributors and original equipment manufacturers.

8-INCH WINCHESTER DISK MARKET STILL TRYING TO GET OFF THE GROUND: Despite the publicity and advertising, only one manufacturer is presently shipping production quantities of 8-inch hard-disk drives. The company is International Memories Inc (IMI), which is currently shipping limited quantities of their 11 M byte drive at $1775. IMI will introduce a 20 M byte unit early next year, and expects to reduce the price on the 11 M byte unit 10 to 20% by midyear as production is increased.

Micropolis expects to start shipping limited quantities of its 27 and 45 M byte drives soon. The introductory price for the 45 M byte drive is $2688 and should drop to under $2000 by midyear.

Shugart has not yet revealed its marketing plans for its 8-inch rigid drive.

COMPUTERIZED PORTABLE HOME ENTERTAINMENT CENTER SHOWN: Sharp Electronics recently showed a portable unit, about the size of a typical portable stereo system, which included the following: a television receiver with a 4.5 inch screen, an AM/FM radio, a stereo cassette, a digital clock, a calculator, and a personal computer. The computer's 48-key keyboard slides into the unit for storage, when it becomes necessary to transport the unit. The video screen is used for display, and the audio cassette recorder is for data and program storage. It uses BASIC, has graphics capabilities, and is expandable. No immediate marketing plans have as yet been announced.

LOOK IT UP IN THE DATA DICTIONARY: Data base management (DBM) systems are growing in size, sophistication, and popularity. Users, therefore, need more advanced tools for defining and keeping track of their data resources. Data dictionaries have been developed to do this and to augment existing data base management systems. The data dictionary is integrated into the data base management system's nucleus and utilities as well as managing the data resources.

On large computer systems such as the large IBM mainframes, the problem of managing these systems is acute, and data dictionaries are popular here. However, data dictionaries are now being developed for minicomputer systems as they increase in complexity. Someday you can expect to see them on microcomputer systems.

IEEE-488 BUS INTERFACING SIMPLIFIED: Now you can interface your computer system to the IEEE-488 bus without a special bus interface. ICS Electronics Corp, San Jose, California, has come up with an easy way of doing it. They have developed a 488-to-RS-232C interface and controller. Just place this device in the line between your terminal and processor and plug your IEEE-488 cable into the device. Now you can program your computer to process data coming from all those instruments with 488 interfaces.

SILICON VALLEY-II DEVELOPING: "Silicon Valley" is the nickname given to the area in California just south of San Francisco that has the highest concentration of integrated circuit manufacturers. A regional shift now appears underway as more and more integrated circuit manufacturers are opening facilities in Texas. Long the stronghold of Texas Instruments, the Dallas and Austin areas have seen the opening of plants by Mostek and Hitachi. Now, Motorola and Advanced Micro Devices are following suit. The desertion of California appears to be due to high operating costs.

GTE TAKES ON VIEWDATA: General Telephone and Electronics Corp has been licensed to offer Viewdata information services in the USA and Canada. Viewdata was developed by the British Post Office, and is a data base information system allowing users to access data on their television receivers via telephone lines.

DUAL-SIDED FLOPPIES STILL IN SHORT SUPPLY: Shugart expects to finally get into quantity production on dual-sided floppy disks by the end of the first quarter of 1980. Presently they are shipping only limited quantities. Originally introduced in early 1977, Shugart did not start shipping until early 1979. Media wear problems caused these delays and has limited production to 100 drives per day at best. Shugart has designed a completely new double-sided head which they expect will cure these problems. However, Shugart has found it necessary to increase the price of the drives. The SA850, an 8-inch drive, in 500-lot quantities will be priced from $485 to $580.

FCC COMPLETES RADIO FREQUENCY RADIATION TESTS: The FCC has completed its test of six personal computer systems and will release its data soon. Reportedly, the FCC has found that all but one exceed the interference levels permitted for devices that connect to television receivers (eg, games). The test included the Atari, Apple, PET, Heath, Southwest Technical Products, and Radio Shack systems. Only the Atari system passed. The rest caused excessive radio frequency (RF) radiation interference on nearby television receivers. None of these systems are required to meet the existing regulations. In the meantime, the large numbers of personal computer systems in use are beginning to generate interference complaints.

8080 STILL GOING STRONG: The 8080 microprocessor, introduced by Intel in 1974 and the integrated circuit that started the microprocessor "revolution," is still going great. This is despite improved successors such as the Z80 and 8085. An estimated 500,000 8080As are being made each month, and many purchasers are finding them in short supply. The 8080A is currently being made by five manufacturers. Prices for large quantities have gone back up to the $3 to 4 range, after they had dipped as low as $2.75 each in late 1978. Demand for the 8080A is expected to continue strong through mid-1980, and it should continue in production for several more years.

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

by Sol Libes
ACGNJ
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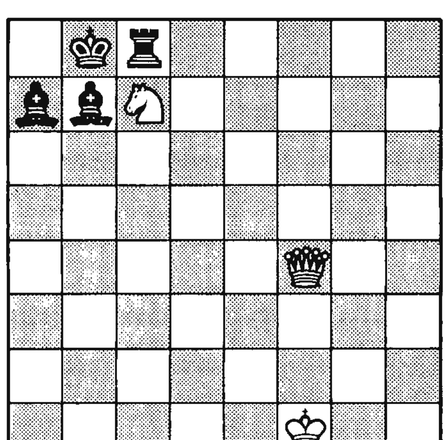
Get your shears out, and get ready to cut back your game trees, thereby saving both space and time

Sooner or later, almost everyone with a small system gets the idea of programming it to play chess, checkers, or some other two-person board game. Most of us give up before we start because we have no idea how to determine the best move in any given situation. The other aspects of playing a game are generally no problem.

We can see how to represent 64 squares on a board by 64 bytes in memory, each of which contains a code number which might be 3 for Bishop, 6 for King, or 0 for a blank square, and so on. We can see how to write a program for each piece, determining where it can move in a given situation depending upon the rules of the game. For example, a Bishop can move as far as possible in any of four directions, so we have to write a program to search in one direction until it finds a square that is not blank (ie: the corresponding byte does not contain 0, the code for a blank square). If this square is n squares away from where the Bishop is currently positioned, then there are $n - 1$ possible moves that the Bishop can make in that direction. This loop is then repeated, once for each of the four directions.

Finally, we can see how to write a program that would find all of the pieces on the board, would determine the type of each piece, and would find all possible moves for each piece, according to its type. In this way we could get a list of all of the moves that could be made by one player in any given situation. But to find the best of these defies the low-level intuition that most of us rely upon.

In this article, I will describe a general procedure for programming board games, relying heavily on chess in my examples, but utilizing procedures that can be applied in any board game where you have to "look ahead." The logic is roughly as follows: if I make move X, then my opponent will make move Y; if I make move Z, then my opponent can make move U, which is better for him than move Y, so I shouldn't make move Z; but if I make move W...and so on.



1. N-R6 dbl ch	K-R1
2. Q-N7 ch	R x Q
3. N-B7 mate	

Figure 1: *Chessboard layout just prior to the conclusion of a famous dramatic ending to a chess game.*

The first illustration will be from a famous dramatic finish to a chess game. This is illustrated in figure 1. White is already far ahead, having a Queen and a Knight, whereas Black has only a Rook and two pawns. To finish the game quickly, White lets Black capture his Queen, then gives checkmate with his Knight. For those who have forgotten their chess (and also to illustrate what the computer does when it sees this position), the entire finish of the game is illustrated in figure 2 (see page 88).

It is clear that the computer has to perform a complete analysis of the given position in a game; much more complete than that given in either figure 1 or figure 2. For example, look at White's first move: N-R6 double check. In chess terminology, as soon as White makes this move, Black's next move is "forced." There is nothing that Black can do except move K-R1. But what does this mean? Black actually has several moves, but all of the others are illegal because White would be able to capture his King. Specifically:

- If Black plays R-B2 (interposing the Rook), then White plays NxK (capturing the King with his Knight).
- If Black plays PxN (capturing the Knight), then White plays QxK

Text continued on page 90

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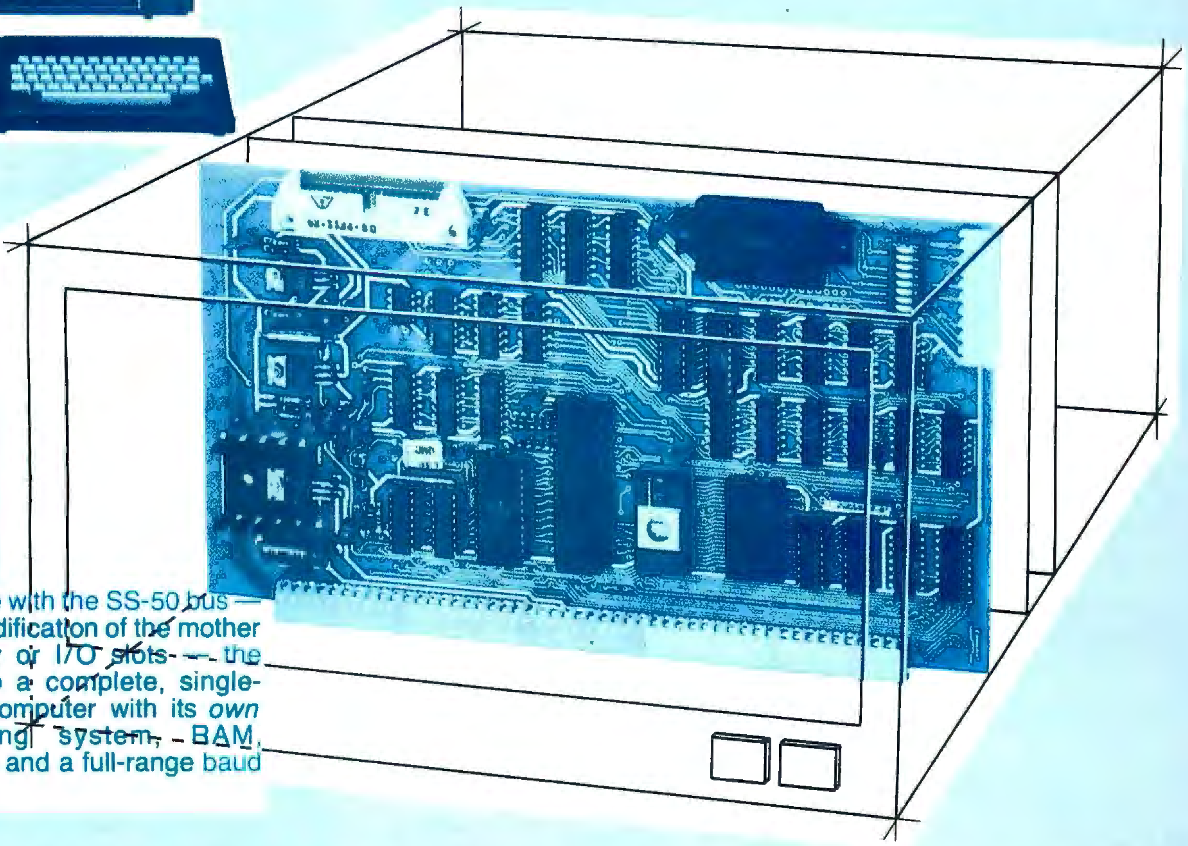

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Although PSYMON™ includes a full complement of operating system commands and 15 externally callable utilities, what really sets PSYMON™ apart is its easy hardware adaptability and command extensibility.

For hardware interfacing, you merely use simple, specific device driver routines that reference a table of parameters called a Device Control Block (DCB). Using this technique, interfacing routines are independent of the operating system.

The basic PSYMON™ command repertoire may be readily enhanced or modified. When PSYMON™ first receives system control, it initializes its RAM area, configures its console and then 'looks ahead' for an optional second ROM which you install in a socket provided on the SBC/9™ card. This ROM contains your own routines that may alter PSYMON™ pointers and either subtly or radically modify the PSYMON™ command set. If a second ROM is not installed, control returns immediately to PSYMON™

- Provision for multi-address, 8-bit bidirectional parallel I/O data lines for interfacing to devices such as an encoded keyboard.
- A serial interface Reader Control output for a cassette, tape punch/reader or similar device.
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- On-board devices which are fully decoded so that off-card devices may use adjoining memory space.
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The SBC/9™, complete with PSYMON™ in ROM, 1K of RAM and a comprehensive users manual™ costs just $199.95.

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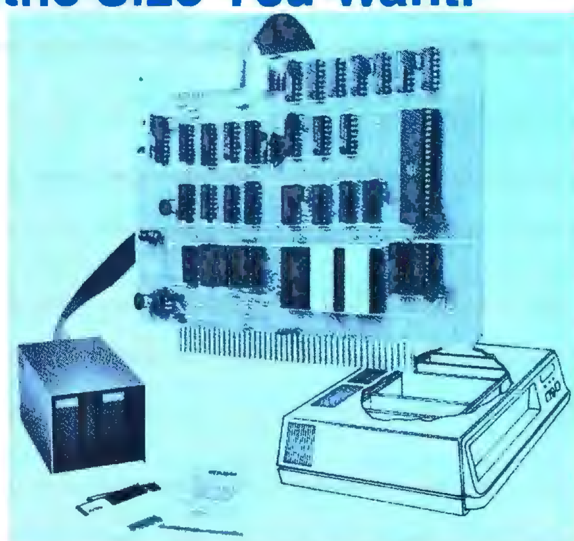
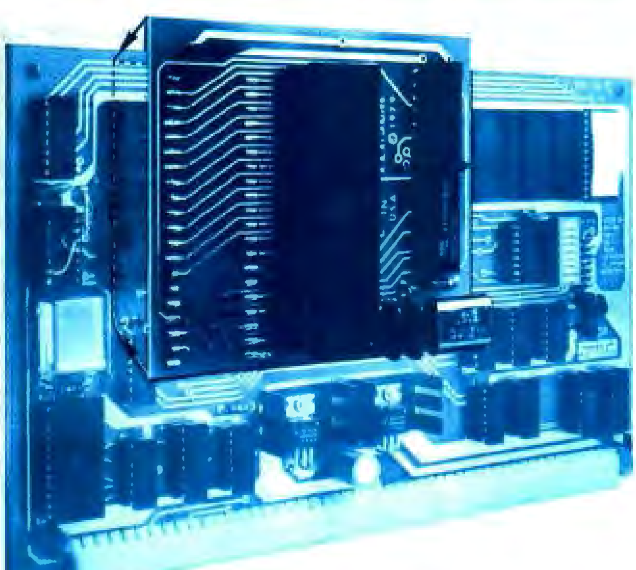


EXORciser Bus LFD-400EX,™ -800EX™ Systems*



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Although designed with the SWTP 6800 owner in mind, this upgrade adapter may also be used with most other 6800 and 6802 MPUs. The adapter is supplied assembled and tested, and includes the 6809 IC, a crystal, other essential components and user instructions. Restore your original system by merely unplugging the adapter and a wire-jumpered DIP header, and re-inserting the original components. Also available for your upgraded system is PSYMON™ (Percom SYstem MONitor), the operating system for the Percom 6809 single-board computer. PSYMON™ on 2716 ROM costs only $69.95. On diskette (source and object files), only $29.95.

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- Select 30, 60 or 120 bytes per second cassette interfacing; 300, 600 or 1200 baud data terminal interfacing.
- Optional mod kits make CIS-30+ work with any microcomputer. (For MITS 680b, ask for Tech Memo TM-CIS-30+-09.)
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Prices: Kit, $79.95; Assembled, $99.95. Prices include a comprehensive instruction manual. Also available: Test Cassette, Remote Control Kit (for program control of recorders), IC Socket Kit, MITS 680b mod documentation and Universal Adapter Kit (converts CIS-30+ for use with any computer).

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6800/6809 SOFTWARE

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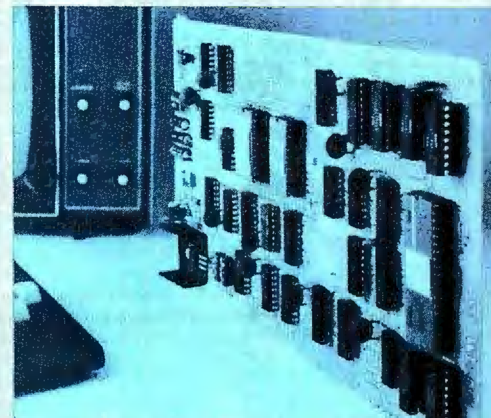

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WINDEX™ is a fast video display driver program for the Electric Window™. WINDEX™ also features: program and keyboard control of character generators • displayable control characters — under program control • automatic scrolling • a driver routine for the parallel input keyboard feature of the Percom 6809 Single-Board Computer, the SBC/9™ • auto-linking to PSYMON™, the ROM operating system for the SBC/9™ • Prices: ROM version: $39.95; LFD-400™ compatible diskette (source and object files): $29.95.

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See full page ad elsewhere in this magazine for all of the SBC/9™ features.

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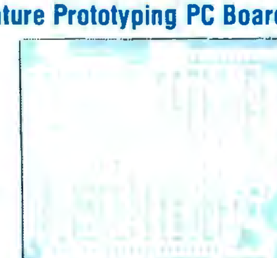
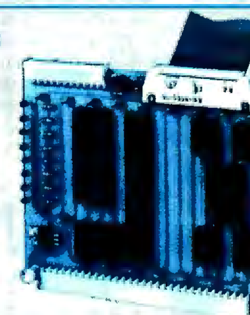
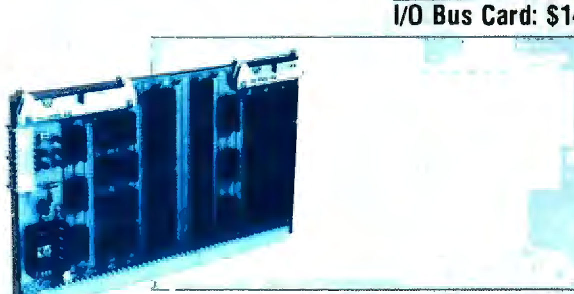




I/O Bus Card: $14.95



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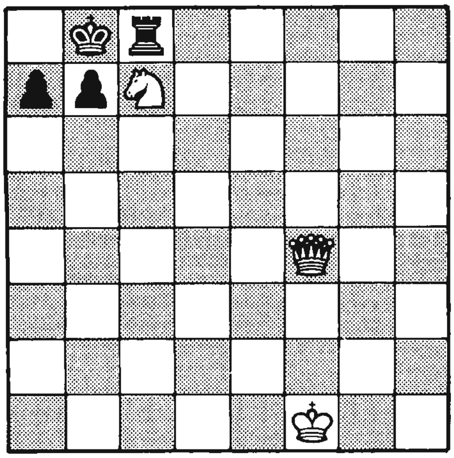
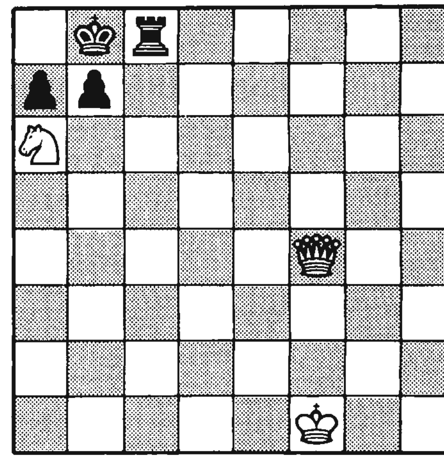
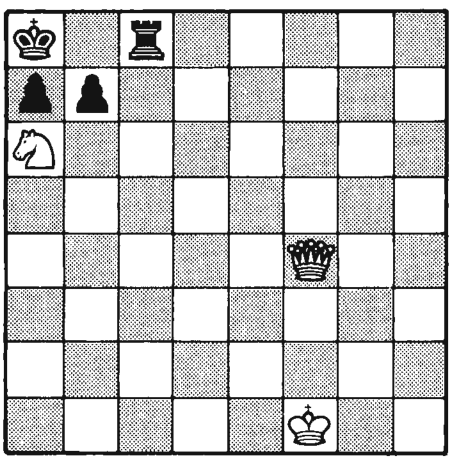
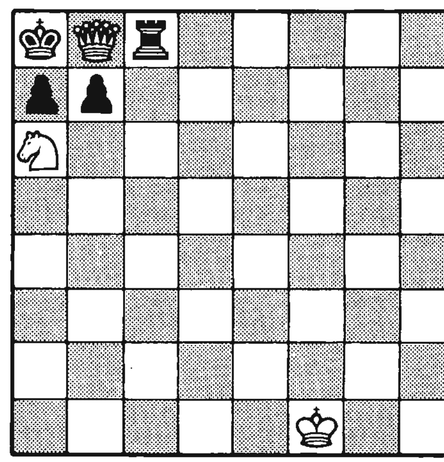


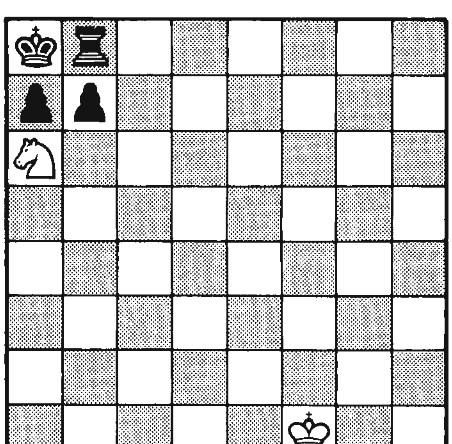


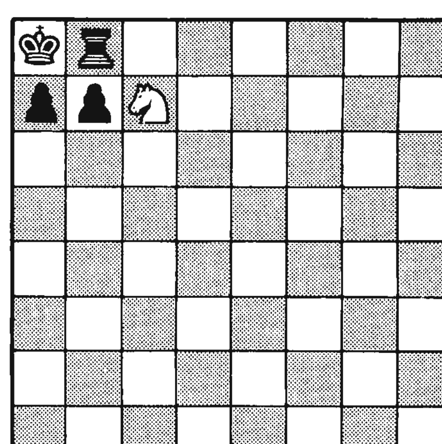
IT IS WHITE'S TURN TO MOVE, AND..............WHITE CHECKS WITH BOTH QUEEN AND KNIGHT. BLACK IS FORCED........





....TO MOVE INTO THE CORNER, AND...........NOW WHITE SACRIFICES THE QUEEN.





THERE IS NOTHING THAT BLACK CAN DO BUT TO TAKE THE QUEEN.........

....WHEREUPON WHITE GIVES CHECKMATE.

Figure 2: *The sequence of moves that White makes to capture Black's King . . . CHECKMATE!*

a PERCOM SAMPLER

For your SS-50 bus computer — the CIS-30+

- Interface to data terminal and *two* cassette recorders with a unit only 1/10 the size of SWTP's AC-30.
- Select 30, 60, or 120 bytes per second cassette interfacing, 300, 600 or 1200 baud data terminal interfacing.
- Optional mod kits make CIS-30+ work with *any* microcomputer. (For MITS 680b, ask for Tech Memo TM-CIS-30+—09.)
- KC-Standard/Bi-Phase-M (double frequency) cassette data encoding. Dependable self-clocking operation.
- Ordinary functions may be accomplished with 6800 Mikbug™ monitor.
- Prices: Kit, $79.95; Assembled, $99.95.

Prices include a comprehensive instruction manual. Also available: Test Cassette, Remote Control Kit (for program control of recorders), IC Socket Kit, MITS 680b mod documentation, Universal Adaptor Kit (converts CIS-30+ for use with any computer).
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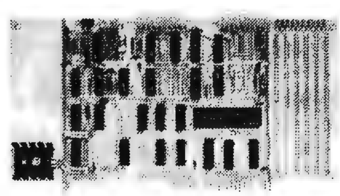
- Five-screw case design virtually precludes deformation during assembly.
- Price: $2.49.



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- Optional firmware (2708 EPROM) Operating System available.
- Prices: kit, $99.95; assembled, $129.95.

Prices include a comprehensive instruction manual. In addition to the EPROM Operating System, a Test Cassette, Remote Control Kit (for program control of recorders), and an IC Socket Kit are also available.

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Text continued:

(capturing the King with his Queen).
- If Black plays anything else, then White can play either NxK or QxK.

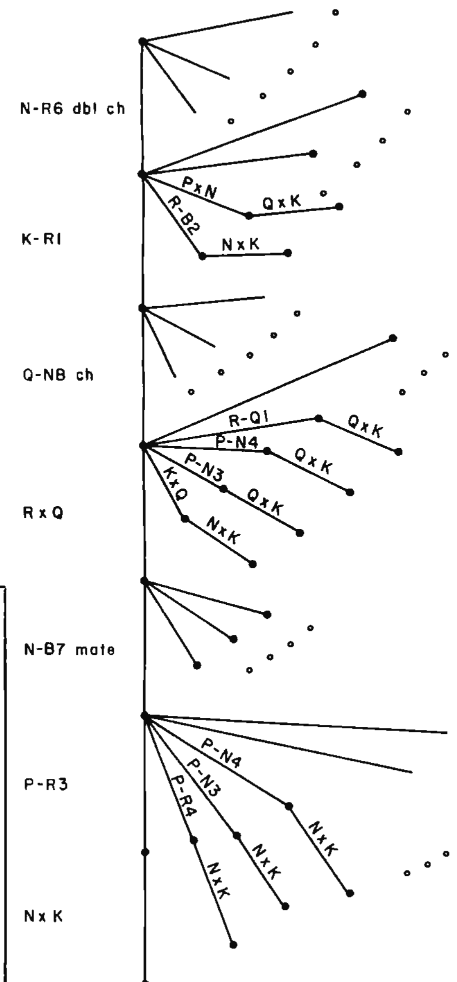
You might argue that the computer does not need to perform all of this analysis, because there is an old rule that states when you are in double check, you have to move your King—there is no other way out. This is perfectly true, but how do you know that you are in double check in the first place, without a similar analysis? It is easier to run through all of the moves, as described above, and verify that, in every case but one, Black's King would be captured. Additionally, look at the next position. Black does play K-R1, and now White plays Q-N8 check. This time Black is not in double check, but his next move is still forced, and Black's King can be captured in two different ways if he does not make the move he is forced to make. Specifically:

- If Black plays KxQ (capturing with the King instead of with the Rook), then White plays NxK.
- If Black plays P-N3 (or any other move than RxQ or KxQ), then White plays QxK.

When Black plays RxQ, White plays N-B7, which is checkmate. But the computer's job is still not finished. How can you tell that this is checkmate? The only way to tell is to look at all of Black's possible moves and make sure that White can capture Black's King in each case. From the computer's point of view, the game is never over until the King is actually captured.

A diagram of the analyses that have been carried out so far would look like figure 3. Each point (dot) in this figure denotes a position of the board. The lines between board positions denote moves. The actual moves that have been made are at the left, but there are other moves which were not taken. In Black's case, each of these led to Black's King being captured. In White's case, they were simply other possible moves that were not made because White has a way, as shown, of winning the game. This diagram is called a *game tree*.

Figure 3: *An illustration of the game tree diagram. A complete game tree diagram would enumerate all possible moves so that the optimum move could be chosen.*



The game tree of figure 3 is a bit hard to visualize because there are so many possible moves. Therefore, in order to illustrate the processing of game trees by computer, I have drawn a simplified game tree in figure 4. In this game tree there are only two possible moves for White at each point, and only two possible moves for Black. This will almost never be the case in a real game situation; here it allows the tree to fit easily on one piece of paper, so that it can be readily visualized. Like any tree, this tree has leaves, branches, and a root; in this case A, B, C...through P are the leaves, 5 is the root, and all of the other nodes are branches.

In any game tree, the first question you must ask is whether or not it is complete. A game tree is complete if every one of its leaves corresponds to the end of the game. In figure 3, all leaves that are shown correspond to the end of the game (the King is captured), but there are some other leaves, not shown, that do not have this property. If a game tree is complete, it should be obvious that we can tell who ought to win, and the winning strategies. Suppose that the leaves B, L, A, C, and K represent a win for Black, and all other leaves represent a win for White. White (moving first) can win by moving to branch 4. Black will move to branch 1, and White now moves to branch U, winning regardless of Black's move (moving to leaf I or J).

Furthermore, this is the only winning strategy for White. If White's first move is to branch 3, then Black moves to branch Y, and Black now wins, no matter what White does (moving to branch Q or R). If White moves to branch V on his second move, then Black wins by moving to either K or L. This state of affairs will not always hold. There are positions in which White can win no matter what his first move is (suppose, for example, Black's winning positions were B, L, A, E, K...figure it out for yourself). There are also positions in which White cannot win, no matter what his first move is. If Black's winning positions are B, L, I, C, and K, and White starts by moving to 3, then Black moves to Y, whereas if White starts by moving to 4, Black moves to 1. In either case, Black can eventually win.

Now suppose that the game tree is not complete. This is presumably because it is so large that you would run out of memory if you tried to store the complete tree, so you would only store part of it. In this case it is still quite possible that there is a winning strategy for one player or the other. Suppose that Black's winning positions are B, L, I, C, and K, as in the last of the three examples above, but the other leaves of the tree are not winning positions for either White or Black. (In fact, these are not really leaves; if I had room to keep more of this game tree, I could consider further moves beyond each of these points.) It is clear that Black can still

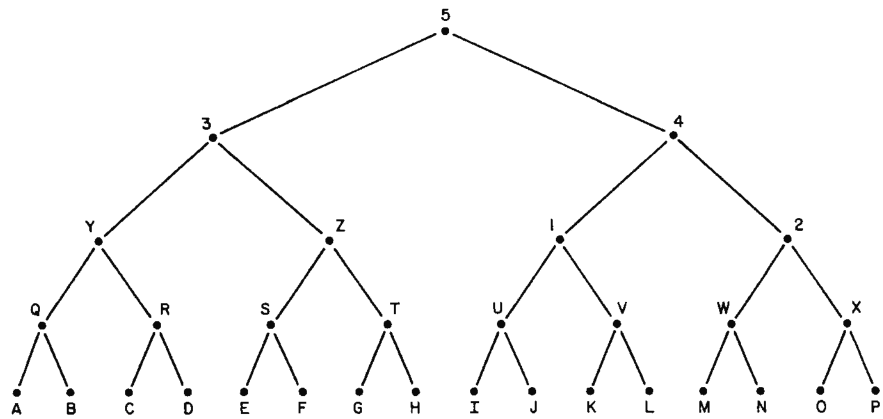


Figure 4: *Simplified version of the game tree that assumes each player has only two possible moves.*

win, no matter what White does, and for exactly the same reason as before.

In most cases, however, the game tree will be far from complete. In chess, for example, you might be in the middle of the game, and neither White nor Black can win the game in the next twenty-five moves. You can still use game trees, but in a slightly different way. The first thing to do is code your knowledge as to when one position is better than another in terms of material gained and lost. For example, if White captures a pawn and loses a Bishop, or captures a Knight and loses a Rook, then Black is obviously ahead. But what if White captures the Queen and loses both Rooks? Is that good or bad? What if White captures two pawns, but loses a Knight?

The usual pawn and piece values are: Queen = nine pawns, Rook = five pawns, Bishop and Knight are three pawns apiece. Greatly improved tables of values have been constructed; table 1 is a reprint of values (in abridged form) from R M Hyatt, the author of a chess program called BLITZ. Through the use of such a table, you can derive, for any position, a total numerical score that represents the value of that position. The function which computes this score is called the *evaluation function* corresponding to the given table.

You might think that with such an evaluation function there would be no further need for game trees. You could simply try all of the possible moves, and then choose the one with the largest value of the evaluation function. This, however, would lead to a very bad chess-playing program, rather like someone who had been playing for only a few months. The reason, of course, is that the evaluation function is only an approximation. It is very easy to lose a piece after you have made what seems to be the best move according to your evaluation function, because you have not looked far enough ahead. The best game programs use a combination of game trees and an evaluation function, together with the special technique of *alpha-beta pruning*, the subject of this article.

Once more I will set up an artificially small and simple game tree, in order to illustrate how this works. Consider the game tree of figure 5, which is exactly the same as the game tree of figure 4 except that a value of the evaluation function at each of the leaves of the tree has been specified. The evaluation function at the branches has *not* been specified, because this will be computed in a different way. Specifically, look at the leaves A and B. Since the value of the function is 26 at A, and 37 at B, you can conclude that, since it is Black's turn to play, at the branch Q Black will play to branch A. (This move assumes that the higher the value of the evaluation function, the better the position is for White, and the worse

the position is for Black. Black will make the move that gives the *lower* evaluation function value. Again, this is only an approximation, but it becomes a better one as the tree gets larger.)

In the same way you may conclude that, since it is Black's turn to move, at branch R Black will move to branch D, since 28 is less than 29. Let us go back to branch Y. Here it is White's turn to play, and White wants to make the move that results in the *highest* value of the evaluation function. Does this mean 37, the largest of the four values at A, B, C, and D? No, it does not. If White plays to Q, Black will play to A. If White plays to R, Black will play to D. Therefore, you should compare only A and D. Since 28 is larger than 26, White should play from Y to R.

This potential source of confusion suggests that you should mark the nodes Q, R, S, T, and so on, with the *expected* evaluation function values (ie: the values that would ensue if Black makes the best play, in a highly approximate sense, on the next move). In this case Q would receive the value 26, R would receive the value 28, and in general each node would receive the *lowest* of the values of the nodes below it. This, of course, is only because it is Black's turn to move. On the next level up, it is White's turn to play, and you can mark each of the nodes Y, Z, 1, and 2 with the *highest* of the values of the nodes below it, because White now wants to make the ultimate value of the evaluation function as large as possible. Continuing this all the way to the top of the tree, you get the situation illustrated in figure 6. The expected value for White at the top of the tree is 25. By following the figure 25 down through the tree, you will see that, at this point in the game, White is expected to move to node 4, Black to reply by moving to node 1, White to then move to U, and Black to play to J.

This does not, of course, have to be what actually happens in the game. Black might be a poor player, and play to node 2 instead of node 1, or Black might discover, upon looking more moves ahead, that node 2 is actually a better play than node 1. This tends to happen in actual games. As you look further ahead (ie: as you consider trees with greater and greater numbers of levels), expected moves at all levels, even the top level, can change.

At this point a very important question is raised: is it really necessary to generate this whole tree? It would be nice to find certain nodes that do not have to be constructed.

Consider the situation at node Z. White has two possible moves: one to node S and one to node T. At node S, White gets a score of at least twenty-two on the next move. Is this a better move for White than the move to node T? To determine the answer, look at node T. The first thing you will see is that if White moves to node T, then Black can move to node G. If Black does that, White ends up with a score of only thirteen. By this point you already know what White should not move to node T because he can do better by moving to node S.

Now look at node H. If White moves to node T, then Black could also move to node H, leaving White with a score of eleven. This is a better move for Black than the move to node G. The point is that *this does not matter*. As soon as you look at node G, you know that White should not move to node T. When you are aware of this it does not matter what

Capturing the Queen	9000
Capturing a Rook	5000
Capturing a Knight or Bishop	3000
Capturing a pawn	1000
Doubled pawns	– 30
Tripled pawns	– 100
Isolated pawns	– 90
Two pawns next to each other	10
One pawn guarding another	36
Knight on opponent's side of the board	40
Same, with pawn guarding it	60
Bishop on strong diagonal	24
Rook on open file	60
Doubled Rooks on open file	170
Rook behind passed pawn	60
Rook on seventh rank, two unmoved opposing pawns	100
Rook on seventh rank, three unmoved opposing pawns	200
Rook on seventh rank, four unmoved opposing pawns	300
Rook moved before castling has occurred	– 200
King moved before castling has occurred	– 200
Castled King	300
Piece or pawn moved twice in the opening	– 30
Taking two moves instead of one to get to a square	– 30
Knight never moved	– 36
Knight in front of King's pawn or Queen's pawn	– 120
Bishop never moved	– 20
Bishop in front of King's pawn or Queen's pawn	– 120

Table 1: *An abbreviated table of the approximate numerical values assigned to a variety of possible moves.*

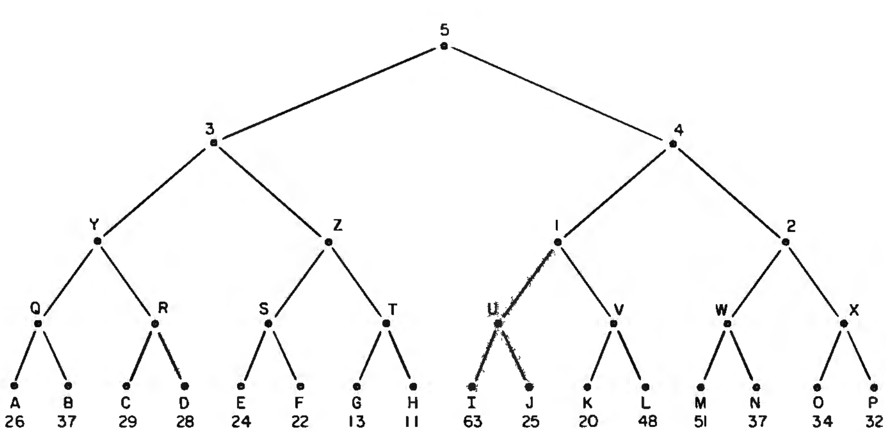


Figure 5: *Same game tree as that shown in figure 4, along with a specification of the evaluation function at each leaf of the tree.*

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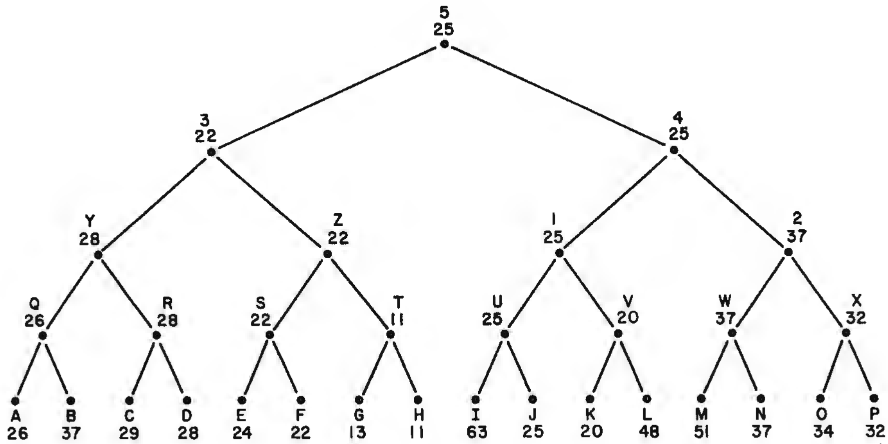


Figure 6: *A more informative version of the game tree shown in figures 4 and 5. Here the* expected *evaluation function values are shown at each of the nodes.*

score node H has—in fact, you do not have to generate node H at all. This kind of logic can be applied to either

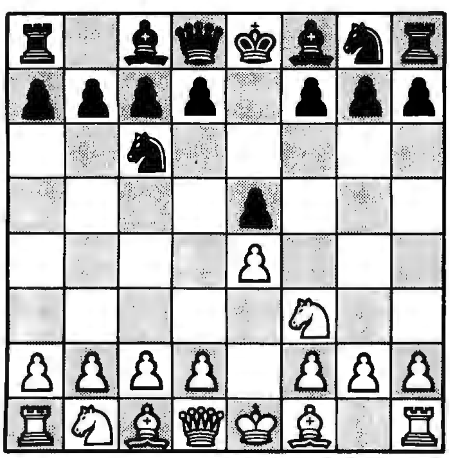


Figure 7: *A simple example to illustrate the principle of alpha-beta pruning. It is now White's turn to move. An obvious bad move would be NxP. Black's reply would be NxN, and White would have captured a pawn but lost a Knight.*

player; it is called *alpha cutoff* in a case like this, where it is White's original move that is being considered (as at node Z here). It is called *beta cutoff* when it is Black's original move that is being considered. *Alpha-beta pruning* is the combination of alpha cutoff and beta cutoff within the general framework described here.

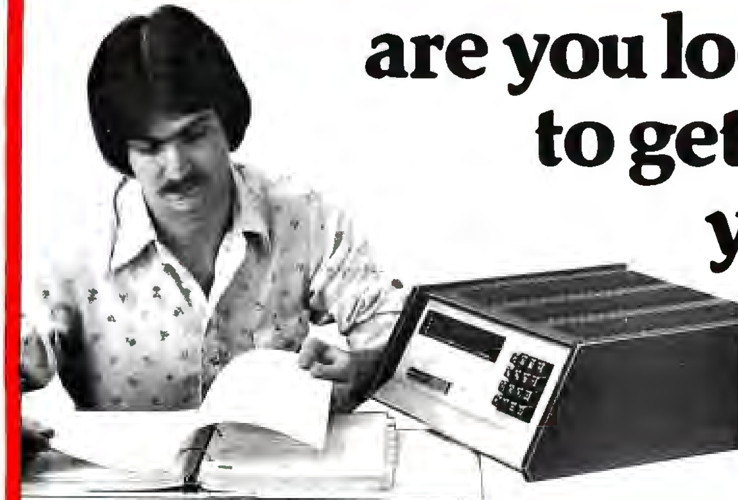
For an example of beta cutoff, look at node 4. It is Black's turn to move. By considering node 1 and all the nodes beneath it (that is, nodes U, V, I, J, K, and L), you will note that Black can eventually expect a score of twenty-five if he moves to node 1. The next question is whether or not a move to node 2 would be any better for Black. Suppose Black moves to node 2, and that White moves to node W. By analyzing the nodes (M and N) beneath node W, you will find that Black can achieve a score of either fifty-one or thirty-seven. Black would naturally choose thirty-seven, that is, node N. But if that is the best that Black can do, then the answer to the original question must be no; that is, a move from node 4 to node 2 would *not* be any better for Black than a move to node 1. Once you know this, it is not necessary to consider node X at all and, more important, you do not have to consider nodes O or P either. In other words, you have pruned not just a single leaf, but a branch with leaves below it.

An informal example of alpha-beta pruning is given in figure 7. Here it is White's turn to move. White has many possible moves, but an obvious *bad* move for White is NxP. In order to determine that this move is bad, it is not necessary to figure out Black's best move; it is only necessary to note that Black can move NxN. Any other possible moves need not be considered as long as White has *any* move that does not result in the loss of a piece, and as long as NxP is not really a viable sacrifice. ■

Glossary

alpha-beta pruning: *In order to guarantee a winning strategy an entire tree search of a complete game tree would be necessary. Alpha-beta pruning is an algorithm devised to optimize the use of game trees by reducing the number of branches needed to be searched.*

game tree: *A graphic representation of the decision making process involved in a sequence of moves between two opponents. A complete game tree is a representation in which all the terminal nodes correspond to the end of the game.*



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Interfacing the PET to a Line Printer

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Introduction

From both software and hardware points of view, this article presents a design example for interfacing the 8-bit user port on the Commodore PET 2001 personal computer to an external device. The design example will show how the user port may be used to develop a handshake interface to a line printer. We shall begin with a brief discussion of the programmable features of the user port.

Peripheral Interface Port

The 8-bit port, described in the PET user manual, is actually a part of the MCS6522 peripheral interface adapter (PIA), manufactured by MOS Technology. The 6522 is a general purpose I/O (input/output) device, configured as two 8-bit I/O ports A and B. It provides handshaking logic associated with parallel data transfers occurring through I/O port A. Counter and timer, and elementary serial I/O logic are associated with the MCS6522 port B. In the PET 2001, most features of port B are reserved for internal use, leaving port A as the only peripheral interface port available to the user.

To the user, the MCS6522 peripheral interface adapter appears as sixteen contiguous memory locations. Table 1 identifies the sixteen addressable locations of the 6522. Locations of direct concern to the PET user (for interfacing to port A) are in italic characters.

PET Memory Location	Function Provided by the 6522
59456	Output register for I/O port B.
59457	Data register for port A with handshake.
59458	I/O port B data direction register.
59459	I/O port A data direction register.
59460	Read timer 1 counter (low-order byte). Write to timer 1 latch (low-order byte).
59461	Read timer 1 counter (high-order byte). Write to timer 1 latch (high-order byte).
59462	Access timer 1 latch (low-order byte).
59463	Access timer 1 latch (high-order byte).
59464	Read low-order byte of timer 2 and reset counter interrupt. Write to low-order byte of timer 2 but do not reset interrupt.
59465	Access high-order byte of timer 2; reset counter interrupt on write.
59466	Serial I/O shift register.
59467	Auxiliary control register.
59468	Peripheral control register.
59469	Interrupt flag register.
59470	Interrupt enable register.
59471	Data register for I/O port A without handshake.

Table 1: *Internal registers of the 6522 peripheral interface adapter given in terms of addresses in the PET memory address space. Addresses that are of direct concern to the PET user (for interfacing to port A) are shown in italics.*

The characteristics and functions of the interface lines on the peripheral interface port A are determined by the operating mode selected under program control. Two modes of operation may be selected under program control: *basic input/output* without handshake, *strobed input/output* with handshake. By selecting the correct operating mode for the data direction register (this may be done using the BASIC statement POKE 59459,X where X=0 for input and 1 for output), interface lines may be configured to fulfill specific interface requirements. Device strobes may be easily generated by software without utilizing external logic by

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Listing 1: *PRINTSCREEN, a program in BASIC which provides a hard copy of any characters displayed on the PET's video display. An image of the text appearing on the screen is sent to the printer. Note that here the program was used to create its own listing. The data transfer rate is about 6 characters per second.*

```
5 REM FILENAME "PRINTSCREEN"
 10 REM OUTPUT DATA TO EXTERNAL DEVICE
 15 REM  HANDSHAKE WITH LINE PRINTER
 16 REM CB2 FOR DATA STROBE;TO DEVICE
 18 REM CA1 FOR ACKNOWLEDGE;FROM DEVICE
 20 POKE 59459,255:REM DIRECTION OUT
 25 GOSUB 100:REM HANDSHAKE NOT READY
 34 FOR I=1 TO 25 :REM SCAN ROWS
 35 FOR J=1 TO 40 :REM SCAN COLUMNS
 36 V=PEEK(32767+J-1+40*(I-1))
 37 IF V>64 THEN V=V+32 :REM LOWER CASE
 38 IF V<=26 THEN V=V+64:REM UPPER CASE
 39 IF V=128 THEN V=V-96:REM SPACE
 40 IF J=1 THEN 180 :REM PRINT SPACE
 50 POKE 59457,V AND 127:REM SEND VALUE
 51 GOSUB 150:REM READY TO OUTPUT
 52 GOSUB 100:REM NOT READY
 56 ACK=PEEK(59469)AND2:REM INT FLG REG
 58 IF ACK <> 2 THEN 56:REM ACKNOWLEDGE
 70 NEXT J

READY.

RUN



READY.
LIST 71-97

 72 POKE 59457,13:REM CR
 73 GOSUB 150:REM READY
 74 GOSUB 100:REM NOT READY
 76 POKE  59457,10:REM LF
 78 GOSUB 150:REM READY
 80 NEXT I
 82 GOSUB 100
 84 POKE 59457,128 :REM STOP PRINT
 85 PRINTCHR$(147) :REM CLEAR SCREEN
 86 END

READY.
RUN
```

```
READY.
LIST 98-199

 98 REM      SUBROUTINES
 100 REM SET CB2 TO LOGIC 1:NOT READY
 110 POKE(59468),PEEK(59468) OR 224
 120 RETURN
 150 REM SET CB2 TO LOGIC 0 :REM READY
 160 POKE (59468),PEEK(59468)AND31OR192
 170 RETURN
 180 V=32 AND 127 :REM SPACE
 182 GOSUB 150:REM READY
 184 GOSUB 100:REM NOT READY
 186 GOTO 50

READY.
RUN



READY.
POKE 59468,14

READY.
LIST 200-

 200 PRINT" Upper and Lower Case "
 240 PRINT"ABCDEFGHIJKLMNOPQRSTUVWXYZ"
 250 PRINT"abcdefghijklmnopqrstuvwxyz"
 300 PRINT" These listings were made on
 310 PRINT" TI Model 810 printer"
READY.
RUN 200
 Upper and Lower Case
ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz
 These listings were made on
 TI Model 810 printer

READY.
RUN 5
```

changing the contents of decimal location 59468 (the peripheral control register).

Interfacing to a Line Printer

This example demonstrates how the PET parallel port can be interfaced to a line printer. The first step in the design is to examine the specification for the printer, and to identify the control and data signals which must be supported by the interface. Figure 1 is a block diagram of the interface design. A *data strobe/acknowledge* interface is supported. The ACKNLG signal notifies the PET that a character transferred to the printer by a data strobe has been accepted. After ACKNLG is issued, the printer is considered idle.

Software Driver

The software driver implemented for the example was specifically

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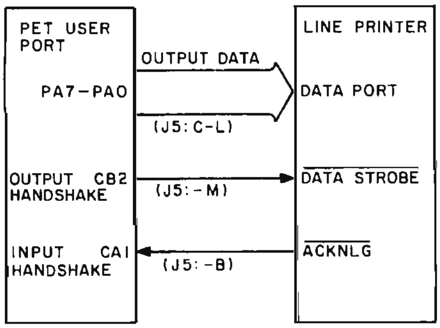

PA7–PAO:	Output data used to support printer data port.
DATA STROBE:	Signals to printer that data is available at the printer data port.
ACKNLG:	Signals to the PET that the printer has accepted the data.
J5: –A	PET user port connector J5–Pin A.

Figure 1: *Block diagram of printer interface using the PET user port (MCS6522 port A). J5 is the PET user port connector; pins are labeled alphabetically. Pin assignments at the line printer are not given since they vary between different manufacturers.*

designed to generate a hard copy listing of the image displayed on the PET screen.

The PET video display presents 1000 characters arranged in twenty-five lines of forty characters each. The display is continuously refreshed from a section of memory called *display memory*. By direct access to these 1000 locations, and using the programmable I/O port connected to a line printer, you can generate a hard copy of the screen image. The flowchart of the procedure is shown in figure 2, and a program listing is included in listing 1. The program is called PRINTSCREEN. It scans the twenty-five lines on the PET screen and transmits the data displayed there to the user port, one character at a time. You will observe that transferring data to the parallel port using BASIC is relatively slow. In this example, the data transfer rate is about six characters per second.■

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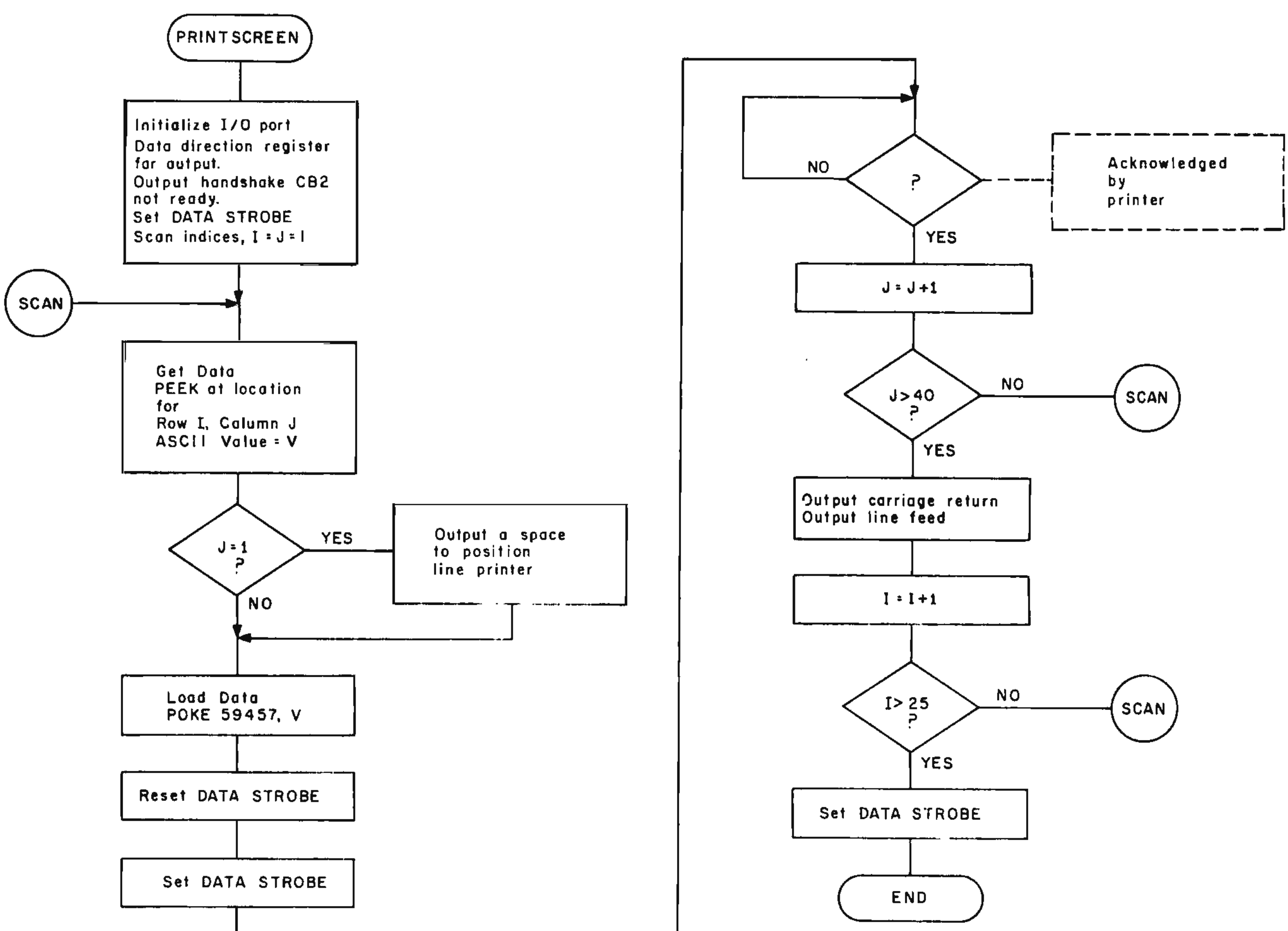

Figure 2: *Flowchart of the BASIC program PRINTSCREEN. This program transmits images of text on the PET video display screen to the line printer.*

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A Spacecraft Simulator

Gary Sivak
19 Madison Trail
Hopatcong NJ 07843

This article describes a BASIC program that enables the user to design and put into orbit a multistage spacecraft launched from Earth-based conditions. By asking for engine throttle settings, thrust angles, and firing times, your computer puts you at the controls of a multistage spacecraft of your own design as you pilot it from the Earth's surface into orbit. Continuous data displays of the user's status after each maneuver are presented, as well as arrays of altitude and range information for possible plotting at the end of the mission. The following is a description of the program operation.

The program first asks for and verifies all ship design parameters, the first being the number of stages. Then the iteration time (dt) in seconds and the height in miles of the desired orbit are required. During each iteration, the computer calculates formulas of the form:

$$V_{final} = V_{initial} + \text{acceleration} \times dt \quad (1)$$

The final values are then taken as the initial ones for the next iteration. An iteration time evenly divisible into one second is recommended; 0.1 seconds is suggested for faster than real-time computation. A figure of 0.01 seconds, for example, will give a slightly better mathematical accuracy but at the expense of ten times more processing time.

The craft is assembled from top down, the weight of the payload in

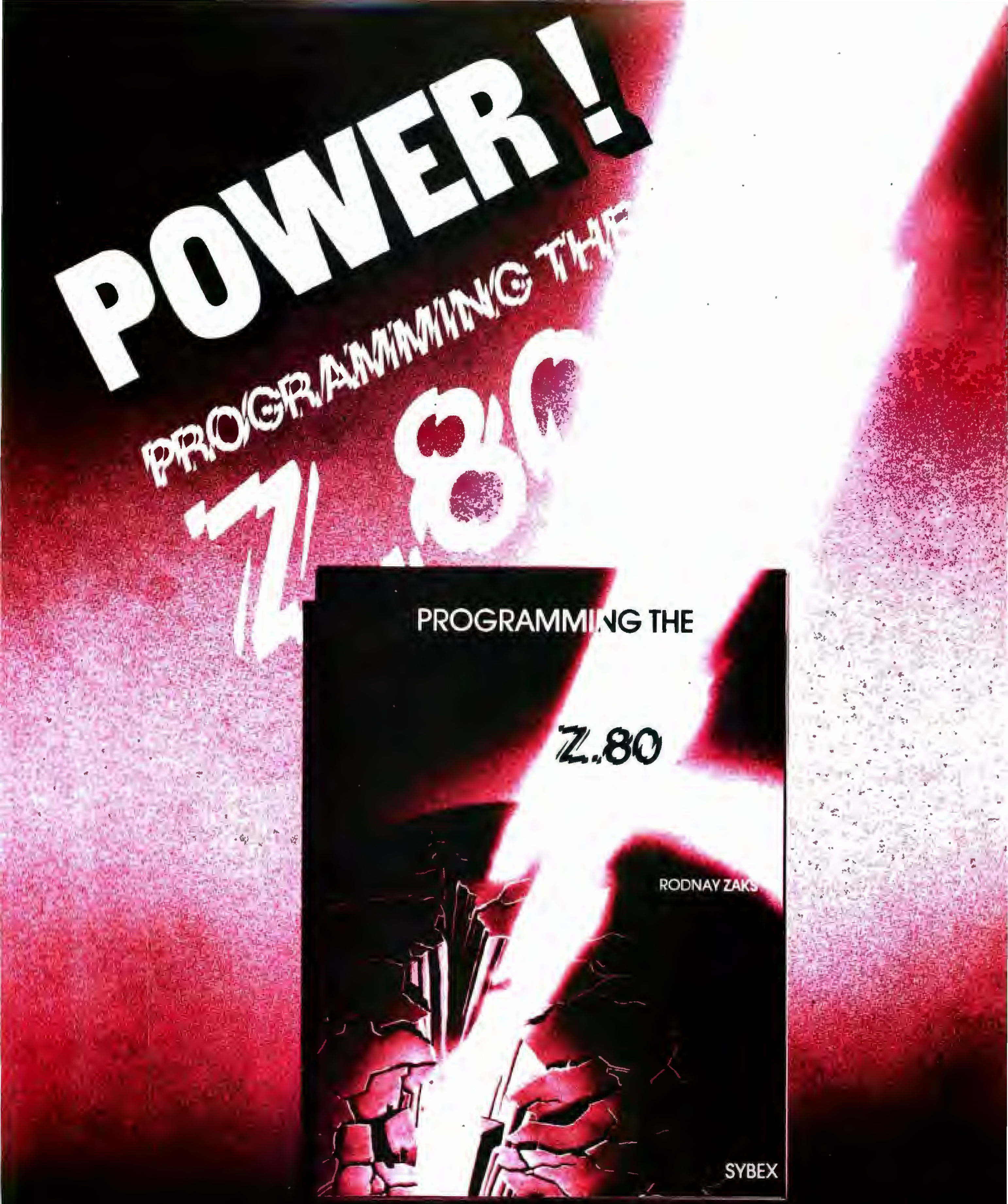
Text continued on page 108

Listing 1: *BASIC listing of the rocket launcher program.*

```
                    ROCKET LAUNCHER PROGRAM

10 DIM A(100),A0(100),A1(7),A2(7),A3(6),A4(6)
20 PRINT "DESIGN AND ORBIT A SPACE SHIP. TYPE NO. STAGES UP TO 6. "
30 INPUT A5
40 PRINT "VERIFICATION, ";A5;" STAGES."
50 A6 = A5 + 1
60 PRINT "ENTER ITERATION TIME IN SEC., AND ORBIT HEIGHT IN MI. "
70 PRINT ".1 SEC. IS OK AND .01 BETTER, BUT WITH MORE CPU TIME. "
80 INPUT A7,A8
90 PRINT "VERIFICATION, ITERATION TIME ";A7;", ORBIT HEIGHT ";A8
100 PRINT "ENTER PAYLOAD WEIGHT IN POUNDS. "
110 INPUT A2(A6)
120 A1(A6) = 0.0
130 PRINT "VERIFICATION, PAYLOAD WEIGHT, ";A2(A6)
140 FOR A9 = 1 TO A5
150 B = A6 - A9
160 B0 = B + 1
170 PRINT "ENTER STAGE ";B;" FUEL AND HULL WEIGHTS IN LBS. "
180 INPUT A1(B), A2(B)
190 PRINT "STAGE ";B;" FUEL ";A1(B);" LBS., HULL ";A2(B);" LBS. "
200 A2(B) = A2(B) + A2(B0) + A1(B0)
210 B1 = A2(B) + A1(B)
220 PRINT "ENTER STAGE ";B;" THRUST AT LEAST ";B1;" .LBS. "
230 INPUT A3(B)
240 PRINT "STAGE ";B;" THRUST, ";A3(B);" LBS. "
250 PRINT "ENTER SPECIFIC IMPULSE OF STAGE ";B;" FUEL/OXIDIZER. "
260 PRINT "THIS IS THE THRUST-TO-BURN RATE RATIO. "
270 PRINT "FOR GASOLINE =250, PEROXIDE =300, LIQUID HYDROGEN =500. "
280 INPUT A4(B)
290 PRINT "VERIFICATION, STAGE ";B;" SPECIFIC IMPULSE ";A4(B)
300 NEXT A9
310 B2 = 10
320 B3 = B2 * A7
330 B4 = 360
340 B5 = B3 / 100.0
350 B6 = 5280. * .3048
360 B7 = 6.67E-11 * 5.983E24
370 B8 = ATN(1.) / 45.
380 B9 = 90.
390 C = 1.0
400 C0 = SQR(B7/9.80665)
410 C1 = C0
420 C2 = SQR(B7/(C0+B6*A8)) / .3048
430 C3 = 0.0
440 C4 = 0.0
450 C5 = 0.0
460 C6 = 0.0
470 C7 = 0.0
480 C8 = 0.0
```

Listing 1 continued on page 108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Software with Manual / Manual Alone

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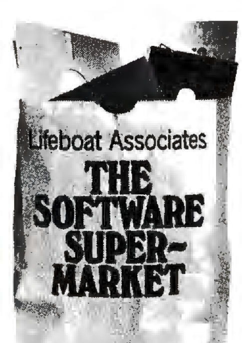

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Listing 1 continued:

```
490 C9 = 0.0
500 D = 0.0
510 D0 = 0.0
520 D1 = 0.0
530 D2 = 0.0
540 D3 = 0.0
550 PRINT "THE SHIP CAN SWIVEL ";B2;" DEG/SEC. "
560 PRINT "EARTH'S GRAVITY IS 32.174 FT/SEC/SEC. "
570 PRINT "FORWARD VELOCITY NEEDED FOR ORBIT ";C2;" FT/SEC. "
580 D = D + 1
590 D4 = A2(D) / 2.2046
600 D5 = A3(D) / A4(D) / 2.2046
610 D6 = A1(D) / 2.2046
620 D7 = D6
630 D8 = A3(D)/2.2046*9.80665
640 PRINT "IGNITION OF STAGE ";D;", ENTER THE STAGE NUMBER. "
645 INPUT X1
650 GO TO 1090
660 PRINT "ENTER THROTTLE SETTING IN %, FROM 0 TO 100, "
670 PRINT "THRUST ANGLE IN DEG. FROM -";B4;" TO ";B4
680 PRINT "AND BURN TIME IN SECONDS. "
690 INPUT D9, E, E0
700 D9 = ABS(D9 / 100.0)
710 E1 = D9 * D8
720 E2 = D9 * D5 * A7
730 E3 = E2 / 100.
740 E4 = E0 - (A7 / 100.0 )
750 E5 = C5 * C1
760 E6 = 0.0
770 IF E0 = 0.0 THEN 1080
780 IF C1 < C0 THEN 1080
790 E6 = E6 + A7
800 E7 = D7 - E2
810 E8 = E1 / (D4 + (D7 + E7 ) / 2.0 )
820 IF E7 >= E3 THEN 850
830 E7 = 0.0
840 E8 = 0.0
850 IF ABS( E - B9 ) < B5 THEN 930
860 IF E < B9 THEN 890
```

Listing 1 continued on page 110

Text continued:

pounds being required first. For each stage, the computer then asks for the weights of the fuel and hull (or tanks), the maximum thrust desired, and the specific impulse of the fuel. To insure the possibility of achieving orbit, a fuel to hull weight ratio of 4 or 5 to 1 is suggested. A thrust of about 20 percent more than the minimum amount required to lift the ship is suggested, so that the ship has sufficient acceleration, even when heavily laden with fuel.

Specific impulse is a figure of merit for fuel performance, the thrust to burn-rate ratio. Suggested values for different fuels are given in the program. Knowing the thrust and specific impulse defines the burn rate, and knowing the amount of fuel on board designates how long it will last at full throttle expenditure. Next, a printout chart, to be described shortly, displays initial fuel, altitude, and the velocity status of the ship.

At this point, the flight begins; the user is in control, and must specify the throttle setting, firing angle, and burn time for each maneuver. The force on the ship (in newtons) is first computed from the throttle setting

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The business programmer will appreciate the versatile PRINT-USING capabilities which include dollar and asterisk fill, trailing minus sign, imbedded commas, and scientific notation. New string functions have been added for string searching (INSTR) and for creating a string which is the date (DATES$). DPEEK and DPOKE are 16-bit peek and poke type functions. The SCALE command has been included to eliminate the round-off errors typically encountered in binary math packages. The INCH$ function allows single-character input from the terminal. Programmer control of control C breaks is also included.

Overall, the Extended BASIC is the most complete BASIC offered for micro users and is only available on FLEX™ disk. A system with at least 32K of user space is recommended. Specify 8" or 5" media (5" 6800 is FLEX™ 2.0) and either the 6800 or 6809 version when ordering.

AP68-12	**6800 Extended BASIC**	**$100**
SP09-6	**6809 Extended BASIC**	**$100**

BASIC Precompiler

This program allows the creation of BASIC programs without the use of line numbers or restrictive two-character variable names. Alphanumeric line and subroutine labels may be used, as well as variable names of any length. Comment lines are marked with non-alphanumerics for easy readability. The output of the precompiler is in the standard BASIC compiled form. This allows applications programs to be written, precompiled, and then distributed in a non-source form. The precompiler can only be used with one of Technical Systems Consultants' BASICs. Specify 8" or 5" (5" 6800 is FLEX™ 2.0) when ordering.

AP68-13	**Single Precision 6800 Precompiler**	**$40**
AP68-14	**Double Precision 6800 Precompiler**	**$50**
SP09-7	**Single Precision 6809 Precompiler**	**$40**
SP09-8	**Double Precision 6809 Precompiler**	**$50**

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Listing 1 continued:

```
870 B9 = B9 + B3
880 GO TO 900
890 B9 = B9 - B3
900 E9 = B9  * B8
910 C4 = COS(E9)
920 C = SIN(E9)
930 F = E8 * C4
940 F0 = E8 * C
950 F1 = C5 + F * A7
960 C6 = ( C5 + F1 ) / 2.0
970 C7 = C7 + C6 * A7
980 F2 = F0 + C6**2 / C1  - B7 / C1**2
990 F3 = C8 + F2 * A7
1000 F4 = C1 + ( C8 + F3 ) / 2.0 * A7
1010 IF D9 <> 0.0 THEN 1030
1020 F1 = E5 / F4
1030 D7 = E7
1040 C5 = F1
1050 C8 = F3
1060 C1 = F4
1070 IF E6 < E4 THEN  770
1080 C3 = C3 +  E6
1090 D2 = D2 + 1
1100 A(D2) = ( C1 - C0 ) / .3048
1110 IF C9 >= A(D2) THEN 1130
1120 C9 =  A(D2)
1130 IF A(D2) >= 0.0  THEN 1150
1140 A(D2) = 0.0
1150 IF A(D2) < 400000.0  THEN 1170
1160 D3 = D3 + 1
1170 F5 = A(D2) / 5280.
1180 F6 = C8 / .3048
1190 F7 = F6 * 15./22.
1200 F8 = C5 / .3048
1210 F9 = F8 * 15./22.
1220 A0(D2) =  C7 / B6
1230 G = 100. * D7 / D6
1240 G0 = D7 / D5
1250 G1 = B7 / C1**2 - C6**2 / C1
1260 G2 = D8 / (D4 + D7) / .3048
1270 G3 = G2 * 15. / 22.
1280 G4 = G2 - ( G1 / .3048 )
1290 G5 = G4 * 15. / 22.
1300 G6 = G1 / .3048 / G2
1310 G7 = 100. * G6
1320 G8 = 90.0
1330 IF G6 >= 1.0 THEN 1350
1340 G8 = ATN( G6 / SQR( 1.0 - G6**2 ) ) / B8
1350 G9 = SQR( B7 / C1 ) / .3048
1360 H = 100. * F8 / C2
1370 H0 = 100. * A(D2) / ( A8 * 5280. )
1380 H1 = 100. * F8 / G9
1390 H2 = ( C2 - F8 ) / G2
1400 H3 = ( G9 - F8 ) / G2
1410 IF F6 = 0.0 THEN 1440
1420 H4 =  (A8*5280. - A(D2) ) / F6
1430 IF H4 <= 9999.99 THEN 1460
1440 H4 = 9999.99
1450 REM-TIMES OVER 9999.99 SET TO 9999.99 TO NOT EXCEED DISPLAY.
1460 IF D3 <> 1.0 THEN 1480
1470 PRINT "400K FT. ACHIEVED, YOU ARE IN VACUUM. "
1480 PRINT "FLIGHT TIME","FUEL LEFT","AT FULL THROT.","SHIP ANGLE"
1490 PRINT C3;"SEC,",G;"%",G0;"SEC,",B9;"DEG."
1500 PRINT "  "
1510 PRINT "ALTITUDE","ASCENT RATE","FORWARD V.","RANGE"
1520 PRINT A(D2);"FT.",F6;"FT/SEC",F8;"FT/SEC",A0(D2);"MI."
1530 PRINT F5;"MI.",F7;"MI/HR.",F9;"MI/HR."
1540 PRINT "  "
1550 PRINT "MAX ACCEL","MAX VERT ACCEL","ANGLE(C.A.)","THROT(C.A.)"
1560REM-ANGLE(C.A.), CRITICAL ANGLE FOR CONST. ASCENT AT FULL THROT.
1570REM-THROT(C.A.), CRITICAL THROT. OF CONST. ASCENT AT 90DEG.
1580 PRINT G2;"FT/S/S",G4;"FT/S/S","FULL THROT.","VERT. POS."
1590 PRINT G3;"MI/H/S",G5;"MI/H/S",G8;"DEG.",G7;"%"
1600 PRINT "  "
1610 PRINT H;"% ORBITAL VELOCITY",H0;"% ORBITAL HEIGHT."
1620 PRINT H1;"% VELOCITY NEEDED FOR ORBIT AT CURRENT ALTITUDE."
1630 PRINT "  "
1640 PRINT " "," ","TIME TO ACHIEVE:"
1650 PRINT "ORB. ALT.","ORB. VEL.","CUR. ALT. ORB. VEL."
1660 PRINT "AT CUR. RATE","AT FULL THROT.","AT FULL THROT."
1670 PRINT H4;"SEC.",H2;"SEC.",H3;"SEC."
1680 PRINT "  "
```

Listing 1 continued on page 111

and maximum specified thrust. Also, note that a firing angle of ninety degrees is vertically upward, and angles less than ninety degrees are to the right, or east, etc. A one hundred percent throttle setting at ninety degrees for fifteen or twenty seconds is suggested to gain altitude before beginning to swivel the ship to achieve horizontal orbital velocity.

The amount of fuel used during an iteration is simply the throttle setting, times the maximum burn rate, times dt. This amount, subtracted from the weight of the fuel at the beginning of an iteration, gives the amount remaining at the end. The amount of fuel available during an iteration is taken as the average of the amounts before and after. This is added to the weight of the tanks and the upper stages that the engines must lift, and is the instantaneous weight (in kilograms) of the craft. Dividing into the thrust force yields the current engine thrust acceleration A_t during the iteration, in meters per second per second (m/s²).

For a given firing angle, the horizontal and vertical components of this acceleration, a_{th} and a_{tv}, are taken. Horizontal velocities and the range are computed by:

$$V_{fh} = V_{ih} + a_{th} \times dt \qquad (2)$$

$$V_{avh} = (V_{ih} + V_{fh})/2 \qquad (3)$$

$$\text{range} = \text{range} + V_{avh} \times dt \qquad (4)$$

where, for a particular iteration, V_{ih} is the initial horizontal velocity, V_{fh} is the final horizontal velocity, and V_{avh} is the average of the two.

The total outward vertical acceleration a_{rv} is computed by adding centrifugal acceleration to the engine acceleration and subtracting gravity's downward contribution as follows:

$$a_{rv} = a_{tv} + (V^2_{avh}/r_{iv}) - GM/r^2_{iv} \qquad (5)$$

where, r_{iv} is the initial value of the vertical distance of the ship from the Earth's center, G is the gravitational constant, and M is the mass of the Earth. From the vertical acceleration, the velocities and altitude are computed just as the horizontal components were computed in equations 2 thru 4.

From physics, it will be noted that if no external force is applied by the engines, the rocket's angular momentum is a constant. For each maneuver, therefore, the computer retains

The following constants were used in listing 1:

G: Gravitational constant,
$6.67 \times 10^{-11} Nm^2/kg^2$
M: Mass of the earth,
$5.983 \times 10^{24} kg$
g: Gravitational acceleration,
9.80665 N/kg,
$m/sec^2 = 32.174\ ft/sec^2$

0.3048 meters/foot
2.2046 pounds/kg

Listing 1 continued:

```
1690 IF H < 100.0 THEN 1760
1700 IF H0 < 100.0 THEN 1760
1710 D0 = D0 + 1
1720 IF D0 > 1 THEN 1760
1730 PRINT "IN DESIRED ORBIT.  TO CONTINUE ENTER 1, TO PLOT ENTER 2. "
1740 INPUT H5
1750 IF H5 = 2 THEN 1920
1760 IF C3 = 0.0 THEN 660
1770 IF D7 <= E3  THEN 1800
1780 IF A(D2) <= 0.0 THEN  1800
1790 GO TO 660
1800 IF A(D2) = 0.0  THEN 1890
1810 IF D < A5 THEN  580
1820 D1 = D1 + 1
1830 IF D1 <> 1 THEN  1850
1840 PRINT "LAST STAGE SHUTDOWN."
1850 IF D0 <> 0.0 THEN 1880
1860 IF A(D2) <= 0.0 THEN 1880
1870 GO TO 660
1880 IF A(D2) > 0.0 THEN 1920
1890 H6 = INT( SQR( F6**2 + F8**2 ) + .5)
1900 H7 = INT( SQR( F7**2 + F9**2 ) + .5)
1910 PRINT "YOU CRASHED AT ";H6;" FT/SEC, ";H7;" MI/HR. "
1920 PRINT "AFTER ";D2;" PLOT POINTS: "
1930 FOR H8 = 1 TO D2
1940REM-PLOT A(H8) Y-AXIS, VS. A0(H8) X-AXIS, ALTITUDE VS. RANGE.
1950 NEXT H8
1960 H9 = 25.0
1970 REM-LOWER 25% CUTOFF OF ALTITUDE FOR A BLOWUP PLOT.
1980 I = C9 * H9 / 100.0 * 1.0001
1990 I0 = D2 + 1
2000 I0 = I0 - 1
2010 IF A(I0) > I THEN 2000
2020 I1 = 100.0 * A0(I0) / A0(D2)
2030 PRINT "LOWER ";H9;"% OR ";I;" MI. OF MAX ALT. ATTAINED."
2040 PRINT "FIRST ";I1;"% OR ";A0(I0);" MI. OF TOTAL RANGE."
2050 PRINT "WITH ";I0;" STEPS:"
2060 FOR I2 = 1 TO I0
2070 REM-PLOT A(I2) Y-AXIS, VS. A0(I2) X-AXIS, LOWER ALT. VS. RANGE."
2080 NEXT I2
2090 END
```

the product of horizontal velocity and distance from the Earth's center. If the engines are off during an iteration, the new horizontal velocity is set equal to this product divided by the new vertical distance value at the end of the iteration. Thus, angular momentum is conserved. As the ship coasts towards Earth, its horizontal velocity increases slightly, and would decrease slightly if the ship were receding. Quantities are then reinitialized and the next iteration begins.

When a firing sequence is completed, an important quantity Q is computed. It is the ratio of the net downward acceleration (gravitational minus centrifugal) to the total acceleration. The engines can currently deliver:

$$Q = \left(\frac{GM}{r_{iv}^2} - \frac{V^2_{avh}}{r_{iv}} \right) \Big/ a_t \qquad (6)$$

Multiplied by 100, this is the critical throttle setting which will cause the ship to hover if stationary, or move vertically at a constant speed without accelerating. It is also the sine of the critical angle of ascent at which the vertical component of thrust equals the current weight of the ship. The angle, equal to the inverse sine of Q is alternatively computed from:

$$\text{angle} = \tan^{-1} (Q/\sqrt{1.0 - Q^2})$$

At this time, distance and velocity values are converted from metric to English units for display purposes.

The first information printed consists of the elapsed flight time, the current ship angle, and the fuel left, both as a percentage of the original amount, and the number of seconds left at full throttle. Next, the program prints the altitude in miles and feet, the ascent rate and forward velocity in miles per hour and feet per second, and the number of miles down range.

The next printed information consists of the critical angle and throttle values of constant ascent, the maximum acceleration the engines can deliver, and the maximum vertical acceleration against gravity in both miles per hour per second and feet per second^2. For example, if the engine can deliver about $40 ft/s^2$ the ship can accelerate at $8 ft/s^2$ against gravity.

Next the percentages of the orbital velocity and altitude are presented. The final items displayed are the time to achieve orbital altitude at the current ascent rate, and the time to achieve orbital velocity at the current full throttle rate of horizontal acceleration.

At this point the user is ready for the next move, and must again specify a new throttle setting, firing angle, and burn time. Finally, at the end of the mission (either when you achieve orbit, or run out of fuel), you can plot a picture of your trajectory, altitude versus range, and an expanded plot of the start of your mission, the lower 25 percent of your total attained altitude.

Have fun. As you will soon learn, getting your spacecraft to achieve orbit is no easy task.■

Circle 355 on inquiry card.

The National Micropastime

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During the past few years I have spent too many Saturdays soldering integrated-circuit sockets into printed-circuit boards and have not had enough time to enjoy a good baseball game. I fulfill my need to participate in our national pastime by having my personal computer simulate the play of a baseball game. I can be the manager of any team I choose. All I have to do is input a few baseball statistics. Presto! Out comes a baseball simulation (assuming that the system I shall describe is set up).

System Demonstration

The search for baseball statistics is easy. *The Sports Encyclopedia: Baseball*, published by Grosset and Dunlap, has all that you could want. A program called Input (shown in listing 1) is used to enter the statistics into the computer. Figure 1 shows the program Input working.

First you enter a file name to correspond to the team (the 1975 Boston Red Sox in the sample run) whose statistics are being entered. Next, the program requires the name and data for seventeen players who are not pitchers. Yastrzemski is input along with his batting code of 1 (0 = bats right, 1 = bats left, 2 = bats from either side), number of times at bat (543), hits (146), doubles (30), triples (1), home runs (14) bases on balls (87), and strikeouts (67). The computer asks us if the data input is correct. A carriage return indicates

Listing 1: *Program Input which accepts data from the terminal and stores it in disk files for use by the baseball simulation. This program and others in the system are written in North Star BASIC and use the North Star disk system.*

```
10 DIMB(7),N$(10)
12 J$='----------'
15 INPUT'TEAM FILE ? ',F$
20 OPEN#0,F$
90 !'HITTERS'
100 FORA=0TO16
110 INPUT'NAME ? ',N$
120 !'BATS,AB,H,D,T,HR,BB,KO'
130 INPUT1'? ',B(7),C,B(1),B(2),B(3),B(4),B(5),B(6)
132 IFC=0THENC=1
135 INPUT' OK ?',Z$\IFZ$<>''THEN110
137 B9=B(1)\H=C-B(1)
140 C=C+B(5)\B(1)=B(1)/C
142 FORF=2TO4\B(F)=B(F)/B9  \IFF=2THEN146
144 B(F)=B(F)+B(F-1)
146 NEXT\B(5)=(B9+B(5))/C\B(6)=B(6)/H
155 N$=N$+J$
160 WRITE#0,N$,B(7)\FORE=1TO6\WRITE#0,B(E)\NEXT\NEXT
190 !'PITCHERS'
200 FORA=0TO9
210 INPUT'NAME ? ',N$
220 !"THROWS,IP',H,BB,KO',
230 INPUT1' ? ',B(0),C,B(1),B(2),B(3)
232 IFC=0THENC=1
235 INPUT' OK ? ',Z$\IFZ$<>''THEN210
237 D=C*2.75
240 C=(C*2.75)+B(1)+B(2)
250 B(1)=B(1)/C
260 B(2)=(B(2)/C)+B(1)
270 B(3)=B(3)/C
275 N$=N$+J$
280 WRITE#0,N$,B(0),B(1),B(2),B(3)
290 NEXT\Z=0\FORA=1TO138\WRITE#0,Z\NEXT\CLOSE#0\END
```

```
TEAM FILE ? 75-BOSTON
HITTERS
NAME ? YASTREMSKI
BATS,AB,H,D,T,HR,BB,KO
? 1,543,146,30,1,14,87,67 OK ?
PITCHERS
NAME ? WISE
THROWS,IP,H,BB,KO ? 0,255,262,72,141 OK ?
```

Figure 1: *Portion of sample execution of the program Input of listing 1. Normally data is entered for sixteen nonpitching players and ten pitchers.*

Listing 2: *A program, Roster, which reads data from a disk file concerning composition of a given baseball team and displays it on the terminal for inspection by the user. Figure 2 shows an example of its use.*

```
10 DIMB(6),N$(10)
12 N$='          '
15 INPUT'TEAM FILE ? ',F$
17 !'"
20 OPEN#0,F$
25 !'ID ',
30 !'HITTERS     BATS HITS   2B    3B    HR    BB    KO'
40 FORA=0TO16
50 READ#0,N$\FORB=0TO6\READ#0,B(B)\NEXT
55 !%2I,A,' ',
60 !N$,TAB(16),B(0),
65 !%5F3,B(1),B(2),B(3),B(4),B(5),B(6)
70 NEXT
75 !' '\!' '\!'ID ',
80 !'PITCHERS     R-L HITS   BB    KO'
90 FORA=0TO9
100 READ#0,N$,B(0),B(1),B(2),B(3)
105!%2I,A,' ',
110 !N$,TAB(16),B(0),
120 !%5F3,B(1),B(2),B(3)
130 NEXT\END
```

```
TEAM FILE ? 75-BOSTON

ID HITTERS       BATS HITS   2B   3B   HR   BB   KO
 0 YASTREMSKI      1 .232 .205 .212 .308 .370 .169
 1 DOYLE           1 .296 .219 .240 .281 .340 .051
 2 BURLESON        0 .234 .171 .178 .219 .306 .101
 3 PETROCELLI      0 .217 .156 .167 .240 .309 .199
 4 EVANS           0 .246 .212 .265 .381 .349 .201
 5 LYNN            1 .297 .269 .309 .429 .402 .255
 6 RICE            0 .290 .167 .190 .316 .350 .313
 7 FISK            0 .300 .161 .207 .322 .393 .182
 8 COOPER          1 .293 .179 .242 .389 .352 .157
 9 CARBO           1 .204 .256 .293 .476 .410 .291
10 GRIGGIN         0 .226 .087 .087 .101 .285 .133
11 BENIQUEZ        0 .262 .192 .247 .274 .351 .144
12 MILLER          1 .163 .095 .143 .143 .326 .230
13 HEISE           0 .208 .111 .111 .111 .238 .061
14 MONTGOMERY      0 .221 .227 .250 .295 .241 .245
15 BLACKWELL       2 .172 .115 .192 .192 .298 .123
16 CONEGLIARO      0 .108 .143 .143 .429 .231 .180

ID PITCHERS       R-L HITS   BB   KO
 0 WISE            0 .253 .323 .136
 1 TIANT           0 .250 .318 .135
 2 LEE             1 .259 .324 .074
 3 MORET           1 .218 .343 .132
 4 CLEVELAND       0 .249 .324 .112
 5 WILLOUGHBL      0 .237 .320 .149
 6 FOLE            0 .267 .351 .110
 7 DRAGO           0 .229 .333 .143
 8 SEGUI           0 .230 .369 .146
 9 BURTON          1 .260 .346 .175
```

Figure 2: *Execution of the program Roster of listing 2. The file name is the same as that used for program Input.*

everything is all right. Any other input allows for the reentry of the data.

Figure 1 omits the other sixteen entries and shows the first of ten pitcher entries. Here, the player's name Wise is entered along with his throwing arm designation of 0 (0 = right, 1 = left), innings pitched (255), hits (262), bases on balls (72), and strikeouts (67).

The next step is to see what information was entered and how the computer translates this data. In order to accomplish this program Roster (listing 2) is run. Figure 2 shows that the execution of this program asks for a file name, and 75—BOSTON is entered to correspond to the information just fed into the computer. The computer assigned identification numbers to the seventeen nonpitchers and ten pitchers, and translated all of the historical statistics into percentages.

That was a lot of data entry. Since I would not want to redo the entire input job again to change one player, program Fix (listing 3) was written; its execution is shown in figure 3. All that must be done to change an entry is to enter a file name and a hitter's identification number (from 0 thru 16), or a number greater than 16 as the identification number to change a pitcher. Once the pitcher correction section is entered, an identification number greater than 9 ends the program execution.

Hypothetical Matchup

With this data I am ready to play a fictitious World Series between the 1961 New York Yankees (led by Roger Maris, who hit 61 home runs that year, along with Mickey Mantle and Whitey Ford) and the 1963 Los Angeles Dodgers (who beat the 1963

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Listing 3: *A program, Fix, which allows the user to selectively correct data for a single player that has been stored on the disk by the Input program.*

```
10 DIMB(7),N$(10)
12 J$="----------"
15 INPUT"TEAM FILE ? ",F$
20 OPEN#0,F$
90 !"HITTERS"
100 INPUT"# ? ",A\IFA>16THEN190\A=A*47
110 INPUT"NAME ? ",N$
120 !"BATS,AB,H,D,T,HR,BB,KO"
130 INPUT1"? ",B(7),C,B(1),B(2),B(3),B(4),B(5),B(6)
132 IFC=0THENC=1
135 INPUT" OK ?",Z$\IFZ$<>""THEN110
137 B9=B(1)\H=C-B(1)
140 C=C+B(5)\B(1)=B(1)/C
142 FORF=2TO4\B(F)=B(F)/B9   \IFF=2THEN146
144 B(F)=B(F)+B(F-1)
146 NEXT\B(5)=(B9+B(5))/C\B(6)=B(6)/H
155 N$=N$+J$
160 WRITE#0%A,N$,B(7),B(1),B(2),B(3),B(4),B(5),B(6),NOENDMARK
170 GOTO100
190 !"PITCHERS"
200 INPUT"# ? ",A\IFA> 9THEN310\A=799+(A*32)
210 INPUT"NAME ? ",N$
220 !"THROWS,IP,H,BB,KO",
230 INPUT1" ? ",B(0),C,B(1),B(2),B(3)
232 IFC=0THENC=1
235 INPUT" OK ? ",Z$\IFZ$<>""THEN210
237 D=C*2.75
240 C=(C*2.75)+B(1)+B(2)
250 B(1)=B(1)/C
260 B(2)=(B(2)/C)+B(1)
270 B(3)=B(3)/C
275 N$=N$+J$
280 WRITE#0%A,N$,B(0),B(1),B(2),B(3),NOENDMARK
300 GOTO 200
310 CLOSE#0\END
```

```
TEAM FILE ? 75-BOSTO
HITTERS
# ? 0
NAME ? YASTREMSKI
BATS,AB,H,D,T,HR,BB,KO
? 1,543,146,30,1,14,87,67 OK ?
# ? 99
PITCHERS
# ? 0
NAME ? WISE
THROWS,IP,H,BB,KO ? 0,255,262,72,141 OK ?
# ? 99
```

Figure 3: *Sample execution of the program Fix of listing 3. This program allows selective correction of the input data.*

Yankees in four straight games in the 1963 World Series on the strong pitching of Sandy Koufax and Don Drysdale). To play this hypothetical series, all that is necessary is to load the program called Game and enter the file names 61-YANKS and 63-LA (assuming these files have been created in the manner just described).

Simulation of the first five games of this hypothetical World Series obtains the following results:

Game 1: Dodgers 6, Yankees 2.
Game 2: Yankees 3, Dodgers 1.
Game 3: Dodgers 6, Yankees 3.
Game 4: Yankees 11, Dodgers 4.
Game 5: Yankees 2, Dodgers 1.

Detailed Play of Game 6

The series now stands with the Yankees having won 3 and the Dodgers 2 games. A win by the Yankees ends the series, so I will show the details of the sixth game. Program Game is loaded and executed as shown in figure 4. The computer asks for a random number; 41 is input. Next, the file name of the visiting team is entered, followed by that of the home team. It is now time to enter the Dodger batting order.

This is done by entering the identification number (taken from the computer roster, a sample was shown in figure 2) and position number of

Text continued on page 122

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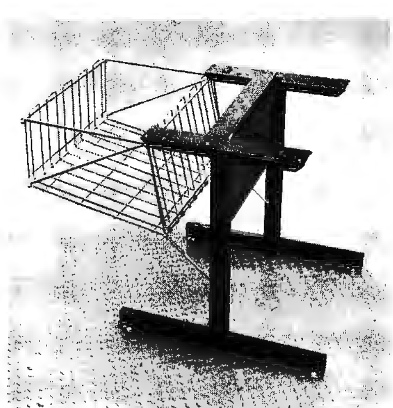

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Figure 4: *Predicted play of a hypothetical baseball game between the 1961 New York Yankees and the 1963 Los Angeles Dodgers, using the Game program described in this article. The entry for NUM? is a seed for generating random numbers; the entries for the TEAM? inquiries are file names to reference data stored on disk by the Input program. The user enters the batting order and pitching staffs, and play of the game proceeds according to statistical probabilities.*

```
NUM? 41
TEAM ? 63-LA
TEAM ? 61-YANKS
GIVE THE LINE-UP
BATTING 1  ID, POS # ?2,6          WILLS-----  SS OK ?
BATTING 2  ID, POS # ?1,4          GILLIAM---  2B OK ?
BATTING 3  ID, POS # ?5,8          DAVIS W---  CF OK ?
BATTING 4  ID, POS # ?6,7          DAVIS T---  LF OK ?
BATTING 5  ID, POS # ?4,3          HOWARD----  1B OK ?
BATTING 6  ID, POS # ?3,5          MCMULLEN--  3B OK ?
BATTING 7  ID, POS # ?7,2          ROSEBORO--   C OK ?
BATTING 8  ID, POS # ?0,9          FAIRLY----  RF OK ?
BATTING 9  ID, POS # ?10,10        OLIVER----  DH OK ?
 ID# OF PITCHER ? 3                PODRES----     OK ?
GIVE THE LINE-UP
BATTING 1  ID, POS # ?15,1         GONDER----   P OK ? NO
ID, POS # ?1,4                     RICHARDSON  2B OK ?
BATTING 2  ID, POS # ?2,6          KUBEK-----  SS OK ?
BATTING 3  ID, POS # ?4,9          MARIS-----  RF OK ?
BATTING 4  ID, POS # ?5,8          MANTLE----  CF OK ?
BATTING 5  ID, POS # ?7,2          HOWARD----   C OK ?
BATTING 6  ID, POS # ?0,3          SKOWRON---  1B OK ?
BATTING 7  ID, POS # ?10,7         CERV------  LF OK ?
BATTING 8  ID, POS # ?8,10         LOPEZ-----  DH OK ?
BATTING 9  ID, POS # ?3,5          BOYER-----  3B OK ?
 ID# OF PITCHER ? 6                DALEY-----     OK ?

INNING # 1
WILLS-----  IS OUT
GILLIAM---  SINGLE
RUNNER ON FIRST
DAVIS W---  DOUBLE PLAY

RICHARDSON  SINGLE
RUNNER ON FIRST
KUBEK-----  SINGLE
RUNNER ON FIRST  RUNNER ON THIRD
MARIS-----  IS OUT
 1 RUNS SCORE  63-LA      0  61-YANKS    1
RUNNER ON SECOND
P,H, OR B ?
MANTLE----  H. R.
 2 RUNS SCORE  63-LA      0  61-YANKS    3
P,H, OR B ? P
P# ? 9
HOWARD----  IS OUT
SKOWRON---  SINGLE
RUNNER ON FIRST
CERV------  STRIKES OUT


INNING # 2
DAVIS T---  STRIKES OUT
HOWARD----  H. R.
 1 RUNS SCORE  63-LA      1  61-YANKS    3
P,H, OR B ?
MCMULLEN--  STRIKES OUT
ROSEBORO--  IS OUT

LOPEZ-----  SINGLE
RUNNER ON FIRST
BOYER-----  IS OUT
RUNNER ON SECOND
RICHARDSON  IS OUT
KUBEK-----  WALK
RUNNER ON FIRST  RUNNER ON SECOND
MARIS-----  IS OUT

INNING # 3
FAIRLY----  IS OUT
OLIVER----  IS OUT
WILLS-----  IS OUT

MANTLE----  SINGLE
RUNNER ON FIRST
HOWARD----  SINGLE
```

Figure 4 continued on page 120

Figure 4 continued:

```
RUNNER ON FIRST  RUNNER ON THIRD
SKOWRON----  DOUBLE PLAY
 1 RUNS SCORE  63-LA       1  61-YANKS   4
P,H, OR B ?
CERV-------  SINGLE
RUNNER ON FIRST
LOPEZ------  SINGLE
RUNNER ON FIRST  RUNNER ON SECOND
BOYER------  STRIKES OUT


INNING # 4
GILLIAM---  SINGLE
RUNNER ON FIRST
DAVIS W---  IS OUT
DAVIS T---  SINGLE
RUNNER ON FIRST  RUNNER ON SECOND
HOWARD-----  STRIKES OUT
MCMULLEN--  IS OUT

RICHARDSON  WALK
RUNNER ON FIRST
KUBEK------  DOUBLE
RUNNER ON SECOND  RUNNER ON THIRD
MARIS------  IS OUT
MANTLE-----  H. R.
 2 RUNS SCORE  63-LA       1  61-YANKS   6
P,H, OR B ? P
P# ? 22@
2
HOWARD-----  SINGLE
RUNNER ON FIRST
SKOWRON---  IS OUT
RUNNER ON SECOND
CERV-------  IS OUT


INNING # 5
ROSEBORO--  STRIKES OUT
FAIRLY----  IS OUT
OLIVER-----  WALK
RUNNER ON FIRST
WILLS-----  WALK
RUNNER ON FIRST  RUNNER ON SECOND
GILLIAM---  SINGLE
 1 RUNS SCORE  63-LA       2  61-YANKS   6
RUNNER ON FIRST  RUNNER ON THIRD
P,H, OR B ?
DAVIS W---  IS OUT

LOPEZ------  IS OUT
BOYER------  WALK
RUNNER ON FIRST
RICHARDSON  DOUBLE PLAY


INNING # 6
DAVIS T---  IS OUT
HOWARD-----  STRIKES OUT
MCMULLEN--  IS OUT

KUBEK------  SINGLE
RUNNER ON FIRST
MARIS------  SINGLE
RUNNER ON FIRST  RUNNER ON THIRD
MANTLE-----  DOUBLE PLAY
 1 RUNS SCORE  63-LA       2  61-YANKS   7
P,H, OR B ?
HOWARD-----  IS OUT

INNING # 7
ROSEBORO--  IS OUT
FAIRLY----  IS OUT
OLIVER-----  SINGLE
RUNNER ON FIRST
WILLS-----  SINGLE
RUNNER ON FIRST  RUNNER ON SECOND
GILLIAM---  IS OUT

SKOWRON---  SINGLE
RUNNER ON FIRST
CERV-------  IS OUT
LOPEZ------  IS OUT
BOYER------  IS OUT
```

Figure 4 continued on page 122

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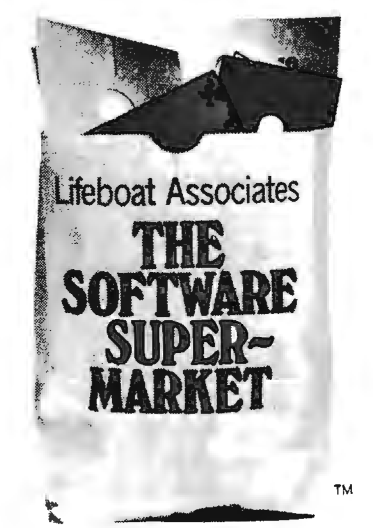

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Text continued:

each player. The position numbers are standard baseball scoring symbols: 1=pitcher, 2=catcher, 3=first baseman, 4=second baseman, 5=third baseman, 6=shortstop, 7=left fielder, 8=center fielder, 9=right fielder, and 10=designated hitter (yes, I am using the designated hitter). The computer asks OK? and a carriage return signifies that all is well. This is done for the nine batting positions, and then the pitcher identification number is entered.

When the Yankee batting order is entered, I intentionally make a mistake. Jesse Gonder was entered as the pitcher, batting leadoff. The comuter asks OK?, but this time "NO" is entered (anything except a carriage return will do) and the computer rejects the input.

Game 6 matches pitchers Podres and Daley. The Yankees start quickly and score 3 runs in the first inning powered by Mickey Mantle's two-run home run.

After each run is scored, the Game program branches to the *substitute* subroutine. As seen in figure 4, that

Figure 4 continued:

```
INNING # 8
DAVIS W----  IS OUT
DAVIS T----  IS OUT
HOWARD-----  H. R.
 1 RUNS SCORE   63-LA        3   61-YANKS     7
P,H, OR B ? B
P# ? 9
BATS, P# ? 6,13
POS ? 5
BATS, P# ? 0,0
ZIMMER-----  IS OUT

RICHARDSON   IS OUT
KUBEK------  IS OUT
MARIS------  H. R.
 1 RUNS SCORE   63-LA        3   61-YANKS     8
P,H, OR B ?
MANTLE----   SINGLE
RUNNER ON FIRST
HOWARD-----  IS OUT


INNING # 9
ROSEBORO---  IS OUT
FAIRLY-----  IS OUT
OLIVER-----  IS OUT
```

in the first inning after Maris made an out to score the first Yankee run, the computer asked "P, H or B". A carriage return in response to this inquiry means "no substitute" and the game continues. Entry of P means a pitching change, H means a substitute for any of the players on the team currently batting, and B means that both changes P and H are desired.

Following Mickey's home run, a pitching change is made—Norm Sherry replaces Podres. The game continues with the Yankees pecking away and adding to their lead. The Dodgers score a run in the eighth inning, but it appears certain that they will lose the game and the series. For

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```
BOX SCORE

63 LA                                                61-YANKS

NAME          POS     AB    H   HR  RBI              NAME          POS     AB    H   HR  RBI

WILLS- ---     SS      3    1    0    0              RICHARDSON     2B      4    1    0    0
GILLIAM---     2B      4    3    0    1              KUBEK------    SS      4    3    0    0
DAVIS W---     CF      4    0    0    0              MARIS------    RF      5    2    1    2
DAVIS T---     LF      4    1    0    0              MANTLE-----    CF      5    4    2    5
HOWARD-----    1B      4    2    2    2              HOWARD-----     C      5    2    0    0
MCMULLEN---    3B      3    0    0    0              SKOWRON---     1B      4    2    0    1
ZIMMER----     3B      1    0    0    0
ROSEBORO--      C      4    0    0    0              CERV-------    LF      4    1    0    0
FAIRLY-----    RF      4    0    0    0              LOPEZ------    DH      4    2    0    0
OLIVER----     DH      3    1    0    0              BOYER------    3B      3    0    0    0

PITCHERS        IP    H    R   ER   K  BB

PERRANOSKI     4.7    6    2    1   0   1
PODRES-----     .3    3    3    3   0   0 LOSSER
SHERRY-----    3.0    8    3    3   2   2
DALEY -----    7.7    8    3    2   5   2 WINNER
DUREN -----    1.3    0    0    0   0   0

           1   2   3   4   5   6   7   8   9   -   T
VISTORS    0   1   0   0   1   0   0   1   0   0   3
HOME       3   0   1   2   0   1   0   1   0   0   8      RETURN TO END ?
 8324
READY
```

Figure 5: *Box score from the game played in figure 4.*

this reason, a pinch hitter and a new pitcher are entered in order to illustrate all of the possible input situations occurring in this simulation.

In answer to the question "P, H or B" in the Dodgers' half of the eighth inning, a B is input. A pitcher's identification number is solicited and 9 is entered, corresponding to Yankee Ryne Duren. Next, the computer asks for the batting (Dodgers) team's substitutes with the question "Bats, P#". Here it is necessary to input what place in the nine batting positions (1 thru 9) the substitute will bat in and the player's identification number. The numbers 6 and 13 are typed in. Six is the sixth batting position; 13 represents Don Zimmer's identification number.

The "Bats, P#" question is again asked, and the user can continue to make substitutes or you can enter a 0 for the batting position in order to end the substituting. In the example, 0,0 is input and the game continues.

The Yankees go on to win the sixth game 8 to 3 and the series 4 games to 2 games. Figure 5 shows the box score for the final game of the series. Typing a carriage return ends the game at this point; typing any other character plays another game between the same two teams.

If the option to play another contest is selected, the computer asks "Line-ups OK"; and typing a carriage return lets the programmer play another game just by entering the identification numbers of two new

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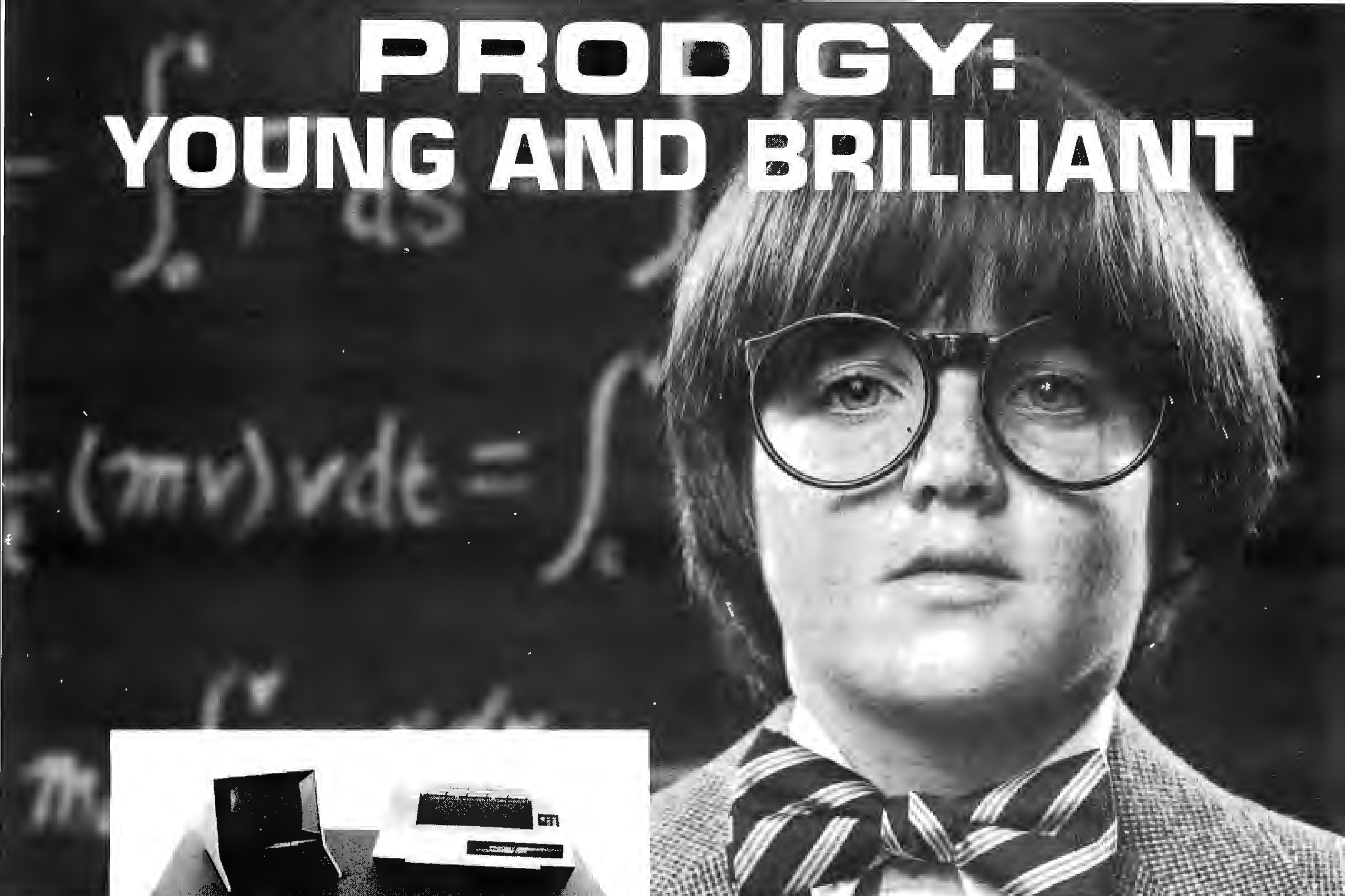

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pitchers. If anything other than a carriage return is entered, the computer branches to the lineup entry section of the program and the user will be required to enter new lineups.

You can keep track of batting averages, earned run averages, and other statistics by loading the program Stats (listing 4) and entering the appropriate file name. This will give you a complete printout of all the statistics as shown in figure 6. The statistics shown are for all six games of the "World Series" that was just played.

The statistics keep accumulating each time the program is run. Therefore, I have provided program Erase (shown in listing 5). Figure 7 shows this program being used; the user merely supplies the file name. This program erases statistics extracted only from the games played, not the ratings information shown on the roster (figure 2) for each player. That is how I run my complete computerized baseball simulation.

Listing 4: *The Stats program, which computes and displays statistics from box scores of simulated baseball games. An example of its use is shown in figure 6.*

```
1 DIMN$(270)
5 LINE 80
10 INPUT"FILE NAME ? ",F$\OPEN#0,F$
12 FORA=0TO16\N=(A*10)+1\READ#0,N$(N,N+9),Z,Z,Z,Z,Z,Z,Z\NEXT
14 FORA=0TO9\N=170+((A*10)+1)\READ#0,N$(N,N+9),Z,Z,Z,Z\NEXT
20 !"NAME          AB   H HR RBI  AVE  NAME          IP    H    R   ER",
30 !"  KO   BB   W   L    ERA"\FORA=1TO79\!"=",\NEXT\!""
40 FORA=0TO16\B=1119+(A*20)\READ#0%B,C,D,E,F\G=0
50 IFC>0THENG=D/C\T1=T1+C\T2=T2+D\T3=T3+E\T4=T4+F
60 N=(A*10)+1\!N$(N,N+9),%4I,C,D,%3I,E,%4I,F,%5F3,G,"   ",
70 IFA>9THEN90\B=1459+(A*35)\N=171+(A*10)
72 READ#0%B,C,D,E,F,G,H,I\J=INT(I/100)\K=I-(100*J)
74 P1=P1+C\P2=P2+D\P3=P3+E\P4=P4+F\P5=P5+G\P6=P6+H\P7=P7+J\P8=P8+K
76 E9=0\IFC>0THENE9=(F*27)/C\C=INT(C/3)
78 !N$(N,N+9),%4I,C,D,E,F,G,H,%3I,J,K,%6F2,E9,
90 !""\NEXT
100 FORA=1TO79\!"-",\NEXT\!""
110 IFT1>0THENT5=T2/T1\IFP1>0THENP9=(P4*27)/P1\P1=INT(P1/3)
120 !"             ",%4I,T1,T2,%3I,T3,%4I,T4,%5F3,T5,
130 !"                ",%4I,P1,P2,P3,P4,P5,P6,%3I,P7,P8,%6F2,P9
```

Necessary System Components

What do you need to run these programs? An 8080-based microprocessor system that can be linked to a North Star floppy-disk system, a North Star disk-operating system including BASIC, 24 K bytes of memory, and a terminal. The memory requirement is large because of the size

6a

```
FILE NAME ? 61-YANKS
NAME          AB   H HR RBI  AVE  NAME          IP    H    R   ER   KO   BB   W   L    ERA
===============================================================================
SKOWRON---    20   4  0   1 .200  FORD-------    8   12   10    3    5    7   0   1   3.12
RICHARDSON    24   4  0   2 .167  TERRY------   13    9    2    1    8    6   2   0    .68
KUBEK-----    23   7  0   0 .304  ARROYO-----    8    3    0    0    5    3   0   0    .00
BOYER-----    19   3  0   0 .158  STAFFORD---    0    0    0    0    0    0   0   0    .00
MARIS-----    23   9  4   8 .391  COATES-----    0    0    0    0    0    0   0   0    .00
MANTLE----    23   6  2   5 .261  SHELDON---     0    0    0    0    0    0   0   0    .00
BERRA-----     7   0  0   0 .000  DALEY------   11   14    7    5    8    3   1   0   3.86
HOWARD----    23   8  2   5 .348  TURLEY-----    0    0    0    0    0    0   0   0    .00
LOPEZ-----    16   5  0   4 .313  RENIFF-----    4    6    2    2    0    2   1   0   4.15
BLANCHARD-     7   3  0   1 .429  DUREN------    6    6    3    2    5    0   0   1   2.84
CERV------    16   8  2   3 .500
GARDNER---     0   0  0   0 .000
DEMASTRI--     0   0  0   0 .000
REED------     0   0  0   0 .000
TORGESSON-     0   0  0   0 .000
GONDER----     0   0  0   0 .000
JOHNSON---     0   0  0   0 .000
-------------------------------------------------------------------------------
             201  57 10  29 .284                53   50   24   13   31   21   4   2   2.21
```

6b

```
FILE NAME ? 63-LA
NAME          AB   H HR RBI  AVE  NAME          IP    H    R   ER   KO   BB   W   L    ERA
===============================================================================
FAIRLY----    22   3  1   1 .136  KOUFAX-----   13   14    8    4    9    5   1   0   2.70
GILLIAM---    24  12  1   4 .500  DRYSDALE---   17   13    5    4    8    5   0   2   2.12
WILLS-----    24   4  0   1 .167  PERRANOSKI     9    8    2    1    0    5   1   0   1.00
MCMULLEN--    20   3  0   2 .150  PODRES-----    5    9    6    5    2    1   0   1   9.00
HOWARD----    21   5  2   4 .238  MILLER-----    0    1    2    0    0    1   0   1    .00
DAVIS W---    24   8  1   5 .333  RICHERT---     0    0    0    0    0    0   0   0    .00
DAVIS T---    25   6  0   4 .240  CALMUS-----    0    0    0    0    0    0   0   0    .00
ROSEBORO--    21   1  0   0 .048  WILLHITE---    0    0    0    0    0    0   0   0    .00
MOON------     6   3  0   0 .500  ROEBUCK----    0    0    0    0    0    0   0   0    .00
TRACEWSKI-     0   0  0   0 .000  SHERRY-----    7   12    6    4    6    6   0   0   4.91
OLIVER----    14   5  0   3 .357
WALLS-----     0   0  0   0 .000
CAMILLI---     0   0  0   0 .000
ZIMMER----     1   0  0   0 .000
FERRIA ---     0   0  0   0 .000
BREEDING--     0   0  0   0 .000
NEN-------     0   0  0   0 .000
-------------------------------------------------------------------------------
             202  50  5  24 .248                52   57   29   18   25   23   2   4   3.12
```

Figure 6: *Statistics for six games of the "World Series" between the 1961 Yankees (6a) and the 1963 Dodgers (6b).*

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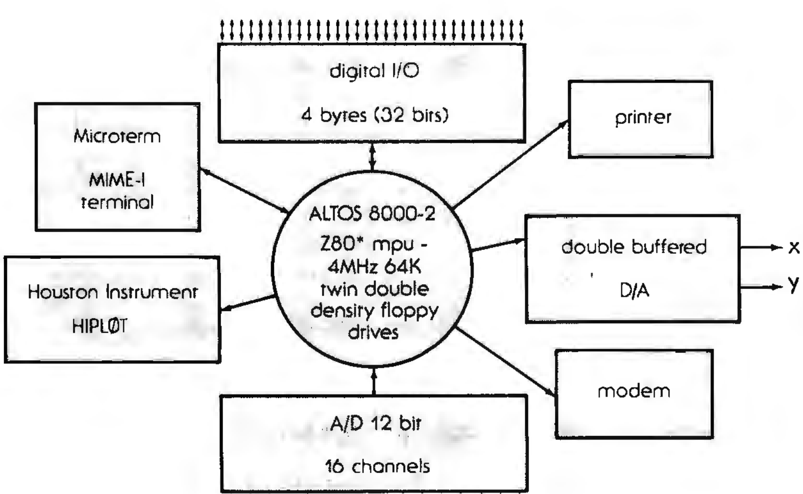

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Listing 5: *The Erase program, which deletes from the data file statistics developed from the games which have been simulated by the Game program. The roster ratings information is retained. See figure 7 for an example.*

```
10 INPUT'FILE TO BE ERASED ? ',F$
20 OPEN#0,F$
30 B=1114\READ#0%B,C\FORA=1TO138\WRITE#0,Z\NEXT
40 CLOSE#0
```

```
RUN

FILE TO BE ERASED ? 61-YANKS
READY
RUN

FILE TO BE ERASED ? 63-LA
READY
```

Figure 7: *Sample execution of the program Erase of listing 5. This program purges statistics from simulated games; it does not alter the roster ratings information.*

Listing 6: *The Game program, written in North Star BASIC, which uses data based on historical performance of real baseball players to simulate any desired contest between various teams. This program occupies 24 K bytes of programmable memory when used with the North Star BASIC system.*

```
1 INPUT'NUM? ',A\FORB=0TOA\C=RND(0)\NEXT
5 LINE80
10 DIMH(1,16,14),P(1,9,17),N$(540),S(1,8,2,1),P$(20),T$(20)
15 DIMH$(24),S1(1,10),B(8),R(8)
17 H$='SINGLEDOUBLETRIPLEH. R. '
20 P$=' P C1B2B3BSSLFCFRFDH'
30 FORA=0TO1\B=(A*10)+10\INPUT'TEAM ? ',T$(B-9,B)\F$=T$(B-9,B)
40 OPEN#0,F$\B=270*A\FORC=0TO16\B=B+10
50 READ#0,N$(B-9,B)\FORD=0TO6\READ#0,H(A,C,D)\NEXTD\NEXTC
60 FORC=0TO9\B=B+10\READ#0,N$(B-9,B)\FORD=0TO3\READ#0,P(A,C,D)\NEXTD
65 NEXTC\CLOSE#0\NEXTA
67 FORA=0TO1
70        !'GIVE THE LINE-UP '\FORC=0TO8\!'BATTING',C+1,'  ',
80 INPUT1'ID, POS # ?',D,E\S(A,C,0,0)=D\S(A,C,0,1)=E
81 IFE<1ORE>10THEN80
82 F=(A*270)+(D*10)+1\G=E*2
83 IFD>16THEN80\!TAB(40),
84 !N$(F,F+9),'  ',P$(G-1,G),\INPUT' OK ? ',Z$
86 IFZ$<>''THEN80\NEXTC
90 INPUT1' ID# OF PITCHER ? ',W(A+2)
91 IFW(A+2)>9THEN90\!TAB(40),
92 F=(A*270)+170+(10*W(A+2))+1\!N$(F,F+9),'     ',
94 INPUT' OK ? ',Z$\IFZ$<>''THEN90\NEXTA
100 I=9\Q=1
110 FORA=QTOI\!''\!'INNING #',A\FORB=0TO1
112 IFA<>9ORB<>1THEN115\IFS1(1,10)>S1(0,10)THENEXIT970
115 C=W(B)\D=1\IFB=1THEND=0\P=W(D+2)
120 FORE=0TO2\IFS(B,C,E,1)>0THENF=S(B,C,E,0)\NEXT
125 G=(270*B)+(10*F)+1
127 L=0\IFH(B,F,0)=2THEN130
128 IFH(B,F,0)=P(D,P,5)THEN129\L=.015\GOTO130
129 L=-.015
130 H=.5*(H(B,F,5)+P(D,P,2))+L+W(D+4)\H(B,F,7)=H(B,F,7)+1
135 !N$(G,G+9),'  ',
140 G=RND(0)\IFG>HTHEN800
150 H=.5*(H(B,F,1)+P(D,P,1))+L+W(D+4)
160 IFG>HTHEN700\P(D,P,5)=P(D,P,5)+1
170 H=RND(0)\FORG=2TO4\IFH(B,F,G)>=HTHENEXIT190
180 NEXT\G=1
190 H=G*6\!H$(H-5,H)\H(B,F,8)=H(B,F,8)+1\GOSUB7000\GOSUB5900
195 IFG=4THENH(B,F,9)=H(B,F,9)+1
200 C=C+1\IFC>8THENC=0\W(B)=C\E9=0
205  IFA>8ANDB=1ANDS1(1,10)>S1(0,10)THENEXIT960
210 IFO<>3THEN120\GOTO950
700 !'WALK'\H(B,F,7)=H(B,F,7)-1\P(D,P,9)=P(D,P,9)+1\G=1\GOSUB6950
710 GOSUB5950\GOTO200
800 H=.5*(H(B,F,6)+P(D,P,3))\IFRND(0)>HTHEN820
810 !'STRIKES OUT'
815 P(D,P,8)=P(D,P,8)+1\GOTO830
820 IFRND(0)<.98THEN825\G=1\K=1\!'ERROR'\O9=O9+1\GOSUB6000\GOTO200
825 IFRND(0)>.5ORB(1)=0ORO>1THEN828\!'DOUBLE PLAY'\O=O+2\B(1)=0\O9=O9+2
826 R(1)=0\IF3>O9THENGOSUB7000
827 G=0\K=1\IF3>OTHENGOSUB6000\P(D,P,4)=P(D,P,4)+2\GOTO200
828 !'IS OUT' \G=0\IFRND(0)>.5THEN830\K=1\IFO9<2THENGOSUB7000
829 IFO <2THENGOSUB6000
830 O=O+1\P(D,P,4)=P(D,P,4)+1\O9=O9+1\GOTO200
950 FORG1=1TO8\B(G1)=0\R(G1)=0\NEXT\O=0\O9=0\!''\NEXT\NEXT
960 IFS1(0,10)<>S1(1,10)THEN970\Q=10\I=10\GOTO110
970 G1=W(6)\G2=W(7)\G3=W(8)\G4=W(9)\P(G1,G2,10)=P(G1,G2,10)+100
971 P(G3,G4,10)=P(G3,G4,10)+1
972 GOSUB1000\FORG1=0TO1\FORG2=0TO16\FORG3=7TO10
```

Listing 6 continued on page 130

of program Game. With Game loaded in memory, only 132 bytes out of 24 K bytes are free, even after releasing the memory allocation for the functions ATN, SIN, COS, LOG, and EXP. The actual memory used by Game is 11,432 bytes.

Table 1 shows the North Star directory of the disk used to store the six programs of the package and the data files. Each team data file is eight blocks long. Five of the programs in the package are short. Programming details will be given only for the one long program, Game. It is likely that if the user wishes to enhance or modify the package, program Game will have to be changed. If you understand the workings of Game, the rest is simple. The North Star BASIC code for Game appears in listing 6.

Table 2 describes the operations of Game by line number groups, while table 3 defines the key variables. Figure 8 is a flowchart of the major divisions of program operation.

Use of Statistics

The program determines if a batter gets a hit by adding his hits rating to the pitcher's hits rating (consult figure 2). This result is combined with the pitcher's tiring factor and a factor determined by the relationship between the batter's hitting side (right or left) and the pitcher's throwing arm (right or left). This result is then multiplied by 0.5 and compared to a random number. Look at table 4 for an example.

If the random number is below the final hit factor, the batter gets a hit. Note that the hits rating is not the player's batting average, because the player has the possibility of walking. Next, a walk rate is determined: Yastrzemski's .370 plus Wise's .323 multiplied by 0.5 = .3465.

This walk rate is compared to the same random number as before to

Listing 6 continued:

```
973 H(G1,G2,G3+4)=H(G1,G2,G3+4)+H(G1,G2,G3)\H(G1,G2,G3)=0\NEXT\NEXT
974 FORG2=0TO9\FORG3=4TO10\P(G1,G2,G3+7)=P(G1,G2,G3+7)+P(G1,G2,G3)
976 P(G1,G2,G3)=0\NEXT\NEXT\NEXT\FORG1=0TO10\W(G1)=0
978 S1(0,G1)=0\S1(1,G1)=0\NEXT\W9=0
990 INPUT"     RETURN TO END ? ",Z$\IFZ$=""THEN998
992 INPUT"LINE-UPS OK ? ",Z$\IFZ$<>""THEN67
994 !T$(1,10),\INPUT" PITCHER ? ",W(2)
995 !T$(11,20),\INPUT" PITCHER ? ",W(3)
996 GOTO100
998 GOSUB2000\!FREE(0)\END
1000 !"BOX SCORE"\!""
1010 FORG=0TO1\B=(G*10)+10\G1=40*G
1020 !TAB(G1),T$(B-9,B),\NEXT\!""
1022 !""\FORG=0TO1\G1=40*G
1024 !TAB(G1),"NAME          POS     AB    H   HR RBI",
1026 NEXT\!""\!""
1030 FORG=0TO8\FORG1=0TO2
1050 G4=0\FORG3=0TO1\IFS(G3,G,G1,1)=0THEN1080\G5=40*G3\G6=S(G3,G,G1,0)
1060 B=(270*G3)+(10*G6)+10\G4=1\G7=(S(G3,G,G1,1)*2)
1070 !TAB(G5),N$(B-9,B),"  ",P$(G7-1,G7),"  ",
1075 FORG8=7TO10\!%4I,H(G3,G6,G8),\NEXT
1080 NEXT\IFG4=1THEN!""\NEXTG1\NEXTG
1090 !""\!"PITCHERS      IP   H   R ER   K BB"\!""
1110 FORG1=0TO1\FORG2=0TO9\IFP(G1,G2,4)>0THEN1130
1120 IFP(G1,G2,5)>0THEN1130\IFP(G1,G2,8)>0THEN1130\GOTO1160
1130 G3=(G1*270)+170+(10*G2)+1\G4=P(G1,G2,4)/3
1140 !N$(G3,G3+9),%5F1,G4,
1150 FORG4=5TO9\!%3I,P(G1,G2,G4),\NEXT\IFP(G1,G2,10)=100THEN!" WINNER",
1152 IFP(G1,G2,10)=1THEN!" LOSSER",\!" "
1160 NEXT\NEXT\!""\!"              1   2   3   4   5   6   7   8   9   -   T"
1170 !"VISTORS",\FORG1=0TO10\!%3I,S1(0,G1),\NEXT\!""
1180 !"HOME    ",\FORG1=0TO10\!%3I,S1(1,G1),\NEXT\RETURN
2000 FORA=0TO1\B=(A*10)+1\OPEN#0,T$(B,B+9)\B=1114
2010 READ#0%B,C\FORB=0TO16\READ#0,H(A,B,7),H(A,B,8),H(A,B,9),H(A,B,10)
2020 FORC=11TO14\H(A,B,C)=H(A,B,C)+H(A,B,C-4)\NEXT\NEXT
2030 FORB=0TO9\READ#0,P(A,B,4),P(A,B,5),P(A,B,6),P(A,B,7),P(A,B,8)
2035 READ#0,P(A,B,9),P(A,B,10)
2040 FORC=11TO17\P(A,B,C)=P(A,B,C)+P(A,B,C-7)\NEXT\NEXT
2050 B=1114\READ#0%B,C\FORB=0TO16
2060 WRITE#0,H(A,B,11),H(A,B,12),H(A,B,13),H(A,B,14)\NEXT
2070 FORB=0TO9\WRITE#0,P(A,B,11),P(A,B,12),P(A,B,13),P(A,B,14)
2075 WRITE#0,P(A,B,15),P(A,B,16),P(A,B,17)\NEXT\CLOSE#0
2080 NEXT\RETURN
5900 K=G\IFRND(0)>.6THENK=K+1\GOTO6000
5950 K=1\IFB(1)=0THEN6005\IFB(2)=0THEN5960\GOTO6000
5960 B(2)=P+1\GOTO6005
6000 FORG1=3TO1STEP-1\B(G1+K)=B(G1)\B(G1)=0\NEXT
6005 IFG=4THENB(8)=P+1\IFG<>4THENB(G)=P+1\G4=0
6010 G2=0\FORG1=4TO8\IFB(G1)=0THEN6040\G4=G4+1\V=B(G1)-1\B(G1)=0
6020 L=A-1\IFA>9THENL=9\S1(B,L)=S1(B,L)+1\S1(B,10)=S1(B,10)+1
6030 B(G1)=0\H(B,F,10)=H(B,F,10)+1\P(D,V,6)=P(D,V,6)+1
6040 NEXT\IFG4<1THEN6042\!G4," RUNS SCORE  ",
6041 !T$(1,10),S1(0,10),"  ",T$(11,20),S1(1,10)
6042 IFG4<2THEN6043\W(4+D)=W(4+D)+.025
6043 M=0
6048 IFB(1)=0THEN6050\!"RUNNER ON FIRST  ",\M=1
6050 IFB(2)=0THEN6060\!"RUNNER ON SECOND  ",\M=1
6060 IFB(3)=0THEN6070\!"RUNNER ON THIRD  ",\M=1
6070 IFM=1THEN!""\IFG4=0THENRETURN\GOSUB6200\GOSUB6100\RETURN
6100 INPUT"P,H, OR B ? " ,Z$\IFZ$=""THENRETURN\IFZ$="H"THEN6150
6110 W(D +4)=0\INPUT"P# ? ",Z\IFZ>9THEN6110\W(2+D)=Z\P=Z
6120 IFZ$="P"THENRETURN
6150 INPUT"BATS, P# ? ",Z,Z1\Z=Z-1\IFZ>8THENRETURN\IFZ<0THENRETURN
6160 FORG1=0TO2\IFS(B,Z,G1,1)=0THENEXIT6180
6170 NEXT\!"TWO SUBS ALREADY USED THERE"\GOTO6150
6180 S(B,Z,G1,0)=Z1\INPUT"POS ? ",Z1\IFZ1>10THENZ1=10
6190 S(B,Z,G1,1)=Z1\GOTO6150
6200 IFW9=0THEN6220\IFB+1=W9THENRETURN
6210 IFS1(0,10)=S1(1,10)THEN6230\IFS1(B,10)>S1(D,10)THEN6220\RETURN
6220 W(8)=D\W(9)=W(2+D)\W(6)=B\W(7)=W(2+B)\W9=1+B\RETURN
6230 W9=0\RETURN
6950 K=1\IFR(1)=0THEN7005\IFR(2)=0THEN6960\GOTO7000
6960 R(2)=P+1\GOTO7005
7000 IFO9>2THENRETURN\FORG1=3TO1STEP-1\R(G1+K)=R(G1)\R(G1)=0\NEXT
7005 IFG=4THENR(8)=P+1\IFG<>4THENR(G)=P+1
7010 FORG1=4TO8\IFR(G1)=0THEN7040
7020 V=R(G1)-1
7030 R(G1)=0\P(D,V,7)=P(D,V,7)+1
7040 NEXT\RETURN
```

```
?
*LI
ERASE        4    4   2
ERASE2       8    4   2
INPUT       12    6   2
INPUT2      18    6   2
ROSTER      24    6   2
ROSTER2     30    6   2
GAME        36   22   2
GAME2       58   22   2
STATS       80    6   2
STATS2      86    6   2
61-YANKS    92    8   3
69-METS    100    8   3
75-BOSTO   108    8   3
63-LA      116    8   3
62-METS    124    8   3
FIX        132    6   2
FIX2       138    6   2
*
```

Table 1: *Directory of the disk files consisting of the baseball-simulation programs and data. Each team data file is eight blocks long on this North Star Computer floppy disk system.*

determine if the batter gets a base on balls. Assuming that the batter makes an out, a strikeout possibility is determined in a similar manner with a new random number (.169 + .136 x 0.5 = .1525 is the Yastrzemski/Wise strikeout factor). If the batter is not a strikeout victim, another random number is generated to see if he hits into a double play, reaches base on an error, or advances the runners that might be on base.

Hits, Runs, and Errors

On the occasions when a batter gets a hit, a random number is compared first to his double rate, then his triple rate, and finally his home run rate (Yastrzemski has ratings of .205, .212, and .308 for these hits). *[By a pleasant coincidence, this article was edited on the same day that Carl Yastrzemski hit his home run number hexadecimal 190....***RSS***]*. If at any point in the comparisons the rate exceeds the random number, the comparison process ceases and the batter is awarded the type of hit currently being considered. If all comparisons fail, the hit is assumed to be a single-base hit. A new random number is generated to see if the possible base runners advance one base more than the hit is valued at (single = 1, double = 2, etc).

The variable array (with seven elements) is used to keep track of base

Text continued on page 134

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Line Numbers	Operation Performed
1 thru 20	a) Generate seed for random number b) dimension variables c)read descriptive data
30 thru 65	Read data from disk files
67 thru 94	Batting order input section
100	Set start and end inning
110 thru 990	Play game
992 thru 998	Select pitchers for new game
1000 thru 1180	Subroutine for printing box game
2000 thru 2080	Subroutine to write updated statistics to disk file
5900 thru 6070	Subroutine to determine run scored and position of base runners
6100 thru 6190	Subroutine for player substitutions
6200 thru 6230	Subroutine for determining winning and losing pitchers
6950 thru 7040	Subroutine for calculating earned runs

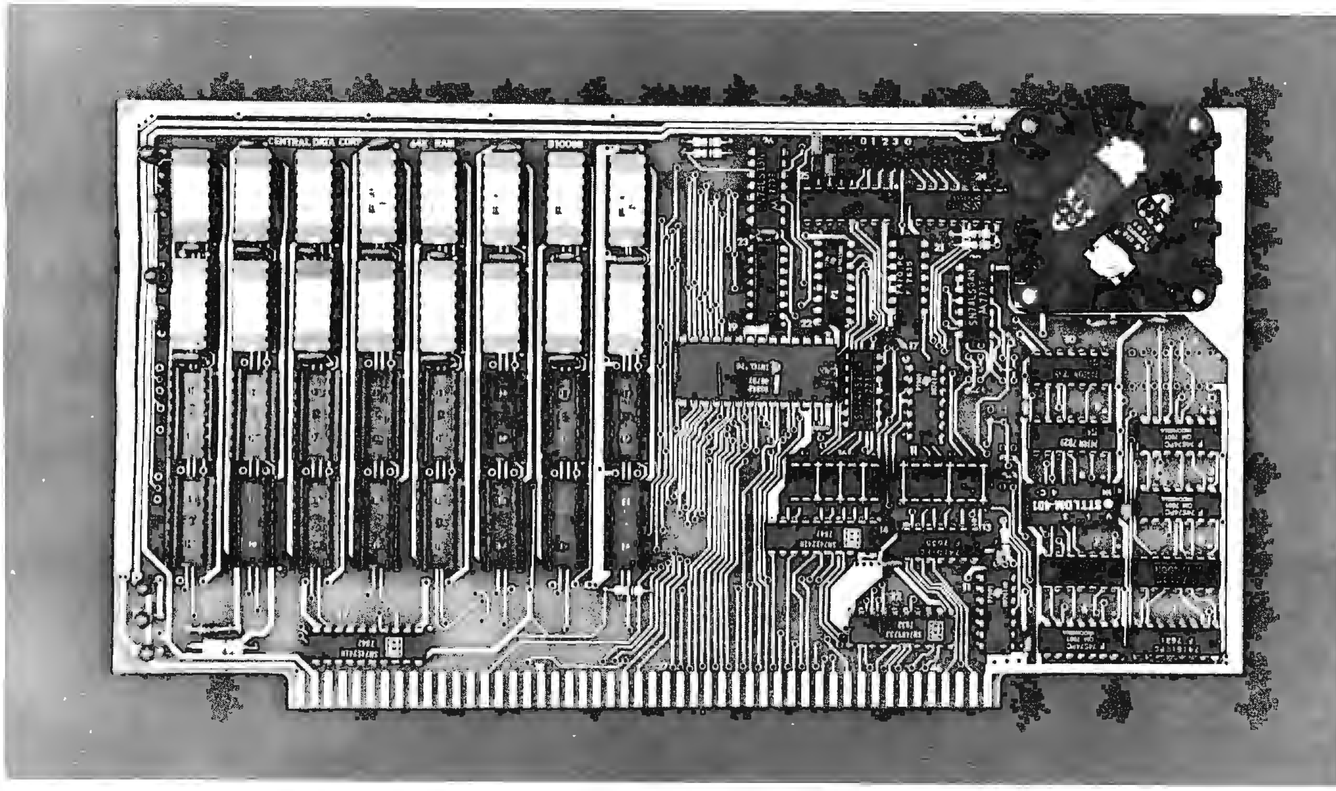
Table 2: *Operations performed by various lines of BASIC code in the Game program of listing 6.*

Variable and Dimensions	Use
S(1,8,2,1)	1 = Teams 8 = batting order 2 = up to three players in each batting position 1 = identification number and position
T$(20)	Team names
P$(20)	Position names
H(1,16,14)	1 = Teams 16 = seventeen players 14 = 0 to 6 = player ratings 7 to 10 = at bats, hits, home runs, and runs batted in for the game 11 to 14 = total at bats, hits, home runs, and runs batted in as read and written to disk
P(1,9,9)	1 = Teams 9 = ten pitchers 9 = 0 to 3 = player ratings 4 to 10 = innings pitched, hits, runs, earned runs, strikeouts, walks and win or loss for the game 11 to 17 = total innings pitched, hits, runs, earned runs, strikeouts, walks and wins or losses as read and written to disk
W(9)	0 who's up (visiting team) 1 who's up (home team) 2 visiting team's pitcher 3 home team's pitcher 4 visting team pitcher's tiring factor 5 home team pitcher's tiring factor 6 leading team number (0 or 1) 7 identification number for leading pitcher 8 trailing team number 9 identification number for trailing pitcher
B(7)	1 runner on first 2 runner on second 4-3 runner on third 4-7 runs scored
R(7)	same as B(7), but tracks earned runs

Table 3: *Use and size of array variables in the Game program of listing 6.*

Yastrzemski Hits	= .232
Wise Hits	= .253
Pitcher tiring factor (assume 0)	= .000
Left handed batter versus right handed pitcher	= .015
	.500 × .5 = .250

Table 4: *Statistical determination of the probability of batter Yastrzemski producing a safe hit from a pitch thrown by Wise. The hits factors for pitcher and batter are added together, along with a factor for pitcher tiring and a factor for the relationship of a left-handed batter facing a right-handed pitcher. The sum of these factors is multiplied by 0.5 and then compared with a random number. If the random number is less than the computed probability, Yastrzemski has hit safely.*



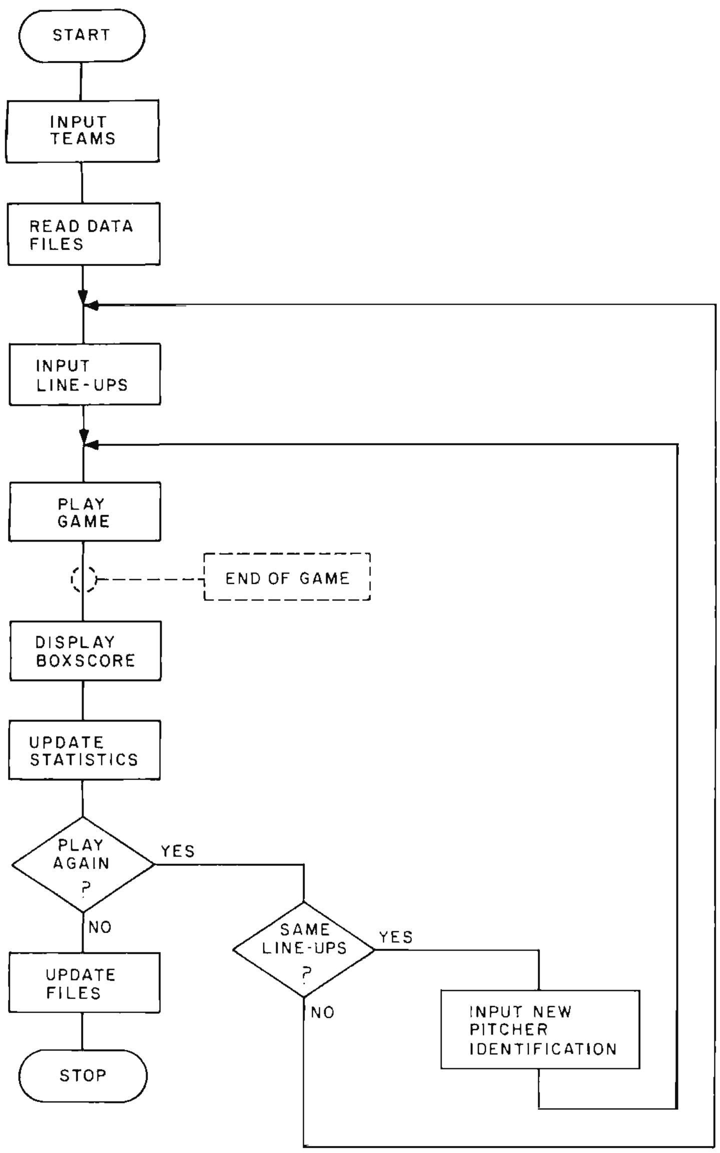


Figure 8: *Flowchart of the major divisions of operation of the Game program of listing 6.*

Text continued:

runners; all B values are set to 0 every half inning. If a batter gets a single that advances all runners by one base, variable B(4) is set to equal the value of B(3), B(3) is set to B(2), B(2) to B(1), and B(1) is set to a value of 1 plus the opposing pitcher's identification number. If a batter gets a single-base hit that moves runners two bases, B(5) is set to the value of B(3) and B(3) is set to 0, B(4) is set to the value of B(2) and B(2) to 0, B(3) to B(1) and B(1) to 0, and B(1) is set to a value of 1 plus the opposing pitcher's identification number. A similar process is used on outs that advance runners.

This procedure is done in the subroutine beginning with line 5900 in listing 6. The second half of this subroutine determines if any runs are scored by seeing how many of the B array elements with subscripts between 4 and 7 are not 0. Each positive number indicates one run. When I first wrote the program, the B array elements were set to either 0 or 1. However, by using the *pitcher's identification number plus 1*, all runs scored can be attributed to the record of the appropriate pitcher.

A similar tracking of runners and runs is recorded in the variable array R (with seven elements). This is needed to register *earned* runs only. All errors are assumed to be outs. Therefore, certain runners and advances are ignored, and innings end earlier with this variable allowing for the proper calculation of earned runs.

A subroutine for calculating winning and losing pitchers (beginning with line 6200 in listing 6) is consulted after each run is scored. If the particular run scored breaks a tie (the game starts with the score 0 to 0), a new winning pitcher is recorded. If the run causes a tie, the current winning and losing pitchers are removed from their particular status.

As demonstrated in the sample, a substitution can be made only after a run is scored. This is due to the fact that the subroutine at line 6100 is currently consulted only at that point. If you desire the option of a substitution after every play, merely add the program line:

```
122 GOSUB 6100
```

and remove the current:

```
"GOSUB 6100"
```

from line 6070.

Program Testing

After you enter the Game program into your computer, a test routine will be necessary to check for possible errors made during the program's entry. Changes in line 990 and in line 6100 of listing 6 will permit the program to loop and play numerous games without requiring any input from the user after the lineups are assigned. The revised lines are:

```
990  C9=C9+1: IF C9=50
     THEN 998 : GOTO 100
6100 RETURN
```

These modifications make the program play fifty consecutive games (C9=50 determines the number of games) with the same lineups and without asking the user for any substitutions.

In order to test the program after I wrote it, I played the 1961 New York Yankees against the 1962 New York Mets for fifty games. The results were amazing. The Yankees (who won 109 of 162 *real* games for a winning percentage of 67% in 1961) won 35 of the 50 games in the simulation for a 70% winning average. The Mets (who won 40 of 160 games, or 25%,

9a

FILE NAME ? 61-YANKS

NAME	AB	H	HR	RBI	AVE	NAME	IP	H	R	ER	KO	BB	W	L	ERA
SKOWRON---	176	43	3	7	.244	FORD------	476	471	228	202	291	251	39	11	3.82
RICHARDSON	233	68	4	27	.292	TERRY------	0	0	0	0	0	0	0	0	.00
KUBEK------	220	70	6	32	.318	ARROYO-----	0	0	0	0	0	0	0	0	.00
BOYER------	193	48	0	15	.249	STAFFORD---	0	0	0	0	0	0	0	0	.00
MARIS------	227	71	29	84	.313	COATES-----	0	0	0	0	0	0	0	0	.00
MANTLE-----	184	66	10	29	.359	SHELDON----	0	0	0	0	0	0	0	0	.00
BERRA------	199	54	9	33	.271	DALEY------	0	0	0	0	0	0	0	0	.00
HOWARD-----	204	90	25	67	.441	TURLEY-----	0	0	0	0	0	0	0	0	.00
LOPEZ------	0	0	0	0	.000	RENIFF-----	0	0	0	0	0	0	0	0	.00
BLANCHARD-	194	45	18	38	.232	DUREN------	0	0	0	0	0	0	0	0	.00
CERV-------	0	0	0	0	.000										
GARDNER----	0	0	0	0	.000										
DEMASTRI---	0	0	0	0	.000										
REED-------	0	0	0	0	.000										
TORGESSON-	0	0	0	0	.000										
GONDER-----	0	0	0	0	.000										
JOHNSON----	0	0	0	0	.000										
	1830	555	104	332	.303		476	471	228	202	291	251	39	11	3.82

9b

FILE NAME ? 62-METS

NAME	AB	H	HR	RBI	AVE	NAME	IP	H	R	ER	KO	BB	W	L	ERA
THRONEBERR	0	0	0	0	.000	CRAIG------	455	555	332	270	158	178	11	39	5.34
NEAL-------	228	48	3	11	.211	HOOK-------	0	0	0	0	0	0	0	0	.00
CHACON-----	170	49	0	14	.288	JACKSON----	0	0	0	0	0	0	0	0	.00
MANTILLA---	0	0	0	0	.000	MACKENZIE-	0	0	0	0	0	0	0	0	.00
ASHBURN----	207	58	4	24	.280	ANDERSON--	0	0	0	0	0	0	0	0	.00
HICKMAN----	195	51	5	29	.262	HILLER-----	0	0	0	0	0	0	0	0	.00
THOMAS-----	220	59	8	35	.268	CISCO------	0	0	0	0	0	0	0	0	.00
CANNIZZARO	175	39	0	15	.223	DAVIAULT---	0	0	0	0	0	0	0	0	.00
KANEHL-----	0	0	0	0	.000	HUMTER-----	0	0	0	0	0	0	0	0	.00
CHRISTOPHE	192	36	4	23	.188	MILLER-----	0	0	0	0	0	0	0	0	.00
WOODLING---	0	0	0	0	.000										
TAYLOR-----	0	0	0	0	.000										
COLEMAN----	0	0	0	0	.000										
HODGES-----	205	59	27	59	.288										
BOUCHEE----	0	0	0	0	.000										
COOK-------	200	72	0	18	.360										
BELL-------	0	0	0	0	.000										
	1792	471	51	228	.263		455	555	332	270	158	178	11	39	5.34

Figure 9: *Individual player statistics derived from the simulated play of fifty baseball games between the 1961 New York Yankees (9a) and the 1962 New York Mets (9b). In this fifty-game series the pitcher-tiring factor was set to 0. In team results, the Yankees won 39 of 50 (78%) of the games, and the Mets won 11 of 50 (or 22%).*

in 1962) won the other 15 games for a 30% winning average.

The numbers of hits and runs scored in this simulation were a little bit high, since the designated hitter was used (this did not occur in either 1961 or 1962) and the pitchers were never removed after tiring. Every time 2 runs are scored in an inning and for every scoring occasion in an inning after the 2 runs have been scored, the pitcher's hit rating is worsened by 0.025. This is done in line 6042 of the Game program.

A second test of fifty games was run. However, this test eliminated the tiring factor by changing the equation in line 6042. This line is branched to by other program statements; thus it could not be removed. Instead it became a nonfunctioning line: W(D+4)=W(D+4). The program was again tested.

In the second test, the Yankees won 39 (or 78%) of the games, while the Mets won only 11 (or 22%). The individual statistics appeared reasonable and are shown in figure 9. The model was clearly performing accurately with the statistically better team winning the majority of the games. The program Game was modified back to its original form, and the World Series described at the beginning of this article was run using the model.

Due to memory limitations, other enhancements were left out of this baseball-simulation model. For example, the display message for outs could be replaced by regular baseball scoring (6-3 meaning ground-out from shortstop to the first baseman), home run rates could be determined by the size of the field the simulation is assumed to be played in, and prepared lineups for each team could be stored on disk to facilitate play. If you modify these programs, please write to me. I would like to know the details. ■

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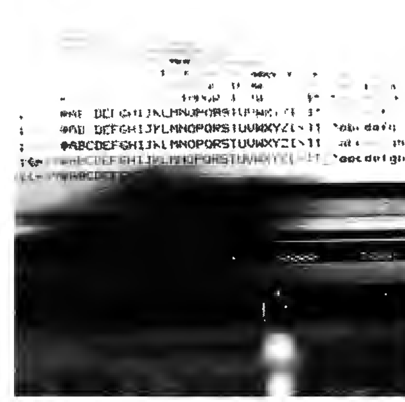

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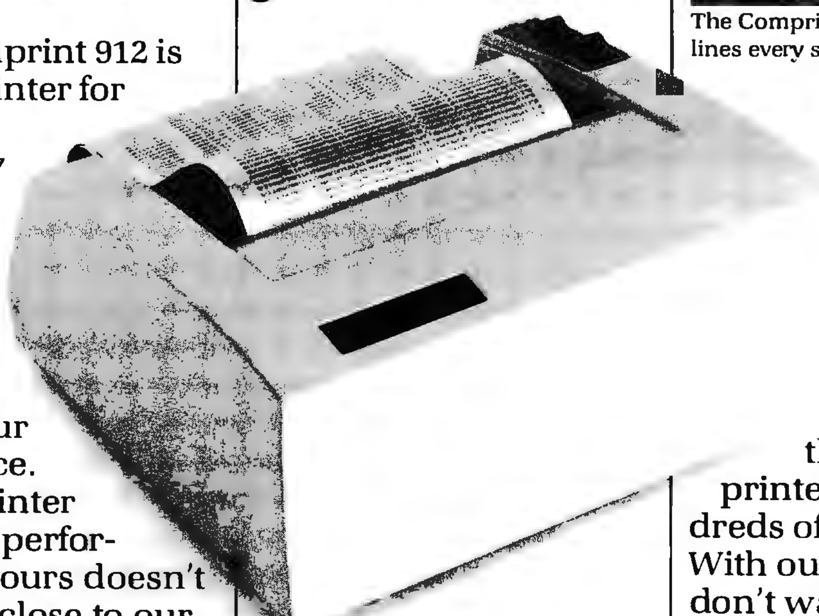

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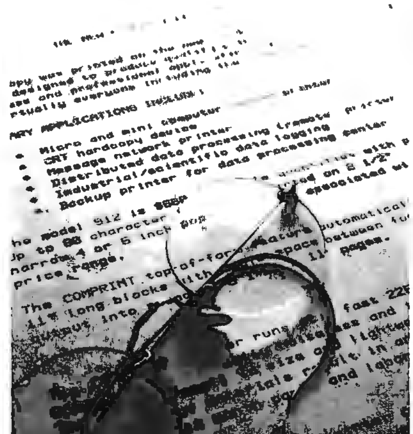

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Stack It Up

Charlton H Allen
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Most microprocessors currently available employ a stack of some sort. This stack is either a scratch memory in the processor itself or an addressable programmable memory characterized by retrieval of information in the reverse order of storage using a pointer. In the common parlance, a stack is a LIFO (last in first out) mechanism. It is a very useful feature for preserving the proper order of subroutine call and return points with minimal hassle. Experienced programmers using 8080 type machines quickly discover its other uses; for example, a direct register store instruction is three bytes long on the 8080, whereas a register stack instruction is only one byte. As a result, saving registers used by subroutines and restoring them later is cheaper if the stack is used in preference to some directly addressed memory area. More importantly, perhaps, the availablity of such a mechanism greatly simplifies the writing of reentrant routines, ie: ones which do not modify themselves in the process of execution. Note, however, that all the mechanisms provided in microprocessors to date for stack operations are explicitly fixed mode and singular. There is only one stack, and it operates on entities of the same width, in number of bits, as the accumulator(s). Moreover, these entities have no attribute other than their fixed width, in bits.

In contrast, several large scale computers, such as the Burroughs 5500 processor with which I am familiar, employ a more generalized stack mechanism in which:

- The storage area for the stack(s) is independent of the central processor's memory, ie: not directly addressable.
- The entities being stored and retrieved have attributes of type (integer, logical, real, string, array) and of length (array size).
- Multiple stacks may be processed simultaneously and independently.

To achieve the latter, the stack controller requires a "stack control block" in central processor addressable memory to be uniquely associated with each active stack. Otherwise, such stack controllers bear approximately the same relation to the central processor and its addressable memory as a

Listing 1: PARSE, a translation procedure written in an informal ALGOL.

```
STRING PROCEDURE PARSE(Exp):
STRING Exp;
BEGIN
   EXTERNAL  INTEGER  PROCEDURE    Intoken  ;
   LOGICAL                Endinput,         Errflag   ;
   INTEGER                Position,     I,     J,     T ;
   INTEGER ARRAY  S  =  (  1  -1   -2    2   -9,
                          -3   3    4   -4   -9,
                           5  -5   -6    6   -9,
                          -7   7    8   -8   -9,
                          -9  -9   -9   -9   -9);
   STACK Q ;

   Errflag  := Endinput   := false;
   PARSE  := null; Position := 0
   I  := Intoken(Exp, Position, Endinput);
   J  := Intoken(Exp, Position, Endinput);
   COMMENT I is last token, J is current  ;
   IF Endinput THEN Errflag := true
   ELSE WHILE NOT Endinput DO BEGIN
      T  := S(I,J);  IF T < 0 THEN Errflag := true
      ELSE CASE T OF BEGIN
         COMMENT valid sequence of tokens  ;
         CASE1: BEGIN
                   Q  := PARSE; PARSE  := null;
                END;
         CASE2: null;
         CASE3: PARSE  := PARSE  .  Q;
         CASE4: PARSE  := PARSE  .  Exp(Position)  .  '$';
         CASE5: BEGIN
                   Q  := PARSE  .  '$'; PARSE   := null;
                END;
         CASE6: PARSE  := PARSE  .  Exp(Position);
         CASE7: PARSE  := PARSE  .  Q;
         CASE8: PARSE  := PARSE  .  Exp(Position)  .  Exp (Position-1);
   END;
   I  := J;
   J  := Intoken(Exp, Position, Endinput);
   END;
   WHILE NOT Q = empty DO PARSE := PARSE .Q;
   IF Errflag THEN PARSE  := null;
END.
```


Input string: 1 + (((A+B)/C) — (D*(E—F)/G)) / H

Position	i	j	t	PARSE	Q
1	4			null	empty
2	4	3	8	+1	
3	3	1	5	null	+1$
4	1	1	1	null	null, +1$
5	1	1	1	null	null, null, +1$
6	1	4	2		
7	4	3	8	+A	
8	3	4	6	+AB	
9	4	2	7		null, +1$
10	2	3	4	+AB/$	
11	3	4	6	+AB/$C	
12	4	2	7		+1$
13	2	3	4	+AB/$C—$	
14	3	1	5	null	+AB/$C—$$, +1$
15	1	4	2		
16	4	3	8	*D	
17	3	1	5	null	*D$, +AB/$C—$$, +1$
18	1	4	2		
19	4	3	8	—E	
20	3	4	6	—EF	
21	4	2	7	—EF*D$	+AB/$C—$$, +1$
22	2	3	4	—EF*D$/$	
23	3	4	6	—EF*D$/$G	
24	4	2	7	—EF*D$/$G+AB/$C—$$	+1$
25	2	2	3	—EF*D$/$G+AB/$C—$$+1$	empty
26	2	3	4	—EF*D$/$G+AB/$C—$$+1$/$	
27	3	4	6	—EF*D$/$G+AB/$C—$$+1$/$H	

Figure 1: Sample parsing process resulting from use of program PARSE.

high speed data channel, in that the data transfers are generally effected through cycle stealing direct memory addressing, and an unmaskable interrupt to the central processor occurs only when an error condition, stack overflow or underflow, is detected.

I don't seriously propose such a stack controller for the representative homebrew computer system. I do propose, however, to show by example that incremental programming development in that direction can provide correspondingly simpler solutions to a large class of computing problems.

A Problem

One of the curious properties of calculators using Polish notation techniques is that any expression using the operators provided on the keyboard can be evaluated in an absolute minimum of keystrokes. Moreover, the required number of temporary storage areas, depth of stack, is at most the number of operands for the most complex operator. In an exactly analogous way, a stack of depth two or a second accumulator is sufficient in digital computers for evaluating any size expression using operators corresponding to native instructions, provided that the terms are calculated in the correct order. The price one pays for this admittedly pleasing property is learning to think things from the inside out. The user mentally seeks the interior of the expression, innermost term in parentheses, and works outward in calculation left to right. The pity is that it doesn't come easily to lots of folks since most people use the algebraic method of solving expressions which is the way they were taught in school. *[If a larger stack is used the expression can be evaluated from the left to right with the intermediate answers pushed onto the stack. . .*RC*]*

A Solution

The main problem with Polish notation is really one of representation. One wants to enter an expression in the same way it appears in, for example, a statistics handbook. If that could be done, if a way could be found to rearrange expressions from algebraic form to Polish notation, a mathematical calculator or computer could be constructed having the computational efficiency of Polish notation without sacrificing ease of use. In fact, this process of rearrangement has been intrinsic to most higher level programming language compilers and interpreters for many years. The manner in which the rearrangement is done is most easily explained in terms of a program which does just that by use of a stack only slightly more general than the native stack in microprocessors.

Explanation

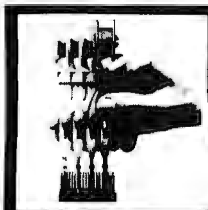
Listing 1 is a procedure for parsing, computer jargon for rearranging, generalized binary operator expressions. In somewhat less prosaic language: PARSE is a program which takes an algebraic form expression and rearranges it to produce a sub-Polish notation form expression containing references, where needed, to the runtime stack. Its output presumes that the result of each calculation is immediately placed on the stack.

Note that PARSE does not count parentheses. In fact, it does not even use them directly. Instead, it uses an external procedure called INTOKEN to scan the input expression, EXP, and produce encoded tokens depending on the current input:

1 for a left parenthesis.
2 for a right parenthesis.
3 for an operator.
4 for a constant or symbol.
5 if none of these.

Text continued on page 144

Circle 291 on inquiry card.



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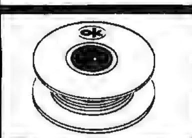

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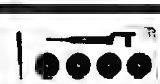

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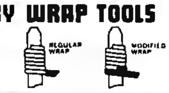

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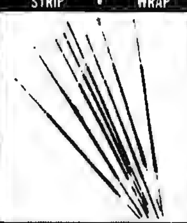

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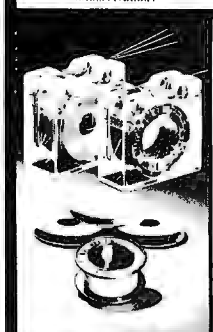
30 Y 50 040	30 AWG Yellow Wire 4" Long	$1 23
30 W 50 040	30 AWG White Wire, 4" Long	$1 23
30 R 50-040	30 AWG Red Wire 4" Long	$1 23
30 B 50-050	30 AWG Blue Wire 5" Long	$1 30
30 Y 50 050	30 AWG Yellow Wire 5" Long	$1 30
30 W 50-050	30 AWG White Wire 5" Long	$1 30
30 R 50-050	30 AWG Red Wire 5" Long	$1 30
30 B 50 060	30 AWG Blue Wire 6" Long	$1 38
30 Y 50-060	30 AWG Yellow Wire 6" Long	$1 38
30 W 50 060	30 AWG White Wire 6" Long	$1 38
30 R 50 060	30 AWG Red Wire 6" Long	$1 38



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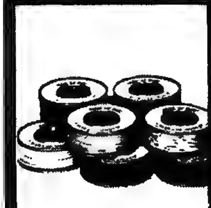

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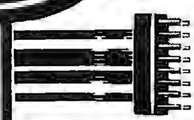

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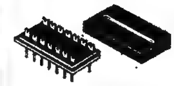

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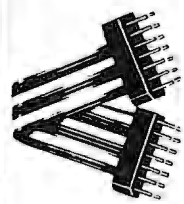

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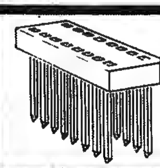

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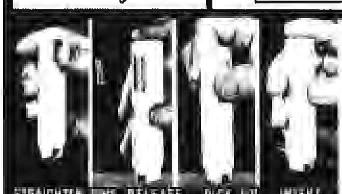

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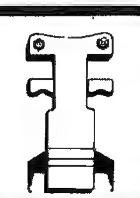

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Listing 2: INTOKEN encodes the current character in the input expression, Exp. As before, an informal ALGOL type notation is used.

```
INTEGER PROCEDURE INTOKEN (Exp, Position, Endinput):
LOGICAL  Endinput;
INTEGER  Position ;
STRING          Exp;
BEGIN INTOKEN := 0;
   IF Position =  SIZE(Exp) THEN Endinput  := true
   ELSE BEGIN
      Position := Position +  1;
      WHILE Exp(Position)  =  '   '   DO Position  := Position + 1,
      IF Exp(Position)  =  '(' THEN INTOKEN  := 1
      ELSE IF Exp(Position)  = ' ) ' THEN INTOKEN  := 2
      ELSE IF Exp(Position)  =  ANY( '+', '-', '*', '/' ) THEN INTOKEN  := 3
      ELSE BEGIN
         INTOKEN  := 5;
         COMMENT Presume error first, determine otherwise later;
         IF NOT ( 0 > Exp(Position) OR '9' < Exp(Position))
         THEN BEGIN
            INTOKEN  := 4;
            WHILE NOT ( 0 > Exp(Position) OR '9' < Exp(Position))
            DO Position     := Position + 1; Position  :=  Position -1;
         END ELSE
         IF NOT ('A' > Exp(Position) OR 'Z' < Exp (Position))
         THEN BEGIN
            INTOKEN  := 4;
            WHILE NOT ('A' > Exp(Position) OR 'Z' < Exp(Position))
            DO Position  :=  Position + 1;  Position  :=  Position --1;
         END;
      END;
   END;
END.
```

Listing 3: Single stack control routines written for the 8080 processor. STACK places a string of characters on a LIFO list, followed by the length of the string. POPSD removes the length of the last entered string, if any, from the list. POPUP removes the last entered string, if any, from the list. (Note: These routines are not debugged; in fact, the symbol STACK is multiply defined, so that it won't assemble correctly. They are included here only to suggest an appropriate technique.)

```
STACK:   PUSH    PSW        ;  COMMENT The following presumes
         PUSH    B          ;  external procedures ABUF and
         PUSH    D          ;  RBUF whose functions are,
         PUSH    H          ;  respectively,
         XCHG               ;     acquire a buffer of byte size
         LHLD    STACK      ;       specified by A, returning
         PUSH    H          ;       address in H,L or zero if
         POP     B          ;       none available
         ADI     3          ;     release a buffer addressed by
         CALL    ABUF       ;       H,L to the buffer pool      ;
         MOV     A,H        ;
         ORA     L          ;  STACK:    SAVE(H,L);
         JZ      STKOF      ;  ABUF (A+3);   IF 0
         SHLD    STACK      ;   THEN SET(Carry)
         MOV     A,C        ;  ELSE BEGIN
         STAX    H          ;     COMMENT Stack entry contents:
         INX     H          ;     +0     addr of previous entry
         MOV     A,B        ;     +2     size of current item
         STAX    H          ;     +3     current item
         INX     H          ;
         POP     PSW        ;     caller provides size in A,
         MOV     B,A        ;     item data address in H,L ;
         STAX    H          ;     RESET(Carry);
         ORA     A          ;     MEMORY(H,L)  := Stack;
         JZ      STKCX      ;     Stack := (H,L);
         INX     H          ;     (H,L) := (H,L)       +  2;
STKCY:   LDAX    D          ;     MEMORY(H,L)  :=     A;
         STAX    H          ;     (H,L)  := (H,L)       +  1;
         INX     H          ;     RESTORE(D,E); SAVE(D,E);
         INX     D          ;     WHILE NOT A = 0 DO
         DCR     B          ;     BEGIN
         JNZ     STKCY      ;        MEMORY (H,L)  := MEMORY (D,E);
STKCX:   POP     H          ;        (H,L) := (H,L) + 1;
         POP     D          ;        (D,E) := (D,E) + 1;
         POP     B          ;        A  := A - 1;
```

Listing 3 continued on page 146

Text continued:

Another peculiar property of PARSE, presuming you haven't figured out how it works yet, is that only one complete INTOKEN scan of the input expression is required because of the use of a stack, Q, for retaining the symbols for intermediate expressions. INTOKEN recognition of parentheses (output codes 1 and 2) effectively controls stacking and popping up symbols for intermediate expressions in the required order.

The operation of PARSE depends critically on the array S. In use, its row subscript is presumed the value of the last INTOKEN output, its column subscript the value of the current INTOKEN output. Specifically, if the last input token was a left parenthesis and the current input token was 'E' (a symbol or constant) then INTOKEN's last and current outputs would be 1 and 4; the matching element in S (row 1 column 4) has value 2, so that the statement CASE2 would be performed. Subsequently, J replaces I and INTOKEN is again invoked to evaluate J anew; a new element of S is fetched using the new values of I and J as subscripts; and the element of the CASE statement list matching the new value taken from S is performed. This process is repeated until INTOKEN sets Endinput true, indicating the end of the input string Exp has been detected. Since the last two tokens might be right parentheses, and PARSE does not in fact process the last token since tokens are used only in pairs, the stack Q is always flushed before PARSE finishes.

PARSE is presented in informal ALGOL only in the hope the process per se of suitably rearranging algebraic form expressions can be made more easily understood than via an equivalent 8080 assembly language program which might prove to be a transliteration nightmare for the novice LSI-11 or PPS-8 programmer. Contrarily, the step by step listing of PARSE and the associated control indices in figure 1 should aid in understanding what PARSE is really doing, with respect to the hypothetical expression. The function of INTOKEN, recognizing and encoding the elements of an expression, is sufficiently straightforward that an explicit statement of it is hardly necessary, but listing 2 is included nonetheless in informal ALGOL. The remaining question, perhaps, is one of making the stack Q of PARSE operable on a microcomputer. To that end, listing 3 shows a hypothetical implementation of single stack control routines STACK, POPUP, and POPSD using 8080 assembler format.

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Now what? Well, for a start let's observe that PARSE will work only with binary operator expressions. Right? Well, not quite. Note that PARSE passes the buck for recognition. If INTOKEN can recognize unary operators, it can also stuff in a dummy operand on the fly, since PARSE initializes Position, and thereafter leaves it alone. That is, the common unary operators are special cases of a binary and either zeroes or ones: NOT FRED is equivalent to ones exclusive-OR FRED; NEGATIVE VIBES is equivalent to 0 – VIBES; and INVERSE HYPOTHESIS is equivalent to 1/HYPOTHESIS.

How about the results? PARSE can easily be modified to directly generate machine language code if INTOKEN is modified to create or at least have access to a symbol table; or its output can be used, as is, by an interpretive calculator program. Obviously, 8080 machines and, for that matter, most microprocessors lack multiply and divide instructions, but nonnative operations can easily be interpreted as operator subprogram calls. PARSE makes no presumption about the computer on which it's run except the availability of a stack to use with its output referenced by '$'. The operators, for example, for which PARSE was developed in the form shown were character string operators of combination and proximity. The PARSE output was interpreted by a program for searching large textual files on an IBM System 360 disk unit. The point is that the results are what you make of them, PARSE being no more than a procedure for rearrangement of expressions.

A final apology before getting under way. FORTRAN freaks may by now have noticed an "error" in that although the tokens 1 and H in the example of figure 1 are at the same parenthesis level, the add-1 parse precedes the divide-H in the final step. Why? I prefer to ask why one bothers anyway with operator priorities so long as the desired order of computation can be explicitly specified by using parentheses. The example of figure 1, in fact, was contrived in part to illustrate that PARSE as shown here presumes a strict left to right evaluation at any parentheses level. Operators are not "ranked" as in FORTRAN and several other higher level programming languages.

Listing 3, continued:

```
        STC                 ;      END;
        CMC                 ;   END;
        RET                 ;   RESTORE(H,L);
STKOF:  POP     H           ;
POPUF:  POP     D           ;
        POP     B           ;
        POP     PSW         ;
        STC                 ;
        RET                 ;
;
;
POPSD:  PUSH    H           ;   POPSD: IF Stack = 0
        STC                 ;   THEN SET(Carry)
        LHLD    STACK       ;   ELSE BEGIN
        MOV     A,H         ;      COMMENT Give caller size
        ORA     L           ;      of next entry to pop, for
        JZ      POPZD       ;      buffering as needed      ;
        INX     H           ;      RESET(Carry);
        INX     H           ;      SAVE(H,L);
        CMC                 ;      (H,L) := Stack + 2;
        LDAX    H           ;      A  := MEMORY(H,L);
        JMP     POPXD       ;      RESTORE(H,L);
POPZD:  SUB     A           ;   END;
POPXD:  POP     H           ;
        RET                 ;
;
;
;       The following must be in R/W
;       memory, since Stack is the
;       list-origin address, and LHLI
;       is externally modified to
;       effect an indirect LHLD.
LHLI:   LHLD    0     ;
        RET           ;
STACK:  0             ;
POPUP:  PUSH    PSW         ;   POPUP: IF Stack = 0
        PUSH    B           ;   THEN SET(Carry)
        PUSH    D           ;   ELSE BEGIN
        PUSH    H           ;      COMMENT Target area is
        LHLD    STACK       ;      specified by caller H,L;
        XCHG                ;      RESET(Carry);
        POP     H           ;      SAVE(D,E,H,L);
        MOV     A,D         ;      (D,E) := Stack;
        ORA     E           ;      B  := MEMORY (D,E + 2);
        JZ      POPUF       ;      SAVE(D,E,H,L);
        PUSH    H           ;      (D,E)    := (D,E) + 3;
        PUSH    D           ;      WHILE NOT B = 0 DO
        INX     D           ;      BEGIN
        INX     D           ;         COMMENT Zero-length entries
        LDAX    D           ;         are removed but not copied   ;
        ORA     A           ;         MEMORY(H,L)   := MEMORY(D,E);
        JZ      POPCX       ;         (D,E)  := (D,E) + 1;
        INX     D           ;         (H,L)  := (H,L) + 1;
        MOV     B,A         ;         B  := B - 1;
POPCY:  LDAX    D           ;   END;
        STAX    H           ;   RESTORE(D,E,H,L);
        INX     H           ;   Stack     := MEMORY(D,E);
        INX     D           ;   RBUF(D,E);
        DCR     B           ;   RESTORE(D,E,H,L);
        JNZ     POPCY       ;   END;
POPCX:  POP     D           ;
        XCHG                ;
        SHLD    LHLI+1      ;
        CALL    LHLI        ;
        SHLD    STACK       ;
        LHLD    LHLI+1      ;
        CALL    RBUF        ;
        POP     H           ;
        POP     D           ;
        POP     B           ;
        POP     PSW         ;
        STC                 ;
        CMC                 ;
        RET                 ;
```

One More Time

If the available stack mechanism is only once more generalized, to provide multiple stacks simultaneously, some conceptual simplification of a large class of problems occurs. As a near trivial example, we illustrate in listing 4 a 2 stack sorting procedure. In essence, it removes records (strings) from a file one at a time and manipulates the two stacks, Highside and Lowside, back and forth until the new record fits in the inclusive interval of values bounded by the top

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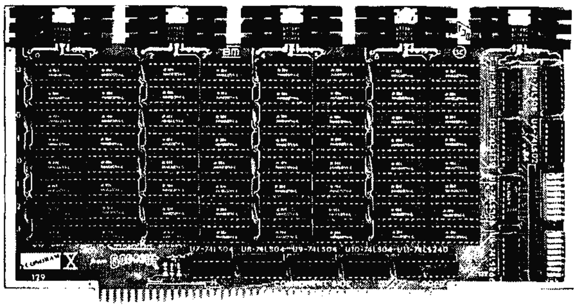

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Listing 4: A SORT procedure expressed in informal ALGOL type notation demonstrates use of two stacks.

```
STRING ARRAY PROCEDURE SORT(File):
STRING ARRAY File;
BEGIN
  INTEGER              K;
  STRING               This;
  STACK  Highside, Lowside;
  Lowside := File (1);
  Highside := File (2);
  COMMENT top function references item
  on the top of some stack;
  IF TOP(Lowside) > TOP(Highside)
  THEN BEGIN
     This        := Highside;
     Highside    := Lowside;
     Lowside     := This;
  END;
  COMMENT size function produces the
  current number of elements in array;
  K  := 3;
  WHILE K ≤ SIZE(File) DO
  BEGIN
     This        := File(K);
     K           := K + 1;
     WHILE This  < TOP(Lowside)  DO Highside  := Lowside;
     WHILE This  > TOP(Highside)  DO Lowside   := Highside;
     Highside    := This;
  END;
  WHILE NOT(Lowside = empty) DO Highside := Lowside;
  K  := 1;
  WHILE K ≤ SIZE(File) DO
  BEGIN
     SORT(K)   := Highside;
     K         := K + 1;
  END;
END.
```

elements of the two stacks. The procedure has two virtues:

- It's easy to describe and understand.
- It requires an absolute minimum of workspace.

The price one pays is speed. It's probably one of the two or three slowest sorting algorithms around. ■

The program examples which appear in this article are written in an informal ALGOL type notation. The basic unit of ALGOL is the statement. It can be either a simple statement such as:

```
Position :=0;
```

which is read "position is evaluated as 0," or a compound statement defined by BEGIN . . . END such as:

```
BEGIN
   Q := PARSE; PARSE := null;
END
```

which is read "Q is evaluated parse, PARSE is evaluated null."

The statements defined between the BEGIN and END statements are not restricted to type. A preceding conditional such as (IF . . . THEN . . ELSE) will affect the entire command statement. One of the constituents of the statement may well be another compound statement. For example, to add an array of samples having subscripts 1 through Limit which is specified elsewhere we could write:

```
BEGIN
   Subscript :=1; Sum :=0;
   WHILE Subscript < Limit DO
   BEGIN
      Sum := Sum + Sample(Subscript) ;
      Subscript := Subscript + 1;
   END;
END;
```

The WHILE statement's operand (the statements after the DO) rather intuitively is in execution so long as the conditional part (Subscript < Limit) is true.

The CASE statement is simpler in effect. It acts approximately like an indexed jump. It has two operands. The first of these (T in the PARSE procedure) is an integer, and the second is a list of statements bracketed by BEGIN and END. The first operand selects for execution the statement from the list whose position matches the value of the index specifier.

Following are the informal extensions that have been made to ALGOL and used in the programs:

- The period indicates concatenation of character strings. Presuming values of 'WHAT' and 'STUFF' for symbols A and B, A . B will have a value of 'WHATSTUFF.'
- Q is declared to be of type STACK which, however implicit in most implementations of ALGOL-60, was not construed to be explicitly available. It is, in effect, a LIFO indexed character string array.
- Null and empty are used for assigning values, respectively, of a character string of length zero and a stack having zero entries.

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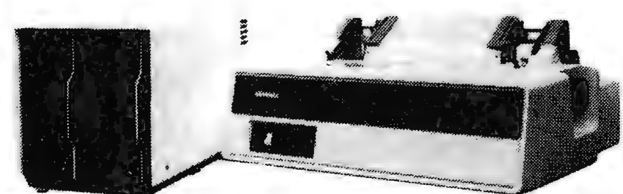
MINIMAX

"FULLY INTEGRATED COMPUTER SYSTEM"



PRINTER NOT INCLUDED IN PRICE

THE MINIMAX SERIES WAS DESIGNED TO OFFER THE MARKET MINICOMPUTER CAPABILITIES AT MICROCOMPUTER PRICES. COMPARE THE CAPABILITIES & PRICE!

MINIMAX SERIES COMPUTER

CONTACT NEECO FOR FULL SPECS - FREE MINIMAX MANUAL.

MEET THE MINIMAX COMPUTER

THE MINIMAX SERIES COMPUTER WAS DESIGNED BY INDUSTRY PROFESSIONALS. COMPARE THE PRICE AND FEATURES TO ANY OTHER COMPUTER IN ITS CLASS!

• THE MINIMAX SERIES COMPUTER IS AN INTEGRATED, COMPACT UNIT CONTAINING THE CPU, DUAL DENSITY DISK STORAGE, 12 INCH CRT, AND FULL STYLE KEYBOARD, WITH SEPARATE NUMERIC ENTRY PAD. ALL KEYS (INCLUDING CURSOR) WITH FULL REPEAT • HYBRID 2 MEGAHERTZ 6502 CPU • 108K SYSTEM RAM (48K USER) • FASTEST FLOPPY DISK ACCESS (24K LOADS IN 4.2 SECONDS) • 16K ROM CONTAINS COMPUTHINK BASIC (AN EXTENDED MICROSOFT BASIC) WITH EXTENDED PRECISION, DOS INCLUDES COMPLETE FILE I/O WITH FULL RANDOM ACCESS, COMPLETE MONITOR WITH DEBUG & TRACE, AND TINY 6502 ASSEMBLER • COMPLETE HIGH RESOLUTION GRAPHICS WITH INDIVIDUAL DOT (240x512) POINT SCREEN ADDRESSABILITY • FULL SCREEN TEXT EDITING WITH OVERWRITE, INSERTION OR DELETION • SPLIT SCREEN/WINDOW MODES • INDIVIDUAL FIELD EDITING WITH FIELD PROTECT AND AUTO SKIP TO NEXT FIELD • DISK STORAGE SYSTEM TRANSFERS 6K PER SECOND WITH AUTO VERIFY AND PARITY CHECK • 12 INCH CRT-64 CHARACTERS BY 30 LINES. UP TO THREE PROGRAMMABLE CHARACTER FONTS FOR LANGUAGES OR SPECIAL CHARACTERS • • • SWITCHABLE 110 OR 220V OPERATION • • • HYBRID CPU IS MICROPROGRAMMABLE WITH 64 USER DEFINABLE OPCODES. CHOICE OF 800K OR 2.4 MEGABYTE DISK STORAGE • FULL SERIAL RS-232C PORT WITH PROGRAMMABLE BAUD RATES AND MODEM CONTROL SIGNAL • DEDICATED DISK PORT • PRINTER PORT SUPPORTS PARALLEL COMMERCIAL PRINTERS • 24 PIN I/O USER PORT • PAGEMATE DATABASE AVAILABLE • PLM COMPILER AVAILABLE • BUSINESS PACKAGES AVAILABLE • COMPLETE DIAGNOSTICS & SCHEMATICS INCLUDED • COMPLETE USER MANUAL INCLUDED

MINIMAX I - $4495 MINIMAX I - .8 MEGABYTE ON LINE MINIFLOPPY STORAGE

MINIMAX II - $5995 MINIMAX II - 2.4 MEGABYTE ON LINE 8" FLOPPY STORAGE

THE MINIMAX WAS DESIGNED AND IS MANUFACTURED BY COMPUTHINK COMPUTER CORP. DISTRIBUTED IN EUROPE AND THE EASTERN U.S. BY NEECO.

COMPUTHINK .4 & .8 MEGABYTE DISK DRIVES FOR THE NEW 16/32K PETS!

DISK SYSTEMS INCLUDE DISKMON OPERATING SYSTEM IN ROM AND INTERFACE TO 16/32 PETS!

- Dual Minifloppy Drives with 200K per diskette side for total 400K/800K on line
- 800K model accesses all 4 diskette sides via dual read and write arm system
- Dual Density Hardware and DOS loads 20K (with verification) in 4 2 seconds complete
- DISKMON (DOS) adds 17 commands to BASIC including Random Access and printer support
- System comes complete with plug in internal board containing 8K RAM, DOS, and Disk Controller Hardware—Board plugs directly onto internal memory expansion pins
- System does not utilize IEEE or USER Port, system functions directly from memory port
- All DISKMON DOS commands reside interactively with BASIC—disk directory command and format command do not interfere with program in RAM—DOS command were designed for simplicity of use System was manufactured for heavy commercial use
- System installs completely in less than ten minutes—immediately ready for use
- $1295 and $1595 prices include all hardware, DOS complete user manual, and demo utility diskette
- Available software includes PLM Compiler ($250) Relocatable Assembler ($70), Source-Editor Program ($70), Autolink Linking Loader ($70) and a complete Database system (Pagemate $495)
- Call or write for complete product information and specifications—User manual $10

FOR 8K PETS
(small keyboards)
.4 Megabytes of Disk Storage for 8K PETS!
(Requires Expandamem)
400K-8S DISK SYSTEM INCLUDES RANDOM ACCESS IN DOS-LOADS 20K IN 4 SECONDS!
24K Expandamem Memory $525
32K Expandamem Memory $615

$1295

(PRODUCT AVAILABILITY IS AUG/SEPT—CALL FOR INFO)

ALL 16/32K MODELS INCLUDE AN INTERNAL PLUG-IN INTERFACE BOARD CONTAINING DOS, 8K OF RAM, AND CONTROLLER

400K-16N	$1295
400K-32N	$1295
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Microcomputer Systems Division

NEW ENGLAND ELECTRONICS CO., INC.
679 HIGHLAND AVE., NEEDHAM, MA 02194
MON-FRI, 9:00-5:30, E.S.T.

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Circle 281 on inquiry card.

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Microcomputer Systems Division

PROUDLY ANNOUNCES THE NEWEST HARDWARE AND SOFTWARE FOR YOUR PET!

The PET is now a truly sophisticated Business System with the announcement of these peripherals and software packages.

PRODUCT	DESCRIPTION	PRICE	AVAILABILITY
PET 2001—8KN (Large Keys)	8K RAM	$ 795	DEC/JAN
PET 2001—8K	8K RAM	$ 795	IMMEDIATE
PET 2001—16KN (Large Keys)	16K RAM*	$ 995	IMMEDIATE
PET 2001—32KN (Large Keys)	32K RAM	$1295	IMMEDIATE
PET 2023 PRINTER	ROLL FEED	$ 850	IMMEDIATE
PET 2022 PRINTER	TRACTOR/ROLL	$ 995	IMMEDIATE
ROMRETRO KIT	UPDATED O/S	$ 90	IMMEDIATE
PET 2040	DUAL FLOPPY*	$1295	IMMEDIATE
PET C2N	2nd Cassette	$ 100	IMMEDIATE

*The 16K/32K (large keyboard) units do not include a cassette drive. Order C2N Cassette. 2040 Floppy Drive requires a 16K or 32K unit. 8K RAM Retrofit available July.

ALL PETS ARE FULLY TESTED BY NEECO BEFORE SHIPMENT. NEECO IS A FULL CUSTOMER-ORIENTED BUSINESS. CALL FOR OUR FREE CATALOG. SEND US A COPY OF THIS AD WITH AN ORDER AND WE WILL WARRANTEE YOUR COMMODORE PET FOR ONE FULL YEAR!

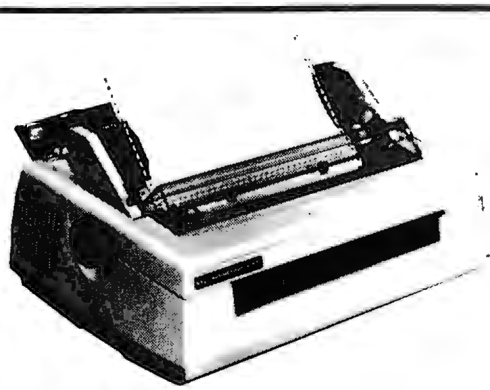
PET-DISK BASED BUSINESS SOFTWARE

SOFTWARE/APPLICATION	*REQUIRES*	*AUTHOR*	*AVAILABILITY*	*PRICE*
WORDPRO II / WORD PROCESSING	2040 + 16K PET	PRO/MICRO	IMMEDIATE	$100
WORDPRO III / WORD PROCESSING	2040 + 32K PET	PRO/MICRO	DECEMBER	$200
GENERAL LEDGER	2040 + 32K PET	CMS SOFTWARE	IMMEDIATE	$295*
ACCOUNTS PAYABLE	2040 + 32K PET	CMS SOFTWARE	DECEMBER	$295*
ACCOUNTS RECEIVABLE	2040 + 32K PET	CMS SOFTWARE	DECEMBER	$295*
MAILING LIST	2040 + 32K PET	CMS SOFTWARE	IMMEDIATE	$100
NEECOLEDGER	COMPUTHINK .4 M DRIVE + 32K PET	NEECO	IMMEDIATE	$795
NEECOMAILER	COMPUTHINK .4 M DRIVE + 32K PET	NEECO	IMMEDIATE	$150

*The CMS Software (G/L, A/R, A/P) are based on Osborne & Associates trial tested business basic software. Software is complete with full documentation and user instructions. All packages require a printer for output. Commodore recommends the NEC Spinwriter (available from NEECO) as the output printer for WORDPRO.

DEALER INQUIRIES INVITED ON SOFTWARE & NEC (PET) SPINWRITER

FOR WORD PROCESSING NEC IS BEST!



* 55 characters per second output speed
* Changeable thimble for different typestyles
* Less than 1% warranty malfunction rate
* IBM quality letter output
* Dealer inquiries invited

THE NEC SPINWRITER
MODEL 5530-P (Centronics I/O modified for PET)

$2995

*Price includes IEEE interface to PET. IEEE Port is available for use with 2040 Dual Disk.

*The NEC 5530-P is the output printer recommended by Commodore for their Word Processing System.

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Writing Animated Computer Games

Tony Estep
Vice President
Kidder, Peabody and Company Inc
10 Hanover Sq
New York NY 10005

It has been quite some time since the arrival of memory-mapped I/O (input/output) boards upon the amateur computer scene, but the voluminous home computer literature rarely contains any listings of animated video games. Since it seems to me that there breathes not a hobbyist with soul so dead that he would not play one of these devilish little time wasters if he had one, I concluded that perhaps the lack of video games was due to some lack of information about how to get one up and going. This was certainly the case with me; I just started with a blank piece of paper and began scratching. But as the reader will see, there really is no mystery to it, and the results are well worth the effort.

A video game works just the same as an animated cartoon; there are a series of frames, each of which shows one or more of the objects in the picture in a slightly different position. Since the viewer's visual system has a certain persistence, the effect is one of continuous motion. In the case of a television picture, each frame is a single rewriting of the raster. This is very fast, and the flicker is seldom noticeable. A computer can pop information in and out of screen memory much faster than the monitor can

Text continued on page 158

Listing 1: *8080 assembly-language program to create an animated computer game.*

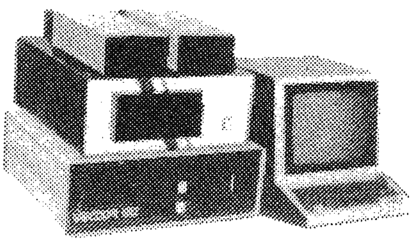
```
0100                *BALLOON*
0100                * A PROGRAM ILLUSTRATING SOME PRINCIPLES OF
0100                * PROGRAMMING AN ANIMATED GAME
0100                *
0100                * COPYRIGHT 1979 TONY ESTEP
0100                *
0100                VDMBAS EQU   0CC00H
0100                MIDL   EQU   0CE1EH ;ALL THESE RELATE TO THE SOL/20 &
0100                CLSCN  EQU   0C0D5H ;ITS VDM AND SCREEN CLEAR ROUTINE
0100                SCBOT  EQU   0CFC0H ;MIDDLE OF LOWEST LINE
0100                RAR    EQU   93H ;THESE ARE ARROWS ON KEYBOARD
0100                LAR    EQU   81H
0100                UAR    EQU   97H
0100                DAR    EQU   9AH
0100                       ORG   100H ;SO IT WILL RUN WITH CPM
0100 31 0C 06              LXI   SP,STACK+46
0103 CD D5 C0              CALL  CLSCN ;FOR NON-SOL, WRITE SIMPLE ROUTINE TO CLEAR
0106 21 00 CC              LXI   H,VDMBAS
0109 36 20                 MVI   M,' '
010B CD 79 02       BEGIN  CALL  WAIT
010E AF             GO     XRA   A ;INITIALIZE FLAGS
010F 32 A3 03              STA   G1
0112 32 9E 03              STA   FLG1
0115 32 88 04              STA   NSCR
0118 32 89 04              STA   PSCR
011B 3E 01                 MVI   A,1
011D 32 47 04              STA   BFLG1
0120 32 30 05              STA   RAFL
0123 32 EA 04              STA   STRTF
0126 CD D5 C0              CALL  CLSCN
0129 21 00 CC              LXI   H,VDMBAS
012C 36 20                 MVI   M,' '
012E 21 1E CE              LXI   H,MIDL
0131 22 F6 02              SHLD  CORNR
0134 CD 89 01              CALL  SHIP
0137 CD 6A 02              CALL  DELAY
013A CD 6A 02              CALL  DELAY
013D CD 6A 02              CALL  DELAY
0140 CD 6A 02              CALL  DELAY
0143 CD 6A 02              CALL  DELAY
0146 CD 6A 02              CALL  DELAY
0149 CD 6A 02              CALL  DELAY
014C                ************************************
014C                *MAIN LOOP STARTS HERE
014C CD C1 01       RUNIT  CALL  TAKOF ;PUT BLANKS IN SHIP IMAGE
014F CD 89 01              CALL  SHIP ;PUT IT ON SCREEN
```

Listing 1 continued on page 154

MUFS FOR EVERYONE (ESPECIALLY DEALERS)
MULTIPLE FLOPPY SYSTEM

MUFS is a prom resident supervisor for the Vector Graphic System B which allows menu selection of all the following operating and disk system configurations* without changing a single board on the system, or plugging in and unplugging peripherals.

Disk Drive Configuration	Disk Size	Disk Controller	Disk Density	Drive Assignment	Operating System
Persci 277	8"	Micromation	Single/Double	A, B	CP/M
Shurgart SA450	5¼"	Northstar	Single/Double	C, D	CP/M
Persci 277	8"	Micromation	Single/Double	A, B	CP/M
Miropolis MODII	5¼"	Micropolis	Quad	C, D	CP/M
Persci 277	8"	Micromation	Single/Double	A, B	CP/M
Shugart SA450	5¼"	North Star	Singe/Double	A, B	CP/M
Micropolis MODII	5¼"	Micropolis	Quad	A, B	CP/M
Micropolis MODII	5¼"	Micropolis	Quad	0, 1	MDOS
Micropolis MODII	5¼"	Micropolis	Quad	1, 2	MZOS
Micropolis MODII	5¼"	Micropolis	Quad	A, B	OASIS
Shugart SA450	5¼"	North Star	Single/Double	1, 2	DOS
Persci 277	8"	Alpha Micro*	Single	1, 2	AMOS*



Those configurations using two types of drives permit file copy from one type to another with the facilities of 'PIP'. MUFS includes Vector Graphics complete System B, all the above mentioned disks/controllers with operating systems fully configured and operational on the System B. OASIS, AMOS and the ALPHA MICRO CPU/Disk Controller are extra. MUFS also includes UNIVID (Universal Video, which allows the mindless terminal which comes with the System B to emulate the Hazeltine 1500 and Adam-3A). Additionally, MUFS also includes the communications software (IC) described below (IC is available separately). With MUFS, computer/software dealers can develop/copy/demo most all of their software on a single system with the snap of a disk drive door! Since MUFS supports multiple terminals, the 'Mime' terminal is available as an option. If purchased, this allows MUFS to run software designed specifically for either memory mapped or serial I/O (most software works on either).

IC FOR CP/M**
INTERSYSTEM COMMUNICATIONS

- Communicates with other computers through a user selected RS232-C Port
- Transmits ASCII Data to/from all computers (Maxi, Mini, Micro, Time Sharing and Single User).Transmits ASCII and Binary Data between CP/M Systems.
- Supports multiple terminals and printers which can be local or remote, and can be logged on and off the system.
- Supports 9600 Baud to printers with the X-on/X-off feature
- Permits an IC installed computer to function both as a computer, and as a terminal or systems console to other computers, with software switching between the two modes.
- Permits dealers to operate customers computers remotely,patching software, sending new software, testing the customer's computer, etc.
- When sending data, IC is programmed to automatically wait for the receiving computer if it cannot keep up with a steady Baud rate.
- Throughly tested with 7 different computer systems, full and half duplex.
- Software available on diskette only, or diskette/prom (prom version boots faster)
- Does not require an interrupt capability

DOC FOR NORTH STAR

DOCUMENTATION

- Prints formated program listings with user selected spacing, titling, dating, and paging
- Prints an alphabatized cross reference listing of all variables with an ordered list of the line numbers they are used in.
- For all lines which are the destination of a 'GOTO' type statement prints a list of all line numbers containing a reference to the selected destination line.

OPTIMIZATION

- Optimizes speed of execution primarily through reduction in execution time of 'GOTO' type statements. This results from a reduction in the number of statements through statement concatenation.
- Optimizes program size through removal of all unnecessary blanks. Optionally removes REM statements. Saves 3 BYTES for every short statement concatenated into a longer statement.

CONFIDENTIALITY

- Protects the confidentiality of your programs by inhibiting the North Star list and edit functions once a program has been optimized by DOC. Offers virtually as much protection as compiler basics.

PRICES:

MUFS $9,500.00 OASIS OPTION - $500.00
IC DISKETTE VERSION $150.00
DOC $59.00

MIME TERMINAL OPTION $825.00
ALPHA MICRO CP/U AND DISK CONTROLLER OPTION - $2,190.00
DISKETTE/PROM VERSION $200.00
MANUALS AVAILABLE SEPARATELY FOR $10.00 EA.
DEALER QUANTITY DISCOUNTS AVAILABLE FOR IC/DOC

SEND ORDERS AND INQUIRES TO:

MINI BUSINESS SYSTEMS • 2461 S. Main • P.O. Box 15587 • Salt Lake City, Utah 84115 • PH (801) 467-1571

*Amos is not menu selectable, and does require removal and insertion of some board's in the S-100 Bus
**CP/M is a trademark of Digital Research

Listing 1 continued:

```
0152 2A F2 02          LHLD   LR
0155 E5                PUSH   H
0156 2A F4 02          LHLD   UD
0159 E5                PUSH   H
015A 2A F6 02          LHLD   CORNR
015D C1                POP    B
015E 09                DAD    B
015F D1                POP    D
0160 19                DAD    D
0161 22 F6 02          SHLD   CORNR ;NEW LOCATION FOR SHIP
0164 CD AC 01          CALL   PUTON ;PUT GRAFIX IN SHIP IMAGE
0167 CD 89 01          CALL   SHIP ; PUT IT ON SCREEN
016A CD D9 01          CALL   KYCHK ;CHECK KEYBOARD
016D CD D5 02          CALL   TOPB ;CHECK TO SEE IF WE'RE AT TOP OR BOTTOM OF SCR.
0170 CD 59 02          CALL   BLNCHK ;IS A BALLOON DROPPING?
0173 CD 6A 02          CALL   DELAY
0176 CD 00 03          CALL   PEA1
0179 CD C9 03          CALL   PEACHK ;IS THERE A SHOOTER ON SCREEN?
017C CD 36 05          CALL   PEAOF ;TAKE IT OFF MAYBE
017F AF                XRA    A
0180 32 E7 04          STA    STRTF
0183 CD 8A 04   SCORIT CALL   SCORE ;UPDATE SCORE
0186 C3 4C 01          JMP    RUNIT
0189            *************************************
0189 2A F6 02   SHIP   LHLD   CORNR ;MOVES MEMORY IMAGE OF SHIP
018C CD 48 04          CALL   HIT ; ONTO SCREEN
018F 3A FA 02          LDA    LEND
0192 77                MOV    M,A
0193 23                INX    H
0194 CD 48 04          CALL   HIT
0197 3A F9 02          LDA    BLAK
019A 77                MOV    M,A
019B 23                INX    H
019C CD 48 04          CALL   HIT
019F 3A F8 02          LDA    WHIT
01A2 77                MOV    M,A
01A3 23                INX    H
01A4 CD 48 04          CALL   HIT
01A7 3A FB 02          LDA    REND
01AA 77                MOV    M,A
01AB C9                RET
01AC 3E 10      PUTON  MVI    A,10H ;THE GRAPHICS WHICH MAKE UP THE SHIP
01AE 32 F8 02          STA    WHIT        ;ARE MADE INTO A PICTURE IN MEMORY
01B1 3E 90             MVI    A,90H
01B3 32 F9 02          STA    BLAK
01B6 3E 3C             MVI    A,3CH
01B8 32 FA 02          STA    LEND
01BB 3E 3E             MVI    A,3EH
01BD 32 FB 02          STA    REND
01C0 C9                RET
01C1 3E 20      TAKOF  MVI    A,' ' ;REPLACES SHIP GRAPHICS WITH BLANKS
01C3 32 F8 02          STA    WHIT        ;SO THAT 'SHIP' ROUTINE WILL BLANK
01C6 32 F9 02          STA    BLAK        ;OUT PICTURE OF SHIP
01C9 32 FA 02          STA    LEND
01CC 32 FB 02          STA    REND
01CF C9                RET
01D0 DB FA      STATUS IN     0FAH ;THESE INPUT ROUTINES ARE FOR SOL
01D2 2F                CMA
01D3 E6 01             ANI    1
```

Listing 1 continued on page 156

Tomorrow's tools. For today's problems.

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Available at selected local distributors.

Circle 78 on inquiry card.

Listing 1 continued:

```
01D5 C9                RET
01D6 DB FC      INP    IN    0FCH
01D8 C9                RET
01D9 CD D0 01   KYCHK  CALL  STATUS
01DC C8                RZ
01DD CD D6 01          CALL  INP
01E0 FE 93             CPI   RAR ;RIGHT ARROW
01E2 CA FA 01          JZ    RIGHT
01E5 FE 81             CPI   LAR ;LEFT ARROW
01E7 CA 05 02          JZ    LEFT
01EA FE 97             CPI   UAR ;UP ARROW
01EC CA 10 02          JZ    UP
01EF FE 9A             CPI   DAR    ;DOWN ARROW
01F1 CA 1B 02          JZ    DOWN
01F4 FE 20             CPI   ' ' ;SPACE BAR DROPS BALLOON
01F6 CA 53 02          JZ    BLNSET
01F9 C9                RET
01FA 2A F2 02   RIGHT  LHLD  LR ;THESE ROUTINES UPDATE THE OFFSETS TO
01FD 11 01 00          LXI   D,1       ;THE SHIP POSITIONS
0200 19                DAD   D
0201 22 F2 02          SHLD  LR
0204 C9                RET
0205 2A F2 02   LEFT   LHLD  LR
0208 11 FF FF          LXI   D,-1
020B 19                DAD   D
020C 22 F2 02          SHLD  LR
020F C9                RET
0210 2A F4 02   UP     LHLD  UD
0213 11 C0 FF          LXI   D,-64 ;64 CHARACTER WIDE SCREEN SO YOU GO U/D 1 LINE
0216 19                DAD   D
0217 22 F4 02          SHLD  UD
021A C9                RET
021B 2A F4 02   DOWN   LHLD  UD
021E 11 40 00          LXI   D,64
0221 19                DAD   D
0222 22 F4 02          SHLD  UD
0225 C9                RET
0226 3E 01      BALN   MVI   A,1
0228 32 FD 02          STA   BLNF
022B 2A F6 02          LHLD  CORNR
022E 11 41 00          LXI   D,41H
0231 19                DAD   D
0232 22 FE 02          SHLD  BLNR
0235 2A FE 02   BLN    LHLD  BLNR ;BLANK OUT BALLOON
0238 36 20             MVI   M,' '
023A 11 40 00          LXI   D,64 ;MOVE IT DOWN A LINE
023D 19                DAD   D
023E 22 FE 02          SHLD  BLNR
0241 36 8C             MVI   M,8CH
0243 7C                MOV   A,H
0244 FE D0             CPI   0D0H
0246 CA 4A 02          JZ    BDWN ;HIT BOTTOM
0249 C9                RET
024A 3E 00      BDWN   MVI   A,0
024C 32 FC 02          STA   BLND
024F 32 FD 02          STA   BLNF
0252 C9                RET
0253 3E 01      BLNSET MVI   A,1
0255 32 FC 02          STA   BLND
```

Listing 1 continued on page 158

NEW FROM MOUNTAIN HARDWARE. CONTROL FROM YOUR APPLE.

INTROL/X-10.

COMPUTERIZE YOUR HOME.
The Introl/X-10 peripheral system for your Apple* Computer allows you to remotely control lights and electrical appliances in your home.

YOU'RE ALREADY WIRED.
Introl/X-10 operates by utilizing your computer's intelligence to command the BSR System X-10 to send signals over regular 110 volt household wiring. That means you can control any electrical device in your home without additional wiring.

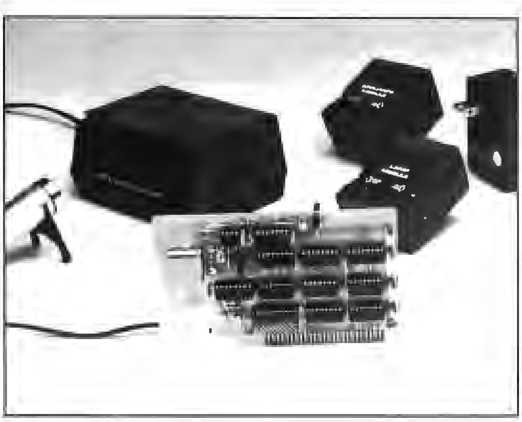
READY TO USE.
Introl/X-10 comes with complete software to control devices on pre-determined schedules, and features: • Control devices at a specific time. • Select a daily or weekly schedule. • Specify a day of the week, or an exact date for a particular event. • Specify an interval of time for an event. • Rate device wattages for a running account of power consumption during your schedule for energy management. • Used with our Apple Clock™ your schedules may run in "background" while other programs may run at the same time in "foreground."

EVERYTHING YOU NEED.
The Introl Controller board plugs into a peripheral slot of your Apple. With an ultrasonic transducer it transmits control signals to the BSR/X-10 Command Console which may be plugged into any convenient AC outlet near your computer. On command, signals are sent to remote modules located at the devices you wish to control. Up to 16 remote module addresses may be controlled from your Apple.

AVAILABLE NOW.
The Introl/X-10 System consists of the Introl Controller board with timer and ultrasonic transducer, the X-10 Command Console and three remote modules. $279. Complete and tested. If you already have a BSR System X-10, the Introl Controller board is available separately for $189. Additional remote modules are available at $15. See your computer dealer for a demonstration. Or, return the coupon below for complete information.

Available through computer dealers worldwide

*Apple is a trademark of Apple Computer Inc.
BSR/System X-10 is a trademark of BSR, Ltd.



Mountain Hardware, Inc.
LEADERSHIP IN COMPUTER PERIPHERALS
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(408) 429-8600

Sounds great.
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That sounds like a great system. Send me all the details.

Name ______________________

Address ______________________

City ____________ State ________ Zip ______

Phone ______________________

Listing 1 continued:

```
0258 C9                  RET
0259 3A FD 02   BLNCH    LDA     BLNF
025C FE 01               CPI     1
025E CA 35 02            JZ      BLN1
0261 3A FC 02            LDA     BLND
0264 FE 01               CPI     1
0266 C0                  RNZ
0267 CD 26 02            CALL    BALN
026A E5         DELAY    PUSH    H ;A USEFUL ALLPURPOSE TIMING ROUTINE
026B 2A 6E 05            LHLD    SPEED
026E EB                  XCHG
026F 15         DELA1    DCR     D
0270 C2 6F 02            JNZ     DELA1
0273 1D                  DCR     E
0274 C2 6F 02            JNZ     DELA1
0277 E1                  POP     H
0278 C9                  RET
0279 21 DA CD   WAIT     LXI     H,VDMBAS+474
027C 11 94 05            LXI     D,MSG
027F CD 64 05            CALL    PRINT
0282 21 14 CE            LXI     H,VDMBAS+532
0285 11 A2 05            LXI     D,MSG2
0288 CD 64 05            CALL    PRINT
028B 21 D0 CF            LXI     H,VDMBAS+976
028E 11 70 05            LXI     D,MSG1
0291 CD 64 05            CALL    PRINT
0294 CD D0 01   IN1      CALL    STATUS
0297 CA 94 02            JZ      IN1
029A CD D6 01            CALL    INP
029D FE 30               CPI     '0'
029F CA 00 00            JZ      0H ;REBOOT CP/M
02A2 FE 31               CPI     '1'
02A4 CA B9 02            JZ      FAST
02A7 FE 32               CPI     '2'
02A9 CA C0 02            JZ      MED
02AC FE 33               CPI     '3'
02AE CA C7 02            JZ      SLOW
02B1 FE 34               CPI     '4'
02B3 CA CE 02            JZ      SPASTIC
02B6 C3 79 02            JMP     WAIT ;GOT A BAD CHAR
02B9 21 19 00   FAST     LXI     H,19H
02BC 22 6E 05            SHLD    SPEED ;HERE WE SET PARAMETERS FOR DELAY LOOP
02BF C9                  RET
02C0 21 24 00   MED      LXI     H,24H
02C3 22 6E 05            SHLD    SPEED
02C6 C9                  RET
02C7 21 32 00   SLOW     LXI     H,32H
02CA 22 6E 05            SHLD    SPEED
02CD C9                  RET
02CE 21 38 00   SPASTIC  LXI     H,38H
02D1 22 6E 05            SHLD    SPEED
02D4 C9                  RET
02D5 2A F6 02   TOPB     LHLD    CORNR
02D8 7C                  MOV     A,H
02D9 FE CC               CPI     0CCH ;TOP 2 DIGITS OF VDMBAS
02DB CA E4 02            JZ      TOP
02DE FE CF               CPI     0CFH ;BOTTOM OF SCREEN
02E0 CA EB 02            JZ      BOT
02E3 C9                  RET
```

Listing 1 continued on page 160

DISPLAY GAME (1, n)

- BEGIN
- PUT DESIRED CHARACTERS IN MEMORY
- MOVE THEM TO SCREEN AT LOCATION L
- TIME DELAY
- ADD DESIRED OFFSET TO L (UP, DOWN, RIGHT, LEFT)
- WRITE BLANKS INTO PRESENT LOCATION OF CHARACTERS
- END

Figure 1: *A Warnier-Orr diagram describing the steps involved in simulating motion.*

Text continued:

rewrite its screen, so the programmer might think that computer games could represent extremely smooth movement.

However, the movement has to be represented in finite increments, which will be determined by the minimum distance between the characters or points that can be written on the screen. In the case of a typical video display board which can put 1024 characters on the screen, the user must move in increments of $\frac{1}{16}$th the height of the screen when moving vertically and $\frac{1}{64}$th the width of the screen when moving horizontally. This means that the movement will necessarily be a little jerky, but smooth enough for games.

The whole essence of writing an animated game is to put a picture on

Listing 1 continued:

```
02E4 21 40 00    TOP    LXI    H,64
02E7 22 F4 02           SHLD   UD
02EA C9                 RET
02EB 21 C0 FF    BOT    LXI    H,-64
02EE 22 F4 02           SHLD   UD
02F1 C9                 RET
02F2 00 00       LR     DW     0
02F4 00 00       UD     DW     0
02F6 1E CD       CORNR  DW     0CD1EH ;STARTS AT MIDDLE OF SCRN
02F8 10          WHIT   DB     10H ;SHIP GRAPHICS
02F9 90          BLAK   DB     90H
02FA 3C          LEND   DB     3CH
02FB 3E          REND   DB     3EH
02FC 00          BLND   DB     0
02FD 00          BLNF   DB     0
02FE 00 00       BLNK   DW     0
0300 3A A3 03    PEA1   LDA    G1
0303 FE 01              CPI    1
0305 CA 3D 03           JZ     SHOT1
0308 CD A4 03           CALL   RND
030B D6 F0              SUI    0F0H
030D D8                 RC
030E 87                 ADD    A
030F 87                 ADD    A
0310 5F                 MOV    E,A
0311 16 00              MVI    D,0
0313 21 C0 CF           LXI    H,SCBOT ;MIDDLE OF BOTTOM OF SCRN
0316 19                 DAD    D
0317 22 45 04           SHLD   PLOC1
031A 36 18              MVI    M,18H
031C 23                 INX    H
031D 36 18              MVI    M,18H
031F 23                 INX    H
0320 36 18              MVI    M,18H
0322 11 BF FF           LXI    D,-65
0325 19                 DAD    D
0326 36 96              MVI    M,96H
0328 11 C0 FF           LXI    D,-64
032B 19                 DAD    D
032C 19                 DAD    D
032D 22 A1 03           SHLD   PY1
0330 3E 01              MVI    A,1
0332 32 A3 03           STA    G1
0335 AF                 XRA    A
0336 32 47 04           STA    BFLG1
0339 CD 98 03           CALL   OFF1
033C C9                 RET
033D CD 0F 05    SHOT1  CALL   JETON
0340 CD 8E 03           CALL   ON1
0343 CD B6 03           CALL   RND4
0346 FE 01              CPI    1
0348 CA EB 04           JZ     JET1
034B FE 02              CPI    2
034D CA EB 04           JZ     JET1
0350 2A A1 03    TEMP   LHLD   PY1
0353 22 C7 03           SHLD   BL1
0356 3E 01              MVI    A,1
0358 32 9E 03           STA    FLG1
035B CD B6 03           CALL   RND4
```

Listing 1 continued on page 164

the screen, leave it there for a short length of time, then write blanks over the parts wanted to be moved and rewrite them in the next space of the motion sequence. After another delay, the process is repeated. It does not take much thinking to realize that the main body of the game will be a loop with these essential elements, plus whatever keyboard checking, score updating, message displaying, and the like are wanted as the game progresses.

This lends itself to a fairly modular program structure (see figure 1). The program I am going to use to illustrate this process is quite simple; elaborate discussion of program logic. Let us start with a description of the program from the point of view of a player.

Let us write a program in which the player flies a motorized delta-wing over his friend's backyard computer-controlled peashooter. The peashooter fires a pea and a water jet at you as you cruise past. When you are hit the peashooter receives 100 points. You try to position yourself directly over your friend's backyard and drop a water balloon on the peashooter. If you hit him with the balloon, you receive 100 points. To make it interesting, we will have the gunner appear and disappear at random times and places.

Before we start burning up coding sheets, or typing madly into the

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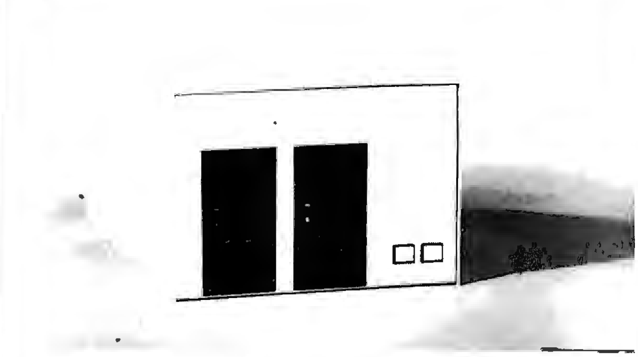

SEE System 6684 Unique Standard Features

- **CPU integrated into Diskette Cabinet with peripheral ports in rear of cabinet**
- **4 Full communications ports RS232 or 20 mA/60 mA CL; 75 to 19,200 bits/sec.**

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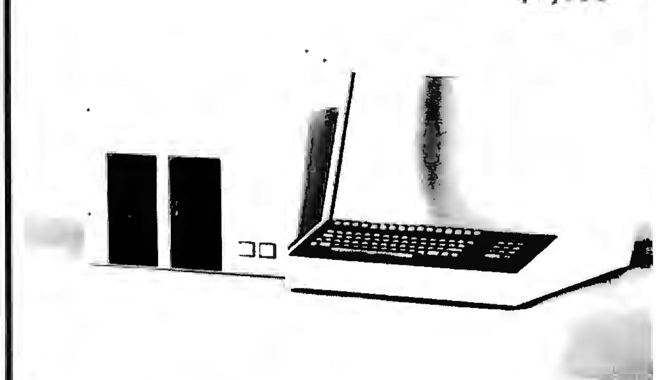

SEE System 6784 Unique Standard Features

- **CPU integrated into video terminal cabinet with peripheral ports in rear**
- **Video has 16 programmable function keys, 128 high resolution characters with graphics, numeric keypad, reversed video, full editing, 24 x 80 display**

Standard Features on All Systems

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- 8 Free Slots for expansion; capacity for 442,368 characters of memory within standard chassis
- 49,152 characters of 200 ns random access memory; 150 ns memory optional
- 8 vectored interrupts; all input and output is interrupt driven
- 1.2 million characters, double sided, dual 8" diskettes. IBM 3740 compatible
- Printer controller; Centronics compatible
- Magnum BASIC. Extremely fast business BASIC with full editing capabilities, print using, sequential and random files, integer and floating point arithmetic with up to 16 digits precision; N-dimensional matrices and much more A superset of Microsoft 16K extended disk BASIC
- Interactive conversational macro assembler and editor for 6800 family microprocessors.
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(301) 468-1822

Circle 350 on inquiry card.

- WATER BALLOON GAME (1, n)
  - BEGIN
    - BEGIN
    - CLEAR SCREEN
    - ASK FOR SPEED
    - INITIALIZE
      - BEGIN
      - SET FLAGS
      - GET UP SHIP
      - INITIALIZE SCORES
      - END
    - CLEAR SCREEN
    - OUTPUT PICTURE
    - END
  - MAIN RUN LOOP (1, n)
    - SEE FIGURE 3
  - END
    - BEGIN
    - FREEZE SCREEN
    - DISPLAY FINAL SCORE
    - END

Figure 2: *The modular components of the balloon game.*

assembler, consider what functions must be added to those in figure 1 to round out the whole game. To get everything ready to play, an initialization routine is needed to clear the screen, set the scores to 0, and so on. After waiting for the player to set the speed, put the delta-wing on the screen, give him a chance to get his fingers on the buttons and survey the situation, and then we will enter the main loop.

The main loop, figure 2, will contain the functions described before; it will put the peashooter and ship on, leave them there for a short time, then write blanks over them and rewrite them, in a new location if required. In addition, there will be keyboard checks to see if the player has fired his acceleration rockets to change the movement of the delta-wing, and update the score. Check for hits by a water balloon or peashooter and see if a water balloon is being dropped. Move the peas and water jet which are being fired, and put on impact marks if any hits have been scored.

Figure 3 summarizes the functions performed in the main loop, and names the subroutines which perform those functions. There are a number of possible changes that could be made in this program to tailor the program to the user's personal taste. The programmer should be able to figure out where to put the wrench by reference to the diagrams and the comments in the listing.

Most of the housekeeping functions of this program are no different from those found in any assembly-language program, so it will be assumed that the user can find the way through those, but a few more comments about the animation techniques might be worthwhile. For an illustration, follow the progress of a pea fired from the peashooter.

Starting at line 1195 the program checks to see if a peashooter is on the screen, since you want peas to come only from a real peashooter. If one is there, jump to SHOT1, where you check to see if a water jet is already on the screen (water jets last for two

Text continued on page 168

Listing 1 continued:

```
035E 5F                 MOV    E,A
035F 16 00              MVI    D,0
0361 21 BB FF           LXI    H,-69
0364 19                 DAD    D
0365 22 9F 03           SHLD   INCR1
0368 2A 9F 03     SHB1  LHLD   INCR1
036B E5                 PUSH   H
036C D1                 POP    D
036D 2A C7 03           LHLD   BL1
0370 36 20              MVI    M,' '
0372 01 40 00           LXI    B,64
0375 09                 DAD    B
0376 36 20              MVI    M,' '
0378 2A C7 03           LHLD   BL1
037B 19                 DAD    D
037C 7C                 MOV    A,H
037D FE CB              CPI    0CBH ;MISSILE IS OFF TOP OF SCREEN
037F CA 98 03           JZ     OFF1
0382 36 07              MVI    M,07H
0384 22 C7 03           SHLD   BL1
0387 11 40 00           LXI    D,64
038A 19                 DAD    D
038B 36 0A              MVI    M,0AH
038D C9                 RET
038E 3A 9E 03     ON1   LDA    FLG1
0391 FE 01              CPI    1
0393 C0                 RNZ
0394 F1                 POP    PSW
0395 C3 6E 03           JMP    SHB1
0398 3E 00        OFF1  MVI    A,0
039A 32 9E 03           STA    FLG1
039D C9                 RET
039E 00           FLG1  DB     0
039F 00 00        INCR1 DW     0
03A1 00 00        PY1   DW     0
03A3 00           G1    DB     0
03A4 21 C0 03     RND   LXI    H,RNDM ;A RANDOM NUM ROUTINE WHICH DOESN'T
03A7 EB                 XCHG   ;REPEAT FOR 40,000 TRIES
03A8 21 C2 03           LXI    H,RND1
03AB 7E                 MOV    A,M
03AC 3C                 INR    A
03AD 0F                 RRC
03AE 47                 MOV    B,A
03AF 1A                 LDAX   D
03B0 07                 RLC
03B1 80                 ADD    B
03B2 77                 MOV    M,A
03B3 78                 MOV    A,B
03B4 12                 STAX   D
03B5 C9                 RET
03B6 CD A4 03     RND4  CALL   RND
03B9 1F                 RAR
03BA 1F                 RAR
03BB E6 07              ANI    7
03BD C6 01              ADI    1
03BF C9                 RET
03C0 00 00        RNDM  DW     0
03C2 00 00        RND1  DW     0
03C4 C3 50 03     SHEL1 JMP    TEMP
```

```
03C7 C0 CF         DL1     DW     SCBOT
03C9 3A 47 04      PEACH   LDA    BFLG1
03CC FE 01                 CPI    1
03CE C8                    RZ
03CF 3A EA 04              LDA    STRTF
03D2 FE 01                 CPI    1
03D4 C8                    RZ
03D5 2A 45 04              LHLD   PLOC1
03D8 7E                    MOV    A,M
03D9 FE 20                 CPI    ' '
03DB CA ED 03              JZ     XPLD1
03DE 23                    INX    H
03DF 7E                    MOV    A,M
03E0 FE 20                 CPI    ' '
03E2 CA ED 03              JZ     XPLD1
03E5 23                    INX    H
03D6 7E                    MOV    A,M
03E7 FE 20                 CPI    ' '
03E9 CA ED 03              JZ     XPLD1
03EC C9                    RET
03ED 22 24 04      XPLD1   SHLD   BLOW ; A VERY DUMB-LOOKING EXPLOSION
03F0 3E 01                 MVI    A,1
03F2 32 47 04              STA    BFLG1
03F5 3E 2B                 MVI    A,'+' ;THESE ARE CHARACTERS WHICH INDICATE A HIT
03F7 CD 26 04              CALL   BLOP
03FA CD 6A 02              CALL   DELAY
03FD 3E 23                 MVI    A,'#'
03FF CD 26 04              CALL   BLOP
0402 CD 6A 02              CALL   DELAY
0405 3E 20                 MVI    A,' '
0407 CD 26 04              CALL   BLOP
040A 2A C7 03              LHLD   DL1
040D 77                    MOV    M,A
040E 01 40 00              LXI    B,64
0411 09                    DAD    B
0412 77                    MOV    M,A
0413 3E 00                 MVI    A,0
0415 32 A3 03              STA    G1
0418 3A 89 04              LDA    PSCR
041B C6 01                 ADI    1
041D 32 89 04              STA    PSCR
0420 32 9E 03              STA    FLG1
0423 C9                    RET
0424 00 00         BLOW    DW     0
0426 06 05         BLOP    MVI    B,5
0428 2A 24 04              LHLD   BLOW
042B 11 FC FF              LXI    D,-4
042E 19            BLP1    DAD    D
042F 77                    MOV    M,A
0430 23                    INX    H
0431 77                    MOV    M,A
0432 23                    INX    H
0433 77                    MOV    M,A
0434 23                    INX    H
0435 77                    MOV    M,A
0436 77                    MOV    M,A
0437 23                    INX    H
0438 77                    MOV    M,A
0439 23                    INX    H
043A 77                    MOV    M,A
043B 23                    INX    H
043C 77                    MOV    M,A
043D 11 BA FF              LXI    D,-70
0440 05                    DCR    B
0441 C8                    RZ
0442 C3 2E 04              JMP    BLP1
0445 C0 CF         PLOC1   DW     SCBOT
0447 00            BFLG1   DB     0
0448 7E            HIT     MOV    A,M
0449 FE 20                 CPI    ' '
044B C8                    RZ
044C FE 10                 CPI    10H
044E C8                    RZ
044F FE 90                 CPI    90H
0451 C8                    RZ
0452 FE 3C                 CPI    3CH
0454 C8                    RZ
0455 FE 3E                 CPI    3EH
0457 C8                    RZ
0458 22 24 04              SHLD   BLOW
045B 3E 2A                 MVI    A,'*'
045D CD 26 04              CALL   BLOP
0460 CD 6A 02              CALL   DELAY
0463 3E 4F                 MVI    A,'O'
0465 CD 26 04              CALL   BLOP
0468 CD 6A 02              CALL   DELAY
046B 3E 20                 MVI    A,' '
046D CD 26 04              CALL   BLOP
0470 3A 88 04              LDA    MSCR
0473 C6 01                 ADI    1
0475 32 88 04              STA    MSCR
0478 21 00 00              LXI    H,0
```

Listing 1 continued on page 166

Listing 1 continued:

```
047B 22 F4 02          SHLD  UD
047E 22 F2 02          SHLD  LR
0481 21 1E CE          LXI   H,MIDL
0484 22 F6 02          SHLD  CORNR
0487 C9                RET
0488 00         MSCR   DB    0
0489 00         PSCR   DB    0
048A 21 04 CC   SCORE  LXI   H,VDMBAS+4
048D 11 BC 05          LXI   D,BLMSG
0490 CD 64 05          CALL  PRINT
0493 23                INX   H
0494 3A 89 04          LDA   PSCR
0497 CD AB 04          CALL  SCOUT
049A 21 30 CC          LXI   H,VDMBAS+48
049D 11 C4 05          LXI   D,THMSG
04A0 CD 64 05          CALL  PRINT
04A3 23                INX   H
04A4 3A 88 04          LDA   MSCR
04A7 CD AB 04          CALL  SCOUT
04AA C9                RET
04AB FE 0A      SCOUT  CPI   0AH ;A VERY DUMB HEX-TO-DECIMAL CONVERTER
04AD D2 BA 04          JNC   LTR
04B0 C6 30             ADI   30H
04B2 77                MOV   M,A
04B3 23                INX   H
04B4 36 30             MVI   M,30H
04B6 23                INX   H
04B7 36 30             MVI   M,30H
04B9 C9                RET
04BA FE 14      LTR    CPI   20
04BC D2 CC 04          JNC   TWEN
04BF 36 31             MVI   M,31H
04C1 23                INX   H
04C2 C6 26             ADI   38
04C4 77                MOV   M,A
04C5 23                INX   H
04C6 36 30             MVI   M,30H
04C8 23                INX   H
04C9 36 30             MVI   M,30H
04CB C9                RET
04CC 36 32      TWEN   MVI   M,32H
04CE 23                INX   H
04CF C6 1C             ADI   28
04D1 77                MOV   M,A
04D2 23                INX   H
04D3 36 30             MVI   M,30H
04D5 23                INX   H
04D6 36 30             MVI   M,30H
04D8 FE 35             CPI   35H
04DA CA DE 04          JZ    OVER
04DD C9                RET
04DE 21 96 CD   OVER   LXI   H,VDMBAS+408
04E1 11 CC 05          LXI   D,FINMSG
04E4 CD 64 05          CALL  PRINT
04E7 C3 0B 01          JMP   BEGIN
04EA 00         STRTF  DB    0
04EB 3E 03      JETI   MVI   A,3
04ED 32 30 05          STA   RAFL
04F0 CD B6 03          CALL  RNDM
04F3 5F                MOV   E,A
04F4 16 00             MVI   D,0
04F6 21 BE FF          LXI   H,-66
04F9 19                DAD   D
04FA 22 9F 03          SHLD  INCP1
04FD 2A 9F 03          LHLD  INCP1
0500 E5                PUSH  H
0501 D1                POP   D
0502 2A A1 03          LHLD  PY1
0505 06 0C             MVI   B,12
0507 19         RX2    DAD   D
0508 36 04             MVI   M,4
050A 05                DCR   B
050B C2 07 05          JNZ   RX2
050E C9                RET
050F 3A 30 05   JETON  LDA   RAFL
0512 FE 01             CPI   1
0514 C8                RZ
0515 3D                DCR   A
0516 32 30 05          STA   RAFL
0519 FE 01             CPI   1
051B C2 31 05          JNZ   RX5
051E 2A 9F 03          LHLD  INCP1
0521 E5                PUSH  H
0522 D1                POP   D
0523 2A A1 03          LHLD  PY1
0526 06 0C             MVI   B,12
0528 19         RX3    DAD   D
0529 36 20             MVI   M,20H
052B 05                DCR   B
052C C2 28 05          JNZ   RX3
052F C9                RET
0530 01         RAFL   DB    1
0531 F1         RX5    POP   PSW
0532 F1                POP   PSW
0533 C3 4C 01          JMP   HUNIT
0536 CD A4 03   PEAOF  CALL  RND
0539 D6 D2             SUI   0D2H
053B D8                RC
053C D6 03             SUI   3
053E D0                RNC
053F 2A 45 04          LHLD  PLOC1
0542 06 20             MVI   B,20H
0544 70                MOV   M,B
0545 23                INX   H
0546 70                MOV   M,B
0547 23                INX   H
0548 70                MOV   M,B
0549 11 BF FF          LXI   D,-65
054C 19                DAD   D
054D 70                MOV   M,B
054E AF                XRA   A
054F 32 A3 03          STA   G1
0552 32 9E 03          STA   FLG1
0555 3E 01             MVI   A,1
0557 32 47 04          STA   DFLG1
055A 2A C7 03          LHLD  BL1
055D 70                MOV   M,B
055E 11 40 00          LXI   D,64
0561 19                DAD   D
0562 70                MOV   M,B
0563 C9                RET
0564 1A         PRINT  LDAX  D
0565 FE 00             CPI   0
0567 C8                RZ
0568 77                MOV   M,A
0569 23                INX   H
056A 13                INX   D
056B C3 64 05          JMP   PRINT
056E 00 00      SPEED  DW    0
```

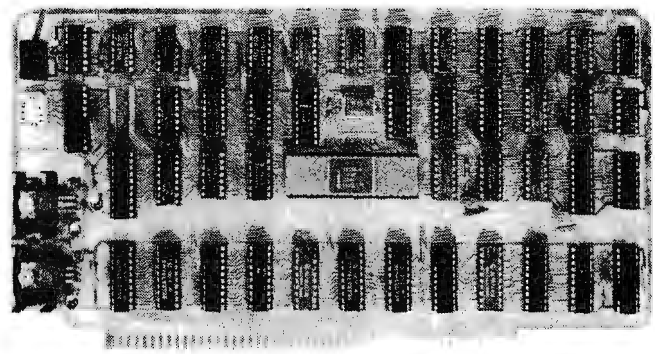
Listing 1 continued on page 168

Now!
For the
S-100 bus

8086 Power

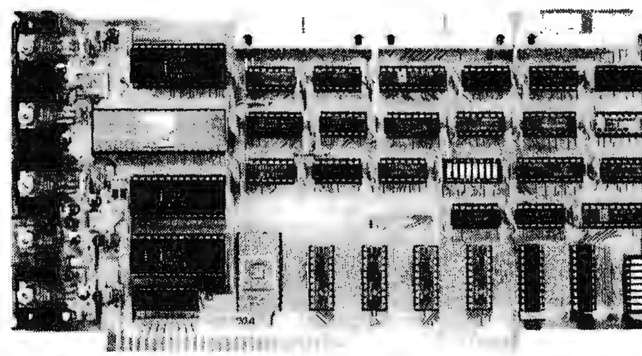
WITH 16-BIT WORD LENGTH

8086 CPU



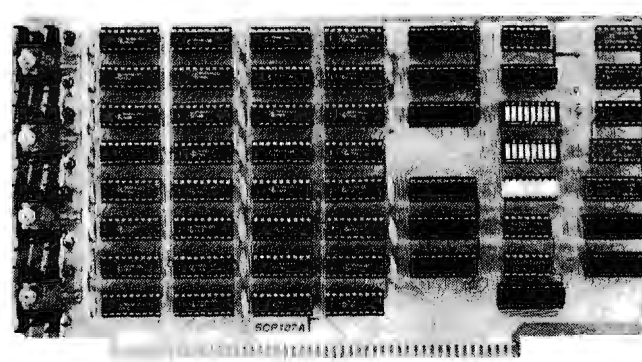
This card brings state-of-the-art performance to the S-100 bus. It may be used to upgrade existing 8-bit systems by "swapping" the CPUs or it may form the foundation for a high performance 16-bit system. It will operate with 8-bit, 16-bit, or mixed memory and peripherals. It has a 1-megabyte addressing range. It can be factory upgraded at nominal cost from 4 Mhz. to 8 Mhz. when the faster CPU chip is available. Price — $895.

CPU Support Card



This is a companion to our 8086 CPU. It includes a 2K monitor with machine language debugger and disk bootstrap loader, serial port with software-selected baud rate, time-of-day clock with battery backup capability, two general purpose timers/counters, and a vectored interrupt controller with 7 interrupts generated on board and 8 accepted from the bus. Price — $395.

8/16 Memory Card



(Prototypes shown)

Through the use of the sXTRQ line of the proposed IEEE Standard, this memory board will appear to be 8K by 16 bits to our 8086 CPU or 16K by 8 bits to 8-bit CPUs. It is offered with 250 nsec. memory chips only and will perform without wait states with our 8086 CPU using an 8 Mhz. clock. It has 24-bit extended addressing. Price — $595.

Z80/8086 Cross Assembler

This cross assembler runs under CP/M and its derivatives. Its mnemonics are the same as or similar to Intel's ASM-86. It is available in 5" soft-sectored, 5" North Star, or 8" soft-sectored (IBM) formats. Price — $250.

Microsoft BASIC-86

Microsoft's BASIC interpreter for the 8086 is essentially identical in features to their 5.0 release for the 8080 and is ANSI compatible. It is a "stand-alone" version and includes all disk and terminal I/0 drivers. Programs written for any earlier version of Microsoft BASIC will run under BASIC-86 with little or no modification. Price — $350.

MCS-86 User's Manual

By Intel — Feb., 1979, edition. This is the primary hardware and software reference manual for the 8086 CPU. Price — $6.25. (Includes shipping)

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Listing 1 continued:

```
0570 2A 2A 53 45      2810 MSG1   ASC   '**SET SPEED, 1 THRU 4, 1=FASTEST **'
     54 20 53 50
     45 45 44 2C
     20 31 20 54
     48 52 55 20
     34 2C 20 31
     3D 46 41 53
     54 45 53 54
     20 2A 2A
0593 00               2815        DB    0
0594 2A 2A 20 42      2820 MSG    ASC   '** BALLOON **'
     41 4C 4C 4F
     4F 4E 20 2A
     2A
05A1 00               2825        DB    0
05A2 43 6F 70 79      2830 MSG2   ASC   'Copyright 1979 Tony Estep'
     72 69 67 68
     74 20 31 39
     37 39 20 54
     6F 6E 79 20
     45 73 74 65
     70
05BB 00               2835        DB    0
05BC 44 52 4F 50      2840 BLMSG  ASC   'DROPPER'
     50 45 52
05C3 00               2845        DB    0
05C4 53 48 4F 4F      2850 THMSG  ASC   'SHOOTER'
     54 45 52
05CB 00               2855        DB    0
05CC 2A 2A 20 46      2860 FINMSG ASC   '** FINAL SCORE **'
     49 4E 41 4C
     20 53 43 4F
     52 45 20 2A
     2A
05DD 00               2865        DB    0
05DE                  2870 STACK  DS    50

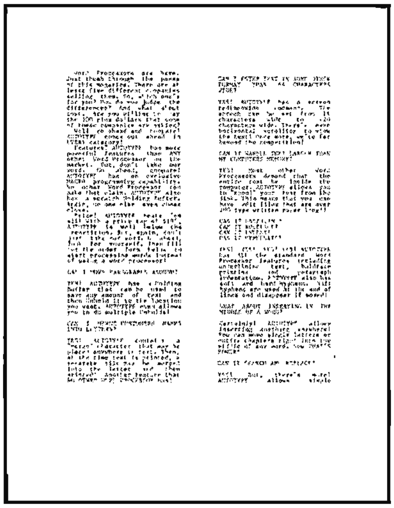
BALN   0226   BDWN   024A   BEGIN  010B   BFLG1  0447
BL1    03C7   BLAK   02F9   BLMSG  05BC   BLN1   0235
BLNCH  0259   BLND   02FC   BLNF   02FD   BLNR   02FE
BLNSE  0253   BLOP   0426   BLOW   0424   BLP1   042E
BOT    02EB   CLSCN  C0D5   CORNR  02F6   DAR    009A
DELA1  026F   DELAY  026A   DOWN   021E   FAST   02B9
FINMS  05CC   FLG1   039E   G1     03A3   GO     010E
HIT    0448   IN1    0294   INCR1  039F   INP    01D6
JET1   04EB   JETON  050F   KYCHK  01D9   LAR    0081
LEFT   0205   LEND   02FA   LR     02F2   LTR    04BA
MED    02C0   MIDL   CC1E   MSCR   0488   MSG    0594
MSG1   0570   MSG2   05A2   OFF1   0398   ON1    038E
OVER   04DE   PEA1   0300   PEACH  03C9   PEAOF  0536
PLOC1  0445   PRINT  0564   PSCR   0489   PUTON  01AC
PY1    03A1   RAFL   0530   RAR    0093   REND   02FB
RIGHT  01FA   RND    03A4   RND1   03C2   RND4   03B6
RNDM   03C0   RUNIT  014C   RX2    0507   RX3    0528
RX5    0531   SCBOT  CFC0   SCORE  048A   SCOR1  0183
SCOUT  04AB   SHB1   0368   SHEL1  03C4   SHIP   0189
SHOT1  033D   SLOW   02C7   SPAST  02CE   SPEED  056E
STACK  05DE   STATU  01D0   STRTF  04EA   TAKOF  01C1
TEMP   0350   THMSG  05C4   TOP    02E4   TOPB   02D5
TWEN   04CC   UAR    0097   UD     02F4   UP     0210
VDMBA  CC00   WAIT   0279   WHIT   02F8   XPLD1  03ED
```

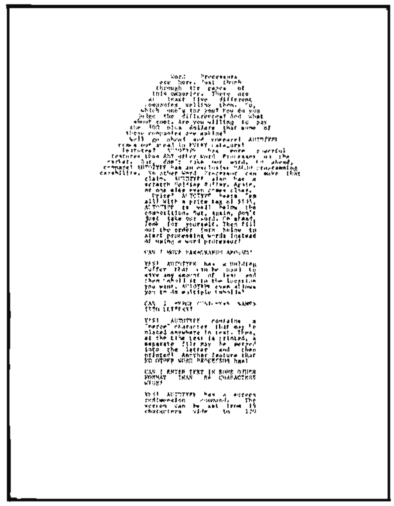
Text continued:

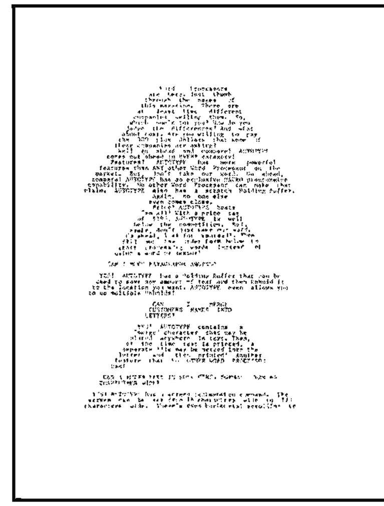
cycles, as you will see when you play). If there is no water jet there, then a random number test decides whether to shoot a pea or water jet. If it is a pea, control falls through to TEMP. This locates the starting point for the pea line and then sets the flag that tells the program that a pea is being fired. The program keeps track of that, since it will be on for several program cycles, until it makes a hit or goes off the screen.

Next, we determine the random direction of fire, and at last the program is ready to start the pea in motion. An increment is computed and stored at lines 1425 thru 1450.

Note at SHB1 that the user should reload the HL register pair with the same values that are already in it. This is a practice I always follow when I will be coming to an entry point from a number of different places. The idea is to eliminate parameter passing, or rather to pass the parameters through a named storage location, which makes it much easier to debug. Be that as it may, you can readily see how in the ensuing instructions, the heart of the matter is reached. Write hexadecimal 20 into the area occupied by the pea and its trail (hexadecimal 07 and 0A respectively in the Processor Technology video display module (VDM) character set), then add the increment. Check to see if it is off the screen, and if not put the characters into the new







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```
                      BEGIN
                      PUT BLANKS INTO
           TAKOF      LOCATION FROM WHICH
                      MOTORIZED DELTA-WING IS MOVED ONTO
                      SCREEN
                      END
                      BEGIN
           SHIP       MOVE MOTORIZED DELTA-WING LOCATION IN
                      MEMORY TO SCREEN
                      END

                      ADD OFFSETS LR, UD

                      BEGIN
                      PUT MOTORIZED DELTA-WING CHARACTERS
           PUTON      INTO MEMORY WHERE
                      BLANKS NOW ARE
                      END
                      BEGIN
           SHIP       MOVE DELTA-WING TO SCREEN
MAIN                  END
RUN                   BEGIN
LOOP       KYCHK      UPDATE UD AND LR FROM KEYBOARD
(1, n)                END
                      BEGIN
           TOPB       DID WE HIT TOP OR
                      BOTTOM OF SCREEN?
                      END
                      BEGIN
           BLNCHK     IS WATER BALLOON CALLED FOR OR ALREADY ON
                      ITS WAY? UPDATE WATER BALLOON CHARACTER LOCATION
                      END
                      BEGIN
           DELAY      LEAVE SCREEN AS IT IS
                      FOR A MOMENT
                      END
                      BEGIN
           PEACHK     UPDATE PEASHOOTER AND PEA
                      END
                      BEGIN
           SCORIT     CALCULATE SCORES
                      PUT THEM ON SCREEN
                      END
```

Figure 3: *A summary of the functions performed in the main loop, along with a definition of the individual tasks executed by each subroutine.*

locations, and return. Checking for a hit is done when the ship is displayed.

I hope that playing around with this program will prove to be as much fun for you as it was for me. In order to adapt it to your system, you may need to change the control keys, the clear routine, and the display location, but if you have a SOL-20 it will work as is. If you tackle the development of an animated game, you will find the simple principles embodied in this program will work in much more elaborate games. One final note: when you first play this, you will be positive that it is impossible to win. The "random" peashooter seems to have an incredible sixth sense about where to aim his pea. However, it can be done . . . in fact, my seven-year-old can beat it on speed 1, so hang in there! Good luck, and have fun. ■

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Five Useful Programs for the SC/MP

Associate Professor Charles A Kapps
Temple University
School of Business Administration
Philadelphia PA 19122

Now that you are the proud owner of one of the least expensive microprocessor kits, what can be done with it? Before that question is answered, why do you own the SC/MP to begin with? You may be someone interested in learning about microprocessors or computers, and since you are a cautious person of modest means, you have chosen to begin slowly.

No computer is useful unless it has a means of communicating with the outside world. The SC/MP is no exception. The SC/MP kit by itself provides no such capability. Thus, some sort of I/O (input/output) hardware must be obtained, such as a teletypewriter. This article assumes that you have the minimum of I/O hardware, probably a video display, which is likely to cost three times as much as the computer. (This is an important thing to know about computers. They are worse than automobiles because the accessories really account for most of the cost. This is even true with the big number-crunching computers).

The main limitation of such a system is it is not feasible to attempt to write very large programs. This is not only because of the SC/MP's rather meager amount of memory (256 bytes). It is also due to the fact that, without any means of assembling, editing, and backing up programs, it becomes humanly impossible to do any serious programming endeavors. For this reason, the programs in this article have been kept short and simple. For more ambitious readers, these programs can be combined or added to in order to accomplish more sophisticated tasks.

Input and Output on the SC/MP

A thorough search of the manuals provided with the SC/MP kit provides little information about programming input and output functions. Clearly, input and output are possible, because the KITBUG monitor program provided in read only memory is able to perform those functions. The assembly listing of KITBUG, which is provided in the *SC/MP Kit User's Manual*, shows how input and output are accomplished. The input and output portions of the monitor are located at the end of the listing, and occupy hexadecimal locations 186 thru 1FB of the read only memory (over 100 bytes).

The main reason those functions require so much coding is that the SC/MP has neither a parallel I/O port nor an internal universal asynchronous receiver/-transmitter (UART), as a more sophisticated processor might. Instead, it is necessary to have a program which simulates the primary functions of a universal asynchronous receiver/transmitter, namely converting between parallel-byte data and asynchronous serial data (ANSI). For example, the output program transmits a 0 (note that the actual bits are inverted). This is the start bit. The program must then idle for 1/110 second because the transmission rate is 110 baud. The least significant bit (LSB) of the data byte is then transmitted, and the program again idles for 1/110 second. This is repeated until all data bits are transmitted. Finally, the program outputs a 1 and idles for 1/55 second for the 2 stop bits needed by a teletypewriter. For input, a similar procedure is operated in reverse.

After study of these programs, it should be possible to imitate these processes and incorporate them into our own programs. Although studying other people's programs is often a good way to learn how to program, copying these programs is not the best thing to do here.

As every good programmer knows, basic processes should be written in the form of subroutines which can be called from various places in the main program. This rule was followed by the writers of KITBUG, and all the various areas of the program assume the form of subroutines. These subroutines can be called from anywhere, including your own program area. In particular, there are 4 subroutines which are useful for all kinds of programs:

PUTC	This subroutine prints a single ASCII character on the output device.
GECO	This program reads 1 character typed in at the keyboard, and returns the ASCII code.
PHEX1 and PHEX2	Here are 2 different entry points to a subroutine which converts a byte into a 2-digit hexadecimal number and prints it.
GHEX	This program reads a hexadecimal number of up to 4 digits, and returns the 16-bit value as 2 bytes.

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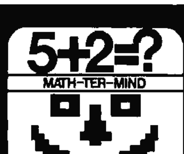

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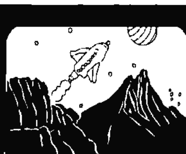

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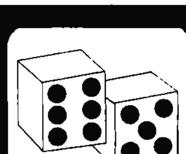

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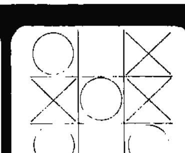

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Using System Subroutines

Before these subroutines can be used, or any subroutines written by someone else, you must be familiar with all of the usage conventions of the subroutines. These conventions include:

- how to call and return from the subroutine
- how to pass information back and forth
- special conventions, such as the saving and restoring of registers, temporary storage used, etc

The standard method for calling subroutines in KITBUG is to use pointer register 3 to contain the return address. This is done by loading pointer register 3 with the address of the subroutine. Then execute the instruction XPPC P3; this exchanges pointer register 3 and the program counter. This leads to the subroutine, and since the program counter value at the time of the call is saved in pointer register 3, the subroutine returns the same way it was called, with XPPC P3.

Of special note here is a peculiarity of the SC/MP processor. Most computers increment their program counters between the fetch and execute cycles. In the SC/MP, the program counter is incremented after the execute cycle. This is, in effect, the same as incrementing it just before the next fetch. The result is that whenever a jump is executed (such as the XPPC instruction), the effective address must be one less than the actual address where you want to jump. For example, the PUTC subroutine is located at hexadecimal 01C5, so when you call PUTC, you must load 1C4 into pointer register 3.

Note that after control has been returned from the subroutine, pointer register 3 no longer has its initial value. In fact, it has the last value that the program counter had in the subroutine, and thus points to the end of the subroutine. Normally this would mean that pointer register 3 would have to be reloaded in order to call the subroutine a second time. Actually, the writers of KITBUG foresaw this problem, and were kind enough to make life simple. Every return instruction (*XPPC P3*) is followed by a jump back to the beginning of the subroutine. This allows a subroutine to be called several times, merely by executing XPPC P3 instructions.

The second matter pertaining to subroutine calling conventions is concerned with how data is passed back and forth between the calling program and the subroutine. The first 3 of the subroutines, PUTC, GECO, and PHEX, deal only with a single byte of information. For these subroutines, the byte is simply passed by means of the accumulator. For example, PUTC prints a single character. When PUTC is called, the ASCII code of the character to be printed must be loaded into the accumulator, then the subroutine is called by executing XPPC P3. (It is assumed that pointer register 3 has already been set up.)

For example, the following program segment would cause an A to be displayed:

```
LDI     C4          ; this loads
XPAL    P3          ; 1C4 into pointer register 3
LDI     01          ; note 1C4 = 1C5 - 1
XPAH    P3          ; the location of PUTC
LDI     41          ; 41 is ASCII code for A
XPPC    P3          ; call PUTC
                    ; control is returned here
```

Subroutine GHEX is not quite as simple, because the data being transferred is a 16-bit quantity, and therefore will not fit in the accumulator. The answer to what GHEX does with its results lies in the third category of subroutine conventions: special conventions.

All of the subroutines in KITBUG use a special convention for dealing with temporary data, saving registers, etc. Note that KITBUG cannot use its own program area for storing data. KITBUG resides in read only memory. KITBUG must then be able to use some of the 256 bytes of programmable memory for its storage needs. It does this through a common storage area known as the *stack*. The stack is an array which holds data in a last-in-first-out fashion. The stack resides in the higher addresses of programmable memory, and advances downward as data is added. Pointer register 2 is used to point to the most recently added piece of information on the stack. Since all of the KITBUG subroutines use the stack, pointer register 2 may not be used except in carefully prescribed and compatible ways.

When the program is started, KITBUG loads pointer register 2 from locations 0FFB and 0FFC. (Note that because of the addressing overlap, these locations are the same as 02FB and 02FC.) Unless these locations are modified, they will contain 0. Thus, pointer register 2 will initially be 0. When an item is stored on the stack, it is done with the instruction ST @ − 1(P2). Negative auto-indexing is performed before the effective address is computed. Therefore, the effective address is 0FFF. (Note that borrows and carries do not propagate into the most significant 4 bits during effective address computation.) Since the address 0FFF is the same as 02FF on the SC/MP, the stack will effectively start at the high end of the programmable memory and proceed downward. This is probably the best place for the stack anyway, so the best thing to do about initializing the stack is nothing.

Program 1: Output

The first program, listing 1, is a simple program which can be used for checking out the machine. It also illustrates how to use subroutine PUTC.

The program is written in an infinite loop and repeatedly prints a message. The message is stored in the form of an ASCII character string starting at location hexadecimal 0220. An ASCII code for 0 is used to terminate the message. Control characters such as carriage return and line feed must be included in the message. In the example, the message is simply "HELLO." However, any message could be put in its place. If the I/O (input/-output) device is a video display, rather than a teletypewriter, some interesting geometric patterns can often be formed by typing messages with random characters and control characters mixed together.

The functioning of the program is quite simple: locations 200 thru 205 set pointer register 1 equal to 0220, the beginning of the message string. Hexadecimal locations 0206 thru 020B set pointer register 3 to point to PUTC, the printout subroutine. At 020C a character is loaded into the accumulator. Auto-indexing is used, so that repeated executions of this instruction will cause successive characters to be fetched. At 020E there is a jump back to the beginning if the zero end code is reached; otherwise, PUTC is called at location 0210, which causes the character in the accumulator to be printed. Then jump back to 0206 to print the next character. (Note that as stated above, it is not necessary to reload pointer register 3 every time the subroutines are called. Therefore, there could be a jump to location 020C and the program would work just as well. This can be done by changing location 0212 to F9.)

Text continued on page 178

Listing 1: The program will print an ASCII message over and over. The message is a string of ASCII character codes followed by a 0.

```
                               .NLIST   TTM
                               .TITLE   PROGRAM #1
                               ;THIS PROGRAM PRINTS OUT A MESSAGE
                               ;OVER AND OVER FOREVER.
                               ;THE MESSAGE TAKES THE FORM OF
                               ;ANY STRING OF ASCII CHARACTER CODES
                               ;FOLLOWED BY A TERMINATION CODE OF ZERO
        0200        .=200
0200      C4  20    START:     LDI      ^L<STRING>      ;P1 IS USED AS A
0202      31                   XPAL     P1              ;POINTER TO THE
0203      C4  02               LDI      ^U<STRING>      ;MESSAGE STRING
0205      35                   XPAH     P1
0206      C4  C4    LOOP:      LDI      ^L<PUTC>-1      ;P3 MUST BE ONE LESS
0208      33                   XPAL     P3              ;THAN THE ADDRESS
0209      C4  01               LDI      ^U<PUTC>        ;OF PUTC = 1C5
020B      37                   XPAH     P3
020C      C5  01               LD       @1(P1)          ;GET NEXT CHARACTER
020E      98  F0               JZ       START           ;ZERO IS END CODE
0210      3F                   XPPC     P3              ;OTHERWISE PRINT CHARACTER
0211      90  F3               JMP      LOOP            ;AND LOOP
        0220        .=0220
0220      48  45    STRING:    .ASCII   /HELLO/<CR><LF><0>
0222      4C  4C
0224      4F  0D
0226      0A  00
        0001        P1=%1
        0002        P2=%2
        0003        P3=%3
        01C5        PUTC=01C5
        000D        CR=0D
        000A        LF=0A
        0200                   .END     START

SYMBOL TABLE

CR    = 000D     LF     = 000A     LOOP    0206
PUTC  = 01C5     P1     =%0001     P2     =%0002
P3    =%0003     START   0200      STRING  0220


ERRORS DETECTED: 0
FREE CORE: 17525. WORDS

.PROG1=PROG1
```

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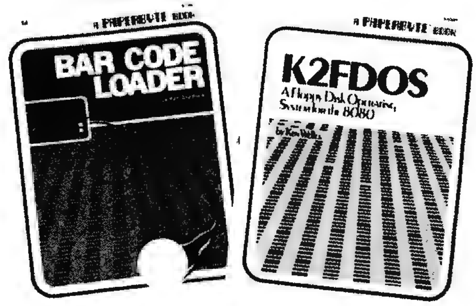

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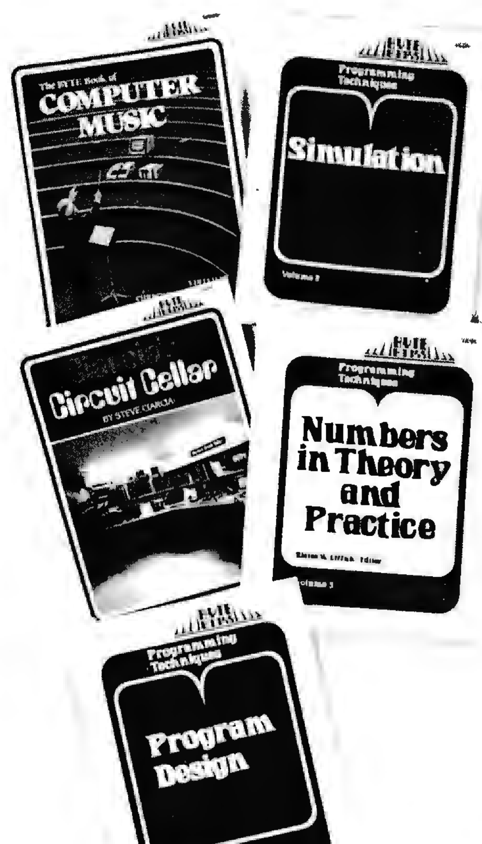

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Text continued:

In order to run this, or any program in this article, it is necessary to initialize the register save locations of KITBUG. These are 0FF7 thru 0FFF. (In the kit setup these are equivalent to 02F7 thru 02FF.) Locations 0FF7 and 0FF8 should contain 0200 (02 in 0FF7, 00 in 0FF8). The remaining locations, especially 0FFB and 0FFC (the stack initialization), should contain 0. Typing G to KITBUG then causes the program to run.

Program 2: Output and Input

The second program, listing 2, is much longer than the first, but is not conceptually more complex. This program combines some message printout with some input.

The program is designed to do the following: first, it prints out HELLO, I'M A COMPUTER, WHO ARE YOU? The computer than waits for a name to be typed, such as JOHN DOE. It responds HI, JOHN DOE, I'M PLEASED TO MEET YOU, and jumps back to the monitor. The initialization registers are saved, so that the program can be rerun by simply typing G.

The input is managed by subroutine GECO. GECO is called by executing XPPC P3, as usual. Routine GECO waits until something is typed at the keyboard. It then returns to the program with the ASCII code for the character typed in the accumulator.

Printout for program 2 is handled by a subroutine of my own called PRINT. This is found starting at line 49 of the listing. PRINT is basically the same as program 1, but modified to have the form of a subroutine. Instead of looping endlessly, when done printing a message, it returns from where it was called. Note that PRINT calls PUTC. Whenever a subroutine calls another subroutine, pointer register 3 must be saved for the return. PRINT uses the stack for this purpose. Note the basic rules for using the stack. Whatever is added to the stack by a subroutine must be removed before exiting. PRINT uses pointer register 1 to point to the message it is printing. Pointer register 1 must be set by the main program before PRINT is called.

The first thing program 2 does is to save pointer register 3. The reason is that KITBUG treats the program as if it were a subroutine. Saving pointer register 3 makes it possible to return to KITBUG when it is done. There is a catch, however. Because of the peculiarity of how the SC/MP treats the program counter, KITBUG must subtract 1 from the number in memory locations 0FF7 and 0FF8 before using it as a jump address. Unfortunately, this will get you into a loop if you try to get subsequent entries to the program by typing G a second time. The problem is that KITBUG does not add 1 back on to the program counter value when you return. To get around this, put 200 into pointer register 3, and then return using an XPPC P1. This fools KITBUG into working properly. The rest of the program is straightforward, and consists of calls to PRINT and GECO.

To keep this program as short as possible, advantage was often taken of the fact that registers (particularly the high-order parts of pointer registers) already contain the right value. Thus, these registers are not reloaded. This saves 2 or 3 bytes of program here and there, and since the programs are being entered into the computer by

Listing 2: This program outputs a prompt, accepts some input, and then outputs another message which has your input embedded.

```
                            .NLIST  TTM
                            .TITLE  PROGRAM #2
                            ;THIS PROGRAM TYPES A MESSAGE
                            ;PROMPTING YOU TO TYPE SOMETHING.
                            ;IT THEN ANSWERS WITH A MESSAGE
                            ;WHICH HAS YOUR TYPEIN IMBEDDED.
             0200   .=200
0200   C4  3E   START:  LDI    ^L<PRINT>-1      ;SET UP TO
0202   33               XPAL   P3               ;CALL THE
0203   CE  FF           ST     @-1(P2)          ;PRINT SUBROUTINE
0205   C4  02           LDI    ^U<PRINT>        ;BUT SAVE THE OLD
0207   37               XPAH   P3               ;VALUE OF P3 ON
0208   CE  FF           ST     @-1(P2)          ;THE STACK
020A   C4  60           LDI    ^L<MSG1>         ;SET P1
020C   31               XPAL   P1               ;TO POINT
020D   C4  02           LDI    ^U<MSG1>         ;TO
020F   35               XPAH   P1               ;FIRST MESSAGE
0210   3F               XPPC   P3               ;CALL PRINT
0211   C4  85           LDI    ^L<GECO>-1       ;SET UP
0213   33               XPAL   P3               ;TO CALL
0214   C4  01           LDI    ^U<GECO>         ;INPUT ROUTINE
0216   37               XPAH   P3               ;IN KITBUG
0217   C4  90           LDI    ^L<MSG2>         ;P1 POINTS TO INPUT
0219   31               XPAL   P1               ;BUFFER (HIGH PART OF P1 OK)
021A   3F       LOOP:   XPPC   P3               ;CALL GECO
021B   CD  01           ST     @1(P1)           ;SAVE CHARACTER IN BUFFER
021D   E4  0D           XRI    CR               ;COMPARE WITH CR
021F   9C  F9           JNZ    LOOP             ;LOOP UNTIL CR TYPED
0221   CD  FF           ST     @-1(P1)          ;CHANGE CR TO ZERO
0223   C4  3E           LDI    ^L<PRINT>-1      ;SET UP CALL
0225   33               XPAL   P3               ;TO PRINT AGAIN
0226   C4  02           LDI    ^U<PRINT>
0228   37               XPAH   P3
0229   C4  B0           LDI    ^L<MSG3>         ;P1POINTS TO MESSAGE 3
022B   31               XPAL   P1               ;(HIGH PART OF P1 OK)
022C   3F               XPPC   P3               ;CALL PRINT
022D   C4  90           LDI    ^L<MSG2>         ;P1 POINTS TO BUFFER
022F   31               XPAL   P1               ;(HIGH PART STILL OK)
0230   3F               XPPC   P3               ;CALL PRINT
0231   C4  C0           LDI    ^L<MSG4>         ;P1 POINTS TO MESSAGE 4
0233   31               XPAL   P1               ;(HIGH PART STILL OK)
0234   3F               XPPC   P3               ;CALL PRINT
0235   C6  01           LD     @1(P2)           ;GET ORIGINAL P3 OFF
0237   35               XPAH   P1               ;STACK AND PUT IN P1
0238   C6  01           LD     @1(P2)           ;WE HAVE TO DO FUNNY
023A   31               XPAL   P1               ;BUSINESS WITH P3 SO THAT
023B   C4  00           LDI    0                ;IT WILL EQUAL 200
023D   33               XPAL   P3               ;FOR RESTART (HIGH ORDER PART OK)
023E   3D               XPPC   P1               ;RETURN TO KITBUG
023F   C4  C4   PRINT:  LDI    ^L<PUTC>-1       ;PRINT SUBROUTINE
0241   33               XPAL   P3               ;P3 IS SET TO PUTC
0242   CE  FF           ST     @-1(P2)          ;BUT IS ALSO SAVED
0244   C4  01           LDI    ^U<PUTC>         ;ON STACK FOR
0246   37               XPAH   P3               ;RETURN
0247   CE  FF           ST     @-1(P2)
0249   C5  01   PLOOP:  LD     @1(P1)           ;GET CHARACTER
024B   98  03           JZ     POUT             ;DONE IF ZERO
024D   3F               XPPC   P3               ;OTHERWISE CALL PUTC
024E   90  F9           JMP    PLOOP            ;AND LOOP
0250   C6  01   POUT:   LD     @1(P2)           ;RESTORE
0252   37               XPAH   P3               ;P3
0253   C6  01           LD     @1(P2)           ;FROM
0255   33               XPAL   P3               ;STACK
0256   3F               XPPC   P3
0257   90  E6           JMP    PRINT            ;JI
0259   90  E4           JMP    PRINT            ;JUMP BACK IF RECALLED
             0260   .=260
0260   48  45   MSG1:   .ASCII /HELLO, I'M A COMPUTER./<CR><LF>
0262   4C  4C
0264   4F  2C
0266   20  49
0268   27  4D
026A   20  41
026C   20  43
026E   4F  4D
0270   50  55
0272   54  45
```

Listing 2 continued on page 180

Listing 2 continued:

```
       0274       52  2E
       0276       0D  0A
69     0278       57  48              .ASCIZ  /WHO ARE YOU?/<CR><LF>
       027A       4F  20
       027C       41  52
       027E       45  20
       0280       59  4F
       0282       55  3F
       0284       0D  0A
       0286       00
70              0290       MSG2=290
71              02B0       .=02B0
72     02B0       0A  0A   MSG3:      .ASCIZ  <LF><LF><LF><LF>/HI! /
       02B2       0A  0A
       02B4       48  49
       02B6       21  20
       02B8       00
73              02C0       .=02C0
74     02C0       2C  0D   MSG4:      .ASCIZ  /,/<CR><LF>/I'M PLEASED TO MEET YOU./
       02C2       0A  49
       02C4       27  4D
       02C6       20  50
       02C8       4C  45
       02CA       41  53
       02CC       45  44
       02CE       20  54
       02D0       4F  20
       02D2       4D  45
       02D4       45  54
       02D6       20  59
       02D8       4F  55
       02DA       2E  00
75              0001       P1=%1
76              0002       P2=%2
77              0003       P3=%3
78              000D       CR=0D
79              000A       LF=0A
80              0186       GECO=0186
81              01C5       PUTC=01C5
82              0200                  .END    START

SYMBOL TABLE

CR     = 000D    GECO   = 0186    LF     = 000A
LOOP     021A    MSG1     0260    MSG2   = 0290
MSG3     02B0    MSG4     02C0    PLOOP    0249
POUT     0250    PRINT    023F    PUTC   = 01C5
P1     =%0001    P2     =%0002    P3     =%0003
START    0200

ERRORS DETECTED: 0
```

hand, it is worth it. However, in the broader sense of programming, taking advantage of these kinds of savings is not a good practice because it destroys the possibility of incorporating programs into a larger system.

Program 3: Time

The third program, listing 3, has some practical utility. It is a digital clock. The logic of the program is simple, consisting of one major loop containing a counter and a delay loop. The delay loop is adjusted so that the time around the entire loop is exactly 1 minute. The count is displayed each time through the loop.

This program was designed to produce output for a video display, so each line overwrites the previous line. The program could be modified to produce output on a teletypewriter, by adding a line feed to the output.

Output for this program uses the routine PHEX, which prints out the 2-digit hexadecimal numbers contained in the accumulator. In this case we are dealing with decimal, not hexadecimal, but since the SC/MP has decimal instructions this only means that neither digit will be greater than 9.

PHEX has two entry points, PHEX1 and PHEX2, the difference being PHEX1 follows its output with a space, and PHEX2 does not. PHEX2 is generally used when a multi-byte number is to be printed. Here two 2-digit numbers for hours and minutes are being printed, so PHEX1 is used. This occurs in lines 8 thru 15 of the program.

The minutes are then incremented. When 60 is reached, go back to 0 and increment the hours. Thirteen hours gets reset to 1.

The program then delays for the remaining part of a minute, and then loops, printing out the next minute's time.

The delay is controlled by the numbers at locations 0228, 022C, and 022E. The numbers shown in the listing worked for the author's own setup, and kept time within a few seconds a day. The timing is controlled by the actual crystal frequency on the SC/MP board. Other

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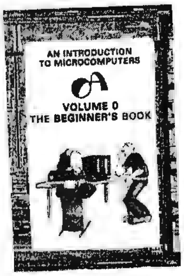

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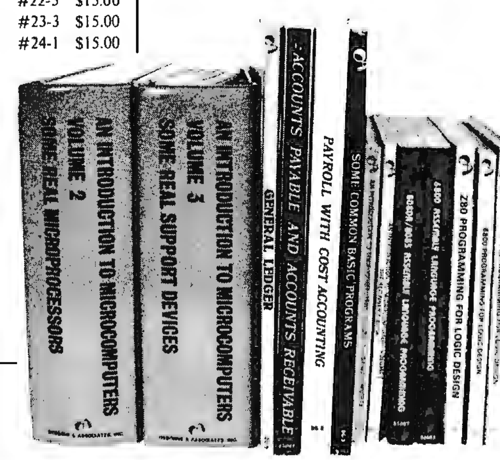

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Listing 3: Looping through several time delays is used to keep track of time. This program displays the time accurate to the minute.

```
                                 .NLIST   TTM
                                 .TITLE   PROGRAM #3
                                 ;THIS PROGRAM DISPLAYS THE
                                 ;TIME OF DAY ON A CRT
                                 ;THE TIME IS RE-WRITTEN
                                 ;EVERY MINUTE
             0200        .=200
     0200    C4   3D     START:  LDI      ^L<PHEX1>-1      ;GET ADDRESS
     0202    33                  XPAL     P3               ;OF NUMERIC
     0203    C4   01             LDI      ^U<PHEX1>        ;PRINT ROUTINE
     0205    37                  XPAH     P3               ;IN P3
     0206    C0   39             LD       HOUR             ;GET HOUR
     0208    3F                  XPPC     P3               ;CALL PHEX1
     0209    C0   37             LD       MINUTE           ;GET MINUTE
     020B    3F                  XPPC     P3               ;CALL PHEX1
     020C    C0   34             LD       MINUTE           ;GET MINUTE
     020E    02                  CCL                       ;CLEAR LINK
     020F    EC   01             DAI      1                ;ADD ONE
     0211    C8   2F             ST       MINUTE           ;STORE NEW VALUE
     0213    EC   40             DAI      40               ;DOES MINUTE = 60?
     0215    9C   10             JNZ      DELAY            ;NO SO DELAY ONE MINUTE
     0217    C8   29             ST       MINUTE           ;MINUTE = 0
     0219    C0   26             LD       HOUR             ;GET HOUR
     021B    EC   00             DAI      0                ;ADD 1 (LINK = 1)
     021D    C8   22             ST       HOUR             ;HOUR = HOUR + 1
     021F    EC   87             DAI      87               ;IS HOUR = 13?
     0221    9C   04             JNZ      DELAY            ;NO SO DELAY
     0223    C4   01             LDI      1                ;OTHERWISE
     0225    C8   1A             ST       HOUR             ;HOUR = 1
     0227    C4   1E     DELAY:  LDI      01E              ;WE WILL DELAY
     0229    C8   18             ST       COUNT            ;225 = (FF-1E) TIMES
     022B    C4   22     DL:     LDI      22               ;THEN DELAY
     022D    8F   FF             DLY      0FF              ;131070 MICRO CYCLES
     022F    A8   12             ILD      COUNT            ;INCREMENT COUNT
     0231    9C   F8             JNZ      DL               ;LOOP UNTIL OVERFLOW
     0233    C4   C4             LDI      ^L<PUTC>-1       ;GET CHARACTER PRINT
     0235    33                  XPAL     P3               ;IN P3
     0236    C4   0D             LDI      CR               ;LOAD CARRIAGE RETURN
     0238    3F                  XPPC     P3               ;CALL PUTC
     0239    90   C5             JMP      START            ;GO BACK TO THE BEGINNING
             0240        HOUR=240
             0241        MINUTE=241
             0242        COUNT=242
             000D        CR=0D
             0001        P1=%1
             0002        P2=%2
             0003        P3=%3
             013E        PHEX1=013E
             01C5        PUTC=01C5
             0200                .END START

SYMBOL TABLE

COUNT = 0242    CR    = 000D    DELAY   0227
DL      022B    HOUR  = 0240    MINUTE= 0241
PHEX1 = 013E    PUTC  = 01C5    P1     =%0001
P2    =%0002    P3    =%0003    START   0200


ERRORS DETECTED: 0
```

crystals might require different settings. Location 022C has the fine setting; the other values give a coarser setting.

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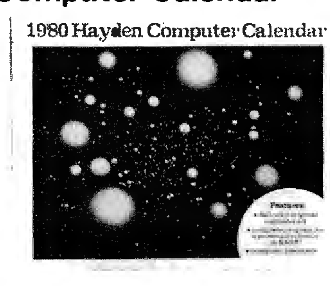

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Listing 4: Calculator functions can be easily programmed into the SC/MP. This routine inputs 2 numbers and outputs the sum.

```
1                             .NLIST   TTM
2                             .TITLE   PROGRAM #4
3                             ;THIS PROGRAM ADDS
4                             ;TWO NUMBERS, WHEN TYPED IN AS
5                             ; "253+792= "
6                             ; INPUT HAS FOUR DIGIT MAX
7                             ;OUTPUT IS FIVE DIGITS
8             0200       .=200
9     0200    C4  DF  START:  LDI     ^L<GHEX>-1      ;SET P3
10    0202    33              XPAL    P3              ;TO ADDRESS
11    0203    C4  00          LDI     ^U<GHEX>        ;OF
12    0205    37              XPAH    P3              ;GHEX
13    0206    3F              XPPC    P3              ;CALL GHEX TWICE
14    0207    3F              XPPC    P3              ;TO GET TWO NUMBERS
15    0208    02              CCL                     ;CLEAR OLD CARRY
16    0209    C2  01          LD      1(P2)           ;GET LOW HALF 2D NO
17    020B    EA  03          DAD     3(P2)           ;ADD TO LOW HALF 1ST NO
18    020D    CA  03          ST      3(P2)           ;STORE AT BOTTOM OF STACK
19    020F    C6  02          LD      @2(P2)          ;GET HIGH HALF 2D NO
20                                                    ;AND BUMP STACK POINTER
21    0211    EA  00          DAD     0(P2)           ;ADD HIGH HALF 1ST NO
22    0213    CA  00          ST      0(P2)           ;STORE ON TOP OF STACK
23    0215    C4  C4          LDI     ^L<PUTC>-1      ;P3 SET FOR CHARACTER PRINT
24    0217    33              XPAL    P3              ;HIGH P3 IS OK (REALLY)
25    0218    C4  30          LDI     30              ;GET ASCII 0
26    021A    F4  00          ADI     0               ;ADD CARRY FOR FIFTH DIGIT
27    021C    3F              XPPC    P3              ;PRINT 0 OR 1
28    021D    C4  43          LDI     ^L<PHEX2>-1     ;P3 SET FOR BYTE PRINT
29    021F    33              XPAL    P3
30    0220    C6  01          LD      @1(P2)          ;POP HIGH BYTE OFF STACK
31    0222    3F              XPPC    P3              ;AND PRINT
32    0223    C6  01          LD      @1(P2)          ;POP LOW BYTE
33    0225    3F              XPPC    P3              ;AND PRINT
34    0226    C4  C4          LDI     ^L<PUTC>-1      ;P3 SET AGAIN FOR CHARACTERS
35    0228    33              XPAL    P3              ;HIGH P3 STILL OK
36    0229    C4  0D          LDI     CR              ;GET CARRIAGE RETURN
37    022B    3F              XPPC    P3              ;PRINT
38    022C    C4  0A          LDI     LF              ;GET LINE FEED
39    022E    3F              XPPC    P3              ;PRINT
40    022F    90  CF          JMP     START           ;LOOP TO BEGINNING
41            0001       P1=%1
42            0002       P2=%2
43            0003       P3=%3
44            000D       CR=0D
45            000A       LF=0A
46            00E0       GHEX=00E0
47            01C5       PUTC=01C5
48            0144       PHEX2=0144
49            0200            .END START

SYMBOL TABLE

CR    = 000D    GHEX  = 00E0    LF     = 000A
PHEX2 = 0144    PUTC  = 01C5    P1     =%0001
P2    =%0002    P3    =%0003    START   0200

ERRORS DETECTED: 0
```

ple way by repeated addition. Thus 573 × 426 is computed by adding 426 to itself 573 times. This may seem like a very slow procedure, but in fact, the SC/MP is fast enough that computation time does not become noticeable until the multiplier is in the 1000s. The computational delay is then about 1.2 seconds per 1000.

Input to the program is performed using GHEX. This program reads a 4-digit hexadecimal number from the keyboard. Since these numbers are decimal, not hexadecimal, this means only that digits greater than 9 must be avoided. Since a 4-digit number cannot fit in 1 byte, GHEX cannot return its answer in the accumulator, as did the other subroutines. GHEX returns the 2-byte result on the stack. (The least significant byte is first, or at the higher address.)

The first 6 lines of both programs cause the data to be read in. Notice that lines 5 and 6 simply call GHEX twice.

Text continued on page 188

Listing 5: As an extension of the addition routine, the multiplication routine inputs 2 numbers and multiplies them.

```
                                .NLIST   TTM
                                .TITLE   PROGRAM #5
                                ;THIS PROGRAM MULTIPLIES
                                ;TWO NUMBERS WHEN TYPED IN AS
                                ;"357X942="
                                ;INPUT HAS FOUR DIGIT MAX
                                ;OUTPUT IS EIGHT DIGITS
          0200          .=200
0200      C4   DF  START:   LDI     ^L<GHEX>-1       ;SET P3
0202      33                XPAL    P3               ;TO ADDRESS
0203      C4   00           LDI     ^U<GHEX>         ;OF
0205      37                XPAH    P3               ;GHEX
0206      3F                XPPC    P3               ;CALL GHEX TWICE
0207      3F                XPPC    P3               ;TO GET TWO NUMBERS
0208      C4   06           LDI     6                ;SET UP LOOP
020A      C8   65           ST      TEMP             ;TO PUT SIX ZEROS
020C      C4   00  L1:      LDI     0                ;ON STACK
020E      CE   FF           ST      @-1(P2)          ;LAST FOUR ZEROS ARE
0210      B8   5F           DLD     TEMP             ;INITIAL PRODUCT
0212      9C   F8           JNZ     L1               ;FIRST TWO EXTEND MULTIPLICAND
                                                     ;TO EIGHT DIGITS
0214      02       L2:      CCL                      ;CLEAR OLD CARRY
0215      C2   09           LD      9(P2)            ;AND SUBTRACT
0217      EC   99           DAI     99               ;ONE FROM
0219      CA   09           ST 9(P2)                 ;MULTIPLIER
021B      C2   08           LD      8(P2)            ;BOTH HALVES
021D      EC   99           DAI     99               ;IN TENS COMPLIMENT
021F      CA   08           ST      8(P2)            ;THERE IS NO CARRY ON
0221      06                CSA                      ;LAST ADD 0-1 = 9999
0222      94   13           JP      OUT              ;SO GET OUT
0224      02                CCL                      ;OTHERWISE CLEAR CARRY
0225      C6   04           LD      @4(P2)           ;TEMPORARILY BUMP STACK BY 4
0227      C4   04           LDI     4                ;COUNT = 4 DIGITS
0229      C8   46           ST      TEMP             ;FOR LOOP
022B      C6   FF  L3:      LD      @-1(P2)          ;NOW ADD
022D      EA   04           DAD     4(P2)            ;MULTIPLICAND TO
```

```
0220F   CA  00           ST     0(P2)          ;PRODUCT AS EIGHT DIGIT
0231    B8  3E           DLD    TEMP           ;OR FOUR BYTE ADD
0233    9C  F6           JNZ    L3             ;LOOP UNTIL DONE, THEN
0235    90  DD           JMP    L2             ;DECREMENT MULTIPLIER AGAIN
0237    C4  04   OUT:    LDI    4              ;WHEN DONE
0239    C8  36           ST     TEMP           ;PRINT OUT FOUR BYTES
023B    C4  43   L4:     LDI    ^L<PHEX2>-1    ;SET P3 TO PHEX2
023D    33               XPAL   P3             ;HIGH P3 IS OK
023E    C6  01           LD     @1(P2)         ;POP PRODUCT OFF STACK
0240    3F               XPPC   P3             ;PRINT
0241    B8  2E           DLD    TEMP           ;DECREMENT AND LOOP
0243    9C  F6           JNZ    L4             ;NOTE INSTRUCTIONS AFTER L4
                                               ;CANNOT BE SKIPPED
0245    C6  06           LD     @6(P2)         ;BUMP GARBAGE OFF STACK
0247    C4  C4           LDI    ^L<PUTC>-1     ;SET P3 TO PUTC
0249    33               XPAL   P3             ;HIGH P3 IS OK
024A    C4  0D           LDI    CR             ;PRINT CARRIAGE RETURN
024C    3F               XPPC   P3             ;THEN
024D    C4  0A           LDI    LF             ;LINE FEED
024F    3F               XPPC   P3             ;AND
0250    90  AE           JMP    START          ;GO BACK TO BEGINNING
            0270     TEMP=270
            00E0     GHEX=00E0
            0144     PHEX2=0144
            01C5     PUTC=01C5
            0001     P1=%1
            0002     P2=%2
            0003     P3=%3
            000D     CR=0D
            000A     LF=0A
            0200                 .END   START

SYMBOL TABLE

CR    = 000D    GHEX  = 00E0    LF    = 000A
L1      020C    L2      0214    L3      022B
L4      023B    OUT     0237    PHEX2 = 0144
```

Listing 5 continued on page 188

Listing 5 continued:

```
PUTC   = 01C5     P1     =%0001   P2    =%0002
P3     =%0003     START  '0200    TEMP  = 0270

ERRORS DETECTED: 0
FREE CORE: 17525. WORDS

,PROG5=PROG5
```

Text continued:

This causes 2 numbers to reside in the top 4 locations on the stack. GHEX "knows" a number has been typed when a nonhexadecimal character, such as W, is typed. Thus, to add 2 to 2 with program 4, the programmer could type 2W2W. "2+2 =" could also be typed, which is much more impressive when demonstrating the program. (Note that GHEX always gives a 2-byte result, even though fewer than 4 digits are typed.)

Lines 14 thru 21 add the 2 numbers, leaving the result on the stack. Note that there may be overflow indicating a fifth digit of 1. Lines 22 thru 26 create this fifth digit of 0 or 1 and print it. (Note the comment on line 23. Originally, the high part of pointer register 3 was 00, but GHEX will leave it as 01. *nb* earlier comments on this programming practice.)

Lines 27 thru 32 pop the rest of the sum off the stack and print it. Lines 33 thru 39 type a carriage return and line feed and loop back to the beginning to solve another problem.

Program 5 is designed to produce an 8-digit or 4-byte result, because the product of two 4-digit numbers can have 8 digits. Steps 14 thru 19 form a loop which places 6 0s on the stack. The lower 4 0s form an accumulator for the product. The 2 other 0s combine with the 2-byte multiplicand to extend its precision to 4 bytes or 8 digits. This simplifies addition of the multiplicand to the product accumulation.

Lines 20 thru 39 form a loop for adding the multiplicand to the product accumulator. The multiplier is decremented each time through the loop. Decrementing is accomplished by adding 9999, which is a 10's complement negative 1.

Finally, steps 40 thru 56 print the result and loop back to the beginning. Note that in the loop beginning at line 42, pointer register 3 is reloaded each time through the loop. If this were not done, subsequent calls would end up at PHEX1 rather than PHEX2, and blank spaces would be interspersed in the result.

Conclusion

The 5 programs described in this article are intended to be simple demonstration programs that can be easily hand loaded into a minimal system. They are also designed to illustrate some of the basic concepts involved in programming the SC/MP. I hope that these programs will give the reader some ideas which can be used to design the applications for the SC/MP. The reader may also be able to apply the concepts of this article to other microcomputer kits, since many of them, such as the KIM-1, have useable system subroutines in read only memory.■

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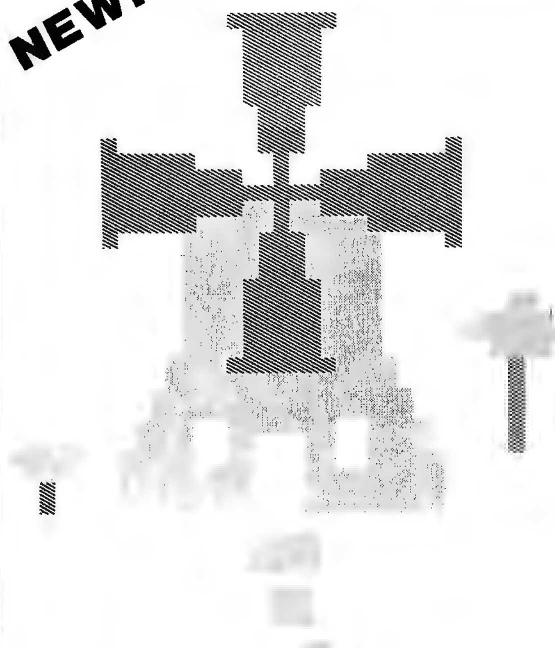

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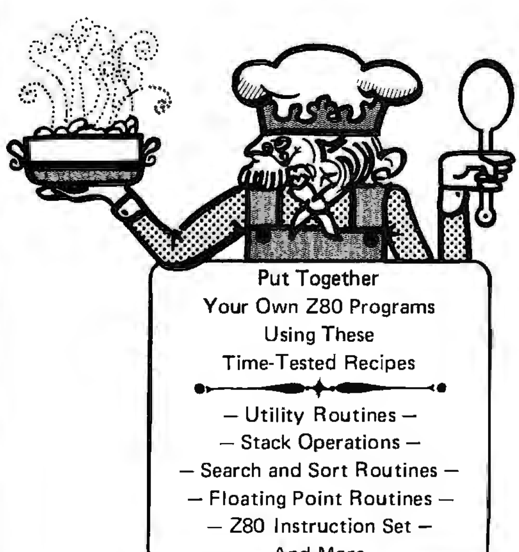

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These problems usually force a choice between two unpleasant alternatives. One alternative is to rely on complex error checking and error messages. The other is to guarantee operation for only a small set of rigidly defined inputs. Error checking sometimes takes more lines of code than the routine that will eventually process the data, while rigidly defined input specifications result in an unfriendly and unforgiving user interface.

The routine KEYIN, shown in listing 1, circumvents these problems by checking as narrow or wide a range of data inputs as desired by the calling routine. KEYIN will not return an invalid input to the calling routine, and bad data can be rejected by a single error message. KEYIN will also convert hexadecimal, decimal, or octal digits to binary while it is doing the error checking. KEYIN may be called by routines with vastly different requirements for alphanumeric data checking.

Knowledge of two variables and the table on which they operate is central to understanding how KEYIN works. The variables are stored in locations TBLPNT and TBLCNT. TBLPNT holds the address pointer for the table, and TBLCNT holds the number of entries in the table. The table these variables operate on may be placed in read-only or programmable memory. If the table is in read-only memory, TBLPNT can move up or down the table as subroutines require larger or smaller sets of input characters. If the table is in programmable memory, one may put its contents under program control in addition to moving TBLPNT.

For example, a subroutine may want to allow entry of one or more hexadecimal digits followed by an alphabetic command such as G for go or R for run. The table for this example would be constructed as shown in listing 2. The routine that calls KEYIN should place the address of TABLE in the location TBLPNT and the number of entries in the table (18 in this example) in location TBLCNT. The variable BASE should be set to 16 for hexadecimal decoding.

When KEYIN is called, routine KEYIN2 will load reg-

Listing 1: *Z80 assembler code for the KEYIN routine. The program uses a table, as shown in listing 2, to determine acceptable input.*

```
ADDR R OBJECT
---- - ------

F200            TBLPNT   EQU 0F200H
F202            TBLCNT   EQU 0F202H
F204            BASE     EQU 0F204H
0007            BELL     EQU 07H

                *ABS
F000                     CODE 0F000H
F000  D5        KEYIN:   PUSH DE
F001  C5                 PUSH BC
F002  F5                 PUSH AF
F003  210000             LD HL,0            ;INITIALIZE HL
F006  E5        KEYIN1:  PUSH HL            ;SAVE NUMERIC INPUT
F007  2A00F2    KEYIN2:  LD HL, (TBLPNT)    ;LOAD THE TABLE POINTER
F00A  ED4B02F2           LD BC, (TBLCNT)    ;LOAD # OF ENTRIES IN TABLE
F00E  CD4AF0             CALL CHARNE        ;ACCEPT INPUT WITHOUT ECHO
F011  EDB1               CPIR               ;SEARCH THE TABLE
F013  2807               JR Z, KEYIN3       ;IF VALID ENTRY NOT FOUND
F015  3E07               LD A, BELL         ;THEN BEEP
F017  CD38F0             CALL CHAROUT       ;OR WRITE AN ERROR MESSAGE
F01A  18EB               JR KEYIN2          ;GO BACK AND GET NEXT ENTRY
F01C  CD38F0    KEYIN3:  CALL CHAROUT       ;ELSE ECHO CHARACTER
F01F  E1                 POP HL             ;RESTORE NUMERIC INPUT
F020  47                 LD B,A             ;SAVE CURRENT INPUT IN REG.B
F021  79                 LD A,C             ;LOAD COUNT REMAINDER INTO A
F022  ED5B04F2           LD DE, (BASE)      ;LOAD BASE INTO DE
F026  BB                 CP E               ;
F027  300A               JR NC, KEYIN4      ;IF ENTRY WAS GREATER THAN
F029  2808               JR Z, KEYIN4       ;OR EQUAL TO BASE THEN EXIT
F02B  29                 ADD HL, HL         ;ELSE FORM THE BINARY
F02C  29                 ADD HL, HL
F02D  29                 ADD HL, HL
F02E  29                 ADD HL, HL
F02F  85                 ADD A, L
F030  6F                 LD L, A
F031  18D3               JR KEYIN1          ;AND GET THE NEXT ENTRY
F033  F1        KEYIN4:  POP AF             ;RESTORE AF
F034  78                 LD A,B             ;PLACE THE COMMAND IN REG A
F035  C1                 POP BC             ;RESTORE BC
F036  D1                 POP DE             ;RESTORE DE
F037  C9                 RET                ;EXIT KEYIN


EEFE            DECODE   EQU  0EEFEH


F038  C5        CHAROUT: PUSH BC
F039  F5                 PUSH AF
      ;------------------HARDWARE DEPENDENT CODE-------------------
F03A  01FEEE             LD BC, DECODE      ;I/O ADDRESS DECODING
F03D  ED78      CHAR01:  IN A,(C)           ;CHECK STATUS OF OUTPUT DEVICE
F03F  CB6F               BIT 5, A           ;IF NOT READY
F041  28FA               JR Z, CHAR01       ;THEN LOOP
F043  0EFF               LD C, 0FFH         ;ELSE SET DECODE FOR DATA OUT
      ;------------------------------------------------------------
F045  F1                 POP AF
F046  ED79               OUT (C),A          ;WRITE TO OUTPUT DEVICE
F048  C1                 POP BC
F049  C9                 RET                ;EXIT
      ;
F04A  C5        CHARNE:  PUSH BC
      ;------------------HARDWARE DEPENDENT CODE-------------------
F04B  01FEEE             LD BC, DECODE      ;I/O ADDRESS DECODING
F04E  ED78      CHAR1:   IN A,(C)           ;CHECK STATUS OF INPUT DEVICE
F050  CB77               BIT 6, A           ;IF NOT READY
F052  28FA               JR Z, CHAR1        ;THEN LOOP
F054  0EFF               LD C, 0FFH         ;ELSE SET DECODE FOR DATA IN
      ;------------------------------------------------------------
F056  ED78               IN A, (C)
F058  C1                 POP BC
F059  C9                 RET                ;EXIT
                         END

ERROR COUNT 0

CPU (SEC)=7

ASSEMBLY COMPLETE - NO ERRORS
```

Listing 2: *Table setup to allow KEYIN to recognize the commands G and R for go and run, along with a hexadecimal number.*

```
TABLE:    DEFM  'GR'
          DEFM  'FEDCBA9876543210'
```

Listing 3: *Multiple tables allow KEYIN to search for one of several different valid commands. Here tables are set up to search for RUN, RES (reset) and REG (register).*

```
TABLE:     DEFM 'R'
TABLE1:    DEFM 'EU'
TABLE2:    DEFM 'SG'
```

ister pair HL with the table pointer and load register pair BC with the number of entries in the table. The routine CHARNE is called and it will accept one character from the keyboard without echoing the character. The routines CHAROUT and CHARNE are hardware dependent and are shown here only to illustrate how KEYIN interacts with the user. CHAROUT can be any routine that sends one character to an output device, and CHARNE can be any routine that accepts one character from an input device. The keyboard entry is passed back from CHARNE to KEYIN in register A.

After CHARNE accepts an entry, the CPIR instruction in KEYIN2 begins searching TABLE for a valid entry. If a valid entry is found, the input character is echoed back to the terminal. If a valid entry is not found, an error message may be returned or the input may simply be ignored or rejected with an audible signal as it is here. Routine KEYIN2 will be reexecuted until it recognizes a valid entry.

The CPIR instruction decrements the BC register pair as it compares the input character against the characters in the table. This is important since the value that is left in the BC register pair will be the binary value of the hexadecimal input when the CPIR instruction terminates. When a valid entry is found, KEYIN checks register C against the variable BASE. If the value in register C is greater than or equal to BASE, KEYIN will return to the calling routine with hexadecimal input in register pair HL and the nonhexadecimal character in register A. If the value in register C was less than BASE, its binary value will be placed in the register pair HL and KEYIN will reset the table pointer and counter and wait for another character.

Another use of KEYIN is searching a tree for valid input. As an example, assume that a program would like to evaluate three similar commands and reject all others. For this example, valid command strings are RESET, REGISTER, and RUN. TABLE would be set up with R as the root letter followed by branches EU and SG, as shown in listing 3. Before KEYIN is called, TBLPNT is set to address TABLE, TBLCNT is set to one and BASE is set to zero. On the first call to KEYIN, all inputs will be rejected except R. Once R is input, the calling routine sets TBLPNT to TABLE1 and TBLCNT to two. Now only the letters E and U will be accepted by KEYIN. If a U is input, a valid command has been found and the appropriate action can be taken. If the input was an E, the calling routine sets TBLPNT to TABLE2 and KEYIN is called again. KEYIN will now only accept the letters S and G, and the appropriate action may be taken once a valid input is accepted.

In general, KEYIN will allow n-way branching from the root or any branch of a tree by setting TBLCNT to n, TBLPNT to the first of the n acceptable inputs, and BASE to zero for character input. ■

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A Proposed Graphics Software Standard, Part 1

Vincent C Jones, 1913 Sheely Dr, Ft Collins CO 80526

A major stumbling block to making good software available in the personal computer market is the lack of standardization. Each manufacturer and software developer establishes internal standards for software and hardware interfaces, and they are usually incompatible with one another. Reasons for this vary from the experimenter's attempts to save 1 byte of memory in a 14 K byte program, to the mainframe manufacturer seeking to protect a development investment. The net result is the same. Extensive modifications are typically required to run software on any machine that differs from the original development's hardware and software configuration.

In an effort to prevent this fragmenting effect from overwhelming graphics applications programming, the following graphics interface software protocol is proposed as a standard.

This two-part article presents a complete microcomputer-oriented graphics software protocol and the algorithms required to implement it on typical raster scan graphics displays. The functions of hardware initialization, screen erase, point display, line generation, character generation, and animation are defined, and their implementation is demonstrated with a sample 8080/Z80 assembly language version for the Cromemco Dazzler. The power of a standard protocol is illustrated by a diagnostic demonstration program using the proposed 1 K byte 8080 assembly language protocol standard.

The standard actually proposes two separate but dependent protocols. The top-level protocol is machine independent. It defines a standard display coordinate system, several standard display modes, the available functions, and what these functions do. For example, a request for a red line from the center of the screen to the bottom right corner would always require the following command sequence:

CHAR (RED)	Set the current color to RED
CURSOR (128,128)	Move to the center of the screen
LINE (255,0)	Draw the line

Obviously, not all displays are capable of color; a black and white display would draw a white line instead. To compensate for any deficiencies in the hardware that is being used, a feedback path is included to inform the user program of the available capabilities. General-purpose programs can check to verify that the display being used is suitable and, if necessary, display an error (or warning) message, or use a different algorithm to accomplish the task at hand. For example, a TV tennis game could check to see if full color was available. If so, it could use red paddles, a yellow ball, a green court, and white boundaries. If only three colors were available, the paddles and ball could be the same color. If only a black and white display was available, all markings could be in white with a black court and background.

The lower-level protocol defines the calling sequences used in a particular programming language. When necessary, it also defines where the routines are loaded in memory, and the addresses of their calling vectors. Returning to the example of drawing a red line, an 8080 (or Z80) assembly language program would use the instruction sequence:

```
MVI    A,11H      ;Code for Red
CALL   0113H      ;Vector for CHAR
LXI    H,8080H    ;X = 128, Y = 128
CALL   010AH      ;Vector for CURSOR
LXI    H,FF00H    ;X = 255, Y = 0
CALL   0110H      ;Vector for LINE.
```

Similarly, a BASIC program would read:

```
REM — Set the current color to RED
CHA 17
REM — Move to the center of the
      screen
CUR 128,128
REM — Draw the line down to corner
LIN 255,0.
```

Suitable standards for other languages remain to be developed. Reader suggestions are welcome.

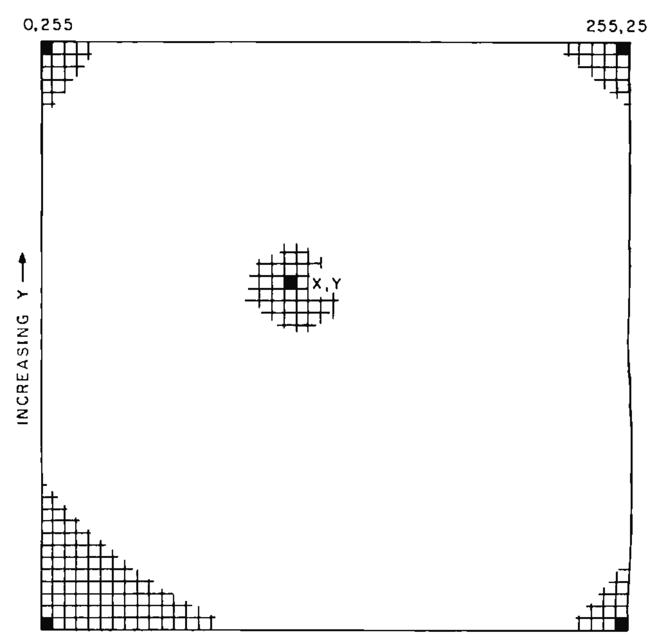

Figure 1: *Standard coordinate system used in the proposed graphics software standard.*

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MSS

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The Standard Display

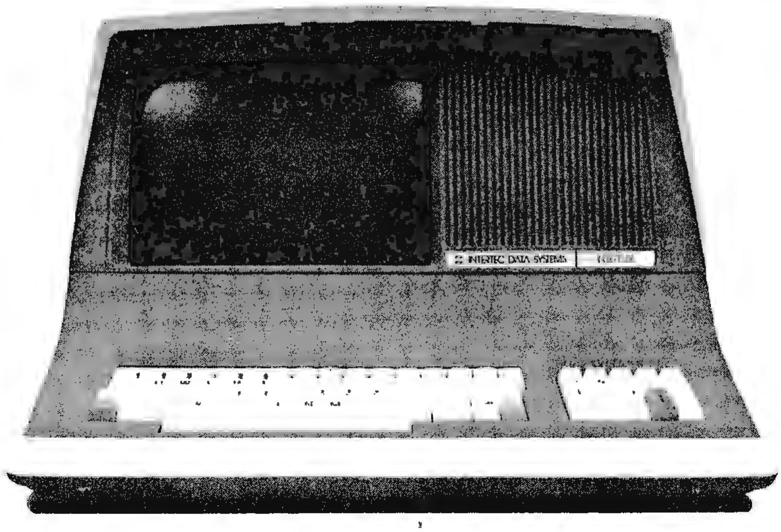
The protocol defines a standard display device to circumvent hardware differences. The standard device displays 256 lines with 256 points on each line. As shown in figure 1, the origin (X = 0, Y = 0) is defined as the bottom leftmost point on the display. X increases to a maximum value of 255 as you move to the right, Y increases to 255 as you rise to the top. This defines the first quadrant of the standard Cartesian coordinate system. Each picture element (pixel) may be black, white, red, green, blue, yellow, cyan, or magenta (any combination of the three primary colors).

The display to be used is programmed to imitate the standard. To facilitate this procedure, four standard display modes are defined. Mode 0 requests the maximum possible resolution while mode 1 requests the maximum choice of colors. This allows for displays, such as the Cromemco Dazzler, which offer a trade-off between resolution and color. Two additional modes provide the ability to deliberately select larger pixels. Mode 2 is 128 by 128 resolution and mode 3 is 64 by 64 resolution. Regardless of the resolution actually used, the coordinate system remains at 256 by 256, as defined above. General-purpose applications programs can check to determine the available resolution and range of colors, whether the display is black and white or color, whether or not individual points can be erased, and if dual-buffered animation is available.

The Standard Functions

A five command repertoire is generally considered to be the bare minimum for a general-purpose graphics display. These commands provide all the output capabilities normally found on commercial nonintelligent graphics terminals, such as the Tektronics 4010. The routines are:

PAGE:	Next page, ie, erase the entire screen.
CURSOR (X,Y):	Position the cursor at the point X,Y.
DOT:	Set the pixel defined by the cursor position to the currently selected color.
LINE (X,Y):	Set the pixels along the line connecting the current cursor position to the point X,Y to the currently selected color.
CHAR (VAL):	Display the character whose ASCII value is VAL at the current cursor position using the currently selected color.



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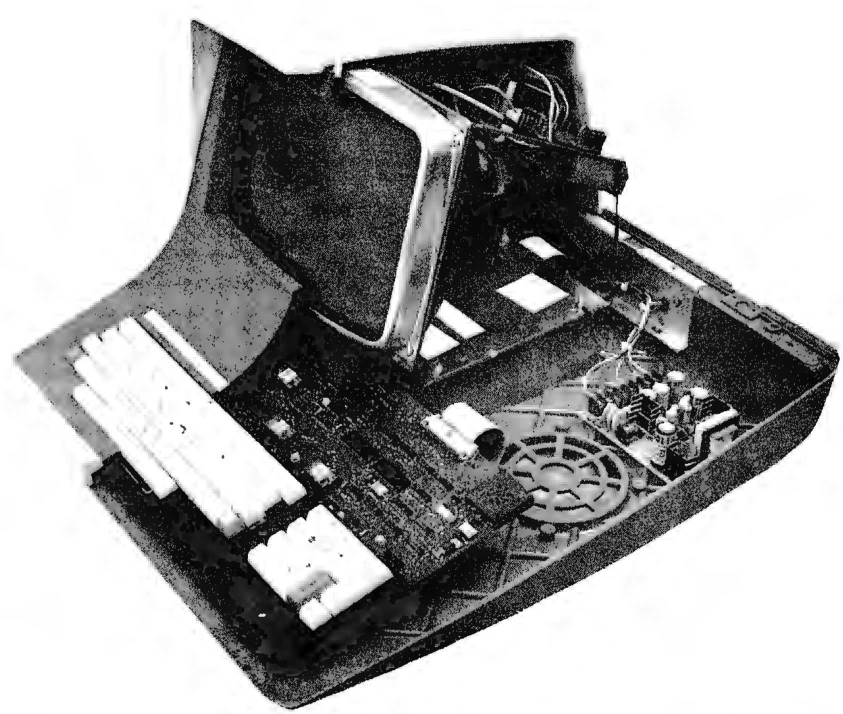

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To facilitate matching the hardware requirements of many displays, an initialization command is also required:

INITG: Initialize the graphics subsystem.

Finally, a 2-buffer animation command is included for interactive graphics and game playing:

ANIMAT: Display the refresh buffer currently being filled and open a second refresh buffer for filling.

Display mode and current color selection are provided by the routine CHAR through ASCII control characters. Standard carriage control characters are also recognized. Display description parameters are returned by the routine INITG.

Let us now examine the function of each of the seven routines in detail.

INITG

The INITG function serves three primary functions. As an aid to the user, the display software is initialized to a standard configuration; the cursor is positioned at X = 0, Y = 0, the current color is set to white, the display is cleared, animation is disabled, and the display mode is set for maximum resolution (mode 0). Special options peculiar to the particular display are also disabled so that general-purpose programs do not have to be aware of them to function correctly. Secondly, this routine performs any initialization functions required by the display hardware. For those displays which refresh from program memory, the routine establishes the refresh buffers. If the display is under program control, it is turned on. Finally, INITG sets the display description variables to the appropriate values. Failure to initialize the display before using any of the other functions may lead to unpredictable and potentially disastrous results.

PAGE

The PAGE function clears the display screen. No other changes are made to the state of the display: the cursor is not moved, the current color is not changed, and the display mode is unaffected.

CURSOR

The CURSOR function sets the display cursor to a particular pixel on the screen. This establishes the initial location for the display functions which affect individual pixels on the screen. Coordinates are always interpreted on the 256 by 256 pixel matrix regardless of the actual resolution of the display. This is true even when the display mode is deliberately set to a lower resolution mode.

When in a lower resolution mode, the low-order bits of the position requested are ignored. For example, when in 128 by 128 resolution mode (mode 2), the points (8,4), (8,5), (9,4), and (9,5) will all be interpreted as the same pixel (the low-order bit in each coordinate has no effect).

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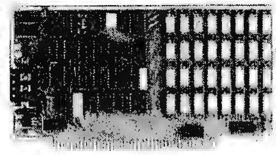

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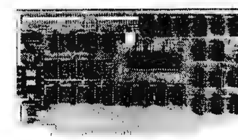

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Mnemonic	ASCII	Hexadecimal	Standard Function
			Display Mode Selection
MAXR	NUL	00	Maximum resolution
MAXC	SOH	01	Maximum colors
R128	STX	02	128 by 128
R64	ETX	03	64 by 64
RXXX	EOT	04	Undefined
			Carriage Control
BS	BS	08	Backspace (optional)
HT	HT	09	Horizontal tab (optional)
LF	LF	0A	Line feed
VT	VT	0B	Vertical tab (optional)
FF	FF	0C	Form feed
CR	CR	0D	Carriage return
			Character Style
SO	SO	0E	Undefined
SI	SI	0F	Undefined
			Current Color Selection
BLK	DLE	10	Black
RED	DC1	11	Red
BLU	DC2	12	Blue
MAG	DC3	13	Magenta
GRN	DC4	14	Green
YEL	NAK	15	Yellow
CYN	SYN	16	Cyan
WHI	ETB	17	White
NONE	ETX to GS	18 to 1F	Eight optional colors

Table 1: *Standard control character functions.*

When changing between display modes, cursor position is not required to be maintained by the interface software. To avoid erroneous results, all changes to display mode should be followed by a cursor positioning command.

DOT

The DOT function sets the display pixel indicated by the cursor to the currently selected color. With some displays in low-resolution mode, several physical pixels may be affected. For example, the Matrox ALT-256**2 turns on (or off, as selected) sixteen hardware pixels for every "dot" when in a 64 by 64 resolution mode.

LINE

The LINE function generates the line connecting the pixel defined by the cursor to the pixel requested. Both endpoints are included in the line. Therefore, a line of zero length is logically equivalent to a call to DOT. Care must be exercised when erasing or otherwise changing the color of a line, since the pixels in a line from pixel A to pixel B may differ from those used when the line is drawn from pixel B to pixel A. When lines are drawn in lower resolution modes, the pixels used are the size made by the DOT function at that resolution.

CHAR

The CHAR function provides the capability to display alphanumeric as well as graphical data. In addition, control characters provide limited cursor positioning and control over display mode and current color as shown in table 1. Control characters that are not recognized are ignored. Note that form feed positions the cursor only—it does not erase the screen.

Characters are positioned so that the cursor defines the lower left corner of a normal character (characters with descenders will extend below the cursor position). The cursor is left at the next character position. No check is made to detect characters off the edge of the screen. Parity is ignored. Lowercase characters, if not supported, are converted to uppercase.

ANIMAT

The function ANIMAT provides for flicker-free changes in the display by permitting the user to load one refresh buffer while displaying another. Each call to ANIMAT displays the buffer which is being filled, and opens another buffer for filling. This buffer exchange is performed at the start of the next vertical blanking period. Those displays without the ability to utilize multiple buffers but which *do* allow the erasing of individual pixels (such as the Matrox ALT-256**2) will just delay until the start of the next vertical blanking period. In either case, no changes are made to either buffer, and the cursor position is maintained. The ANIMAT function does nothing on those displays which support neither double buffering nor selective erase. To return to normal mode where updates are displayed in real time, it is necessary to reinitialize with INITG.

Standard Calling Sequences

To encourage maximum software interchange, two standard programming language protocols are currently defined. The first protocol is for 8080 and Z80 assembly language users, the second is for BASIC programs. By following one of these protocols, a program written for one display will work with any other display of sufficient resolution and color flexibility. The standard display and function definitions described previously are common to both protocols.

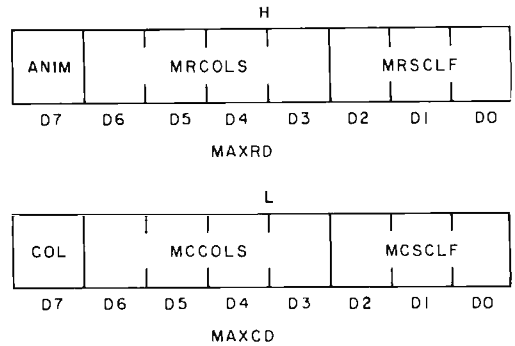
8080 Assembler Protocol

The 8080 assembly language interface is loaded into hexadecimal memory locations 0104 to 04FF. This provides a standard location for the package, regardless of memory size. To avoid conflict with programs requiring use of the restart (RST) instruction and most popular 8080 monitors, a lower starting address is not used. The first 21 bytes (hexadecimal 0104 to 0118) are the entry points to the different routines, as indicated in table 2. All arguments are passed to the called routine in register pair HL, except for the CHAR routine, which uses register A. The contents of all registers and flags are preserved, except for the INITG routine.

Routine INITG is called with the address of the first unused memory location above the program, to indicate

Routine	Vector Address (hexadecimal)	Parameters
INITG	104	HL = first free address Returns display description in HL
PAGE	107	None
CURSOR	10A	H = X coordinate; L = Y coordinate
DOT	10D	None
LINE	110	H = X end coordinate; L = Y end coordinate
CHAR	113	A = ASCII value of character
ANIMAT	116	None

Table 2: *8080 assembly language standard vector addresses.*



ANIM = 0 - Delay to start of vertical blanking.
1 - Double buffered animation supported.

COL = 1 - Display is in color.
0 - Display is black and white.

MRCOLS - Colors (grey shades) in MAXR mode.

MCCOLS - Colors (grey shades) in MAXC mode.

MRSCLF - $\frac{256}{\text{Display resolution}}$ in MAXR mode.

MCSCLF - $\frac{256}{\text{Display resolution}}$ in MAXC mode.

Figure 2: *8080 assembly language standard display parameter fields.*

available space for refresh buffers. While some displays do not require this information, it should always be included for compatibility. The address in HL is replaced by INITG with a 2-byte description of the display being used (all other registers and flags are left undisturbed). The format for these bytes is given in figure 2. The colors and scale factor fields which are available in register H describe the display when maximum resolution is selected; the same fields in register L describe the maximum color selection mode.

The available colors field gives the number of colors, other than white, to which a point can be written. If the field is zero, it means that the way to erase what has been written is to page the display. The scale factor field indicates the physical size of display points in standard coordinates. If the X and Y scale factors differ, the larger of the two is used. For example, if the display had 64 lines with 100 points on each, the scale factor would be four, based on the Y axis resolution.

The animation and color fields apply to all display modes. If the animation field is one, the display supports double buffered animation. If this field is zero, it is impossible to build one display scene while another is displaying. In this case the ANIMAT routine is a delay until the start of vertical blanking. The color/black and white field is self-explanatory: if it is one, the display is in color; otherwise it is black, grey, and white. Note that this field has no real meaning if the number of available colors is zero or one.

BASIC Protocol

For maximum flexibility and machine independence, a BASIC language usage protocol is also defined. Table 3 summarizes the commands and their arguments. Display initialization (IGR command) sets the variables A1

Mnemonic	Function	Arguments
IGR	INITG	None
PAG	PAGE	None
CUR	CURSOR	<X>, <Y>
DOT	DOT	None
LIN	LINE	<X>, <Y>
CHA	CHAR	<numeric ASCII value>
ANM	ANIMAT	None
TXT	PRINT	Equivalent to print except on display

Variable Name	Display Parameter
A1	X scale factor, high-resolution mode
A2	Y scale factor, high-resolution mode
A3	Available colors, high-resolution mode
A4	X scale factor, maximum color mode
A5	Y scale factor, maximum color mode
A6	Available colors, maximum color mode
A7	Animation support
A8	Grey scale

Table 3: *BASIC standard protocols.*

through A8 to reflect the display parameters. The scale factors A1, A2, A4, and A5, normally given exactly, are permitted to be rounded off to the nearest integer. These variables are ordinary BASIC variables and may be used and set as desired by the program.

The additional command TXT provides the user with the full flexibility of the BASIC PRINT command. Text and variables are displayed using the formats requested in the TXT statement starting at any location on the screen by using CUR to position the cursor. All characters are displayed using the current color.

Function Algorithms

To facilitate development of this standard, the algorithms used to produce the Matrox ALT-256**2 and the Cromemco Dazzler implementations of the 8080 assembly language standard are provided here. Of particular interest to most readers will be the line and character generation algorithms, which are independent of the hardware configuration of the display used.

For those readers not familiar with Nassi-Schneiderman design charts, a brief explanation is in order. More detailed information can be found in the original article published in the *SIGPLAN Notices* (August 1973). The Nassi-Schneiderman chart is a stylized flowchart for structured programming. By supporting only standard structured programming constructs (see figure 3) and not GOTOs and off page connectors, the chart forces the software designer to avoid the convolutions and obscurities in logic which make programs excruciating to debug and impossible to maintain.

The INITG and DOT routines are the only routines which normally require extensive adaptation to suit different displays. Since the Matrox ALT-256**2 is the only currently available low-cost display which is not direct memory access (DMA) refreshed from program memory and an enhanced 8080 assembly language package that is compatible with this standard is available from Matrox, the special considerations required to program I/O port driven displays are not included in this article. For direct memory access displays, the only other adaptations normally required are the refresh memory size parameter in

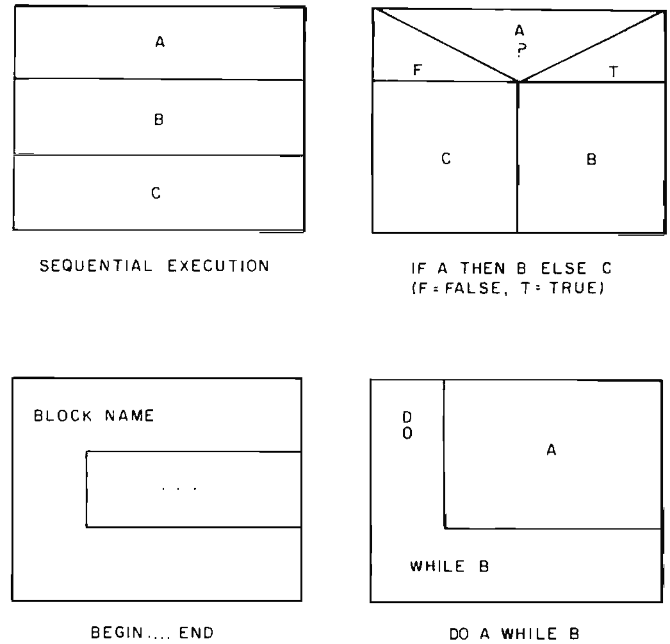


Figure 3: *Nassi-Schneiderman charts, a system of stylized flowcharts which are designed for use with structured programming techniques. Each of the charts physically resembles the program section it emulates. The charts are read from top to bottom.*

PAGE, the color and mode select controls in CHAR, and the scale factors used by the internal subroutine SCALE.

INITG Logic

Initialization is normally required for both hardware and software (see figure 4). The first step is to establish the refresh buffer. This requires taking the address which defines the top of the user program and moving up to the first address legal for refresh buffers. This address is needed by other routines, as well as for starting the display hardware. The different variables and flags are then set to the required values, and the page routine is called to clear the screen. The appropriate display

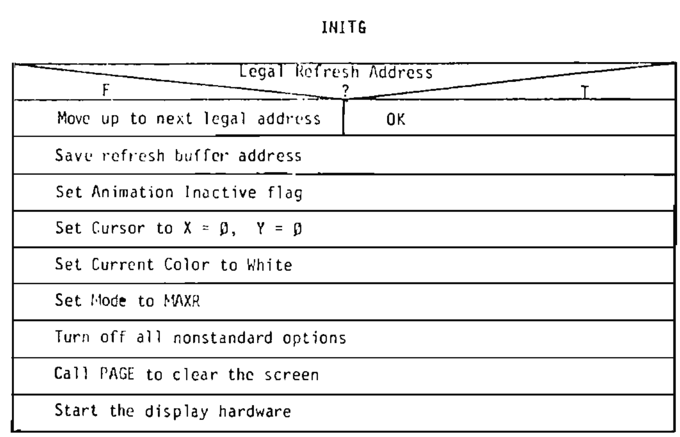


Figure 4: *The INITG function. INITG serves three purposes as an aid to the user: it initializes the system, performs any initialization functions required by the display software, and sets the display description variables to the appropriate values.*

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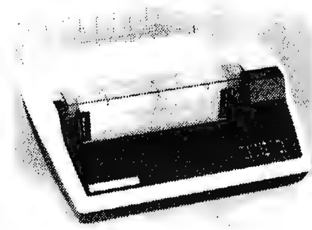

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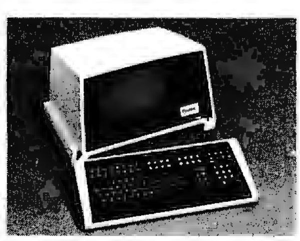

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PAGE

```
ADR = Refresh buffer address
CNT = Refresh buffer length
DO
    Set [ADR] to zero (black)
    ADR = ADR + 1
    CNT = CNT - 1
UNTIL CNT equals Ø
```

Figure 5: *The PAGE function. PAGE is used to clear the display screen.*

CURSOR

```
Call SCALE to interpret coordinates
Set the software cursor to the scaled values.
```

Figure 6: *The CURSOR function which sets the display cursor to a particular pixel on the screen.*

description is generated, and control is returned to the calling program.

PAGE Logic

The PAGE command clears all the memory used for display refresh (see figure 5). The most general algorithm, and the one that is charted, is clear byte, increment address, decrement byte count, and test for done. In machines with indexed addressing, the byte count can double as an index register. In machines with a memory-to-memory block transfer instruction, it is usually possible to clear one byte and transfer it to all of the display refresh memory.

CURSOR Logic

The CURSOR routine must convert from standard coordinates to software coordinates (see figure 6). Software coordinates are required by the LINE and CHAR algorithms to have a one-to-one correspondence with the actual display pixels being used. CHAR further requires X coordinates to increase to the right and Y coordinates to increase to the top. Since LINE must also scale its arguments, CURSOR and LINE can usually share the same internal scaling routine for efficiency.

DOT Logic

DOT is the only routine (other than PAGE) which actually modifies the refresh memory (see figure 7). Both LINE and CHAR use it to modify the desired pixels in the display. This routine is extremely hardware-dependent. Indeed, one of the primary reasons for defining this protocol was protection from differing display idiosyncracies. The DOT routine must translate the coordinates in the software cursor to the actual corresponding bits in memory. Remember that the software cursor is scaled so that a unit change in a coordinate is equivalent to the adjacent pixel. The logic presented here assumes a linear scan through refresh memory to generate the entire display, a line at a time, with the top line displayed first. Note that this algorithm is not adequate for the Dazzler, nor is it suitable for self-refreshed displays like the

DOT

```
MAXR MODE ?
F:  Determine the Mode in use and proceed in the same manner as MAXR to
    calculate the address of the affected byte and obtain a mask of the
    affected bits.
T:  Calculate the address of the affected byte
        Convert Y coordinate to Line Number
        Y_OFFSET = Line Number • Bytes/line
        X_OFFSET = X coordinate / Pixels per byte
        Address = Base address + X offset + Yoffset
    Determine the affected bits in the byte
        X even ?
            F: MASK = Ø1Ø1Ø1Ø1
            T: MASK = 1Ø1Ø1Ø1Ø
        X/2 even ?
            F: MASK = MASK AND ØØ11ØØ11
            T: MASK = MASK AND 11ØØ11ØØ
        X/4 even ?
            F: MASK = MASK AND ØØØØ1111
            T: MASK = MASK AND 1111ØØØØ
Modify refresh memory to current color at addressed pixel
    Temp = MASK(inverted) AND [Address]
    MASK = MASK AND Color
    [Address] = Temp OR MASK
```

Figure 7: *The DOT function which sets the display pixel indicated by the cursor to the currently selected color.*

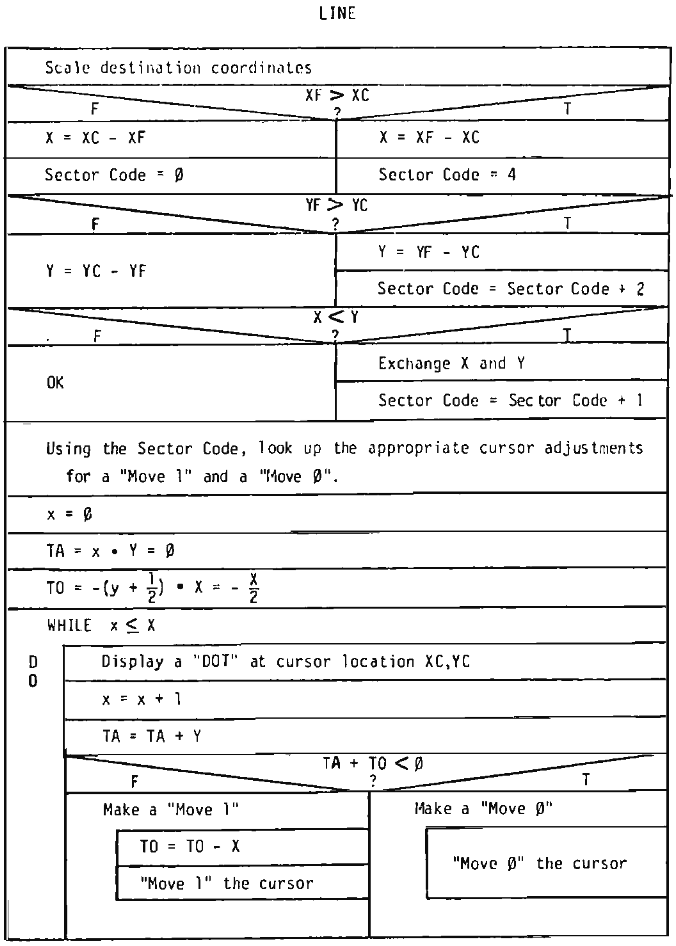

Figure 8: *The LINE function which generates the line connecting the pixel defined by the cursor to the pixel requested.*

Matrox ALT-256**2. The former divides the display into four quadrants, each in its own block of memory with every byte describing points on more than one line. The modifications to the algorithm are explained in the sample implementation, and need not concern the non-Dazzler owner. The Matrox's refresh memory is directly addressed by X,Y coordinates and no conversion is required.

The first step is to determine the address of the byte which contains the requested point. The cursor Y coordinate is converted to a display line number which, when multiplied by the number of bytes per line, gives the offset into the refresh buffer of the first byte on the line. The X coordinate corresponds directly to the desired point along the line. Dividing the X coordinate by the number of points in each byte gives the offset from the first byte in the line. Taking the base address of the refresh buffer (set up by INITG) and adding the offsets to the desired line in the buffer and the desired point on the line yields the address of the byte which requires modification.

The second step is to determine which bits in the byte correspond to the desired pixel. The hypothetical display depicted by the Nassi-Schneiderman chart has eight pixels in each byte. The selected bits are then changed to match the current color, and the refresh memory is updated to reflect the revised point. An effective procedure is to generate a mask which contains ones at bit positions corresponding to the addressed point, and zeros elsewhere in the byte. The byte of refresh memory is ANDed with the complement of the mask to delete the old contents. The mask itself is then ANDed with the bit pattern for a byte with every pixel. The current color and the result are ORed into the cleaned up byte of refresh memory.

LINE Logic

Perhaps the most crucial facet of any graphics system is its line generator (see figure 8). Before introducing the actual algorithm used, it may prove beneficial to discuss its theoretical development.

We wish to generate an arbitrary line from a point (XC, YC) to a point (XF, YF) (see figure 9). The goal is to determine those discrete points (x_n, y_n) which best approximate the desired line.

To simplify the derivation, we will only consider generating a line from point (0,0) to point (X,Y), where X is greater than or equal to Y and both are greater than or equal to 0 (figure 10). (This situation is general because any arbitrary line may be rotated and translated to match the proposed conditions.) Under these conditions, there is a point along the line for every value of x ($0 \leq x \leq X$), and for every value of x there is only one value of y. Closer examination reveals that for any value of x, the y value for the following point (x + 1) will either remain unchanged or increase by 1. No other value of y is possible. Furthermore, it can be shown that the decision to increment y for the next x is based solely on whether the point (x + 1, y + ½) lies above or below the line. If it lies above the line, y remains unchanged. If it lies below the line, y is incremented. In the event (x + 1, y + ½) is exactly on the line, either option is correct. For convenience, "on the line" is arbitrarily treated as equivalent to "above the line."

Assuming that we have a method to determine the position of the point (x + 1, y + ½) relative to the desired line, we can generate an optimal approximation of the line from (0,0) to (X,Y), where $X \geq Y \geq 0$, using the following algorithm:

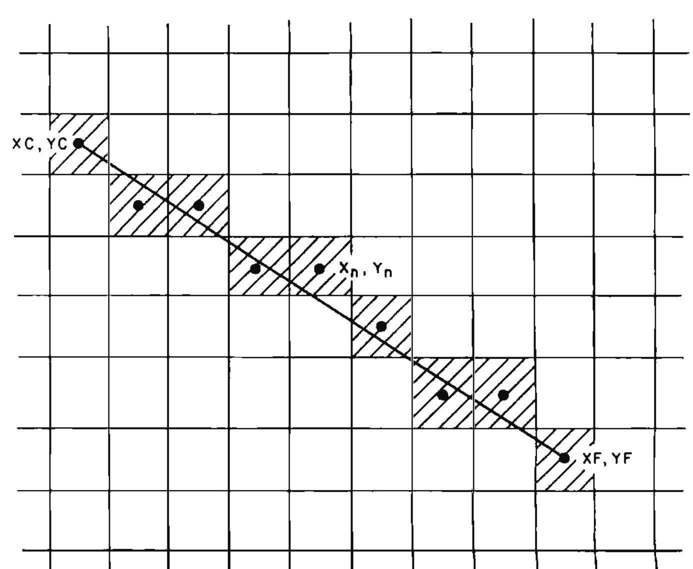

Figure 9: *Generating an arbitrary line.*

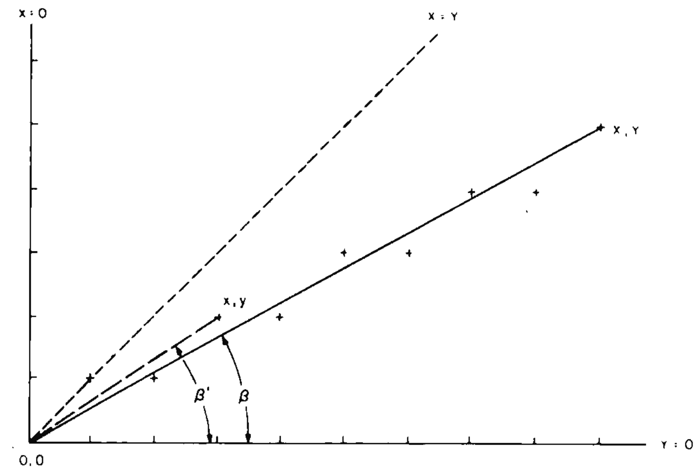

Figure 10: *Simplified line generation.*

1)Initialize x ← 0, y ← 0.
2)Display the point (x,y).
3)Test for done: x = X?
4)Calculate the position of the point (x + 1, y + ½) relative to the desired line.
5)Set dy to 1 if below the line; 0 if on or above.
6)Calculate the next point:
x ← x + 1
y ← y + dy
7)Go to step 2.

There are only two obstacles to overcome before implementing this algorithm: step 4 and the restrictive initial conditions. Let us examine each in turn.

A brief excursion into trigonometry is required to evaluate step 4. Referring to figure 10, if we call the angle between the desired line and the X axis θ, and the angle formed by the current point (x,y) the origin and the X axis θ', then if (x,y) lies above the desired line, $\theta < \theta'$. Conversely, if (x,y) lies below the desired line, $\theta > \theta'$. Of course, if the two coincide, $\theta = \theta'$. We know from trigonometry that for angles in the first quadrant, the greater the angle, the greater its tangent. We also know that the tangent of θ is $\frac{Y}{X}$, while that of θ' is $\frac{y}{x}$. Therefore, we can easily determine the position of any point relative to the desired line by comparing the quotients $\frac{Y}{X}$ and $\frac{y}{x}$.

Unfortunately, performing division on microcomputers is a time-consuming process. Using the properties of inequalities to eliminate the divisions, we can build a decision table (see table 4) which requires only multiplication. Returning to our original algorithm, we set dy to 1 if:

$$(x + 1) \times Y > X \times (y + ½)$$

and to 0 if it is not. Further advantage can be gained by realizing that at each iteration the product on the left side of the inequality increases by Y, while the right either remains the same or increases by X. By remembering the

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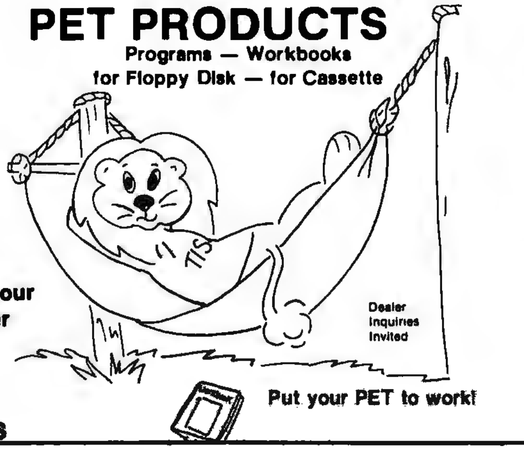

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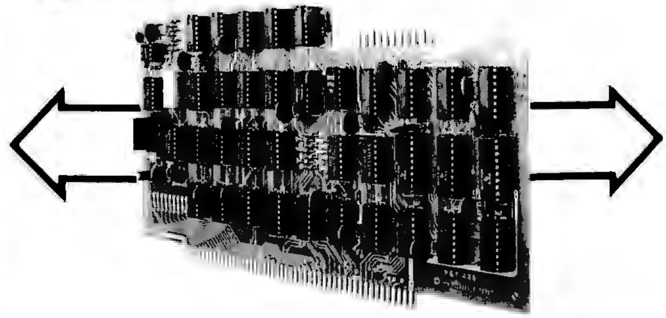

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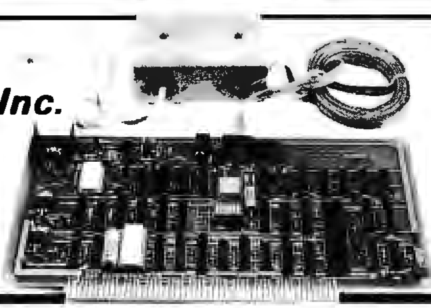

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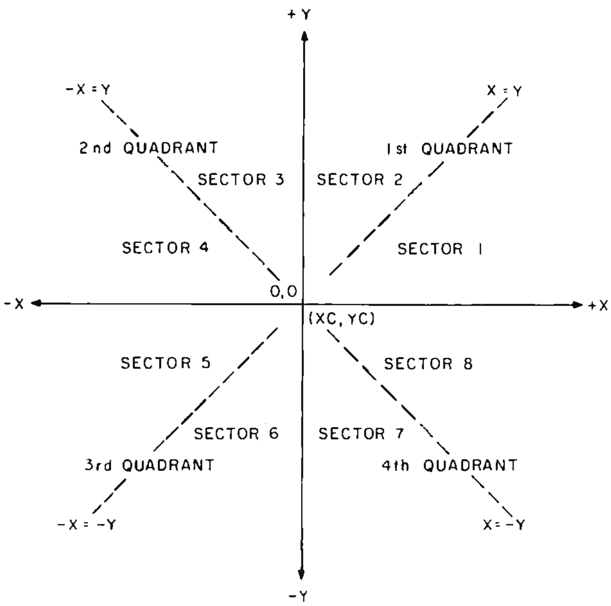

Figure 11: *Quadrant and sector definition.*

	Above	On	Below
Angle Relationship	$\theta < \theta'$	$\theta = \theta'$	$\theta > \theta'$
Tangent Relationship	$\frac{Y}{X} < \frac{y}{x}$	$\frac{Y}{X} = \frac{y}{x}$	$\frac{Y}{X} > \frac{y}{x}$
Relationship after Multiplying through by x.X	xY < Xy	xY = Xy	xY > Xy
Result of xY - Xy	Negative	Zero	Positive

Table 4: *Point position relative to a line.*

Quadrant	XM	YM
1	XF - XC	YF - YC
2	XC - XF	YF - YC
3	XC - XF	YC - YF
4	XF - XC	YC - YF

Table 5: *Component magnitudes in the four quadrants.*

Sector	Sector Weight	X	Y	Move 0 x incr	Move 0 y incr	Move 1 x incr	Move 1 y incr
1	6	XM	YM	+1	0	+1	+1
2	7	YM	XM	0	+1	+1	+1
3	3	YM	XM	0	+1	−1	+1
4	2	XM	YM	−1	0	−1	+1
5	0	XM	YM	−1	0	−1	−1
6	1	YM	XM	0	−1	−1	−1
7	5	YM	XM	0	−1	+1	−1
8	4	XM	YM	+1	0	+1	−1

Table 6: *Coordinate equivalents for each sector.*

products from the previous iteration, and whether or not y is incremented, the multiplication can be reduced to addition. For maximum efficiency, the right-hand product can be maintained negated so that the comparison can be made with a single addition.

The restriction that the line runs from (0,0) to a point (X,Y) with X≥ Y ≥ 0 requires the use of coordinate translations, rotations, and reflections. The first step is to translate the line so that it starts at (0,0). Since the line originates at the cursor, we would traditionally subtract the cursor from the other endpoint to obtain its relative position. However, because a 256 by 256 display does not give us room for a sign-bit in an 8-bit byte, it is first necessary to rotate the line to the first quadrant and then calculate the magnitude of the endpoint displacements from the cursor.

While all these coordinate transformations may seem complicated, the actual implementation is quite simple. Consider the command to generate the line from the current cursor position (XC,YC) to a final point (XF,YF). The first step is to compare XF to XC. If XF ≥ XC then we are in the first or fourth quadrant (see figure 11); otherwise, we are in the second or third. Similarly, if YF ≥ YC, we are in the first or second quadrant; otherwise, the third or fourth quadrant. By combining the two results, the quadrant is uniquely determined, and we can proceed to determine the magnitude of the X and Y displacements, XM and YM, as shown in table 5. Finally XM and YM are compared to determine the exact sector.

The easiest technique for remembering this multiple logical decision is to weight the results of each decision and check the sum. Each sector is then assigned an equivalent weight, and the sector parameter table is reordered accordingly. Column 2 of table 6 applies a weight of 4 to (XF > XC),2 to (YF > YC) and 1 to (YP > XP).

Once the sector is determined, we have all the information required to construct any arbitrary line. Referring to step 5 of the fundamental sector 1 algorithm, we call setting dy to 0 "move 0," setting dy to 1 "move 1," and generate the equivalence chart in table 6. As the algorithm steps along in transformed coordinates, it uses the "move 0" and "move 1" to modify the cursor position using X and Y increments appropriate for the sector the line is actually in.

CHAR Logic

One of the most common formats for displaying characters is the 5 by 7 matrix of points (see figure 12). However, not many people realize why 5 by 7 is the smallest common size. The limiting width is, of course, the minimum number of points capable of displaying the three separate parallel lines required for the letters M and W. This sets the minimum possible width to 5, but why must 7 be the minimum height? The answer is, it need not be! However, human engineering studies have indicated that the average person finds it easier to read characters which are proportioned the same as in standard printing. Ratios of width to height far removed from the "normal" 0.75 increase fatigue and error rates.

To generate easily read lowercase characters, even larger matrices are required. This is a result of the greater complexity and finer detail of the lowercase characters. The full ASCII character set can be generated with a 7 by 9 matrix if provision is made for characters with descenders (g, j, p, etc). This requires the use of an extra

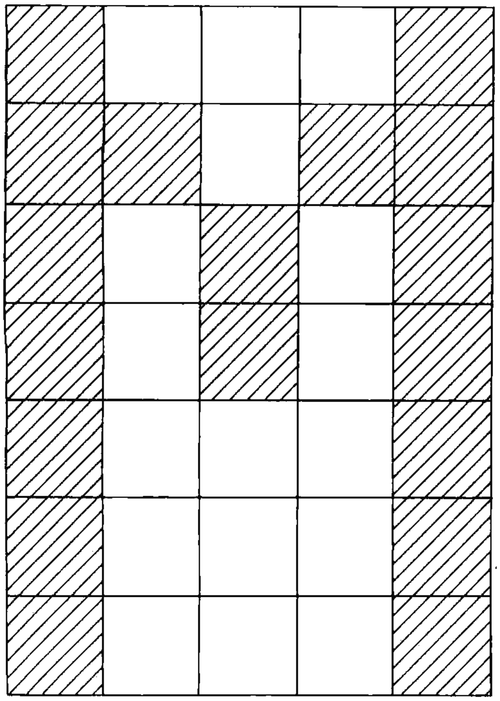

Figure 12: *Typical character generation.*

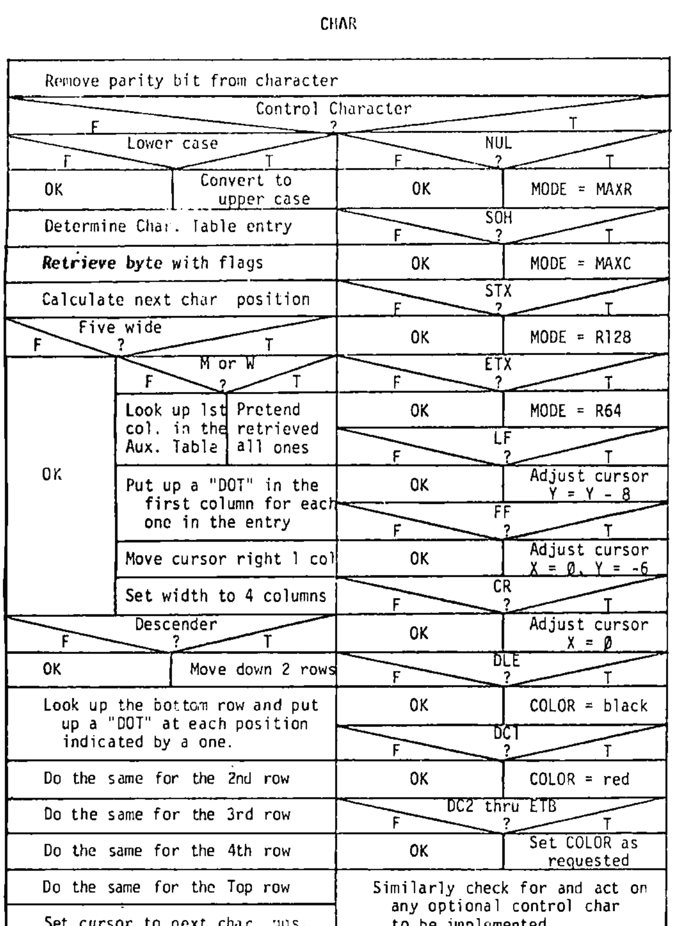

Figure 13: *The CHAR function which provides the capability to display alphanumeric as well as graphical data.*

Char Size	LC	Char/Line (256 by 256)	Lines/Page (256 by 256)	Memory For Tables (bytes)
9 x 11	Y	25	18	1200
7 x 9	Y	32	21	864
5 x 7	N	42	32	320
4 x 5*	N	64	32	192

*See text

Table 7: *Effects of differently sized character matrices.*

bit to determine if the matrix is displayed normally or shifted down two positions. As far as the display is concerned, the character uses a 7 by 11 matrix of display points. Larger display matrices can be used for greater legibility and varying character fonts, but even a 7 by 11 character matrix severely restricts the total number of characters that will fit on the low-resolution displays for which this standard is designed. If even one row of blank points is left between adjacent characters, then only sixteen 7 by 9 characters will fit across a 128-wide display. Memory requirements for large matrix character pattern storage are also severe. The table space required is directly proportional to the area of the matrix (see table 7).

A character matrix size less than the "absolute minimum" 5 by 7 was desirable, since even 5 by 7 characters require 320 bytes for their lookup table. Readable versions of 58 of the 64 uppercase printing ASCII characters can be generated within a 4 by 5 matrix. The remaining 6 characters (#, $, &, %, M, and W) fit in a 5 by 5 matrix. Since these are normally considered wide characters, their unity width-to-height ratio is not objectionable.

To simplify table lookups and the special handling of 5 wide characters, 3 bytes are used for each character. Twenty bits are used for the 4 by 5 display matrix; the four extra bits are used as flags to define the specific parameters for each character. Two flag-bits are used to indicate the width of the character. Proportional spacing also fits the maximum number of characters into any given space. The third flag-bit is used by 5 wide characters to indicate whether the first column is all ones (M and W), or must be retrieved from an auxiliary lookup table (#, $, %, and &). The remaining flag is used to indicate descending characters (, ; and _). These characters are displayed two positions lower than their matrices indicate. Each character is therefore displayed in an n by 7 display area, where n ranges from 2 to 5.

The basic character generation algorithm (figure 13) is applicable to any size character matrix, whether the character is stored by column (more efficient for 5 by 7 and 6 by 8 matrix characters), or by row (more efficient for variable 4 by 5, 7 by 9, and 8 by 11). If the character set being used does not include lowercase, it is necessary to shift lowercase characters to their uppercase equivalents. Comparing the ASCII value of the character to 32 separates control characters for special handling.

The character table is ordered by ASCII value and lookup is done by indexing on the ASCII value requested. Since the first 32 ASCII characters are control characters,

ANIMAT

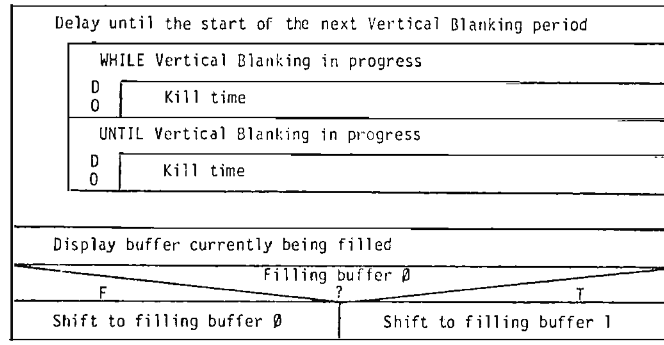

Figure 14: *The ANIMAT function which provides for flicker-free changes in the display by permitting the user to load one refresh buffer while displaying another.*

the physical contents of the table start with character 32 (blank). To index into the table, the ASCII value of the first table entry is subtracted from the value requested. This index value is then multiplied by the number of bytes per character, and the product is added to the address of the first character in the table in order to obtain the address of the first byte of the character desired. The cursor is then sequenced through the character matrix, turning on the points indicated. Only the points actually making up the character are affected, so background data is not erased and an overprint results.

Control characters are handled separately. Mode and color changes will depend on the DOT routine. Since these will be overly hardware-dependent, their implementation is left as an exercise to the reader. Carriage control characters modify the cursor position without otherwise affecting the display. Any unrecognized characters should be ignored.

ANIMAT Logic

The first requirement of the ANIMAT logic is to wait for vertical blanking to start (see figure 14). Most displays provide an input port with a status-bit which indicates when vertical blanking is in progress. By delaying until the status-bit indicates normal scan, then delaying until it indicates vertical blanking in progress, we are assured of a full vertical blanking period being available. If the display being programmed does not support changing the location of the refresh buffer by software controls, the routine is finished.

Displays in which refresh buffer locations can be changed are programmed to provide double buffering. After waiting for the vertical blanking period, the refresh buffer currently being filled is put on display. The alternate buffer is then opened for filling. Note that this algorithm is valid whether the buffer being filled is displayed (first call to ANIMAT after an INITG) or is being filled while another buffer is being displayed (all subsequent calls to ANIMAT).

In part 2 we will present an implementation of the 8080 assembly language protocol for the proposed graphics software standard, plus a series of demonstration programs. ■

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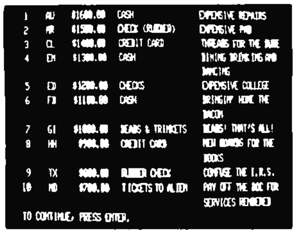

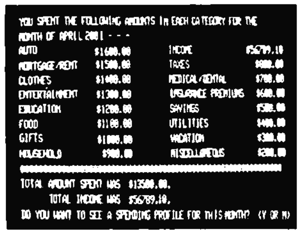

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8080/8085: Assembly Language Programming is another in the series of Osborne and Associates' books on microcomputers. Those who are familiar with earlier works published by this company know that, in its contents, the entire series is comprehensive. Unfortunately, these books have been extremely difficult to read due to the use of bold and regular type and the appearance of obscure abbreviations in their diagrams. I am pleased to say that this new book upholds the reputation for completeness, and it is also quite readable.

Chapter 1 defines and justifies assembly language programming. I doubt that anyone who purchases this book needs this chapter, but it is reassuring to us assembly language enthusiasts.

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Chapters 4 thru 13 give sample programs ranging from very simple to extraordinarily complex. The early examples are slightly beyond the information given in chapter 3, but they progress through arithmetic and tables to I/O (input/output) routines and interrupts. Each chapter ends with self-testing examples where the answers, but not the methods, are given. These self-tests are well-thought-out variations of earlier examples and, therefore, double the learning experience.

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BYTE's Bugs

Broken Text

Several readers have brought to our attention that line 1790 of the Quest program on page 181 of the July 1979 BYTE is difficult to read. The line should read 1790 ON A1 GOTO 1000, 9999, 1760. ■

Build a Simple Digital Oscilloscope

Frank DeCaro
103 Spit Brook Rd, Apt C-2
Nashua NH 03060

A digital-logic probe is a convenient device for examining signals. A typical probe has one or more light emitting diodes (LEDs) to indicate logic states. The LED lights to indicate a high (1) logic state, and turns off to indicate a low (0) logic state. It is not possible, however, to compare these signals with the state of the system clock. The system clock is the square wave source from which all other signals are derived.

The digital oscilloscope presented here allows comparison of selected signals with the system clock. The schematic diagram is given in figure 1. The digital oscilloscope converts a serial digital signal into a visible display on 16 LEDs. Each LED corresponds to ½ of a clock cycle. Figure 2 shows some typical waveform traces and their corresponding displays on the digital oscilloscope. Figure 3 shows a typical method of connection for displaying serial waveforms. One limitation of the 16 LED display is that it cannot completely show a signal which is derived from the clock signal by dividing by more than 8.

A block diagram of the digital oscilloscope is shown in figure 4. The major sections are:

- data and enable sequencer
- enable strobe
- data strobe
- latch
- display

The clock is fed into a circuit which divides the frequency by 8. These 2 signals comprise the data and enable sequencer. Eight clock cycles are required for the sequencer to complete 16 transitions. The 16 address inputs

Text continued on page 226

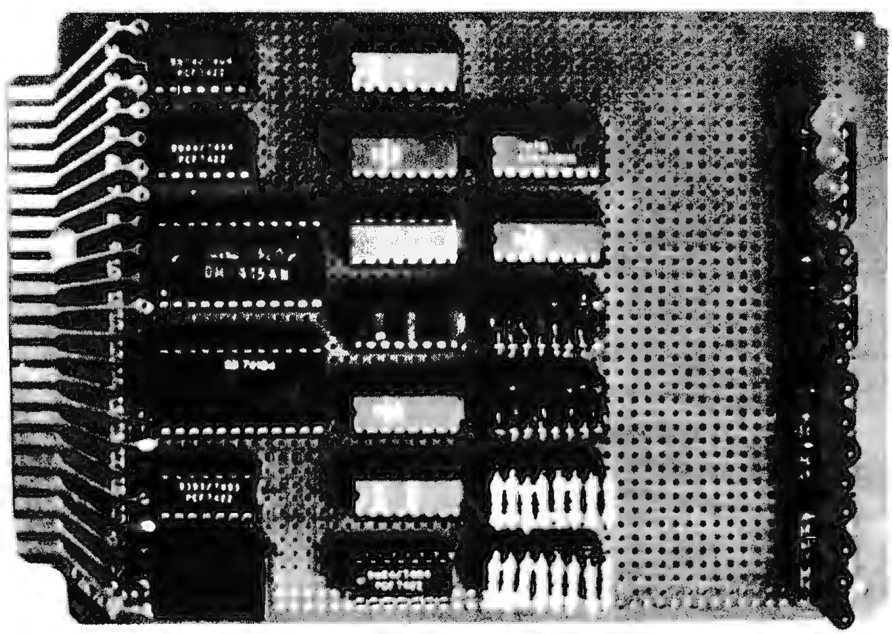

Photo 1: Digital oscilloscope as constructed on a project board. The photo shows the original design (the schematic diagram in figure 1 shows an updated version which eliminates all capacitors on the output lines).

Device	Type	+5 V	GND
IC1	74154	24	12
IC2	7404	14	7
IC3	7404	14	7
IC4	7404	14	7
IC5	7474	14	7
IC6	7474	14	7
IC7	7474	14	7
IC8	7474	14	7
IC9	7474	14	7
IC10	7474	14	7
IC11	7474	14	7
IC12	7474	14	7
IC13	74154	24	12
IC14	7493	5	10

Table 1: Power and ground connections for integrated circuits in figure 1 schematic diagram.

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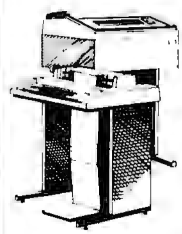

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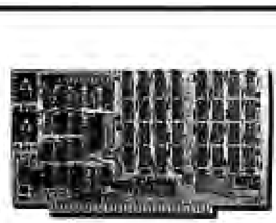

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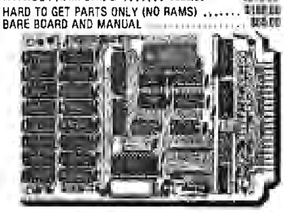
BARE BOARD AND MANUAL		[illegible]



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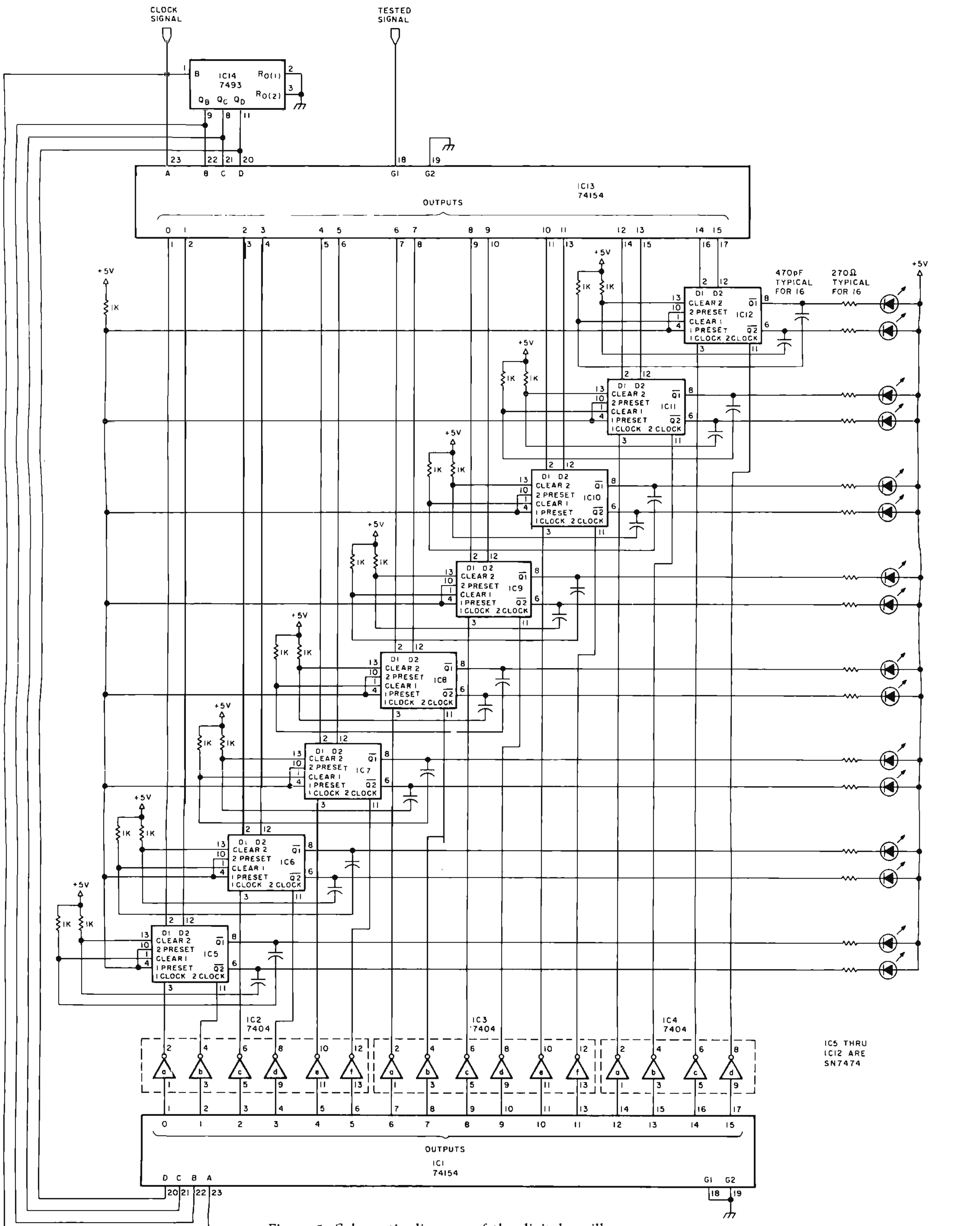


Figure 1: Schematic diagram of the digital oscilloscope.

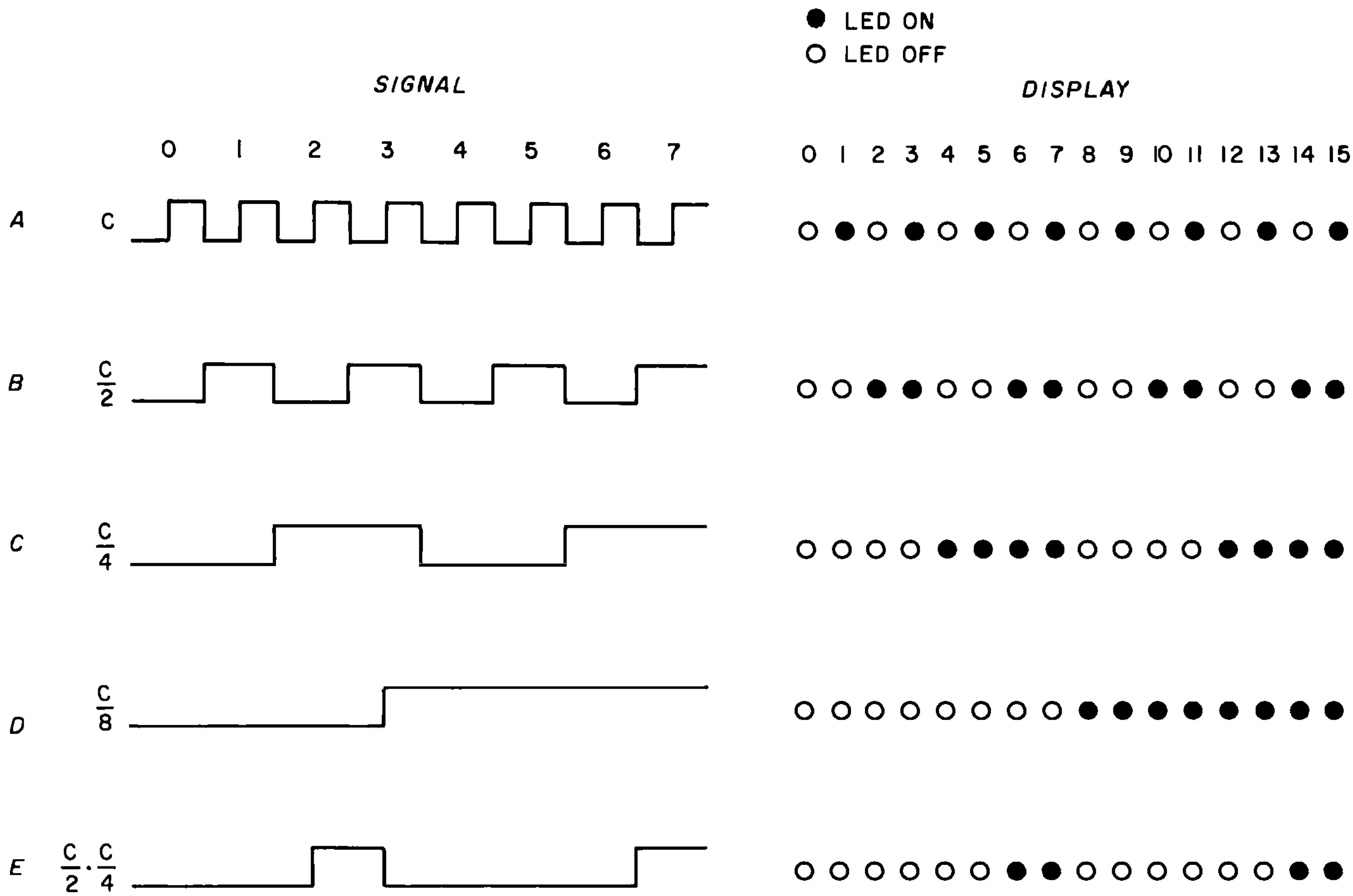


Figure 2: Comparison of waveforms as they might be displayed on an analog oscilloscope, and as they are displayed on the digital oscilloscope. The dark circles indicate lighted light emitting diodes (LEDs). The open circles show unlighted LEDs.

Text continued:

of the enable and data strobes are sequentially scanned.

The data and enable strobe signals are sent to latches. The data strobe provides the information to be stored when the enable strobe of the same latch goes low. The latches are updated every 8 clock cycles. The output of each latch is used to drive an LED. The LED will glow if the output of the latch is low (a 0 state). In this manner, the serial digital signal is mapped onto the array of 16 LEDs.

The digital oscilloscope is also useful as a logic design and analysis aid. It can generate a truth table for a combinational logic network of up to 4 inputs. To accomplish this, simply connect the clock signal, the clock divided by 2, the clock divided by 4, and the clock divided by 8 to the inputs of the logic network (pins 23, 22, 21, and 20 of IC1.) Connect the output of the logic network to the signal input of the digital oscilloscope. Figure 5 illustrates how to make these connections to a logic network. ■

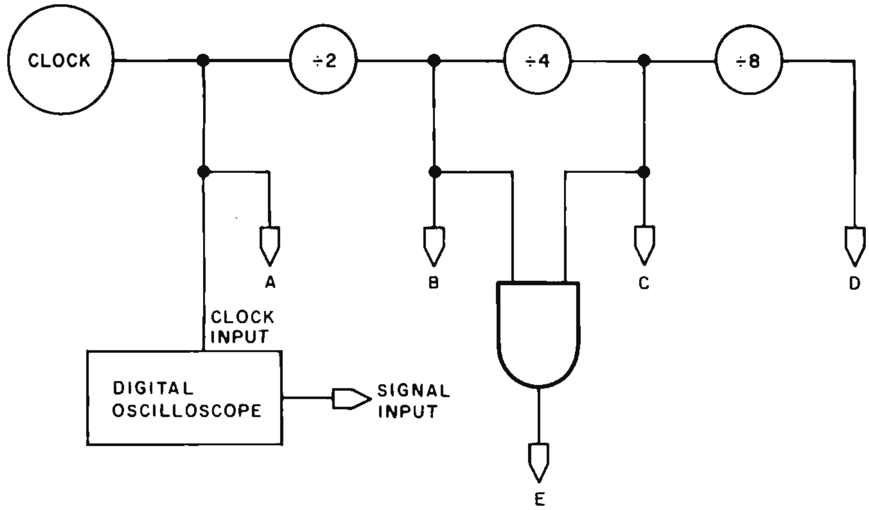


Figure 3: Typical method of connection for displaying serial waveforms.

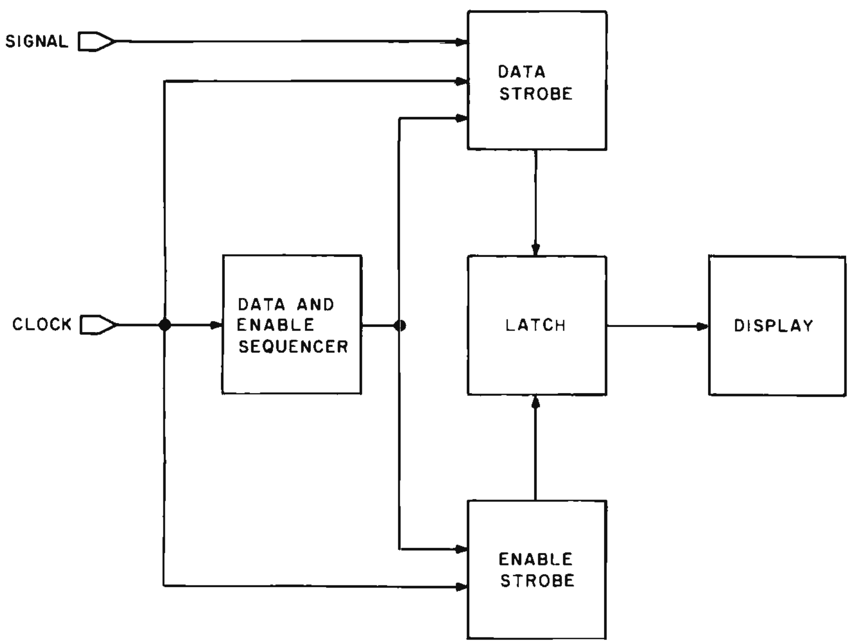


Figure 4: Block diagram of digital oscilloscope function.

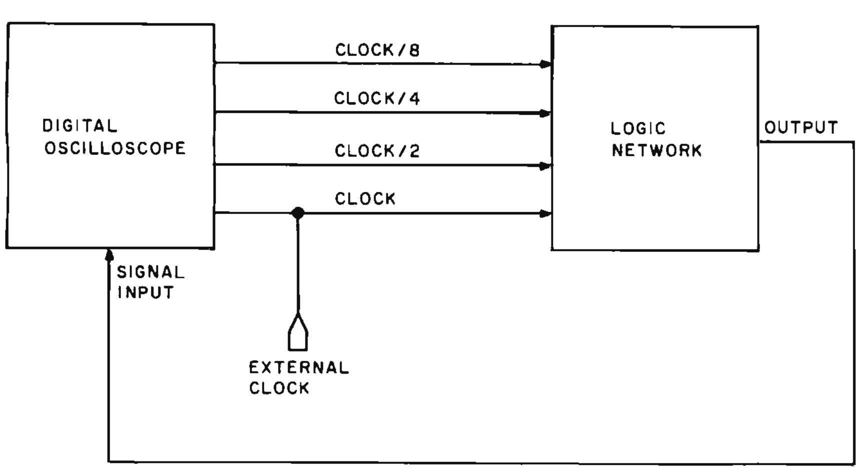


Figure 5: Connections to determine truth table for a logic network.

Event Queue

In order to gain optimum 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.

NOVEMBER 1979

November 1
Invitational Computer Conference, Cherry Hill NJ. This conference is directed to the quantity buyer and will feature the newest developments in computer and peripheral technology. Contact B J Johnson and Associates, 2503 Eastbluff Dr, Suite 203, Newport Beach CA 92660.

November 5-7
Thirteenth Asilomar Conference on Circuits, Systems and Computers, Asilomar Hotel and Conference Grounds, Pacific Grove CA. Contact Roger C Wood, Electrical and Computer Engineering Dept, University of California, Santa Barbara CA 93106.

November 5-8
Electronics Production Engineering Show, Kosami Exhibition Center, Seoul Korea. This international industrial exposition will be devoted to the needs of manufacturers of electronic products in Korea. Contact Expoconsul, Clapp and Poliak International Sales Division, 420 Lexington Ave, New York NY 10017.

November 6-8
IEEE Third International Conference on Computer Software and Applications, The Palmer House, Chicago IL. Contact IEEE Computer Society, POB 639, Silver Spring MD 20901.

November 6-8
Midcon/79 Show and Convention. O'Hare Exposition Center and Hyatt Regency O'Hare, Chicago IL. Contact Electronic Conventions Inc, 999 N Sepulveda Blvd, El Segundo CA 90245.

November 6-8
New England Printed Circuits and Micro-Electronics Exposition, Northeast Trade Center, Woburn MA. This show is devoted to the equipment, materials, tools, supplies, and test instruments needed to manufacture electronic and microelectronic circuits, components, and systems. The show is sponsored by the International Electronics Packaging Society. Contact Industrial and Scientific Conference Management Inc, 222 W Adams St, Chicago IL 60606

November 6-8
Third Digital Avionics Systems Conference, Ft Worth TX. This conference will probe the expectations and challenges of the digital revolution in avionics systems. Contact John C Ruth, Technical Program Chairman, POB 12628, Ft Worth TX 76116.

November 8-10
Entering a Decade of Experience - Where Are We and Where Are We Going?, Atlanta Hilton, Atlanta GA. Sponsored by the Society for Computer Medicine, this conference will cover microprocessing in medicine, computers and medical records, automated ill-patient monitoring and other related topics. Contact the Society for Computer Medicine, Suite 602, 1901 N Ft Myer Dr, Arlington VA 22209.

November 12-14
Computer Cryptography, The George Washington University, Washington DC. The objective of this course is to provide each participant with a working knowledge of the use of

cryptography in computer applications. Contact Continuing Education, George Washington University, Washington DC 20052.

November 12-16

Communications Satellite Antenna Technology, University of Southern California, Los Angeles CA. This course is for engineers engaged in the design of military or commercial satellite communication systems, spacecraft antenna and ground stations. Multiple beams, frequency reuse, polarization control, the new generation of satellites, and other topics will be discussed. For more information, call (213) 741-2410.

November 13-15

DPMA Education Foundation Sponsors Systems Conversion Symposium, Washington DC. The theme of the three-day meeting is "Converting Today's Systems to Tommorow's Technology." Hardware and software aspects of computer conversion, strategies and techniques, and transition to a distributed data base system will be discussed. Contact Ken Burroughs, DBD Systems Inc, 1500 N Beauregard St, Alexandria VA 22311.

November 14-16

Advanced Programming Techniques Using Pascal, Allentown PA. This class will teach Pascal programmers how to build a comprehensive and effective Pascal-based software development environment. Emphasis will be on programming exercises with group and individual instruction. Contact Software Consulting Services, 901 Whittier Dr, Allentown PA 18103.

November 14-16

1979 International Micro and Minicomputer Conference, Astro Village, Houston TX. This conference concerns micro and minicomputer systems, a survey of the range of current applications, and exploration of potential areas for future development. Emphasis will be placed on technical papers and exhibits. Contact Dr S C Lee, School of Electrical Engineering and Computer Sciences, University of Oklahoma, Norman OK 73019.

November 15

Invitational Computer Conference, Southfield MI. See November 1 for details.

November 15-19

White House Conference on Library and Information Services, Washington DC. This conference has been called to help shape policies on public access and dissemination of information in this country. Two issues to be covered are the libraries' ability to help stop functional illiteracy and the use of computers, cable television, audio and video systems as alternative routes of information delivery. Contact Susanne Roschwalb, (202) 466-7800 or Vera Hirschberg, (202) 653-6252.

November 27-29

Sixth Datacommn, Pacific Grove CA. This symposium is sponsered by the IEEE Computer Society, the IEEE Communications Society, and the Association for Computing Machinery. Some of the subjects of the eleven sessions are electronic fund transfer, protocols, routing and flow control, new data network services in Europe, and local networks.

For more information, contact Sixth Datacomm, POB 639, Silver Spring MD 20901.

November 28-30

Business and Personal Computer Sales Expo '80, Philadelphia Civic Center, Philadelphia PA. Contact Produx 2000 Inc, Roosevelt Blvd and Mascher St, Philadelphia PA 19120.

November 29-30

Metric Management Workshop, Dallas North Park Inn, Dallas TX. The workshop is designed to help personnel at all levels plan and implement a cost-effective transition to metric in their company. The sessions will cover establishing a metric plan and strategy, assigning responsibility for the transition within the existing organizational structure, and developing a sensible apporach to controlling conversion costs. Contact Len Boselovic, ANMC, 1625 Massachusetts Ave NW, Washington DC 20036.

DECEMBER 1979

December 2-6

MUSE North American Annual Meeting, Bahia Mar Hotel and Yachting Center, Ft Lauderdale FL. This conference of Modcomp Users Exchange (MUSE) will feature technical sessions, workshops and user/manufacturer interface sessions on the use of Modcomp computers and their related software. Contact Kathy Black, MUSE, 4620 W Commercial Blvd, Suite 6C, Tamarac FL 33319.

December 3-5

The Application of Computer Technology to Accounting Systems, Washington DC. The theme of the conference is "Information Systems as a Management Tool for the Financial Executive." It is sponsored by the Association of Government Accountants (AGA). Contact Ken Burroughs, DBD Systems Inc, 1500 N Beauregard St, Alexandria VA 22311.

December 3-5

COMDEX '79, MGM Grand Hotel, Las Vegas NV. This conference and exposition for third party sellers of computer systems, word processing systems, peripherals and software packages and media will focus on solutions to business problems normally encountered in structuring a successful dealership and the operational aspects of the dealership from both the supplier and the customer side. Contact The Interface Group, 160 Speen St, Framingham MA 01701.

December 3-5

Implementing Cryptography in Data Processing and Communications Systems, New York NY. Going beyond an introduction to cryptographic systems, the seminar will stress implementation of the DES and address public key implementation considerations. Contact Ms Jansen, Cryptotech, 12 State Rd, Bellport NY 11713.

December 3-5

Winter Simulation Conference, Holiday Inn, Embarcadero, San Diego CA. This conference will feature papers and panel discussions on discrete and combined (discrete and continuous) simulations. Contact Professor Robert E Shannon, University of Alabama in Huntsville, School of Science and Engineering, POB 1247, Huntsville AL 35807.

December 8-9

Data Processing for Businesspeople, Cherry Hill Inn, Cherry Hill NJ. Management Information Corporation presents this seminar to meet the needs of company management in understanding computers. The seminar includes basic concepts of data processing alternatives (service bureaus, timesharing), small business computer systems, program packages availability and selection, managing the computer system, and the future of data processing. Contact Management Information Corporation, 140 Barclay Ctr, Cherry Hill NJ 08034.

December 10-11
Mini and Microcomputers in Control, Galt Ocean Mile Hotel, Ft Lauderdale FL. This symposium will cover computer architecture and hardware for control, languages for control, algorithms for control, hierarchical control, methodology, and other topics. Contact The Secretary, Computers in Control Symposium, POB 2481, Anaheim CA 92804.

December 10-12
Project Managment for Computer Systems, Chicago IL. This seminar will illustrate techniques for planning, implementing, installing, and controlling projects. Contact The University of Chicago, 1307 E 60th St, Chicago IL 60637.

December 10-13
1979 Fall DECUS US Mini/Midi Symposium, San Diego CA. This symposium is an opportunity for Digital Equipment Computer users to participate in a technical exchange. Contact DECUS, One Iron Way, MR2-3, Marlboro MA 01752.

December 10-14
IEEE Computer Society's Tutorial Week 79, Hotel Del Coronado, San Diego CA. Fifteen different one-day seminars will be offered throughout the week. Contact IEEE Computer Society, POB 639, Silver Spring MD 20901.

JANUARY 1980

January 3-4
Hawaii International Conference on System Sciences, Honolulu HI. The conference will cover developments in theory or practice in software and hardware, and advanced computer systems applications in selected areas with emphasis on medical information processing and computer-based decision support systems for upper-level managers in organizations. For more information, contact Perry G Patteson, Office of Management Programs, University of Hawaii, 2404 Maile Way, Honolulu HI 96822.

January 23-26
International Microcomputers Minicomputers Microprocessors (IMMM), Harumi Exhibition Centre, Tokyo Japan. This is a show for manufacturers, commercial and financial establishments, service industries and institutions, and design engineers interested in buying computer systems, components and services. For more information, contact Industrial and Scientific Conference Management Inc, 222 W Adams St, Chicago IL 60606.

January 28-30
Principles of Programming Languages, Las Vegas NV. This symposium concerns practical and theoretical aspects of principles and innovations in the design, definition, and implementation of programming languages. Some topics are algorithms and complexity bounds for language processing tasks, specification languages, error detection and recovery, and unusual or special-purpose languages that raise issues of principle. Contact Professor John Werth, Department of Mathematical Sciences, University of Nevada, Las Vegas NV 89154.

January 30-February 1
MIMI '80 Asilomar, Asilomar Conference Grounds, Pacific Grove, CA. This symposium covers all aspects of mini and microcomputers including technology, hardware, software engineering, languages, education and more. Contact The Secretary, MIMI '80 Asilomar, POB 2481, Anaheim CA 92804. ■

BYTE's Bits

The Formation of a New Personal Computer Society

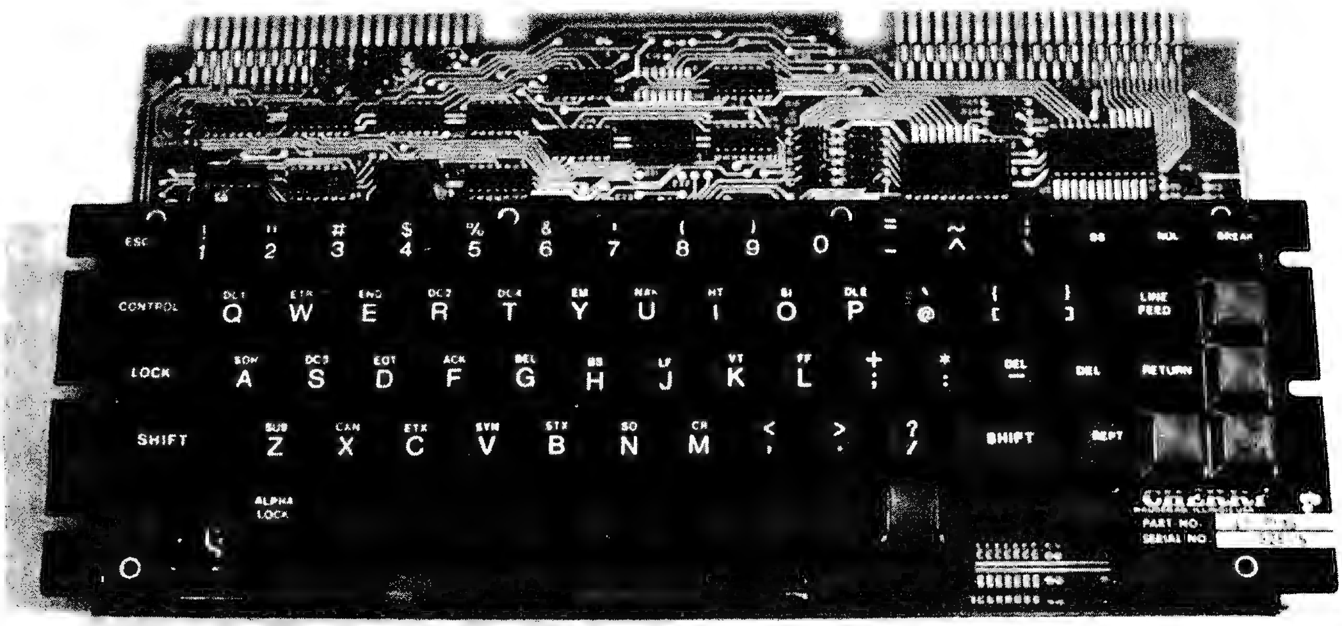
Do personal computer owners need a national organization? A personal computer user named Abby Gelles would answer in the affirmative. She was interacting with a number of the attendees of the National Computer Conference Personal Computer Festival last June when the usual pro and con arguments were raised in her conversations. She is convinced there is a need.

So, with some kindred spirits in New York City, Abby has formed the *Personal Computer Society.* You can find out about what she is proposing by writing her at: Ms Abby Gelles, Executive Director, Personal Computer Society, POB 147, Village Sta, New York NY 10014.

ICS Announces New Courses

Integrated Computer Systems Inc (ICS), 3304 Pico Blvd, POB 5339, Santa Monica CA 90405, has announced the fall and winter schedule for their Short Course series. Courses on computer graphics, digital signal processing, troubleshooting microprocessor systems, and other topics, will be covered. The courses will be held in cities around the United States from November through February. These courses are structured for technical and managerial personnel. ■

Circle 92 on inquiry card.



Dan S Parker
1007 Third St #3
Davis CA 95616

In the few short years since the birth of the personal computer, the list of peripheral devices has grown tremendously: printers, video displays, mass storage devices, and keyboards. At first, many of these items were overruns from original manufacturers, or were removed from used business or military systems. Documentation was scarce and complete schematics were often nonexistent. Keyboards were available in a myriad of styles, but not with all the features of a professional unit. If they were encoded at all, it was often in half ASCII (upper case ASCII only, as available on the Teletype Model 33).

About the Author

Dan S Parker is presently completing work on a PhD degree in Physics at the University of California at Davis. His area of research is magnetic properties of rare earth crystals in solid state, low temperature physics. He is also actively developing a data acquisition and cryogenic control microcomputer for his research equipment.

No more! Enter the PRO, Cherry's new entry into the personal computer keyboard market (Cherry model B70-05AB). Aptly named, it is indeed a professional keyboard that comes fully assembled, tested, and ready for installation in your computer system. Its features rival those of keyboards found in expensive terminals.

General Features

The PRO features the full 128 ASCII character set of upper case, lower case, and control characters. A total of 67 gold contact keys, engraved in white on durable matte black injection molded plastic, are easy on the eyes. The shift, shift lock, control, linefeed, and return keys are oversize for easier operation (see photo 1). Cherry lists the operating force of the keys at 2.5 ounces. They feel solid, positive, and very smooth. The keys are wave soldered to 1/16 inch glass epoxy circuit board material and anchored to a 1/16 inch black anodized aluminum cover subplate. No wobble in those keys or flexing of the circuit board when a key is pressed.

Five of the keys are unassigned and

available for user defined functions. They can be relabeled (clear plastic covers to put labels under) and are all momentary contact. The operation and customizing manual is easy to read and has the full set of diagrams including schematics.

Electrical Specifications

The PRO operates from a single +5 V power supply and draws 325 mA maximum current as listed in the operator's manual. I measured it and found that it draws considerably less: 200 mA nominal. Outputs are via one of two 22 pin edge connectors and are TTL and DTL (transistor-transistor logic and diode-transistor logic) compatible. Pinouts include the seven ASCII bits, optional parity, +5 V, ground, strobe and inverted strobe, shift, break, repeat, control, and keyboard lockout. Cherry has conveniently placed these contacts so that only one side of a 22 pin edge connector (not supplied) is needed. Thus a single readout 22 pin connector may be used. The other pins are available with solder pads for customizing.

A second 22 pin edge connector (the one in the upper right of photo 1) is designed for piggybacking a numeric keypad onto the PRO. The matrix scanning technique employed makes it easy to modify key assignments and generate custom output codes.

The strobe pulse is generated 2.5 μs after a key is pressed to insure data stability and is nominally 100 μs wide. This seems to be ideal for both the Dajen SCI and Processor Technology 3P+S that I've used the keyboard with. The manual describes how to modify this timing.

Customizing

The keyboard is truly designed for the experimenter; Cherry is to be commended for making the keyboard user adaptable with a minimum of effort. As shipped, the keyboard is ready to use for most applications. As an example of the ease of modification, two of the integrated circuits are provided in sockets. Changing these two circuits to other integrated circuits (not provided but standard parts) and making no other changes converts the board to negative logic. Yet a different exchange of these two circuits results in a positive logic 3 state output so that two or more PRO keyboards can be wired in parallel. Still a fourth choice of circuits gives high voltage CMOS drive compatibility.

All schematic reference points, integrated circuit designations, and modification points are marked on the circuit board. All of the keys are equipped with dual plated-through holes so that the link connecting them can be cut to isolate the keyswitch. This makes it easy to add custom features. A large number of solder pads and a spare integrated circuit pad have also been provided.

A provision has been made for the addition of an automatic repeat key by installing a 74123 monostable multivibrator in a provided integrated circuit pad along with appropriate timing capacitors and resistors. The manual's suggested timing components made this very easy to implement. My only complaint is that the holes on the empty pad are filled with solder which has to be removed (eg: the board is wave soldered).

The repeat function has two modes. In the first mode, holding down any key for more than 1/2 second causes that character to repeat at about nine characters per second. In the second mode, simultaneously holding down the repeat and character keys causes the automatic repeat.

A few of the other documented changes that can be made include the generation of odd or even parity, latched output, and a shift control mode in which, by depressing both the shift and control keys, additional 8 bit codes can be generated.

Alpha Lock versus Shift Lock

Shift lock and alpha lock are not the same thing, and a lot of confusion among experimenters and dealers seems to exist about this point. Put simply, alpha lock (often called caps lock or teletypewriter lock) simply locks out the lower case characters so that the keyboard generates only numbers and upper case letters. In this mode the shift key still operates and gives the shifted mode characters above the numbers such as ") (*&%$#. The advantage of this mode is that much software, like most BASICs and assemblers, accepts only upper case letters and numbers.

In the second mode, with the alpha lock not engaged, the keyboard generates upper and lower case just like a typewriter, such as might be needed for text editing. In both modes the shift and shift lock keys are active. The alpha lock key is shown in photo 1 just to the left of the space bar and is an alternate action key, as is the shift lock key. My preference would have been to position the alpha lock key a bit further from the main section of the keyboard.

Enclosures

The PRO comes without an enclosure but is provided with mounting wings. A recommended panel cutout diagram is included with the manual for custom cutting if you so desire. Fortunately, the cutout is simplified by a minimum of contour "stair step" cuts. Dimensions of the keyboard are 14 by 7¼ by 7/8 inches (34.6 by 18.4 by 0.9 cm). The thickness is measured from bottom of the printed circuit board to top of aluminum cover plate. Hence the keyboard can be mounted extremely low profile either flat or tilted. At present, the only custom precut keyboard enclosures available commercially, I believe, are offered by Electrolabs (POB 6721, Stanford CA 94305) and Ironman (POB 1260D, Southgate CA 90280). A number of firms offer blank enclosures which also appear to be suitable for use with the PRO. Better yet, make your own.

Concluding Remarks

The PRO is priced at $135 in single quantities. For two to four pieces, the price is $107 each, directly from Cherry. The price plummets to $94.50 for five or more keyboards. Delivery takes two or three weeks.

For more information, contact Cherry Electrical Products Corp, 3600 Sunset Av, Waukegan IL 60085.■

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Clubs and Newsletters

ACM Special Interest Group Publishes Newsletters

The Special Interest Group on Language Analysis and Studies in the Humanities' *SIGLASH Newsletter* is published in March, June, September and December by the Association for Computing Machinery (ACM). The newsletter contains unrefereed papers, reviews of books and articles, abstracts of members' work, a "rap" section for short communications, announcements of general interest, and letters to the editor. Membership in this special interest group, which includes the newsletter, is $4 a year for ACM members and $10 for non-ACM members. Contact ACM Inc, POB 12105, Church St Station, New York NY 10249.

Tri-State Computer Club

The Tri-State Computer Club is a newly established hobbyist group serving the river cities in the Ohio, West Virginia and Kentucky areas. They have over 40 members representing 6800s, TRS-80s, Digital Equipment Corporation (DEC) and Heath equipment. The meetings are held on the second Saturday of the month at 3:30 PM in the Lawrence County OH public library. Meetings are open and the public is invited to attend. Contact Douglas Troughton, 508 Colony Dr, Wheelersburg OH 45694.

Apple Computer Users Group in Honolulu HI

Honolulu HI now has its own Apple Computer Users Group. The Honolulu Apple Users Society (HAUS) supports a newsletter containing the latest up-to-date information concerning the Apple, including program tips and techniques, listings, reviews, etc. Meetings are held the first Monday of each month at the Computerland store in Honolulu. The president is Bob McDowell, and Randy Brumback is vice-president. The club holds weekly sessions on programming, BASIC, hi-res graphics, etc. Annual dues are $10 which include a newsletter. Additionally, the group is interested in exchanging information and software with other clubs. Contact Bill Mark, 98-1451-A Kaahumanu St, Aiea HI 96701 or phone (808) 488-2026.

PPC Journal for Hewlett-Packard Programmable Calculator Users

The PPC Journal is the monthly publication of the Personal Programmers Club (PPC) which is a volunteer, nonprofit, loosely organized, world-wide group of Hewlett-Packard programmable calculator users. The purpose of the publication is to disseminate user information related to the selection, evaluation, care and application of all Hewlett-Packard programmable calculators. The journal is available through membership in PPC. Interested individuals should write to PPC, 2541 W Camden Pl, Santa Ana CA 92704. A sample issue of the *PPC Journal* and other information materials may be obtained by sending a self-addressed 9 by 12 inch envelope with 2 ounces of first class US postage attached.

Non-Mikbug 6800 Series System User Group

According to a letter received from Mark Siebart, he is attempting to set up a users group and newsletter for non-MIKBUG 6800 series systems with emphasis on the Capitol Radio Engineering Institute (CREI) and National Radio Institute (NRI) machines. These are based on a J-Bug compatible monitor using the MEK format. Anyone interested in such a group should write to Mark at 2599 Caulfield, San Diego CA 92154.

Bulletin for TRS-80 tiny-c and Assembler

The TRS-80 *tiny-c and Assembler Programming Bulletin* specializes in programs and techniques for Radio Shack's editor and assembler and tiny-c associates' tiny-c interpreter for the TRS-80. An annual subscription (4 issues) costs $8.50 and a single issue is priced at $2.50. Contact Rob Varty, 2193 Haygate Cr, Mississauga, Ontario CANADA L5K 1L7.

Wake is the Word for Washington Area KIM Enthusiasts

WAKE, Washington Area KIM Enthusiasts, meets each month at the McGraw-Hill Continuing Education Center in Wasington DC to study operation, expansion and applications of KIM-1 microcomputers. The

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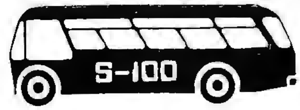

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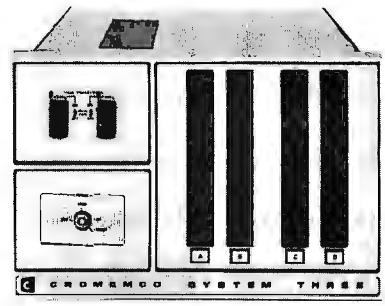

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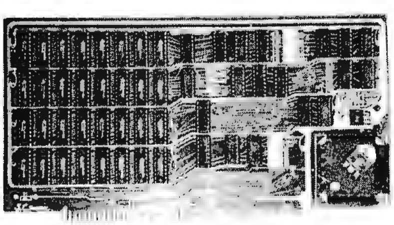

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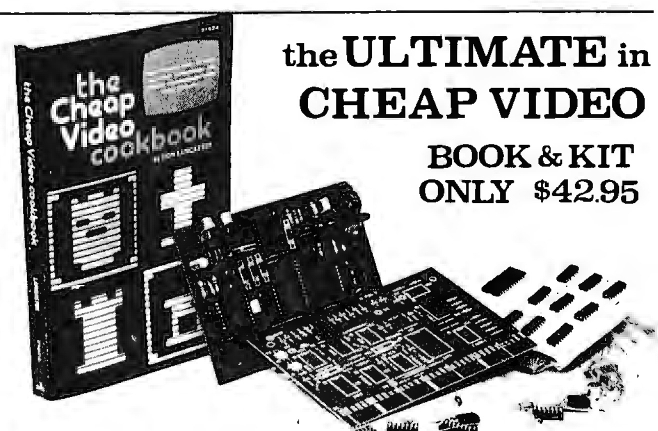

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meetings are at 7:30 PM on the third Wednesday of every month. For a copy of the current WAKE newsletter, send a stamped, self-addressed envelope to WAKE, c/o Ted Beach, 5112 Williamsburg Blvd, Arlington VA 22207 or phone (703) 538-2303.

Microcomputer Investors Association

The most recent issue of the MicroComputer Investors Association journal contains 200 pages with 20 articles that deal with utilizing microcomputers to make and manage investments. Practical computer programs accompany half of the articles. The Association is a nonprofit group which was formed 3 years ago to enable members to share data and information. An information packet is available for $1. Contact Jack Williams, MCIA, 902 Anderson Dr, Fredericksburg VA 22401.

Free Newsletter for Science and Technology Educators

Hands On! is a free newsletter published 3 times a year by the Technical Education Research Centers (TERC), 575 Technology Sq, Cambridge MA 02139. TERC is a nonprofit curriculum research and development corporation. Billed as a forum for science and technology educators, the latest issue of the newsletter contains articles such as *A Biased Introduction to the World of the 6502 Microprocessor; Toward Affordable Computers: Networking and Graphics; Microcomputers in Instrument and Control* and much more. To be added to TERC's mailing list, contact the company at the above address.

Computer Club in Venezuela

The Cuatro Computer Club, Los Pinos Ave, EDF Airosa 5, La Florida, Caracas VENEZUELA, has a monthly newsletter entitled *Micronews.* The newsletter includes short programs on computer graphic art and game programs, as well as future conferences and events, and anecdotes.

The Delmarva Computer Club

The Delmarva Computer Club has been formed to create a community awareness of microcomputer uses for business and pleasure. The club meets at Arcadia High School in Oak Hill VA at 7:30 PM on the first and third Wednesday of each month. Beginners are able to get hands-on programming instruction in BASIC, and advanced members work on community projects and software development and exchange. Contact Jean Trafford, POB 36, Wallops Island VA 23337.

Albany-Schenectady NY Microcomputer Society

Capital Area Microcomputer Soceity (CAMS) is a newly organized group interested in information exchange among members, solving software and hardware problems, and presentation of programs of general interest. Presently there are about 30 members and meetings are held at various locations around the Capital District on the second Wednesday of each month. Contact Stanley L Mathes, Box 348 Ridge Rd, RD#1, Scotia NY 12302, (518) 372-3767.

Electronotes for Musicians

Electronotes 99 is a newsletter for knowledgeable designers, technicians and hobbyists in the music synthesizer field. There are projects, diagrams, items for sale and articles of general interest to sound engineers and designers. For more information, contact *Electronotes 99,* 1 Pheasant Ln, Ithaca NY 14850.

Utah Computer Association

The Utah Computer Association (UCA) meets every second Thursday of the month at 7 PM at Murray High School, 5440 S State St, Salt Lake City UT. The club also has special interest groups that meet at different times to review new products and exchange

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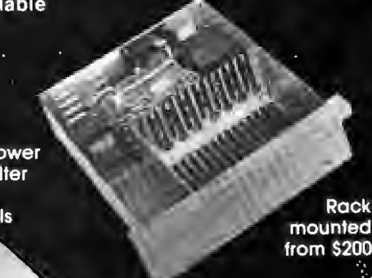

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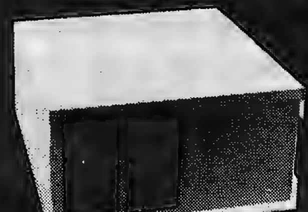

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information on programs. Their newsletter, *Bits*, is published monthly and includes articles concerning club meetings, programs and instructions for microcomputers, advertisements, and general information for computer users. Membership in the club is $7.50 per year which includes subscription to *UCA Bits*. For more information, contact UCA, 378 E 9800 S, Sandy UT 84070.

Chicago Area Computer Hobbyist Exchange

The Chicago Area Computer Hobbyist Exchange (CACHE) meets at 1 PM on the third Sunday of the month at the Northern Illinois Gas Building, Golf and Shermer, Glenview IL. Annual dues are $10 which includes the monthly newsletter, the *CACHE Register*. For further information, call the club's hotline at (312) 849-1132 or write to CACHE, POB 52, S Holland IL 60473.

Computer Club in Tucson

The Pima Community College Computer Club has been formed at the East Side campus at 7830 E Broadway and meets the second Friday of each month at 7:30 PM. Most of the members have already purchased systems, but those still searching for the best buy are welcome, as are nonstudents. Contact Mike Blicharz (602) 749-9157 or Saul Levy (602) 793-0670.

Institute for Computers in Jewish Life (ICJL)

The ICJL recently sponsored a conference on the use of the microprocessor in Jewish education. The conference was open to all educators interested in the application of computers in education. The *Use of Microprocessors in Jewish Education* newsletter covers programs used for teaching

parts of the Bar Mitzvah, for determining proper times of prayer and other daily responsibilities in a Jewish home. Other courses of interest to everyone concerned with Jewish education are included. For more information, write to the ICJL, Hebrew Theological College, 7135 N Carpenter Rd, Skokie IL 60077.

The Eastern Iowa Computer Club

This group meets on the last Sunday of each month. Their newsletter deals with the events of the meeting and future activities of the club. They have printed game programs in the report and are currently working on a software contest. The club invites inquiries from other computer groups and users. For more information, contact the Eastern Iowa Computer Club, POB 164, Hiawatha IA 52233.

The Homebrew Computer Club

The Homebrew Computer Club, POB 626, Mountain View CA 94042, meets at the Fairchild Auditorium in the Stanford Medical Center on the third Wednesday of each month from 7 to 10 PM. The group exchanges programs, works out bugs and tries out new microcomputer systems. Their newsletter covers new products, conferences, and has a section of used computers for sale.

The Popular Computing Newsletter

This is a newsletter for TRS-80 users. It includes programming tips, various programs for home and business, reviews of books and programs, and one edition has programs for two games and a program for add-on interest comparison. It is available from Popular Computing Inc, POB 16875, FT Lauderdale FL 33318, at $24 for one year, $36 for two years, and $48 for three years. ■

Desk Top Wonders

Extended Multiplication with the TI-58

Michael E Manwaring, 3608 73rd Ave N,
Minneapolis MN 55429

Most calculators have 8 to 10 digits of display. A few have as many as 14 digits. For most applications, we have very little interest in any more than 8 significant digits; there are, however, a few fields, such as cryptology, in which someone might want many more digits of answer. The Number Cruncher is a mathematical program that will enable the user to multiply two numbers with a total of up to 90 digits, using a TI-58. The TI-59 can handle a total of 300 digits using this program.

After entering the program (see listing 1), press E. Subroutine E clears the memories, sets the program pointers, and repartitions the memory space to give the

Listing 1: *TI-58 program for multiplying two numbers with an answer totaling up to 90 digits long.*

```
TI 58
NUMBER CRUNCHING

LABEL LIST

   001  15  E
   017  11  A
   026  12  B
   048  13  C
   122  14  D

PROGRAM LIST

   000  76 LBL
   001  15  E
   002  47 CMS
   003  01   1
   004  00   0
   005  42 STO
   006  01  01
   007  02   2
   008  42 STO
   009  00  00
   010  42 STO
   011  06  06
   012  04   4
   013  69 OP
   014  17  17
   015  92 RTN
   016  76 LBL
   017  11  A
   018  72 ST*
   019  01  01
   020  69 OP
   021  21  21
   022  69 OP
   023  22  22
   024  92 RTN
   025  76 LBL
   026  12  B
   027  72 ST*
   028  01  01
   029  97 DSZ
   030  00  00
   031  00  00
   032  38  38
   033  69 OP
   034  21  21
   035  69 OP
   036  24  24
   037  92 RTN
   038  43 RCL
   039  01  01
   040  42 STO
   041  03  03
   042  69 OP
   043  33  33
   044  61 GTO
   045  00  00
   046  33  33
   047  76 LBL
   048  13  C
   049  97 DSZ
   050  06  06
   051  01  01
   052  31  31
   053  73 RC*
   054  05  05
   055  65  ×
   056  73 RC*
   057  03  03
   058  54  )
   059  74 SM*
   060  01  01
   061  73 RC*
   062  01  01
   063  69 OP
   064  33  33
   065  55  ÷
   066  01   1
   067  52 EE
   068  06   6
   069  54  )
   070  59 INT
   071  69 OP
   072  21  21
   073  74 SM*
   074  01  01
   075  65  ×
   076  01   1
   077  52 EE
   078  06   6
```

Listing continued on opposite page

Listing 1 continued:

```
079  22 INV     104  29  29    129  61 GTO
080  52 EE      105  43 RCL    130  14  D
081  54  )      106  09  09    131  43 RCL
082  69 OP      107  42 STO    132  02  02
083  31  31     108  01  01    133  42 STO
084  22 INV     109  97 DSZ    134  07  07
085  74 SM*     110  04  04    135  43 RCL
086  01  01     111  00  00    136  04  04
087  69 OP      112  49  49    137  42 STO
088  21  21     113  43 RCL    138  00  00
089  97 DSZ     114  02  02    139  43 RCL
090  07  07     115  75  -     140  01  01
091  00  00     116  01  1     141  42 STO
092  49  49     117  54  )     142  05  05
093  69 OP      118  44 SUM    143  42 STO
094  35  35     119  01  01    144  09  09
095  43 RCL     120  92 RTN    145  69 OP
096  02  02     121  76 LBL    146  35  35
097  42 STO     122  14  D     147  43 RCL
098  07  07     123  73 RC*    148  03  03
099  43 RCL     124  01  01    149  42 STO
100  08  08     125  99 PRT    150  08  08
101  42 STO     126  69 OP     151  61 GTO
102  03  03     127  31  31    152  00  00
103  69 OP      128  91 R/S    153  53  53
                               154  00  0
                               155  00  0
```

greatest possible capacity. The partition will be displayed. Now you can enter the multiplications, 6 digits at a time, pressing **A** after each 6 digits of the first multiplicand, reading from left to right.

Each multiplicand is divided into groups of 6 digits from right to left, then the numbers are entered from left to right. If the number of digits in a multiplicand is not exactly divisible by 6, the first group of digits of that multiplicand will have less than 6 digits. When the first multiplicand has been entered, the second multiplicand may be entered in the same manner by pressing **B** after each group of 6 digits.

For example, 6,853,233,214,307,635,533,673. × 5,822,756,618,783,644,505,626,130. must be entered in the following manner:

6853	A
233214	A
307635	A
533673	A
5	B
822756	B
618783	B
644505	B
626130	B

When the multiplicands have been entered, press **C** to calculate the result and enter it into computer memory. It may take 5 seconds for each 6 digits of the multiplicands entered to perform this step. When the calculation is completed, a meaningless number is displayed. The result can be extracted from memory by pressing **D** several times. Pressing **D** causes the result to be read from left to right. In this case, the result is on the order of 4×10^{46}, so it will be necessary to press **D** 8 times to recall the entire result. If **D** is pressed one too many times, the last entered group of digits from the second multiplicand will be displayed. Each time **D** is pressed 6 more digits of the result are displayed.

D	0
D	39904
D	709058
D	677695
D	645793
D	103475
D	894028
D	753563
D	675490

It appears at first that the TI-58 uses the 10-digit display value in its calculations. In reality, all calculations are done using a 13-digit internal register or accumulator which allows it to multiply two 6-digit numbers and retain all eleven or twelve digits.

The algorithm used in this program is very similar to the old method of pencil and paper multiplication, where you multiplied one digit of one multiplicand by one digit of the other multiplicand at a time, carrying the tens digit to be added to the next multiplication. The main difference is that instead of multiplying and carrying one digit at a time, the computer does 6 digits at a time, greatly speeding up the calculation. ■

Calculator Airborne Navigation

The HP-25 Finds Ground Speed and True Heading

L J Kuhns
801 Hastings Dr
Kissimmee FL 32741

The program in listing 1 calculates the ground speed and true heading for all quadrants when the true course, wind direction, air speed, and wind speed are known.

The addition of 0.1 degrees to the wind direction eliminates any problems with head and tail winds (which otherwise result in division by zero) without any major effect on the answer.

Storage of 180 degrees and 360 degrees facilitates taking care of the different quadrants for making drift corrections.

NAVIGATION - CALCULATES GROUND SPEED AND TRUE HEADING FOR ALL QUADRANTS

DISPLAY LINE	DISPLAY CODE	KEY ENTRY	COMMENTS
00			0.1° ADDED TO
01	2401	RCL 1	WIND DIRECTION
02	2400	RCL 0	TAKES CARE OF
03	41	—	TAIL AND HEAD
04	2407	RCL 7	WINDS
05	41	—	
06	2304	STO 4	
07	2407	RCL 7	
08	51	+	
09	1551	8 ≥ 0	
10	1313	GTO 13	
11	1312	GTO 12	
12	2304	STO 4	
13	2404	RCL 4	
14	1541	8 x < 0	
15	1320	GTO 20	
16	09	9	
17	00	0	
18	51	+	
19	2304	STO 4	
20	1404	f SIN	
21	2403	RCL 3	
22	61	×	
23	2402	RCL 2	
24	71	÷	
25	1504	8 SIN $^{-1}$	
26	2305	STO 5	
27	2404	RCL 4	
28	2406	RCL 6	
29	51	+	
30	1551	8 ≥ 0	
31	32	CHS	
32	2405	RCL 5	
33	1551	8 ≥ 0	
34	32	CHS	
35	51	+	
36	2406	RCL 6	
37	51	+	
38	1404	f SIN	
39	2403	RCL 3	
40	61	×	
41	2405	RCL 5	
42	1404	f SIN	
43	71	÷	
44	1541	8 x < 0	
45	32	CHS	
46	74	RS	GROUND SPEED
47	2400	RCL 0	
48	2405	RCL 5	
49	51	+	TRUE HEADING ■

REGISTERS
R_0 TRUE COURSE (DEGREES)
R_1 WIND DIRECTION +0.1°(DEGREES)
R_2 AIR SPEED MILES/HR.
R_3 WIND SPEED MILES/HR.
R_4 AIR SPEED θ
R_5 WIND SPEED θ
R_6 180°
R_7 360°

CIRCUIT BREAKER PRICE SLASHING

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- •200 NS for TRS-80*, Apple II, Sorcerer (specify) $85.00

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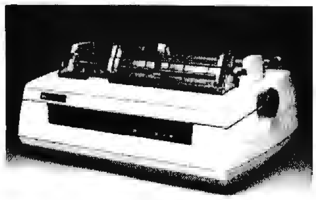
NEC Spinwriter

$2679.00



Includes TRS-80* interface software, quick change print fonts, 55 cps, bidirectional, high resolution plotting, graphing, proportional spacing. 90 DAY WARRANTY.

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Languages Forum

SNOBOL Commentary

Jonathan Sachs, 6713 Richmond Ave,
Richmond View CA 94805

As a long-time SNOBOL addict, I enjoyed Bruce Burns' "SNOBOL Conquers All?" (June 1979 BYTE, page 220), but I want to protest two things he said.

First, that "opponents to the language say they feel that the language's power invites unstructured programming..." I think we are basically in agreement on this one, but uncareful readers may get the idea that if you understand what you are doing, unstructured programming in SNOBOL is OK. Make no mistake: when the full power of SNOBOL4 is applied to a problem, it is beyond the power of a human to understand the resulting program without extensive documentation *and* thorough study. It is wise to use the language below its capabilities 99% of the time, and end up with readable code.

While I am on the subject of structure, I will add that SNOBOL's lack of strong structure (WHILE/DO, IF/THEN/ELSE) is its single intolerable vice. I object, not because it allows fools to write bad code, but because it prevents *me* from writing *good* code unless I sweat blood. Because of this, I am planning to modify my SNOBOL compiler (FASBOL II on the DECsystem-10) to support the above constructs. I would like to hear from anyone else who has tried this.

Now, for my second objection. It concerns the one-line code segment to put the characters of a string in lexical order. The one-liner works, but it is horribly inefficient for long strings. When it finds characters N and N+1 are out of order it transposes them, then *returns to the beginning of the string*, even though we know characters 0 through N−1 are ordered.

Gross inefficiency is not a sin, but there is no justification for it unless it buys some overbalancing benefit such as storage economy or generality. Here, the only benefit we get is a one-liner. I think that is a poor demonstration of elegance. I wish Mr Burns had come up with a one-liner (if he had to use one at all) that someone might want to use in a real program.

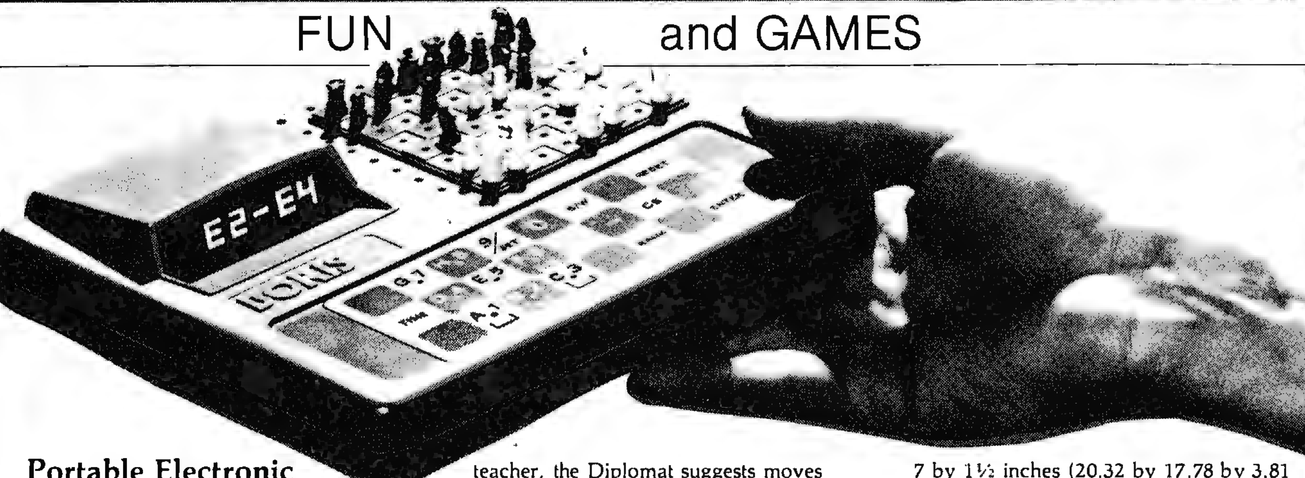
Incidentally, the following "3-liner" benchmarks almost 4 times faster on my system, for the string 'THE QUICK BROWN FOX JUMPS OVER THE LAZY DOG':

```
            P = 0
LEXORD      S   TAB(*P) $ A @Q LEN(1) $ B @P LEN(1) $ C
+                   *LGT(B,C) = A C B            :F(ORDERED)
            P = ?GT(Q) Q - 1                     :(LEXORD)
ORDERED     .....
```

But these are minor complaints. Mr Burns' crusade to implement SNOBOL on microcomputers is a worthy one, and if there is anything I can do to support it, I will.

What's New?

FUN and GAMES



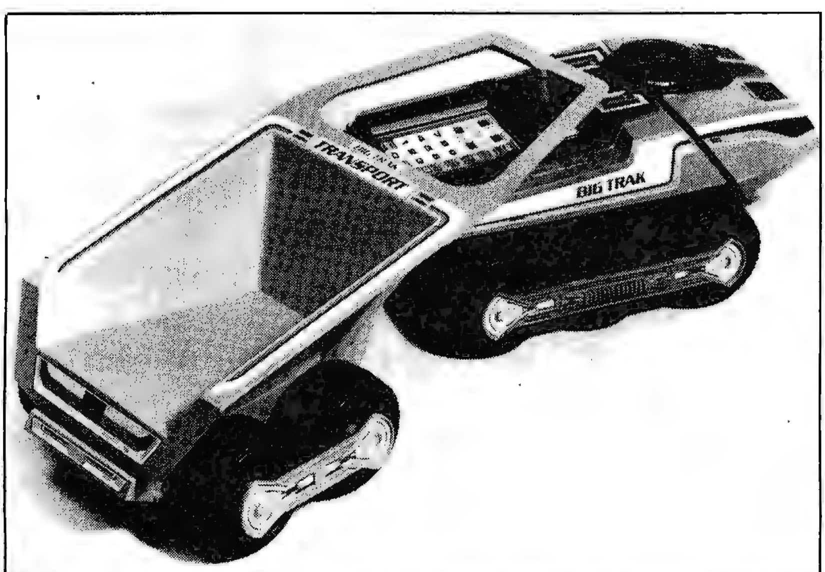
Portable Electronic Chess Game

The Boris Diplomat is a compact, portable, battery-operated electronic chess computer. Designed with various operational strengths, the Diplomat will play at a level that will teach a child or will keep the attention of a master. As a teacher, the Diplomat suggests moves for the unsure beginner. The Position Programmer allows more advanced players to set up special board positions to practice specific strategies. Beginners use the Position Programmer to remove pieces for handicapping or for practice of specific positions. The Diplomat has a built-in chess board with pieces, is 8 by 7 by 1½ inches (20.32 by 17.78 by 3.81 cm), and operates several hours on six AA battery cells or on the AC adapter which is included.

The price of the Boris Diplomat is $119.95. For further information, contact Chafitz Inc, 1055 First St, Rockville MD 20850.

Circle 624 on inquiry card.

Programmable High-Performance Toy Vehicle



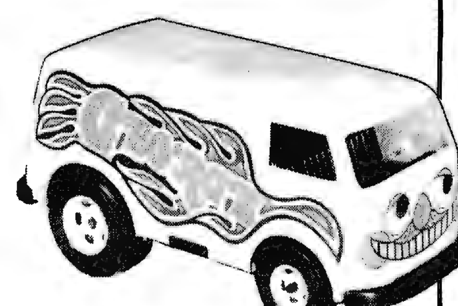
Milton Bradley's Big Trak is a toy vehicle which is programmed to follow an extremely complex route. Big Trak advances for as many as 99 units, each unit being the measure of its own 13-inch length. By pushing the Repeat button, it travels twice as far. It gives the same performance in reverse. The vehicle pivots either right or left in a full circle or more. It also pivots in tiny fractions of a circle, for Big Trak possesses 60 swiveling positions. It can make a turn, proceed in a straight line, turn again, and continue traveling on whatever course has been set.

Big Trak has a total of 16 programming steps which direct its functions. By estimating the distances and punching in commands, the user may send it around tables, chairs, and other obstacles, and have it return. The user may input a command which will call up its arsenal of weaponry, firing a single shot, or short or long bursts of sound and light laser-cannon fire. It may be strategically deployed, firing at some target as it maneuvers, or lurk silently in ambush.

Big Trak has a companion item called Big Trak Transport. The Transport attaches to Big Trak and hauls and dumps loads on a preprogrammed command. The approximate retail price of Big Trak is $43 and the Big Trak Transport is priced at $13. For further information, contact Milton Bradley Co, Springfield MA 01101.

Circle 626 on inquiry card.

Voice Controlled Toy Van



George, the toy van controlled by voice, is available from Beneficial Marketing, Suite 1920, Wall St Plz, New York NY 10005. George will go where you tell him only to the extent that you control him with your voice. The number of words used, the length of the words, and the combination of words are all controls. George is priced at $24.95.

Circle 625 on inquiry card.

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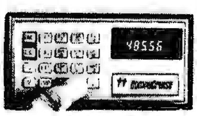

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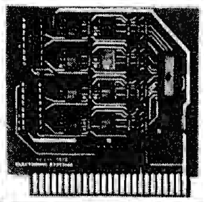

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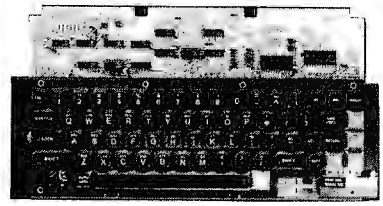
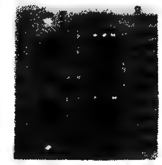


RS-232/20mA INTERFACE

This board has two passive, opto-isolated circuits. One converts RS-232 to 20mA, the other converts 20mA to RS-232. All connections go to a 10 pin edge connector. Requires +12 and -12 volts. Board only $9.95, part no. 7901, with parts $14.95 Part No. 7901A.



6502 APPLICATIONS BOOK Z80 APPLICATIONS BOOK*

This book will teach you how to connect a board to the outside world and implement practical applications for the 6502, (or Z80). Applications range from home control (a complete alarm system, including heat sensor), to industrial applications. You will learn techniques ranging from simulated traffic control to analog-digital conversion. All experiments can be realized with a minimum of external (low-cost) components. They are directly applicable to any 6502-based board such as SYM, KIM, AIM 65. This book also studies in detail input-output techniques and components, and is the logical continuation of C202 (or C280). By Rodney Zaks. SYBEX. 6502: Ref. D302; Z80: Ref D380. Each $12.95

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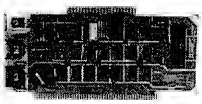
TIDMA

• Tape Interface Direct Memory Access • Record and play programs without bootstrap loader (no prom) has FSK encoder/decoder for direct connections to low cost recorder at 1200 baud rate, and direct connections for inputs and outputs to a digital recorder at any baud rate • S-100 bus compatible • Board only $35.00 Part No. 112, with parts $110 Part No. 112A



SYSTEM MONITOR

8080, 8085, or Z-80 System monitor for use with the TIDMA board. There is no need for the front panel. Complete with documentation $12.95.

ASCII TO CORRESPONDENCE CODE CONVERTER

This bidirectional board is a direct replacement for the board inside the Trendata 1000 terminal. The on board connector provides RS-232 serial in and out. Sold only as an assembled and tested unit for $229.95. Part No. TA 1000C

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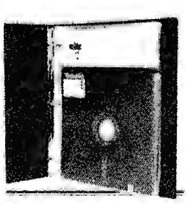

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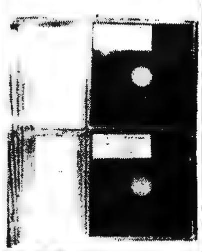

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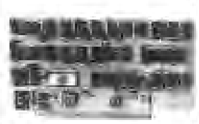
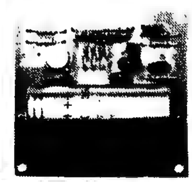


PET COMPUTER

With 32K & monitor - $1195. Dual Disk Drive - $1195.

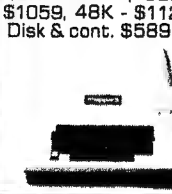
T.V. INTERFACE

● 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 C.T., or +5 volts DC ● Board only $7.60 part No. 107, with parts $13.50 Part No. 107A



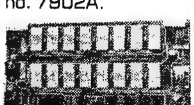
apple II or APPLE II PLUS

16K - $995, 32K - $1059, 48K - $1123. Disk & cont. $589



16K EPROM

Uses 2708 EPROMS, memory speed selection provided, addressable anywhere in 65K of memory, can be shadowed in 4K increments. Board only $24.95 part no. 7902, with parts less EPROMs $49.95 part no. 7902A.



INTERNATIONAL MICROPROCESSOR DICTIONARY

English, French, Danish, German, Italian, Hungarian, Norwegian, Polish, Spanish, Swedish. 10 languages, 28 pp. SYBEX. Ref. IMD. $4.95

PARALLEL TRIAC OUTPUT BOARD FOR APPLE II

This board has 8 triacs capable of switching 110 volt 6 amp loads (660 watts per channel) or a total of 5280 watts. Board only $15.00 Part No. 210, with parts $119.95 Part No. 210A.

To Order: Mention part no. description, and price. In USA shipping paid by us for orders accompanied by check or money order. We accept C.O.D. orders in the U.S. only, or a VISA or Master Charge no., expiration date, signature, phone no., shipping charges will be added. CA residents add 6.5% for tax. Outside USA add 10% for air mail postage and handling. Payment must be in U.S. dollars. Dealer inquiries invited. 24 hour order line (408) 448-0800

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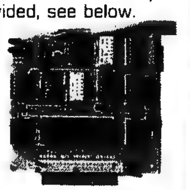
Circle 125 on inquiry card.

TRS-80 E.S. SERIAL I/O

• Can input into basic • Can use LLIST and LPRINT to output, or output continuously • RS-232 compatible • Can be used with or without the expansion bus • On board switch selectable baud rates of 110, 150, 300, 600, 1200, 2400, parity or no parity odd or even, 5 to 8 data bits, and 1 or 2 stop bits. D.T.R. line • Requires +5, -12 VDC • Board only $19.95 Part No. 8010, with parts $59.95 Part No. 8010A, assembled $79.95 Part No. 8010 C. No connectors provided, see below.

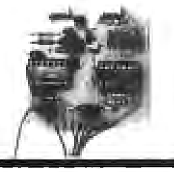


EIA/RS-232 connector Part No. DB25P $6.00, with 9', 8 conductor cable $10.95 Part No. DB25P9

3' ribbon cable with attached connectors to fit TRS-80 and our serial board $19.95 Part No. 3CAB40.

MODEM

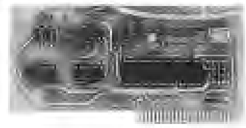
• Type 103 • Full or half duplex • Works up to 300 baud • Originate or Answer • No coils, only low cost components • TTL input and output-serial • Connect 8 Ω speaker and crystal mic. directly to board • Uses XR FSK demodulator • Requires +5 volts • Board only $7.60 Part No. 109, with parts $27.50 Part No. 109A



DISKETTES

Box of 10, 5" $29.95, 8" $39.95.
Plastic box, holds 10 diskettes, 5" - $4.50, 8" - $6.50.

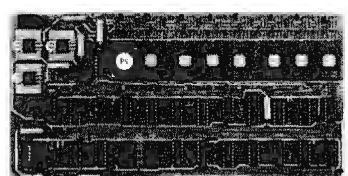
APPLE II* SERIAL I/O INTERFACE



Baud rate is continuously adjustable from 0 to 30,000 • Plugs into any peripheral connector • Low current drain. RS-232 input and output • On board switch selectable 5 to 8 data bits, 1 or 2 stop bits, and 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 selectrics. • Also watches DTR • Board only $15.00 Part No. 2, with parts $42.00 Part No. 2A, assembled $62.00 Part No. 2C

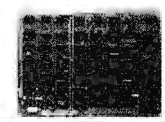
8K EPROM PIICEON

Saves programs on PROM permanently (until erased via UV light) up to 8K bytes. Programs may be directly run from the program saver such as fixed routines or assemblers. • S-100 bus compatible • Room for 8K bytes of EPROM non-volatile memory (2708's). • On-board PROM programming • Address relocation of each 4K of memory to any 4K boundary within 64K • Power on jump and reset jump option for "turnkey" systems and computers without a front panel • Program saver software available • Solder mask both sides • Full silkscreen for easy assembly. Program saver software in 1 2708 EPROM $25. Bare board $35 including custom coil, board with parts but no EPROMS $139, with 4 EPROMS $179, with 8 EPROMS $219.



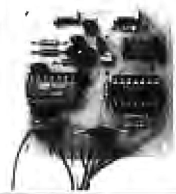
T.V. TYPEWRITER

• Stand alone TVT • 32 char/line, 16 lines, modifications for 64 char/line included • Parallel ASCII (TTL) input • Video output • 1K on board memory • Output for computer controlled curser • Auto scroll • Non-destructive curser • Curser inputs: up, down, left, right, home, EOL, EOS • Scroll up, down • Requires +5 volts at 1.5 amps, and -12 volts at 30 mA • All 7400, TTL chips • Char. gen. 2513 • Upper case only • Board only $39.00 Part No. 106, with parts $145.00 Part No. 106A



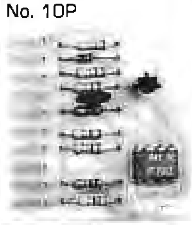
TAPE INTERFACE

• Play and record Kansas City Standard tapes • Converts a low cost tape recorder to a digital recorder • Works up to 1200 baud • Digital in and out are TTL-serial • Output of board connects to mic. in of recorder • Earphone of recorder connects to input on board • No coils • Requires +5 volts, low power drain • Board only $7.60 Part No. 111, with parts $27.50 Part No. 111A



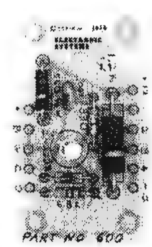
RS-232/ TTL INTERFACE

• Converts TTL to RS-232, and converts RS-232 to TTL • Two separate circuits • Requires -12 and +12 volts • All connections go to a 10 pin gold plated edge connector • Board only $4.50 Part No. 232, with parts $7.00 Part No. 232A 10 Pin edge connector $3.00 Part No. 10P



RS-232/TTY INTERFACE

This board has two active circuits, one converts RS-232 to 20mA, and the other converts 20mA to RS-232. Requires +12 and -12 volts. Board only $4.50 Part No. 600, with parts $7.00 Part No. 600A.

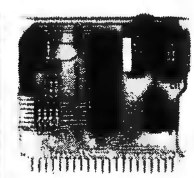


WAMECO PRODUCTS WITH ELECTRONIC SYSTEMS PARTS

FDC-1 FLOPPY CONTROLLER BOARD will drive shugart, pertek, remex 5" & 8" drives up to 8 drives, on board PROM with power boot up, will operate with CPM (not included). PCBD $42.95
FPB-1 Front Panel. (Finally) IMSAI size hex displays Byte or instruction single step. PCBD $42.95
MEM-1A 8Kx8 fully buffered, S-100, uses 2102 type RAMS. PCBD .... $24.95, $168 Kit
QMB-12 MOTHER BOARD, 13 slot, terminated, S-100 board only .... $34.95 $89.95 Kit
CPU-1 8080A Processor board S-100 with 8 level vector interrupt PCBD .. $25.95 $89.95 Kit
RTC-1 Realtime clock board. Two independent interrupts. Software programmable. PCBD .... $25.95, $60.95 Kit
EPM-1 1702A 4K EPROM card PCBD .... $25.95 $49.95 with parts less EPROMS
EPM-2 2708/2716 16K/32K EPROM card PCBD .... $24.95 $49.95 with parts less EPROMS
QMB-9 MOTHER BOARD. Short Version of QMB-12. 9 Slots PCBD .... $30.95 $67.95 Kit
MEM-2 16Kx8 Fully Buffered 2114 Board PCBD .... $25.95, $269.95 Kit

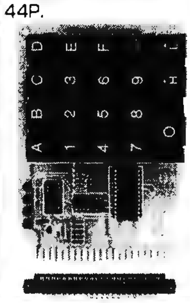
UART & BAUD RATE GENERATOR

• Converts serial to parallel and parallel to serial • Low cost on board baud rate generator • Baud rates: 110, 150, 300, 600, 1200, and 2400 • Low power drain +5 volts and -12 volts required • TTL compatible • All characters contain a start bit, 5 to 8 data bits, 1 or 2 stop bits, and either odd or even parity. • All connections go to a 44 pin gold plated edge connector • Board only $12.00 Part No. 101, with parts $35.00 Part No. 101A, 44 pin edge connector $4.00 Part No. 44P



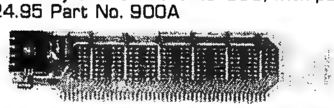
HEX ENCODED KEYBOARD E.S.

This HEX keyboard has 19 keys, 16 encoded with 3 user definable. The encoded TTL outputs, 8-4-2-1 and STROBE are debounced and available in true and complement form. Four onboard LEDs indicate the HEX code generated for each key depression. The board requires a single +5 volt supply. Board only $15.00 Part No. HEX-3, with parts $49.95 Part No. HEX-3A. 44 pin edge connector $4.00 Part No. 44P.



S-100 BUS ACTIVE TERMINATOR

Board only $14.95 Part No. 900, with parts $24.95 Part No. 900A



DC POWER SUPPLY

• Board supplies a regulated +5 volts at 3 amps., +12, -12, and -5 volts at 1 amp. • Power required is 8 volts AC at 3 amps., and 24 volts AC C.T. at 1.5 amps. • Board only $12.50 Part No. 6085, with parts excluding transformers $42.50 Part No. 6085A

To Order: Mention part no. description, and price. In USA shipping paid by us for orders accompanied by check or money order. We accept C.O.D. orders in the U.S. only, or a VISA or Master Charge no., expiration date, signature, phone no., shipping charges will be added. CA residents add 6.5% for tax. Outside USA add 10% for air mail postage and handling. Payment must be in U.S. dollars. Dealer inquiries invited. 24 hour order line (408) 448-0800

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Circle 125 on inquiry card.

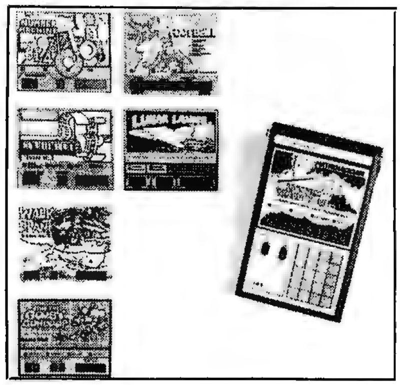
What's New?

FUN and GAMES

Game Playing Device Is Also a Teaching Calculator

Mathemagician is a teaching calculator and game-playing device for adults and children of all ages. It can teach children arithmetic operations: multiplication tables, division tables, addition and subtraction. Children and adults can play any of six different games, which are: Number Machine, Counting On, Walk the Plank, Gooey Gumdrop, Football, and Lunar Lander. Mathemagician's games can be played by one or two people. All functions let the user know at the end of each problem if he or she has given the correct answer, and if not, will then display the correct answer.

Mathemagician sells for $29.95. For further information, contact APF Electronics Inc, 444 Madison Ave, New York NY 10022.



Circle 627 on inquiry card.

Game Software for the TRS-80

The Software Association has announced a new line of entertainment programs for the TRS-80. All programs are written in machine language and provide fast response times. The initial offerings include:

Z-Chess — a full-featured chess opponent providing seven levels of difficulty, from Blitz to Expert. Six moves of look-ahead are possible, and Z-Chess can solve mate-in-two problems quickly. Numbered squares and a board setup mode are provided for ease of play.

Back-40 — a backgammon challenger with an unrivaled graphic board display. Doubling is permitted, and every feature of a regulation backgammon match is provided including the score.

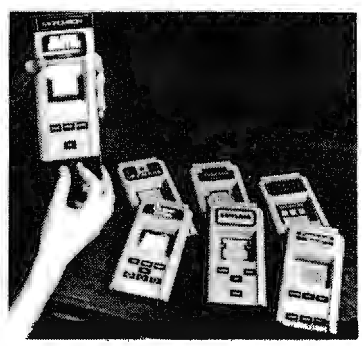
Dr Chips — a fascinating program based on Doctor and Eliza programs. Machine language allows Dr Chips to analyze sentences and talk back instantly.

All programs require a 16 K byte Level II machine. Z-Chess is priced at $17.95, Back-40 and Dr Chips are $14.95 each. For further information, contact The Software Association, POB 58365 Houston TX 77058.

Circle 628 on inquiry card.

Microvision Features Seven Different Game Cartridges

Milton Bradley's Microvision is a hand-held mini "video" game with its own screen. The electronically operated Microvision comes equipped with the game Blockbuster; moreover, six additional game cartridges may be purchased, including Bowling, Pinball, Connect 4, Star Trek Phaser Strike, Vegas Slots, and Mindbuster. Microvision is priced at $51.25. Game cartridges range in price from $16.50 to $18. Contact Milton Bradley Co, Springfield MA 01101.



Circle 629 on inquiry card.

Electronic Robot Promises Preschool Fun

Alphie is an electronic toy robot offering action, lights, sounds, music and games for children 3 to 8 years old. Preschoolers will enjoy Alphie's Question and Answer games. Once the child makes a decision, Alphie lights up the correct answer. If the child has made the right selection, Alphie plays a rendition of Sousa's "Stars and Stripes Forever." If the child's answer does not match, Alphie gives a good-natured "razzberry." Alphie also plays other tunes, and there is a choice of five popular children's songs.

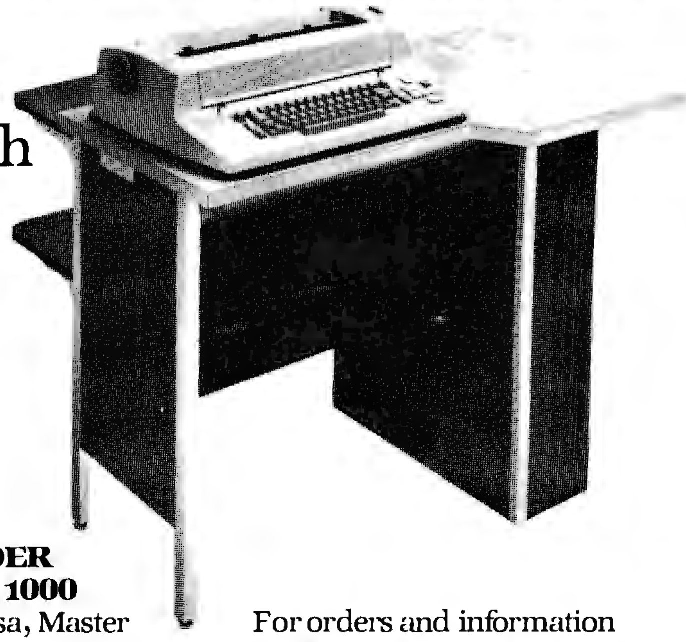
Slightly older children will enjoy playing Robot Land. In this color matching game, the child tries to beat Alphie or a friend by being the first to move a miniature Alphie piece along the path from the Robot Factory to Spaceship XK-3. In the Lunar Landing game, children count the tones Alphie makes in order to be first to assemble an Alphie puzzle on the lunar game board.

Alphie is priced at approximately $28. For further information, contact Playskool Inc, 4501 W Augusta Blvd, Chicago IL 60651.

Circle 630 on inquiry card.

The DATA-TRANS 1000

A completely refurbished IBM Selectric Terminal with built-in ASCII Interface.



$1395

Features:

- 300 Baud
- 14.9 characters per second printout
- Reliable heavy duty Selectric mechanism
- RS-232C Interface
- Documentation included
- 60 day warranty - parts and labor
- High quality Selectric printing Off-line use as typewriter
- Optional tractor feed available
- 15 inch carriage width

HOW TO ORDER DATA-TRANS 1000

1. We accept Visa, Master Charge. Make cashiers checks or personal check payable to:

DATA-TRANS

2. All orders are shipped F.O.B. San Jose, CA
3. Deliveries are immediate

For orders and information

DATA-TRANS
2154 O'Toole St.
Unit E
San Jose, CA 95131
Phone: (408) 263-9246

MICRO-PROCESSORS: FROM CHIPS TO SYSTEMS

This book cover all aspects of microprocessors, from the basic concepts to advanced interfacing techniques, in a progressive presentation. It is independent from any manufacturer, and presents uniform **standard** principles and design techniques, including the interconnect of a **standard** system, as well as specific components. It introduces the MPU, how it works internally, the system components (ROM, RAM, UART, PIO, others), the system interconnect, applications, programming, and the problems and techniques of system development. By R. Zaks. SYBEX. Ref. C201. $9.95

MICRO-PROCESSOR INTERFACING TECHNIQUES

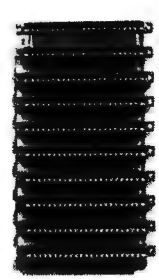
Microprocessor interfacing is no longer an art. It is a set of techniques, and in some cases just a set of components. This comprehensive book introduces the basic interfacing concepts and techniques, then presents in detail the implementation details, from hardware to software. It covers all the essential peripherals, from keyboard to floppy disk, as well as the standard buses (S100 to IEEE 488) and introduces the basic troubleshooting techniques. (2nd Expanded Edition). By Austin Lesea and R. Zaks. Ref. C207 SYBEX. $11.95

PROGRAMMING THE 6502 PROGRAMMING THE Z80 PROGRAMMING THE 8080*

It covers all essential aspects of programming, as well as the advantages and disadvantages of the 6502 and should bring the reader to the point where he can start writing complete applications programs. For the reader who wishes more, a companion volume is available: The 6502 Applications Book. By R. Zaks. 6502: Ref. C202; Z80: Ref. C280; 8080: Ref. C208. SYBEX. Each $10.95

44 BUS MOTHER BOARD

Has provisions for ten 44 pin (.156) connectors, spaced 3/4 of an inch apart. Pin 20 is connected to X, and 22 is connected to Z for power and ground. All the other pins are connected in parallel. This board also has provisions for bypass capacitors. Board cost $15.00 Part No. 102. Connectors $3.00 each Part No. 44WP.



AN INTRODUCTION TO PERSONAL AND BUSINESS COMPUTING

No computer background is required. The book is designed to educate the reader in all the aspects of a system, from the selection of the microcomputer to the required peripherals. By Rodnay Zaks. Ref. C200, SYBEX $6.95

TVT COOKBOOK

Bk 1064 — by Don Lancaster. Describes the use of a standard television receiver as a microprocessor CRT terminal. Explains and describes character generation, cursor control and interface information in typical, easy-to-understand Lancascaster style. $9.95

COMPUTER PROGRAMMING HANDBOOK

A complete guide to computer programming & data processing. Includes many worked-out examples. By Peter Staak, TAB $9.95

DIGITAL CASSETTE

5 min. each side. Box of 10 $9.95. Part No. C-5.

To Order: Mention part no. description, and price. In USA shipping paid by us for orders accompanied by check or money order. We accept C.O.D. orders in the U.S. only, or a VISA or Master Charge no., expiration date, signature, phone no., shipping charges will be added. CA residents add 6.5% for tax. Outside USA add 10% for air mail postage and handling. Payment must be in U.S. dollars. Dealer inquiries invited. 24 hour order line (408) 448-0800

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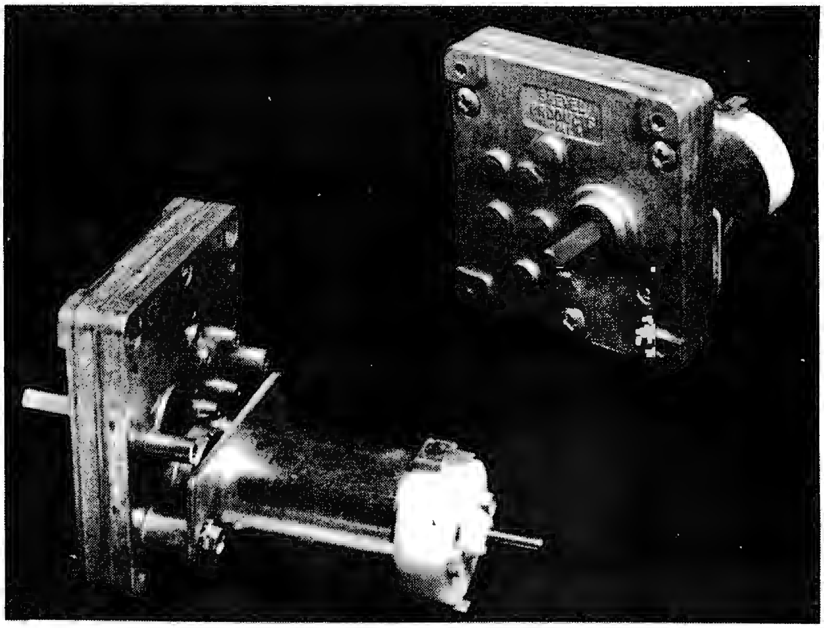
What's New?

of INTEREST to DESIGNERS

Muscles for Robots

This 12 V DC, 17 RPM, reversible gearmotor has been designed for robotic applications. The motor produces 11 inch-pounds of torque and operates on 750 mA full load current. The motor is priced at $18. Contact Gledhill Electronics, POB 1644, Marysville CA 95901.

Circle 634 on inquiry card.



Pascal Processor for the S-100 Bus

The Pascal-100 processor is a 16-bit central processor board for the S-100 bus, especially designed for use with the Pascal programming language. The processor directly executes p-code instructions generated by the Pascal compiler written at the University of California, San Diego (UCSD Pascal). It runs the latest version of the entire UCSD Pascal operating system, including the Pascal compiler, screen editor, filing system, BASIC compiler, graphics package, games library, computer-based learning system, and utilities and cross-assemblers for other micro and minicomputers.

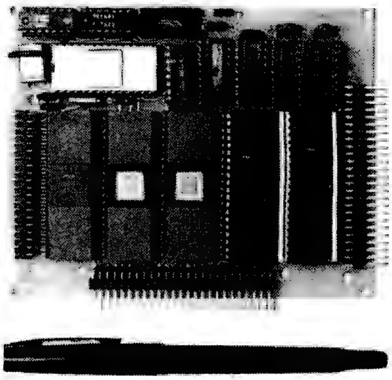
Other features of the Pascal-100 processor include support of up to 128 K bytes of directly addressed main memory, 16-bit data bus transfers, vectored interrupts and floating point operations. The processor complies with the Institute of Electrical and Electronic Engineers standard for the S-100 bus, and will also operate with most peripheral and memory boards designed prior to the standard.

The Pascal-100 processor is priced at $995. For further information, contact David Lewis, Digicomp Research Corp, Terrace Hill, Ithaca NY 14850.

Circle 635 on inquiry card.

Microprocessor Controller Card

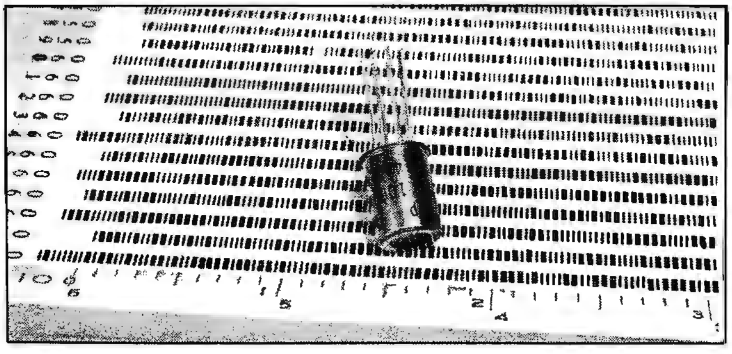
The System A process control board utilizes an 8085 microprocessor and can interface to 76 I/O (input/output) lines. The board contains 4 K bytes of erasable read-only memory and up to 4.6 K bytes of programmable memory. It also has RS-232 teletypewriter control and 14-bit binary counter and timers. The board can be purchased with a resident program that allows the user to program interface requirements and data rates from an external source. Minimal configuration boards may also be purchased. The board dimensions are 4 by 5 inches (10.16 by 12.20 cm). The System A board starts at $295. For further information, contact FH and M



Enterprises Inc, 1850 Gravers Rd, Norristown PA 19401.

Circle 636 on inquiry card.

Hewlett-Packard Introduces High-Resolution Optical Reflective Sensor



The HEDS-1000 is a fully integrated module designed for optical reflective sensing. The module contains a 0.007 inch (0.178 mm) diameter light-emitting diode (emitting visible 700nm wavelength light) and a matched integrated circuit photodetector. A bifurcated aspheric lens is used to direct the active areas of the light-emitter and the detector to a single image spot 0.171 inch (4.34 mm) in front of the package. The reflected signal can be sensed directly from the photodiode or through an internal transistor that can be configured as a high-gain amplifier. Applications include pattern recognition, object sizing, optical limit switching, tachometry, defect detection, dimensional monitoring, line locating, mark and bar code scanning, and paper edge detection.

For further information, contact Hewlett-Packard, Optoelectronics Division, 640 Page Mill Rd, Palo Alto CA 94304.

Circle 637 on inquiry card.

Circle 137 on inquiry card.

What's New?

MASS STORAGE

Intelligent Disk System for S-100 Computers

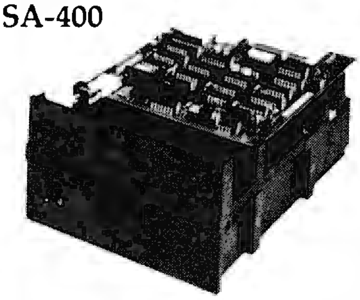
A 10 M byte intelligent rigid disk system has been introduced by Corvus Systems, 900 S Winchester Blvd, San Jose CA 95128. Plug compatible with the Radio Shack TRS-80, Apple and all S-100 bus-type computers, the system adds cost-effective mass storage to these computers, while maintaining total compatibility with existing hardware and software. The disk system consists of a compact IMI 7710 disk drive employing Winchester technology with two 8-inch rigid disks; a Corvus Z80 intelligent disk controller with comprehensive disk diagnostics; and an intelligent personality module and associated software for each form of computer. Each drive has a capacity of 10 M bytes of formatted storage. Up to four drives can be supported in a simple daisy chain. The price of the system is $5350, including disk drive, controller, and personality module. Add-on disk drives are priced at $2900.

Circle 631 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 homebrewers who read BYTE, we print it in some form. We openly solicit releases and photos from manufacturers and suppliers to this marketplace. The information is printed more or less as a first in first out queue, subject to occasional priority modifications. While we would not knowingly print untrue or inaccurate data, or data from unreliable companies, our capacity to evaluate the products and companies appearing in the "What's New?" feature is necessarily limited. We therefore cannot be responsible for product quality or company performance.

5-Inch Disk Drive Is Compatible with Shugart SA-400



The Teac FD-50A 5-inch disk drive moves its data-transfer head directly to the selected track, giving the drive a track-to-track access time of 25 ms and an average access time of 298 ms. A precision built stepper motor ensures accurate head positioning while an improved head configuration is used for precise erasing. In its basic 35-track configuration, the capacity of the FD-50A is 109.4 K bytes (unformatted). This may be extended if desired by addressing an additional 5 tracks. Recording on a total of 40 tracks expands the capacity to 125 K bytes. Up to four FD-50A 5-inch disk drives can be daisy-chained to a single controller. The FD-50A is fully plug-to-plug and disk-compatible with the Shugart SA-400.

For further information, contact Teac Corp, 3-7-3, Naka-cho, Musashino, Tokyo, JAPAN.

Circle 632 on inquiry card.

5-Inch Double Density Disk Drive for TRS-80

Percom Data Company has expanded its TFD line of add-on 5-inch disk systems for the Radio Shack TRS-80 computer to include a dual drive unit featuring double-density storage. Designated the TFD-1000, the unit provides 800 K bytes of on-line storage. Two systems (four drives) may be used with a TRS-80 to provide 1.6 M bytes on line.

The TFD-1000 is supplied complete with an interconnecting cable (which accommodates either one or two units), a Peripheral Adapter Module (PAM) printed circuit card, Percom's MICRODOS operating system, and support documentation. The PAM card replaces the RS-232C card in the TRS-80 expansion interface and includes RS-232C circuitry so that serial interfacing capability is retained. The MICRODOS operating system, which replaces TRSDOS, was developed especially for business and professional applications. It provides full random-access capability, is faster than TRSDOS and requires less than 7 K bytes of programmable memory. It is supplied on a system disk that includes BASIC program examples and a menu of the programs. The menu is activated on power-up or reset.

The TFD-1000 complete with cable, operating system, PAM card and documentation costs $2495. Two TFD-1000 units (four drives) cost $4950. For further information contact the company at 211 N Kirby, Garland TX 75042.

Circle 633 on inquiry card.

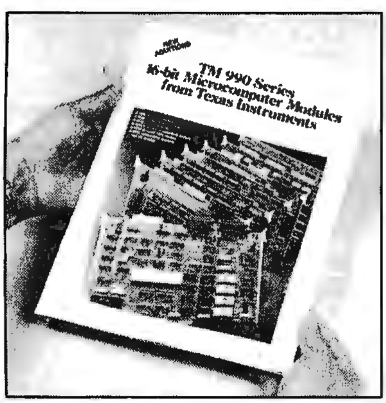
PUBLICATIONS

Predict Object Motion With Your Programmable Calculator

Countdown, a book by Robert Eisberg and Wendell Hyde, will show the reader how to use a programmable calculator to accurately predict the motion of a variety of interesting objects. Using only basic math and physics, the book explains how to calculate the motion of skydivers, single and multistage rockets, Earth satellites, planets, and alpha particles. The book is written without the assumption that the reader has any familiarity with a programmable calculator. This 114 page paperback book is priced at $6.95. For further information contact Dilithium Press, POB 92, Forest Grove OR 91776.

Circle 598 on inquiry card.

TM990 Series Microcomputer Module Selection Guide Available from Texas Instruments



A 20-page product selection guide and catalog covering the TM990 Series of 16-bit microcomputer modules is available free from Texas Instruments Inc, POB 1443, MS-6404, Houston TX 77001. It provides engineers with a convenient reference to TI's line of TM990 Series microcomputer modules and other TM990 Series software, firmware, and hardware products. The publication, CL 377A, covers TM990 Series microcomputer modules; memory expansion modules; I/O (inut/output) expansion modules; industrial AC and DC I/O modules; analog-to-digital and digital-to-analog interface modules; university educational module; and software development module. Product descriptions include key specifications and features.

Also included in CL 377A are descriptions, key features and specifications for TI's data entry and display Microterminal; firmware support, including TIBUG Monitor and line-by-line assembler; software, including Power BASIC high-level language and TIPMX Executive Library, a collection of assembly language programs available for users of TI's TMS9900 family of microprocessors; TM990 transportable cross support; Advanced Microprocessor Prototyping Lab (AMPL); and TM990 Series accessories.

Circle 600 on inquiry card.

Free Technical Catalog

The 1979 edition of *Engineering Guide: AC/DC and DC/DC Power Sources* contains 44 pages and includes 10 pages of design, applications, and selection information for both linear and switch mode regulated power sources. Designed to help the engineer select the most cost effective power source for an application, this reference includes complete specifications, dimension drawings and extended pricing information for 23 product families ranging from dual-in-line packaged single and dual output DC/DC converters to high-efficiency 76 W multioutput open frame power supplies. The Guide presents a variety of new products and lists price reductions for certain existing product groups. For further information, contact Semiconductor Circuits Inc, 218 River St, Haverhill MA 01830.

Circle 601 on inquiry card.

Publications on Business Computing

BusinessComputing Press has announced a series of publications informing businessmen and professionals about the effective utilization of low-cost microcomputers in business. The bimonthly journal, *BusinessComputing Review*, provides research reporting on business computers and applications software. The information is presented in a concise review format that simplifies the selection of systems based on business requirements. Related articles and commentary compliment the reviews.

The report, *Evaluating Small Business Software*, details the characteristics that any quality software package must possess in order to be used successfully. Specific evaluation criteria are provided for General Ledger, Accounts Receivable, Accounts Payable, Payroll, and Inventory Control packages.

BusinessComputing Newsletter, published 6 times annually, presents newsworthy information about the use of microcomputers in business. The newsletter contains tutorials on business computing and abstracts of new products. The newsletter is sent to subscribers of *BusinessComputing Review*.

BusinessComputing Review is available for an annual subscription rate of $25. The report, *Evaluating Small Business Software*, is $15 per copy. Contact Business Computing Press, POB 55056, Valencia CA 91355.

Circle 599 on inquiry card.

Computers for Business People

DDC Publications has announced the publication of a new book for people planning to buy a business computer system. The book, entitled *Winning the Computer Game* by Chris Kloek, presents a business computer guide to the layman or professional. The book recommends when a company should computerize, when it should not, how to buy systems and services, and how to live happily with them. *Winning the Computer Game* goes into detail on such subjects as custom versus packaged software, contract negotiation, installation management, and financing alternatives. Appropriate cautions are also provided.

The 178 page guide costs $12.95 and is available from DDC Publications, 5386 Hollister Ave, Santa Barbara CA 93111.

Circle 602 on inquiry card.

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The Minimax Series Computer is an integrated, compact unit containing the CPU, Disk Storage, 12 inch CRT, and Full Style Keyboard.

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PET to RS232 Serial	169
2 Way Serial/Communication	229
Modem Board for PET	375
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Second Cassette Drive	95
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apple

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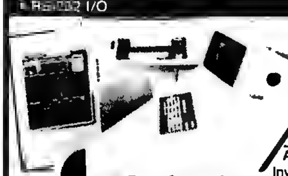

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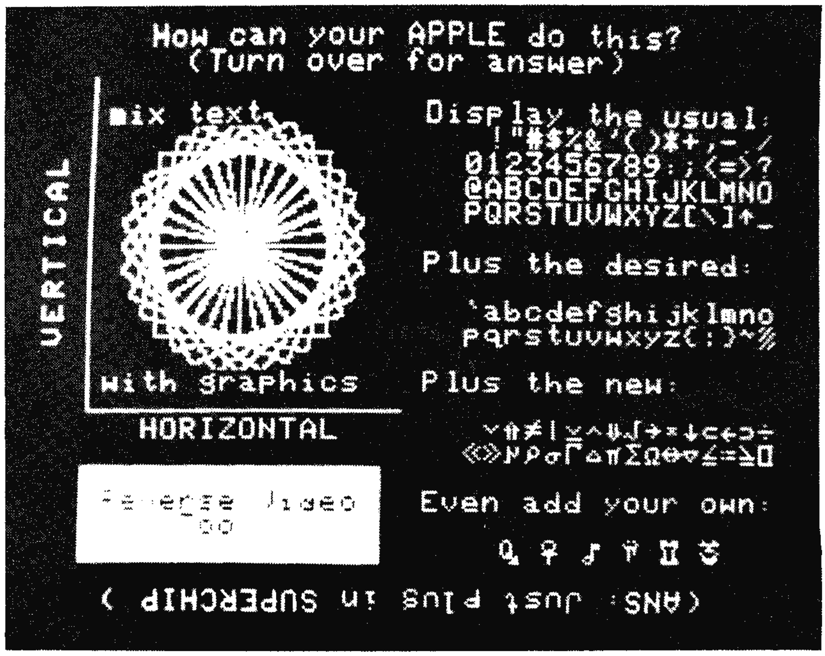
Foreign order desk - Telex 640055

What's New?

SOFTWARE

Add-on Graphics for Apple II Software

Superchip is a 16 K bit read-only memory designed to be plugged into the Apple II computer. The device provides an alternate set of I/O (input/output) service routines. The output routine can display, within the window concept, the full American Standard Code for Information Interchange (ASCII) character set (lowercase included), along with 32 new characters. User defined characters and character sets are also supported. Text is available in reverse video and may be freely mixed with high-resolution graphics. Characters can be rotated in 90 degree steps to achieve vertical and upside down printing. The new input routine permits the generation of all the new characters from the standard keyboard. An enhanced full screen editor is also provided with full cursor motion, character insertion and deletion, and several other features to increase the speed of editing. The Character Edit Program, which is available on cassette, permits one to construct or modify a character pattern by working with a magnified grid. Superchip was designed to be transparent to existing Apple software, and most programs run under it with no modification.



Superchip supports printing through either the communications or printer interface board and requires a 16 K byte system to operate. The Applesoft board is also supported. Superchip is priced at $99.95, and the Character Edit Program is $19.95. A disk interface is available for $19.95, and a word processing package costs $19.95. For further information, contact Eclectic Rentals Inc, 2830 Walnut Hill Ln, Dallas TX 75229.

Circle 638 on inquiry card.

Full Standard PILOT on PET

Commodore PET owners can get full standard PILOT on a minimum size PET with the PETPILOT language processor and editor which is suitable for preparing long programs of up to 80,000 characters. The product features full BASIC in compute statements as well as two new keywords designed to make PILOT programming easier and faster. All language features of the most recent PILOT standard are implemented. Only the tape drive supplied with the PET is required to run any PILOT program. While simple PILOT programs can be created on a single drive PET, authors writing long programs will need the second cassette drive offered by Commodore.

The package offered by the PET-PILOT project contains both programs, a sample PILOT program, a teacher's manual, a quick reference card, and licenses to run the programs on a single PET. The basic package costs $25. Specify the PET serial number to be licensed when ordering. Contact Dave Gomberg, 7 Gateview Ct, San Francisco CA 94116.

Circle 640 on inquiry card.

User-Oriented Database Management System

Global is a comprehensive and versatile user-oriented database management system for database creation and list maintenance. Global runs under CP/M and CBASIC2 on a microcomputer system in 40 K bytes of programmable memory. This general-purpose tool can be used for diverse applications such as inventory systems, mail lists, indexing collections, history reports, payroll files, accounting files, price lists, client lists, etc.

Some features include completely user-defined file structure with sequential, random, and linked file maintenance; user-defined number of fields; data transfer between records; automatic high-speed search algorithms with global search function, built-in indexed sequential-access method, etc; fast sort and merge utility; record-selectable output that can be formatted and printed on various forms; links to CP/M commands or programs with automatic return to Global; status reports on disk, data file and hardware environment; and disk used as extended memory.

Global is supplied on standard 8-inch IBM-compatible disks and comes complete with a BASIC subroutine library supplied in source code, and a comprehensive manual for $295. The manual alone is $35. For further information, contact Global Parameters, 1505 Ocean Ave, Brooklyn NY 11230.

Circle 639 on inquiry card.

Educational Software for Apple and TRS-80

Mind-Memory Improvement (Course Steps 1 and 2) has been designed for the Apple and the TRS-80 (Level I and II). It combines the advantages of the home computer with a teaching manual and audio cassettes. The Mind course teaches a system for memorizing lists of items easily. In addition, the course develops memorizing skills for more difficult material as well as teaching a system for listening and remembering. Emphasis is placed on remembering people's names and faces. The price for Mind-Step 1 is $24.95 and Mind-Step 2 is priced at $29.95. Both courses are available for $49.90. For further information, contact TYC Software, 40 Stuyvesant Manor, Geneseo NY 14454.

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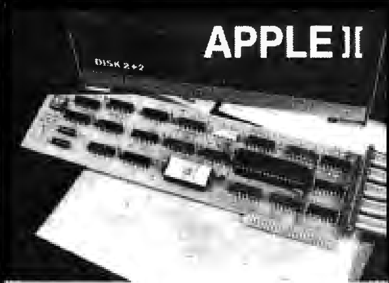
Circle 100 on inquiry card.

Circle 170 on inquiry card.



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each with max 6 relations with float
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• ALF MUSIC SYNTHESIZER	249.95
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tinyFORTH

tinyFORTH is the TRS-80 cassette oriented version of the dictionary based computer language called FORTH.

tinyFORTH includes these features: ✓ Dictionary-oriented structured high-level language ✓ Built-in assembler and text editor ✓ Enhanced graphics ✓ Cassette tape input and output ✓ Interpreter for quick program development ✓ Compiler for fast execution ✓ tinyFORTH is faster, more compact, and more powerful than BASIC ✓ tinyFORTH and FORTH programs are interchangeable ✓ Easy to use.

tinyFORTH cassette for 16K TRS-80 and full documentation....................... $29.95
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- fully programmable hand shake lines on each port
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page

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Length	100	500	1,000	Length	100	500	1,000
2.5 inches	1.04	2.98	5.16	6.5 inches	1.60	5.37	9.84
3	1.08	3.22	5.65	7	1.66	5.63	10.37
3.5	1.13	3.46	6.14	7.5	1.73	5.89	10.91
4	1.18	3.70	6.62	8	1.78	6.15	11.44
4.5	1.23	3.95	7.12	8.5	1.82	6.41	11.97
5	1.28	4.20	7.61	9	1.87	6.76	12.51
5.5	1.32	4.48	8.10	9.5	1.92	6.93	13.04
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Kit #1 $7.95 Less than 2.7¢/ft. (#30)	Kit #2 $19.95 Less than 2¢/ft. (#30)	KIT #3 $24.95 Less than 1.7¢/ft. (#30)	Kit #4 $44.95 Less than 1.6¢/ft. (#30)
250 3" 100 4"	250 2½" 250 5"	500 2½" 500 4½"	1000 2½" 1000 4½"
250 3" 100 5"	500 3" 100 5½"	500 3" 500 5"	1000 3" 1000 5"
100 4" 100 6"	500 3½" 250 6"	500 3½" 500 5½"	1000 3½" 1000 5"
	500 4" 100 6½"	500 4" 500 6"	1000 4" 1000 6"
	250 4½" 100 7"		

#30 Spools	1-4	5-9	10+
50 ft.	1.75	1.60	1.40
100 ft.	3.00	2.75	2.50
250 ft.	4.75	4.50	4.25
500 ft.	8.50	8.00	7.50
1000 ft.	14.50	12.50	10.50

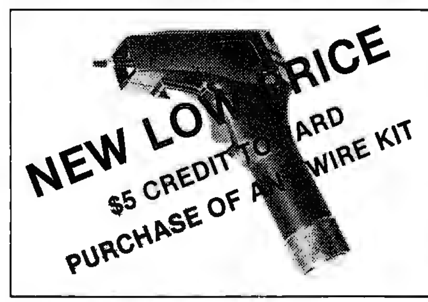
Wire Wrap Tool

BATTERY HOBBY TOOL*

- Auto Indexing
- Anti-Overwrapping
- Modified Wrap
- Includes #30 Bit

BW2628	Tool	**$19.85**
BT30	#30 Bit	**2.95**
BT2628	#26 Bit	**7.95**
BC1	Batteries & Charger	**11.00**

*Requires 2 "C" Niced Batteries



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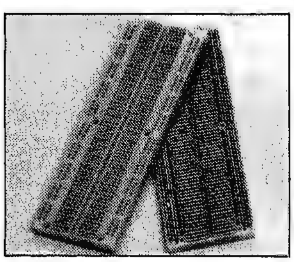

TI Edge Card Connectors

44 pin	ST	(.156" centers)	Gold	**1.95**
100 pin	ST	(.125" centers)	Gold	**2.50**
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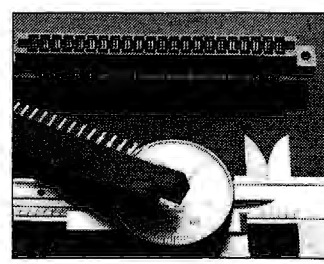
All are Gold 100 pin, IMSAI spacing.



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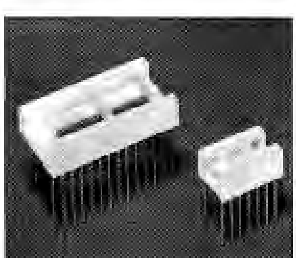

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3-level Gold Closed Entry Design

All prices include Gold

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14 pin	60	.32	$19.20
16 pin	52	.34	$17.68
18 pin	23	.50	$11.50
20 pin	21	.65	$13.65
22 pin	19	.70	$13.30
24 pin	10	.70	$7.00
28 pin	10	.95	$9.50
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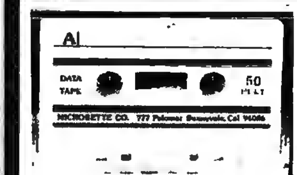

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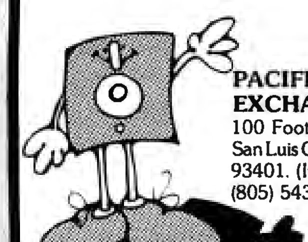

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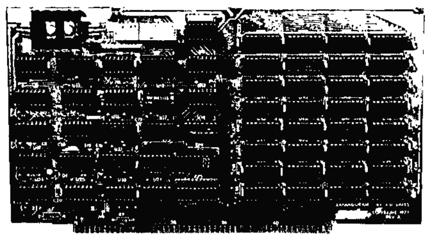

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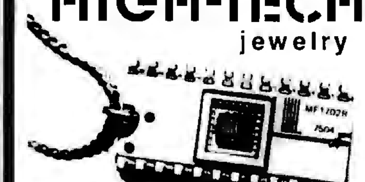

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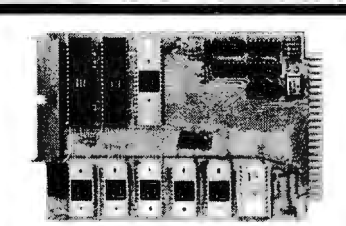

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This real-time audio spectrum analyzer is designed to fit inside the Commodore PET computer. The analyzer divides the audio spectrum from 20 Hz to 20 kHz into 31 one-third octave bands, and displays those bands, with their relative amplitudes, on the PET screen. The unit can be used for measuring sound and noise levels, for optimizing the equalization of a music or public address system, for checking the frequency response of audio components, and for speech and sound pattern recognition (useful for voice control systems).

Because of the capabilities of the Commodore PET, great flexibility in the manipulation of the analyzed data is permitted. The PET can store and recall spectral data, and make comparisons with past, future, or other channel data. There is a Peak Hold feature, which enables the unit to determine whether any preset levels have been exceeded. Programs to access the analyzer are written in BASIC; accordingly, three programs are provided with the unit: interactive operation, self-test, and minimal operation.

The analyzer comprises a single circuit board, which installs in about 5 minutes inside the PET. It has 31 one-third octave filters, detectors, an analog-to-digital converter, a 1 K byte read-only memory which contains machine language routines, and the necessary peripheral circuitry for transferring data into the PET memory. The board draws its power from the PET transformer.

The cost of the analyzer is $595. For further information, contact Eventide Clockworks Inc, 265 W 54th St, New York NY 10019.

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The Model 440 Paper Tiger printer is a low-cost impact printer from Integral Data Systems Inc, 14 Tech Cr, Natick MA 01760. Standard Paper Tiger features include full upper and lowercase 96-character set; adjustable form width; forms control with eight standard form lengths; both 80- and 132-column formats; choice of six or eight lines per inch vertical spacing; software-selectable character density; automatic multiline buffering; and both RS-232C serial and Centronics-compatible parallel interfaces. Multiple transmission rates from 110 to 1200 bits per second (bps) are also switch selectable. The new printer uses a stepper motor paper feed, and an automatic re-inking mechanism extends ribbon life. A variable character-size feature permits program controlled highlighting and formatting of copy.

The modular Paper Tiger uses a single printed circuit board that contains all printer electronics and uses a printhead rated at a life of over 100 M characters. An optional 2 K byte buffer and graphics package provides full dot-plotting graphics capability. The larger 2 K byte buffer holds the contents of a full video screen or 1920 characters. The Paper Tiger is priced at $995.

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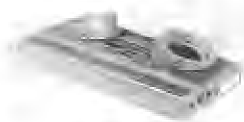

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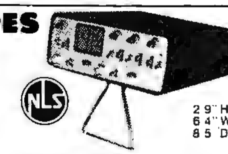

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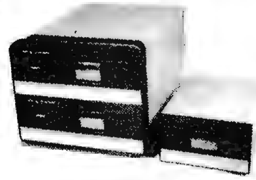

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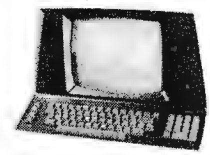

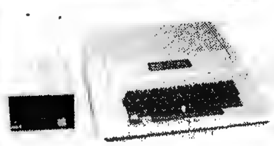

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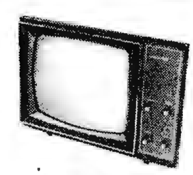

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- WORKS WITH Z-80, 8080 & 8085
- POWER CONSUMPTION 5 WATTS
- BANK SELECT • PHANTOM REFRESH
- NO WAIT STATES REQUIRED

WITHOUT MEMORY	$149 00
16K KIT	215 00
32K KIT	269 00
48K KIT	349 00
64K KIT	409 00

ADD $50 FOR ASSEMBLED & TESTED

• TO ORDER •

Phone orders invited, using credit cards. Or send personal check or money order. Add 1% for packing and handling. California resident add 6% sales tax. All equipment is shipped freight collect in factory carton with manufacturers warranty. All equipment subject to availability and price change without notice.

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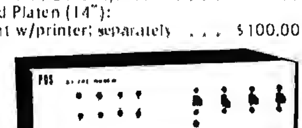
Pacific Office Systems — formerly at 2600 El Camino Real, Palo Alto, CA 94306
New Address: 918 INDUSTRIAL AVENUE, PALO ALTO, CA 94303
New Telephone: (415) 493-7455

PRINTER TERMINALS

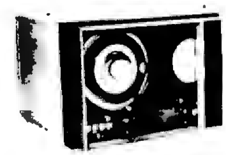
- ASCII SELECTRIC PRINTER/TYPEWRITER: Why settle for less than letter-quality printout from your computer? IBM Model 725 can be used as off-line typewriter or on-line printer. Complete with solenoids, power supply, case and ASCII interface card (TTL to CPU parallel port). Interface includes programmable ASCII translation table on EPROM with up to 8 tables for use with various type spheres. Feedback signals on completion of each print cycle insures fastest printing speed (15 cps), cleaned and adjusted.
  Price: programmed w/3 translation tables (one type sphere) $795.00
- SELECTRIC I/O TERMINALS by GTE/Information Systems). Both ASCII & IBM code versions with microcomputer interface software & hardware (RS-232 connector). Cassette drive models permit up to 2400 baud data transfer rate as well as off-line data storage, use as memory typewriter, & use as data entry device for office personnel familiar with Selectric typewriters but not computers. Wide-carriage, interchangeable type spheres; optional built-in modem. All units cleaned, adjusted & warranted.
  Model 5541 (IBM Correspondence code) . . . . $ 795.00
  Model 5550 (corres. code, built-in cassette drive) . . . $1195.00
  Model 5560 (ASCII code, built-in cassette drive) . . . $1295.00
- "DAISY-WHEEL" I/O TERMINALS: Both DIABLO and QUME versions of the industry standard "daisy-wheel" printing terminals are available. All have keyboards w/full ASCII character set & RS-232 serial interface. Models in stock usually include Diablo 1550, DTC 300 & 300Q, GenCom 300 & 300Q, and others. Prices for refurbished units range from $1800.00 to $2400.00
- DIABLO HYTYPE I Model 1200 PRINTER MECHANISM: Used, complete and tested. Requires power supply, case & mCPU interface. Tested: . . . $750.00
  6' Ribbon cable and connector for printer Main Logic PCB . . . . $ 10.00
  "As-is" spare printer PCB's for parts (Logic, Heat Sink, Control); each . . . . $ 20.00
  New Pin-feed Platen (14"): $50 if bought w/printer; separately . . . $100.00

MODEMS



- POS 103/202 "*MIX or MATCH*" MODEM: BELL 103 and/or BELL 202 FREQUENCIES: Unique POS control design permits use in one housing of both Bell-compatible 103 (0-300 baud) and 202 (0-1200 baud) modem modules originally made by VADIC Corp. for a telephone company subsidiary. FEATURES: RS-232 serial interface, auto-answer, auto-dial, LED display, telephone line interface via acoustic coupler, manual DAA, or auto-answer DAA (sold separately). FULLY ADJUSTED; no special tools required. 3,000 mile range over standard dial-up telephone lines.
  POS 103 MODEM $179.95
  POS 202 MODEM $249.95
  POS 202 MODEM (Auto-Answer) $279.95
  POS 103/202 MODEM $399.95

TAPE DRIVES & CONTROLLERS



- POS-100 NRZ1 TAPE DRIVE CONTROLLER/FORMATTER: Designed as interface between S-100 bus mCPU and 9-track, 800 BPI, NRZ1 tape drive. Allows microcomputerist to read and write IBM-compatible ½" mag tapes. Software provided for 8080 or Z-80 systems. Requires modification for drives of various mfrs. Std. version: 2 MHz 8080/Z-80 CPU for use with 12"/sec. PERTEC-style Tape Drive.
  Price: (Includes S-100 card, controller card, 10' cable, software listing) $750.00
- NRZ1 TAPE DRIVE by CIPHER Data Products: Full size PERTEC-style 800 BPI drive model 1008XX; 2400' Tape, 9 track, 25 to 37 ips, used, refurbished. Wt. approx. 120 lb. Price: $1500.00
- CONVERT 15" IBM OFFICE SELECTRIC TO I/O TYPEWRITER: Kit includes assembled solenoids, switches, wire harness, magnet driver PCB plus instructions for installation and mCPU interface . . $200.00
- DIGITAL CASSETTE DRIVE (from GTE/IS Terminal): 1800 baud, 6"/sec; AC motor; fwd/rewnd circuitry plus tape head, no read/write electronics . . . $25.00
- FORMS TRACTORS, Moore Variable width "Form A-Liner" for print terminals:
  a) Model 565P for 15" Carriage IBM Selectrics (used) $75.00
  b) Model K81 for QUME or DIABLO Hytype I or II printers (new) $90.00
- POWER SUPPLIES for Disk Drive, mCPU, tested under load shown:
  No. 519 (w/fan & AC cord): +5V reg. +12V reg., +24V, @4A (10 lb.) $39.95

NO RISK!! 15 DAY APPROVAL ON ALL MAIL-ORDERS

Full documentation included PLUS interface instructions where indicated. All equipment is shipped insured FOB Palo Alto within 14 days after check clears or COD order is received. Prices may change without notice. Call or write for details, quantity prices, catalog. 15 day return privilege PLUS 90 day no charge replacement of defective parts. All orders shipped from stock. No back orders, no substititions. Master Charge and VISA accepted.

Circle 296 on inquiry card.

Circle 54 on inquiry card.

7400 TTL

SN7400N	.16	SN7470N	.29	SN74160N	.89
SN7401N	.18	SN7472N	.29	SN74161N	.89
SN7402N	.18	SN7473N	.35	SN74162N	1.95
SN7403N	.18	SN7474N	.35	SN74163N	.89
SN7404N	18	SN7475N	.49	SN74164N	.89
SN7405N	.20	SN7476N	.35	SN74165N	.89
SN7406N	29	SN7479N	5.00	SN74166N	1.25
SN7407N	29	SN7480N	.50	SN74167N	1.95
SN7408N	.20	SN7482N	99	SN74170N	1.59
SN7409N	.20	SN7483N	.59	SN74172N	6.00
SN7410N	.18	SN7485N	.79	SN74173N	1.25
SN7411N	.25	SN7486N	.35	SN74174N	.89
SN7412N	25	SN7489N	1.75	SN74175N	.79
SN7413N	.40	SN7490N	.45	SN74176N	.79
SN7414N	.70	SN7491N	.59	SN74177N	.79
SN7416N	.25	SN7492N	.43	SN74179N	1.95
SN7417N	.25	SN7493N	.43	SN74180N	79
SN7420N	.20	SN7494N	65	SN74181N	1.95
SN7421N	29	SN7495N	65	SN74182N	.79
SN7422N	.39	SN7496N	.65	SN74184N	1.95
SN7423N	.25	SN7497N	3.00	SN74185N	1.95
SN7425N	.29	SN74100N	89	SN74186N	9.95
SN7426N	.29	SN74107N	.35	SN74188N	3.95
SN7427N	.25	SN74109N	.59	SN74190N	1.25
SN7429N	39	SN74116N	1.95	SN74191N	1.25
SN7430N	.20	SN74121N	35	SN74192N	.79
SN7432N	.25	SN74122N	.39	SN74193N	.79
SN7437N	25	SN74123N	.49	SN74194N	89
SN7438N	.25	SN74125N	.49	SN74195N	.69
SN7439N	.25	SN74126N	.49	SN74196N	.89
SN7440N	.20	SN74132N	.75	SN74197N	.89
SN7441N	.89	SN74136N	.75	SN74198N	1.49
SN7442N	.49	SN74141N	.79	SN74199N	1.49
SN7443N	.75	SN74142N	2.95	SN74S200	4.95
SN7444N	.75	SN74143N	2.95	SN74251N	.99
SN7445N	.75	SN74144N	2.95	SN74279N	.79
SN7446N	69	SN74145N	79	SN74283N	2.25
SN7447N	.59	SN74147N	1.95	SN74284N	3.95
SN7448N	.79	SN74148N	1.29	SN74285N	3.95
SN7450N	.20	SN74150N	89	SN74365N	.69
SN7451N	20	SN74151N	59	SN74366N	.69
SN7453N	.20	SN74152N	.59	SN74367N	.69
SN7454N	.20	SN74153N	.59	SN74368N	.69
SN7459A	.25	SN74154N	.99	SN74390N	1.95
SN7460N	.20	SN74155N	.79	SN74393N	1.95
		SN74156N	.79		
		SN74157N	65		

C/MOS

CD4000	.23			CD4070	.55
CD4001	.23			CD4071	.23
CD4002	.23	CD4028	.89	CD4072	.49
CD4006	1.19	C8029	1.19	CD4076	1.39
CD4007	25	CD4030	.49	CD4081	.23
CD4009	49	CD4035	.99	CD4082	.23
CD4010	49	CD4040	1.19	CD4093	.99
CD4011	.23	CD4041	1.25	CD4098	2.49
CD4012	.25	CD4042	.99	MC14409	14.95
CD4013	39	CD4043	.89	MC14410	14.95
CD4014	1.39	CD4044	.89	MC14411	14.95
CD4015	1.19	CD4046	1.79	MC14419	4.95
CD4016	.49	CD4047	2.50	MC14433	19.95
CD4017	1.19	CD4048	1.35	MC14506	.75
CD4018	.99	CD4049	49	MC14507	.99
CD4019	.49	CD4050	49	MC14562	14.50
CD4020	1.19	CD4051	1.19	MC14583	3.50
CD4021	1.39	CD4053	1.19	CD4508	3.95
CD4022	1.19	CD4056	2.95	CD4510	1.39
CD4023	.23	CD4059	9.95	CD4511	1.29
CD4024	79	CD4060	1.49	CD4515	2.95
CD4025	23	CD4066	.79	CD4518	1.29
CD4026	2.25	CD4068	.39	CD4520	1.29
CD4027	.69	CD4069	.45	CD4566	2.25

74C00

74C00	.39			74C163	2.49
74C02	.39			74C164	2.49
74C04	.39	74C85	2.49	74C173	2.60
74C08	.49	74C90	1.95	74C192	2.49
74C10	.39	74C93	1.95	74C193	2.49
74C14	1.95	74C95	1.95	74C195	2.49
74C20	39	74C107	1.25	74C922	7.95
74C30	.39	74C151	2.90	74C923	6.25
74C42	1.95	74C154	3.00	74C925	8.95
74C48	2.49	74C157	2.15	74C926	8.95
74C73	.89	74C160	2.49	80C95	1.50
74C74	.89	74C161	2.49	80C97	1.50

LINEAR

78MG	1.75			LM710N	.79
LM106H	.99			LM711N	.39
LM300H	.80	LM340K-18	1.35	LM723N/H	.55
LM301CN/H	.35	LM340K-24	1.35	LM733N	1.00
LM302H	75	LM340T-5	1.25	LM739N	1.19
LM304H	1.00	LM340T-6	1.25	LM741CN/H	.35
LM305H	.60	LM340T-8	1.25	LM741-14N	.39
LM307CN/H	35	LM340T-12	1.25	LM747N/H	.79
LM308CN/H	1.00	LM340T-15	1.25	LM748N/H	.39
LM309H	1.10	LM340T-18	1.25	LM1310N	1.95
LM309K	1.25	LM340T-24	1.25	LM1458CN/H	.59
LM310CN	1.1 5	LM358N	1.00	MC1488N	1.95
LM311N/H	90	LM370N	1.95	MC1489N	.85
LM312H	1.95	LM373N	3.25	LM1496N	.95
LM317K	6. 50	LM377N	4.00	LM1556V	17 5
LM318CN/H	1.50	LM380N	1.25	MC1741SCP	3.00
LM319N	1.30	LM380CN	.99	LM2111N	1.95
LM320K-5	1.35	LM381N	1.79	LM2901N	2.95
LM320K-5.2	1.35	LM382N	1.79	LM3053N	1.50
LM320K-12	1.35	NE501N	8.00	LM3065N	1.49
LM320K-15	1.35	NE510A	6.00	LM3900N(3401)	59
LM320K-18	1.35	NE529A	4.95	LM3905N	1.49
LM320K-24	1.35	NE531H/V	3.95	LM3909N	1.25
LM320T-5	1.25	NE536T	6.00	MC5558V	59
LM320T-5.2	1.25	NE540L	6.00	8038B	4.95
LM320T-8	1.25	NE544N	4.95	LM75450N	49
LM320T-12	1.25	NE550N	1.30	75451CN	39
LM320T-15	1.25	NE555V	.39	75452CN	39
LM320T-18	1.25	NE556N	99	75453CN	39
LM320T-24	1.25	NE560B	5.00	75454CN	39
LM323K-5	5.95	NE561B	5.00	75491CN	.79
LM324N	1.49	NE562B	5.00	75492CN	.89
LM339N	99	NE565N/H	1.25	75493N	.89
LM340K-5	1.35	NE566CN	1.75	75494CN	.89
LM340K-6	1.35	NE567V/H	.99	RC4136	1.25
LM340K-8	1.35	NE570N	4.95	RC4151	3.95
LM340K12	1.35	LM703CN/H	.69	RC4194	4.95
LM340K-15	1.35	LM709N/H	29	RC4195	4.49

74LS00TTL

74LS00	29			74LS138	89
74LS01	29			74LS139	89
74LS02	29	74LS47	89	74LS151	.89
74LS03	29	74LS51	29	74LS155	89
74LS04	35	74LS54	29	74LS157	.89
74LS05	35	74LS55	.29	74LS160	1.15
74LS08	.29	74LS73	.45	74LS161	1.15
74LS09	.35	74LS74	45	74LS162	1.25
74LS10	29	74LS75	.59	74LS163	1.15
74LS11	.75	74LS76	45	74LS164	1.25
74LS13	.59	74LS78	49	74LS175	99
74LS14	1.25	74LS83	89	74LS181	2.49
74LS15	35	74LS85	1.25	74LS190	1.15
74LS20	29	74LS86	45	74LS191	1.15
74LS21	35	74LS90	59	74LS192	1.15
74LS22	.35	74LS92	75	74LS193	1.15
74LS26	.35	74LS93	75	74LS194	1.15
74LS27	.35	74LS95	99	74LS195	1.15
74LS28	.35	74LS96	1.15	74LS253	.99
74LS30	.29	74LS107	45	74LS257	.89
74LS32	.35	74LS109	.45	74LS258	1.75
74LS37	.45	74LS112	.45	74LS260	.69
74LS40	.35	74LS123	1.25	74LS279	.75
74LS42	.89	74LS125	89	74LS367	.75
		74LS132	99	74LS368	.75
		74LS136	.49	74LS670	2.49

INTERNATIONAL TIME ZONE CLOCK

- Four individually programmed clocks to time zone of your choice
- Single synch. switch to synchronize time zones
- Alterable vinyl lettering (change zone identity lettering when desired)
- Hrs., minutes & seconds displayed for each zone
- Hi-bright LED digits (.6" character height)
- Continuous AM or PM indication using 12 hr. format

SPECIFICATIONS:
Power: Wall plug transformer input voltage 117VAC60Hz output voltage 12VAC 60Hz.
Case: Standard: wood molding w/simulated walnut finish redplexiglasslens. Black textured ABS back.
Dimensions: 5" x 18"

T2-4 Assembled. $159.95

DIGITAL STOP TIMER OR CLOCK

- 10 hour stopwatch timer
- 12 or 24 hour operation
- 6 function controls: fast, slow, hold, reset, 12/24 hour and 5/6 digit
- Large .560" red display
- 50Hz or 60Hz operation
- Includes mounting bracket
- Size: 4" x 2" x 5"

JB1001A Assembled. . . $59.95

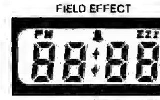
DISCRETE LEDS

.200" dia.			.125" dia.		
XC556R	red	5/$1	XC209R	red	5/$1
XC556G	green	4/$1	XC209G	green	4/$1
XC556Y	yellow	4/$1	XC209Y	yellow	4/$1
XC556C	clear	4/$1			
.200" dia.			.185" dia.		
XC22R	red	5/$1	XC526R	red	5/$1
XC22G	green	4/$1	XC526G	green	4/$1
XC22Y	yellow	4/$1	XC526Y	yellow	4/$1
.170" dia.			XC526C	clear	4/$1
MV10B	red	4/$1	.190" dia.		
.085" dia.			XC111R	red	5/$1
MV50	red	6/$1	XC111G	green	4/$1
			XC111Y	yellow	4/$1
			XC111C	clear	4/$1

INFRA-RED LED
1/4"x1/4"x1/16" flat
5/$1

TIMEX T1001

LIQUID CRYSTAL DISPLAY
CLASS II
FIELD EFFECT



4 DIGIT — .5" CHARACTERS
THREE ENUNCIATORS
2.00" X 1.20" PACKAGE
INCLUDES CONNECTOR

T1001-Transmissive $7.95
T1001A-Reflective 8.25

TELEPHONE/KEYBOARD CHIPS

AY-5-9100	Push Button Telephone Dialler	$14.95
AY-5-9200	Repertory Dialler	14.95
AY-5-9500	CMOS Clock Generator	4.95
AY-5-2376	Keyboard Encoder (88 keys)	14.95
HD0165	Keyboard Encoder (16 keys)	7.95
74C922	Keyboard Encoder (16 keys)	7.95
74C923	Keyboard Encoder (20 keys)	6.25

ICM CHIPS

ICM7045	CMOS Precision Timer	24.95
ICM7205	CMOS LED Stopwatch/Timer	19.95
ICM7207	Oscillator Controller	7.50
ICM7208	Seven Decade Counter	19.95
ICM7209	Clock Generator	6.95

NMOS READ ONLY MEMORIES

MCM6571	128 X 9 X 7 ASCII Shifted with Greek	13.50
MCM6574	128 X 9 X 7 Math Symbol & Pictures	13.50
MCM6575	128 X 9 X 7 Alpha Control Char. Gen	13.50

MISCELLANEOUS

TL074CN	Quad Low Noise bi-fet Op Amp	2.49
TL494CN	Switching Regulator	4.49
TL496CP	Single Switching Regulator	1.75
11C90	Divide 10/11 Prescaler	19.95
95H90	Hi-Speed Divide 10/11 Prescaler	11.95
4N33	Photo-Darlington Opto-Isolator	3.95
MK50240	Top Octave Freq. Generator	17.50
DS0026CH	5Mhz 2-phase MOS clock driver	3.75
TIL308	.27" red num. display w/integ. logic chip	10.95
MM5320	TV Camera Sync. Generator	14.95
MM5330	4½ Digit DPM Logic Block (Special)	3.95
LD110/111	3½ Digit A/D Converter Set	25.00/set
MC14433P	3½ Digit A/D Converter	13.95

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Photo Transistor Opto-Isolator
(Same as MCT 2 or 4N25)
49¢ each

SN 76477
SOUND GENERATOR
Generates Complex Sounds
Low Power - Programmable
$3.95 each

TV GAME CHIP AND CRYSTAL
AY-3-8500-1 and 2.01 MHZ Crystal (Chip & Crystal includes score display, 6 games and select angles. etc. **7.95/set**

EXAR

XR205	$8.40			XR2242CP	1.50
XR210	4.40			XR2264	4.25
XR215	4.40			XR2556	3.20
XR320	1.55			XR2567	2.99
XR-L555	1.50	JE2206KB	19.95	XR3403	1.25
XR555	.39	XR1800	3.20	XR4136	1.25
XR556	.99	XR2206	4.40	XR4151	3.95
XR567CP	.99	XR2207	3.85	XR4194	4.95
XR567CT	1.25	XR2208	5.20	XR4202	3.60
XR1310P	1.95	XR2209	1.75	XR4212	2.05
XR1468CN	3.85	XR2211	5.25	XR4558	.75
XR1488	1.95	XR2212	4.35	XR4739	1.15
XR1489	1.95	XR2240	3.45	XR4741	1.47

DISPLAY LEDS

TYPE	POLARITY	HT	PRICE	TYPE	POLARITY	HT	PRICE
MAN 1	Common Anode-red	270	2.95	MAN6730	Common Anode-red ± 1	.560	.99
MAN 2	5 x 7 Dot Matrix-red	.300	4.95	MAN 6740	Common Cathode-red-D.D.	.560	.99
MAN 3	Common Cathode-red	125	.25	MAN 6750	Common Cathode-red ± 1	.560	.99
MAN 4	Common Cathode-red	187	1.95	MAN 6760	Common Anode-red	.560	.99
MAN 7G	Common Anode-green	.300	1.25	MAN 6780	Common Cathode-red	.560	.99
MAN 7Y	Common Anode-yellow	.300	.99	DL701	Common Anode-red ± 1	.300	.99
MAN 72	Common Anode-red	300	.99	DL704	Common Cathode-red	.300	.99
MAN 74	Common Cathode-red	.300	1.25	DL707	Common Anode-red	.300	.99
MAN 82	Common Anode-yellow	.300	.49	DL728	Common Cathode-red	.500	1.49
MAN 84	Common Cathode-yellow	.300	.99	DL741	Common Anode-red	.600	1.25
MAN3620	Common Anode-orange	.300	.49	DL746	Common Anode-red ± 1	.630	1.49
MAN 3630	Common Anode-orange ± 1	.300	.99	DL747	Common Anode-red	.600	1.49
MAN 3640	Common Cathode-orange	.300	.99	DL749	Common Cathode-red ± 1	.630	1.49
MAN-1610	Common Anode-orange	300	.99	DL750	Common Cathode-red	.600	1.49
MAN4640	Common Cathode-orange	.400	.99	DL338	Common Cathode-red	.110	.35
MAN 4710	Common Anode-red	400	.99	FND70	Common Cathode	.250	.69
MAN 4730	Common Anode-red ± 1	.400	.99	FND358	Common Cathode ± 1	.357	.99
MAN 4740	Common Cathode-red	.400	.99	FND359	Common Cathode	.357	.75
MAN 4810	Common Anode-yellow	.400	.99	FND503	Common Cathode(FND500)	.500	.99
MAN 4840	Common Cathode-yellow	.400	.99	FND507	Common Anode (FND510)	.500	.99
MAN6610	Common Anode-orange-D.D	.560	.99	5082-7730	Common Anode-red	.300	.99
MAN 6630	Common Anode-orange ± 1	.560	99	HDSP-3400	Common Anode-red	.600	1.50
MAN 6640	Common Cathode-orange-D.D	.660	99	HDSP-3403	Common Cathode red	.800	1.50
MAN 6650	Common Cathode-orange ± 1	.560	.99	5082-7300	4 x 7 sgl Digit-RHDP	.600	19.95
MAN 6660	Common Anode-orange	.560	.99	5082-7302	4 x 7 Sgl. Digit-LHDP	600	19.95
MAN 6680	Common Cathode-orange	.560	.99	5082-7304	Overrange character (±1)	.600	15.00
MAN 6710	Common Anode-red-D.D.	.560	.99	5082-7340	4 x 7 Sgl. Digit-Hexadecimal	.600	22.50

DIODES

TYPE	VOLTS	W	PRICE	TYPE	VOLTS	W	PRICE
				1N4002	100 PIV	1 AMP	12/1.00
				1N4003	200 PIV	1 AMP	12/1.00
1N746	3.3	400m	4/1.00	1N4004	400 PIV	1 AMP	12/1.00
1N751	5.1	400m	4/1.00	1N4005	600 PIV	1 AMP	10/1.00
1N752	5.6	400m	4/1.00	1N4006	800 PIV	1 AMP	10/1.00
1N753	6.2	400m	4/1.00	1N4007	1000 PIV	1 AMP	10/1.00
1N754	6.8	400m	4/1.00	1N3600	50	200m	6/1.00
1N757	9.0	400m	4/1.00	1N4148	75	10m	15/1.00
1N759	12.0	400m	4/1.00	1N4154	35	10m	12/1.00
1N959	8.2	400m	4/1.00	1N4733	5.1	1w	28
1N965	15	400m	4/1.00	1N4734	5.6	1w	28
1N5232	5.6	500m	28	1N4735	6.2	1w	28
1N5234	6.2	500m	28	1N4736	6.8	1w	28
1N5235	6.8	500m	28	1N4738	8.2	1w	28
1N5236	7.5	500m	28	1N4742	12	1w	28
1N5242	12	500m	28	1N4744	15	1w	28
1N5245	15	500m	28	1N1183	50 PIV	35 A	1.60
1N456	25	40m	6/1.00	1N1184	100 PIV	35 AMP	1.70
1N458	150	7m	6/1.00	1N1185	150 PIV	35 AMP	1.70
1N485A	180	10m	5/1.00	1N1186	200 PIV	35 AMP	1.80
1N4001	50 PIV	1 AMP	12/1.00	1N1188	400 PIV	35 AMP	3.00

RCA LINEAR

CA3013T	2.15	CA3082N	2.00
CA2023T	2.56	CA3083N	1.60
CA3035T	2.48	CA3086N	.85
CA3039T	1.35	CA3069N	3.75
CA3046N	1.30	CA3130T	1.39
CA3059N	3.25	CA3140T	1.25
CA3060N	3.25	CA3160T	1.25
CA3080T	.85	CA3401N	59
CA3081N	2.00	CA3600N	3.50

CALCULATOR CHIPS/DRIVERS

MM5725	$2.95
MM5738	2.95
DM8864	2.00
DM8865	1.00
DM8887	.75
DM8889	.75
9374 7 seg.	
C.A. LED driver	1.50

CLOCK CHIPS

MM5309	$4.95
MM5311	4.95
MM5312	4.95
MM5314	4.95
MM5316	6.95
MM5318	9.95
MM5369	2.95
MM5387/1998A	4.95
CT 7001	6.95

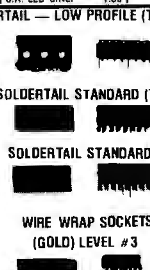
MOTOROLA

MC1408L7	$4.95
MC1408L8	5.75
MC1439L	2.95
MC3022P	2.95
MC3061P	3.50
MC4016(74416)	7.50
MC4024P	3.95
MC4040P	6.95
MC4044P	4.50

SCR AND FW BRIDGE RECTIFIERS

C36D	15A @ 400V	SCR(2N1849)	$1.95
C36M	35A @ 600V	SCR	1.95
2N2328	1.6A @ 300V	SCR	.50
MDA 980-1	12A @ 50V	FW BRIDGE REC.	1.95
MDA 980-3	12A @ 200V	FW BRIDGE REC.	1.95

IC SOLDERTAIL — LOW PROFILE (TIN) SOCKETS



	1-24	25-49	50-100		1-24	25-49	50-100
8 pin LP	$.17	.16	.15	22 pin LP	$ .37	.36	.35
14 pin LP	.20	.19	18	24 pin LP	.38	.37	.36
16 pin LP	.22	.21	.20	28 pin LP	.45	.44	.43
18 pin LP	.29	.28	.27	36 pin LP	.60	.59	.58
20 pin LP	.34	.32	.30	40 pin LP	.63	.62	.61

SOLDERTAIL STANDARD (TIN)

	1-24	25-49	50-100		1-24	25-49	50-100
14 pin ST	$.27	.25	.24	28 pin ST	$ .99	.90	.81
16 pin ST	.30	.27	.25	36 pin ST	1.39	1.26	1.15
18 pin ST	.35	.32	.30	40 pin ST	1.59	1.45	1.30
24 pin ST	49	.45	42				

SOLDERTAIL STANDARD (GOLD)

	1-24	25-49	50-100		1-24	25-49	50-100
8 pin SG	$.30	.27	.24	24 pin SG	$ .70	.63	.57
14 pin SG	.35	.32	.29	28 pin SG	1.10	1.00	.90
16 pin SG	.38	.35	32	36 pin SG	1.65	1.40	1.26
18 pin SG	.52	.47	.43	40 pin SG	1.75	1.59	1.45

WIRE WRAP SOCKETS (GOLD) LEVEL #3

	1-24	25-49	50-100		1-24	25-49	50-100
8 pin WW	$.39	.38	.31	22 pin WW	$ .95	.85	.75
10 pin WW	.45	.41	.37	24 pin WW	1.05	.95	.85
14 pin WW	.39	38	37	28 pin WW	1.40	1.25	1.10
16 pin WW	43	.42	.41	36 pin WW	1.59	1.45	1.30
18 pin WW	.75	.68	62	40 pin WW	1.75	1.55	1.40
20 pin WW	.85	.79	.72				

1/4 WATT RESISTOR ASSORTMENTS – 5%

ASST. 1	5 ea	10 OHM / 27 OHM	12 OHM / 33 OHM	15 OHM / 39 OHM	18 OHM / 47 OHM	22 OHM / 56 OHM	50 PCS	$1.75
ASST. 2	5 ea	68 OHM / 180 OHM	82 OHM / 220 OHM	100 OHM / 270 OHM	120 OHM / 330 OHM	150 OHM / 390 OHM	50 PCS	1.75
ASST. 3	5 ea.	470 OHM / 1.2K	560 OHM / 1.5K	680 OHM / 1.8K	820 OHM / 2.2K	1K / 2.7K	50 PCS	1.75
ASST. 4	5 ea.	3.3K / 8.2K	3.9K / 10K	4.7K / 12K	5.6K / 15K	6.8K / 18K	50 PCS	1.75
ASST. 5	5 ea.	22K / 56K	27K / 68K	33K / 82K	39K / 100K	47K / 120K	50 PCS	1.75
ASST. 6	5 ea	150K / 390K	180K / 470K	220K / 560K	270K / 680K	330K / 820K	50 PCS	1.75
ASST. 7	5 ea	1M / 2.7M	1.2M / 3.3M	1.5M / 3.9M	1.8M / 4.7M	2.2M / 5.6M	50 PCS	1.75

ASST. 8R Includes Resistor Assortments 1-7 (350 PCS.) **$9.95 ea.**

TRANSISTORS

C106B1	.50			2N3904	4/1.00
MPSA05	.30	2N3055	.89	2N3905	4/1.00
MPSA06	5/1.00	MJE3055	1.00	2N3906	4/1.00
TIS97	6/1.00	2N3392	5/1.00	2N4013	3/1.00
TIS98	6/1.00	2N3398	5/1.00	2N4123	6/1.00
40409	1.75	PN3567	3/1.00	PN4240	4/1.00
40410	1.75	PN3568	4/1.00	PN4250	4/1.00
40673	1.75	PN3569	4/1.00	2N4400	4/1.00
2N918	4/1.00	MPS3638A	5/1.00	2N4401	4/1.00
2N2219A	2/1.00	MPS3702	5/1.00	2N4402	4/1.00
2N2221A	4/1.00	2N3704	5/1.00	2N4403	4/1.00
2N2222A	5/1.00	MPS3704	5/1.00	2N4409	5/1.00
PN2222 Plastic	7/1.00	2N3705	5/1.00	2N5086	4/1.00
2N2369A	4/1.00	MPS3705	5/1.00	2N5087	4/1.00
MPS2369	5/1.00	2N3706	5/1.00	2N5088	4/1.00
2N2484	4/1.00	MPS3706	5/1.00	2N5089	4/1.00
2N2906	4/1.00	2N3707	5/1.00	2N5129	5/1.00
2N2907	5/1.00	2N3711	5/1.00	PN5134	5/1.00
PN2907 Plastic	7/1.00	2N3724A	.65	PN5138	5/1.00
2N2925	5/1.00	2N3725A	1.00	2N5139	5/1.00
MJE2955	1.25	2N3772	2.25	2N5210	5/1.00
2N3053	2/1.00	2N3823	1.00	2N5449	3/1.00
		2N3903	5/1.00	2N5951	3/1.00

CAPACITOR CORNER

50 VOLT CERAMIC DISC CAPACITORS

	1-9	10-99	100+		1-9	10-99	100+
10 pf	.05	.04	.03	.001µF	.05	.04	.035
22 pf	.05	.04	.03	.0047 µF	.05	.04	.035
47 pf	.05	.04	.03	.01µF	.05	.04	.035
100 pf	.05	.04	.03	.022µF	.06	.05	.04
220 pf	.05	.04	.03	.047µF	.06	.05	.04
470 pf	.05	.04	.035	.1µF	.12	.09	.075
100 VOLT MYLAR FILM CAPACITORS							
.001mf	.12	.10	.07	.022mf	.13	.11	.08
.0022	.12	.10	.07	.047mf	.21	.17	.13
.0047mf	.12	.10	.07	.1mf	.27	.23	.17
.01mf	.12	.10	.07	.22mf	.33	.27	.22
+20% DIPPED TANTALUMS (SOLID) CAPACITORS							
.1/35V	.28	.23	.17	1.5/35V	.30	.26	.21
.15/35V	.28	.23	.17	2.2/35V	.35	.31	.27
.22/35V	.28	.23	.17	3.3/25V	.35	.31	.27
.33/35V	.28	.23	.17	4.7/25V	.33	.28	.23
.47/35V	.28	.23	.17	6.8/25V	.49	.45	.35
.68/35V	.28	.23	.17	15/25V	.75	.68	.59
1.0/35V	.28	.23	.17	22/6V	.75	.60	.50
MINIATURE ALUMINUM ELECTROLYTIC CAPACITORS							
Axial Lead				Radial Lead			
.47/50V	.15	.13	.10	.47/25V	.15	.13	.10
1.0/50V	.16	.14	.11	.47/50V	.16	.14	.11
3.3/50V	.14	.12	.09	1.0/16V	.15	.13	.10
4.7/25V	.15	.13	.10	1.0/25V	.16	.14	.11
10/25V	.15	.13	.10	1.0/50V	.16	.14	.11
10/50V	.16	.14	.12	4.7/16V	.15	.13	.10
22/25V	.17	.15	.12	4.7/25V	.15	.13	.10
22/50V	.24	.20	.18	4.7/50V	.16	.14	.11
47/25V	.19	.17	.15	10/16V	.14	.12	.09
47/50V	.25	.21	.19	10/25V	.15	.13	.10
100/25V	.24	.20	.18	10/50V	.16	.14	.12
100/50V	.35	.30	.28	47/50V	.24	.21	.19
220/25V	.32	.28	.25	100/16V	.19	.15	.14
220/50V	.45	.41	.38	100/25V	.24	.20	.18
470/25V	.33	.29	.27	100/50V	.35	.30	.28
1000/16V	.55	.50	.45	220/16V	.23	.17	.16
2200/16V	.70	.62	.55	470/25V	.31	.28	.26

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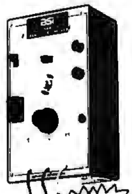
Circle 200 on inquiry card.

Transistor Checker



— Completely Assembled —
— Battery Operated —

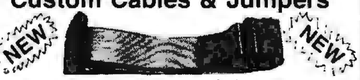
The ASI Transistor Checker is capable of checking a wide range of transistor types, either "in circuit" or out of circuit. To operate, simply plug the transistor to be checked into the front panel socket, or connect it with the alligator clip test leads provided. The unit safely and automatically identifies low, medium and high-power PNP and NPN transistors. Size: 3¾" x 6¼" x 2"
"C" cell battery not included.

ON SALE!

Trans-Check $19.95 ea.

Custom Cables & Jumpers

NEW! NEW!



DB 25 Series Cables

Part No.	Cable Length	Connectors	Price
DB25P-4-P	4 Ft.	2-DP25P	$15.95 ea.
DB25P-4-S	4 Ft.	1-DP25P/1-25S	$16.95 ea.
DB25S-4-S	4 ft.	2-DP25S	$17.95 ea.
		Dip Jumpers	
DJ14-1	1 ft.	1-14 Pin	$1.59 ea.
DJ16-1	1 ft.	1-16 Pin	1.79 ea.
DJ24-1	1 ft.	1-24 Pin	2.79 ea.
DJ14-1-14	1 ft.	2-14 Pin	2.79 ea.
DJ16-1-16	1 ft.	2-16 Pin	3.19 ea.
DJ24-1-24	1 ft.	2-24 Pin	4.95 ea.

For Custom Cables & Jumpers, See JAMECO 1979 Catalog for Pricing

CONNECTORS

25 Pin-D Subminiature

DB25P (as pictured)	PLUG (Meets RS232)	$2.95
DB25S	SOCKET (Meets RS232)	$3.50
DB51226-1	Cable Cover for DB25P or DB25S	$1.75

PRINTED CIRCUIT EDGE-CARD

156 Spacing-Tin-Double Read-Out — Bifurcated Contacts — Fits .054 to .070 P.C. Cards

15/30 SE	PINS (Solder Eyelet)		$1.95
18/36 SE	PINS (Solder Eyelet)		$2.49
22/44 SE	PINS (Solder Eyelet)		$2.95
22/44 WW	PINS (Wire Wrap)		$3.95
50/100 WW	PINS (Wire Wrap)	R681-1	$6.95
(.125 Spacing)			

4-Digit Clock Kit

- Bright .357" ht. red display
- Sequential flashing colon
- 12 or 24 hour operation
- Extruded aluminum case (black)
- Pressure switches for hours, minutes & hold functions
- Includes all components, case and wall transformer
- Size: 3¼ x 1¾ x 1¼

JE730 .... $14.95

Jumbo 6-Digit Clock Kit

- Four .630"ht. and two .300"ht. common anode displays
- Uses MM5314 clock chip
- Switches for hours, minutes and hold functions
- Hours easily viewable to 30 feet
- Simulated walnut case
- 115VAC operation
- 12 or 24 hour operation
- Includes all components, case and wall transformer
- Size: 6¾ x 3⅛ x 1¾

JE747 .... $29.95

- Bright .300 ht. comm. cathode display
- Uses MM5314 clock chip
- Switches for hours, minutes and hold modes
- Hrs. easily viewable to 20 ft.
- Simulated walnut case
- 115 VAC operation
- 12 or 24 hr. operation
- Incl. all components, case & wall transformer
- Size: 6¾" x 3-1/8" x 1¾"

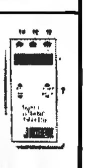
JE701

6-Digit Clock Kit $19.95

REMOTE CONTROL TRANSMITTER & RECEIVER

$19.95

Digital Stopwatch Kit



- Use Intersil 7205 Chip
- Plated thru double-sided P.C. Board
- LED display (red)
- Times to 59 min. 59.59 sec. with auto reset
- Quartz crystal controlled
- Three stopwatches in one: single event, split (cummulative) & taylor (sequential timing)
- Uses 3 penlite batteries
- Size: 4.5" x 2.15" x .90"

JE900 $39.95

MICROPROCESSOR COMPONENTS

8080A/8080A SUPPORT DEVICES

8080A	CPU	$ 7 95
8212	8-Bit Input/Output	3,25
8214	Priority Interrupt Control	5.95
8216	Bi-Directional Bus Driver	3.49
8224	Clock Generator/Driver	3.95
8226	Bus Driver	3 49
8228	System Controller/Bus Driver	4 95
8238	System Controller	5.95
8251	Prog. Comm. I/O (USART)	7.95
8253	Prog. Interval Timer	14.95
8255	Prog. Periph. I/O (PPI)	9.95
8257	Prog. DMA Control	19.95
8259	Prog. Interrupt Control	19.95

6800/6800 SUPPORT DEVICES

MC6800	MPU	$14.95
MC6802CP	MPU with Clock and Ram	24.95
MC6810API	128X8 Static Ram	5.95
MC6821	Periph. Inter. Adapt (MC6820)	7.49
MC6828	Priority Interrupt Controller	12.95
MC6830L8	1024X8 Bit ROM (MC68A30-8)	14 95
MC6850	Asynchronous Comm Adapter	7 95
MC6852	Synchronous Serial Data Adapt	9 95
MC5850	0-600 bps Digital MODEM	12.95
MC6862	2400bps Modulator	14 95
MC6880A	Quad 3-State Bus. Trans. (MC8T26)	2 25

MICROPROCESSOR CHIPS—MISCELLANEOUS

Z80(780C)	CPU	$14 95
Z80A(780-1)	CPU	16.95
CDP1802	CPU	19.95
2650	MPU	19.95
6502	CPU	11 95
8035	8-Bit MPU w/clock, RAM, I/O lines	19.95
P8085	CPU	19 95
TMS9900JL	16-Bit MPU w/hardware, multiply & divide	49.95

SHIFT REGISTERS

MM500H	Dual 25 Bit Dynamic	$ .50
MM503H	Dual 50 Bit Dynamic	.50
MM504H	Dual 16 Bit Static	.50
MM506H	Dual 100 Bit Static	.50
MM510H	Dual 64 Bit Accumulator	.50
MM5016H	500/512 Bit Dynamic	.89
2504T	1024 Dynamic	3.95
2518	Hex 32 Bit Static	4 95
2522	Dual 132 Bit Static	2.95
2524	512 Static	.99
2525	1024 Dynamic	2.95
2527	Dual 256 Bit Static	2.95
2528	Dual 250 Static	4 00
2529	Dual 240Bit Static	4 00
2532	Quad 80 Bit Static	2 95
3341	Fifo	6.95
74LS670	4X4 Register File (TriState)	2.49

UART'S

A-Y-5-1013	30K BAUD	5 95

MICROPROCESSOR MANUALS

M-Z80	User Manual	$7.50
M-CDP1802	User Manual	7.50
M-2650	User Manual	5.00

ROM'S

2513(2140)	Character Generator(upper case)	$9.95
2513(3021)	Character Generator(lower case)	9.95
2516	Character Generator	10.95
MM5230N	2048-Bit Read Only Memory	1.95

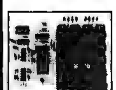
RAM'S

1101	256X1	Static	$1.49
1103	1024X1	Dynamic	.99
2101(8101)	256X4	Static	3.95
2102	1024X1	Static	1.75
21L02	1024X1	Static	1.95
2111(8111)	256X4	Static	3.95
2112	256X4	Static MOS	4.95
2114	1024X4	Static 450ns	7.95
2114L	1024X4	Static 450ns low power	10.95
2114-3	1024X4	Static300ns	10.95
2114L-3	1024X4	Static 300ns low power	11.95
5101	256X4	Static	7.95
5280/2107	4096X1	Dynamic	4.95
7489	16X4	Static	1.75
74S200	256X1	Static Tristate	4.95
93421	256X1	Static	2.95
UPD414 (MK4027)	4K	Dynamic 16 pin	4.95
UPD416 (MK4116)	16K	Dynamic 16 pin 250ns	9.95
TMS4044-45NL	4K	Static	14.95
TMS4045	1024X4	Static	14.95
2117	16,384X1	Dynamic 350ns (house marked)	9.95
MM5262	2KX1	Dynamic	4/1.00

PROM'S

1702A	2048	FAMOS	$5.95
2716INTEL	16K*	EPROM	59.95
TMS2516	16K*	EPROM	49.95
(2716)	*Requires single +5V power supply		
TMS2532	4KX8	EPROM	89.95
2708	8K	EPROM	10.95
2716T.I	16K**	EPROM	29.95
	**Requires 3 voltages, —5V, +5V, +12V		
5203	2048	FAMOS	14.95
6301-1(7611)	1024	Tristate Bipolar	3 49
6330-1(7602)	256	Open C Bipolar	2 95
82S23	32X8	Open Collector	3.95
82S115	4096	Bipolar	19 95
82S123	32X8	Tristate	3.95
74186	512	TTL Open Collector	9 95
74188	256	TTL Open Collector	3.95
74S287	1024	Static	2.95

JE600 HEXADECIMAL ENCODER KIT



FEATURES:

- Full 8 bit latched output for microprocessor use
- 3 User Define keys with one being bi-stable operation
- Debounce circuit provided for all 19 keys
- LED readout to verify entries
- Easy interfacing with standard 16 pin IC connector
- Only - 5VDC required for operations

FULL 8 BIT LATCHED OUTPUT—19 KEYBOARD

The JE600 Encoder Keyboard provides two separate hexadecimal digits produced from sequential key entries to allow direct programming for 8 bit microprocessor or 8 bit memory circuits. Three (3) additional keys are provided for user operations with one having a bistable output available. The outputs are latched and monitored with LED readouts. Also included is a key entry strobe

JE600 .... $59.95
Hexadecimal Keypad only $14.95

DIGITAL THERMOMETER KIT

- Dual sensors—switching control for indoor/outdoor or dual monitoring
- Continuous LED .8" ht. display
- Range: -40°F to 199°F / -40°C to 100°C
- Accuracy: ±1° nominal
- Set for Fahrenheit or Celsius reading
- Sim. walnut case - AC wall adapter incl.
- Size: 3-1/4" H x 6-5/8" W x 1-3/8" D

JE300 .... $39.95

62-Key ASCII Encoder Keyboard Kit

The JE610 62-Key ASCII Encoder Keyboard Kit can be interfaced into most any computer system. The JE610 Kit comes complete with an industrial grade keyboard switch assembly (62 keys), IC's, sockets, connector, electronic components and a double-sided printed wiring board. The keyboard assembly requires +5V @ 150mA and −12V @ 10mA for operation.

FEATURES:

- 60 Keys generate the full 128 characters, upper and lower case ASCII set
- Fully buffered
- 2 user-define keys provided for custom applications
- Caps lock for upper case only alpha characters
- Utilizes a 2376 (40 pin) encoder read only memory chip
- Outputs directly compatible with TTL/DTL or MOS logic arrays
- Easy interfacing with a 16-pin dip or 18-pin edge connector

JE610 ..... $79.95
62-Key Keyboard only . . $34.95

REGULATED POWER SUPPLY

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JE200 5V-1 AMP POWER SUPPLY

- Uses LM309K
- Heat sink provided
- PC Board construction
- Provides a solid 1 amp @ 5 volts
- Can supply up to ±5V, ±9V and ±12V with JE205 Adapter
- Includes components, hardware & instructions
- Size: 3½"x5"x2"H

JE200 $14.95

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- PC Brd. construction
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Data Transmission Method	Frequency-Shift Keying, full-duplex (half-duplex selectable).
Maximum Data Rate	300 Baud.
Data Format	Asynchronous Serial (return to mark level required between each character)
Receive Channel Frequencies	2025 Hz for space; 2225 Hz for mark
Transmit Channel Frequencies	Switch selectable: Low (normal) 1070 space, 1270 mark; High = 025 space, 2225 mark
Receive Sensitivity	−46 dbm accoustically coupled.
Transmit Level	−15 dbm nominal Adjustable from −6 dbm to −20 dbm.
Receive Frequency Tolerance	Frequency reference automatically adjusts to allow for operation between 1800Hz and 2400Hz.
Digital Data Interface	EIA RS-232C or 20 mA current loop (receiver is optoisolated and non-polar)
Power Requirements	120 VAC, single phase, 10 Watts
Physical	All components mount on a single 5" by 9" printed circuit board All components included

Requires a VOM, Audio Oscillator, Frequency Counter and/or Oscilloscope to align

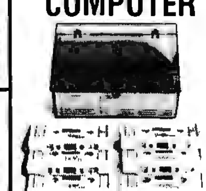
TRS-80 16K Conversion Kit

Expand your 4K TRS-80 System to 16K. Kit comes complete with:

- 8 each UPD416-1 (16K Dynamic Rams) 250NS
- Documentation for conversion

TRS-16K $75.00

COMPUTER CASSETTES



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CAS-6 $14.95
(Case and 6 Cassettes)

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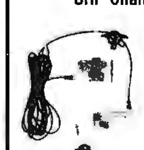
UHF Channel 33 TV Interface Unit Kit



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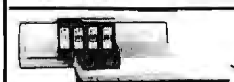

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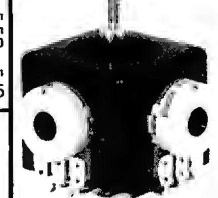

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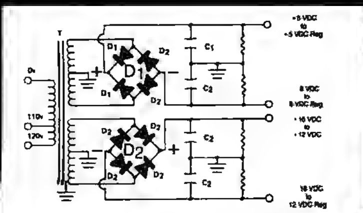

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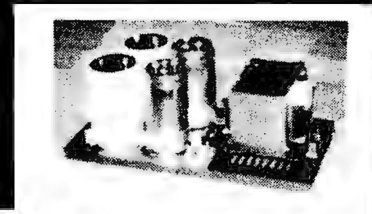

POWER TRANSFORMERS (WITH MOUNTING BRACKETS)

ITEM NO.	USED IN KIT NO.	PRI. WINDING TAPS	SECONDARY WINDING OUTPUTS 2×8 Vac	2×14 Vac	2×24 Vac	SIZE W×D×H	UNIT PRICE
T_1	1	0V, 110V, 120V	2×7.5A	2×2.5A	———	3¾"×3⅝"×3⅛"	**19.95**
T_2	2	0V, 110V, 120V	2×12.5A	2×3.5A	———	3¾"×4⅜"×3⅛"	**25.95**
T_3	3	0V, 110V, 120V	2×9A	2×2.5A	2×2.5A	3¾"×4⅜"×3⅛"	**27.95**
T_4	4	0V, 110V, 120V	2×4.5A	———	2×4.5A	3¾"×3⅝"×3⅛"	**19.95**

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ITEM	USED FOR	@+8 Vdc	@−8 Vdc	@+16 Vdc	@−16 Vdc	@+28 Vdc	SIZE W×D×H	UNIT PRICE
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KIT 2	SYSTEM SOURCE	25A	———	3A	3A	———	12"×6"×4⅞"	**54.95**
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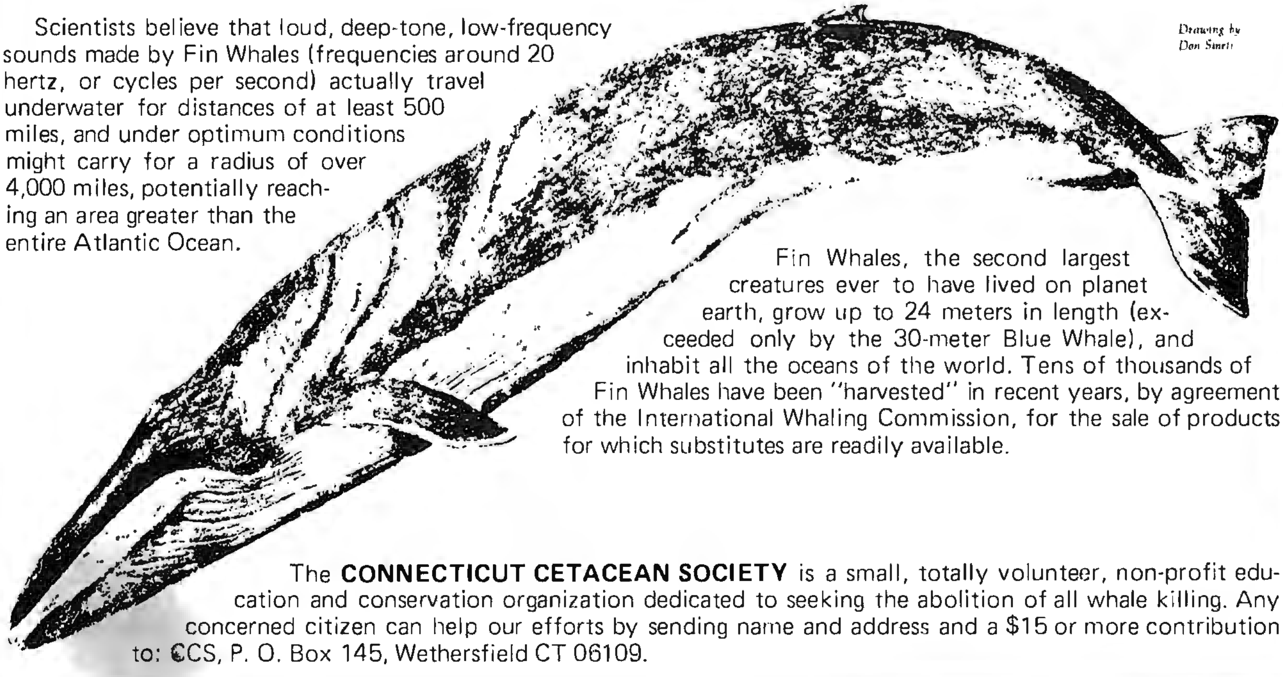

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The **CONNECTICUT CETACEAN SOCIETY** is a small, totally volunteer, non-profit education and conservation organization dedicated to seeking the abolition of all whale killing. Any concerned citizen can help our efforts by sending name and address and a $15 or more contribution to: CCS, P. O. Box 145, Wethersfield CT 06109.

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Electrolabs' new operating system for the Z-80 designed to have exactly the appearance of UNIX, including virtual I/O, "set TTY", a tree and a shell, filters and pipes PLUS total compatability with CP/M software!**

OS-1© FEATURES

(Because OS-1 is truly a comprehensive "OS", and not merely a file handling "DOS", we have changed the name from "Superdos" to "OS-1")

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"LOGIN" - automatically executes user selected programs and "set TTY".
OCCUPIES 12KBy - only 50% larger than CP/M, but 500% more features.
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*(Naturally, we are not giving away the version of CP/M written by Digital Research, Please pardon our pun, but they might object. What we ARE giving you is a greatly enhanced version of CP/M which resides on OS-1, and allows the user of OS-1 to run any and all of his programs, packages or system utilities which are already running on CP/M. We give you the source code at no charge so that you may modify any part of the CP/M to suit your own system requirements. At no charge, you also receive the enhancement allowing 4MBy files instead of 256K.)

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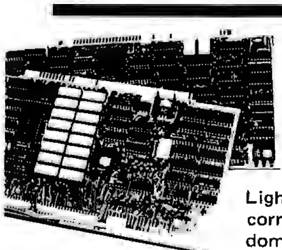

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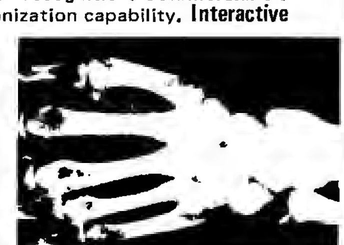
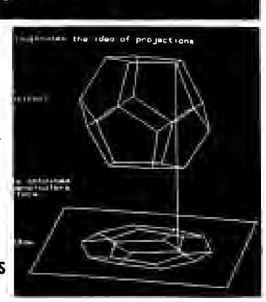
Light pen, A-D, D-A, TV synchro (needs no time base correction or adjustment with anything between random interface & NTSC commercial standard). T.V. single frame grabber ("snapshot"). Up to 1 Byte of attributions per pixel.

LSI-100 & S-100 applied to:

Graphic Presentation – such as computer generated animation & other graphic displays up to 256 colors & up to 256 b&w gray scales. **Image Analysis** – using built-in FRAME GRABBER, for medical image enhancement, contour analysis, & pattern recognition. **Commercial TV Tilting & Advertising** – using synchronization capability. **Interactive graphics** – using light pen accessory.



BASIC CONFIGURATION –
LSI-11 $1995. S-100 $1265.
For TRS-80/Exidy Add $595.00
Includes: Data Board - 32K (480 x 512 x 1 pixel) D-A 16 level video generator. Video Synchronization Circuitry. Address Control & Timing Board.



FEATURES – High speed. DMA or 2KBy window memory mapped interface. Full NTSC commercial color capability. Low power consumption. Excellent Software

Options – Accessories – Software
Options include: light pen, auxilliary outputs, text mode, memory and much more. Accessories include: b&w and color cameras and monitors. Software: "Plot" 2D or 3D, "Tilting", "Contour", "Image Enhancement", "Vector Curve Generation".

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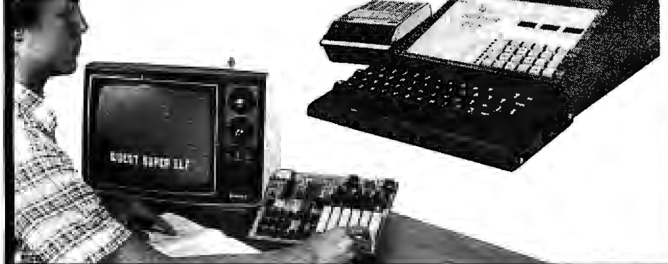

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RCA Cosmac Super Elf Computer $106.95

Compare features before you decide to buy any other computer. There is no other computer on the market today that has all the desirable benefits of the **Super Elf** for so little money. The Super Elf is a small single board computer that does many **big** things. It is an excellent computer for training and for learning programming with its machine language and yet it is easily **expanded** with **additional memory, Full Basic, ASCII Keyboards, video character generation, etc.**

Before you buy another small computer, see if it includes the following features: ROM monitor; State and Mode displays; Single step; Optional address displays; Power Supply; Audio Amplifier and Speaker; Fully socketed for all IC's; Real cost of in warranty repairs; Full documentation.

The **Super Elf** includes a **ROM** monitor for program loading, editing and execution with **SINGLE STEP for program debugging** which is not included in others at the same price. With **SINGLE STEP** you can see the microprocessor chip operating with the **unique Quest** address and data bus displays **before, during** and **alter** executing instructions. Also, CPU mode and instruction cycle are decoded and displayed on 8 LED indicators.

An RCA 1861 **video graphics** chip allows you to connect to your own TV with an inexpensive video modulator to do graphics and games. There is a **speaker system** included for writing your own music or using many music programs already written. The speaker amplifier may also be used to drive relays for control purposes.

A 24 key **HEX keyboard** includes 16 HEX keys plus **load, reset, run, wait, input, memory protect, monitor select** and **single step.** Large, on board displays provide output and optional **high and low address**. There is a 44 pin standard connector slot for PC cards and a 50 pin connector slot for the Quest Super Expansion Board. Power supply and sockets for **all** IC's are included in the price plus a detailed 127 pg. instruction manual which now includes over 40 pgs. of software info. including a series of lessons to help get you started and a music program and graphics target game.

Many schools and universities are using the Super Elf as a course of study. OEM's use it for training and research and development.

Remember, other computers only offer Super Elf features at additional cost or not at all. **Compare before you buy. Super Elf Kit $106.95, High address option $8.95, Low address option $9.95. Custom Cabinet** with drilled and labelled plexiglass front panel **$24.95.** Expansion Cabinet with room for 4 S-100 boards **$41.00. NiCad Battery Memory Saver Kit $6.95.** All kits and options also completely assembled and tested.

Questdata, a 12 page monthly software publication for 1802 computer users is available by subscription for $12.00 per year.

Tiny Basic Cassette **$10.00**, on ROM **$38.00**, original Elf kit board **$14.95. 1802 software;** Moews Video Graphics **$3.50.** Games and Music **$3.00,** Chip 8 Interpreter **$5.50.**

Super Expansion Board with Cassette Interface $89.95

This is truly an astounding value! This board has been designed to allow **you** to decide how you want it optioned. **The Super Expansion Board comes with 4K of low power RAM** fully addressable anywhere in 64K with built-in memory protect and a **cassette interface**. Provisions have been made for all other options on the same board and it fits neatly into the hardwood cabinet alongside the **Super Elf.** The board includes slots for up to 6K of **EPROM** (2708, 2758, 2716 or TI 2716) and is fully **socketed.** EPROM can be used for the monitor and Tiny Basic or other purposes.

A 1K Super ROM Monitor $19.95 is available as an on board option in 2708 EPROM which has been preprogrammed with a program loader/editor and error checking multi file cassette read/write software, (relocatable cassette file) another exclusive from Quest. It includes register save and readout, block move capability and video graphics driver with blinking cursor. Break points can be used with the register save feature to isolate program bugs quickly, then follow with single step. The Super Monitor is written with subroutines allowing users to take advantage of monitor functions simply by calling them up. Improvements and revisions are easily done with the monitor. If you have the **Super Expansion Board** and **Super Monitor** the monitor is up and running at the push of a button.

Other on board options include **Parallel Input and Output Ports with full handshake.** They allow easy connection of an ASCII keyboard to the input port. **RS 232 and 20 ma Current Loop** for teletype or other device are on board and if you need more memory there are two **S-100** slots for static RAM or video boards. A Godbout 8K RAM board is available for $135.00. Also a 1K Super Monitor version 2 with video driver for full capability display with Tiny Basic and a video interface board. **Parallel I/O Ports $9.85, RS 232 $4.50, TTY 20 ma I/F $1.95, S-100 $4.50. A 50 pin connector set** with ribbon cable is available at $12.50 for easy connection between the **Super Elf** and the **Super Expansion Board.**

The **Power Supply Kit** for the Super Expansion Board is a 5 amp supply with multiple positive and negative voltages $29.95. Add $4.00 for shipping. Prepunched frame $7.50. Case $10.00. Add $1.50 for shipping.

Multi-volt Computer Power Supply
8v 5 amp, ±18v .5 amp, 5v 1.5 amp, −5v .5 amp, 12v .5 amp, −12 option. ±5v, ±12v are regulated. Kit $29.95. Kit with punched frame $37.45. Woodgrain case $10.00.

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Opens shorted cells that won't hold a charge and then charges them up, all in one kit w/full parts and instructions. **$7.25**

PROM Eraser
Will erase 25 PROMs in 15 minutes. Ultraviolet, assembled **$34.50**

Hickok 3½ Digit LCD Multimeter
Batt/AC oper. 0.1mv–1000v. 5 ranges. 0.5% accur. Resistance 6 low power ranges 0.1 ohm–20M ohm. DC curr. .01 to 100ma. Hand held, ½" LCD displays, auto zero, polarity, overrange. **$69.95.**

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Indoor and outdoor. Switches back and forth. Beautiful. .50" LED readouts. Nothing like it available. Needs no additional parts for complete, full operation. Will measure −100° to +200°F, tenths of a degree, air or liquid. Beautiful woodgrain case w/bezel **$11.75**

TERMS: $5.00 min. order U.S. Funds. Calif residents add 6% tax. BankAmericard and Master Charge accepted. Shipping charges will be added on charge cards.

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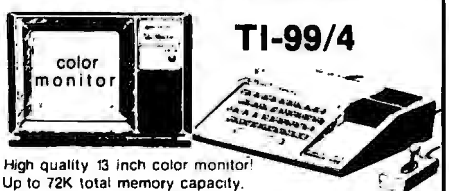
TEXAS INSTRUMENTS

TI-99/4



High quality 13 inch color monitor!
Up to 72K total memory capacity.
16-color graphics capability - easy to access high resolution graphics have special features that let you define your own characters, charts, graphs, etc.
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Programs are sealed securely in SOLID STATE SOFTWARE COMMAND MODULES. These ROM pack acctually add memory to the TI-99/4 so that the console's memory can be utilized for user input. **SYO-8994A** **$1150.00**

SD SYSTEMS
Z-80 STARTER KIT

Based on the powerful Z-80 CPU, this kit is an ideal introduction to microprocessors. It has an on-board keyboard and display, plus cassette tape interface, and expansion provisions for two S-100 connectors. This "Do-it-all-Board" will also program the 2716 2K.

Kit **$249.95**
Assembled and tested **$439.00**

SD SYSTEMS
SBC-100

An S 100 single board computer Z 80 CPU with 1024 bytes of RAM 8-32K bytes of PROM Serial I/O port.

Kit **$239.95**
Assembled **$369.95**

Solid State Music
I/O 4

2 Serial and 2 Parallel I/O.
Ports S 100 with full hand shaking.

JADE Kit **$149.95**
Assembled **$199.95**
Bare Board **$29.95**

PARALLEL/SERIAL INTERFACE

S-100 compatible, 2 serial I/O ports, 1 parallel I/O

Kit **$124.95**
Assembled & Tested **$179.95**
Bare Board W/ Manual **$30.00**

PROTO BOARD

Includes gold plated fingers S-100 size, holds 72-16 pin dips, accomodates all 8 thru 40 pin dip packages. Reg. 19.95
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6502- Based single board computer with keyboard/display. KIM 1 hardware compatible, complete documentation.

SYM-1 CPK-5002A **$245.00**
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The only motherboard availible today that is designed to IEEE S-100 Bus Standards--a unique network theory of design in which each signal line is surrounded by current mirrored ground lines, significantly reducing RF radiation virtually eliminating crosstalk. No need for active termination. The perfect foundation for a 4MHz system.

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BARE BOARD **$59.95**
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FOR
TRS-80 APPLE EXIDY

Everything you need to add 16K of memory to your computer. Your kit comes neatly packaged with easy to follow instructions. In just minutes your computer is ready to tackle more advanced software.

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THE BIG Z
THE NEW Z-80 CPU BOARD FROM JADE

Features include ● S-100 Compatible available in 2MHz or 4MHz versions ●On-board 2708, 2716 or 2532 EPROM can be addressed on any 1K, 2K or 4K boundary with power-on jump to EPROM ● On-board EPROM may be used in SHADOW mode, allowing full 64K RAM to be used ● Automatic MWRITE generation in front panel is not used ●On-board USART for synchronous or asynchronous R232 operation (on-board baud rate generator) ●Reverse channel capability on USART allows use with buffered peripherals or devices with not-ready signal

2MHz Kit: CPU-30200K. 2lbs **$149.95**
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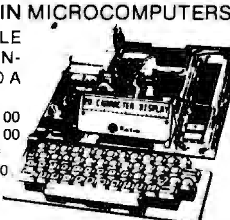
THE HEAD-START IN MICROCOMPUTERS

A KIM-1 COMPATIBLE MACHINE WITH ON-BOARD PRINTER AND A REAL KEYBOARD!



AIM-65 w/1K of RAM $375.00
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Special Package Price $599.00
4K AIM-65 8K BASIC ROM Power Supply, and Case

SD SYSTEMS
EXPANDORAM
Expandable to 32K or 64K

EXPANDO-32K KITS

Uses 4115 (8K X 1,250ns) Dynamic RAMs. Can be expanded in 8K increments up to 32K

8K	**$159.95**	**24K**	**$249.95**
16K	**$199.95**	**32K**	**$299.95**

EXPANDO-64K KITS

Uses 4116 (16K X 1 200ns) Dynamic RAMs. Can be expanded up to 64K in 16K increments

16K	**$249.95**	**48K**	**$469.95**
32K	**$369.95**	**64K**	**$569.95**

STATIC RAM BOARDS

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8K 4MHz ASSEMBLED & TESTED **$180.00**
8K BARE BOARD & MANUAL **$25.00**
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16K 2MHz ASSEMBLED & TESTED **$325.00**
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16K 4MHz ASSEMBLED & TESTED **$350.00**
16K BARE BOARD & MANUAL **$35.00**
32K 2MHz KIT **$539.95**
32K 2MHz ASSEMBLED & TESTED **$650.00**
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SD SYSTEMS
VDB-8024

An **80 by 24** I/O mapped video board for S-100 systems. An on-board Z-80 processor is used to control all functions. A total of 256 user-programmable characters are available, including 128 characters that are supplied with the board. **This is virtually a stand-alone terminal!**

KIT **$319.95**
ASSEMBLED AND TESTED **$469.95**

JADE VB-1B

This 64 by 16 memory-mapped video board is ideal for use with word processing software such as the Electric Pencil

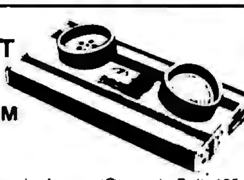
KIT **$127.50**
ASSEMBLED AND TESTED **$169.95**
BARE BOARD/MANUAL **$35.00**

VECTOR GRAPHICS
FLASHWRITER II

The ultimate memory-mapped 80 character by 24 line video board, the Vector Graphics FWII has many advanced features: Onboard parallel keyboard port, Power-on jump circuit, 8 X 10 dot character matrix, and the optional ability to program your own characters and/or graphics symbols. this is THE perfect board for text editing systems

ASSEMBLED AND TESTED **$320.00**

NOVATION CAT



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Features include 300 Baud Answer/Originate.Bell 103
Assembled and Tested **$189.00**

Circle 195 on inquiry card.

Memory War Shop and Compare

Circle 312 on inquiry card.

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HICKOK LX303
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.5%, 3½ digit 19 Range DVM. ½" LCD displays runs 200 hrs on 1 battery. 10 Meg Ohm Input. 1 yr. guarantee. made in U.S.A.. test leads included.

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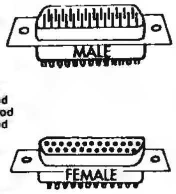
CS-1 10 Amp Current Shunt	$14.95

*FREE
Just for Asking.
FREE BATTERY with your meter.

RS232 & "D" TYPE CONNECTORS
P = Plug Male S = Socket-Female C = Cover Hood

PART NO	DESCRIPTION	PRICE 1-4	5-9	10-24
DE-9P	9 Pin Male	1.50	1 30	1.20
DE-9S	9 Pin Female	2 15	2 05	1.95
DE-9C	9 Pin Cover	1 50	1 30	1.15
DA15P	15 Pin Male	2.20	2.00	1 80
DA15S	15 Pin Female	3.20	3.00	2.80
DA15C	15 Pin Cover	1.60	1.45	1.30
DB-25P	25 Pin Male	2.90	2.60	2.50
DB-25S	25 Pin Female	3.75	3.85	3.40
DB51212-1	1 pc. Grey Hood	1.85	1.40	1.20
DB1226-1A	2 pc. Black Hood	1.90	1.60	1.50
DB110963-3	2 pc. Grey Hood	1.80	1.55	1.35
DC37P	37 Pin Male	3.95	3.80	3.60
DC37S	37 Pin Female	5.75	5.50	5.20
DC37C	37 Pin Cover	2.20	1.95	1.75
DD50P	50 Pin Male	4.95	4.75	4.50
DD50S	50 Pin Female	7.50	7.20	6.90
DD50C	50 Pin Cover	2.50	2.20	2.10
D20418-S	Hardware Set (2 pair)	1 00	.80	.70



Connector for CENTRONICS 700 SERIES:
Amphenol 57 30360 for back of Centronics 700 Series printers
1-4 $9.00 5 up – $7.50

SALE S-100 BUS EDGE CONNECTORS SALE

S100-WWG 50/100 Cont 125 ctrs 3 LEVEL WIRE WRAP 025" sq posts on 250 spaced rows GOLD PLATED
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S100SE 50/100 Cont 125 ctrs PIERCED SOLDER EYELET tails GOLD
1-4 $5.00 5-9 $4.50 10-24 $4.00

Other Popular Edge Connectors

D2244-SSE 22/44Cont 156ctrs PIERCED SOLDER EYELET tails GOLD plated
1-4 $3.00 5-9 $2.60 10-24 $2.20

D2244-SWW 22/44 Cont 156 ctrs WIRE WRAP tails GOLD
1-4 $3.95 5-9 $3.70 10-24 $3.40

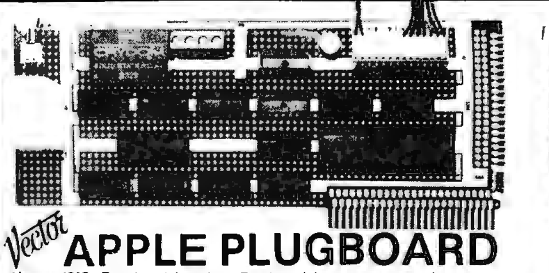
CG 1 IMSAI Style Card Guides 5/$1 00

See our July Ad for many other connectors.

3 LEVEL GOLD WIRE WRAP SOCKETS
Sockets purchased in multiples of 50 per type may be combined for best price.

	1-9	10-24	25-99	100-249	250-999
8 pin	.40	.36	.34	.31	.27
14 pin	.39	.38	.36	.34	.32
16 pin	.50	.42	.40	.36	.34
18 pin	.70	60	55	.50	.45
20 pin	.90	.80	75	.65	.62
22 pin	.95	.85	.80	70	.65
24 pin	.95	.85	80	.70	.65
28 pin	1.25	1.15	1.00	95	.90
40 pin	1.65	1.45	1.35	1.20	1.10

All sockets are GOLD 3 level closed entry. 2 level Tail. Low Profile. Tin Sockets and Dip Plugs available. CALL FOR QUOTATION.



Vector APPLE PLUGBOARD
Vector 4609 Peripheral Interface Plugboard for construction of custom circuits Plug compatible with Apple II. Commodore PET and Super Kim microcomputers Three connectors, in addition to the standard 25/50 system bus, are available for input/output A 20/40-contact card-edge connector, fabricated on the rear of the board, mates with a 3-M type ribbon connector Alternatively, a right-angle solder-tail header may be positioned in this same location The Model 4609 also accomodates the miniature SIP-type connectors which may be placed on the periphery or in mid-board.

1-4	5-9	10-24
$21.50	$19.36	$17.26

7520 APPLE EXTENDER CARD $24.95

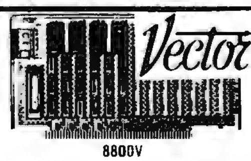
HICKOK LX303 $74.95 HICKOK LX303 $74.95

8803 MOTHER BOARD FOR S100 BUS MICRO-COMPUTERS — Vector

- includes 12 tantalum capacitors for +5 +12 —12 buses and insulated mounting spacers
- Wiring side shown. Component side bare epoxy glass with white markings for component locations
- G10 epoxy glass board with 2 ounce copper solder coated and .036 diameter holes for leads
- Solder mask with solder windows on etched circuits to avoid accidental short circuits
- Mounts 11 receptacles with 100 contacts (2 rows) on .125 centers with .250 row spacing vector part number R681-2 or mounts 10 receptacles plus connections to another mother board for expansion
- Includes etched circuits and instructions for option of active, passive or floating terminations
- Large buses +5V and GND (10 AMPs) ±12V or 16V (? AMPS). Current ratings are per MIL STD 275 with 10°C rise
- Fits in Vector card enclosures
- Fits in IMSAI 8080 microcomputer as expander board

Price: $29.50

Vector Plugboards



8800V
Universal Microcomputer processor plugboard use with S 100 bus Complete with heat sink & hardware 5.3 x 10 x 1 16

1-4	5-9	10-24
$19 95	$17 95	$15 96

8801-1
Same as 8800V except plain less power buses & heat sink

1-4	5-9	10-24
$15.22	$13.79	$12.18

3682 9.6" x 4.5" **$12.97**
3682-2 6.5" x 4.5" **$9.81**
Hi-Density Dual-In-Line Plugboard for Wire Wrap with Power & Grd Bus Epoxy Glass 1/16" 44 pin con spaced .156

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Gen. Purpose D.I.P. Boards with Bus Pattern for Solder or Wire Wrap. Epoxy Glass 1/16" 44 pin con. spaced .156

3662 6.5" x 4.5" **$8.95**
3662-2 9.6" x 4.5" **$11.45**
P pattern plugboards for IC's Epoxy Glass 1/16" 44 pin con spaced .156

3690-12
CARD EXTENDER
Card Extender has 100 contacts 50 per side on .125 centers-Attached connector-is compatible with S-100 Bus Systems $25.83
3690 6.5" 22/44 pin .156 ctrs. Extenders $13.17

1/16 Vector BOARD
.042 dia holes on 0.1 spacing for IC's

	SIZE	PRICE 1-9	10-19
Phenolic			
PART NO.			
64P44XXXP	4.5x6.5"	$1.56	$1.40
169P44XXXP	4.5x17"	$3.69	$3.32
Epoxy Glass			
64P44	4.5x6.5"	$1.79	$1.61
84P44	4.5x8.5"	$2.21	$1.99
169P44	4.5x17"	$4.52	$4.07
169P84	8.5x17"	$8.83	$7.95

TRS-80/APPLE
MEMORY EXPANSION KITS
4116's RAMS
from Leading Manufacturers
(16Kx1 200/250ns)
1,000's SETS SOLD! 100% GUARANTEED
8 for $75.00
Add $3.00 for programming Jumpers for TRS-80 Keyboard

Extender/ Terminator
— NEW — S-100
- Active and/or dynamic termination
- All power lines fused for protection
- All S-100 lines labeled and numbered
- Can be used as an extender and/or terminator
- Solder mask both sides of board
- Silkscreened reference designations
- Gold plated fingers

Cat.No.2520 KIT **$39.95**

WOW
14 & 16 PIN GOLD 3 LEVEL WIRE WRAP SOCKES
14 - G3 100 for **$33.00**
16 - G3 100 for **$33.00**
50 of each for $35.00

HICKOK LX303 $74.95 HICKOK LX303 $74.95

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2708	8K 450ns EPROM	8/65.00 $9.00
2716	16K 5 Volt Only EPROM	$40.00

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Perfectly balanced fluorescent lighting with precision magnifier lens. Tough thermoplastic shade. Easy lens removal. New wire clip design permits easy installation and removal of fluorescent tube. Comes with plastic shield to protect tube from soiling and damage
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Vector WRAP POST
for .042 dia. holes (all boards on this page)

T44/C pkg 100	$ 2.34
T44/M pkg 1000	$14.35
A-13 hand installing tool	$ 4.19

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$395.00

widen the ability of your TRS-80

The Vista V80 Mini Disk System is the perfect way to widen the capabilities of your TRS-80* Micro-computer. Quickly and inexpensively. Our $395 price tag is about $100 less than the Radio Shack equivalent. Our delivery time is immediate. And our system is fully interchangeable. That's just the start.

It will give you 23% more storage capacity by increasing useable storage from 55.000 to 65.000 bytes per drive with our new software patch.

It can work 8 times faster than the TRS-80 Mini-Disk system, because track-to-track access is 5ms versus 40ms for the TRS-80. You can realize this added speed once the new double disk expansion interface is available without expensive modification of the existing unit.

It has a better warranty than any comparable unit warranty available - a full 120 days on all parts and service. When you consider how much more goes into the Vista V80. that shows a lot of faith in our product.

A full 3 amp power supply means you have 2½ times the power necessary to operate the V80. and full ventilation insures that there will be no problems due to overheating.

The Vista V80 Mini Disk System requires Level II Basic with 16K RAM Expansion interface (it operates from the Radio Shack interface system. It comes complete with a dependable MPI Minifloppy disk drive, power supply, regulator board and vented case. It's shipped to you ready to run-simply take it out of the box and plug it in. You're in business. From the company that means business -Vista Computer Company.

DATA CABLES, VC80-2 (2 drive) **$29.95**
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SPECIAL: Box of 10 DISKETTES
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FREE 15MHZ DUAL TRACE SCOPE* SAVE $124.00

NLS

*no not really, but here is our deal. The NLS **MS-230 DUAL TRACE 30MHZ MINISCOPE,** regularly sells for **$559.00,** but we will sell it for **$435.00** (The price of the MS-215 Dual Trace 15 MHZ Miniscope) when you **purchase** any **2 probes** listed below and your order prepaid or paid by credit card.*

•30-Megahertz bandwidth•Accuracy 3% full scale.•Internal, line or external trigger.•Batteries and charger/transformer unit included•Graticule: 4 x 5 divisions, each division 0.25"•Time base: 1 micro sec. to 0.5 sec/div 21 settings•Verticle Gain: 0.01 to 50 Volts/div. 12 settings•Size 2.9"H x 6.4" W x 8.5"D. 3.5 lbs. • TEST MOST DIGITAL LOGIC CIRCUITS INCLUDING MICROPROCESSORS•

MS-230 Dual Trace 30 MHz .... ~~$559~~ $435.00
41-141 Deluxe 10tol probe with 4 interchangeable tips $27.00
41-37 Deluxe 10tol/1tol probe with 4 interchangeable tips $38.50
41-180 Leather carrying case $45.00
MS-15 Single trace 15 MHz $318.00
MS-215 Dual trace 15 MHz $435.00

M-XVI

California Computer Systems

SHOP & COMPARE

The true 16K Static Ram module for S-100 bus systems.

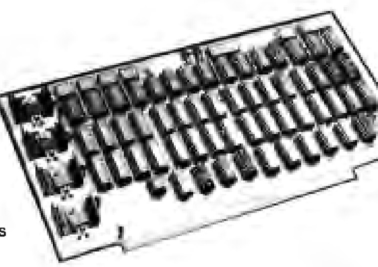
ASSEMBLED & TESTED--100% BURN IN

The M-XVI gives you unbelievable expansion capability for your S-100 bus system—even beyond 64K. Manufactured to the highest industry standards documented and designed to make assembly, use, and programming a snap. The M-XVI board is a true revelation for the serious hobbyist and use in practical business or industrial applications.

FEATURES:

- Fully static
- Uses popular 2114 static RAMS
- +5 volt operation only
- Bank Select available by bank port and bank byte
- Phantom line capability
- Addressable in 4K blocks
- 4K blocks can be addressed anywhere within 64K in 4k increments
- Meets IEEE proposed S-100 signal standards
- LED indicators for board selection and bank selection
- FR-4 epoxy PC boards
- Solder masked on both sides
- Silk screen of part number and part designator

SPECIAL



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741-0	1/double	Soft-Shugart Dbl	$59.00
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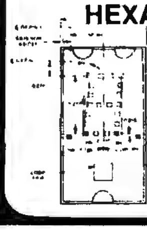

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CSC

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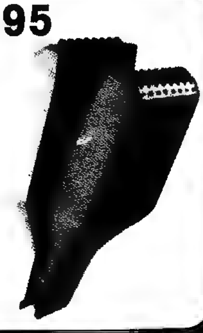
$59.95



Trace signals through all types of digital circuits. Unit clips over any DIP IC up to 16 pins. Each of its 16 contacts connects to a single-bit level detector that drives a high-intensity, numbered LED readout activated when the applied voltage exceeds a fixed 2 V threshold. Logic "1" turns LED on; logic "0" keeps LED off. A power-seeking gate network automatically locates supply leads and feeds them to the LM-1's internal circuitry. Saves minutes, even hours in design, troubleshooting, debugging of equipment. **Voltage Threshold:** 2 V ± 0.2 V. **Input Impedance:** 100,000 ohms. **Input Voltage Range:** 4-15 V max. across any two or more inputs. **Current Drain:** 200mA at 10 V. **Size:** 4" l. x 2" w. x 1.75" d. when open. **Weight:** 3 ozs.

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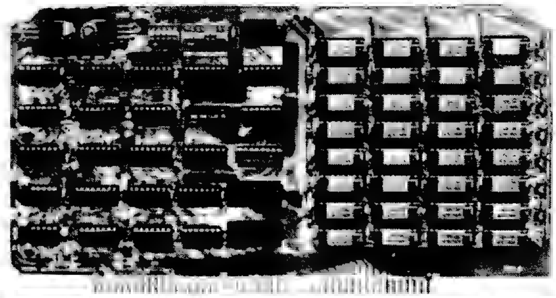

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EXPANDO 64 KIT (4116)

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110 KB, 35 tracks,
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with attractive metal case with cutouts for Data Cable switch, fuse and power cord
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5. CDC 9404/9406
6. GSI/Siemans FDD120-8
34 Pin Connector for Mini Floppy. 50 Pin Connector for Standard Floppy. Operates with modified CP/M operating system and C-Basic Compiler. The new "Versafloppy" from S.D. Computer Products provides complete control for many of the available Floppy Disk Drives. Both Mini and Full Size. FD1771B-1 Single Density Controller Chip. Listings for Control Software are included in price.

CPM for SD Versafloppy $100.00

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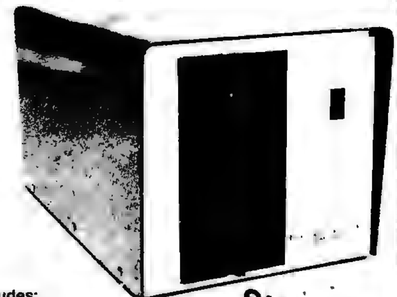
DM2700S DISK & CABINET with POWER SUPPLY



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- Fan
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DM2700 Cabinet, less Drive **$249.00** **$225.00**

THE MICROBYTE M32KSS 32K STATIC MEMORY BOARD

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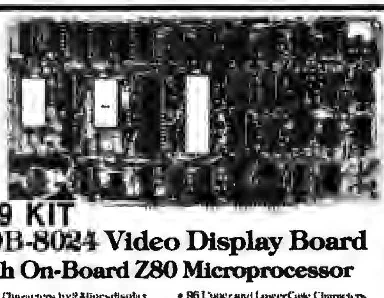
ASSEMBLED & TESTED
SALE PRICED

M32 KSS-L (2 MHz)
List $650 — SALE $530.00

M32 KSS-H (4 MHz)
List $680 — SALE $560.00

• Fully S100 Bus Compatible, IMSAI, SOL, ALTAIR, ALPHA MICRO. • Uses National's Low Power 5257 4K x 1 Static Rams. • 2 MHz or 4 MHz operation. • Gold contacts for higher reliability. • On board single 5 amp regulator. • Thermally designed heat sink (board operating temperature 0° — 70°C). • Commercially designed power bus, 7 ground bus bars, 0.1 uf decoupling capacitors. • Fully tri-state buffered. • Inputs fully low power Shottky Schmitt, Trigger buffered on all address and data lines. • Phantom is jumper selectable to pin 67. • Each 4K bank addressable to any 4K slot with in a 64K boundary. • 4K hardware or software selectable. • One on board 8-bit output port enables or disables the 32K in 4K blocks. • Selectable port address. • 4K banks can be selected or disabled on power on clear or reset. • Will operate with or without front panel. • Compatible with ALPHA MICRO, with extended memory management for selection beyond 64K. • No DMA restriction. • Low power consumption 2.3 — 2.5 amps. • Fully warranted for 120 days from date of shipment.

SD COMPUTER BOARDS



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With On-Board Z80 Microprocessor

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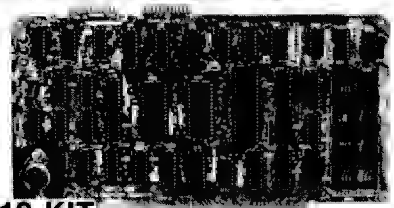
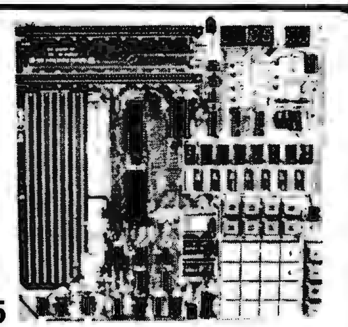
- 96 Upper and Lower Case Characters
- 32 Special Character Set
- 128 Additional user Programmable Characters
- Full Cursor Control
- Forward and Reverse Scrolling Capability
- Operates as an Independent Terminal
- Variable Speed Display Rate
- Blinking, Underlining, Field Reverse, Field Protect and Combinations



$219 KIT
SBC-100 Single Board Computer
with On-board RAM, PROM, CTC

- Four Channel Counter/Timer (Z80-CTC)
- Software Programmable Baud Rate Generator
- S-100 Bus Compatible
- No Front Panel Required for Operation
- Optional Vectored Interrupts
- Z80 Central Processing Unit
- 1024 Bytes of Random Access Memory
- 8K Bytes of Available PROM
- Serial Input/Output Port with both Synchronous and Asynchronous Operation
- Parallel Input and Output Ports



$225
Z80 Starter Kit
A Complete Microcomputer on a Board

- Z80 Central Processing Unit with 158 Instructions
- On Board Keyboard and Display
- Kansas City Standard Cassette Interface
- PROM Programmer Built on-board
- Expansion provision for two S-100 Connectors
- Wire Wrap area for custom circuitry
- Single 5 Volt Operation when not programming
- 1K Bytes of RAM (Expandable to 2K Bytes)
- 1K Bytes of RAM (Expandable to 2K Bytes)
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- 2K Byte Z80 Monitor ROM
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Unclassified Ads

FOR SALE: Sharp and Associates Selectric conversion with instructions. Also Axiom EX-801P printer, 20/40/80 columns, software selectable, with cable and software driver for TRS-80. Like new. Make offer. J R Reich Jr, 585 E Market St, Marietta PA 17547.

FOR SALE: Morrow processor/front panel card. 8080, S-100, octal display, built-in keyboard, operating system in read-only memory. Works perfectly, with all documentation. $82 postpaid in 48 states. Money order or certified check. Ron Tipton, POB 227, Greenwood MO 64034, (816) 537-7927.

FOR SALE: Super ELF operating and in good condition. Also have expansion board completed, but not connected. Includes RS-232, teletypewriter, cassette input/output (I/O), and 8-bit parallel I/O ports. Power supply for ELF board only. I'll include encoded ASCII keyboard. $300. Jess Hillman, POB 642, Columbus MS 39701, (601) 327-1244 after 5 PM.

WANTED: 1802 computer systems and parts. Any condition, any quantity, immediate cash. Prefer RCA systems, but will accept ELF II by Netronics, memory, and support boards. Tom Inskip, 6504 Democracy Blvd, Bethesda MD 20034.

FOR SALE: Teletype ASR33 teletypewriter with paper-tape reader punch and stand. $595 and shipping. 32 K static programmable memory, four 8 K, S-100 boards factory assembled and tested. $150 each. I pay postage. Mark Lyon, 6320 Red Prairie Rd, Sheridan OR 97378.

FOR SALE: Vandenberg 16 K static-memory board. 4 MHz, each 4 K block addressable to any 4 K boundary; S-100 bus compatible; $275. Also Practical Automation DMPT-6-3 96-column printer with cabinet, power supply, and two CY-480 universal printer controllers; serial or parallel hookup with all documentation and driving software; $650. Both items presently in use with a SOL-20 system. Send SASE for sample printout. Larry Rosen, POB 2197, Williamson WV 25661.

FOR SALE: TRS-80, 16 K, Level II processor. Perfect working condition. In original carton with cassettes, cables, power pack, manuals, and software. Will include Pixie-Verter to connect to regular TV for $10 more. Retail price $690, will sell for $595 or best offer. I pay freight anywhere in US. Charles Fields, 924 W Washington Pl, Broken Arrow OK 74012.

FOR SALE: IMSAI 8080 processor kit. Still in factory box with warranty. $600 or best offer. (Interface boards also available.) I am moving. Jim Siegman, 17602 Oakwood Dr, Hazel Crest IL 60429, (312) 798-2536.

FOR SALE: Complete set of BYTE magazine thru December 1978. Excellent condition. Best offer. I pay shipping. Netronics/RCA Cosmac 1802 ELF II computer kit unassembled in original carton, RCA User's Manual, applications articles; all for $75 or best offer, postpaid. Mike Au, 2006 Alaeloa St, Honolulu HI 96821, (808) 548-5318.

WANTED: TI-59 or HP-67 calculator with all standard accessories in perfect condition. The more accessories the better. Willing to trade Shugart SA400 minifloppy disk drive (never been used) for calculator. Best offer will be notified by mail or phone. Gary R Eschborn, 513 Follett Run Rd, Warren PA 16365.

APPLE USERS: Add line input capabilities to your Applesoft II programs which will enable you to input commas, colons, quotes, etc. This fix is available for $1 to cover the cost of postage and duplication. Jules H Gilder, 2022 79th St, Brooklyn NY 11214.

FOR SALE: PDP-8/L minicomputer; $600. PDP-8/L with BA08 memory extension 8 K and peripheral adapter; $1200. Checked out with DEC diagnostics. Certified checks only. O Glaser, 508 3rd St, West Roundup MT 59072, (406) 323-2339.

WANTED: TRS-80 complete and ready to use. Level II with 16 K programmable memory; Level II with 4 K programmable memory; Level I with 16 K programmable memory, or Level I with 4 K programmable memory. I am also interested in TI-59. Price must be right. S Castiglioni, 2245 Glenwood Rd, Brooklyn NY 11210.

PET OWNERS: Group of three PET owners have 26 game programs. We will trade one for one for other PET programs. Those wishing to trade should send their cassette with programs. Keith Selby, 7205 S Utica Av Apt 1016 Cinnamon Stick Apartments, Tulsa OK 74136.

FOR SALE: Texas Instruments new TI-59 card programmable calculator with PC-100A printer. Includes aviation library, extra cards, programs, and PPX materials. Almost new. Meticulously maintained. Packed in original cartons. Sent UPS. $287 total cost. Dave Balmer, POB 325, Union Lake MI 48085, (313) 739-4280 (bus) or 669-9319 (res).

FOR SALE: TRS-80 4 K, Level II 12 inch video display, CTR-41 cassette recorder, twenty program tapes. List price $900, will sell for $750. J Kennedy, 5179 Eliot St, Denver CO 80221, (303) 477-4114.

FOR SALE: Centronix printer Model 306. Prints 64 ASCII characters, 5 by 7 dot-matrix impact, 120 cps, up to 80 columns, tractor feed to 9½ inches wide, parallel input. Includes RS-232 interface to 9600 bps, HW vertical form control, auto motor control, stand, and paper tray. Technical manual. Excellent condition. $800. Tom Jacobs, 100 W University Pky Apt 3G, Baltimore MD 21210, (301) 467-0703.

FOR SALE: Texas Instruments SR-52 handheld programmable calculator. Factory reconditioned on April 13, 1978. In perfect working order. Unit comes with two AC adapters, three sets of cards, and copies of Statistics, Financial, and EE program libraries. Best offer. Donald L Mitchell, 24466 Mulholland Hwy, Calabasas CA 91302, (213) 347-3617.

FOR SALE: New factory-wired, Meca Alpha-1 dual-cassette. Includes Meca OS Version 3.0. Couldn't figure out how to use it with my system! Take advantage of my mistake. $600 (or make reasonable offer). Send certified check or money order, I'll pay shipping. W D Wilkens, 24 N 3rd St, Womelsdorf PA 19567.

FOR SALE: Altair 8800A, VDM-11 video, MITS 1 K, S and D Sales 4 K, SwTPC/CT-1024 and seven or eight assorted boards with documentation. Mostly Mini Micro Mart stuff, not working. $450 or best offer. Dave Johnson, 3054 Roundtree, Ypsilanti MI 48197, (313) 434-3832 after 6 PM EST.

WANTED: Seeking documentation for the Merlin display board. Also seeking super-dense graphics option and documentation. Dick Walter, 2891 Baylis Dr, Ann Arbor MI 48104, (313) 991-7944.

FOR SALE: Three 32 K static programmable-memory boards. S-100, assembled and working perfectly (with 2114's low-power 250 ns), used for 300 hours. $495 each. Also have 2114s for $5 each, 4116s at 150 ns for $15 each, Dynamic N MOS ceramic 8 K by 1 22-pin with specification sheets, $4 each, eight for $30 and 4 K by 1 Dynamic 16 pin, $3 each, eight for $22. Richard Smith, 3648 Madrid Dr, San Jose CA 95132, (408) 946-0735.

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Please note that it may take three or four months for an ad to appear in the magazine.

FOR SALE: Apple 1 with 8 K programmable memory and 44-pin mother board, power supply, keyboard and 4 K BASIC on cassette plus documentation. $250. National Multiplex SwTPC 2SIO controller board and CC-8 recorder set up for 4800 bps. Unit is for SWATBUG read-only memory with serial interface in control port. Documentation included. Best offer over $330. Digital Group Phi-Deck controller card plus Triple I single-deck controller card and remote control box. Included is one Phi-Deck, documentation, and 8080/Z80 program on cassette. Unit used only a few times; guaranteed to work. Best offer over $290. Items shipped collect. Clinton Cook, 2737 Beachwood Dr, Merced CA 95340, (209) 723-0516.

FOR SALE: SYM-1 in original carton and under warranty. First check for $230 gets it. COD is ok. Darian Carr, 13709 Peyton, Dallas TX 75240.

WANTED: Jolt computer and Martin Research 8008-based computer. Can also use an Intel SIM-8 board. J Titus, POB 242, Blacksburg VA 24060, (703) 951-9030 or (703) 951-2684.

WANTED: I wish to purchase two random-beam video displays for use as vectored graphic displays. Displays must measure 12 inches or larger. Prefer working units, but can repair or modify if necessary. Will pay top dollar for quality equipment. Send description and price. Edward Rees, 8835 S Oak Park Dr, Apt #20, Oak Creek WI 53154, (414) 764-3093.

FOR SALE: IBM Selectric-based input/output (I/O) writer (Series 731), heavy-duty, all solenoids, 8½ inch platen. Was working, now needs repair. Ideal for talented tinkerer. $200, including cable and connector. Joe Brennan, 13 W 13th St, New York NY 10011, (212) 691-7939.

FOR SALE: TRS-80 which uses any RS-232 keyboard printer or video display as remote terminal. Performs all keyboard functions, places video-display data on terminal. Run BASIC or disk operating system from terminal. For information send SASE. H S Gentry, Rt 1 POB 39B, Earlysville VA 22936.

FOR SALE: H11 LSI processor with maximum memory. Also contains parallel and serial interface and cables. $1000. Also, H10 paper-tape reader punch. $150. H9 video terminal. $300. Can be bought individually or save $100 by buying all three. Complete with documentation, tapes, and several programs. Will deliver within a 200 mile radius. Jean P Bonin, 44 Pearl St, Sidney NY 13838.

FOR SALE: Up and running IMSAI 8080 with 22-slot mainframe, MIO board, 8 K Seals memory, 16 K Godbout memory, active terminator, logic-extender board, Poly VDM board, SDS 16 K erasable read-only memory board with 9.1 K IMSAI BASIC, microswitch keyboard. Cost over $3000, will sell for first certified check for $900. David Rosenblatt, POB 2600, Tampa FL 33601, (813) 988-3007.

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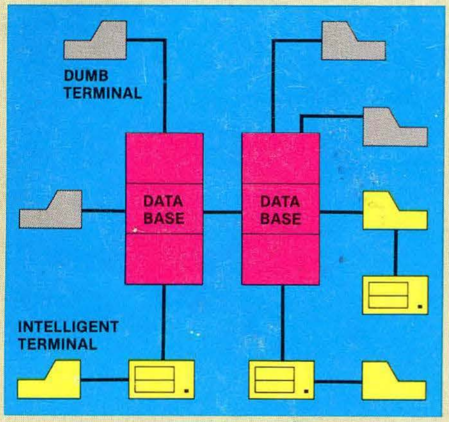
BOMB— BYTE's Ongoing Monitor Box

August BOMB Results

The first and second place winners of the August BOMB were "Anyone Know the Real Time?" by Steve Ciarcia (page 50) and "An Overview of LISP" by John Allen (page 10). These articles placed 1.30 and 1.09 standard deviations above the mean. First and second prizes of $100 and $50 will be awarded to the authors. Third place went to "A Preview of the Motorola 68000" by A I Halsema (page 170) followed by "Exploring TRS-80 Graphics" by George H Yeager (page 82). ■

Microcomputing comes of age.

Ohio Scientific's OS-65U Level 3 operating system software brings new networking and distributed processing capabilities to microprocessor based computer systems.



Until now, the only alternative for low cost multiple-user computer applications was time-shared systems. However, a serious drawback of microcomputer or mini-computer multi-user time-share systems is the fact that under heavy work loads they slow down to a crawl since the central processor time in such a system is shared by all of the users.

In a microprocessor based distributed processing system, using floppy based microcomputers as intelligent terminals (local systems) most of the work load is handled locally. Overall system performance does not degrade under heavy job loads. Each local system performs entry, editing and execution while utilizing the central data base for disk storage, printer output, and other shared resources.

For more demanding applications it is desirable to have several data bases, each with its own collection of local systems. Such an inter-connected set of data bases is called a network. Each data base and its local intelligent and dumb terminals is called a cluster.

Level III

OS-65U Level 3 now supports this advanced networking and distributed processing capability as well as conventional single user operation and time-sharing. Level 3 now supports local clusters of intelligent microcomputer systems as well as dumb terminals for the purpose of utilizing a central Winchester disk data base and other shared resources. The system also has full communications capability with other Level 3 data bases providing full network capability.

The system utilizes Ohio Scientific's low cost, ultra high performance computer systems throughout for intelligent terminals as well as data bases. This general systems configuration provides a cost/performance ratio never before attained in this class of computer power.

Level 3 resides in each network data base. A subset system resides in each intelligent terminal. Each data base supports up to 16 intelligent systems and up to 16 dumb terminals. However, since dumb terminals can heavily load the system, they should be kept to a minimum. Level 3 also supports a real time clock, printer management, and other shared peripherals.

Data Base Requirements

Minimal requirements for a Level 3 network data base are a C3-C or C3-B computer system with 23 or 74 megabytes respectively, console terminal, 100K bytes RAM and a CA-10X 16 port I/O board for network and cluster communications.

Intelligent Terminal Requirements

Any Ohio Scientific 8″ floppy based computer with 56K RAM and one data base communications port.

Connections

Intelligent terminals and networked data bases are connected by low-cost cabling. Each link can be up to 10,000 feet long at a transfer rate of 500K bits per second, and will cost typically 30¢ a foot (plus installation).

Syntax

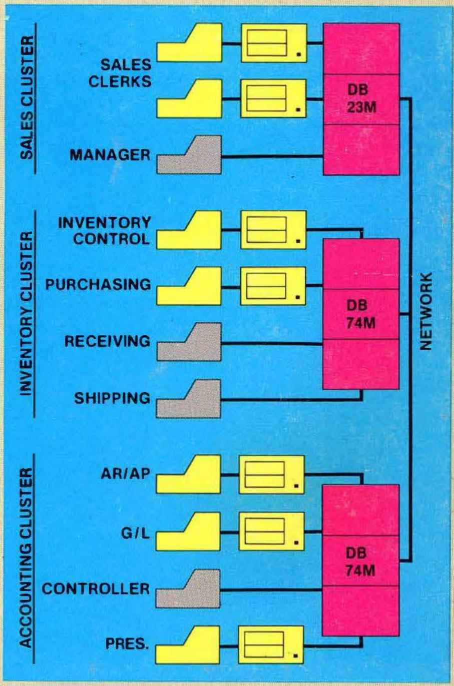
Existing OS-65U based software can be directly installed on the network with only *one* statement change! Level 3 has the most elegantly simple programming syntax ever offered on a computer network.

File syntax is as follows:

DEV A,B,C,D.	Local Floppies	} unchanged from single user and timeshare systems
DEV E	Local hard disks	
DEV K-Z	Specific network Data Bases	

Each of up to 8 open files per user can be from 8 separate origins. Specific file and shared peripheral contentions are handled by 256 network semaphores with the syntax Waite N
Waite N, close.

The network automatically prioritizes multiple resource requests and each user can specify a time out on resource requests. Semaphores are automatically reset on errors and program completion providing the system with a high degree of automatic recovery.



A Typical System

A typical system with two network data bases will have 148 megabytes of disk, four intelligent subsystems equipped with dual floppies, two dumb terminals, a word processing printer, a fast line printer, network data base manager software and 1000 ft. of inter-connecting cable. Utlizing .7 MIPS processors throughout it will cost less than $50,000 plus installation. GT option computers (1.2 MIPS) can be utilized at a slightly higher cost.

One Step at a Time

Best of all, Ohio Scientific users can develop distributed processing systems economically one step at a time. A user can start with a single user floppy system, add a hard disk, then time-sharing, then a second Winchester data base for backup and finally cluster intelligent terminals to achieve a full network configuration.

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