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PRESENT CROMEMCO USERS
We've kept you in mind, too. Ask about the new Model HDD Disk Drive which can combine with your present Cromemco computer to give you up to 22 megabytes of disk storage.

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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 Garcia 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 excessive amounts of memory or time. This was one problem facing Douglas Macdonald and Yekta Gursel 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 technique 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 demonstrates a simple procedure for obtaining 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 A 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 you your recent endeavors with your personal computer been all work and no play? Charles A 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
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BYTE November 1979 5
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,” i.e., 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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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 “biorhythmianologist,” “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 pseudo-science 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-

---

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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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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 your 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 Carito 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:
A b c d E F G H C J U L M N O P R S T V W X Y Z

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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The Intel 8086

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.

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...

Photo 1: SDK-86 system as delivered from factory.
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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-
8086 REGISTER MODEL; (8080 REGISTERS SHADEd)

<table>
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<tr>
<th>AX</th>
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<th>DESTINATION INDEX</th>
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<th>INSTRUCTION POINTER</th>
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Memory Interface

Execution Unit

BUS INTERFACE UNIT

Instruction Stream Byte Queue

CONTROL SYSTEM

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
\[ V_{cc} = +5 \text{ V (±5%), 3.5 A} \]
\[ V_{rry} = -12 \text{ V (±10%), 0.3 A (required if teletypewriter (TTY) or video display terminal connected to serial interface port)} \]

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-

Photo 2: Typical page from the construction manual. Each instruction step is clearly explained and each component is accurately identified.
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The proven North Star disk controller was originally designed to accommodate the two-sided drives. North Star DOS and BASIC are upgraded to handle the new capacity, yet still run existing programs with little or no change. Of course, single sided diskettes are compatible with the new disk system.

North Star Horizon Computer Prices (includes 32K RAM, one parallel and two serial I/O ports), assembled, burned-in and tested:
- Horizon-1-32K-Q $2565
- Horizon-2-32K-Q $3215
- Horizon-1-32K-D $2315
- Horizon-2-32K-D $2765

Get both sides now! Quad capacity is available from your North Star dealer.
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 FFFFO. 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.

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

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

Text continued on page 24
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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 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.

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

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Solving Soma Cube and Polyomino Puzzles Using a Microcomputer

Douglas A Macdonald
Yekta Giirsel
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 $3.2 \times 10^{18}$ for the Pentomino puzzle and $4.7 \times 10^{11}$ 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.
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
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 you 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.

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

---

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.

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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 (i.e., 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.

```basic
10 REM COPYRITHT 1979 ORIENAlATION fABLE GENERATOR
20 INPUT "NUMBER OF DIMENSIONS":D:UP R: IF D=3 THEN J=24
30 INPUT "NUMBER OF PIECES":P:PRINT "NUMBER OF SQUARES PER PIECE":S
40 PRINT "FIRST ADDRESS OF ARRAY OF LENGTH":P:INPUT R0
50 PRINT "FIRST ADDRESS OF ARRAY OF LENGTH": (S-1)*P*D
60 REM PRINT "RECORD ARRAYS R AND B ON APE TO SAVE":END
70 DIM X(I),Y(I),Z(I):T=0:N=P*C*(S-1):FOR I=0 TO R0
80 POKE I+I0: NEXT I
90 FOR I=80 TO 50+S-1*I:POKE I+I0: NEXT I
100 REM PRINT RECORDS DATA COORDINATES OF EACH SQUARE OP EACH PIECE
110 FOR I=1 TO S
120 PRINT "***** DONC *****"
130 INPUT "ENTER X(I)=0:Y(I)=0:Z(I)=0:NEXT I:
140 PRINT PIECE #I:FOR I=1 TO S:PRINT SQUARE #I:
150 PRINT ENTER X","Y","Z":END
160 PRINT "RECORD STANDBY .......
170 REM TRANSLATE PIECE SO THAT BASE SQUARE IS AT ORIGIN
180 A=(I=0):C=0:E=0:F=0
190 U=1 TO S:IF X(I)<U THEN U=X(I):NEXT I
200 NEXT I:FOR I=1 TO S:IF Z(I)<U AND X(I)=0 AND Y(I)=0 THEN
210 NEXT I: FOR I=1 TO S:IF Z(I)<U AND X(I)=0 AND Y(I)=0 THEN
220 NEXT I: FOR I=1 TO S:IF Z(I)<U AND X(I)=0 AND Y(I)=0 THEN
230 REM ORDER SQUARES ACCORDING TO THEIR DISTANCE FROM THE BASE SQUARE
240 FOR I=1 TO S1: FOR J=1 TO S: IF Z(I)<Z(J) AND X(I)=X(J) AND Y(I)=Y(J) THEN
250 NEXT I: FOR I=1 TO S:IF Z(I)<Z(J) AND X(I)=X(J) AND Y(I)=Y(J) THEN
260 NEXT I: FOR I=1 TO S:IF Z(I)<Z(J) AND X(I)=X(J) AND Y(I)=Y(J) THEN
270 NEXT I: FOR I=1 TO S:IF Z(I)<Z(J) AND X(I)=X(J) AND Y(I)=Y(J) THEN
280 REM COMPARE ORIENTATION TO THOSE ALREADY OBTAINED
290 FOR I=1 TO S: FOR J=1 TO S: I=U=60+J-1*(S-1)**(K*1-K)-1)
300 Y(J)=Y(J)+I:IF Y(J)<Y(J) THEN Y(J)=Y(J)+1:IF Y(J)>Y(J) THEN Y(J)=Y(J)-1:
310 FOR I=1 TO S: FOR J=1 TO S: FOR K=1 TO S:
320 IF X(I)=X(J) AND Y(I)=Y(J) AND Z(I)=Z(J) THEN
330 PRINT "RECORD X","Y","Z":END
340 FOR I=1 TO S: FOR J=1 TO S: FOR K=1 TO S:
350 IF X(I)=X(J) AND Y(I)=Y(J) AND Z(I)=Z(J) THEN
360 IF X(I)=X(J) AND Y(I)=Y(J) AND Z(I)=Z(J) THEN
370 IF X(I)=X(J) AND Y(I)=Y(J) AND Z(I)=Z(J) THEN
380 REM PUT ENTERIES IN TABLE
390 J=0:A=1: FOR I=2 TO S: J=J+1:U=60+J-1*(S-1)**(K*1-K)-1)
400 FOR I=1 TO S:FOR J=1 TO S: FOR K=1 TO S:
410 IF X(I)=X(J) AND Y(I)=Y(J) AND Z(I)=Z(J) THEN
420 NEXT I: FOR I=1 TO S: FOR J=1 TO S: FOR K=1 TO S:
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)=Z(I)=Z(I):W=NEXT I: GOTO 150
460 C=C+1: IF C=2 THEN GOTO 10
470 GOTO 150
480 IF X(I)=X(J) AND Y(I)=Y(J) AND Z(I)=Z(J) THEN
490 NEXT I: FOR I=1 TO S: FOR J=1 TO S: FOR K=1 TO S:
500 REM PRINT "ORIENTATIONS":POKE R0+K,A:IF I=1 GOTO 570
510 NEXT K: FOR I=1 TO S: FOR J=1 TO S: FOR K=1 TO S:
520 REM PRINT "CORRECT MISTAKES"
530 T=1:INPUT "ENTER L.D. NUMBER OF A PIECE YOU NEED TO CORRECT(0 IF NONE)":K
540 IF K<>0 GOTO 90
550 PRINT "PUBLIC" DICE " PUBLIC"
560 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, i.e.: at (0,0,0) 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 (i.e.: 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
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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.

Table: Orientation table entries for example of Pentomino 9.

<table>
<thead>
<tr>
<th>K=9</th>
<th>( I )</th>
<th>( J )</th>
<th>( 1 )</th>
<th>( 2 )</th>
<th>( 3 )</th>
<th>( 4 )</th>
<th>( M )</th>
</tr>
</thead>
<tbody>
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<td>1</td>
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<td>1</td>
<td>2</td>
<td>1</td>
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<td></td>
<td>0</td>
<td>-1</td>
<td>1</td>
<td>1</td>
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<td></td>
</tr>
<tr>
<td>5</td>
<td>3</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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:

\[
A(1,1,1), A(1,1,2), \ldots, A(1,1,5),
A(1,2,1), A(1,2,2), \ldots,
A(1,2,5), \ldots, A(5,5,1),
A(5,5,2), \ldots A(5,5,5)
\]

(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

\[
B0 + J - 1 + (S - 1) \times \{ Q \times \left[ P \times (M-1)+K-1 \right]+I-1 \},
\]

and the number of elements in the table is given by \((S-1) \times Q \times P \times D\). 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.

Definition of Variables

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

```basic
1 REM POKE 115,20 TO PROTECT MACHINE CODE FROM BASIC INTERPRETER
2 REM AS HELPS PRINTOUT SYMBOLS FOR PIECES
3 AS=""KVHLEspK"'
4 REM COPYRIGHT 1979 JUMA-POLYOMINOES DRIVER PROGRAM
5 INPUT VERT NUMBER OF DIMENSIONS":D
6 POKE 31,D
7 INPUT "ENTER THE NUMBER OF PIECES";P
8 POKE 27,P
9 INPUT "NUMBER OF SQUARES PER PIECE";S
10 POKE 25,S
11 PRINT "ENTER DIMENSIONS OF THE BOX";INPUT "WX";WX;INPUT "WY";WY
12 WX=1:IP D=0 THEN PRINT "WX":WY
13 PRINT "ificates corresponding to"
14 POKE 29,WY
15 PRINT "VALUES TO \&0,\&0,\&C,\&2,\&5 AGREED WITH"
16 REM AS HELPS EACH SOLUTION FOR PRINTOUT
17 REM ARRAYS X AND Y ARE PRODUCED BY TAB. GEN. PROGRAM AND
18 POKE 28,J-1:POKE J,J-1
19 Q=P:IP D THEN D=24
20 POKE 33,J2:SPACE*Q*P*(S-1):1=IN(T/(SPACE/256)):J=SPACE/256*I
21 POKE 30,J:POKE 31,J:J=J5
22 INDEX}=0:INDEX=INDEX/256:J=INDEX/256*H
23 POKE 39,J2:POKE J,J
24 POE{=A) TO A+X+WY*WX+1:POKE IP0:J0:NEXT I
25 POKE 12 TO C2:POKE J,0:NEXT 1
26 REM PLACE HOBODY OF (1)'s ARROW BOX
27 J=(WX-1)*WY+X=WY+X=WY*WY+X
28 POKE 1=9 TO A0:HAO+I-1:POKE 1,255:POKE I+J,255:NEXT 1
29 POKE 1=W-2 TO AO+J+1
30 FOR X=AO TO A+X*L-1 STEP A+X+J+1 STEP A+X*L-1,255:POKE I,NJ,255
31 NEXT X NEXT 1
32 POKE 1,WX+2 TO AO+J+1 NEXT 1:
33 POKE 1,J+WY+1 TO AO+J+1 NEXT J W+1 NEXT J
34 PRINT "ENTER COORDINATES OF FREE LIMITS SQUARES.";
35 PRINT "WHERE DONE ENTER 999 FOR X";
36 INPUT X,Y,Z=2:IF D THEN INPUT "NZ":Z
37 POKE AO+WY+X+Z,255:PRINT:GOTO 130
38 FOR I=1 TO PRINT X:POKE C1+I:X:IF J THEN 140
39 PRINT "ENTER NUMBER OF PIECES FIXED":7
40 POKE 1=W-2:POKE 0,21:POKE W-1,9:IF Z=0 GOTO 100
41 REM PUT IN FIXED PIECES, IF ANY
42 FOR I=1 TO Z:PRINT:PRINT "ENTER COORDS. OF EACH SQUARE OF";
43 PIECE*PEEK[C1+1]
44 IF D THEN S:PRINT "SQUARE":J:INPUT X:1:INPUT Y:Z=0
45 IF D THEN INPUT "NZ":Z
46 POKE AO+Z(WY+X+9,255:PRINT:GOTO 130
47 REM IN LIZE BASE SQUARE
48 POE{=A) TO W*W+X+Z-1:IF PEEK(A+C1)=3 THEN POKE 111,
49 T0 J20
50 NEXT X
51 POKE 18,1
52 SYS(520)
53 C=0
54 REM PRINT A SOLUTION
55 IF PEEK(18)=0 THEN PRINT:PRINT" DONE !!!!":END
56 C="C":C="C":PRINT:PRINT"SOLUTION ":I=C
57 J=3:AS="":FOR Y=W-2 TO 1 STEP -1
58 IP D THEN FOR Z=1 TO W-2
59 IF X=1 AND Z<X0 AND Z<W-2 THEN AS=AS+" "
60 IF IP 0 THEN AS=AS+"":GOTO 1090
61 IF A=255 THEN AS=""""+"blackout":GOTO 1090
62 AS=""""MID(B,A,1)
63 NEXT X:IP D THEN NEXT Z
64 NEXT Y
65 H=W-2:IF D=Z THEN U=(WX-1)+(WZ-2)+1
66 FOR I=1 TO WY-2:PRINT MIDS(AS,1) (1-1)+1):NEXT I
67 REM TYPING "T" WILL CAUSE EXECUTION TO STOP ON NEXT RETURN
68 REM TO BASIC program, the user should be careful to1140 GET YS:";IF YS="" THEN PRINT:PRINT " STOP":END
69 SYS(5759)
```

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.
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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.

<table>
<thead>
<tr>
<th>Variable or Location Name</th>
<th>Location (Hexadecimal)</th>
<th>Variable or Location Name</th>
<th>Location (Hexadecimal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>0</td>
<td>REMOVED</td>
<td>14CD</td>
</tr>
<tr>
<td>I</td>
<td>1</td>
<td>SAVE</td>
<td>14ED</td>
</tr>
<tr>
<td>K</td>
<td>2</td>
<td>LOOP3</td>
<td>1508</td>
</tr>
<tr>
<td>J</td>
<td>A</td>
<td>JUMP1</td>
<td>1524</td>
</tr>
<tr>
<td>L</td>
<td>B</td>
<td>ISOSQ</td>
<td>1527</td>
</tr>
<tr>
<td>T</td>
<td>E</td>
<td>LEAVE</td>
<td>159C</td>
</tr>
<tr>
<td>Z</td>
<td>F</td>
<td>JUMP2</td>
<td>15A8</td>
</tr>
<tr>
<td>SAFE</td>
<td>10</td>
<td>REFEDIT</td>
<td>15AB</td>
</tr>
<tr>
<td>U</td>
<td>11</td>
<td>PERMUTE</td>
<td>15C2</td>
</tr>
<tr>
<td>FLAG</td>
<td>12</td>
<td>ILOOP</td>
<td>15CC</td>
</tr>
<tr>
<td>BXLO</td>
<td>13</td>
<td>LOOP</td>
<td>15D7</td>
</tr>
<tr>
<td>BXHI</td>
<td>24</td>
<td>MAX</td>
<td>15F4</td>
</tr>
<tr>
<td>BYLO</td>
<td>25</td>
<td>SWITCH</td>
<td>1612</td>
</tr>
<tr>
<td>BYHI</td>
<td>26</td>
<td>ZERO2</td>
<td>162B</td>
</tr>
<tr>
<td>BZLO</td>
<td>27</td>
<td>ORDER</td>
<td>1643</td>
</tr>
<tr>
<td>BZHI</td>
<td>28</td>
<td>NEXTJ</td>
<td>164A</td>
</tr>
<tr>
<td>s</td>
<td>29</td>
<td>NEXTU</td>
<td>1651</td>
</tr>
<tr>
<td>SM1</td>
<td>3A</td>
<td>NOSWITCH</td>
<td>166C</td>
</tr>
<tr>
<td>P</td>
<td>2B</td>
<td>LSTPO</td>
<td>167F</td>
</tr>
<tr>
<td>WX</td>
<td>2C</td>
<td>TAKEOUT</td>
<td>168F</td>
</tr>
<tr>
<td>WY</td>
<td>2D</td>
<td>LOOKUP</td>
<td>16BC</td>
</tr>
<tr>
<td>WZ</td>
<td>3E</td>
<td>TOP</td>
<td>16CD</td>
</tr>
<tr>
<td>D</td>
<td>3F</td>
<td>MULT1</td>
<td>16D7</td>
</tr>
<tr>
<td>PM1</td>
<td>20</td>
<td>STEP1</td>
<td>16DE</td>
</tr>
<tr>
<td>Q</td>
<td>21</td>
<td>STORE1</td>
<td>16E5</td>
</tr>
<tr>
<td>OLDK</td>
<td>22</td>
<td>STORE2</td>
<td>16E6</td>
</tr>
<tr>
<td>OLDI</td>
<td>23</td>
<td>MIDDLE</td>
<td>1721</td>
</tr>
<tr>
<td>SPACELO</td>
<td>24</td>
<td>MULT3</td>
<td>1729</td>
</tr>
<tr>
<td>SPACEHI</td>
<td>25</td>
<td>STEP3</td>
<td>1730</td>
</tr>
<tr>
<td>INDEXLO</td>
<td>26</td>
<td>ADD</td>
<td>1737</td>
</tr>
<tr>
<td>INDEXHI</td>
<td>27</td>
<td>DIM3</td>
<td>174F</td>
</tr>
<tr>
<td>START</td>
<td>1400</td>
<td>MULT4</td>
<td>1753</td>
</tr>
<tr>
<td>LOOP1</td>
<td>1413</td>
<td>STEP4</td>
<td>175A</td>
</tr>
<tr>
<td>TEST</td>
<td>1428</td>
<td>END</td>
<td>1761</td>
</tr>
<tr>
<td>INSERT</td>
<td>1437</td>
<td>C1</td>
<td>1838</td>
</tr>
<tr>
<td>LOOP2</td>
<td>143B</td>
<td>C2</td>
<td>184C</td>
</tr>
<tr>
<td>NXTBASE</td>
<td>146D</td>
<td>E0</td>
<td>1860</td>
</tr>
<tr>
<td>INCX</td>
<td>146F</td>
<td>A0</td>
<td>189C</td>
</tr>
<tr>
<td>ISOTEST</td>
<td>14CB</td>
<td>R0</td>
<td>1984</td>
</tr>
<tr>
<td>REPLACE</td>
<td>14B4</td>
<td>B0</td>
<td>19C8</td>
</tr>
<tr>
<td>JSTART</td>
<td>14C8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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 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 RO and BO, 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:

(\((X,Y) = (1,0)\)) \hspace{1cm} \((X,Y) = (4,2)\)

\((0,0) \hspace{1cm} (0,1) \hspace{1cm} (3,2) \hspace{1cm} (3,3)\)

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 RO and BO should be recorded on tape. They can be recorded as one file if RO and BO 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
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Listing 3 continued:

<table>
<thead>
<tr>
<th>LOOP2: JSR LOOKUP</th>
<th>;insert piece (K) by putting the number (K) into the appropriate squares of the box</th>
</tr>
</thead>
<tbody>
<tr>
<td>LDA K</td>
<td></td>
</tr>
<tr>
<td>STA A0,X</td>
<td></td>
</tr>
<tr>
<td>INC J</td>
<td></td>
</tr>
<tr>
<td>LDA SM1</td>
<td></td>
</tr>
<tr>
<td>CMP J</td>
<td></td>
</tr>
<tr>
<td>BCS LOOP2</td>
<td></td>
</tr>
<tr>
<td>LDX L</td>
<td></td>
</tr>
<tr>
<td>LDA K</td>
<td></td>
</tr>
<tr>
<td>STA A0,X</td>
<td></td>
</tr>
<tr>
<td>TAX</td>
<td></td>
</tr>
<tr>
<td>LDA L</td>
<td></td>
</tr>
<tr>
<td>STA E0,X</td>
<td>;save base square of piece (K)</td>
</tr>
<tr>
<td>LDA P</td>
<td>;if all of the pieces are in the box,</td>
</tr>
<tr>
<td>CMP N</td>
<td>;return to BASIC to print solution</td>
</tr>
<tr>
<td>BCS WITBASE</td>
<td>;otherwise, find next base square</td>
</tr>
<tr>
<td>STS</td>
<td></td>
</tr>
<tr>
<td>NXTBASE: LDX L</td>
<td>;scan for next base square</td>
</tr>
<tr>
<td>INCX: INX</td>
<td></td>
</tr>
<tr>
<td>LDA A0,X</td>
<td></td>
</tr>
<tr>
<td>BEQ ISOTEST</td>
<td></td>
</tr>
<tr>
<td>JMP INCX</td>
<td></td>
</tr>
<tr>
<td>ISOTEST: STX J</td>
<td>;put new base square in location J</td>
</tr>
<tr>
<td>LDA D</td>
<td></td>
</tr>
<tr>
<td>CMP #3</td>
<td></td>
</tr>
<tr>
<td>BEQ REPLACE</td>
<td>;if (D)=3, skip isolated square test</td>
</tr>
<tr>
<td>TXA</td>
<td>;test if new base square is isolated</td>
</tr>
<tr>
<td>CLC</td>
<td></td>
</tr>
<tr>
<td>ADC #1</td>
<td></td>
</tr>
<tr>
<td>TAX</td>
<td></td>
</tr>
<tr>
<td>LDA A0,X</td>
<td></td>
</tr>
<tr>
<td>BEQ REPLACE</td>
<td></td>
</tr>
<tr>
<td>TXA</td>
<td></td>
</tr>
<tr>
<td>CLC</td>
<td></td>
</tr>
<tr>
<td>ADC WY</td>
<td></td>
</tr>
<tr>
<td>TAX</td>
<td></td>
</tr>
<tr>
<td>DEX</td>
<td></td>
</tr>
<tr>
<td>LDA A0,X</td>
<td></td>
</tr>
<tr>
<td>BEQ REPLACE</td>
<td>;if it is not, go to REPLACE</td>
</tr>
<tr>
<td>JMP ISOTEST2</td>
<td>;if it is, go to isolated square routine</td>
</tr>
<tr>
<td>REPLACE: LDA J</td>
<td></td>
</tr>
<tr>
<td>STA L</td>
<td>;set new base square</td>
</tr>
<tr>
<td>INC N</td>
<td>;increment piece counter</td>
</tr>
<tr>
<td>LDA T</td>
<td>;(T)=greatest number of pieces</td>
</tr>
<tr>
<td>CMP N</td>
<td>successfully fitted into box in current permutation</td>
</tr>
<tr>
<td>BCS JSTART</td>
<td></td>
</tr>
<tr>
<td>LDA W</td>
<td></td>
</tr>
<tr>
<td>STA T</td>
<td></td>
</tr>
<tr>
<td>JSTART: JMP START</td>
<td>;return to START</td>
</tr>
<tr>
<td>REMOVE: LDN N</td>
<td>;remove last piece inserted</td>
</tr>
<tr>
<td>LDA #0</td>
<td></td>
</tr>
<tr>
<td>STA C2,X</td>
<td>;set orientation number to zero</td>
</tr>
<tr>
<td>DEX</td>
<td>;decrement piece counter</td>
</tr>
<tr>
<td>STX N</td>
<td></td>
</tr>
<tr>
<td>LDA C1,X</td>
<td></td>
</tr>
<tr>
<td>STA K</td>
<td></td>
</tr>
<tr>
<td>LDA C2,X</td>
<td></td>
</tr>
<tr>
<td>STA I</td>
<td></td>
</tr>
<tr>
<td>LDA Z</td>
<td></td>
</tr>
<tr>
<td>CMP N</td>
<td></td>
</tr>
<tr>
<td>BCC SAVE</td>
<td>;if no, take it out</td>
</tr>
<tr>
<td>JMP PERMUTE</td>
<td>;if yes, go to next permutation of pieces</td>
</tr>
<tr>
<td>SAVE: LDY K</td>
<td>;recover base square of the piece to be taken out</td>
</tr>
<tr>
<td>LDN E0,Y</td>
<td></td>
</tr>
<tr>
<td>STX L</td>
<td></td>
</tr>
<tr>
<td>LDA #0</td>
<td></td>
</tr>
<tr>
<td>STA A0,X</td>
<td></td>
</tr>
<tr>
<td>LDY #1</td>
<td></td>
</tr>
<tr>
<td>STY J</td>
<td></td>
</tr>
<tr>
<td>LOOP3: JSR LOOKUP</td>
<td>;take out piece by putting zeroes in each square it occupies</td>
</tr>
<tr>
<td>LDA #0</td>
<td></td>
</tr>
<tr>
<td>STA A0,X</td>
<td></td>
</tr>
<tr>
<td>INC J</td>
<td></td>
</tr>
<tr>
<td>LDA SM1</td>
<td></td>
</tr>
<tr>
<td>CMP J</td>
<td></td>
</tr>
<tr>
<td>BCS LOOP3</td>
<td></td>
</tr>
<tr>
<td>LDX K</td>
<td></td>
</tr>
<tr>
<td>LDA I</td>
<td>;check if piece has any more orientations</td>
</tr>
</tbody>
</table>

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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 |
| DEC ILOP |
| LDA #0 |
| STA FLAG |
| RETS |

SWITCH: INC N

;interchange elements found by 1 and J loops

ORDER:
| LDA I |
| ADC #1 |
| STA J |
| NEXTJ: LDA J |
| LDX J |
| LDA C1,X |
| CMP C1,Y |
| BCS NOSWITCH |
| STA V |
| LDA C1,Y |
| STA C1,X |
| LDA V |
| STA C1,Y |

NOSWITCH: INC U

;return to START

LISTPC: LDX K

;BASIC returns control to here after printing a solution so that the (P)-th piece can be taken out

LDA 50,X

STA L

LDA #1

STA J

TAKEOUT: JSR LOOKUP

LDA #0

STA A0,X

INC J

Listing 3 continued on page 48
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Circle 301 on inquiry card.
Listing 3 continued:

LDA SM1
CMP J
BCS TAKEOUT
LDX L
LDA #0
JMP REMOVE

LOOKUP: LDY J
       ;put square number in Y register
LDA I
       ;it (I) and (K) are the same as in the
CMP OLD1
       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
       
STEP1: DEY
BEQ STORE1
ASL A
JMP MULT1

STORE1: ADC I
STA BXLO
       ;store result in BXLO
LDX SM1
MULT2: DEY
       ;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: DEY
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)=1, go to DIM3
CPX #3
BEQ DIM3
CLC

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 pro­

blem under consideration. When run,
the driver routine asks the user for in­
put 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 de­
sceding 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 (ex­clusing boundary) has the coordi­
nates (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 permuta­
tions should be kept in mind. Thus,
entering the piece numbers in ascend­
ing 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 speci­

fied as fixed should be put at the
beginning of the initial permutation.
For example, to find all of the solu­
tions with pieces 2 and 4 fixed in par­
ticular locations, the initial permuta­
tion array should have 2 and 4 at the
beginning, and the rest of the num­
bers 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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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 OLDRK
LDA I
STAOLDI
RTS ; return to main routine
```

```
DIM: LDA 
LDX #8
MUL:
ASL TEMP ; multiply (TEMP) by (42)
BCC STEP4
CLC
ADC WZ
STEP4: DEK
BEQ END
ASL A
JMP MULT4
EOD
ADC (DIZO),Y ; add Z coordinate of square
TAX ; transfer result to X register
LDA K ; store old (K) and (I) values
STA OLDRK
LDA I
STAOLDI
RTS ; return to main routine
```

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 PET Analog Input System. 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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Circle 22 on inquiry card.
Listing 4: Hexadecimal object code dump for the Soma Cube — Polyominoes program given in list 3.

**HEX DUMP OF**

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

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to be continued, continuously!

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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.)
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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 9 10 11 12 13 14 15 16 17 18 19"
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 T(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 THAU MOVE AT I,J
0992 REM FOR FIVE SQUARES EITHER SIDE OF MOVE
0993 REM IN EIGHT DIRECTIONS,
1000 LET K = 1
1001 LET L = -1
1002 IF I < N THEN IF I > 5 THEN LET N = I
1003 IF I > 0 THEN IF I < 23 THEN LET 0 = 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 THAUS MOVE
1009 LET D = 0
1010 LET D = D + 1
1011 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 O = T(U + K, V + L)
1034 REM CALCULATE PRIORITY OF POSITION
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 O = 1 THEN LET P = 37
1043 IF R > 71 THEN IF B > 53 THEN IF B < 63 THEN LET P = 80
1044 IF R > 71 THEN IF B > 71 THEN LET P = 80
1045 IF R > 53 THEN IF R < 63 THEN IF O = 2 THEN LET P = 72
1046 IF R = 72 THEN IF R = 71 THEN LET P = 31
1047 IF Q < 2 THEN GOTO 1058
1048 IF R = 71 THEN IF R = 70 THEN LET P = 80
1049 IF R = 79 THEN LET P = 80
1050 IF R = 41 THEN LET R = 81
1051 IF R = 42 THEN IF R = 5 THEN IF R = 4 THEN LET R = 41
1052 IF R = 1 THEN GOTO 1058
1053 IF R = 7 THEN LET P = 80
1054 IF R = 79 THEN LET P = 80
1055 IF R = 41 THEN LET R = 81
1056 IF R = 42 THEN IF R = 5 THEN IF R = 4 THEN LET R = 41
1057 IF R = 1 THEN GOTO 1058
1058 IF R = 7 THEN LET P = 80
1059 IF R = 79 THEN LET P = 80
1060 IF R = 41 THEN LET R = 81
1061 IF R = 42 THEN IF R = 5 THEN IF R = 4 THEN LET R = 41
1062 IF R = 1 THEN GOTO 1058
1063 IF R > 27 THEN IF R > 54 THEN IF R > 58 THEN
1064 IF R = 79 THEN IF A = 51 THEN LET M(E,G) = 41
1065 IF R = 79 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
1068 IF S[R] < 41 THEN LET R = 74
1069 IF S[R] = S[R]/10*10 = 9 THEN IF A = A/10*10 = 9 THEN
1070 IF S[R] < 41 THEN LET R = 74
1071 IF R > 4 THEN GOTO 1090
1072 LET U = U + K
1073 LET V = V + L
1074 GOTO 1011
1075 REM CHANGE DIRECTION
1076 IF K = 0 THEN LET L = 0 THEN RETURN
1077 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 = 0 THEN LET K = -1
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

Circle 13 on inquiry card.

Circle 303 on inquiry card.
Listing 2: Sample output of the 19 by 19 board.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
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<tbody>
<tr>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>14</td>
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<td>16</td>
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<tr>
<td>17</td>
<td>18</td>
<td>19</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>LINE NUMBER</th>
<th>PATTERN</th>
<th>PRIORITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1234</td>
<td>x1-xx</td>
<td>65</td>
</tr>
<tr>
<td>2345</td>
<td>-0-00</td>
<td>94</td>
</tr>
<tr>
<td>3456</td>
<td>00+00</td>
<td>94</td>
</tr>
<tr>
<td>4567</td>
<td>0++0-</td>
<td>94</td>
</tr>
<tr>
<td>5678</td>
<td>000-0-</td>
<td>94</td>
</tr>
<tr>
<td>6789</td>
<td>0000-</td>
<td>94</td>
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<tr>
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<td>0xxxxx</td>
<td>68</td>
</tr>
<tr>
<td>8901</td>
<td>xx0x</td>
<td>68</td>
</tr>
<tr>
<td>9012</td>
<td>x0xx</td>
<td>68</td>
</tr>
<tr>
<td>1012</td>
<td>0xxx</td>
<td>68</td>
</tr>
<tr>
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<td>0xx0</td>
<td>68</td>
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<tr>
<td>7879</td>
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<td>100</td>
</tr>
<tr>
<td>8980</td>
<td>0xxxx</td>
<td>100</td>
</tr>
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</table>

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

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 Nantucket 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 A = E : Z = Z - 176 :
   A = Z + 1 : 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 : A = A + 8 :
   FOR THE Apple II
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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<tbody>
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</tr>
<tr>
<td>Word-Master T.M.</td>
<td>$150/25</td>
</tr>
<tr>
<td>Tex-Writer T.M.</td>
<td>$ 75/15</td>
</tr>
<tr>
<td>Super-Sort T.M.</td>
<td>$250/25</td>
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<tr>
<td>Super-Sort II T.M.</td>
<td>$200/25</td>
</tr>
<tr>
<td>Super-Sort III T.M.</td>
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</tr>
</tbody>
</table>

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Programming Strategies in the Game of Reversi

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

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. 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 lan-
guages) 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 trade-
mark, “Othello,” and the publication of
a well written book on the game. (See
“Othello, a New Ancient Game,” Octo-
ber 1977 BYTE, page 60, and the bibili-
ography 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 show-
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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.

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.)

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 multi-byte 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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<th>Features</th>
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<th>Anadex DP-8000</th>
<th>Centronics 736-1 (Radio Shack 26-1154)</th>
<th>Super Brain LP-80</th>
<th>Integral Data 440</th>
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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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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 $10^n$, 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 (i.e., 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.

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 A with value 100 or play D with value 50 (see figure 5). Suppose the computer evaluates B, 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, i.e.: 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

---

**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.
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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
60 REM A(100) - FOR SAVING BOARD
62 REM B(100) - 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 COMPUTER'S BEST PLAY
66 REM COMPUTER'S CURRENT PLAY
67 REM G - VALUE OF OPPONENT'S BEST REPLY TO COMPUTER'S CURRENT PLAY
68 REM H - VALUE OF OPPONENT'S CURRENT REPLY
69 REM I - NOT USED
70 REM J, K, L - COUNTERS
71 REM M - PLAY
72 REM N - COUNTER
73 REM O - NOT USED
74 REM P - PLAYER, BLACK=-1, WHITE=1
75 REM Q - TOTAL MOVES
76 REM R, S - NOT USED
77 REM T - LOGICAL VALUE, TRUE=1, FALSE=0
78 REM U - COUNTER
79 REM V, W - TO SAVE PLAY
80 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 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
195 GOSUB 8000
200 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
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
233 IF B[Z]=-1 THEN 244
235 LET J=J+1
237 GOTO 244
239 GOTO 9998
245 PRINT "NEXT 2"
246 PRINT "BLACK HAS "':N:' ', WHITE HAS "':J:' PIECES"
247 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"
262 GOTO 950
265 GOSUB 1100
270 IF M<>1 THEN 500
271 IF O<>4 THEN 430
305 REM COMPUTER PLAYS
310 REM FIRST 4 PLAYS
315 LET M=45
320 IF B[M]=2 THEN 540
324 LET M=M+1
325 GOTO 403
330 GOSUB 3000
340 REM CHECK PLAY
342 IF M<1 THEN 800
347 IF M>100 THEN 800
350 IF O>4 THEN 800
360 IF B[M]<>2 THEN 800
370 LET B[M]=P
380 GOTO 830
390 LET O=O+1
395 LET P=-P
400 REM COMPUTER PLAYS
405 GOTO 8030
410 GOSUB 1400
420 IF T<0 THEN 950
430 PRINT "ILLEGAL PLAY"
440 GOTO 200
450 LET B[M]=P
460 GOTO 8030
470 LET Q=Q+1
480 LET P=-P
490 GOTO 185
500 REM COMPUTER PLAYS
510 GOTO 950
520 PRINT "ILLEGAL PLAY"
530 GOTO 200
540 LET B[M]=P
550 GOTO 8030
560 LET O=O+1
570 LET P=-P
580 GOTO 185
590 REM COMPUTER PLAYS
600 GOTO 950
610 PRINT "ILLEGAL PLAY"
620 GOTO 200
630 LET B[M]=P
640 GOTO 8030
650 LET O=O+1
660 LET P=-P
670 GOTO 185
680 REM COMPUTER PLAYS
690 GOTO 950
700 PRINT "ILLEGAL PLAY"
710 GOTO 200
720 LET B[M]=P
730 GOTO 8030
740 LET O=O+1
750 LET P=-P
760 GOTO 185
770 REM COMPUTER PLAYS
780 GOTO 950
790 PRINT "ILLEGAL PLAY"
800 GOTO 200
810 LET B[M]=P
820 GOTO 8030
830 LET O=O+1
840 LET P=-P
850 GOTO 185
860 REM COMPUTER PLAYS
870 GOTO 950
880 PRINT "ILLEGAL PLAY"
890 GOTO 200
900 LET B[M]=P
910 GOTO 8030
920 LET O=O+1
930 LET P=-P
940 GOTO 185
950 REM COMPUTER PLAYS
960 GOTO 950
970 PRINT "ILLEGAL PLAY"
980 GOTO 200
990 LET B[M]=P
995 GOTO 8030
999 GOTO 9998

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 then 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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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 "TURN, ENTER X,Y";
1150 INPUT X,Y
1160 LET M = X + 10 * Y
1170 RETURN
1299 REM * CHECK FOR LEGAL PLAY *
1300 LET T = 1
1301 PRINT "CHECKING";
1302 LET N = 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(IN)
1345 IF B(M + J) <> -P THEN 1385
1350 LET K = M + J
1355 REM FOUND MORE HARMFUL REPLY
1360 IF B(K) = P THEN 1390
1370 LET K = M + J
1380 IF B(K) = 0 THEN 1385
1385 LET K = K + J
1395 GOTO 1380
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(IN)
1444 IF B(M + J) <> -P THEN 1700
1450 LET K = M + J
1460 IF B(K) = 0 THEN 1700
1470 LET K = M + J
1480 IF B(K) = -P THEN 1700
1490 IF B(K) = P THEN 1530
1500 IF B(K) = P THEN 1700
1510 IF B(K) = 0 THEN 1700
1515 GOTO 1480
1530 LET T = 1
1531 LET L = M
1532 IF L = K THEN 1700
1533 LET B(L) = P
1534 LET I = L + J
1535 GOTO 1532
1536 LET M = NV
1537 PRINT "FORGET THIS PLAY"
1538 LET M = NV
1539 REM CHECK COMPUTER'S PLAYS *
2999 PRINT "THINKING";
3000 PRINT "CHEC";
3680 LET F = 9999
3690 FOR Z = 12 TO 99
3700 LET C(I) = 812(I)
3710 NEXT Z
3770 GOTO 3900
3780 LET T = 0 THEN 3860
3790 LET C(Z) = 812(I)
3800 IF H = F THEN 3840
3810 IF H < F THEN 3810
3820 REM CHOOSE RANDOM OF EQUAL PLAYS
3830 LET Z = RND(D)
3835 LET Z = RND(D)
3840 IF Z > 0.7 THEN 3840
3850 LET F = H
3855 LET B(Z) = C(I)
3880 REM * INITIALIZE *
3890 LET H = 9999
3891 FOR Z = 12 TO 89
3892 LET A(Z) = B(Z)
3893 NEXT Z
3894 LET P = -P
3895 LET V = M
3896 LET M = 12
3897 GOSUB 1400
3898 IF T = 0 THEN 4080
3899 REM CHECK OPPONENT'S REPLIES *
3900 LET H = 9999
3920 FOR Z = 12 TO 89
3925 LET A(Z) = B(Z)
3926 NEXT Z
3930 LET P = -P
3940 LET V = M
3950 LET M = 12
3970 GOSUB 1400
3980 IF H = 9999
3990 GOSUB 1430
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
4055 LET B(Z) = A(Z)
4070 NEXT Z
4080 LET M = M + 1
4090 IF M <> 90 THEN 3970
4100 LET V = M
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)
4200 REM FORGET THIS PLAY
4210 IF G > F THEN 4500
4230 LET Z = Z + 1
4240 IF Z < 90 THEN 4150
4250 RETURN
4299 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
5040 IF M < 19 THEN 5200
5050 LET E(18) = 5
5110 LET E(28) = 5
5120 LET E(62) = 5
5130 LET E(69) = 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 "";
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
Circle 77 on inquiry card.

9076 LET B(N)=3
9078 LET B(10+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
9176 LET Q=1
9190 LET P=-1
9191 RETURN
9220 DATA 0, 64, -30, 10, 5, 10, -30, 64, 0
9222 DATA 0, -30, -40, 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, 2, 5, 0
9228 DATA 0, 5, 2, 1, 1, 1, 2, 5, 0
9230 DATA 0, 10, 2, 5, 1, 1, 5, 2, 10, 0
9232 DATA 0, -30, -40, 2, 2, 2, -40, -30, 0
9234 DATA 0, 64, -30, 10, 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
73,4
1 2 3 4 5 6 7 8
8 7 6 5 4 3 2 1
5 4 3 2 1 0
1 2 3 4 5 6 7 8

OWNER'S TIP: If you want to reset the game, enter 0, 0, or any move that
is not possible. For example, if the computer has just played
1, 1, you should enter 0, 0 or 2, 2.

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EVERY THREE MONTHS onComputing will bring the latest developments in the field of personal computing: use, applications, books, selection—all in an easy-to-read style.
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 SYSTEMS: 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 280 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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We’re about to make a new name for ourselves.

Not that the old one was so bad. As Ithaca Audio, we’ve made quite a name for ourselves. As the source for CPU, memory, video display and disk controller boards to upgrade other makers’ mainframes and peripherals. The company that makes those neat little RAM expansion kits. And the folks behind the world’s only Z-80 Pascal compiler.

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InterSystems

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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 (i.e., 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.

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.
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Although PSYMOW™ includes a full complement of operating system commands and 15 externally callable "trademark of Percom Data Company, Inc.

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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.

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Circle 307 on inquiry card.
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 ...WHEREUPON WHITE GIVES CHECKMATE.

TO TAKE THE QUEEN....

Figure 2: The sequence of moves that White makes to capture Black's King... CHECKMATE!
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- Interface to data terminal and two casette recorders with a unit only 1/10 the size of SWTP's AC-30.
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(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.

![Game Tree Diagram](image-url)

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.

---

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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, 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
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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

<table>
<thead>
<tr>
<th>Evaluation Function Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capturing the Queen</td>
</tr>
<tr>
<td>Capturing a Rook</td>
</tr>
<tr>
<td>Capturing a Knight or Bishop</td>
</tr>
<tr>
<td>Capturing a pawn</td>
</tr>
<tr>
<td>Doubled pawns</td>
</tr>
<tr>
<td>Tripped pawns</td>
</tr>
<tr>
<td>Isolated pawns</td>
</tr>
<tr>
<td>Two pawns next to each other</td>
</tr>
<tr>
<td>One pawn guarding another</td>
</tr>
<tr>
<td>Knight on opponent's side of the board</td>
</tr>
<tr>
<td>Same, with pawn guarding it</td>
</tr>
<tr>
<td>Bishop on strong diagonal</td>
</tr>
<tr>
<td>Rook on open file</td>
</tr>
<tr>
<td>Doubled Rooks on open file</td>
</tr>
<tr>
<td>Rook behind passed pawn</td>
</tr>
<tr>
<td>Rook on seventh rank, two unmoved opposing pawns</td>
</tr>
<tr>
<td>Rook on seventh rank, three unmoved opposing pawns</td>
</tr>
<tr>
<td>Rook on seventh rank, four unmoved opposing pawns</td>
</tr>
<tr>
<td>Rook moved before castling has occurred</td>
</tr>
<tr>
<td>King moved before castling has occurred</td>
</tr>
<tr>
<td>Castled King</td>
</tr>
<tr>
<td>Piece or pawn moved twice in the opening</td>
</tr>
<tr>
<td>Taking two moves instead of one to get to a square</td>
</tr>
<tr>
<td>Knight never moved</td>
</tr>
<tr>
<td>Knight in front of King's pawn or Queen's pawn</td>
</tr>
<tr>
<td>Bishop never moved</td>
</tr>
<tr>
<td>Bishop in front of King's pawn or Queen's pawn</td>
</tr>
</tbody>
</table>

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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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 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 importantly, 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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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.

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.

<table>
<thead>
<tr>
<th>PET Memory Location</th>
<th>Function Provided by the 6522</th>
</tr>
</thead>
<tbody>
<tr>
<td>59456</td>
<td>Output register for I/O port B.</td>
</tr>
<tr>
<td>59457</td>
<td>Data register for port A with handshake.</td>
</tr>
<tr>
<td>59458</td>
<td>I/O port B data direction register.</td>
</tr>
<tr>
<td>59459</td>
<td>I/O port A data direction register.</td>
</tr>
<tr>
<td>59460</td>
<td>Read timer 1 counter (low-order byte).</td>
</tr>
<tr>
<td>59461</td>
<td>Write to timer 1 latch (low-order byte).</td>
</tr>
<tr>
<td>59462</td>
<td>Read timer 1 counter (high-order byte).</td>
</tr>
<tr>
<td>59463</td>
<td>Write to timer 1 latch (high-order byte).</td>
</tr>
<tr>
<td>59464</td>
<td>Access timer 1 latch (low-order byte).</td>
</tr>
<tr>
<td>59465</td>
<td>Access timer 1 latch (high-order byte).</td>
</tr>
<tr>
<td>59466</td>
<td>Read low-order byte of timer 2 and reset counter interrupt.</td>
</tr>
<tr>
<td>59467</td>
<td>Write to low-order byte of timer 2 but do not reset interrupt.</td>
</tr>
<tr>
<td>59468</td>
<td>Access high-order byte of timer 2.</td>
</tr>
<tr>
<td>59469</td>
<td>reset counter interrupt on write.</td>
</tr>
<tr>
<td>59470</td>
<td>Serial I/O shift register.</td>
</tr>
<tr>
<td>59471</td>
<td>Auxiliary control register.</td>
</tr>
<tr>
<td>59472</td>
<td>Peripheral control register.</td>
</tr>
<tr>
<td>59473</td>
<td>Interrupt flag register.</td>
</tr>
<tr>
<td>59474</td>
<td>Interrupt enable register.</td>
</tr>
<tr>
<td>59475</td>
<td>Data register for I/O port A without handshake.</td>
</tr>
</tbody>
</table>

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 CALL FOR ACKNOWLEDGE FROM DEVICE
20 POKE 59457:255:REM DIRECTION OUT
25 GOSUB 100:REM HANDSHAKE NOT READY
34 FOR J=1 TO 25:REM SCAN ROWS
35 FOR J=1 TO 40:REM SCAN COLUMNS
36 V=PEEK(122767+J-1+40K(1-1))
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(59459) AND 2:REM INT FLG REG
58 IF ACK<>0 THEN 56:REM ACKNOWLEDGE
70 NEXT J

```

---

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.

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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.

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

REFERENCES
1. An Introduction to Your New PET Commodore Systems, 901 California Ave, Palo Alto CA 94304.
2. PET User Notes, Volume 1, Issue 2, January 1978. PET User Group, POB 371, Montgomeryville PA 18931.
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A Spacecraft Simulator

Gary Sivak
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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:

\[ V_{f_{\text{final}}} = V_{\text{initial}} + \text{acceleration} \times dt \]  

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

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 AS
40 PRINT "VERIFICATION, "; A5; " STAGES."
50 AS = AS + 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
145 A9 = A6 - A9
150 AS = AS + 1
160 B0 = 3 + 1
170 PRINT "ENTER STAGE "; B0; "; FUEL AND HULL WEIGHS IN LBS."
180 INPUT A1(B0), A2(B0)
190 PRINT "STAGE "; B0; "; FUEL "; A1(B0); " LBS., HULL "; A2(B0); " LBS."
200 A2(B0) = A2(B0) + A2(B0) + A1(B0)
210 B1 = A2(B0) + A1(B0)
220 PRINT "ENTER STAGE "; B0; "; THRUST AT LEAST "; A3(B0); "; LBS."
230 PRINT "STAGE "; B0; "; THRUST, "; A3(B0); " LBS."
240 PRINT "ENTER SPECIFIC IMPULSE OF STAGE "; B0; " FUEL/OXIDIZER."
250 PRINT "THIS IS THE THRUST-TO-BURN RATE RATIO."
260 PRINT "FOR GASOLINE =250, PEROXIDE =300, LIQUID HYDROGEN =500."
270 PRINT "FOR GASOLINE =250, PEROXIDE =300, LIQUID HYDROGEN =500."
280 INPUT A4(B0)
290 PRINT "VERIFICATION, STAGE "; B0; "; SPECIFIC IMPULSE "; A4(B0)
300 NEXT A9
310 B1 = 10
320 B3 = 8 * 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 C1 = 1.0
400 C0 = SQRT(B7/9.80665)
410 C1 = C0
420 C2 = SQRT((B7/(C0+46*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

Text continued on page 108
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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 (DATESS$). DPEEK and DPOKE are 16-bit peek and poke type functions. The SCALE command has been included to eliminate the round-off errors typically encountered in binary math packages. The INCH$ function allows single-character input from the terminal. Programmer control of control C breaks is also included.
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Listing 1 continued:

870 \texttt{IF C9 \geq A(D2) THEN 1130}
875 \texttt{C9 = \texttt{REM-THROT(C.A. l, CRITICL THROT. OF CONST. ASCENT AT 90DSG.}}
880 \texttt{G9 = \texttt{SQR( 87}}
885 \texttt{1100 \texttt{IF G6 \geq 1.0 THEN 1350}}
890 \texttt{1350 F6 = C7 / .304B}
895 \texttt{1360 GB = 90.0}
900 \texttt{1000 A(D2) = 0.0}
905 \texttt{1150 IF A(D2) \leq 400000.0 THEN 1170}
910 \texttt{1170 D3 = 3 + 1}
915 \texttt{1180 D5 = 5280.}
920 \texttt{1190 P7 = P6 \times 15./22.}
925 \texttt{1200 F8 = \texttt{SQR( .3048}}
930 \texttt{1210 F9 = F8 \times 15./22.}
935 \texttt{1220 A0(D2) = C7 / B6}
940 \texttt{1230 S = 100. \times D7 / D6}
945 \texttt{1240 G0 = D7 / D5}
950 \texttt{1250 G1 = B7 / C1**2 - C6**2 / C1}
955 \texttt{1260 G2 = D8 / (D4 + D7) / .3048}
960 \texttt{1270 G3 = G2 \times 15. / 22.}
965 \texttt{1280 G4 = G2 - (G1 / .3048}}
970 \texttt{1290 G5 = G4 \times 15. / 22.}
975 \texttt{1300 G6 = G1 / .3048}
980 \texttt{1310 G7 = 100. \times G6}
985 \texttt{1320 G8 = 90.0}
990 \texttt{1330 IF G6 \geq 1.0 THEN 1150}
995 \texttt{1150 G9 = \texttt{SQR( B7 / C1) / .3048}}
1000 \texttt{1160 H = 100. \times F8 / C2}
1005 \texttt{1170 H0 = 100. \times A(D2) / (A8 * 5280.)}
1010 \texttt{1180 H1 = 10U. \times F8 / G9}
1015 \texttt{1190 H2 = (C2 - F8) / G2}
1020 \texttt{1200 H3 = (G9 - F8) / G2}
1025 \texttt{1100 IF P6 = 0.0 THEN 1440}
1030 \texttt{1440 H4 = (A8*5280. - A(D2)) / P6}
1035 \texttt{1430 IF H4 \leq 9999.99 THEN 1460}
1040 \texttt{1460 H4 = 9999.99}
1045 \texttt{REM-TIMES OVER 9999.99 SET TO 9999.99 TO NOT EXCEED DISPLAY.}
1050 \texttt{1140 IF D3 \leq 1.0 THEN 1480}
1055 \texttt{1470 PRINT \"400K FT. ACHIEVED, YOU ARE IN VACUUM. \"
1060 \texttt{11480 PRINT \"FLIGHT TIME," FUEL LEFT," AT FULL THROT.," SHIP ANGLE\"
1065 \texttt{1490 PRINT C3; \"SEC., \"G; \% \"GO; \"SEC., \"B9; \"DEG.\"
1070 \texttt{1500 PRINT \"\"
1075 \texttt{1510 PRINT \"ALTITUDE," ASCENT RATE," FORWARD V., \"RANGE\"
1080 \texttt{1520 PRINT A(D2); \"FE., \"P4; \"FT/SEC, \"P8; \"FT/SEC, \"A0(D2); \"MI.\"
1085 \texttt{1530 PRINT F5; \"MI., \"P7; \"MI./HR., \"F9; \"MI./HR.\"
1090 \texttt{1540 PRINT \"\"
1095 \texttt{1550 PRINT \"MAX ACCEL," MAX VERT ACCEL," ANGLE(C.A.), \"THROT(C.A.), \"\"
1100 \texttt{1560 PRINT \"MAX ACCEL, \"MAX VERT ACCEL, \"ANGLE(C.A.), \"THROT(C.A.), \"\"
1105 \texttt{1570 REM-THROT(C.A.), CRITICAL THROT. OF CONST. ASCENT AT 90DSG.\"
1110 \texttt{1580 PRINT G2; \"FT/S/S, \"J4; \"FT/S/S, \"FULL THROT., \"VERT. POS.\"
1115 \texttt{1590 PRINT G3; \"MI/H/S, \"G5; \"MI/H/S, \"G8; \"DEG. \"G7; \"\"
1120 \texttt{1600 PRINT \"\"
1125 \texttt{1610 PRINT \"% ORBITAL VELOCITY," H0; \"% ORBITAL HEIGHT.\"
1130 \texttt{1620 PRINT H1; \"% VELOCITY NEEDED FOR ORBIT AT CURRENT ALTITUDE.\"
1135 \texttt{1630 PRINT \"\"
1140 \texttt{1640 PRINT \"\" ; \"TIME TO ACHIEVE: \"
1145 \texttt{1650 PRINT \"CUR. ALT. OR3. VEL., \"CUR. ALT. OR3. VEL.\"
1150 \texttt{1660 PRINT \"AT CUR. RATS, \"AT FULL THROT., \"AT FULL THROT.\"
1155 \texttt{1670 PRINT D4; \"SEC., \"H2; \"SEC., \"H3; \"SEC.\"
1160 \texttt{1680 PRINT \"\"

Listing 1 continued on page 111
The following constants were used in Listing 1:

G: Gravitational constant, \(6.67 \times 10^{-11} \text{Nm}^2/\text{kg}^2\)

M: Mass of the earth, \(5.983 \times 10^{24} \text{kg}\)

g: Gravitational acceleration, 9.80665 N/kg, \(32.174 \text{ft/sec}^2 = 2.2046 \text{pounds/kg}\)

\[ \text{the product of horizontal velocity and distance from the Earth’s center.} \]

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:

\[ Q = \frac{\left( \frac{G M}{r_i^2} - \frac{V_{\text{orb}}^2}{r_i} \right)}{a} \]

Multiplying 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:

\[ \text{angle} = \tan^{-1} \left( \frac{Q}{\sqrt{1.0 - Q^2}} \right) \]

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 second². For example, if the engine can deliver about 40ft/s² the ship can accelerate at 8ft/s² 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.

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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 D(N$(7),N$(10)
12 J$='-'
15 INPUT*TEAM FILE ? *','F$
20 OPEN0+F$
90 'HITTERS'
100 FORA=10D16
110 INPUT*NAME ? *','N$
120 '*BAT$=AB+H+D+T+HR+BB+K0'
130 INPUT1? '*B(7)+C(1)+B(2)+B(3)+B(4)+B(5)+B(6)
132 IFC=OTHENC=1
135 INPUT* OK ?*','Z$','F$','C'THEN110
137 B9=B(1)-W-N+C(1)
140 C=C'B(5)/B(1)+B(1)/C
142 FORF=2TO4B(F)=B(F)/B9 \IFF=2THEN146
144 B(F)=B(F)+B(F-1)
146 NEXTX(5)=(B9*B(5))/C\B(6)+B(6)/H
155 N$=N$+1J$
160 WRITE0,N$,B(7),W@RE=1TO6\WRITE0,B(E)\NEXT\NEXT
190 'PITCHERS'
200 FORA=1TD9
210 INPUT*NAME ? *','N$
220 '*THROWS=IF\H,B,BB,KO*'
230 INPUT1? '*B(0)+C(1)+B(2)+B(3)
232 IFC=OTHENC=1
235 INPUT* OK ?*','Z$','F$','C'THEN210
237 B=1.25
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$=N$+1J$
280 WRITE0,N$,B(0)+B(1)+B(2)+B(3)
290 NEXT\Z=0\FORA=1TD13B\WRITE0,Z\NEXT\CLOSE0\END
```

TEAM FILE ? 75-BOSTON
HITTERS
NAME ? YASTREMSKI
BATS=AB+H+D+T+HR+BB+K0
? 1,543,146,30,1,14,87,67 OK ?
PITCHERS
NAME ? WISE
THROWS=IF\H,B,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.

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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$(10)
20 INPUT "TEAM FILE? " ,F$ 6 RICE
100 READ B(0),B(1),B(2),B(3),B(4),B(5),B(6)
70 NEXT
55 "21,Ar",* ,
60 "N$,TAB(16),B(0),",120 "15F3+B(1)+B(2)+B(3)"
130 NEXT
END
```

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 (262), hits (242), 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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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-Yanke3s 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.

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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.

```text
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 DIMR(7),N$(10)
20 OP#:---------
30 INPUT"TEAM FILE?",F$
40 INPUT"HITTERS"
50 INPUT"NAME?",N$
60 INPUT"BATS,AB•H•D•T,HR,88,KO"
70 INPUT"PITCHERS"
80 INPUT"NAME?",N$
90 INPUT"THROWS,IP•H•BA•KO"
100 GOTO40
110 TEAM FILE? 75-BOSTO
120 HITTERS
130 NAME? YASTREMSKI
140 BATS:AB•H•D•T,HR,BB,KO
150 20 543:146:30:1:14:87:67 OK?
160 PITCHERS
170 NAME? WISE
180 THROWS:IP•H•BA•KO? 0:255:262:72:141 OK?
190
```

Figure 3: Sample execution of the program Fix of listing 3. This program allows selective correction of the input data.
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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 the game proceeds according to statistical probabilities.

NUM? 41  
TEAM? 63-LA  
TEAM? 61-YANKS

GIVE THE LINE-UP

BATTING 1 ID$ FOS $72.6  
BATTING 2 ID$ FOS $71.4  
BATTING 3 ID$ FOS $75.8  
BATTING 4 ID$ FOS $76.7  
BATTING 5 ID$ FOS $74.3  
BATTING 6 ID$ FOS $73.5  
BATTING 7 ID$ FOS $77.2  
BATTING 8 ID$ FOS $70.9  
BATTING 9 ID$ FOS $710.10

ID# OF PITCHER? 3

GIVE THE LINE-UP

ID$ FOS $751  
ID$ FOS $71.4

BATTING 2 ID$ FOS $72.6  
BATTING 3 ID$ FOS $74.9  
BATTING 4 ID$ FOS $75.6  
BATTING 5 ID$ FOS $77.2  
BATTING 6 ID$ FOS $70.3  
BATTING 7 ID$ FOS $710.7  
BATTING 8 ID$ FOS $7610  
BATTING 9 ID$ FOS $74.5

ID# OF PITCHER? 6

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
F+6 OR B ?

MANTLE----- H. R.

1 RUNS SCORE 63-LA 0 61-YANKS 3
F+6 OR B ? F

HOWARD----- IS OUT

SLOWBUN----- 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
F+6 OR B ?

MCMLLENN----- STRIKES OUT  
ROSEBORG----- 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
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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 computer 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 Rods 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 subroutine. As seen in figure 4, that 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.

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In answer to the question "P, H or Ryne Duren," the computer asks for pitcher identification numbers of two new players. If 0 is chosen instead of entering a number, the player is replaced. The numbers 6 and 13 are typed in. The Yankees go on to win the sixth game 8 to 3 and the series 4 games to 2. 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 players and 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. 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.

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Every so often an individual is born exhibiting extraordinary talent at a very early age. Often, they rise above the multitude establishing themselves as masters in their fields. These individuals are called prodigies.

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- DATA BASE MANAGEMENT
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- INDEXED FILES
- SPOOLING
- MULTI-TASKING

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Speed, sophistication, and low cost; an incredible combination for a small business computer. Would you expect less from a prodigy?
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 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 rating information shown on the roster (figure 2) for each player. That is how I run my complete computerized baseball simulation.

### 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

---

**Figure 6:** Statistics for six games of the "World Series" between the 1961 Yankees (6a) and the 1963 Dodgers (6b).
to your data acquisition and display problems with COMPCO'S Analog - Digital I/O System.

The complete ADI/OS system includes everything required for a research and development laboratory, and many OEM systems: 16 channels of single-ended analog input (or 8 differential channels); two double-buffered D/A channels for driving a X-Y display (display not included); 32 bits of programmable digital I/O; 4 completely independent RS232 serial ports with software-selectable Baud rates; a Microterm MIME-I CRT terminal; a Houston Instruments HIPL0T incremental plotter; and an ALTOS 8000-2 microcomputer system, with 4MHz Z80* processor, 64K of RAM memory, twin Shugart double-density floppy disk drives, CP/M operating system, and Microsoft FORTRAN. COMPCO's GSP interactive graphics package is included to provide graphics output on the CRT terminal, HIPL0T plotter, and/or a X-Y display. A FORTRAN-callable subroutine package is also provided to perform the analog data acquisition. In addition, two unused serial ports may be used to drive a modem (permitting the system to talk to a larger machine), an additional CRT terminal for color graphics, or a serial line printer such as a TI-810 or NEC Spinwriter. * Z80 is a trademark of Zilog. 1 TM - Digital Research

This entire ADI/OS system is available from COMPCO for $9,995

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COMPUTER SPECIALISTS
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 F$ + 1 FOR OUTPUT AS # 1
30 B = 11111111110ZD
40 FOR A = 1 TO 26
50 PRINT # 1, A, A, B
60 NEXT A
70 CLOSE # 1
```

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.

```
10 INPUT NUM, A, FORB = 0 TO A
20 OPEN 2 FOR OUTPUT AS # 1
30 B = 11111111110ZD
40 FOR A = 1 TO 26
50 PRINT # 1, A, A, B
60 NEXT A
70 CLOSE # 1
```

Listing 6 continues on page 130
ANNOUNCING COMPANION I & II.

Beneath this beautiful teakwood roll-top desk exterior, there beats a heart of pure Radio Shack TRS-80 Microcomputer.

But don't let the good looks fool you. This beauty's got a brain that's right at home in your office, home, classroom or laboratory.

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Assembly Office: 3620 Lake Pontchartrain Drive, Arlington, Texas 76016.

Dealer inquiries invited.
Listing continued:

7/1 H:G12,G34+H(G12,G34)+H(G12,G34)+H(G12,G34)+H(G12,G34)+H(G12,G34)=ONEXT/ NEXT
7/4 FORG1=G10+G10+G10=FORG1=G10+G10+G10+G10+G10+G10=ONEXT/ NEXT
7/7 FORG1=G12,G34+ONEXT/ NEXT/ NEXT/ FORG1=G10+G10=ONEXT/ NEXT
7/8 SC12,G12=ONEXT/ NEXT/ NEXT/ FORG1=G10+G10=ONEXT/ NEXT
9/0 IFM*:FIF RETURN TO END? **ZAFZ** :THEN998
9/2 INPUT* LINE=IFS? **ZAFZ**:THEN67
9/4 IF(4,10) INPUT 'PITCHER' ? *W(2)
9/5 IF(4,12) INPUT 'PITCHER' ? *W(3)
9/6 RETURN
10/0 FORG6=ONEXT/ NEXT/ NEXT/ NEXT
10/1 FORG6=ONEXT/ NEXT/ NEXT
10/2 FORG6=ONEXT/ NEXT/ NEXT
10/3 FORG6=ONEXT/ NEXT/ NEXT
10/4 FORG6=ONEXT/ NEXT/ NEXT
10/5 FORG6=ONEXT/ NEXT/ NEXT
10/6 FORG6=ONEXT/ NEXT/ NEXT
10/7 FORG6=ONEXT/ NEXT/ NEXT
10/8 FORG6=ONEXT/ NEXT/ NEXT
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.

<table>
<thead>
<tr>
<th>Team</th>
<th>Hits</th>
<th>Runs</th>
<th>Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>METS</td>
<td>62</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>YANKS</td>
<td>92</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>WHITE</td>
<td>100</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>BOSTON</td>
<td>108</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>LA</td>
<td>116</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>BRONX</td>
<td>124</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>FIX</td>
<td>132</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>FIX2</td>
<td>138</td>
<td>6</td>
<td>2</td>
</tr>
</tbody>
</table>

Table continued on page 134
Do TRS-80’s new lower prices mean you get “cheaper” computers?

No Way!

Here’s why . . .

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Retail prices may vary at individual stores and dealers.
Table 2: Operations performed by various lines of BASIC code in the Game program of listing 6.

<table>
<thead>
<tr>
<th>Line Numbers</th>
<th>Operation Performed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 thru 20</td>
<td>a) Generate seed for random number</td>
</tr>
<tr>
<td></td>
<td>b) dimension variables</td>
</tr>
<tr>
<td></td>
<td>c) read descriptive data</td>
</tr>
<tr>
<td>30 thru 65</td>
<td>Read data from disk files</td>
</tr>
<tr>
<td>67 thru 94</td>
<td>Batting order input section</td>
</tr>
<tr>
<td>100</td>
<td>Set start and end inning</td>
</tr>
<tr>
<td>110 thru 990</td>
<td>Play game</td>
</tr>
<tr>
<td>992 thru 998</td>
<td>Select pitchers for new game</td>
</tr>
<tr>
<td>1000 thru 1180</td>
<td>Subroutine for printing box game</td>
</tr>
<tr>
<td>2000 thru 2080</td>
<td>Subroutine to write updated statistics to disk file</td>
</tr>
<tr>
<td>5900 thru 6570</td>
<td>Subroutine to determine run scored and position of base runners</td>
</tr>
<tr>
<td>6100 thru 6190</td>
<td>Subroutine for player substitutions</td>
</tr>
<tr>
<td>6200 thru 6230</td>
<td>Subroutine for determining winning and losing pitchers</td>
</tr>
<tr>
<td>6950 thru 7040</td>
<td>Subroutine for calculating earned runs</td>
</tr>
</tbody>
</table>

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

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

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.

<table>
<thead>
<tr>
<th>Yastrzemski Hits</th>
<th>Wise Hits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>= .232</td>
</tr>
</tbody>
</table>

Pitcher tiring factor (assume 0): .253

Left handed batter versus right handed pitcher: .015

\[
\text{Yastrzemski Hits} \times \text{Wise Hits} = 0.500 \times 0.250 = 0.125
\]
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Central Data
Figure 8: Flowchart of the major divisions of operation of the Game program of listing 6.

Text continued:

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%,...
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- Memory bank size can be incremented to 64k bytes in 16k increments.
- Four (4) 16k byte, functionally independent memory banks.
- Eight (8) 64k byte banks of memory per output port for expansion to 512k bytes for each output port.

Model DM-6400 Series dynamic 64k memory boards feature IEEE S-100 compatible timing and on board transparent refresh.

- Memory selectable and deselectable in 4k byte increments.
- 25 MHz on board crystal oscillator for independent timing.
- 4 MHz Z80 operation with no wait states.
- Tested and burned-in.
- Low power- 8 watts maximum.
- Reliable, expandable memories.

DMB-6400 and DM-6400 Common Features:

- Low power- 8 watts maximum.
- Reliable, expandable memories.

ONE YEAR GUARANTEE
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 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 ability to change 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.

---

**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%).
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Speed. At 225 characters per second (170 LPM) the Comprint 912 is up to 4 times faster than impact printers costing hundreds of dollars more. With our printer you don't waste time and money waiting for your print-out.

Print Quality. Our 9x12 matrix provides sharp, crisp characters. Compare that with our competition. Their very best is a 9x7 matrix, which means no lower case descenders and cramped letters. With the Comprint 912 you don't have to put up with the irritation of fuzzy, hard to read computer printing. This

CRT hardcopy is an excellent application for the Comprint 912.
The superior print quality provided by the Comprint 912 is obvious in this actual size sample. This means increased productivity. And because the Comprint 912 makes better originals, our originals make better Xeroxes.

**Quiet Operation.**
Most computer printers are irritatingly noisy. They can disrupt concentration and reduce the efficiency of anyone working near them. They're noisy because they're impact. The Comprint 912 has no mechanical print head banging on the paper. It's electronic. It's quiet.

**Reliability.**
Since the Comprint 912 prints electronically, rather than mechanically like ordinary impact printers, we have fewer moving parts and less vibration. The Comprint 912 has fewer things to go wrong and less wear. That's why we offer a 6 month warranty, twice the industry standard. The key to all this superior performance is our special paper. This aluminized "silver paper" works just like ordinary paper. It won't fade or discolor and actually costs less than plain paper and one time ribbons. For the vast majority of printing applications it's just plain better than plain paper. Especially when you consider the hidden costs of plain paper printers due to their inferior performance compared to the Comprint 912. And on those rare occasions when you really do need a plain bond paper copy, just run your Comprint 912 printout through your plain bond copy machine and you've got it. Even though our paper is special, it's available everywhere; from your dealer or distributor, or from us.

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**The Comprint 912.**
$660 with parallel interface, $699 with serial interface.

We could talk about our other advantages, like our 80-character lines on 8-1/2" wide paper, or our compact, light-weight size, and the fact that the Comprint 912 has no ribbons to mess with, no chemicals, nothing to add but paper.

But you have to see for yourself. Before you buy any printer, insist on seeing the Comprint 912, the performance leader, at your local computer store or industrial distributor. Or contact us for a descriptive brochure, a sample print-out, and applications literature.

The performance leader.
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 addressable memory area. More importantly, perhaps, the availability 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.
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.

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.

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

<table>
<thead>
<tr>
<th>Position</th>
<th>i</th>
<th>j</th>
<th>t</th>
<th>PARSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td></td>
<td></td>
<td>null</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>3</td>
<td>8</td>
<td>+1</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>1</td>
<td>5</td>
<td>null</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>null</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>null</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>4</td>
<td>3</td>
<td>8</td>
<td>+A</td>
</tr>
<tr>
<td>8</td>
<td>3</td>
<td>4</td>
<td>6</td>
<td>+AB</td>
</tr>
<tr>
<td>9</td>
<td>4</td>
<td>2</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>+AB/S</td>
</tr>
<tr>
<td>11</td>
<td>3</td>
<td>4</td>
<td>6</td>
<td>+AB/SC</td>
</tr>
<tr>
<td>12</td>
<td>4</td>
<td>2</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>+AB/SC$</td>
</tr>
<tr>
<td>14</td>
<td>3</td>
<td>1</td>
<td>5</td>
<td>+AB/SC$</td>
</tr>
<tr>
<td>15</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>4</td>
<td>3</td>
<td>8</td>
<td>*D</td>
</tr>
<tr>
<td>17</td>
<td>3</td>
<td>1</td>
<td>5</td>
<td>null</td>
</tr>
<tr>
<td>18</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>4</td>
<td>3</td>
<td>6</td>
<td>-E</td>
</tr>
<tr>
<td>20</td>
<td>3</td>
<td>4</td>
<td>6</td>
<td>-EF</td>
</tr>
<tr>
<td>21</td>
<td>4</td>
<td>2</td>
<td>7</td>
<td>-EF*D$</td>
</tr>
<tr>
<td>22</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>-EF*D$/S</td>
</tr>
<tr>
<td>23</td>
<td>3</td>
<td>4</td>
<td>6</td>
<td>-EF*D$/SG</td>
</tr>
<tr>
<td>24</td>
<td>4</td>
<td>2</td>
<td>7</td>
<td>-EF*D$/SG+AB/SC$</td>
</tr>
<tr>
<td>25</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>-EF*D$/SG+AB/SC$+1$</td>
</tr>
<tr>
<td>26</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>-EF*D$/SG+AB/SC$+1$/S</td>
</tr>
<tr>
<td>27</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>-EF*D$/SG+AB/SC$+1$/S/H</td>
</tr>
</tbody>
</table>

Text continued on page 144
CM-300 and CM-400 have two separated rows of five interconnected contacts each. Each pin of a DIP inserted in the strip will have four additional tie-points per pin to insert connecting wires. They accept leads 20-30 AWG solid wire, white insulation.

The board contains a matrix of 240 in. diameter holes on 300 in. centers. Component side contains 76 two-hole pads. Two independent bus systems are provided for voltage and ground on both sides of the board.

TERMINAL BOARD
.062 thick glass-coated epoxy laminate. Outside dimensions 6.3 in. x 3.94 in. Not plated.

PC BOARD
Same specifications as A-PC-01 except matrix pattern is copper plated and solder coated on one side.

PC BOARD
Same specifications as A-PC-01. Each line of holes is connected with copper plated and solder coated parallel strips on one side.

PC BOARD
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HK-22 22AWG 50 FT. SOLID CONDUCTOR
HK-24 24 AWG 50 FT. SOLID CONDUCTOR
HK-26 26AWG 50 FT. SOLID CONDUCTOR
SHK-18 18 AWG 25 FT. STRANDED CONDUCTOR
SHK-20 20AWG 25 FT. STRANDED CONDUCTOR

Removes 24-40 pin ICs, .600" centers. CMOS safe.
Includes terminal lug for attachment of ground strap.
GROUND STRAP NOT INCLUDED

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AWG 30 (0.25mm) KYNAR wire, 50 wires per package stripped both ends.

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WD-30-TRI TRI-COLOR DISPENSER $5.95
R-30-TRI REPLACEMENT ROLLS $3.95

WIRE DISPENSER
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WD-30-Y YELLOW WIRE $3.95
WD-30-W WHITE WIRE $3.95
WD-30-R RED WIRE $3.95

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R-JW-W WHITE WIRE 50 ft. Roll $2.98
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just wrap kit
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Aligns bent out pins, includes terminal lug for attachment of ground strap.
GROUND STRAP NOT INCLUDED

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Removes 24-40 pin ICs, .500" centers. CMOS safe, includes terminal lug for attachment of ground strap.
GROUND STRAP NOT INCLUDED

Circle 291 on inquiry card.
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) = '+' OR '-' OR '*' OR '/' THEN INTOKEN := 3;
    ELSE IF Exp(Position) = ')' THEN INTOKEN := 2;
    ELSE BEGIN
        WHILE Exp(Position) = ' ' DO Position := Position + 1;
        IF NOT ('A' > Exp(Position) OR 'Z' < Exp(Position))
        THEN BEGIN
            INTOKEN := 5;
            COMMENT Presume error first, determine otherwise later;
            IF NOT (0 > Exp(Position) OR '9' < Exp(Position))
            THEN BEGIN
                INTOKEN := true;
            ELSE BEGIN
                Position := Position - 1;
            END;
        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
        PUSH B
        PUSH D
        PUSH H
        XCHG
        LHLD STACK
        PUSH H
        POP B
        ADI 3
        CALL ABUF
        MOV A, H
        ORA A
        MOV A, L
        CALL STKF
        SHR D
        MOV A, C
        ELSE BEGIN
            MOV A, H
            CALL STACK;  \lz[131x274]  Loop to the buffer pool
            MOV A, H
            ORA A
            MOV A, L
            CALL STKF;
            MOV A, C
            ELSE BEGIN
                MOV A, H
                ORA A
                MOV A, L
                CALL STACK;
                MOV A, C
            END;
            END;
        END;
        JZ STKCX
        ADD(D,E), +1
        JNZ STKCX
        MOV H
        MOV D
        MOV B
```

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. INTOKE 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 INTOKE output, its column subscript the value of the current INTOKE output. Specifically, if the last input token was a left parenthesis and the current input token was 'E' (a symbol or constant) then INTOKE'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 INTOKE 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 INTOKE 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 INTOKE, 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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RUSH FOR FREE CATALOG
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 recogni-
tion. 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 exclu-
sive-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
referred to by ‘$’. The operators, for exam-
ple, 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 rear-
rangement 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 pre-
cedes 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 explicitely speci-
fied 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.

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 illus-
trate 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 in-
clusive interval of values bounded by the top

---

Listing 3, continued:

```plaintext
STC | END: RET | END: RET:
STKOF: POP H | RESTORE(H,L):
POPUF: POP D | RET:
POP P | SC:
POPSD: | POPSD: IF Stack = 0
POPD: | POPSD: IF Stack = 0
LHLD STACK | ELSE BEGIN
MOV A,H | THEN SET(Carry)
ORA L | END:
JZ POPZD | PUSH H
POP D | THEN SET(Carry)
POP B | END:
POP PSW | MOV A,H
RET | COMMENT Give caller size
 |
 |
LHLD STACK | MOV A,H
MOV A,D | COMMENT Target area is
ORA E | specified by caller H,L:
JZ POPUD | XCHG
POP H | RESET(Carry);
MOV A,D | (D,E) := Stack;
ORA A | B := MEMORY(D,E + 2);
JZ POPOX | SAVE(D,E,H,L);
POHD | (D,E) := (D,E) + 3;
POP D | WHILE NOT B = 0 DO
INX D | BEGIN
INX D | COMMENT Zero-length entries
LHAX D | are removed but not copied;
ORA A | MEMORY(H,L) := MEMORY(D,E);
JZ POPOX | (D,E) := (D,E) + 1;
INX D | SAVE(D,E,H,L);
MOV B,A | (H,L) := (H,L) + 1;
POP CY: | MOV B,A
POPCY | BEGIN
POPCY: | END;
POP D | RESTORE(D,E,H,L);
XCHG | INX H
SHLD LHLI | Stack = MEMORY(D,E);
CALL LHLI | INX D
SHLD STACK | RBUF(D,E);
LHLD LHLI+1 | DCR B
CALL RBUF | RESTORE(D,E,H,L);
POP H | END;
POP D | POPZD:
POP B | POPXD:
POP PSW | POPOD:
STC | END:
CMC | RET:
```
We supply memory.

All our Econoram* memory is fully static, 2ips along at 4 MHz with the 2.6 GHz or 5 MHz with the 6085, supports a number of popular buses, is available from us through computer stores world-wide, includes a 1 year warranty, and comes in three configurations to suit your needs. For lowest cost, choose an "unkit" with sockets and bypass caps pre-soldered in place for an easy, one-evening assembly. When you just can't wait to get going, order our assembled and tested version. For critical systems, specify boards qualified under our Certified System Component (CSC) highreliability program. These boards are extensively tested, burned in for 200 hours, and are immediately replaced in event of failure within 1 year of invoice date. Refer to chart below for pricing.

<table>
<thead>
<tr>
<th>Name</th>
<th>Bus &amp; Notes</th>
<th>Unit Kit</th>
<th>Assm Kit</th>
<th>CSC</th>
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<tbody>
<tr>
<td>8K Econoram IIA</td>
<td>S-100</td>
<td>$149</td>
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<tr>
<td>32K Econoram IX</td>
<td>Dig Grp</td>
<td>$559</td>
<td>$659</td>
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<tr>
<td>32K Econoram X</td>
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<tr>
<td>24K Econoram XII</td>
<td>S-100 (1)</td>
<td>$429</td>
<td>$539</td>
<td>$649</td>
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<tr>
<td>32K Econoram XIII</td>
<td>S-100 (2)</td>
<td>$559</td>
<td>$699</td>
<td>$849</td>
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<tr>
<td>16K Econoram XIV</td>
<td>S-100 (3)</td>
<td>$289</td>
<td>$349</td>
<td>$448</td>
</tr>
<tr>
<td>16K Econoram XV-16</td>
<td>H8 (4)</td>
<td>$329</td>
<td>$395</td>
<td>n/a</td>
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<tr>
<td>32K Econoram XV-32</td>
<td>H8 (4)</td>
<td>$599</td>
<td>$729</td>
<td>n/a</td>
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<tr>
<td>16K Memory Expansion (5)</td>
<td></td>
<td>$87.20</td>
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<td></td>
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<tr>
<td>16K x 16 or 32K x 8 Econoram XVI — coming soon!</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:
1. Bank select board — 1 independent banks addressable on 8K boundaries.
2. Bank select board — 2 independent banks addressable on 16K boundaries.
3. Extended addressing (24 address lines). Single block addressable on 4K boundaries.
4. Bank select option for implementing memory systems greater than 64K.

*

Econoram is a trademark of Godbout Electronics.

We supply the S-100 revival.

Why S-100? Because S-100 machines are not consumer-oriented toys — but flexible, modular, professional-level systems that are easy to upgrade, modify, and adapt to specific applications. As a result over the years the S-100 bus has proven to be the ideal choice for commercial, industrial, and scientific applications. It doesn’t obsolete itself, but simply adapts to innovation.

We use the experience we’ve acquired in the past, along with the very best technology offered by the present, to build products for the future… products that meet, and often exceed, the demands of the new wave of professional S-100 users. Our expanded S-100 line is the right approach at the right time; we invite you to write for further information.

NEW!

HIGH-PERFORMANCE S-100 MOTHERBOARDS

<table>
<thead>
<tr>
<th>Slot Size</th>
<th>Kit Price</th>
<th>Assm Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>19 slot</td>
<td>$174</td>
<td>$214</td>
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<tr>
<td>12 slot</td>
<td>$129</td>
<td>$169</td>
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<tr>
<td>6 slot</td>
<td>$89</td>
<td>$129</td>
</tr>
</tbody>
</table>

*Edge connectors and termination resistors are pre-soldered in place for assembly.

These 3rd generation motherboards, designed to work with the latest 5- and 10-MHz CPUs coming on line, exceed the latest S-100 specs and offer superior performance. Includes true active termination (with half of the termination load at each end of every bus line), guarded Fanuc shield between all bus signal lines to minimize crosstalk, and edge connectors included for all slots. All sizes fit Godbout, Vector, TEL, IMSAI, and similar enclosures.

These high quality motherboards are a welcome addition to any system — or the start of a great one.

NEW!

Memory Management S-100 board

$59 kit, $85 assm, $100 CSC

Now you can add bank select and extended addressing to older S-100 machines like the Altair, IMSAI, Sky, Polyomorphic, etc. Either use this board with our new extended addressing boards, or retrofit our high density Econorams (the ones with phantom or extra qualifier lines) for use with the Memory Management Board to get up to 3 or 5 megabytes of memory space for your computer.

NEW!

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External serial port with 2 full duplex parallel ports for RS-232c handshaking, EIA232C line drivers and receivers (+60/-60 v) along with current loop (20 mA) and TTL signals on both ports. On-board crystal controlled timebase with independently selectable baud rate generators for each port up to 14.4 Kbps. Hardware UARTs don’t tie up the CPU. And, there’s much more… this is a no-excuses serial board that does things the others only dream about.

NEW!

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Plugs into any S-100 motherboard (although ours don’t need it) to reduce ringing, noise, crosstalk, and other bus-related problems. Here is an upgrade that is simple and effective.

NEW!

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Circle 150 on inquiry card.

Byte November 1979 147
Listing 4: A SORT procedure expressed in informal ALGOL type notation demonstrates use of two stacks.

```algonnotation
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.
```

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 (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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Circle 75 on inquiry card.

BYTE November 1979 149
NEECO PROUDLY ANNOUNCES THE
 
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THE MINIMAX SERIES WAS DESIGNED TO OFFER THE MARKET MINICOMPUTER CAPABILITIES AT MICROCOMPUTER PRICES. COMPARE THE CAPABILITIES & PRICE!

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• DISK STORAGE SYSTEM TRANSFERS 6K PER SECOND WITH AUTO VERIFY AND PARITY CHECK
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• 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
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<table>
<thead>
<tr>
<th>PRODUCT DESCRIPTION</th>
<th>PRICE</th>
<th>AVAILABILITY</th>
</tr>
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<tbody>
<tr>
<td>PET 2001—6KN (Large Keys) 8K RAM</td>
<td>$795</td>
<td>DEC/JAN</td>
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<td>PET 2001—BK 8K RAM</td>
<td>$795</td>
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<tr>
<td>PET 2001—16KN (Large Keys) 16K RAM</td>
<td>$995</td>
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<tr>
<td>PET 2001—32KN (Large Keys) 32K RAM</td>
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<tr>
<td>PET 2023 PRINTER ROLL FEED</td>
<td>$850</td>
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<tr>
<td>PET 2022 PRINTER TRACTOR/ROLL</td>
<td>$995</td>
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<tr>
<td>ROMRETRO KIT UPDATED O/S</td>
<td>$90</td>
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</tr>
<tr>
<td>PET 2040 DUAL FLOPPY*</td>
<td>$1295</td>
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</tr>
<tr>
<td>PET C2N 2nd Cassette</td>
<td>$100</td>
<td>IMMEDIATE</td>
</tr>
</tbody>
</table>

*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.

**PET-DISK BASED BUSINESS SOFTWARE**

<table>
<thead>
<tr>
<th>SOFTWARE/APPLICATION</th>
<th>REQUIRES</th>
<th>AUTHOR</th>
<th>AVAILABILITY</th>
<th>PRICE</th>
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<tr>
<td>WORDPRO II / WORD PROCESSING</td>
<td>2040 + 16K PET</td>
<td>PRO/MICRO</td>
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<td>WORDPRO III / WORD PROCESSING</td>
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<tr>
<td>GENERAL LEDGER</td>
<td>2040 + 32K PET</td>
<td>CMS SOFTWARE</td>
<td>IMMEDIATE</td>
<td>$295*</td>
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<td>ACCOUNTS PAYABLE</td>
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<td>CMS SOFTWARE</td>
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<td>$295*</td>
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<td>MAILING LIST</td>
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</tr>
<tr>
<td>NEECOLEDGER</td>
<td>M DRIVE + 32K PET</td>
<td>COMPUTHINK 4</td>
<td>IMMEDIATE</td>
<td>$150</td>
</tr>
</tbody>
</table>

*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
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**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.
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.

Listing 1: 8080 Assembly-Language Program to Create an Animated Computer Game

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

0100 0005 *GALLOP*
0100 0010 *A PROGRAM ILLUSTRATING SOME PRINCIPLES OF
0100 0015 PROGRAMMING AN ANIMATED GAME
0100 0020 *COPYRIGHT 1979 TONY ESTEP
0100 0025 *
0100 0030
0100 0035 VHRDAS EQU 0000H
0100 0040 VHRDL EQU OFFEH ;ALL THESE RELATE TO THE 8080/20 &
0100 0044 CLSCH EQU OCCOH ;ITS VHR AND SCREEN CLEAR routines.
0100 0048 SECH EQU OOFFCH ;MIDDLE OF LOWEST LINE.
0100 0050 BAR EQU 93H ;THESE ARE ARMS ON KEYPAD
0100 0055 LAR EQU O1H
0100 0060 UAR DUN 97H
0100 0065 UAR DLCR 9AH
0100 0070 DMN 100H ;SO IT WILL RUN WITH CMII.
0100 0075 LAX SP, STACK+46
0100 0080 CALL CLSCH ;FOR NON-SOL, WRITE SIMPLE ROUTINE TO CLEAR
0100 0085 LAX H, VHRDAS
0100 0090 MVX N,,
0100 0095 BEGIN CALL WAIT
0100 009A DD XBA A ;INITIALIZE FLAGS
0100 009F 32 A3 03
0110 32 9E 03
0115 32 88 04
0118 32 68 04
011B 9E 01
011D 32 47 04
0120 32 30 05
0123 32 2A 04
0126 CD 05 CD
0129 21 00 CC
012C 36 20
012E 21 1E CD
0131 22 FE 02
0134 CD 89 01
0137 CD 6A 02
013A CD 6A 02
013D CD 6A 02
0140 CD 6A 02
0143 CD 6A 02
0146 CD 6A 02
0149 CD 6A 02
014C 0210
014C CD CI 01
014F CD 89 01
```

Text continued on page 158

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.

<table>
<thead>
<tr>
<th>Disk Drive Configuration</th>
<th>Disk Size</th>
<th>Disk Controller</th>
<th>Disk Density</th>
<th>Drive Assignment</th>
<th>Operating System</th>
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<td>Single/Double</td>
<td>A, B</td>
<td>CP/M</td>
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<td>Northstar</td>
<td>Single/Double</td>
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<td>CP/M</td>
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<td>Micropolis</td>
<td>Quad</td>
<td>A, B</td>
<td>CP/M</td>
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<tr>
<td>Persci 277</td>
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<tr>
<td>Micropolis MODII</td>
<td>5¼&quot;</td>
<td>Micropolis</td>
<td>Quad</td>
<td>A, B</td>
<td>OASIS</td>
</tr>
<tr>
<td>Shugart SA450</td>
<td>5¼&quot;</td>
<td>North Star</td>
<td>Single/Double</td>
<td>1.2</td>
<td>DOS</td>
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<tr>
<td>Persci 277</td>
<td>8&quot;</td>
<td>Alpha Micro*</td>
<td>Single</td>
<td>1.2</td>
<td>AMOS*</td>
</tr>
</tbody>
</table>

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
- Allows 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.
- Allows 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.
- Thoroughly 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

DOCUMENTATION
- Prints formatted program listings with user selected spacing, titling, dating, and paging.
- Prints an alphabetized 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.

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- 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.

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PRICES:
- MUFS $9,500.00
- IC $59.00
- DOC DISKETTE VERSION $150.00
- OASIS OPTION - $500.00
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- DISKETTE/PROM VERSION $200.00
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*Amos is not menu selectable, and does require removal and insertion of some board's in the 5-100 Bus
**CP/M is a trademark of Digital Research
The number 2 manufacturer of stand alone POS terminals needs software based products in 1979.

You are currently looking at an advertisement for CRT interfaces, black, white, and color, and an aircraft simulator for Apple II. For more details, please see the listings on pages 156 and 157.
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Circle 78 on inquiry card.
Listing 1 continued:
0105 CX 0525 RET
0106 DU FC 0530 INH IN UPCH
0107 CD 00 01 0535 RET
0108 CD 00 01 0540 RYCR REGS
0109 CD 05 0545 RS
0110 CD 06 01 0550 CALL INH
0111 FE 53 0555 CFV INH; HIZON ARG1
0112 CA FC 00 01 0560 J2 IPRT
0113 FE 81 0565 CPI LAR; LEFT ARG2
0114 CH 05 02 0570 J2 LEFT
0115 FE 97 0575 CPI UP ARG3
0116 CD 10 02 0580 J2 UP
0117 FE 56 0585 CPI DSK; RIGHT ARG4
0118 CH 00 02 0590 J2 DSK
0119 FC 20 0595 CPI ' ' ; SPACE BAR DOWN; BALLOON
011E CH 53 02 0600 J2 6F81
011F CF 00 0605 RET
0120 FA 0F 02 0610 RIGHT LAR; RIGHT POINTERS UPDATE THE OPTIONS TV
0121 11 01 00 0615 LRI D, 1; THE LRP POSITIONS
0122 19 0620 WLD D
0123 22 FC 02 0625 SEND LR
0124 CF 00 0630 RET
0125 2A FC 02 0635 LEFP LPILE LA
0126 11 FL FF 0640 LRI D,-1
0127 19 0645 WLD D
0128 22 FC 02 0650 SEND LR
0129 CF 00 0655 RET
012A 0A FC 02 0660 UP LPILE UD
012B 11 CF FF 0665 LRI D,-64; 64 CHARACTER HIDE SCRN; SO YOU GO U/D 1 LINE
012C 19 0670 WLD D
012D 22 FC 02 0675 SEND UD
012E CF 00 0680 RET
012F 2A FC 02 0685 DOWN LPILE UD
0130 11 FL FF 0690 LRI D,64
0131 19 0695 WLD D
0132 22 FC 02 0700 SEND UD
0133 CF 00 0705 RET
0134 2E 01 0710 WLD INI A,1
0135 32 00 0715 STA H,1
0136 2A FC 02 0720 LPILE OMDR
0137 11 FL FF 0725 LRI D,415
0138 19 0730 WLD D
0139 22 FC 02 0735 SEND HSL
013A 25 FL FE 02 0740 LPILE UD: LPILE UD: HSL:纽 OUT: DULL: ES
013B 36 20 0745 INI H,'1
013C 11 FL FF 0750 LRI D,64; HOME POISON A LINE
013D 19 0755 WLD D
013E 22 FC 02 0760 SEND HSL
013F 35 EC 0765 INI H,1001
0140 7C 0770 VNM A,11
0141 FC 00 0775 CPI DOLL
0142 46 CA 47 02 0780 J2 (NUM H,1 H, H 777
0143 CF 00 0785 RET
0144 30 00 0790 DMA: INI A,0
0145 32 FC 02 0795 STA L,1
0146 32 FD 02 0800 STA L,1
0147 CF 00 0805 RET
0148 36 01 0810 BLDG INI A,1
0149 32 FC 02 0815 STA L,1

Listing 1 continued on page 158

TUNE-UP YOUR PET®...$109.95 with enclosure $134.95

- Exact Pet keyboard layout
- Double-shot keytops with graphics legends
- Duplicate Return, Space and Shift keys on numeric pad for programming ease
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The Introl/X-10 peripheral system for your Apple* Computer allows you to remotely control lights and electrical appliances in your home.

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- Rate device wattages for a running account of power consumption during your schedule for energy management.
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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.

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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.
**Apple is a trademark of BSR, Ltd.

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Sounds great.
Home control from my Apple?
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City ___________________ State _______ Zip ______
Phone ____________________________

Circle 257 on inquiry card.
Figure 1: A Warnier-Orr diagram describing the steps involved in simulating motion.

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

A Warnier-Orr diagram describing the steps involved in simulating motion.

Text continued:

The whole essence of writing an animated game is to put a picture on the 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 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 the 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 means that the movement will necessarily be a little jerky, but smooth enough for games.
Upgrades your Level II TRS-80 and brighten your programming without the cost of a Radio Shack expansion interface and disk drives.

Microsoft's Level III BASIC is an enhancement to the Level II, loading from a cassette tape right on top of the Level II ROM. It contains all Disk BASIC features not already in Level II, except for file management commands. And it adds six new Level III exclusives not available in Level II or Disk BASIC.

No one knows better than Microsoft how to increase your TRS-80's BASIC power. Microsoft created the TRS-80 Level II and Disk BASIC plus the industry standard Microsoft BASIC.

Advanced graphics is Level III's most exciting addition to the TRS-80—and it's exclusive. Draw a line, outline or solid box by specifying just two points, then save it and put it back with BASIC statements. You'll find yourself writing more programs with charts, graphs and even animation.

Other Level III exclusives include 20 user-definable stroke instructions you can enter any command, statement or string with a shift-key entry. New SAVE and LOAD commands improve the reliability of loading tape programs by eliminating problems with cassette recorder volume sensitivity. Aggravating keyboard bounce is also eliminated. INPUT ≠ LEN and LINE INPUT ≠ LEN statements allow you to write programs with a time limit. And, joy of joys, Level III has automatic line renumbering.

TRS-80 power increases with Level III's seven Disk BASIC features. Ten user-defined subroutines can be used in a program. Error messages are spelled out. LINE INPUT instruction accepts punctuation marks within a string and eliminates the automatic "?" from the INPUT prompt. A more flexible MIDs increases string manipulation power. INSTR function searches a string for a specified substring. And Level III performs hex and octal conversion.

Level III even adds new capabilities to a TRS-80 system with an expansion interface by outputting to the RS-232 port in BASIC and setting and reading time and date from BASIC.

Level III occupies only 5.2K RAM with something for every TRS-80 from the 16k Level II minimum system requirement and up. It can be stored on disk as a file, but it only works in conjunction with Level II; it will not work with Disk BASIC. Programs written in Level III BASIC are stored on cassette tape.

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Microsoft Level III BASIC is sold at Computer retailers nationwide. If your local computer store doesn't have Level III, ask them to call us. You can call us, too, for the name of your nearest Microsoft dealer. Phone (206) 454-1315. Or write Microsoft Consumer Products, 10800 Northeast Eighth, Suite 819, Bellevue, WA 98004

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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
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• Choice of 6809 and/or 6512 CPU board with speed of up to 4 MHZ with 150 ns memory
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• BASIC compiler
• COBOL compiler
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Circle 350 on inquiry card.

BYTE November 1979  161
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
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• See all 4 voices at the same time you’re hearing the music—a must for music editing!
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Circle 226 on inquiry card.
Listing I continued:

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<thead>
<tr>
<th>Address</th>
<th>Opcode</th>
<th>Label</th>
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<td>E,A</td>
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<td>035F 16 00</td>
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<td>0361 22 EF FF 1420</td>
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<td>0364 19</td>
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<td>D</td>
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<td>MWI</td>
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</tr>
</tbody>
</table>

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The CBM™ 16K $995
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Expand to 32K for an additional $149
Dual floppy disk drive 2040 w/cable $1295
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- LSI - $750.00
- 6800 - $750.00

CI-100 64K x 8
CI-1103 32K x 16
CI-6800 64K x 8
CI-8080 64K x 8

CI-100 — 64K x 8 on a single board. Plugs directly into the IMSAI, MITS, TDL, SOL and most other S-100 Bus computers. No wait states even with 280 at 4Mhz. Addressable in 4K increments. Power requirement 6 watts. Price $750.00.

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Tested and burned-in. Full year warranty.

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Computer Products Division
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Circle 47 on inquiry card.
Listing 1 continued:

047B 24 F4 02 2165 SLED UJ
047C 22 F2 02 2170 SLED LA
0481 21 E3 CE 2175 LDL d,MBL
0484 22 F6 02 2180 SLED UHBR
0487 C9 2185 "RETP"
0488 00 2190 NGCR DB 0
0489 00 2195 NGCR DB 0
049A 21 04 OC 2200 IFNKE XIX,MSKING+$4
048D 11 EC 05 2205 LD1 dB,MBLS
0493 23 2245 0490
0494 3A 89 04 2220 LDL NGCR
0497 CD AB 04 2230 LDL SCEOAN
0498 21 30 OC 2235 LDL d,MBLS+4
049D 11 C4 05 2235 LDL d,MBLS
04AD 2D 64 05 2240 "GILL PRINT"
04A3 23 2245 "INX"
04A4 3A 88 04 2250 LDL NGCR
04A7 CD AD 04 2255 "GILL SCOUNT"
04A8 C9 2260 "GILL"
04AB FE 0A 2265 "GOUNT CFPS I, A VERY DENSE HEX-TO-DIGITAL CONVERTER"
04AD D2 1A 04 2270 JNC ITR
04AD CE 30 2275 ANI 30H
04A2 77 2280 INX d3H
04A3 23 2285 INX II
04A4 36 30 2290 INX d3H
04A6 23 2295 INX H
04A7 36 30 2300 INX d3H
04A9 CF 14 2310 LTR CF, 20
04AC 02 CC 04 2315 JNC II
04AB 36 31 2320 INX d3H
04C1 23 2325 INX H
04C2 CE 36 2330 INX d3H
04C4 77 2335 INX d3H
04C5 23 2340 INX II
04C6 36 30 2345 INX d3H

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HIGH CAPACITY: 22 16-pin DIPs or 2 40-pin plus 18 sixteen-pin DIPs.

VERSATILE
- 1 inch grid; .042 inch diameter holes.
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- Quick solder mounting of any IC sockets.
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Component side wiring side

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Listing 1 continued on page 168
**8086 Power**

**Now!**

**For the S-100 bus**

WITH 16-BIT WORD LENGTH

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**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**

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/O 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:

<table>
<thead>
<tr>
<th>Location</th>
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<th>C Source Code</th>
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<td>24255</td>
<td>2610 ASCII</td>
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<tr>
<td>0576 3h</td>
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<td>2610 ASCII</td>
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</tr>
<tr>
<td>0576 Fh</td>
<td>24268</td>
<td>2610 ASCII</td>
</tr>
</tbody>
</table>

Title: "Copyright 1979 Tony Derr"
Word Processors are here. Just thumb through the pages of this magazine. There are at least five different companies selling them. So, which one's for you? How do you judge the difference? And what about cost? Are you willing to pay the 300 plus dollars that some of the companies are asking?

Well go ahead and compare AUTOTYPE comes out ahead in EVERY category!

Features? AUTOTYPE has more powerful features than ANY other Word Processor on the market. But, don't take our word. Go ahead, compare! AUTOTYPE has an exclusive MACRO programming capability No other Word Processor can make that claim. AUTOTYPE also has a scratch holding buffer. Again, no one else even comes close.

Price? AUTOTYPE beats 'em all With a price tag of $195. AUTOTYPE is well below the competition. But, again, don't just take our word. Go ahead, look for yourself! Then fill out the order form below to start processing words instead of using a word processor!

CAN I MOVE PARAGRAPHS AROUND?
YES! AUTOTYPE has a holding buffer that can be used to save any amount of text and then Unhold it to the location you want. AUTOTYPE even allows you to make multiple Unholds.

CAN I MERGE CUSTOMERS NAMES INTO LETTERS?
YES! AUTOTYPE contains a "merge" feature that may be placed anywhere in text. Then, at the time text is printed, a separate file may be merged into the letter and then printed! Another feature that NO OTHER WORD PROCESSOR has!

CAN I ENTER TEXT IN SOME OTHER FORMAT THAN 64 CHARACTERS WIDE?
YES! AUTOTYPE has a screen redisplay command. The screen can be set from 16 characters wide to 120 characters wide. There's even horizontal scrolling to view the text! Once more, we're far beyond the competition!

CAN I HANDLE TEXT LARGER THAN MY COMPUTERS MEMORY?
YES! Most other Word Processors demand that the entire text be inside the computer. AUTOTYPE allows you to "spool" your text from the disk. This means that you can have editor files that are over 1000 pages long!

CAN IT UNDERLINE?
YES! CAN IT BOLDFACE?
YES! CAN IT INDENT?
YES! CAN IT HYPHENATE?
YES! YES! YES! AUTOTYPE allows you to underline, boldface, indent, and hyphenate any where in the text! You can move single letters or entire chapters right into the middle of any word. Now THAT'S POWER!

CAN IT SEARCH AND REPLACE?
YES! But, there's more AUTOTYPE allows simple searches or search and replace. AUTOTYPE also allows wildcard characters in the search string for prohibitive matching! This single feature that AUTOTYPE makes very powerful!

CAN IT DO AUTOMATIC PAGE NUMBERING AND TITLING?
Of course! Any length title up to the current line length. Page numbers can start anywhere. And If it's not enough, the number of blank lines below the title is adjustable!

DOES IT HAVE "DYNAMIC" PRINT FORMATTING?
OH YES! And with a flair! The pages that you see printed here were all printed from the same file! Only AUTOTYPE has a screen redisplay command that can be accomplished with NO alteration of text! Let's see the competition make that claim!

CAN I DO SUBSCRIPTS AND SUPERSCRIPTS?
YES! Once again, AUTOTYPE has the features to be called a true processor of words and not just another word processor.

CAN IT VERTICAL TAB?
YES! And negative vertical tabs to the top of page also! This is invaluable for two column printing.

CAN YOU ADJUST THE INDEX, LINE LENGTH AND JUSTIFICATION?
COMPLETELY! Either in the text itself, by manual formatting commands or with a print macro. Only AUTOTYPE gives you that kind of choice!

WILL IT EXECUTE A SERIES OF COMMANDS AUTOMATICALLY?
YES! That's one of AUTOTYPE's standard features. No other Word Processor has the ease of use or the powerful commands that AUTOTYPE has.

ARE THE TABS ADJUSTABLE?
All tab stops are displayed graphically with a simple command. Tab removal and setting are simple cursor movements and a single key command! No more "guessing" where your tabs are set. They're all laid out in front of you.

HOWN MUCH DOES AUTOTYPE COST?
$195. This question is the easiest answer! It's simple. We want you to use your computer to its fullest extent. And we want you to be able to do it at a reasonable price. This is the area where our competition is way ahead of us! They simply charge more than we do!

HOW DO I ORDER?
We thought you'd never ask! Just fill out the order form below and mail to INFINITY MICRO. Or call us directly and place your order. It'll be shipped the same day.

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PO. BOX 4627
SANTA CLARA, CA 95050
(408) 988-1867

□ Memory mapped Video at CC00 hex. as 64 characters by 16 lines. Processor Tech or equivalent.
□ *Cursor addressable terminal. (ADM-3A)
□ *Cursor addressable terminal. (HAZELTINE 1500)

DISK
□ CP/M on IBM standard 8" □ CP/M on Micropolis MOD I
□ CP/M on Micropolis MOD II □ CP/M on North Star
□ CP/M on Double Density 8" Please specify Manufacturer.

NAME ______________________________
ADDRESS -------------
CITY __________________ STATE ___ ZIP __
PHONE ____________________________

Please ship ___ AUTOTYPE disks and manuals immediately! Please find enclosed $ ___________ at $195/each.

*Available Nov-Dec of 1979

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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 locations, 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.

G. W. COMPUTERS LTD.

This is how your business appears on the screen

Approximately 60-100 entries/inputs require only 2-4 hours weekly and your entire business is under control.

*PROGRAMS ARE INTEGRATED —

01 = ENTER NAMES/ADDRESS, ETC
02 = ENTER/PRINT INVOICES
03 = ENTER PURCHASES
04 = ENTER A/C RECEIVABLES
05 = ENTER A/C PAYABLES
06 = ENTER/UPDATE INVENTORY
07 = ENTER/UPDATE ORDERS
08 = ENTER/UPDATE BANKS
09 = EXAMINE/MONITOR SALES LEDGER
10 = EXAMINE/MONITOR PURCHASE LEDGER
11 = EXAMINE/PRINT INCOMPLETE RECORDS
12 = EXAMINE PRODUCT SALES

SELECT FUNCTION BY NUMBER
13 = PRINT CUSTOMER STATEMENTS
14 = PRINT SUPPLIER STATEMENTS
15 = PRINT AGENT STATEMENTS
16 = PRINT TAX STATEMENTS
17 = PRINT WEEK/MONTH SALES
18 = PRINT WEEK/MONTH PURCHASES
19 = PRINT YEAR AUDIT
20 = PRINT PROFIT/LOSS ACCOUNT
21 = UPDATE END MONTH FILES
22 = PRINT CASH FLOW FORECAST
23 = ENTER/UPDATE PAYROLL (NOT YET AVAILABLE)
24 = RETURN TO BASIC

WHICH ONE? ENTER 1-24
Each program goes to a sub menu, e.g.,
9 alters: A. LIST ALL SALES, B. MONITOR SALES BY STOCK CODES,
C. RETRIEVE INVOICE OR SALES, D. AMEN D/EDGER FILES,
E. LIST TOTAL ALL SALES.

Think of the possibilities and add those here if you wish.

Price for current package Version 1 is $550, or Version 2 including aged debtors analysis, etc. is $750, or full listing, $800.
PET 1632K disk-based version, SWTP 600B, IMS/CPA/ZIP/5-100. Compatible systems shortly available for Apple and Tandy.

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If you've wanted to own your own computer, but didn't think you could afford it, we may have the answer you've been looking for.

Computer Ideas, Inc. has developed a small computer system that can be used for many purposes...in business, in the home, and as a source of full or part-time earnings to help you pay for it.

Designed around a Digital PDP-11 computer, our new system features a 3-color matrix plotter/printer (Centronics 102BL) that produces sharp, graphic printouts in color on standard computer paper in minutes.

The equipment is reliable, versatile, and easy to operate. It can be used in business to relieve you of a lot of paperwork. And in the home for money management, fun and games, learning, and more.

The key to making it pay for itself is its capability to produce color pictures or portraits that can be transferred to tops, T-shirts, jackets and other apparel. There is nothing else like it on the market today, and many owners have discovered it to be a proven moneymaker in high-traffic areas such as shopping malls, resort areas, fairs, and other locations.

Everybody is a photo sketch customer! Every sale is for cash! The profit margin is high.

So if you want to own your own computer...and put some big dollars in your pocket in your spare time, call or write for more information on how we make it easy for you to do both!

Computer Ideas, Inc.
10 Keith Way, Hingham, Mass. 02043
(617) 749-9555
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.
Get Ready to Make Your Own Magic

Math-Ter-Mind® A delightful educational learning experience for your pre-school child. Watch the smile on your child's face as a correct answer makes the mathematician smile on the screen before you. A nursery song also serves as a reward for learning elementary addition and subtraction. With Aladdin's Math-Ter-Mind® your child's pathway to learning will be fun-filled . . . for both of you. Math-Ter-Mind®. The first release from the Aladdin Education Series. (nursery song currently available only on Apple II® program)

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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 02FF. (Note that borrow and carries do not propagate into the most significant 4 bits during effective address computation.) Since the address 0FF 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.)

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.

```
1 .NLIST TTM
2 .TITLE PROGRAM #1
3 ;THIS PROGRAM PRINTS OUT A MESSAGE
4 ;OVER AND OVER FOREVER.
5 ;THE MESSAGE TAKES THE FORM OF
6 ;ANY STRING OF ASCII CHARACTER CODES
7 ;FOLLOWED BY A TERMINATION CODE OF ZERO
8 .B 0200 .=200
9 0200 C4 20 START: LDI 'L<STRING> ;PL3 IS USED AS A
10 0202 31 XPAL P1 ;POINTER TO THE
11 0203 C4 02 LDI 'L<STRING> ;MESSAGE STRING
12 0205 35 XPAL P1
13 0206 C4 C4 LOOP: LDI 'L<PUTC> -1 ;P3 MUST BE ONE LESS
14 0208 33 XPAL P3 ;OF PUTC = 01C5
15 0209 C4 01 LDI 'L<PUTC> ;THAN THE ADDRESS
16 020B 37 XPAL P3
17 020C C5 01 LD @I(P1) ;GET NEXT CHARACTER
18 020E 98 F0 .JZ START ;ZERO IS END CODE
19 0210 3F XPPC P3 ;OTHERWISE PRINT CHARACTER
20 0211 90 F3 JMP LOOP ;AND LOOP
21 0220 .=0220
22 0220 48 45 STRING: .ASCII /HELLO/<CR><LF><0
22 0222 4C 44
22 0224 4F 0D
22 0226 0A 00
23 0001 P1=31
24 0002 P2=32
25 0003 P3=33
26 01C5 PUTC=01C5
27 000D CR=0D
28 000A LF=0A
29 0200 .END START
```

Symbol Table

```
CR = 000D LF = 000A LOOP 0206
PUTC = 01C5 P1 = 30001 P2 = 30002
P3 = 30003 START 0200 STRING 0220
```

Errors Detected: 0
Free Core: 17525. Words

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In order to run this, or any program in this article, it is necessary to initialize the register save locations of KITBUG. These are OFF7 thru OFFF. (In the kit setup these are equivalent to 02F7 thru 02FF.) Locations OFF7 and OFF8 should contain 0200 (02 in OFF7, 00 in OFF8). The remaining locations, especially OFFB and OFFC (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 then 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 OFF7 and OFF8 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.

0200 0200
0208 0208
0216 0216
0224 0224
0232 0232
0240 0240
0248 0248
0256 0256
0264 0264
0272 0272

Listing 2 continued on page 180
hand, it is worth it. However, in the broader sense of pro-
gramming, 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 pro-
gram.

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

```
TIMESTART: LDI "L<PHEXI>-1 ;GET ADDRESS
0205 C4 01 LDI "L<PHEXI> ;PRINT ROUTINE
0206 C0 37 LD MINUTE ;GET MINUTE
0207 C4 01 LDI "L<PHEXI> ;PRINT ROUTINE
0208 C0 39 LD HOUR ;GET HOUR
0209 C0 37 LD MINUTE ;GET MINUTE
0210 C0 26 LD HOUR ;GET HOUR
0211 C8 2F ST MINUTE ;STORE NEW VALUE
0212 C4 40 DAI 0 ;DOES MINUTE = 60?
0213 C0 3E JT DELAY
0214 C0 26 LD HOUR ;GET HOUR
0215 C8 22 ST HOUR ;HOUR = HOUR + 1
0216 C8 28 ST HOUR ;HOUR = HOUR + 1
0217 C8 29 ST MINUTE ;MINUTE = 0
0218 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0219 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0220 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0221 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0222 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0223 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0224 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0225 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0226 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0227 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0228 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0229 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0230 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0231 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0232 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0233 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0234 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0235 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0236 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0237 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0238 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0239 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0240 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0241 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0242 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0243 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0244 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0245 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0246 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0247 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0248 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0249 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0250 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0251 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0252 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0253 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0254 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0255 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0256 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0257 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0258 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0259 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0260 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0261 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0262 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0263 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0264 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0265 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0266 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0267 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0268 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0269 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0270 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0271 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0272 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0273 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0274 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0275 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0276 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0277 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0278 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0279 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0280 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0281 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0282 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0283 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0284 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0285 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0286 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0287 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0288 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0289 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0290 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0291 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0292 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0293 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0294 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0295 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0296 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0297 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0298 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0299 C0 00 DAI 0 ;ADD 1 (LINK = 1)
0300 C0 00 DAI 0 ;ADD 1 (LINK = 1)
```

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

Programs 4 and 5: Calculation
Programs 4 and 5, listings 4 and 5, are designed to perform calculator-like arithmetic functions. Program 4 is an adder, and program 5 is a multiplier. The functions were kept separate in order to make the programs simple; however, an enterprising reader could easily combine the functions into a single program, and even include subtraction and division.

Both programs use the decimal addition instruction, as did program 3. Multiplication is performed in a very sim-
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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.

```
.0200 C4 DF START: LDI <L<HEX>-1 ;SET P3
.0202 33 XPAL P3 ;TO ADDRESS
.0203 C4 00 LDI <U<HEX> ;OF
.0205 37 XPAH P3 ;CHEX
.0206 3F XPPC P3 ;CALL CHEX TWICE
.0207 3F XPPC P3 ;TO GET TWO NUMBERS
.0208 C2 01 LD 1(P2) ;GET LOW HALF 2ND NO
.0209 EA 03 DAD 3(P2) ;ADD TO LOW 1ST NO
.020D CA 03 ST 3(P2) ;STORE AT BOTTOM OF STACK
.020F C6 02 LD @2(P2) ;GET HIGH 2ND NO
.0211 EA 00 DAD 0(P2) ;AND BUMP STACK POINTER
.0213 CA 00 ST 0(P2) ;ADD HIGH 1ST NO
.0215 C4 C4 LDI <L<PUTC>-1 ;P3 SET FOR CHARACTER PRINT
.0217 33 XPAL P3 ;HIGH P3 IS OK (REALLY)
.0218 C4 30 LD 30 ;GET ASCII 0
.021A F4 00 ADI 0 ;ADD CARRY FOR FIFTH DIGIT
.021C 3F XPPC P3 ;PRINT 0 OR 1
.021D C4 43 LDI <L<PHEX2>-1 ;P3 SET FOR BYTE PRINT
.021F 33 XPAL P3 ;AND PRINT
.0220 C6 01 LD @1(P2) ;POP HIGH BYTE OFF STACK
.0222 3F XPPC P3 ;AND PRINT
.0223 C6 01 LD @1(P2) ;POP LOW BYTE
.0225 3F XPPC P3 ;AND PRINT
.0226 C4 C4 LDI <L<PUTC>-1 ;P3 SET AGAIN FOR CHARACTERS
.0228 33 XPAL P3 ;HIGH P3 STILL OK
.0229 C4 0D LDI CR ;GET CARRIAGE RETURN
.022B C3 3F XPPC P3 ;PRINT
.022C C4 0A LDI LF ;GET LINE FEED
.022E 3F XPPC P3 ;PRINT
.022F 90 CF JNP START ;LOOP TO BEGINNING
0000 CR=%0001
0002 P2=%0202
0003 P3=%0303
000D CR=0D
000A LF=0A
00E0 GHEX=%00E0
01C5 PUTC=%01C5
0144 PHEX2=%0144
0200 END START
```

Symbol Table

```
CR = 000D GHEX = 00E0 LF = 000A
PHEX2 = 0144 PUTC = 01C5 P1 = 00001
P2 = 0200 P3 = 0003 START 0200
```

Errors Detected: 0

Tile way by repeated addition. Thus 573 \times 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.
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Listing 5: As an extension of the addition routine, the multiplication routine inputs 2 numbers and multiplies them.

0200 C4 DF LIST: TTN
0202 33 TITLE PROGRAM #5
0203 3F ;THIS PROGRAM MULTIPLIES
0205 3D ;TWO NUMBERS WHEN TYPED IN AS
0207 3F ;35789425 =
0209 3C ;INPUT HAS FOUR DIGIT MAX
020B 3C ;OUTPUT IS EIGHT DIGITS
020D 4F
020E 34 START:
020F 0A 00 LDH ^1(GHEX)-1
0211 34 SET P3
0212 34 TO ADDRESS
0213 33 XPAH P3
0214 3E LDI ^0(GHEX)
0215 3E 0F
0216 3E XPAH P3
0217 3E GHEX
0218 34 CALL GHEX TWICE
0219 3C XPPC P3
021A 3C TO GET TWO NUMBERS
021B 3F XPPC P3
021C 3F SET UP LOOP
021D 3F ST TEMP
021E 3F TO PUT SIX ZEROS
021F 3E LDI 0
0220 3E ON STACK
0221 3E 02E GHEX CE FF ST <=1(P2)
0222 3F LAST FOUR ZEROS ARE
0223 3F INITIAL PRODUCT
0224 3F 0210 BB 5F DLH TEMP
0225 3E ;FIRST TWO EXTEND MULTIPLICAND
0226 3F TO EIGHT DIGITS
0227 3F ;CLEAR OLD CARRY
0228 3F ;CLEAR OLD CARRY
0229 3F ;AND SUBTRACT
022A 3F ;ONE FROM
022B 3F ;MULTIPLIER
022C 3F ;BOTH HALVES
022D 3F ;IN TENS COMPLIMENT
022E 3F ;THERE IS NO CARRY ON
022F 3F ;LAST ADD 0-1 = 9999
0230 3F ;SO GET OUT
0231 3F ;OTHERWISE CLEAR CARRY
0232 3F ;TEMPORARILY BUMP STACK BY 4
0233 3F ;COUNT = 4 DIGITS
0234 3F ;FOR LOOP
0235 3F ;80% ADD
0236 3F ;MULTIPLICAND TO

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97 0227 CA 00 ST 06 (P2)
98 0231 B8 3E DLD TEMP
99 0232 9C F6 JNZ L3
100 0255 90 DD JMP L2
101 0237 C4 04 OUT: LD1 4
102 0239 C3 36 ST TEMP
103 0238 C4 33 L4: LD1 *(PH2) - 1
104 0239 33 XPAL P3
105 023A C6 01 LD *(P2)
106 0249 3F XPCC P3
107 0244 B9 2E DL D TEMP
108 0243 9C F6 JNZ L4
109 0245 C6 06 LD *(P2)
110 0247 C4 C4 LD 1 PUTC - 1
111 0249 33 XPAL P3
112 024A C4 6D LD1 CR
113 024C 3F XPCC P3
114 024D C4 0A LD1 LF
115 024F 3F XPCC P3
116 0250 0270 TEMP=270
117 0270 00E0 GHEX=00E0
118 0144 PH2=0144
119 0155 PUTC=0155
120 0001 P1=1
121 0002 P2=2
122 0003 P3=3
123 0004 CR=0
124 000A LF=0A
125 0200 .ENI START

Listing 5 continued on page 188
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LISTING 5 CONTINUED:

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

Errors detected: 0

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, PROC5 = PROC5

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 Os on the stack. The lower 4 Os form an accumulator for the product. The 2 other Os 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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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:** 280 assembler code for the KEYIN routine. The program uses a table, as shown in listing 2, to determine acceptable input.

```
LINE Address Object
  15     17200   TBLPNT EQU 0F2000H
  26     17202   TBLCNT EQU 0F2026H
  37     17204   BASE EQU 0F204BH
  48     00077   HELL EQU 07H
  59     00078   CODE EQU 0F00H

82     00080   KEYEN: PUSH DE
  93     00081   PUSH AF
  104     00082   CALL CHARIN
  115     00083   CALL CHAROUT

126     00084   EIOHJH: COUNl 1
  137     00085   DBH111

148     00086   PC11111

159     00087   DB11111

170     00088   DBH11111

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

<table>
<thead>
<tr>
<th>BASE</th>
<th>DEFM 'GR'</th>
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<tbody>
<tr>
<td>TBLCNT</td>
<td>DEFM 'FEDCBA9876543210'</td>
</tr>
</tbody>
</table>
```
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 ig­
nored 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 hexa­
decimal 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 char­
acter.

Another use of KEYIN is searching a tree for valid in­
put. 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 re­
jected 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 ac­
tion 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 in­
put 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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<td>EXPANSION INTERFACE</td>
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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 8080/280 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:

CH (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.
The Electric Pencil II is a Character Oriented Word Processing System. This means that text is entered as a string of continuous characters and is manipulated as such. This allows the user enormous freedom and ease in the movement and handling of text. Since line endings are never delineated, any number of characters, words, lines or paragraphs may be inserted or deleted anywhere in the text. The entirety of the text shifts and opens up or closes down or pulled up in a wrap around display as it occurs, which eliminates guesswork. Text may be reviewed at will by variable speed scrolling both in the forward and reverse directions. By using the search or search and replace functions, any string of characters may be located and/or replaced with any other string of characters as desired.

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<td>$300.</td>
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**Attention: TRS-80 Users!**

The Electric Pencil has been designed to work with both Level I (16K system) and Level II models of the TRS-80, and with virtually any printer you choose. Two versions, one for use with cassette, and one for use with disk, are available on cassette. The TRS-80 disk version is easily transferred to disk and is fully interactive with the READ, WRITE, DIR, and KILL routines of TRS-DOS 2.1.

<table>
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<td>TRD</td>
<td>Disk</td>
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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 application 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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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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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

Table 1: Standard control character functions.

<table>
<thead>
<tr>
<th>Mnemonic</th>
<th>ASCII</th>
<th>Hexadecimal</th>
<th>Standard Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAXR</td>
<td>NUL</td>
<td>00</td>
<td>Display Mode Selection</td>
</tr>
<tr>
<td>MAXC</td>
<td>SOH</td>
<td>01</td>
<td>Maximum resolution</td>
</tr>
<tr>
<td>R128</td>
<td>STX</td>
<td>02</td>
<td>Maximum colors</td>
</tr>
<tr>
<td>R64</td>
<td>ETX</td>
<td>03</td>
<td>128 by 128</td>
</tr>
<tr>
<td>RXXX</td>
<td>EOT</td>
<td>04</td>
<td>64 by 64</td>
</tr>
<tr>
<td>BS</td>
<td>BS</td>
<td>08</td>
<td>Carriage Control</td>
</tr>
<tr>
<td>HT</td>
<td>HT</td>
<td>09</td>
<td>Backspace (optional)</td>
</tr>
<tr>
<td>LF</td>
<td>LF</td>
<td>0A</td>
<td>Horizontal tab (optional)</td>
</tr>
<tr>
<td>VT</td>
<td>VT</td>
<td>0B</td>
<td>Line feed</td>
</tr>
<tr>
<td>FF</td>
<td>FF</td>
<td>0C</td>
<td>Vertical tab (optional)</td>
</tr>
<tr>
<td>CR</td>
<td>CR</td>
<td>0D</td>
<td>Form feed</td>
</tr>
<tr>
<td>SO</td>
<td>SO</td>
<td>0E</td>
<td>Carriage return</td>
</tr>
<tr>
<td>SI</td>
<td>SI</td>
<td>0F</td>
<td>Undefined</td>
</tr>
<tr>
<td>BLK</td>
<td>DLE</td>
<td>10</td>
<td>Black</td>
</tr>
<tr>
<td>RED</td>
<td>DC1</td>
<td>11</td>
<td>Red</td>
</tr>
<tr>
<td>BLU</td>
<td>DC2</td>
<td>12</td>
<td>Blue</td>
</tr>
<tr>
<td>MAG</td>
<td>DC3</td>
<td>13</td>
<td>Magenta</td>
</tr>
<tr>
<td>GRN</td>
<td>DC4</td>
<td>14</td>
<td>Green</td>
</tr>
<tr>
<td>YEL</td>
<td>NAK</td>
<td>15</td>
<td>Yellow</td>
</tr>
<tr>
<td>CYN</td>
<td>SYN</td>
<td>16</td>
<td>Cyan</td>
</tr>
<tr>
<td>WHI</td>
<td>ETB</td>
<td>17</td>
<td>White</td>
</tr>
<tr>
<td>N</td>
<td>ETX</td>
<td>18</td>
<td>Eight</td>
</tr>
<tr>
<td>O</td>
<td>to</td>
<td>to</td>
<td>optional</td>
</tr>
<tr>
<td>E</td>
<td>GS</td>
<td>1F</td>
<td>colors</td>
</tr>
</tbody>
</table>

Table 1: Standard control character functions.
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 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

Table 2: 8080 assembly language standard vector addresses.
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Table 3: BASIC standard protocols.

<table>
<thead>
<tr>
<th>Mnemonic</th>
<th>Function</th>
<th>Arguments</th>
</tr>
</thead>
<tbody>
<tr>
<td>IGR</td>
<td>INITG</td>
<td>None</td>
</tr>
<tr>
<td>PAG</td>
<td>PAGE</td>
<td>None</td>
</tr>
<tr>
<td>CUR</td>
<td>CURSOR</td>
<td>&lt;X&gt;, &lt;Y&gt;</td>
</tr>
<tr>
<td>DOT</td>
<td>DOT</td>
<td>None</td>
</tr>
<tr>
<td>LIN</td>
<td>LINE</td>
<td>&lt;X&gt;, &lt;Y&gt;</td>
</tr>
<tr>
<td>CHA</td>
<td>CHAR</td>
<td>&lt;numeric ASCII value&gt;</td>
</tr>
<tr>
<td>ANM</td>
<td>ANIMAT</td>
<td>None</td>
</tr>
<tr>
<td>TXT</td>
<td>PRINT</td>
<td>Equivalent to print except on display</td>
</tr>
</tbody>
</table>

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
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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.

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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PAGE

ADR = Refresh buffer address
CNT = Refresh buffer length

D O
Set [ADR] to zero [black]
ADR = ADR + 1
CNT = CNT - 1
UNTIL CNT equals 0

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 idiosyncrasies. 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
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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 (Xn, Yn) 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 ≤ x ≤ 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 

\[ y_{n+1} = \begin{cases} 
\text{remains unchanged} & \text{if } (x_{n+1}, y_{n+1}) \text{ lies above the line} \\
\text{increased by 1} & \text{if } (x_{n+1}, y_{n+1}) \text{ lies below the line} 
\end{cases} \]

In the event \( x_{n+1}, y_{n+1} \) 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 \( (x_{n+1}, y_{n+1}) \) 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:
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---

**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 \((x + 1, y + 1/2)\) 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 \( \theta \), and the angle formed by the current point \((x, y)\) the origin and the X axis \( \theta' \), then if \((x, y)\) lies above the desired line, \( \theta < \theta' \). Conversely, if \((x, y)\) lies below the desired line, \( \theta > \theta' \). 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 \( \theta \) is \( y/x \), while that of \( \theta' \) is \( y/x \). Therefore, we can easily determine the position of any point relative to the desired line by comparing the quotients \( y/x \) and \( y/x \).

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:

\[
(x + 1) \times Y > X \times (y + 1/2)
\]
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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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 \geq Y \geq 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 \geq XC then we are in the first or fourth quadrant (see figure 11); otherwise, we are in the second or third. Similarly, if YF \geq 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 \geq XC), 2 to (YF \geq YC) and 1 to (YP \geq 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
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Figure 12: Typical character generation.

Figure 13: The CHAR function which provides the capability to display alphanumeric as well as graphical data.

<table>
<thead>
<tr>
<th>Char Size</th>
<th>LC</th>
<th>Char/Line (256 by 256)</th>
<th>Lines/Page (256 by 256)</th>
<th>Memory For Tables (bytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 x 11</td>
<td>Y</td>
<td>25</td>
<td>18</td>
<td>1200</td>
</tr>
<tr>
<td>7 x 9</td>
<td>Y</td>
<td>32</td>
<td>21</td>
<td>864</td>
</tr>
<tr>
<td>5 x 7</td>
<td>N</td>
<td>42</td>
<td>32</td>
<td>320</td>
</tr>
<tr>
<td>4 x 5*</td>
<td>N</td>
<td>64</td>
<td>32</td>
<td>192</td>
</tr>
</tbody>
</table>

*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.

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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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Circle 337 on inquiry card.
8080/8085: Assembly Language Programming

Lance R Leventhal
Osborne and Associates Inc
Berkeley, California 1978
467 pages softcover
$9.50

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.

Chapter 2 describes how an assembler works and gives a very complete view of all the available features. As with all this publisher's books, it is not merely an overview. This chapter will greatly assist you in choosing among the available assemblers.

Chapter 3 is technical writing at its finest. Each assembly language instruction given is elaborated upon with diagrams the reader has become acquainted with in the earlier books—minus the incomprehensible abbreviations. Bold type is used only where it should be—for titles.

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.

The final chapters give detailed advice on programming. These are mandatory if one expects his programs to be useful to anyone else. Leventhal repeatedly emphasizes that commercial programs must be written for the program buyer, not the writer.

In summary, this is an excellent encyclopedia of assembly language programming. If you understand all of this book and have it for reference, you will have few problems.

Bruce R Evans MD
16 Marwin Rd
Pickering Ontario
CANADA
L1V 2N7

Technical Aspects of Data Communication

John E McNamara
Digital Press
Digital Equipment Corp,
Educational Services Dept
12 Crosby Dr
Bedford MA 07130
$19.95

Technical Aspects of Data Communication by John E McNamara is the book I was looking for five years ago. It could have saved me hundreds of hours of searching and reading. The last paragraph of the introduction states why: 'This book will not teach anyone every thing about data communication. Knowledge of data communication is acquired by a bootstrapping process in which one learns enough to read the next book or explore the next problem, from which one learns enough to go on further. This book is intended to fill
a place in that process.

This book deals with the real nitty-gritty of data communications from "what is a stop bit?" all the way through an explanation of packet switching. All the information is presented in practical terms—rather than through mad and theory. A glossary in the back of the book defines all the terms used. Various accompanying tables list character codes, pin connections, and usable line lengths. If you need to know what a UART is and how it works, there is an appendix devoted entirely to UARTs.

If you need to know about asynchronous or synchronous communication, common protocols and what they are suited for, how telephones work, the characteristics of different modems, and what types of automatic-calling units are available and how to write a program to talk to them, you can find it in this book. If you only need to know what pin 8 on the 25-pin connector on your terminal is used for, you can also find that information in this book.

There are about 400 pages of good reference information with readable explanations for anyone who must deal with data communications hardware or software. Technical Aspects of Data Communication is worth the price.

Phil Hughes
POB 2847
Olympia WA 98507

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 A 1 GOTO 1000, 9999, 1760."

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"Level I" includes a metal sheet superstructure, a 3-card gold plated 512-k extension PC board which plugs into the motherboard assembly. Just add any number of S-100 expansion cards.
Build a Simple Digital Oscilloscope

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 ¼ 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

<table>
<thead>
<tr>
<th>Device</th>
<th>Type</th>
<th>+5 V</th>
<th>GND</th>
</tr>
</thead>
<tbody>
<tr>
<td>IC1</td>
<td>74154</td>
<td>24</td>
<td>12</td>
</tr>
<tr>
<td>IC2</td>
<td>7404</td>
<td>14</td>
<td>7</td>
</tr>
<tr>
<td>IC3</td>
<td>7404</td>
<td>14</td>
<td>7</td>
</tr>
<tr>
<td>IC4</td>
<td>7404</td>
<td>14</td>
<td>7</td>
</tr>
<tr>
<td>IC5</td>
<td>7474</td>
<td>14</td>
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<tr>
<td>IC6</td>
<td>7474</td>
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<td>IC11</td>
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<tr>
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<td>74154</td>
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<td>12</td>
</tr>
<tr>
<td>IC13</td>
<td>7493</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>IC14</td>
<td>7493</td>
<td>5</td>
<td>10</td>
</tr>
</tbody>
</table>

Table 1: Power and ground connections for integrated circuits in figure 1 schematic diagram.
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Figure 1: Schematic diagram of the digital oscilloscope.
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BYTE November 1979 225

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Circle 351 on inquiry card.
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.
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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.

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**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


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. Multi-beam, 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 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

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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 Datacomm, Pacific Grove CA. This symposium is sponsored 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 approach to controlling conversion costs. Contact Len Boselovic, ANMC, 1625 Massachusetts Ave NW, Washington DC 20036.

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 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

December 5
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.
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.

Project Management 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.

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, MK2-3, Marlboro MA 01752.

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.

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 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.
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).

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

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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.
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.

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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 keys. 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 7½ 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.
**TRX-80 disk software**

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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 unreferenced 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.

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 Washington DC to study operation, expansion and applications of KIM-1 microcomputers. The

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Package contains: compiler, linker, library manager; standard function library; sample source files include games, a terminal emulator with disk I/O plus the source for many standard library functions; DBCS User's Guide; Book -The C Programming Language by Dennis Ritchie and Brian Kernighan of Bell Labs.

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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.

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Microcomputer Investors Association

The most recent issue of the MicroComputer Investors Association newsletter 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.

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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 Writings of 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.

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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.

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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.

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Albany Schenectady NY Microcomputer Society

Capital Area Microcomputer Society (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.

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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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Microcomputer Association

Investors

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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

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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.

New! PROBLEMS FOR COMPUTER SOLUTION, Second Edition (Spencer) Offers a wide selection of problems for solution for those who wish to test their programming skills. Problems include mathematical disciplines, science, business, game playing, and more. #5191-3, $5.95

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**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 Crumber 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  | 0:7 11  A  | 0:8 13  C  
NUMBER PUNCHING  | 0:8 72  ST+  | 0:8 57  DISC  
              | 0:9 01  01  | 0:9 06  06  
LABEL : ST    | 0:20 69  DF  | 0:21 01  01  
              | 0:22 69  DF  | 0:23 31  31  
001  15  E    | 0:23 22  22  | 0:24 05  05  
017  11  A    | 0:24 92  RTN  | 0:25 65  X  
026  12  B    | 0:25 76  LBL  | 0:26 73  RC+  
048  13  C    | 0:26 12  B  | 0:27 03  03  
142  14  D    | 0:27 72  ST+  | 0:28 54  54  
              | 0:28 01  01  | 0:29 74  $M+  
PROGRAM LIST  | 0:29 97  DSC  | 0:30 01  01  
000  76  LBL  | 0:30 00  00  | 0:30 73  RC+  
001  15  E    | 0:31 00  00  | 0:31 01  01  
002  47  CMS  | 0:32 00  00  | 0:32 69  DF  
003  01  1    | 0:33 21  21  | 0:33 55  +  
004  00  0    | 0:34 69  DF  | 0:34 66  01  
005  42  STD  | 0:35 24  24  | 0:35 52  EE  
006  01  01   | 0:36 32  RTN  | 0:36 68  6  
007  02  2    | 0:37 43  RCL  | 0:37 54  +  
008  42  STD  | 0:38 01  01  | 0:38 72  $M+  
009  00  00   | 0:39 40  STD  | 0:39 69  EE  
010  42  STD  | 0:40 00  00  | 0:40 72  $M+  
011  06  06   | 0:41 00  00  | 0:41 72  $M+  
012  04  4    | 0:42 00  00  | 0:42 72  $M+  
013  69  DF   | 0:43 00  00  | 0:43 72  $M+  
014  17  17   | 0:44 00  00  | 0:44 72  $M+  
015  92  RTN  | 0:45 00  00  | 0:45 72  $M+  
016  76  LBL  | 0:46 00  00  | 0:46 72  $M+  
```

Listing continued on opposite page
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 | 790058 |
| 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.

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| IMSAI 1800D Kit | $686.95 |
| IMSAI KB-1 Intelligent Keyboard | $275.95 |
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Navigation - Calculates ground speed and true heading for all quadrants

<table>
<thead>
<tr>
<th>DISPLAY</th>
<th>KEY ENTRY</th>
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R6 WIND DIRECTION + 0.1°(DEGREES)
R7 AIR SPEED MILES/HR.
R8 WIND SPEED MILES/HR.
R9 AIR SPEED °
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Note: SBSG maintains a time-sharing computer where you can dial-up and leave your problems, 24 hours, 7 days a week.

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BYTE November 1979 247
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 $ TAB(*P) $ A @Q LEN(1) $ B @P LEN(1) $ C + $ LGT(B,C) = A C B = (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.
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 1/2 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.

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FLOPPY DISK STORAGE BINDER
This black vinyl three-ring binder comes with ten transparent plastic pockets which accommodate either twenty, five-inch or ten, eight-inch floppy disks. The plastic sleeves may be ordered separately and added as needed. A content record is included with each sleeve for easy identification and organization. Binder & 10 holders $18.95 Part No. 800. Existing holders $9.95 each. Part No. 800.

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**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 AIF Electronics Inc., 444 Madison Ave, New York NY 10022. Circle 627 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.

**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, PO Box 5363 Houston TX 77058. Circle 628 on inquiry card.
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Phone: (408) 263-9246

Circle 126 on inquiry card.
Muscles for Robots

This 12 V DC, 17 RPM, reversible gear motor 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.

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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.

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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.

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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 1M 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.

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.

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.

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.
The MEGABOX includes provision to add 32K of RAM and a UART with the RS-232 interface, so the MEGABOX can be used with the TRS-80 alone to provide a complete 48K system, capable of supporting a printer. (By MICROMATION, of course!)

One MByte Storage: $2295
Two MByte Storage: $3095
Software Patch: $249 *
Microsoft FORTRAN: $199 *

TRS-80 TM Tandy Corp.

Add Capacity and Power to your S-100 System.

--- DISK STORAGE ---

Micromation 'Doubler'
(2D / Disk Controller) $449.00
One MByte Disk Sub-System
(Two REMEX 8" RFD-2000)
(Controller / Housing & CP/M) $2,295
Two MByte Disk Sub-System
(Two REMEX 8" RFD-4000 dual head)
(Controller / Housing & CP/M) $2,595 *

--- MEMORY BOARDS ---

Measurement Systems & Controls
48K Dynamic (DM-4800) $549.00 *
Seattle Computer Products
'16K Plus' Static (250ns) $325.00 *

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All for ONLY $3390.*
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 97116.

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 TIs'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 (input/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 TIs’s data entry and display Microterminal; firmware support, including TIBUG Monitor and line-by-line assembler; software, including Power BASIC high-level language and TIFMX Executive Library, a collection of assembly language programs available for users of TIs’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 bi-monthly 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.


Circle 602 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 603 on inquiry card.
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- Business Software...
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- On line mini-floppy storage...
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**MINIMAX II - 2 Megabyte**
- On line floppy storage...
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Advanced hardware and software technology gives you:
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**BYTE November 1979 259**
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.

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 PETPILOT 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.

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 $395. The manual alone is $35. For further information, contact Global Parameters, 1505 Ocean Ave, Brooklyn NY 11230.

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.
16K EPROM CARD—$100 BUSS
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USES 2708's!
Thousands of personal and business systems around the world use this board with complete satisfaction. Puts 16K of software on line at ALL TIMES! Kit features a top quality soldermasked and silk-screened PC board and first run parts and sockets. All parts (except 2708’s) are included. Any number of EPROM locations may be disabled to avoid any memory conflicts. Fully buffered and has WAIT STATE capabilities.

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WHY THE 2114 RAM CHIP?
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ASSEMBLED AND TESTED/READY TO USE! Over 3 years of design efforts were required to produce a TRUE S-100 Z80 CPU at a genuinely bargain price! 4 MHZ! $159.95

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- Allows DMA data chain
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The 7470A allows conversion of a DC voltage to a BCD number in computer monitoring and analy.
- Typical inputs would be DC inputs from temperature or pressure transducers
- Selectable interrupt on end of conversion
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- 4 to 20 VDC full scale
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- Calibration adjustment
- Input offset adjustment
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- Supports interrupt data chain
- Allows DMA data chain
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- All holes plated thru
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The 7510A is used to the 7500A except it is designed for soldering of circuits.
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Model 7509A - Apple II Etch Board
The 7509A is used for etching boards which allows the actual etching of circuits for use in the Apple II computer.
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The 7520A is a handy tool when adding or testing modules in the Apple II computer.
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Four levels of difficulty.
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<table>
<thead>
<tr>
<th>Length</th>
<th>100</th>
<th>500</th>
<th>1,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5 inches</td>
<td>1.04</td>
<td>2.98</td>
<td>5.16</td>
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<tr>
<td>3</td>
<td>1.08</td>
<td>3.22</td>
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<td>Kit #4</td>
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Wire Wrap Tool

BATTERY HOBBY TOOL

- Auto Indexing
- Anti-Overwrapping
- Modified Wrap
- Includes #30 Bit

*Requires 2 "C" Niced Batteries

Solderless Breadboarding

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All are Gold 100 pin, IMSAI spacing.

IC Sockets

RN HIGH RELIABILITY eliminates trouble. "Side-wipe" contacts make 100% greater surface contact with the wide, flat sides of your IC leads for positive electrical connections.

<table>
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<tr>
<th>Type</th>
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ORDERING INFORMATION
- Orders under $25, add $2 handling
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- CODs, VISA & MC orders will be charged shipping
- Most orders shipped next day

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BYE November 1979 265
The PROM-100 Programmer is a development tool for S-100 Bus computer systems. The Force Programming Socket extends above the card cage height for easy access to PROM devices. Soft-time for 16,389 bits is 100 seconds. Programs: 2708, 2716, 2732 and Tl 2516. DIP Selectable EPROM type.

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- Complete kit includes all Sockets for 64K
- Memory access time: 375ns, Cycle time: 500ns.
- No wait states required
- 16K boundaries and Protection, via Dip Switches
- Designed to work with Z-80, 8080, 8085 CPU's

EXPANDORAM 64K Kit ($199.00)

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Circle 224 on inquiry card.
Circle 16 on inquiry card.
Real-Time Third Octave Audio Spectrum Analyzer

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 kHz 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.

Circle 642 on inquiry card.

New Tractor-Feed Impact Printer

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 12-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 2K byte buffer and graphics package provides full dot-plotting graphics capability. The larger 2K byte buffer holds the contents of a full video screen or 1920 characters.

The Paper Tiger is priced at $595.

Circle 643 on inquiry card.
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- PET 2023 Pressure Feed Printer $99
- PET 2100 External Cassette Deck $9

**WRITE FOR 6502 AND S-100 PRODUCT LIST**

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- Cassette Port $1.45
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- ABBREVIATIONS: S/T Toaster Taps; S/E Self-Eject

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**ASCII KEYBOARD KIT** - **KIT** $79.95

- Single +5V Supply
- Full ASCII Set (Upper and Lower Case)
- Parallel Output
- Positive and Negative Strobe
- 2-Key Rollover
- 3 User Definable Keys
- P.C. Board Size: 17-3/16" x 5"
- Control Characters Molded on Key Caps
- Optional Provision for Serial Output
- Edge Connectors
- Sockets
- Upper Case Lock Switch
- Shift Register (for Serial Output)

Dealer inquiries invited.

**APPLE II 1/0 BOARD KIT** - **KIT** $49.00

- 1 8-Bit Parallel Output Port (expands to 3 Ports)
- 1 Input Port
- 15mA Output Current Sink or Source
- Can be used for peripheral equipment such as printers, floppy discs, cassettes, paper tapes, etc.
- 1 Free Software Listing for SWTP PR40 or IBM selectric

**VENUS 2001 VIDEO BOARD** - Assembled and Tested $199.95

- Complete with Input Cable and Rechargeable Batteries and Charger Unit

**THE APPLESTICK™** $49.95

Just plug it into your game connector and make your present games more enjoyable.

The APPLESTICK is a wonderful add-on for your Apple II. With an APPLESTICK you can enjoy the smooth, easy control of a true 360° joystick.

**NEW! A DREAM COME TRUE!**

Introducing: 30 MZH DUAL TRACE PORTABLE SCOPE for an amazing **$555.**

- Dual trace 2-channel, separate, chopped or alternate modes
- 30 megahertz bandwidth
- External and internal trigger
- Time base -0.05, Microseconds to 0.2 SEC/div 21 settings
- Battery or line operation
- Line synchronization mode
- Power consumption less than 50W
- Vertical gain 0.1 to 50 volts/div-12 settings
- Size: 2 9/16" H, 6 4/8" W, 9 5/16" D
- Weighs only 3.5 lbs with batteries
- Complete with input cable and rechargeable batteries and charger unit

**SHIPPING $3.50**

California residents add 6% sales tax

ELECTRONICS WAREHOUSE Inc.
15820 Hawthorne Boulevard
Lawndale, CA 90260
(213) 370-5551

---

Circle 130 on inquiry card.
**EXCITING MAIL ORDER DISCOUNTS**

---

**MICROPOLIS**

**Metafloppy DRIVEs**

1043 (Single) 315kB .. $90.00
1053 (Dual) 630kB .. $100.00

---

**SOROC IQ 120**

**PORTABLE MINICOMPES**

LOW POWER CONSUMPTION

- MS-15 SINGLE TRANCE 15 MHz .. $289
- MS-215 DUAL TRANCE 15 MHz .. $389
- MS-320 DUAL TRANCE 30 MHz .. $519

---

**LEEDEX VIDEO 100**

12" BLACK & WHITE MONITOR

- VIDEO BANDWIDTH 12MHz ± 5dB
- COMPOSITE VIDEO INPUT

---

**G S COMPUTER SPECIALTIES**

Circle 67 on inquiry card.

---

**MICRON**

**PRINT TERMINALS**

- ASCII SELECTIVE PRINTER/TYPEWRITER: Win settle for less that letter quality printout from your computer? IBM Model 725 can be used as of-line printer or on-line printer. Complete with solenoids, power supply, case, and ASCII interface card (TTL to CPU parallel port). Interface compatible ASCII translation_tab control and up to 8 tables for use with various typefaces. Immediate signals on completion of each print cycle ensures fastest printing speed (at 15 ips), cleaned and adjusted.

Price programmed w/translation tables (100 type faced) .. $795.00

- ELECTRIC I/O TERMINAL IN C.U. Information System: Both ASCII & IBM code versions with microcomputer interface software & hardware (RS-232 connector). Cassette drive models permit up to 3000 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-carrige, interchangeable type symbols, optional built-in modem. All units cleaned, adjusted & warranted.

Model 551

- IBM Correspondence code .. $795.00
- Model 550

Model 550B

- (carries code, built-in cassette drive) .. $1355.00
- Model 550D

ASCII code, built-in cassette drive) .. $1295.00

---

**TEDATA**

**POS-100**

- NRZI MAGNETIC TAPE DRIVE CONTROL/FORMATTER: Designed as interface between 5 1/4 inch mcmicru and 9-track, 800M, 80X (IBM) tape drives. Allows microcomputer to read and write IBM-compatible magnetic tape. Software provided for 8080 or Z-80 systems. Requires modification for drives of various densities. Std. version 2 MHz S-100/80P CPU 10 units use with 12 1/2 Its. PI-TY/Tape Style Drive.

Price: (Includes S-100 card, controller card, 10 cable, software listing) .. $750.00

- NRZI TAPE DRIVE BY LIPHER Data Products: Std 800 BPI drive model 1008; 2400 Tape, 8 track, 9 1/2s 7 ips, used, refurbished.

Price: approx. 125 @ $150.00

- CONVERT IBM OFFICE SELECTRIC TO I/O TYPEWRITER: Kit includes assembled read/write, switch, coaxial cabling, 50-foot ribbon cable, and 10-foot RS-232 cable. U.S. Dept. of Commerce Tested.

Price: .. $75.00

- POWER SUPPLIES FOR IBM DRIVERS: MCPL, def, MC1, RS-232, tested under load shown in manual.

Price: .. $190.00

- POWER SUPPLIES FOR IBM DRIVERS: MCPL, def, MC1, RS-232, tested under load shown in manual.

Price: .. $190.00

- POWER SUPPLIES FOR IBM DRIVERS: MCPL, def, MC1, RS-232, tested under load shown in manual.

Price: .. $190.00

**XGA**

**TAPE DRIVES & CONTROLLERS**

- POS-100 NRZI TAPE DRIVE CONTROLLER/FOR-MATTER: Designed as interface between 5 1/4 inch micromicru and 9-track, 800M, 80X (IBM) tape drives. Allows microcomputer to read and write IBM-compatible magnetic tape. Software provided for 8080 or Z-80 systems. Requires modification for drives of various densities. Std. version 2 MHz S-100/80P CPU 10 units use with 12 1/2 Its. PI-TY/Tape Style Drive.

Price: (Includes S-100 card, controller card, 10 cable, software listing) .. $750.00

---

**LEEDRIX**

**PORTABLE MINICOMPES**

LOW POWER CONSUMPTION

- MS-15 SINGLE TRANCE 15 MHz .. $289
- MS-215 DUAL TRANCE 15 MHz .. $389
- MS-320 DUAL TRANCE 30 MHz .. $519

---

**274**

**BYTE November 1979**

Circle 296 on inquiry card.
**10-DAY FREE TRIAL**

Send for our FREE Catalog

**$100 FREE ACCESSORIES WITH 16K or 32K PET**

Buy our 16K or 32K PET and we’ll give you your first $100 worth of accessories FREE. Just indicate on your order that you have reduced the cost of your accessories by $100.

**FREE Terminal Package with 8K PETs**

**PET ACCESSORIES**

<table>
<thead>
<tr>
<th>Item Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commodore Dual Floppy Disk Drive</td>
<td>$395.00</td>
</tr>
<tr>
<td>Commodore Printer (tractor feed)</td>
<td>$395.00</td>
</tr>
<tr>
<td>Commodore Printer (interim feed)</td>
<td>$395.00</td>
</tr>
<tr>
<td>Commodore Cassette - from Commodore</td>
<td>$395.00</td>
</tr>
<tr>
<td>Commodore PET Service Kit</td>
<td>$395.00</td>
</tr>
<tr>
<td>Beeper - Tells when tape is loaded</td>
<td>$24.95</td>
</tr>
<tr>
<td>Petunia - Plays music from PET</td>
<td>$24.95</td>
</tr>
<tr>
<td>Video Buffer - Attatch another CRT</td>
<td>$24.95</td>
</tr>
<tr>
<td>Combo - Petunia and Video Buffer</td>
<td>$49.95</td>
</tr>
<tr>
<td>New Serial Printer Interface for PET</td>
<td>$19.95</td>
</tr>
</tbody>
</table>

**Call for Availability**

PET - Compatible Selectic in Desk                      | $88.00  |

**Super Sale Price Too Low to Advertise!**

Immediate Delivery - 2-Year Factory Warranty

You may have seen the Hazeltine advertised at $850. You may have seen it at $749 or even $629 but our new prices are so low that we can’t even advertise it. Call us for a quote. Hurry, we have a limited quantity at this price. The 8048-based Hazeltine 1400 has a 12” screen, 24 x 80 display, TTY-style keyboard, addressable cursor, and RS-232 I/O from 110 to 800 Baud.

**Hazeltine 1400**

<table>
<thead>
<tr>
<th>Model</th>
<th>Price</th>
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</thead>
<tbody>
<tr>
<td>1410</td>
<td>$835</td>
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<tr>
<td>1510</td>
<td>$1195</td>
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<tr>
<td>1520</td>
<td>$1495</td>
</tr>
</tbody>
</table>

**Cat Coupler**

New 260 baud
Originals Answer Acoustic Coupler
Looks good, works great

**IN STOCK NOW!**

1-3-RIGHT!

Educators order your FREE PET TODAY!

Between now and Nov 30th any educational institution which buys 2 PET’s at list price will receive a 3rd PET ABSOLUTELY FREE! That’s right. FREE! For example, buy 2 $795 each and get 1 $995 PET. FREE. Buy 1 $16K at $995 and 1 $12K at $1295 and your school will receive 1 16K PET absolutely FREE! Join the hundreds of public & private schools, colleges, and Universities who have bought from us with confidence. Look at our PET box in the upper left hand corner of this ad for descriptions and prices of the Commodore PET product line. If you need more information just call, we love questions.

**Sanyo Monitor**

<table>
<thead>
<tr>
<th>Model</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>1590</td>
<td>$279</td>
</tr>
<tr>
<td>1592</td>
<td>$599</td>
</tr>
</tbody>
</table>

**Sanyo Monitor**

15-inch $249, 13-inch $219

**IMPORTANT ORDERING INFORMATION**

All orders must include 4% shipping and handling. Michigan residents add 4% for state sales tax. All foreign orders (except Canada) need an additional 10% for shipping and handling.

Phones open from 9:00 a.m. to 7:00 p.m. EST Monday-Friday, 10:00 a.m. to 8:00 p.m. Saturday. Saturday orders are accepted from D & B Baked Goods! ship ment contingent upon receipt of signed purchase order. All prices subject to change without notice. Most items in stock. Immediate shipment. See delivery question. Sorry, no C.O.D. Orders placed at the Ann Arbor area store will be charged state sales tax.

**Hey, Did You Know?**

- We carry a wide range of computer accessories for all your hardware needs.
- Our inventory includes everything from printers to monitors, ensuring you find the perfect match for your system.
- Don’t forget to check out our special deals and promotions — we have discounts on select items.
- If you need any help with your order or have questions, our knowledgeable staff is here to assist you.

- **PET ACCESSORIES**
  - Commodore Dual Floppy Disk Drive
  - Commodore Printer (tractor feed)
  - Commodore Printer (interim feed)
  - Commodore Cassette - from Commodore
  - Commodore PET Service Kit
  - Beeper - Tells when tape is loaded
  - Petunia - Plays music from PET
  - Video Buffer - Attatch another CRT
  - Combo - Petunia and Video Buffer
  - New Serial Printer Interface for PET

- **Call for Availability**
  - PET - Compatible Selectic in Desk

- **Super Sale Price Too Low to Advertise!**
  - Immediate Delivery - 2-Year Factory Warranty
  - You may have seen the Hazeltine advertised at $850. Our prices are so low that we can’t even advertise it. Call us for a quote. Hurry, we have a limited quantity at this price.

- **Hazeltine 1400**
  - Models 1410, 1510, and 1520
  - Prices: $835, $1195, $1495

- **Cat Coupler**
  - New 260 baud
  - Originals Answer Acoustic Coupler

- **IN STOCK NOW!**
  - 1-3-RIGHT!
  - Educators order your FREE PET TODAY!

- **Sanyo Monitor**
  - Models 1590 and 1592
  - Prices: $279, $599

- **IMPORTANT ORDERING INFORMATION**
  - 4% shipping and handling included. Michigan residents add 4% for state sales tax. Foreign orders (except Canada) need an additional 10% for shipping and handling.

- **Hey, Did You Know?**
  - We carry a wide range of computer accessories.
  - Discounts on select items.
  - Assistance available for orders and questions.

**Thank you for shopping with us!**
**Transistor Checker**

- Completely Assembled
- 6 Digit LCD
- Front panel connections: Universal adapter
- PCB pack

**Microprocessor Components**

- SMD Edition
- 8008 or 8085
- 8085A
- 6502
- 8080
- 8085
- 6507
- 8089
- 6509
- 8086
- 6510
- 8081
- 6512
- 8082
- 6514
- 8084
- 6516
- 8085

**Regulated Power Supply**

- 5V 1 Amp
- 12V 0.5 Amp
- 24V 0.25 Amp

**Microphones**

- Handheld, 3.5mm jack
- Headset, 3.5mm jack

**Custom Cables & Jumpers**

<table>
<thead>
<tr>
<th>Part No.</th>
<th>Cable Length</th>
<th>Connectors</th>
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<tbody>
<tr>
<td>DB25P-4-P</td>
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<td>2 x 25P</td>
</tr>
<tr>
<td>DB25S-5-S</td>
<td>5 ft</td>
<td>2 x 25S</td>
</tr>
</tbody>
</table>

**JS600 Hexadecimal Encoder Kit**

- Fully Assembled
- 62 Keys

**JE601 Digital Thermometer Kit**

- 22°C to 44°C

**JE703 Jumbo 6-Digit Clock Kit**

- Bright 300 in.
- Black LED display

**JE730 Remote Control Transmitter & Receiver**

- Universal
- 20 Keys

**JE747 Digital Stopwatch Kit**

- 100 Hours
- 24-Hour Display

**TR5-80 16K Conversion Kit**

- Expand your 4K TRS-80 System to 16K. Kit comes complete with:
  1. 8 each UPD416-1 (16K Dynamic RAMs)
  2. 256K CA112 Nickel Cadmium Battery Pack for version for conversion

**TR5-16K**

- $75.00

**Computer Cassettes**

- 6 each 10 MINUTE HIGH QUALITY ASCII/ROMS
- PLASTIC CASE INCLUDED
- 12 CASES PER SHELF
- ADDITIONAL CASES AVAILABLE (each .50)

**MOD II**

- $29.95 Kit

**EPROM Erasing Lamps**

- ERASERS
  - TRS-80 2708, 2716, 1729A, 32D0, 32D04, etc.
- ERASERS BY 4 CHIPS WTE 2.75 each
- Maintains constant exposure distance of one inch
- Allows easy, short-wavelength build-up
- Built-in safety lock to prevent UV exposure
- Compact – only 2.98" x 2.98"
- Complete with holding tray for 4 chips

**UVS-11E**

- $69.50

**Ultraviolet Products, Inc.**

**New Micro-Top Controllers**

- 8 Bit Top Controller
- 16 Bit Top Controller
- 32 Bit Top Controller

**New Micro-Top Controllers**

- 8 Bit Top Controller
- 16 Bit Top Controller
- 32 Bit Top Controller

**Jameco Electronics**

- Mail Order Electronics – Worldwide
- 1821 Howard Avenue, San Carlos, CA 94070
- ADVERTISED PRICES GOOD THRU NOVEMBER

**Phonewriter 103**

- $139.95 in

- Ideal for use with 4K TRS-80, provides 16K of memory.
FDC-1 FLOPPY CONTROLLER BOARD will drive shugart, pertek, remic 5" & 8" drives up to 8 drives on board PROM with power boot up, will operate with CP/M (not included).
PCBD ........................................ $42.95
FPB-1 Front Panel, IMSAI size, hex displays, Byte, for single board PCBD
PCBD ........................................ $47.50
MEM-1 8K6 fully buffered, S-100, uses 2102 type RAM PCBD .................. $27.95
QM-12 MOTHER BOARD, 13 slot, terminated, S-100 board only .......................... $34.95
CPU-1 8080A Processor board S-100 with 8 level vector interrupt PCBD ..... $26.95
RTC-1 Real time clock board, Two independent interrupts, Software programmable, PCBD $23.95
EPM-1 1702A 4K Eprom card PCBD ........................................ $25.95
EPM-2 2702/2715 16K/32K PROM CARD PCBD ........................................ $25.95
QM-6 MOTHER BOARD, Short Version of OM-12, 9 Slots PCBD .................. $30.95
MEM-2 16K x 8 Fully Buffered 2114 Board PCBD ........................................ $26.95
8080A .............................................. $9.95 5101-BP . $8.40
B212 .............................................. $12.49 1450 NS low power 7.25
B214 .............................................. $24.95 1702 (250 NS) low power 8.99
B214 .............................................. $24.95 1702A-4L .... ............... 1.20
5101-1P ........................................ $13.49 2102CA-4L .... ....... 2.40
MB-4 Basic 8KX8 ram uses 2102 type RAM, S-100 bus, Kit 450 NSC ........ $139.95 PCBD $26.95
MB-7 16KX8, Static RAM Uses 2114 Protection, fully buffered Kit .................. $299.95
MB-8A 270B EPROM Board, S-100, 8KX8 or 16KX8 kit without PROMS $75.00 PCBD $28.95
MB-5 8KX4 RAM/PROM Board uses 2112 RAMs or 625129 PROM kit without RAMS or PROMS $72.00
IO-2 5-10 8 bit parallel /I/O port. 1/2 of board is for kludging. Kit .............. $46.00 PCBD ................ $26.95
IO-4 Two serial I/O ports with full handshaking 20/60 ma current loop: Two parallel I/O ports. Kit $130.00 PCBD ................ $26.95
VIB-16 64 x 16 video display, upper lower case Greek, composite and parallel video with software, S-100 board only $39.95 With 15 connectors $34.95
With Connector Kit ...................... $12.49 SP-1 Synthesizer Board S-100 PCBD .................. $42.95 KIT .................. $135.95

WAMECO INC.

WAMECO INC. 111 GLENN WAY #8, BELMONT, CA 94002 (415) 592-6141

NOV. SPECIAL SALE ON PREPAID ORDERS
(Charge cards not included on this offer)
WAMECO PWR SUPPLY AND TERMINATOR BOARD
12 Regulators for driving external equipment $24.95
8KX8 RAM, Fully buffered 450 NSEC, 2.5 amp typical assembled parts may be unmarked or house numbered $99.99
NMiks PARTS ASSORTMENT
WAMECO AND CYBERCOM PCBDS
MEM-2 with Mikos #17 16K ram with 2714 16K NSEC $127.95
MEM-2 with Mikos #13 16K ram with 2714 16K NSEC $127.95
MEM-1 with Mikos #1 450 NSEC 8K RAM ................................ $119.95
CPU-1 with Mikos #1 8080A CPU ........................................ $94.95
MEM-1 with Mikos #3 250 NSEC 8K RAM ................................ $144.95
QM-12 with Mikos #4 13 slot motherboard .................................. $69.95
RTC-1 with Mikos #5 real time clock ....................................... $54.95
EPM-1 with Mikos #10 4K 1702 250 NS EPROMS ........................ $49.95
EPM-2 with Mikos #11 16-32K EPROMS ...................................... $59.95
QM-5 with Mikos #12 S slot mother board ................................ $79.95
FPB-1 with Mikos #14 all parts for front panel ................................ $134.95
QMiks PARTS ASSORTMENTS ARE ALL FACTORY PRIME PARTS. KITS INCLUDE ALL PARTS LISTED AS REQUIRED FOR THE COMPLETE KIT LESS PARTS LISTED. ALL SOCKETS INCLUDED.

WAMECO INC. THE COMPLETE PC BOARD HOUSE
EVERYTHING FOR THE S-100 Buss

NEW! POWER SUPPLY AND TERMINATOR BOARD PROVIDES UP TO 12 REGULATORS TO DRIVE ALL THOSE PERIPHERALS FROM THE COMPUTERS POWER SUPPLIES. TERMINATES THE MOTHER BOARD.

KIT (ALL HEAT SINKS, RESISTORS, CAPACITORS AND PARTS FOR TERMINATOR EXCLUDES THE 12 REGULATORS) ........................................ $55.95
PCBD ........................................ $30.95

AT YOUR DEALER NOW!

FUTURE PRODUCTS: 80 CHARACTER VIDEO BOARD, IO BOARD WITH CASESET INTERFACE.

DEALER INQUIRIES INVITED, UNIVERSITY DISCOUNTS AVAILABLE AT YOUR LOCAL DEALER
Circle 354 on inquiry card.

BUILD YOUR OWN LOW COST MICRO-COMPUTER POWER SUPPLIES FOR S-100 BUS, FLOPPY DISCS, ETC.

POWER TRANSFORMERS (WITH MOUNTING BRACKETS)

<table>
<thead>
<tr>
<th>ITEM NO</th>
<th>KIT NO</th>
<th>PRI. WINDING</th>
<th>TAPS</th>
<th>SECONDARY WINDING OUTPUTS</th>
<th>SIZE</th>
<th>UNIT PRICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>1</td>
<td>0V, 110V, 120V</td>
<td>2x7.5A</td>
<td>2x2.5A</td>
<td>3¾” x 3¾” x 3¾”</td>
<td>19.95</td>
</tr>
<tr>
<td>T2</td>
<td>2</td>
<td>0V, 110V, 120V</td>
<td>2x12.5A</td>
<td>2x3.5A</td>
<td>3¾” x 3¾” x 3¾”</td>
<td>25.95</td>
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<tr>
<td>T3</td>
<td>3</td>
<td>0V, 110V, 120V</td>
<td>2x9A</td>
<td>2x2.5A</td>
<td>3¾” x 3¾” x 3¾”</td>
<td>27.95</td>
</tr>
<tr>
<td>T4</td>
<td>4</td>
<td>0V, 110V, 120V</td>
<td>2x4.5A</td>
<td>2x4.5A</td>
<td>3¾” x 3¾” x 3¾”</td>
<td>19.95</td>
</tr>
</tbody>
</table>

POWER SUPPLY KITS (OPEN FRAME WITH BASE PLATE, 3 HRS. ASSY. TIME)

<table>
<thead>
<tr>
<th>ITEM</th>
<th>USED FOR</th>
<th>+8 VDC</th>
<th>@-8 VDC</th>
<th>+16 VDC</th>
<th>@-16 VDC</th>
<th>+28 VDC</th>
<th>SIZE</th>
<th>W x D x H</th>
<th>UNIT PRICE</th>
</tr>
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<tbody>
<tr>
<td>KIT 1</td>
<td>15A</td>
<td>2.5A</td>
<td>2.5A</td>
<td></td>
<td></td>
<td></td>
<td>12” x 6” x 4”</td>
<td>46.95</td>
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<td>KIT 2</td>
<td>SYSTEM</td>
<td>3A</td>
<td>3A</td>
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<td>12” x 6” x 4”</td>
<td>54.95</td>
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<td>KIT 3</td>
<td>DISC</td>
<td>2A</td>
<td>2A</td>
<td></td>
<td></td>
<td></td>
<td>14” x 6” x 4”</td>
<td>62.95</td>
<td></td>
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<tr>
<td>KIT 4</td>
<td>DISC</td>
<td>1A</td>
<td>1A</td>
<td></td>
<td></td>
<td></td>
<td>10” x 6” x 4”</td>
<td>44.95</td>
<td></td>
</tr>
</tbody>
</table>

EACH KIT INCLUDES: TRANSFORMER, CAPACITORS, RESIS., BRIDGE RECTIFIERS, FUSE & HOLDER, TERMINAL BLOCK, BASE PLATE, MOUNTING PARTS AND INSTRUCTIONS.

REGULATED POWER SUPPLY "R2" ASSY. & TESTED, OPEN FRAME, SIZE: 9” (W) x 5” (D) x 5” (H) ........ $69.95

SPECs: +5V ±1%, @ 5A, +24V, ±1%, @5A. OVERCURRENTPROTECTION AND +5% ADJ. FOR BOTH VOLTAGES.

REMARK: IDEAL FOR ROCKWELL AIM-65 MICROCOMPUTER. ALSO -5V, ±1A OPTIONAL.

SUNNY INTERNATIONAL
(TRANSFORMERS MANUFACTURER)

MAIL ORDER:
P.O. BOX 4296
TORRANCE, CA 90510

STORE:
7245 E. ALONDRA BLVD.
PARAMOUNT, CA 90723

STORE HOURS: 9 AM - 6 PM

10% OFF 20% OFF
YOUR OWN TRS-80 SYSTEM AT TREMENDOUS SAVINGS

1 TRS-80 Complete System

2 Line Printer

3 Mini Disk System

4 C-10 Cassettes

5 Verbatim Diskettes

DISK DRIVEs NOW IN STOCK!

<table>
<thead>
<tr>
<th>ITEM</th>
<th>REG. PRICE</th>
<th>OUR PRICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level II-4K</td>
<td>$988.00</td>
<td>$898.20</td>
</tr>
<tr>
<td>Level II-16K</td>
<td>$998.00</td>
<td>$898.00</td>
</tr>
<tr>
<td>Expansion Interface</td>
<td>$299.00</td>
<td>$269.10</td>
</tr>
<tr>
<td>Centronics 779 Printer</td>
<td>$159.95</td>
<td>$129.95</td>
</tr>
<tr>
<td>Centronics 101 Printer</td>
<td>$199.95</td>
<td>$169.95</td>
</tr>
<tr>
<td>Anadex DP-8000 Printer</td>
<td>$329.95</td>
<td>$299.95</td>
</tr>
<tr>
<td>Centronics P1 Printer</td>
<td>$334.95</td>
<td>$294.95</td>
</tr>
<tr>
<td>Treadata 100</td>
<td>$199.95</td>
<td>$169.95</td>
</tr>
</tbody>
</table>

FREE INSTALLATION
Verbatim Diskettes 3 |
| 3 |
| 3 |
| 3 |
| 3 |
| 5 |
| 25 |
| Paper (9½” x 11”) fanfold. 3500 sheets. | $ 35.00 | $ 29.95 |

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JADE IS PROUD TO Announce THE LOW-COST SOLUTION TO YOUR HARD COPY NEEDS. THE JADE JP80 T PRINTER IS A HIGH QUALITY 80 COLUMN DOT MATRIX PRINTER WITH AN ADJUSTABLE WIDTH TRACTOR FEED MECHANISM. WE ARE CERTAIN THAT YOU CAN NOT GET A BETTER PRINTER IN THIS PRICE RANGE.

FAST AND SLOW PRINTHEAD SPEEDS: 80 COLUMNS PER LINE.
VERSATILE ADJUSTABLE TRACTOR FEED: 20" TO 10".
UPPER AND LOWER CASE CHARACTER ASCII SET WITH 24 OR 40 CHARACTER SELECTABLE CHARACTER WIDTHS.
CENTRONICS-TYPE PARALLEL INTERFACE, INTERFACE CABLES AVAILABLE FOR MOST POPULAR MICROCOMPUTERS.

PRM-27081 .................................... $749.95

CENTRONICS 730 PRINTER
THE ANY-PAPER PRINTER
THIS PRINTER CAN USE ROLL PAPER, FANFOLD PAPER, OR SINGLE SHEETS BECAUSE IT IS EQUIPPED WITH FRICTION FEED AND PIN FEED MECHANISMS.

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EXIDY SOURCERON
FREE 12 INCH B & W MONITOR WITH EVERY 16K SOURCERON
FLEXIBILITY IS THE KEY. THE SOURCERON COMPUTER GIVES YOU THE FLEXIBILITY OF USING READY-TO-RUN, PRE-PACKAGED PROGRAMS OR DOING YOUR OWN THING AND PERSONALIZING THE PROGRAMS FOR YOURSELF. WHOEVER YOU CHOOSE, THE SOURCERON IS THE PERSONAL COMPUTER THAT SPEAKS YOUR LANGUAGE.

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- HANDSOME PLASTIC CASE

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MINI-DISK CABLE KIT---CONNECTS TWO 5 1/4" MINI-FLOPPIES TO YOUR DISK CONTROLLER BOARD AND POWER SUPPLY.

INCLUDES 5' SIGNAL CABLE WITH 34 PIN EDGE CONNECTORS, PLUS POWER SUPPLY CONNECTORS AND CABLES. WCA-3431K ................................ $34.95

SIGNAL CABLE ONLY---CONNECTS ONE 5 1/4" DRIVE TO EDGE TYPE CONTROLLER CARD SUCH AS THE VERSAFLOPPY DOUBLE D. INCLUDES 5' SIGNAL CABLE WITH 30 PIN EDGE CONNECTORS, PLUS POWER SUPPLY CABLES AND CONNECTORS. WCA-5033K ................................ $38.45

""""D DISK CABLE KIT---CONNECTS TWO 8" DISK DRIVES TO EDGE TYPE CONTROLLER CARD SUCH AS THE VERSAFLOPPY DOUBLE D. INCLUDES 5' SIGNAL CABLE WITH 30 PIN EDGE CONNECTORS, PLUS POWER SUPPLY CABLES AND CONNECTORS. WCA-5032K ................................ $38.95

FOR 8" DRIVES WCA-3433K ................................ $29.95

FOR 2" DRIVES WCA-3434K ................................ $24.95

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High quality 13 inch color monitor. Up to 72k total memory capacity. 16-color graphics capability - easy to access high resolution graphics. Features special data that tell you about your own characters, charts, graphs, etc. Music and sound effects - build three-note chords and adjust frequency, duration, and volume. Five full octaves Built-in equalizer - Unique convenience feature helps you find solutions to everyday math problems, as well as complex scientific calculations. Program access to your computer is easy and does not require any special knowledge. The only motherboard available today that is eliminating crosstalk. No need for active termination. The perfect foundation for a 4MHz system...

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Everything you need to add 16k of memory to your computer comes ready packaged with easy to follow instructions. In just minutes your computer is ready to tackle more advanced software.

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The NEW Z-80 CPU BOARD FROM JADE

Features include: 1k-1024K compiler 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 WARRITE general in front panel is not used. • On-board USBT for synchronous or asynchronous R232 operation (on-board baud rate generator) • Reverse channel capability, on-board allows for buffered peripherals or devices with non-ready signal.

$599.95

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Range DVM in LCD displays runs 200 hrs on 1 battery. 10 Meg Ohm input. 1 yr. guarantee. Made in U.S.A., test leads included. Runs 200 hrs on 1 battery. 10 MegVP -10 X10 DCV Probe Adapter:

FREE BATTERY WITH YOUR METER.

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CS-110 Amp Current Shunt ...... $14.95

FREE
Just For Asking.

FREE BATTERY WITH YOUR METER.

RS322 & "D" TYPE CONNECTORS

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<th>DESCRIPTION</th>
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<tr>
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<td>5 pin Female</td>
<td>3.50</td>
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<tr>
<td>5 pin Female</td>
<td>3.75</td>
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<tr>
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<td>18 pin Female</td>
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<tr>
<td>24 pin Female</td>
<td>6.25</td>
</tr>
<tr>
<td>30 pin Female</td>
<td>7.25</td>
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3 LEVEL GOLD WIRE WRAP SOCKETS

Sockets purchased in multiples of 50 per type may be combined for best price.

<table>
<thead>
<tr>
<th>Description</th>
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<td>2 pin Gold</td>
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<tr>
<td>3 pin Gold</td>
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<tr>
<td>5 pin Gold</td>
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<tr>
<td>20 pin Gold</td>
<td>400.00</td>
</tr>
<tr>
<td>24 pin Gold</td>
<td>500.00</td>
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</table>

All sockets are GOLD level closed entry. 2 level Tall. Pin, Socket, and Dip plugs available. CALL FOR QUOTATION.

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PRICING

- PANAVIS R C BOARD HOLDER $18.95
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BYPASS CAPACITORS

2' LEAD SPACING

6/100 100/14.90
Memory War Shop and Compare

The Vista V80:

$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 Microcomputer. 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 usable 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 extensive 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 Mini-Floppy 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.

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SPECIAL: Box of 10 DISKETTES $20.00 with Purchase of VISTA 80

Features:

- Use with TRS-80
- Parallel interface
- Continuous variable printing density 80-123 characters per line
- 5x7 dot matrix
- Prints on plain paper, sheets, rolls, fan fold
- Form thickness control
- Horizontal and vertical form positioning
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730-1 PARALLEL INTERFACE
730-3 RS-232 INTERFACE

SHOP and COMPARE

- 3M Scotch® Brand DISKETTES

- NOVATION CAT ACOUSTIC MODEM

- 0-300 Baud
- Bell 103
- Answer, Originate

Regular $198.00

Sale $189.00

Logisys SPECIAL

- LOGIC MONITOR 1

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. 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 such 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: 4.5 V max. across any two or more inputs. Current Drain: 200mA at 10 V. Size: 4” x 1” x 2” w. x 1.75” d. when open. Weight: 3 ozs.

CSC Model LM-1 Logic Monitor—Complete.

FREE 15MHZ DUAL TRACE SCOPE: SAVE $124.00

*No not really, but here's our deal. The NLS MS-230 DUAL TRACE 30MHZ MINISCOPE, regularly sells for $559.00, but we will sell it for $435.00. It 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 trigger
- Batteries and charger transformer unit included
- Graticule: 4 x 5 divisions, each division 0.25’’
- Time base: micro sec to 0.5 sec/div 21 setting
- Vertical Gain: 0.01 to 60 Volts/div 12 settings

SST 25’’ x 6.4’’ W x 6.5’’ D. 3.5 lbs. *TEST MOST DIGITAL LOGIC CIRCUITS INCLUDING MICROPROCESSORS

- MS-230 Dual Trace 30 MHz
- 41-141 Deluxe 10101 probe with 4 interchangeable tips...
- 41-37 Deluxe 1000 probe with 4 interchangeable tips...
- Leico 3910A 1000 probe with 8 interchangeable tips...
- MS-15 Single trace 15 MHz...
- MS-215 Dual trace 15 MHz...

Reg. $335.00...

$455...

$45.00...

$335.00...

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The true 16K Static RAM module for S-100 bus systems.

ASSEMBLED & TESTED-100% BURN IN

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The M-XVI board is a true revelation for the serious hobbyist and use in practical business or industrial applications.

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- Uses popular 2114 static RAMs
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- Bank Select available
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- 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
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2016BY Bare Board only

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HEXADECIMAL DISPLAY WITH LOGIC

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The EXPANDORAM is available in versions from 16K up to 64K, so for a minimum investment you can have a memory system that will grow with your needs. This is a dynamic memory with the invisible on-board refresh, and it works!

• Interfaces with Altair, IMSAI, SOL-8, Cromemco, SBC-100, and others.
• Bank Selectable
• Phantom
• Power BYDC, ±16VDC, 5 Watts
• Lowest Cost Per Bit
• Uses Popular 4116 RAMS
• PC Board is doubled sided masked and has silk-screen parts layout.

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LO Bo $395.00
SHUGART SA 400 with Cabinet and Power Supply
Assumed to be $425.00
LO Bo SA400 $395.00
SHUGART SA400 8½"
5¼" magazine, single cassette density, hard disk or soft disk, write erased and more
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DM2700S DISK & CABINET with POWER SUPPLY
DM2700S includes Siemens FD120-8" Disk Drive with the following features:

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• Hard or Soft Sector
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DM2700S Kit
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32K STATIC MEMORY BOARD

ASSEMBLED & TESTED
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32K STATIC MEMORY BOARD

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VDB-8024 Video Display Board
With On-Board 250 Microprocessor

• Own dedicated color display controller
• Character Generator by High Resolution
• 8,000 line pens
• Four programable product
• Separate TTL level backplane and video signals
• 8K ROM independent on-board memory
• Output levels 240 volts
• Price $595.00

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With On-Board 250 Microprocessor

• Own dedicated color display controller
• Character Generator by High Resolution
• 8,000 line pens
• Four programable product
• Separate TTL level backplane and video signals
• 8K ROM independent on-board memory
• Output levels 240 volts
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SBC-100 Single Board Computer with On-Board RAM, PROM, CTC

• 6800 Central Processing Unit
• 8K Character Generator/Matrix
• 8K Data RAM
• 8K ROM for standard CTC
• 8K ROM for extended CTC
• Fully Tested

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• 6800 Central Processing Unit
• 8K Character Generator/Matrix
• 8K Data RAM
• 8K ROM for standard CTC
• 8K ROM for extended CTC
• Fully Tested

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Terms: Visa, MC, BAC, Check, Money Order, COD. U.S. Funds, DOM. CA Residents add 6% sales tax. Minimum order $10.00 Prepaid. U.S. orders less than $75.00 include 5% shipping and handling. MINIMUM $25.00. Excess refunded. Just in case... please include your phone number.

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**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).
Low Cost Add-On Storage for Your TRS-80®
In the Size You Want.

When you're ready for add-on disk storage, we're ready for you.
Ready with six mini-disk storage systems — 102K bytes to 591K bytes of additional on-line storage for your TRS-80®.

- Choose either 40-track TFD-100™ drives or 77-track TFD-200™ drives.
- One-, two- and three-drive systems immediately available.
- Systems include Percom PATCH PAK #1™ on disk, at no extra charge. PATCH PAK #1™ de-glitches and upgrades TRSDOS® for 40- and 77-track operation.
- TFD-100™ drives accommodate “flippy disks.” Store 205K bytes per mini-disk.
- Low prices. A single-drive TFD-100™ costs just $399. Price includes PATCH PAK #1™ disk.
- Enclosures are finished in system-compatible “Tandy-silver” enamel.

Whether you need a single, 40-track TFD-100™ add-on or a three-drive add-on with 77-track TFD-200™s, you get more data storage for less money from Percom.

Our TFD-100™ drive, for example, lets you store 102.4K bytes of data on one side of a disk — compared to 80K bytes on a TRS-80® mini-disk drive — and 102.4K bytes on the other side, too. Something you can't do with a TRS-80® drive. That's almost 205K bytes per mini-disk.

And the TFD-200™ drives provide 197K bytes of on-line storage per drive — 197K, 394K and 591K bytes for one-, two and three-drive systems.

PATCH PAK #1™, our upgrade program for your TRSDOS®, not only extends TRSDOS® to accommodate 40- and 77-track drives, it enhances TRSDOS® in other ways as well. PATCH PAK #1™ is supplied with each drive system at no additional charge.

The reason you get more for less from Percom is simple. Peripherals are not a sideline at Percom. Selling disk systems and other peripherals is our main business — the reason you get more engineering, more reliability and more back up support for less money.

In the Product Development Queue... a printer interface for using your TRS-80® with any serial printer, and... the Electric Crayon™ to map your computer memory onto your color TV screen — for games, animated shows, business displays, graphs, etc. Coming PDQ!

To order add-on mini-disk storage for your TRS-80®, or request additional literature, call Percom's toll-free number: 1-800-527-1592. For detailed Technical information call (214) 272-3421.

Orders may be paid by check or money order, or charged to Visa or Master Charge credit accounts. Texas residents must add 5% sales tax.

Percom 'peripherals for personal computing'
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-sharing systems. However, a serious drawback of microcomputer or minicomputer multi-user time-sharing 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¢ per 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:

```
DEVA,B.C.D. Local floppy
DEV E Local hard disks
DEV KZ 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 interconnecting cable. Utilizing 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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