Someday all terminals will be smart........

- 128 Functions—software controlled
- 7 x 12 matrix, upper/lower case letters
- 50 to 38,400 baud—selectable
- 82 x 16 or 92 x 22 format—plus graphics
- Printer output port
- "CHERRY" keyboard

CT-82 Intelligent Terminal, assembled and tested. . . . . . . . $795.00 ppd in Cont. U.S.

SOUTHWEST TECHNICAL PRODUCTS CORPORATION
219 W. RHAPSODY
SAN ANTONIO, TEXAS 78216

Circle 350 on inquiry card.
Here's how you can be fully computerized for so much less than you thought

BUSINESS — EDUCATION — ENGINEERING — MANUFACTURING

We are pleased to announce the first professional time-sharing system in the microcomputer field.

Naturally, it's from Cromemco.

This new multi-user system will do all of the tasks you usually associate with much more expensive time-sharing computers. Yet it's priced at an almost unbelievably low figure.

Look at these features:

• You can have up to 7 terminals plus a fast, 132-column line printer
• You can have a large system RAM memory that's expandable to ½ megabyte using the Bank Select feature
• Each user has an independent bank of RAM
• You can have floppy disk storage of up to 1 megabyte
• You have confidentiality between most stations
• And, make no mistake, the system is fast and powerful. You'll want to try its fast execution time yourself.

PROGRAMMERS LOVE OUR BASIC

This new system is based on Cromemco's well-known System Three Computer and our new Multi-User BASIC software package.

Programmers tell us that Cromemco Multi-User BASIC is the best in the field. Here are some of its attractions:

• You can use long variable names and labels up to 31 characters long — names like “material on order” or “calculate speed reduction.”
• You get many unusual and helpful commands that simplify programs and execution — commands such as PROTECT, LIST VARIABLES, NOLIST, and many more.
• No round-off error in financial work (because our BASIC uses binary-coded decimal rather than binary operation). And we've still been able to make it FAST.
• Terminals and printer are interrupt-driven — no additional overhead until key is pressed.
• The conveniences in this Multi-User BASIC make it much easier to write your own application software.
• A line editor simplifies changes.

BENCHMARK IT — NOW

In the final analysis, the thing to do is see this beautiful new system at your dealer. See its rugged professional quality. Evaluate it. Benchmark it for speed with your own routine (you'll be agreeably surprised, we guarantee you).

Find out, too, about Cromemco's reputation for quality and engineering.

Look into it now because you can have the capabilities of a fully computerized operation much quicker and for much less than you ever thought.
The single card computer with the features that help you in real life

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

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

Other features include 24 bits of bi-directional parallel I/O and five on-board programmable timers.

Add to that vectored interrupts.

ENORMOUS EXPANDABILITY
Besides all these features the Cromemco single card computer gives you enormous expandability if you ever need it. And it's easy to expand. First, you can expand with the new Cromemco 32K BYTESAVER PROM card mentioned above. Then there's Cromemco's broad line of S100-bus-compatible memory and I/O interface cards. Cards with features such as relay interface, analog interface, graphics interface, opto-isolator input, and A/D and D/A conversion. RAM and ROM cards, too.

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

Finally, to simplify things to the ultimate, we even have convenient card cages. Rugged card cages. They hold cards firmly. No jiggling out of sockets.

AVAILABLE NOW/LOW PRICE
The Cromemco Model SCC is available now at a low price of only $450 factory assembled ($395 kit). So act today. Get this high-capability computer working for you right away.
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Tinney is called "Infinite Regression"—an appropriate way to introduce you to several articles in this issue dealing with computer simulation.

The term "simulation" can have a bewildering variety of meanings; we have restricted ourselves herein to simulations of galaxy projections, digital circuits, celestial mechanics, and an ideal two-dimensional gas—all using your personal computer or programmable calculator.

By adding special controls to a microcomputer, a user can input special information or information in particular forms. The addition of four switches and four colored lights allows your computer to play a memory game such as the one found in department stores. Steve Ciarcia tells how The Toy Store Begins at Home.

By adding special controls to a microcomputer, a user can input special information or information in particular forms. The addition of four switches and four colored lights allows your computer to play a memory game such as the one found in department stores. Steve Ciarcia tells how The Toy Store Begins at Home.

Delmer D. Hinchliffe presents a combination three-dimensional Mars lander and introduction to celestial mechanics in Marsport Here I Come: The Three-Dimensional Celestial Mechanics Simulation for the HP 67/97.

The Standard Data Encryption Algorithm by Robert V. Meushaw discusses its implementation on the basic KIM-I system. A detailed description of the algorithm and generalized flowcharts are also given.

In everyday life we wait in lines before we can do particular things. The same happens with computers. The study of waiting, called Queuing Theory, and how computers handle the situation is discussed by Len Gorney.

The pocket calculator can be used to encrypt and decipher messages. John Costas provides us with working examples of Cryptography in the Field, Part 2: Using the Pocket Calculator.
Suddenly everyone is talking about personal computers. Are you ready for one? The best way to find out is to read Apple Computer’s “Consumer Guide to Personal Computing.” It will answer your unanswered questions and show you how useful and how much fun personal computers can be. And it will help you choose a computer that meets your personal needs.

Who uses personal computers.
Thousands of people have already discovered the Apple computer — businessmen, students, hobbyists. They’re using their Apples for financial management, complex problem solving — and just plain fun.
You can use your Apple to analyze the stock market, manage your personal finances, control your home environment, and to invent an unlimited number of sound and action video games. That’s just the beginning.

What to look for.
Once you’ve unlocked the power of the personal computer, you’ll be using your Apple in ways you never dreamed of. That’s when the capabilities of the computer you buy will really count. You don’t want to be limited by the availability of pre-programmed cartridges. You’ll want a computer, like Apple, that you can also program yourself. You don’t want to settle for a black and white display. You’ll want a computer, like Apple, that can turn any color TV into a dazzling array of color graphics.

The more you learn about computers, the more your imagination will demand. So you’ll want a computer that can grow with you as your skill and experience with computers grows. Apple’s the one.

How to get one.
The quickest way is to get a free copy of the Consumer Guide to Personal Computing. Get yours by calling 800/538-9696. Or by writing us. Then visit your local Apple dealer. We’ll give you his name and address when you call.

*Apple II plugs into any standard TV using an inexpensive modulator (not included).
On the Importance of Backups

by Carl Helmers

The other day I had a problem using my computer system which many readers may have had. The lesson to be learned from my experience forms the subject of this essay.

This problem is one of zapping the file structure of a disk. Sooner or later everyone who uses a small computer system will encounter a similar situation. One could be tempted to think, naively, that such problems are limited to large computer systems with large sensitive flying head disk media, but this is by no means the case. Floppy disks can be logically zapped just as easily.

I, like many of our readers with systems, have not been letting my system lie idle in the house. In the years since starting this publication with my associates in 1975, I have been suffering withdrawal symptoms from big computers and associated time sharing software. In my case it was everyone's favorite target of criticism, TSO running on a large IBM 360 system. Well, finally small computers got to the point where they could support my style of language, Pascal. Last summer, I bought the Northwest Microcomputer Systems model 85/P with UCSD Pascal as its operating system, filing system, editor and high level language package.

(An aside: at present, the options are hardly limited to the 85/P as many other small computer manufacturers have begun offering versions of this excellent software; at present one can get it on machines ranging from a dual mini-floppy Apple II or North Star Horizon, to machines with full size floppy like my 85/P, or the Cromemco system we are using at BYTE as an editorial computer, to the most exotic of all Pascal machines, the Western Digital "Pascal Micro Engine" which directly executes the p-code intermediate output of the UCSD compiler. Recent word from Apple has it that the UCSD Pascal system with full Turtle graphics will be available in June of this year for approximately $400 hardware and software cost. The hardware consists of a special 16 K programmable memory card added to a 48 K Apple II with single or dual disks. The software is the complete UCSD system of editor, file system, Pascal compiler and utilities.)

Recently I have been writing my editorials for BYTE using the excellent screen oriented editor program of the UCSD system. I have been learning Pascal so that I can make it my principal software development tool. I have been learning the details of using Pascal as a significant hardware oriented programming aid, a limited function with the 85/P but one which will blossom to full fruition when I get the Pascal microengine sometime in the coming months.

All this is but a prelude. I have also learned anew the opportunities for making foolish mistakes. One of the most foolish is that of not periodically backing up files against possible losses. The losses I refer to can stem from numerous causes.

We all, quite naturally, assume that the systems software is perfect, but there is that nagging 1 percent of doubt that everyone has. So even if we had perfect media, it would be necessary to back up files by copying from one disk to another as insurance against software failure. But that is hardly the major problem.

Continued on page 196.
"My 8 to 5 minifloppy now works nights and weekends."

"I own a fast-growing business and before I bought my computer system I put in a lot of late hours keeping up with my accounting and inventory control. Now the computer does my number crunching quickly, so I have time after hours to have some fun with the system. My son and I started out playing Star Trek on the system, and now we're learning to play chess.

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

"I'm glad I went with Shugart drives. Look, when you lay out your own money for a system, you want dependable performance and good value. Do what I did. Ask for the system with the minifloppy."

If it isn't Shugart, it isn't minifloppy.

Shugart Associates
435 Oakmead Parkway, Sunnyvale, California 94086

For a list of manufacturers featuring Shugart's minifloppy in their systems, circle reader response number.

TM minifloppy is a registered trademark of Shugart Associates.
SUCCESSFUL TRANSFORMATION

I thoroughly enjoyed the article "Fast Fourier Transforms on Your Home Computer," by William D. Stanley and Steven J. Peterson (December 1978 BYTE, page 14). I have the program running on Radio Shack TRS-80 disk BASIC. I also tried the BASIC code in "Tic-Tac-Toe in BASIC" (December 1978 BYTE, page 174). It would be helpful if Mike Stoddard, the author, had explained the characteristics of his source machine. I spent some time converting the "215" enclosed in backslashes to CHR$(215) for formatting purposes.

I enjoy your magazine and use it regularly. Keep it up.

Joseph X Brennan
POB 302
Upland CA 91786

Another problem with "Tic-Tac-Toe in BASIC" was the accidental omission of program lines 2590 through 3080. The missing lines were printed in the "BYTE's Bugs" section of the February 1979 BYTE, page 43. . .CH.

MAKING CENTS

Being an avid reader of BYTE I have received many helpful hints about how to use my computer more efficiently. I have enclosed a simple program that puts dollars and cents into business programs.

A lot of small businesses need calculated results in a print out in the form of at least two digits, complete with Os. This second factor is that some major market broadcasters subscribe to music syndication services. Some of these services (notably Jim Schule's SRP service) have been known to write clauselike contracts that forbid the subscribing station from using an SCA signal.

As a sidenote, two years ago while I was still in broadcast engineering, I was contacted by an outfit called Cables & Wireless Ltd. They were looking for a SCA signal to use for electronic message (or mail) service. My station was under a "no SCA" clause with a music syndicator and I had to turn them down, but recently Computer Decisions magazine published an article on electronic mail that briefly discussed the Cables & Wireless Ltd system.

I look forward to digicasting with great anticipation but I fear that it will become mired in the infinite jungle of federal regulations.

Noel M Moss
UniCard
1034 S Brentwood Blvd
St Louis MO 63117

DIGICAST DATA

I just read Mr. Halsema's article, "The Digicast System: Receiving Data and Information over Your FM Radio" (January 1979 BYTE, page 100) and I noted a few technical deficiencies in his description of an FM station's signal spectrum.

Mr. Halsema describes the L-R difference signal centered around 38 Khz as the pilot tone. In actual practice, the station transmits a 19 Khz (±2 Hz) stereo pilot tone at 8 to 10 percent modification. This is the synchronizing signal used by the receiver in demodulating the L-R and L-R signals into discrete L and R channels.

In FM broadcasting, the 75 Khz deviation Mr. Halsema refers to is the 100 percent modulation point. We could get into modulation index and other parameters, but the BYTE letters column is not the place for that. Suffice it to say that "high fidelity music" transmission is not restricted by the current modulation limits.

Two factors that may limit the growth of digicasting in metropolitan areas are present. Assuming that the 67 Khz SCA (Subsidiary Communications Authorization) signal is used for digicasting, the first factor is the "loudness" game that many stations get caught up in. The quest for larger market shares.

19 Khz pilot eats up 10 percent of the modulation capability. The 67 Khz SCA signal eats up another 10 percent of the modulation capability. This leaves a maximum of 80 percent modulation capability for your main carrier program material. While this is only a 1 db to 2 db decrease in "loudness" compared to a nonSCA or a mono station, there are many programming and time sales people who believe that they need to be the loudest station on the dial. The second factor is that some major market broadcasters subscribe to music syndication services. Some of these services (notably Jim Schule's SRP service) have been known to write clauselike contracts that forbid the subscribing station from using an SCA signal.

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Noel M Moss
UniCard
1034 S Brentwood Blvd
St Louis MO 63117

Continued on page 206.
If the truth is that you want a computer... then we want to be your computer store.

We're Computer Land, the #1 computer store chain in the U.S. What's meaningful about that fact is, that Computer Land has been chosen by more people as having what they've been looking for. And, since you're looking, let us tell you what you'll find, when you visit a Computer Land store.

You'll find a product line that's continually evaluated to provide you with the widest and best selection in quality, brand name microcomputers anywhere. You'll find an enthusiastic and knowledgeable staff able to interpret all the equipment specifications, in terms of how they apply to you, and in a way you'll understand. You'll find demonstration areas where you can get a firsthand experience of running a computer yourself.

Enough about us. How about what computers do. To attempt to describe all the things your computer might do, would be to describe your imagination. So instead, we'll briefly list some of the many things for which small computers are already being used.

In business, the advent of the versatile and compact microcomputer has put the benefits of computing within reach of small companies. With systems starting at less than $6000, the businessman can computerize things like accounting, inventory control, record keeping, word processing and more. The net result is the reduction of administrative overhead and the improvement of efficiency which allows the business to be managed more effectively.

In the home, a computer can be used for personal budgeting, tracking the stock market, evaluating investment opportunities, controlling heating to conserve energy, running security alarm systems, automating the garden's watering, storing recipes, designing challenging games, tutoring the children... and the list goes on.

In industry, the basic applications are in engineering development, process control, and scientific and analytical work. Users of microcomputers in industry have found them to be reliable, cost-effective tools which provide computing capability to many who would otherwise have to wait for time on a big computer, or work with no computer at all.

And now we come to you, which leads us right back to where we started: If you want a computer, then we want to be your computer store.

Whether you want a computer for the home, business or industry, come to Computer Land first. We'll make it easy for you to own your first computer. Because, simply put, we really want your business. When you come right down to it, that's what makes us #1.
The Toy Store Begins at Home

Simon is a trademark of the Milton Bradley Corporation.

Figure 1a: Hardware tone generator for the musical tone sequencer. The computer plays a sequence of lights and associated tones and detects the player's response. (All transistors are 2N2222.)

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<td>IC3</td>
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April 1979 © BYTE Publications Inc
"Mister? Mister?"

A little boy was tugging on my sleeve. It startled me that in today’s sophisticated society anyone would attempt to attract my attention by such an obvious, though effective, means. Impatient and undaunted by the scowl I flashed in his direction, he said, "Mister? Do you know where the toy department is?"

I have never acquired what some people call the ability to commune with children. Perplexed therefore as to the presentation of a proper reply, I considered an indignant, wave-of-the-hand dismissal of “Over there, kid.” On the other hand, should I consider a character reversal with a Santa Claus imitation and invite the young man to hop up on my shoulder while we looked over the store directory together? The latter seemed hardly my style and the former was much too harsh even considering his still firm attachment to my sleeve.

"Mister? Mister?"

The delay only heightened his fervor.

I looked up and found myself staring straight at the shirt pocket button of a very large man. Instantly I calculated that this male figure dressed in jeans, heavy boots and a woolen shirt was a foot taller than I.

His relationship with the boy was quickly clarified as he said in a deep paternal voice, "Come on Brucie, I think it’s over there where that crowd is." I waited for Paul Bunyan and son to be safely on their way before I made my next move.

Stark reality returned, however, when I remembered that I, too, was looking for the toy department. It verges on humiliation actually. Why do they have to categorize everything? Just because an item is manufactured by a toy company doesn’t immediately classify it as a toy. I mean, big people have constructive leisure time manipulatives and little people have toys. Department stores should realize the embarrassment of crossing this line and have an "amusements for the sophisticated" department and a "toys for tots" department.

Finding the toy department was no problem. I simply stood where I was and slowly rotated 360°. The noise peaked at about 160° SSE and I cautiously proceeded in that direction. The noise in my immediate vicinity became sharply amplified as two young boys raced by, carrying some unidentifiable toy devices.

I spied my objective ahead – the electronic games counter. I got into line between two youngsters and their parents. Were these PG or R rated games? I saw no parents with the kids playing basketball in the next aisle. Perhaps the cost of computerized games warranted closer parental scrutiny. $5 for a hockey stick is one thing, but $50 for a talking plastic robot is another. All the games at this counter incorporated microprocessors as their intelligence. Some simulated war games...
and produced authentic battle sounds while others proved to be formidable challengers in games of chance.

I looked through the products in the case, hoping to spot the one I so desperately wanted. Would this be another store that was completely sold out? Would I never get my Simon?

"Sir? Can I help you?" the salesman asked. His attitude was surprisingly pleasant considering that he worked in the store's combat zone.

"I don't see it!"

"See what, sir?"

Still vaguely pleasant, his tone changed to "I've had a long day, buddy. Let's not play 20 questions."

"Simon of course!" I replied. "But I know you don't have any. No one does."

"You're in luck, sir. I believe we re-

ceived a back ordered shipment yesterday. I'll check."

A young girl behind me said, "Did you hear that, mommy? They have Simon! I can practice for the competition after all."

"Sure. Everybody's got one. Except me, that is. We have contests in school to see who can remember the longest tune. It's fun. Oh, I can't wait!" she responded, tugging on my sleeve.

"That sounds exciting. I hope you do well in the contest," I said.

The salesman returned.

"I have one left. You're in luck."

I hardly had time to smile as he passed it to me. I heard a whimper from behind me and sensed the little girl's disappointment. Saying nothing I turned to look at her. She tried to hide her anguish.

"What is your name, little girl?" I asked, stooping down a bit to be more at her level.

"Brenda," she said wistfully.

"That's a coincidence. I have a little ... er, girl named Brenda too," I had to catch myself — as I have a female Scottish Terrier named Brenda. Parents might get upset if you compare their children to dogs. "She's a little smaller than you are."

"Is Simon for her, Mister?"

"No, she likes playing with tennis balls. But no matter. I've only been looking at this game. I'm not sure I really want to buy it just yet. Would you like it?"

She offered several relieved thank-yous as I bolted for the door. I was in a hurry to get to the department store two blocks up the street before they closed. . .

Musical Games Are Addicting

Some time ago I was in a stuffy business meeting. When it became apparent to the chairman that most of the attendees were asleep, he pulled out a saucer shaped object with four colored areas on it and slid it along the table. It stopped in front of me and went "beep" and lit a red light. Instructed to respond in kind, I pressed the red area which turned out to be an oversized lighted push-button. The saucer replied "beep-boop" and lit the red and green lights sequentially. It became immediately apparent that the plastic saucer was a game and the object was to duplicate the sequential tones it played. The task became increasingly difficult as it added another note each time around. If missed, it made a sound like a "raspberry" before starting a new game.

This "game" turned out to be Simon, from Milton Bradley Corporation. It uses a microprocessor to synthesize the tones, light the lights, and generate the sequence.
“If this M-XVI from CCS had been available in the ’30s, I would have had the secret of invisibility wrapped up in half the time.”

The Invisible Man

The place was alive with “mad doctors” 40 years ago. For good reasons. They couldn’t get what they wanted. Labs were piled high with incomplete kits, defective gear, and undecipherable support documentation.

All that’s history now that California Computer Systems has arrived on the computer hobbyist scene. We’ll see that no electronics maverick goes away mad.

Three proofs positive: our new M-XVI Static RAM Module for S-100 bus systems…our new PT-1 Wire-Wrap Board…and our new Soldertail Prototyping Board. The M-XVI features include: fully static design, use of popular 2114 static RAMs, ability to meet IEEE proposed S-100 signal standards, full buffering, addressability in 4K blocks, and bank select by bank port and bank byte. The PT-1 Wire-Wrap Board has all S-100 signals specified and provisions for four regulators. The Soldertail Board has all S-100 signals labelled, provisions for four regulators, and can accept 16-24-and-40 pin spacing.

Take a tip from the Invisible Man. He’s quit derailing trains, robbing banks, and scaring helpless damsels since CCS gave him what he wants. If you’re looking for satisfaction, too, check out our new product line today at your nearby computer store.

California Computer Systems
309 Laurelwood Road
Santa Clara, CA 95050
(408) 988-1620

So Nobody Goes Away Mad.
Circle 37 on inquiry card.
Build Your Own Musical Game

It is only logical that any of the $30 to $50 electronic toys in department stores can be simulated with the average $6000 personal computer. (This is why critics frequently call computers illogical.) The distinguishing feature between a toy built around a microprocessor and the average home computer is the packaging and I/O (input/output) interface. With the exception of addressable memory, the microprocessor in a battleship game has a processing capability comparable to the more general purpose processors like the 8080 and 6800. The major difference is that single chip computers incorporate limited quantities of programmable memory, read only memory, and I/O in one package. This is the most cost-effective approach for a dedicated task like a game. The most popular single chip com-

Figure 2: Flowchart for the computerized musical game.
Now You Can Make Your Own Magic

Unleash the Full Power of Your Personal Computer With the All-New Aladdin Personal Programs™

Aladdin Automation now offers you the magic of a full range of Personal Program™ series especially designed to support the most popular personal computers available today. Some Personal Programs™ will take you to faraway places of exciting, action-packed adventures. Others will bring fun-filled learning experiences home to you and your child. Still others are designed for your own use in the home or office. All Aladdin Personal Programs™ are moderately priced. Visit your personal computer dealer today to see and experience the magic waiting for you in every one of the Aladdin Personal Programs™. (And if your dealer hasn’t ordered his supply yet, then ask him to write Aladdin Automation for complete information on all the Personal Programs™ available now.)

Welcome To The All-New World Of Aladdin. And Get Ready To Make Your Own Magic
Computer in the computer games market is the Texas Instruments TMS 1000. Customized versions of this integrated circuit are used in the majority of electronic games.

Presuming that we can write a program on our large computer that accomplishes the same logical objective as the dedicated game, the only real difference becomes I/O. Most personal computers incorporate ASCII keyboards, video displays, and tape cassette interfaces for I/O. Electronic board games use a few switch inputs (constant closures) and lights or buzzers for output and, because there is little operating system overhead, sound effects are directly synthesized by program timing loops. Theoretically, if we attach these switches and lights to a convenient I/O port on our computer we should be able to program a similar or even more challenging game.

Building a musical game that tests the players' ability to memorize a string of tones is a simple task. Input to the computer consists of four switches, one for each of four tones. Output from the computer is likewise four signals which light four colored lights on the player console. Each light corresponds to a distinctive tone.

The game is simple to play. The computer plays a tone and the player responds by pressing the button for that same tone. Next, the computer plays two notes and the player replies accordingly. Each correct exchange results in adding one more note to the string. Eventually either the player misses by being unable to replay the exact tone sequence, or wins by attaining some preset number of notes without failure. The former is signified by an ungracious combination of tones and the latter by a distinctive tune played by the computer in celebration.

There are two possible design approaches. One is to use machine language and a "bare bones" interface consisting of four switches and four lights directly connected to a parallel input and output port. Timing loops written into the software produce the tones. This method uses the least hardware but requires considerably more software.

The second alternative is to use a high level language such as BASIC and use an external hardware interface for tone generation. This is the approach I have taken. Experimenters wishing to use another approach can easily follow the logic flow of BASIC and in this way I am not confining the reader to a particular microprocessor. Also, on-the-spot program variations to accommodate individual players are more easily implemented in a high level language.
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Specifications subject to change without notice.

Circle 160 on inquiry card.
Listing 1: Program for the musical tone game, written in 8 K Zapple BASIC.

```basic
90 REM 100 PRINT "THIS IS A MUSICAL GAME TO TEST YOUR MEMORY"
92 REM .. CIARCIA'S CIRCUIT CELLAR COPYRIGHT 1979 ••
105 REM
110 REM
115 REM FIRST THING WE DO IS SET UP A TABLE OF 64
120 REM RANDOM NUMBERS WITHIN THE CHOICES OF 1,2,4, OR 8.
125 REM THESE NUMBERS ARE SINGLE BITS WHICH INDICATE A
130 REM PARTICULAR TONE AND COLORED LIGHT.
135 REM THE COMPUTER INTERFACE IS BITS 0 THRU 3 OF I/O PORT 3
140 REM
145 REM 200 DIM R(64) :DIM S(64) :DIM A (64)
150 A=0
155 FOR S=0 TO 63
160 R = INT(RND(1)+10)
170 IF R> 3 THEN 160
175 R(S) =255-2*R :REM THE INPUT TO THE INTERFACE IS LOW TRUE LOGIC
180 REM TO TURN ON A TONE ALL BITS ARE HIGH EXCEPT THE
185 REM ONE WHICH IS TO BE COMMUNICATED
190 NEXT S
200 REM
205 REM
210 S=0 :A=A +1
215 OUT 3,R(S) :GOSUB 2000 :REM TURN ON TONE
220 OUT 3,255 :REM TURN OFF TONE
225 S=S+1
230 IF S=A THEN 450 ELSE 215
240 REM A IS PRESET TO EQUAL WIN NUMBER. THIS CAN BE 1 TO 64 TONES
245 REM
250 NEXT S
255 REM
260 REM
270 REM
400 S=0 :A=A+1
410 IF S=A THEN 450 ELSE 410
420 OUT 3,255
425 REM TURN OFF TONE
430 S=S+1
435 IF S=A THEN 450 ELSE 430
440 W=INP(3)
445 IF W<> 255 THEN 450 ELSE 440 :REM HAS A BUTTON BEEN PUSHED?
450 IF W=255 THEN 470 ELSE 450
455 W=INP(3)
460 IF W<> 255 THEN 470 ELSE 460
465 REM THE PLAYER'S RESPONSE WAS NOT CORRECT
470 IF W<>R(S) THEN 480 ELSE 470
475 REM THE PLAYER'S RESPONSE WAS NOT CORRECT
480 S=S+1
485 REM A A IS PRESET TO EQUAL WIN NUMBER. THIS CAN BE 1 TO 64 TONES
490 IF S=A THEN 580 ELSE 480
500 IF S=A THEN 580 ELSE 500
510 GOTO 460
520 REM
530 REM
540 REM RETRY DELAY
545 FOR T=0 TO 3 :GOSUB 2000 :NEXT T
550 GOTO 460
560 PRINT "SORRY, YOU MISSED IT . . . . YOU HAD ";A;" NOTES IN THE
570 REM
580 REM TRY AGAIN"
590 OUT 3,0 :REM TURN ON ALL TONES
600 FOR T=0 TO 3 :GOSUB 2000 :NEXT T
610 OUT 3,255
620 GOTO 460
630 GOTO 205
640 FOR T=0 TO 6 :REM PLAY TUNE TO INDICATE A WINNER
650 OUT 3,254 :GOSUB 2050 :OUT 3,253 :GOSUB 2050
660 OUT 3,251 :GOSUB 2050 :OUT 3,247 :GOSUB 2050
670 OUT 3,255 :NEXT T
680 GOTO 205
690 REM
700 REM THE VALUE OF T1 SETS THE TONE DURATION
710 FOR T1=0 TO 250 :NEXT T1 :RETURN
720 GOTO 205
730 REM WIN DELAY TIMER
740 FOR Q1=0 TO 80 :NEXT Q1 :RETURN
```

Figure 1a illustrates the hardware interface of this musical game; photos 1 and 2 demonstrate typical layouts. A more detailed description of an individual tone generating section is given in figure 1b. Normally, both signal points A and B are at a high logic level and the tone is off. The tone and light can be turned on by either a low output signal from the computer or the pushbutton being pressed. The resulting high level output of IC1a turns on the oscillator formed from IC1b and IC1c and drives the light through transistor Q1.

A flowchart of the software as written in BASIC is shown in figure 2. When the game is initialized, a random number generator sets up a tone sequence of 64 notes. After playing the first note it waits for the player's response and then repeats the action adding another note. The software is written so that the speed of player response is not important. Player frustration is strictly limited to remembering the tone sequence. The BASIC program which plays this game is shown in listing 1.

I have found that this game is a good way to demonstrate my computer to people totally unfamiliar with them. Some of my more computer oriented friends jokingly suggest that I may be doing things the hard way using a 64 K byte dual disk Z-80 system for the game.

If you have any questions, good ideas or comments on this or previous articles, please write to me, enclosing a self-addressed, stamped envelope. Eventually I answer them all.

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Circle 285 on inquiry card.
Cross-Pollinating the Apple II

About the Author

Richard Campbell is a software engineer working for Lexicon Corporation, a manufacturer of 8080 based text processors. His hobbies include computing, flying and photography.

Richard Campbell
7032 Quakertown
Canoga Park CA 91306

I have an Apple II personal computer, which I like a great deal. I have noticed that most construction articles dealing with custom interfaces for the Apple assume that one must use Motorola or MOS Technology peripheral integrated circuits. Since I use the Intel 8080 family of devices in my work, and want to add a serial interface to my Apple, I’ve decided to try a little crossbreeding. The interface was designed to be RS-232 compatible and to allow receiving and transmitting with the ability to add modem control signals easily in the future.

Circuit Design

The heart of the interface is the Intel 8251 programmable communications interface. The 8251 performs serial-to-parallel and parallel-to-serial conversion. The operating characteristics and mode of the 8251 are programmable by sending the proper bytes to it from the Apple bus. The interface is set up to handle asynchronous communications. National Semiconductor's 1488 and 1489 integrated circuits handle the RS-232 and TTL (transistor-transistor logic) level conversions. Since I am using only one of four buffers per chip, many other RS-232 signals could easily be added such as Data Set Ready and Clear To Send.

Data rate generation is handled by dividing the 7 MHz signal from the Apple bus by 8, using a 74LS161 synchronous 4 bit counter. This 895.125 kHz output is applied to the input of National Semiconductor's MM5307AA programmable divider. Four switches select the data rate as shown in table 2. The resulting data rates are 3 percent low, but in actual practice this is close enough. Two gates of a 74LS04 device are required to interface the 8251 circuit to the Apple bus.

Construction

The circuit was constructed using point-to-point wiring on an Apple prototype board. This board comes with a manual which provides an excellent explanation of the Apple bus. Nothing is particularly critical about the wiring (although I wouldn’t run the 7 MHz signal all around). A 0.1 µF capacitor should be placed near each integrated circuit be-

Photo 1: The serial interface circuit as constructed using the Intel 8251 programmable communications interface. Point-to-point wiring on an Apple prototype board was used. The board is pictured lying on page 12-46 of the Intel Component Data Catalog.
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Photo 2: The serial interface board installed inside the Apple II.

Listing 1: Program in assembler language for the 6502 processor. This enables the Apple II to function as a full duplex terminal.

Listing 1: Program in assembler language for the 6502 processor. This enables the Apple II to function as a full duplex terminal.

0300 A9 CE LDA #$CE     SET 8251 MODE (SEE 8251 DATA SHEET)
0302 8D C1 C0 STA $C0C1
0305 A9 27 LDA #$27
0307 8D C1 C0 STA $C0C1
030A 20 58 FC JSR $FC58  CLEAR THE SCREEN AND HOME
030D A9 60 LDA #$60 GET CURSOR CHAR
030F 20 ED FD JSR $FDED PUT CURSOR ON SCREEN
0312 CB 24 DEC $24 BACKUP SCREEN INDEX TO OVERWRITE CURSOR
0314 AD C1 C0 LDA $C0C1 CHECK 8251 STATUS
0317 29 02 AND #$02 MASK OFF RECEIVE READY BIT
0319 F0 12 BEQ $032D BRANCH IF NOT READY
031B A9 A0 LDA #$A0 GET A BLANK
031D 20 ED FD JSR $FDDE OVERWRITE THE CURSOR
0320 CB 24 DEC $24 BACKUP SCREEN INDEX
0322 AD C0 C0 LDA $C0C0 GET CHAR FROM 8251
0325 09 80 ORA #$80 SET BIT 7 HIGH
0327 20 ED FD JSR $FDDE PUT CHAR ON THE SCREEN
032A 4C 00 03 JMP $030D PUT UP NEXT CURSOR AND LOOP
032D 2C 00 C0 BIT $C000 CHAR ENTERED ON KEYBOARD?
0330 10 E2 BPL $0314 BRANCH IF NO
0332 AD 00 C0 LDA $C000 GET CHAR FROM KEYBOARD
0335 8D C0 C0 STA $C0C0 OUTPUT CHAR TO BE SENT BY 8251
0338 AD 10 C0 LDA $C010 RESET KEYBOARD
033B 4C 14 03 JMP $0314 CHECK FOR NEXT CHAR

tween ground and +5 V. The +12 V and -12 V supply lines should also be decoupled to ground using 0.1 µF capacitors. Do not use high value electrolytic capacitors, since this interferes with the Apple's switching power supply. The RS-232 input, output, and ground should go to a standard DB25 connector.

Using the Interface

Listing 1 contains a program, entered with the Apple's assembler, that sets the Apple up for use as a terminal. Data received from the input port is displayed on the screen, and whatever is typed on the keyboard is sent out the transmit line. This program operates the Apple as a full duplex terminal. In other words, there is no internal logical connection between the keyboard and the screen. The characters that are typed.
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Figure 1: Schematic diagram for the serial interface.

Table 1: Power wiring table for figure 1.

<table>
<thead>
<tr>
<th>Number</th>
<th>Type</th>
<th>+5 V</th>
<th>Gnd</th>
<th>-12 V</th>
<th>+12 V</th>
</tr>
</thead>
<tbody>
<tr>
<td>IC1</td>
<td>74LS04</td>
<td>14</td>
<td>7</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>IC2</td>
<td>8251</td>
<td>26</td>
<td>4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>IC3</td>
<td>74LS161</td>
<td>16</td>
<td>8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>IC4</td>
<td>MM5307-AA</td>
<td>4</td>
<td>-</td>
<td>12</td>
<td>-</td>
</tr>
<tr>
<td>IC5</td>
<td>1488</td>
<td>-</td>
<td>7</td>
<td>1</td>
<td>14</td>
</tr>
<tr>
<td>IC6</td>
<td>1489</td>
<td>14</td>
<td>7</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Data Rate Selection

<table>
<thead>
<tr>
<th>S4</th>
<th>S3</th>
<th>S2</th>
<th>S1</th>
<th>Data Rate (bps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>C</td>
<td>C</td>
<td>N</td>
<td>50</td>
</tr>
<tr>
<td>C</td>
<td>C</td>
<td>N</td>
<td>C</td>
<td>75</td>
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<tr>
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<td>N</td>
<td>C</td>
<td>N</td>
<td>110</td>
</tr>
<tr>
<td>C</td>
<td>N</td>
<td>N</td>
<td>C</td>
<td>134.5</td>
</tr>
<tr>
<td>C</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>300</td>
</tr>
<tr>
<td>N</td>
<td>C</td>
<td>C</td>
<td>N</td>
<td>600</td>
</tr>
<tr>
<td>N</td>
<td>N</td>
<td>C</td>
<td>N</td>
<td>900</td>
</tr>
<tr>
<td>N</td>
<td>N</td>
<td>N</td>
<td>C</td>
<td>1200</td>
</tr>
<tr>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>1800</td>
</tr>
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<td>2400</td>
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<td>N</td>
<td>N</td>
<td>3600</td>
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<td>4800</td>
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<td>N</td>
<td>7200</td>
</tr>
<tr>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>9600</td>
</tr>
</tbody>
</table>

C = closed  
N = open (not closed)

8251 set for 16 mode

Table 2: Switch settings to select various data rates for this serial interface. A dual in line pin-type switch may be used.

appear on the screen only if the device you are communicating with echoes them back to you. With this program the board has communicated perfectly with an Intel single board computer at a data transmission rate of 600 bits per second.

Conclusion

Some experimenters have faced difficulty in attempting to interface the Apple II to such devices as the Motorola 6820 PIA (peripheral interface adapter). Most of the problems stem from a 25 ns timing delay on the bus lines of the Apple. I advise erstwhile interfacer not to become bogged down in this sort of thing; there are too many new and useful integrated circuits available with which to work.

Not all highly programmable devices are as fussy about timing as are the standard support devices for the 6800 and 6502 processors. My design shows that other families of circuits may be utilized without much trouble. The design using the 8251 device has suffered no timing glitches such as the ones that plague circuits using the 6820 device.

The moral is to keep your eyes open to discover new and versatile integrated circuits and to experiment with them, whatever processor you use. Signetics has invented an interface circuit, the 2651, which is similar to the 8251. The principal difference is a built-in data rate generator. If I can obtain one, I know what my next experiment will be.

After programming a 2708 or 2716 EPROM you won't need a screwdriver to pry it out of SSM's new PBI board equipped with Textool sockets. Just flip the lever and lift it out. And on the same board there are 4 sockets waiting for 2708 or 2716 EPROMs that can be independently addressed to any 4k or 8k boundary above 8000 hex. Two boards in one.

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How does one go about setting up a physical simulation? It's necessary to determine the most important laws that govern the system under investigation. A star cluster, for example, is controlled mainly by Newton's law of gravitation. The nuclear reactions which power individual stars are interesting, but probably not very important to the structure of the cluster as a whole. (An exception might be a cluster of extremely massive stars; such stars could run out of fuel and blow up before there was time for their orbits to settle down.)

The first step in programming any physical system is to cut away all the features except those which are crucial to it — in other words, to make a model. If the correct effects and features have been included, the model will act enough like the physical system to be useful and accurate, and the model will be small and simple enough to be computable in a reasonable amount of time and space.

Secondly, one must take the equations that govern the model and translate (and sometimes simplify) them into a form which a machine can handle. Today, only a few very high-level systems (such as MACSYMA, REDUCE, SHEEP, and FORMAC) can handle abstract equations and functions, and even these sophisticated systems can't do very much. Until people learn how to explain the details of problem solving mathematics better, most machines are best at manipulation of discrete, finite precision numbers. So, if one wants to compute the flight of a Frisbee, one needs to turn the continuous differential equations for its motions into discrete difference equations. It's analogous to the way one plots a diagonal line on a teletypewriter — the continuous line is broken up into a discrete set of points that the printer then approximates as best it can. If the printer can type smaller, the approximation is better. Similarly, if the smooth equations describing the Frisbee's flight are broken up into tinier steps, then the approximate solution the machine generates comes closer to the actual motion.
Finally, given the model of the physical system to be simulated, and given a translation of the equations controlling that model into a machine acceptable form, the rest is easy: just write the program! Ah, if it were only so. To avoid gross errors and smaller bugs, it's best to write in a high-level language (BASIC, FORTRAN, Pascal, etc), but then the resulting code usually runs unacceptably slowly. It seems to be a general consequence of Murphy's Law ("Anything that can go wrong, will!") that any physical system interesting enough to be worth simulating is too complex to be effectively simulated. So, compromises are always necessary. Astronomers try to simulate galaxies using a thousand point masses and an approximate force law, instead of using the actual ten billion stars with $1/r^2$ fields. Chemists settle for a few hundred molecules in their "liquid," instead of $10^{23}$ or so. All they can do is hope that enough of the many-body collective effects show up for their too small models to be interesting, and that the cost of computing comes down enough for them to simulate bigger systems next year. As calculations get cheaper, that last hope seems to be the best.

Another way to compromise between the human speed and efficiency of programming in a high-level language, and the computer speed and efficiency of programming in machine language is obvious: do both, and produce a hybrid program. The BASIC (or Pascal, or whatever) program provides the framework and handles non-time-critical tasks; it then calls machine language modules to perform the innermost loops, the time-consuming parts of the program which are simple enough to write accurately and rapidly in such a low-level language. As a developmental tool, this top-down approach is infinitely better than writing all machine language code and then spending days debugging it. In fact, if the program can be entirely written in the high-level language...
and then run (slowly, perhaps) on small, special cases to test out the fundamental equations, so much the better. The machine language subroutines can then be written and substituted in only as necessary.

With this 3 step approach (model, translate, program), simulating physical systems isn't necessarily easy, but it is systematic and can be interesting and educational.

The Ideal Gas

As an application of the above principles, I've programmed in BASIC and 6502 machine language (on a Commodore PET) a simulation of an ideal gas—a gas made of pointlike particles that interact only by direct collisions. An actual gas, of course, is made of molecules or atoms which have size and internal structure. The molecules may react when they collide with sufficient energy, and they may influence each other (via electrical forces) even when they are quite far apart. The gas may condense into a liquid or solid phase if its temperature is low enough and its pressure high enough.

The model I made does not include those features. It doesn't even include the three dimensions in which the physical gas moves! For speed and simplicity, I restricted the gas particles to move in two dimensions within the 50 by 80 cell “box” of the PET’s video screen. The two-dimensional gas is interesting in itself, and it actually occurs, approximately, when atoms get adsorbed on the surface of some crystals. The adsorbed particles are relatively free to move from place to place on the crystal surface, but they are not free to leave the surface if the temperature is low enough. (If this physical system isn't exciting enough for you, you can imagine that the program is simulating a large number of balls on a billiard table, or perhaps hockey pucks sliding on ice.)

Several other features of the model I made are important. I used only 256 gas particles for two reasons: it made the machine language routines simpler, and more particles would have filled up too large a fraction of the screen. As a general rule, the errors in simulating a random process shrink as 1/\sqrt{N}, where N is the number of objects in the simulation. For example, if a pollster asks 100 randomly chosen people for their opinion on some issue, he or she typically makes about 1/\sqrt{100} = 10% errors in estimating the general opinion based on the finite sample. If the average number of molecules in one cubic centimeter of air is
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*CP/M is a trademark of Digital Research.
Table 7: Comments on Gas machine language modules given in listing 2.

<table>
<thead>
<tr>
<th>Decimal Memory Address</th>
<th>Contents Or Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>5632 thru 5799</td>
<td>Move particles one step forward in time, bouncing off walls as necessary.</td>
</tr>
<tr>
<td>5800 thru 6036</td>
<td>Plot particles on screen, colliding ones which fall in same cell on the 50 by 80 grid.</td>
</tr>
<tr>
<td>6144 thru 6399</td>
<td>High bytes of X coordinates.</td>
</tr>
<tr>
<td>6400 thru 6595</td>
<td>High bytes of Y coordinates.</td>
</tr>
<tr>
<td>6512 thru 6717</td>
<td>Low bytes of X coordinates.</td>
</tr>
<tr>
<td>7168 thru 7423</td>
<td>Low bytes of Y coordinates.</td>
</tr>
<tr>
<td>7424 thru 7679</td>
<td>Low bytes of VX velocities.</td>
</tr>
<tr>
<td>7680 thru 7935</td>
<td>Low bytes of VY velocities.</td>
</tr>
<tr>
<td>7936 thru 8191</td>
<td>Low bytes of VY velocities.</td>
</tr>
<tr>
<td>5632 thru 5654</td>
<td>Current screen character at location to be plotted.</td>
</tr>
<tr>
<td>5655 thru 5660</td>
<td>Table of PET ¼ graphics symbols; translates to and from &quot;binary graphics symbols.&quot;</td>
</tr>
<tr>
<td>5661 thru 5679</td>
<td>Low, high bytes of current screen address.</td>
</tr>
<tr>
<td>5810 thru 5824</td>
<td>&quot;Binary graphics symbol&quot; to be put onto current location (1, 2, 4, or 8).</td>
</tr>
<tr>
<td>5800 thru 5685</td>
<td>Check see if in box; fix if not.</td>
</tr>
<tr>
<td>5808 thru 5689</td>
<td>High, low bytes of M = (A + B + C + D)/2.</td>
</tr>
<tr>
<td>5825 thru 5848</td>
<td>High, low bytes of TEMP=M-B.</td>
</tr>
<tr>
<td>5849 thru 5866</td>
<td>Low bytes of table of left ends of screen lines.</td>
</tr>
<tr>
<td>5867 thru 6036</td>
<td>Low bytes of table of left ends of screen lines.</td>
</tr>
<tr>
<td>5887 thru 6036</td>
<td>Table of graphics symbols, in order defined to be 1, 2, 3, 4, ..., 15 in &quot;binary graphics symbols.&quot;</td>
</tr>
<tr>
<td>5916 thru 5924</td>
<td>Move X coordinate.</td>
</tr>
<tr>
<td>5974 thru 5979</td>
<td>Check to see if in box; fix if not.</td>
</tr>
<tr>
<td>5980 thru 5989</td>
<td>Move Y coordinate.</td>
</tr>
<tr>
<td>5988 thru 5689</td>
<td>Check to see if in box; fix if not.</td>
</tr>
<tr>
<td>6075 thru 6099</td>
<td>Increment counter; do next particle if not done.</td>
</tr>
<tr>
<td>6090 thru 5726</td>
<td>Fix if gone off left edge.</td>
</tr>
<tr>
<td>5727 thru 5746</td>
<td>Fix if gone off right edge.</td>
</tr>
<tr>
<td>5747 thru 5779</td>
<td>Fix if gone off bottom.</td>
</tr>
<tr>
<td>5780 thru 5799</td>
<td>Fix if gone off top.</td>
</tr>
<tr>
<td>5800 thru 5809</td>
<td>Transfer table to page 0 of memory.</td>
</tr>
<tr>
<td>5910 thru 5824</td>
<td>Put address of screen left edge of line to be plotted into 26, 27.</td>
</tr>
<tr>
<td>5825 thru 5848</td>
<td>Put &quot;binary graphics symbol&quot; to be plotted into 26, and add location in line to be plotted to 26, 27.</td>
</tr>
<tr>
<td>5849 thru 5866</td>
<td>Find current graphics symbol which occupies space to be plotted in; look up in table and translate to &quot;binary graphics symbol.&quot;</td>
</tr>
<tr>
<td>5867 thru 5882</td>
<td>Plot particle if space to which it goes isn't already occupied.</td>
</tr>
<tr>
<td>5883 thru 5886</td>
<td>Increment counter and go back to 5810 if not through.</td>
</tr>
<tr>
<td>5887 thru 6036</td>
<td>A collision has occurred! Scan back to see which particle has collided with the one about to be plotted, and fix their velocities, as in text.</td>
</tr>
<tr>
<td>6037 thru 6049</td>
<td>This space intentionally left blank.</td>
</tr>
</tbody>
</table>

Table 1: Comments on Gas machine language modules given in listing 2.

Text continued from page 28:

$3 \times 10^{19}$, then the fractional fluctuation in this number is about $1\sqrt{3} \times 10^{19} \approx 0.2$ parts per billion — small, but measurable. (The human ear is sensitive enough to barely hear these fluctuations — try it, if you can find a quiet enough place!) So, the errors that the 256 particle gas model will tend to make are of the order of $1\sqrt{3}6 \approx 6\%$ — not terribly bad.

A second important feature of my model is the way it handles collisions. Time is broken into steps, and two particles which end a timestep in the same cell are considered to collide. It would be far more complicated to calculate distances between particles as they move and to declare a collision only if their center-to-center distance fell below a certain limit. It also turns out not to matter much, as far as the final equilibrium state of the gas is concerned. Actual collisions are sometimes grazing, sometimes head-on, and generally everywhere in between, depending on the details of the interactions between the molecules and their impact parameters. None of that really matters for our purposes.

The important feature of all collisions in gases is that the collisions always conserve energy and momentum. Energy is just kinetic energy for pointlike particles: $\frac{1}{2}mv^2$. To simplify the arithmetic, I let all of my gas particles have mass $m = 2$, so their energies are just the squares of their velocities. In two dimensions, velocity has components along the X and Y axes; call them VX and VY. The momentum of a particle is just its mass times its velocity. Momentum thus has X and Y components, each of which must separately be conserved, that is, remain constant during a collision.

To be specific, suppose that VX and VY are arrays, and that particles numbered 1 and 2 are colliding. If arrays WX and WY are used to hold their velocities after the collision, then conservation of energy says that (total energy after) = (total energy before), that is, $WX(1)^2+Wy(1)^2+WX(2)^2+WY(2)^2=VX(1)^2+VY(1)^2+VX(2)^2+VY(2)^2$. Conservation of X momentum says that $WX(1)+WX(2)=VX(1)+VX(2)$, and conserving Y momentum implies that $WY(1)+WY(2)=VY(1)+VY(2)$.

Now, if the velocities before the collision are known, then there are four velocities afterwards to solve for: $WX(1)$, $WY(1)$, $WX(2)$, and $WY(2)$. Three equations are not enough information to solve for four unknowns. The missing equation contains the details of the collision — whether it is head-on or glancing or what. One might write out this fourth equation (it's done in most freshman physics textbooks) in terms
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of the scattering angle, and then use the details of the particles’ positions to choose that angle, but that would involve calculating sines and cosines of the angle, and it’s unnecessarily slow and complicated (especially to program in machine language). Instead, I chose one special type of collision, which enabled WX(1), WX(2), WY(1), and WY(2) to be calculated using only addition, subtraction, and division by 2. (I can program those!) This special collision scatters two particles by 90 degrees, if they approach each other with opposite velocities, as shown in figure 1. The resulting equations for the velocities after the collision are simple. Let M=(VX(1)+VY(1)+ VX(2)+VY(2))/2. Then WX(1)=M-VY(1), WY(1)=M-VX(2), WX(2)=M-VY(2), and WY(2)=M-VX(1). It’s an exercise in elementary algebra to see that these values for the velocities after the collision conserve energy and momentum.

So that’s the specific model: a two-dimensional gas made of 256 particles on a 50 by 80 grid, which make 90 degree type collisions whenever two fall in the same cell. Now for step 2: make the equations of motion computable. The equation that governs the particles’ positions between collisions is, in words, that the time-rate-of-change of the position is the velocity; the equation that is also simple: particles move in straight lines at constant speed between collisions. But in a machine, nothing moves continuously. It’s rather like Zeno’s Paradox: if you look at an arrow in flight, at some moment it certainly is where it is, not somewhere else—it’s at a definite location, not smeared out or blurred. So, how can the arrow move? Zeno couldn’t answer this (or chose not to), but later mathematicians (Newton, Leibnitz, and others) did. Their answer involves looking at the motion as a series of tiny discrete jumps. The computer can do that too. If a particle is at position X,Y at one moment, and has velocity VX, VY, then a time T later it will be at X+TXVX, Y+TXVY. When I wrote the original (high-level language) version of this simulation, I used precisely these “time-step” formulae; in the machine language version, I set T = 1 for simplicity. I also chose a specific precision arithmetic: two bytes for each number, in 2’s complement notation, with the decimal point (it’s really a binary point!) between the two bytes. The high byte (to the left of the point) gives a number that can be directly plotted on the screen; the low byte keeps several decimal places of accuracy and holds down roundoff
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All prices, suggested retail.
Listing 2: The 6502 assembly language modules for use with the ideal gas program.

<table>
<thead>
<tr>
<th>LABEL</th>
<th>MNEMONIC</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>BEGINMOVE:</td>
<td>LDX #0</td>
<td>;initialize particle counter</td>
</tr>
<tr>
<td></td>
<td>LDY #0</td>
<td>;clear Y register</td>
</tr>
<tr>
<td></td>
<td>ADC XLO,X</td>
<td>;move x coordinate of particle</td>
</tr>
<tr>
<td></td>
<td>STA XLO,X</td>
<td>;by adding VX to X</td>
</tr>
<tr>
<td></td>
<td>LDA VXHI,X</td>
<td>;bounce off left wall if x.LT.0</td>
</tr>
<tr>
<td></td>
<td>CMP #80</td>
<td>;bounce off right wall if x.GE.80</td>
</tr>
<tr>
<td></td>
<td>RETX:</td>
<td>;move y coordinate</td>
</tr>
<tr>
<td></td>
<td>LDA VYLO,X</td>
<td>;by adding VY to Y</td>
</tr>
<tr>
<td></td>
<td>STA YLO,X</td>
<td>;bounce off bottom if y.LT.0</td>
</tr>
<tr>
<td></td>
<td>CMP #50</td>
<td>;bounce off top if y.GE.50</td>
</tr>
<tr>
<td></td>
<td>RETY:</td>
<td>;do all 256 particles</td>
</tr>
<tr>
<td></td>
<td>INX</td>
<td>;back to BASIC control</td>
</tr>
<tr>
<td></td>
<td>BNE TOP</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RTS</td>
<td></td>
</tr>
<tr>
<td>NEGX:</td>
<td>TYA</td>
<td>;prepare to reflect -x to x</td>
</tr>
<tr>
<td></td>
<td>SEC</td>
<td>;by subtracting from 0</td>
</tr>
<tr>
<td></td>
<td>SBC XLO,X</td>
<td>;another 0 in accumulator</td>
</tr>
<tr>
<td></td>
<td>STA XLO,X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TYA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>STA VXHI,X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>STA VXHI,X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>REFLVX:</td>
<td>;reflect velocity vx also</td>
</tr>
<tr>
<td></td>
<td>TYA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>STA VXLO,X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>STA VXLO,X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TYA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>STA VXHI,X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>STA VXHI,X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BIGX:</td>
<td>;return to main program</td>
</tr>
<tr>
<td></td>
<td>LDA #255</td>
<td>;prepare to reflect x to 160-x</td>
</tr>
<tr>
<td></td>
<td>(actually, 159.99...-x)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SEC</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SBC XLO,X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>STA XLO,X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LDA #159</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SBC XHI,X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>STA XHI,X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>JMP REFLVX</td>
<td>;reflect velocity vx using previous code</td>
</tr>
<tr>
<td>NEGY:</td>
<td>TYA</td>
<td>;reflect y using previous code</td>
</tr>
<tr>
<td></td>
<td>SEC</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SBC YLO,X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>STA YLO,X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TYA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>STA YHI,X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>STA YHI,X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>REFLVY:</td>
<td>;reflect velocity vy also</td>
</tr>
<tr>
<td></td>
<td>TYA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>STA VYLO,X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>STA VYLO,X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TYA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>STA VYHI,X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>STA VYHI,X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BIGY:</td>
<td>;use previous code to reflect vy</td>
</tr>
<tr>
<td></td>
<td>LDA #255</td>
<td>;prepare to reflect y to 99.99...-y</td>
</tr>
<tr>
<td></td>
<td>SEC</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SBC YLO,X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>STA YLO,X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LDA #99</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SBC YHI,X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>STA YHI,X</td>
<td></td>
</tr>
<tr>
<td></td>
<td>JMP REFLVY</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Specific addresses used in the 8 K byte PET Gas program. Addresses are given in decimal.

<table>
<thead>
<tr>
<th>Address</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>5632</td>
<td>BEGINMOVE</td>
</tr>
<tr>
<td>5800</td>
<td>BEGINPLOT</td>
</tr>
<tr>
<td>6144</td>
<td>XHI</td>
</tr>
<tr>
<td>6400</td>
<td>XLO</td>
</tr>
<tr>
<td>6656</td>
<td>YHI</td>
</tr>
<tr>
<td>6912</td>
<td>YLO</td>
</tr>
<tr>
<td>7168</td>
<td>VXHI</td>
</tr>
<tr>
<td>7424</td>
<td>VXLO</td>
</tr>
<tr>
<td>7680</td>
<td>VYHI</td>
</tr>
<tr>
<td>7936</td>
<td>VYLO</td>
</tr>
<tr>
<td>8050</td>
<td>OLDCHAR</td>
</tr>
<tr>
<td>8075</td>
<td>GRAFTAB</td>
</tr>
<tr>
<td>8100</td>
<td>SYMBTAB</td>
</tr>
</tbody>
</table>

Table 3: The PET uses special graphics symbols to denote cursor control characters. Since these special characters cannot be typeset, the above notation is used in the program.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>cls</td>
<td>clear screen</td>
</tr>
<tr>
<td>b</td>
<td>backspace (cursor left)</td>
</tr>
<tr>
<td>d</td>
<td>down (cursor down)</td>
</tr>
<tr>
<td>r</td>
<td>right (cursor right)</td>
</tr>
<tr>
<td>u</td>
<td>up (cursor up)</td>
</tr>
<tr>
<td>home</td>
<td>cursor home</td>
</tr>
</tbody>
</table>

Listing 2 continued on next page.
Tinker, Tailor, Soldier, Sailor ... Doctor, Lawyer ... the Chieftain's here.

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---

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State/Zip __________________________

---

Hail to the Chieftain

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Circle 328 on inquiry card.
First, it's easy to write a loop to add up the kinetic energy of each particle; the total energy of the system should be conserved. Roundoff (from the division by 2, in particular) does make small errors occur, but I've found them to be tiny even after hundreds of timesteps. It is interesting to note that the energy is directly proportional to the temperature of the system. The eye can easily tell the difference between "hot" and "cold" gasses, with some experience.

It is also interesting to plot the velocities of the gas particles. In theory, after lots of collisions have occurred, the distributions of VX and VY velocities should be bell shaped (also called "Gaussian" or "normal") curves (see photos). It's quite satisfying to see a ridiculous initial distribution, with all the particles at rest except for one, evolve as collisions happen toward the normal curve. (The width of the distribution is proportional to the square root of the temperature.) There are fluctuations away from this equilibrium distribution, of course, but they are small, roughly 1/N^1/2% in this model.

Another educational phenomenon that this model can illustrate is called Brownian motion, the "random walk" that a particle in the gas executes as it is buffeted by other objects. It's a line addition to the original program to change the symbol for one particle (number 0, for example) to something distinctive, so its motion can be followed. (An asterisk was used in the photos here.) On long timescales, the net motion of a particular particle is less than one might expect — the average distance it moves is not (average speed)X(time), but (average speed)^2/(2*time). (Albert Einstein got his Nobel Prize partly for his explanation of Brownian motion, published in 1905.)

There are many other "theoretical experiments" that one can do with this model of a gas. One could count the collisions off a wall and check the ideal gas law which relates pressure, density, and temperature. Another experiment could be to measure the "speed of sound" in the gas, by giving a push to the particles on one side of the box, and seeing how long it takes the resulting density wave to move across. (The box may be too small and the gas too dilute to do this cleanly, however; I'm not sure.) It might be nice to connect up the screen edges, so that particles which move off the right side appear at the left, etc. That way, one could set up a "wind" (a net nonzero momentum in some direction) and it would last forever within roundoff without hitting any box walls. Another possibility is to evolve a system forward in time for a while, and then reverse all velocities.

Listing 2 continued on next page.
Effectively, this reverses time—if roundoff is unimportant, the particles should retrace their paths and return to the initial configuration, like a movie run backwards!

This simulation of a gas is extraordinarily simple in principle, but displays a surprising wealth of realistic physical phenomena. It's not surprising that slightly more complicated laws, acting on larger numbers of particles, can make galaxies and DNA molecules, snowflakes and cyclones. The challenge is to simplify and then simulate them!

BIBLIOGRAPHY


2. Lykos, Peter (editor), “Minicomputers and Large Scale Computations,” from a symposium sponsored by the ACS Division of Computers in Chemistry, American Chemical Society, Washington DC, 1977. (See chapters 11 and 12 in particular.)


Listing 2, continued:

ROR A :otherwise sign bit will be lost!!!
STA MHI
ROR MLO :division by 2 completed
LDA MLO :calculate after-collision velocities now, as described
SEC :in text
SBC VYLO,X STA TPMLO :save in temporary place
LDA MHI
SBC VYHI,X STA TMPHI
LDA MLO :proceed to collide all velocities
SEC
SBC VXLO,Y STA VYLO,X LDA MHI
SBC VXHI,Y STA VYHI,X LDA MLO
SEC
SBC VYLO,Y STA VXLO,Y LDA MHI
SBC VYHI,Y STA VXHI,Y LDA MLO
SEC
SBC VXLO,X STA VYLO,Y LDA MHI
SBC VXHI,X STA VYHI,Y LDA TPMLO
STA VXLO,X STA VYLO,Y LDA TMPHI
STA VXHI,X JMP INCRX ;collision finished — go back to main program

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Adaptive Information Processing: An Introductory Survey
by Jeffrey R Sampson
Springer-Verlag, New York 1976
214 pages $14.80

A book that deals with theoretical computing machines, the biology of an amoeba, and a very good checkers program should pique the interest of many readers. Adaptive Information Processing: An Introductory Survey is excellent for someone who wants a thorough overview of the subjects covered. The book deals with three broad topics: information and automata, biological information systems and artificial intelligence. The second and third are at opposite ends of the spectrum of adaptive information processors: living organisms and "intelligent" computer programs that mimic human thought. But the first topic, which deals with the nature of information, and with certain imaginary, idealized computing machines, summarizes a body of knowledge that sets an upper bound on the transmission of data and on the problem solving limits of any computer. It is only in the light of these limitations that the later examination of living and nonliving information processing systems becomes meaningful.

The first section has five chapters on communication theory, coding information, finite automata, Turing machines, and cellular automata. The last three subjects refer to three levels of idealized computing machines that mathematicians and computer scientists have devised and studied to determine what problems can and cannot be solved on a given machine. Most important are two facts: firstly, the Turing machine is capable of solving any problem that any computer can solve; and secondly, there are certain problems that a Turing machine cannot solve. This implies that there are problems insoluble by computer. The fourth chapter is especially good for its concentration of the work done along these lines, in particular, the famous "halting" problem for the universal Turing machine.

The "Biological Information Processing" section devotes a chapter each to information processors on four levels: the biochemical, genetic, neural, and nervous system levels. The first chapter gives a concise description of the role of enzymes and DNA in the processes of biological information transfer. The fifth chapter deals with limited attempts of scientists to simulate various levels of biochemical processes via computer programs.

The final section deals with five artificial intelligence topics: pattern recognition, game playing, theorem proving, generalized problem solvers and natural language processing. Here, the author admits that his mate-
A lot of semantic nonsense is being tossed around by some of the makers of so-called "personal" computers. To hear them tell it, an investment of a few hundred dollars will give you a computer to run your small business, do financial planning, analyze data in the engineering or scientific lab — and when day is done play games by the hour.

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Processor Technology
material emphasizes the heuristic programming school of thought, which favors the methods that produce the maximum amount of intelligence, rather than those schools that try to model human thought processes. Each chapter in this section describes the terminology, basic concepts, and techniques of the subject. The game playing chapter is useful for readers interested in designing sophisticated game playing programs.

These last chapters describe the most impressive "intelligent" programs in several fields: Guzman's See, which analyzes and recognizes solid geometric forms from a video picture; Samuels' checker playing program, one of the most successful game playing programs; the theorem proving Logic Theorist and the General Problem Solver (both by Newell, Shaw, and Simon); Weizenbaum's Eliza and Raphael's Sir, both written to appear to understand conversational English.

Each chapter ends with a complete bibliography and a short set of exercises. A lot of material is presented in a short space, and the readability of the book varies with the reader's familiarity with the basic concepts of the subject being presented. Except for this one necessary shortcoming, the book still manages to cover some of the most important ideas and programs in computer science history. The section on biological information processing systems augments the book's value.

Gregg Williams
1605 Eastmoreland •3
Memphis TN 38104•

BASIC Programming for Scientists and Engineers
by Wilbert N Hubin
$9.95 paperbound

With personal computers currently following a geometric growth curve, I think BASIC will become the Esperanto of the cognoscenti; it nearly is now. Since the professional community forms a large user group, I feel the science and engineering people will need the ability to work in other languages besides the ubiquitous FORTRAN. Mr Hubin's fine book is one of the best first books of BASIC that I have seen. It is suitable for both the experienced programmers seeking to add BASIC to their repertoires, and for the beginning science students who need both computer and technical problem solving experience.

The first portion of the book is devoted to learning the language. The various statements of BASIC are defined and illustrated, and there is a discussion of elementary terminal usage as well as hints for using BASIC in the most efficient manner. Each type of statement has review questions and problems for each subsection, and, for the insecure among us, answers. Hints on troubleshooting are a nice bonus for the newcomer, since it takes a little ACL (accumulated computer lore) before one develops a feel for debugging code. Segments of programs show just how code consisting of BASIC statements can be used to accomplish the reader's purpose.

The chapter on flowcharting ably demonstrates the fundamentals of this art, discusses their applications, and then provides a diverse sampling of problems to sharpen the reader's skills. The author's editorial on flowcharting may even bring old hands back to the fold of those who document programs before they become operational. Handily, once again, solution flowcharts are in the appendix.

The concluding two chapters are devoted to solving technical problems with a computer. The problems deserve a mention here, since they form a nucleus of problems suitable for a science course. Equations of motion, centers of mass, Hermite polynomials, and others serve to show the student how to apply the computer to classroom concepts. The range of problems is superb, from simultaneous equations and least squares fit to solutions of differential equations and error analysis. Each application mastered will mean a valuable addition to the reader's skills. The problems are drawn from the gamut of the engineering ranks and the physical sciences, and footnotes refer the reader to the journals of science. Completion of these exercises will give the practitioner a mastery of BASIC and a few fundamentals of science.

The appendices offer a summary of BASIC statements and the meaning of each. There is a short example of terminal usage employing a Digital Equipment Corp PDP-11 as an example. Especially handy is the section on BASIC error messages, although it is a bit brief. In familiarizing yourself with a new machine or language, deciphering the error messages is usually a headache. The computer's opinion of the defects in a program is often expressed in a cryptic manner.

While machines vary, beginners' mistakes do not, and the common ones are listed. In addition, there is a useful index. The bibliography focuses on books applying computers to the physical sciences. Throughout the book, the print is well-displayed and easy to read. If you are thinking of learning BASIC, think of this book.

Noel K Julkowski
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Sources of Numerical Error

Daniel R Buskirk
POB 211
The Rockefeller University
New York NY 10021

A growing number of microcomputer enthusiasts are finding the need to perform control operations, evaluate complicated mathematical expressions and analyze statistical data. In short, many hackers want to tackle problems conventionally left to larger computers. To do this, they must become acquainted with error analysis.

Programmers need to be concerned about errors in any program involving the evaluation of a function or algebraic expression, or one which involves a large number of simple but repetitive operations. Even in control applications, it is often critical to be aware of the potential for error.

What do we mean by error? The numerical analyst, a professional mathematician involved with the design and analysis of numerical algorithms, recognizes three distinct types of error. The first is the blunder, which is not an error at all in the mathematical sense. A blunder is a gross error: a mistake in program logic, a typographical error, or perhaps only a misplaced decimal point. The mathematician, like the rest of us, must shrug his shoulders at a blunder, and hope to do better next time. Blunders need not concern us here.

Certainly blunders account for the vast majority of errors; but what other types of errors are there if we ignore blunders? One type is the truncation error. For example, take the infinite series representation of the function \( \sin(x) \):

\[
\sin(x) = \frac{x}{1!} - \frac{x^3}{3!} + \frac{x^5}{5!} - \ldots
\]

If we were to use this relation to evaluate \( \sin(x) \) in a computer, we could not carry this series on forever. Whenever we stop, we have failed to evaluate the remaining terms in the expression, or truncated the series. Those who understand a little calculus will recognize that this series converges; that is, it gets arbitrarily close to the correct value when sufficiently many terms are calculated. But there must always be a small but finite truncation error (if this computation is carried out on a digital computer).

Another calculation involving truncation error is the evaluation of integrals using the trapezoidal rule. Though an infinite series of trapezoids, each approaching zero width, will give us the area under the curve (its definite integral) exactly, any computer evaluation must settle for a finite number of trapezoids. Thus there will be truncation error. To be sure, it is generally possible to avoid the consideration of truncation error by simply requiring that the truncation error be less than the precision of the whole calculation. However, the clever programmer recognizes that there are usually several different infinite series representations of any function. Often, one of these series will require significantly fewer terms to come within the required precision.

The error of most concern to numerical programmers is not truncation error but rather roundoff error. Since the word length in most computers is fixed, any number that exceeds this length must be rounded off before it can be stored in the computer's memory. This error is the most significant, so we shall consider it in more detail.

Although almost all "big" computers store numbers in binary digits, the following examples are given in base ten because it is more familiar (and it is similar to the binary coded decimal format often used in microcomputer floating point packages).

Most computers store a real number by breaking it down into a mantissa and an exponent, much like scientific notation. A word which looks like this:

About the Author

Daniel Buskirk is currently a graduate fellow at Rockefeller University, where he is studying neurobiology. He has a bachelor's degree in mathematics and zoology. His current professional interest is the application of mathematical and computer methods to the study of neuronal structure. When not working, he enjoys photography, playing the piano, and, of course, fiddling with microcomputers.
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would represent the real number 0.7352 x 10^5 or 73520. Now, if we wish to store a number larger than four decimal places, we must round it off. (It is true that our exponent here is limited to two decimal places. Any exponent with three or more places in this case represents an overflow condition. Since overflow is generally easily avoided, we will not discuss it here.) Consider the numbers 8,931,724 and 0.761253. In the first case, rounding off to 0.8931 x 10^7 represents an error of 724. The error in rounding the second is 53 x 10^-6. Thus, it is most common for the numerical analyst to speak of relative error rather than absolute error. In this case, both errors will be on the order of 10^-4 of the value being stored in memory.

If this error seems trivial, let us look at an example, albeit a contrived one (more realistic examples will be examined later). For instance, if we wish to evaluate the expression:

\[
\frac{1}{a - b}
\]

where \( a = .89136 \) and \( b = .89134 \). Rounding \( a \) and \( b \) and subtracting, we get 10,000 rather than 50,000, the correct answer. Thus our answer was off by a factor of five even though our round off error was very small. It might be argued that double precision calculation would have eliminated the problem completely. Clearly, accuracy increases with increased word length, but roundoff never disappears. Since some hand calculators use up to 13 decimal digits in storing numbers while displaying ten digits, we might expect them to have "more than enough" accuracy. But in many engineering and statistical problems, calculators can make significant errors. The reader concerned with calculator accuracy might wish to read the short article by Bernard Cole in the November 25 1976 issue of *Electronics*.

The reason for the problem with roundoff, even with 13 digit accuracy, is the situation most frustrating for numerical programmers. Roundoff occurs at every step of any program. In a very long program, roundoff error may have been introduced many millions of times. This error may propagate itself and accumulate into a very large error in the result. Programs in which this propagation of error is likely to occur (finding the inverse of a large matrix, for instance) are generally so complicated that it is impossible to predict precisely what the effect of constant rounding off will be. Often the numerical analyst resorts to probability theory to get an idea of how much error is likely to be in the results.

Errors often become critical when functions are calculated. Let us assume we have a value for the variable \( x \) stored in memory. There is some error associated with \( x \) (perhaps roundoff error, or maybe \( x \) is the result of a physical measurement). We'll call this error \( \delta \). Thus \( x = x_0 + \delta \), where \( x_0 \) is the unknown true value of \( x \). It may be very easy to calculate some function of \( x \), \( f(x) \), but what is the error of the result? Let us define the error of the result as \( \epsilon \). Then:

\[
f(x_0) + \epsilon = f(x_0 + \delta)
\]

If we know our initial error \( \delta \) is small, we would like to assume the error \( \epsilon \) is small as well. If the function is simple, or involves only one variable, we can be confident the resulting error is not large if neither \( \delta \) nor the derivative of the function at \( x_0 \) is large. But what about functions of more than one variable? What about complex algorithms such as the solution to simultaneous equations, often done using a process mathematicians know as Gaussian elimination? Very often, small errors in the input values will yield results which are off by a significantly large amount. So large, in fact, that the results are worthless and the programming is futile. This situation is distressingly common in everyday problems in science, engineering and the social sciences. Numerical analysts call a problem *well posed* if small errors in input still result in a reliable answer. However, even a well posed problem can be solved inaccurately if the programmer has not chosen his algorithm cautiously.

With all this talk about errors, what can be done? Is there any hope at all of obtaining consistently reliable results? Unfortunately, there are no general methods. However, the programmer who is aware of how errors can occur is in a better position to compensate for them. For instance, let's look at the general quadratic equation:

\[
x^2 + 2bx + c = 0
\]

[Note: The expression on the left side of this equation is equivalent to the familiar form used to generate the quadratic formula, \( ax^2 + bx + c \). However, it leads directly to the computationally simpler form of the two roots \( X_1 \) and \( X_2 \ldots CM \) ]
If we have a computer of word length $t$, we might reasonably hope to solve for $x$ by using the formulas

$$x_1 = -b + \sqrt{b^2 - c}$$
$$x_2 = -b - \sqrt{b^2 - c}$$

These formulae work well in most cases, but the astute programmer should notice that there is a problem if $b < 0$ and

$$\frac{|b|}{b^2} < 10^{-T}.$$  

In that case:

$$x_2 = -b - \sqrt{b^2 - c}$$

will give an erroneous result. A programmer who tests for this condition can then calculate the correct result simply, using the relation

$$x_2 = c/x_1$$

For another example, consider the experimenter who wishes to record the temperature of his home hourly, 24 hours a day, and print out the average of the last 24 readings (perhaps he also wants to execute some control operation based on this average). Being inclined toward efficiency, this fellow decides that after having added 24 readings for the first average, for each of the succeeding averages he need only add the newest reading and subtract the oldest from his running total, rather than read all the readings every hour. What might happen here is that small errors which occur during the arithmetic are never disposed of and can accumulate without any upper limit. Perhaps the error might eventually become as large as the measurement itself! If this programmer were not quite so "efficient" and calculated using the last 24 readings each hour, the error would be, at most, 24 times the error for each data point.

Folk wisdom claims, "There's more than one way to skin a cat." Likewise, there's more than one way to do most calculations. $A+B-A$ does not always equal $B$ to a computer. Algebra tells us that $A(B+C) = AB+AC$, but again, the computer sometimes disagrees. It is the programmer's responsibility and challenge to understand his algorithms and to choose them wisely. The reward for the trouble is results he can trust!

**REFERENCE**

A Comparison of Bar Code Encoding Schemes

The purpose of this article is to compare some of the encoding schemes which might be used for bar code software. The three most important characteristics of an encoding scheme are:

- Packing efficiency: how many data bytes per printed page.
- Vulnerability to wand speed changes and other timing errors.
- Number of storage bytes required for timing information, assuming post read processing of timing data.

Other less important factors include human readability and the constancy of DC output level.

Three methods have previously been defined in "A Proposed Standard for Publishing Binary Data in Machine Readable Form," by Walter Banks and Carl Helmers, November 1976 BYTE, page 10: bar width modulation (format 1), ratio recording (format 2), and fixed gap bar width modulation (format 3). The other schemes listed in table 1 include frequency modulation (FM), phase encoding (PE), nonreturn to zero inverted (NRZI), synchronized nonreturn to zero inverted (SNRZI), modified frequency modulation (MFM), group coded recording (GRC) and zero modulation (ZM).

In phase encoding (PE), a 1 is represented by a transition from white to black and a 0 by the opposite transition. Additional transitions are added to account for successive 1s or 0s. The frequency modulation (FM) encoding method provides a transition in either direction at every bit boundary, and an additional transition to mark each 1. The resulting code is very similar to that created by the phase encoding method, since both provide timing information at least once per bit.

The nonreturn to zero inverted (NRZI) encoding scheme generates a black to white (or vice versa) transition for every 1. The absence of a transition denotes a 0. This method has the disadvantage that no timing information is generated during a string of 0s. The synchronized nonreturn to zero inverted (SNRZI) method adds a 1 to every byte to guarantee at least one piece of timing information per byte. If the redundant clock transitions are eliminated from the frequency modulation code, the number of transitions per bit is halved, doubling the possible density of data for a given minimum module width; this is modified frequency modulation (MFM).

Zero modulation (ZM) and group coded recording (GCR) are modifications of the nonreturn to zero inverted method which are designed to guarantee timing information at least once every two or three bits, respectively. In group coded recording, each 4 bit

<table>
<thead>
<tr>
<th>Encoding scheme</th>
<th>Packing density</th>
<th>Timing tolerances</th>
<th>Memory requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average data bit duration (&quot;modules&quot;)</td>
<td>Data bytes per page</td>
<td>Absolute timing tolerance (&quot;modules&quot;)</td>
</tr>
<tr>
<td>Format 2</td>
<td>3</td>
<td>1170</td>
<td>0.5</td>
</tr>
<tr>
<td>Format 3</td>
<td>2.5</td>
<td>1400</td>
<td>0.5</td>
</tr>
<tr>
<td>FM/PE</td>
<td>2</td>
<td>1750</td>
<td>0.5</td>
</tr>
<tr>
<td>Format 1</td>
<td>1.5</td>
<td>2330</td>
<td>0.5</td>
</tr>
<tr>
<td>NRZI</td>
<td>1</td>
<td>3500</td>
<td>0.5</td>
</tr>
<tr>
<td>SNRZI</td>
<td>1.125</td>
<td>3100</td>
<td>0.25</td>
</tr>
<tr>
<td>MFM</td>
<td>1</td>
<td>3500</td>
<td>0.25</td>
</tr>
<tr>
<td>GCR</td>
<td>1.25</td>
<td>2800</td>
<td>0.25</td>
</tr>
<tr>
<td>ZM</td>
<td>1.125</td>
<td>3100</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Table 1. Comparisons of various encoding schemes. Overheads such as parity and sync bytes were not included in the packing density calculations. The maximum timing bytes per data bit were determined assuming perfect bar codes and do not allow for such problems as dirty bar codes.
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unit of data is mapped into a unique 5 bit word chosen to assure no more than two consecutive 0s. In zero modulation each bit is mapped into two bits and the result encoded in nonreturn to zero inverted format. The net result is comparable to that provided by group coded recording with the advantage, useful in the magnetic recording field, of a constant DC level.

All these schemes can be handled relatively simply in software. The deciding factor should be made on other grounds.

Table 1 compares the number of data bytes which can be printed on an 8.5 by 11 inch (21.6 by 27.5 cm) page, assuming a narrow bar width of 0.014 inches (0.04 cm) and a line to line spacing of 0.15 inches (0.38 cm). Several of the methods listed will provide between 2500 and 3500 bytes per page. Since packing density is not particularly critical in this application, the choice should be made on the basis of the remaining and crucial criterion: vulnerability to word speed changes and other timing errors.

It is in this area that the requirements of hand held optical reading diverge from those of machine driven magnetic recording. In the magnetic recording field, short term variations of the relative velocity between the medium and the head are held to a minimum. The designer's main concern is with the absolute value of the permissible phase error; i.e. the amount by which timing error may apparently move a transition before playback errors occur. The speed of a hand held wand may vary widely from place to place on the data track. In this case we are concerned with the permissible percent speed change which can occur between two transitions relative to the average speed over the previous few transitions. This may be calculated as the percentage ratio of the permissible phase error to the maximum time which can occur between transitions.

Table 1 expresses the timing tolerance of each scheme in terms of the permissible speed change and the absolute timing error. Since the modified frequency modulation and zero modulation methods have to distinguish between bars which are 1, 1.5 and 2 modules wide, they are both twice as sensitive as the others to absolute errors such as printing tolerances, and may be rejected for bar code printing for this reason.

The choice between the remainder may be made on the basis of a compromise between packing density and speed tolerance. The percent speed variations listed in table 1 are permissible only in the ideal case, in which printing tolerances and other timing errors are zero. In real life, short term consistency of wand speed is more critical than table 1 makes it appear to be. ASCII code printed by the nonreturn to zero inverted method can have eight successive zeros, even if the null character is not permitted. This leads to a very low speed change tolerance. The synchronized nonreturn to zero inverted method reduces the number of consecutive zeros to five by introducing an extra 1 per byte. Nevertheless, the speed tolerance is still low and both methods may be eliminated for this reason.

Of the remainder, group coded recording has the greatest packing density, by 20 percent, but the others have a 50 percent greater tolerance to speed variations. It is questionable whether the software complication and lower speed tolerance of group coded recording are worthwhile in this application.

This leaves frequency modulation, phase encoding, bar width modulation, ratio recording and fixed gap bar width modulation as alternatives. All these methods have the same speed and absolute timing tolerances. The choice may be made on the basis of packing density. The bar width modulation method comes out far ahead of the other methods. Bar width modulation is the logical choice for the encoding of printed software intended for recovery by a hand held light wand.
Puzzling Machine Language Puzzler

The "Machine Language Puzzler" in BYTE January 1979, page 52 was very interesting. However, I must disagree with the author's detailed analysis of how the program works. It is a CALL FFFD instruction located at address FFFD which repeatedly calls itself, pushing a return address of 0000 on the stack, until all of memory is zeroed including the program itself.

Let's take a detailed look at what happens after memory locations 0001 through FFF2 have been zeroed. First, the CALL FFFD instruction is fetched from locations FFFD, FFFE, and FFFF. This causes the program counter to be loaded with FFFD, and Os are written into locations 0000 and FFFF. At this point the CALL instruction has been changed to a CALL 00FD, but the program does not yet branch to address 00FD as stated. The next instruction is still fetched starting at address FFFD, since the CALL FFFD was fetched from memory before location FFFF changed from FF to 00. Now the CALL 00FD is fetched, Os are written into locations FFFE and FFFF, and the program starts executing NOPs at address 00FD. Note that no NOPs are executed at all until all of memory has been zeroed.

In the case where memory only exists at addresses 0000 to 00FF and 0100 to 01FF, operation of the program is very complex. It proceeds as above through zeroing all existing memory and branching to a NOP at 00FD. When the FF (RST 7) is executed at location 0100, a 0101 is pushed on the stack at locations FFFC and FFFB. Memory continues to fill up with 0101s until a 01 is written at location 00FF. Starting at this point the return address pushed on the stack may be 0101, 0102, or 0103 depending on whether the RST 7 is executed at 0100, 0101, or 0102. Remember that one or two bytes of FF may be read as data of a LXI B, data instructions. The program ends up executing a complex sequence of LXI B, STAX B, and INX B instructions in a loop starting at address 0038 and ending with a RST 7 instruction at 0100, 0101, or 0102. The program will keep changing itself as the stack wraps around forever.

It is still an interesting program. The net effect, in the first case, is still the same. I wonder if a similar program that zeros out all of memory including itself exists for other microprocessors as well?
There is a useful distinction being made today between two types of display terminals: so-called "dumb" terminals perform the necessary functions of data reception, transmission, and display. Their intelligent counterparts, however, are capable of performing sophisticated data manipulations on their own, relieving the host processor of some of the routine burden. The same distinction could be drawn from memory systems. In most machines the memory component forms a passive blackboard: its function, the principal one of any memory, is to remember. Yet memory systems can be built which take a more active processing role.

What kinds of things could a smart memory do? The normal random access memory has unique addresses for its cells, and an address must be provided to read or write information, one cell at a time. The concept of address or location as a necessary attribute of content may be difficult for beginning programmers to grasp. A far more palatable idea to the human thinker is that words, shapes, or sounds serve to "call up" the information associated with them.

Suppose we distribute some intelligence throughout our special memory system, animating it by changing each memory word into a demon. These demons are jumbled about together in a darkened cave, and their principal characteristic is that they recognize when they are being spoken about. Aside from that, they are rather lazy, working only when standing up, and sitting down for a snooze at the earliest opportunity. For example, our demons might represent inventory information for a hardware store.

"Alright, everybody on your feet!"
(Otherwise nobody would pay attention.)
"I want anyone who knows anything about hammers."
(There is a resounding thud as all sorts of appliance demons, chainsaw demons, etc sit down and resume their naps.)
"Specifically, ball-peeve hammers."
(Claw hammer and jackhammer demons drop out, leaving, in this example, one solitary demon.)
"How many do we have on hand?"

We did not need to know where the demon was who answered us. A reply to our query emanated from the mouth of the cave. We don't even know how many demons lurk inside — since all demons work simultaneously, we got our answer in a time independent of their number. Consider what this means for information retrieval: if the preceding "program" takes $N$ microseconds for a file of 10 inventory items, and the file grows to 10,000,000 items, the processing time required is still $N$ microseconds. Therein lies one of the most tantalizing aspects of a memory system like this — adding more information (more memory) improves system performance:

- More items are processed in the same time;
- There are no address space saturation or segmentation problems, since addresses are not used — a single bit signal (on/off) can distinguish accesses to this memory from normal addressed memory requests.

A memory having qualities like those just illustrated is called an associative memory or CAM (content addressable memory). Not too surprisingly, associative computer memories in varying forms have been proposed many times before. The reasons why people

---

**Figure 1:** An example of full word parallel information retrieval.
(including the author) “reinvent” the concept with some regularity are twofold: the descriptions of this form of memory rarely make it past technical parallel machine architecture symposia or journals into the more commonplace world; and the beauty and power of a memory that can by its very nature eliminate or ease searching, sorting, table lookup, and pattern matching is so striking—the idea is so natural in human terms that it occurs to many individuals.

Figure 1 shows a conceptual associative memory word holding information from the previous example. It can be seen that a long word is desirable to store related data. Exact match was the only comparison function used (and is the basic, sometimes only, associative function available in the integrated circuit forms of this memory). A mask is applied to all the words and selects the part of the words to be treated (either matched against, or read out). The comparand is the common information that all words test. Due to the length of associative words, some real designs compare the words with the comparand one bit at a time (bit serial, word parallel). This reduces the amount of comparison logic and size of the data paths to reasonable levels, although a full word comparison takes longer.

Comparisons are usually over lengths much less than the full word size, so the compromise is a good one. With each word there is one separate bit of information for the response status, called the tag. The SET function forces the tags to their responding state (1), thereby activating all words initially. A good survey of associative memory articles and architectures is found in Yau and Fung. There is also a new, easy to follow book on the subject by Foster (see bibliography). The full word parallel design of figure 1 will be used for the examples, since it is the simplest conceptually. A more practical architecture that can be built for an S-100 computer will be outlined in part 2.

Selection

More intelligence can be added to our demons.

"Everybody up!"

(1) SET — Load personnel file from diskette.

"Who, in my employ, — an engineer, brown hair and eyes,"

(2) JOB = "engineer"

& (3) HAIR = "br"

& (4) EYES = "br"

last name “J...” something, between 25 and 30 years old — has been dating my daughter?”

Text continued on page 58.
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Figure 2 shows another example of information retrieval, this time with a personnel file, and again with a single demon finally selected. Response of the demons is shown after each step. Any of the relational comparisons as well as exact match can be added easily to the function set. Information has been broken down into fields and field lengths the user deemed most valuable. Since this word format can be stored on floppy disk with the data, the driving program or operating system has easy access to it and can manipulate the mask to select

the field requested for each operation. A top level program could be as utterly readable as the one given with the example. So far, only the first step in utilizing information in the associative memory has been illustrated — the selection process. The overall set of entries is logically reduced by selection criteria to the subset of interest. Members of the smaller set may now be updated in parallel, or read out (in part, if desired) on some priority basis; the former involves parallel writing of the associative words, and the latter, responder resolution (when there is more than one answer).

Multiwrite

Now that the demons we want are on their feet, what kind of work can they do besides checking their description? They can all be told to change it at the point specified by the mask (ie: all responding words can be made to change their values at once to the value on the comparand bus). This process of writing a common datum, in parallel into all responding words, is called multiwrite responders by Foster, and he calls associative memories possessing this ability CAPPS (content addressable parallel processors). Whole sets of items can be updated (eg: marking certain bills as paid), or, if the selection criterion is known to produce a unique result, more specific information can be written (change John Q Williams job title to manager).

Again, we can be sending these associative write commands into the interior of a dark cave. We know which demons are reacting, but we don’t know where they are, nor do we care. The nearest use of address information occurs when the mask is changed to operate on a specific field (whose relative location inside each word has been previously established).

By setting the mask to enable the writing of only a single bit (or bits), parallel program flags can be kept with each word, recording the word’s membership in some selected group, with the flag itself possibly becoming

---

Table 1: A complete information processing example with parallel update, and the use of disjunctive sets.

<table>
<thead>
<tr>
<th>Command</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) SET</td>
<td>Activate all words.</td>
</tr>
<tr>
<td>(2) MW FL1,FL2,FL3,FL4,0 FL1</td>
<td>Initialize all four flags at once.*</td>
</tr>
<tr>
<td>(3) ADD LASTMO TO STD</td>
<td>STD—STD + LASTMO for all words.</td>
</tr>
<tr>
<td>(4) REGION = 'W'</td>
<td>Select western region salesmen.</td>
</tr>
<tr>
<td>(5) STD &gt; 100</td>
<td>FL1 = 0 marks the members of this group with sales to date over $100,000.</td>
</tr>
<tr>
<td>(6) MW FL1,0</td>
<td></td>
</tr>
<tr>
<td>(7) SET</td>
<td>Eastern region salesmen with sales to date over $75,000.</td>
</tr>
<tr>
<td>(8) REGION = 'E'</td>
<td>Central region salesmen with sales to date over $50,000.</td>
</tr>
<tr>
<td>(9) STD &gt; 75</td>
<td>All salesmen not included in the three* subsets above have FL4 = 0.</td>
</tr>
<tr>
<td>(10) MW FL3,0</td>
<td>The union of the three subsets Any members left in this set?</td>
</tr>
<tr>
<td>(11) SET</td>
<td>Transfer to statement 26 if not.</td>
</tr>
<tr>
<td>(12) REGION = 'C'</td>
<td>READ(LASTNAME,FIRSTNAME)</td>
</tr>
<tr>
<td>(13) STD &gt; 50</td>
<td>PRINT(LASTNAME,FIRSTNAME)</td>
</tr>
<tr>
<td>(14) MW FL3,0</td>
<td>Read the specified fields of the first responder and print them.</td>
</tr>
<tr>
<td>(15) SET</td>
<td>Turn off first responder (select next one).</td>
</tr>
<tr>
<td>(16) FL1,FL2,FL3 = 1112</td>
<td></td>
</tr>
<tr>
<td>(17) MW FL4,0</td>
<td></td>
</tr>
<tr>
<td>(18) SET</td>
<td></td>
</tr>
<tr>
<td>(19) FL4 = 1</td>
<td></td>
</tr>
<tr>
<td>(20) QUERY</td>
<td></td>
</tr>
<tr>
<td>(21) JUMP Z, (26)</td>
<td></td>
</tr>
<tr>
<td>(22) READ(LASTNAME,FIRSTNAME)</td>
<td></td>
</tr>
<tr>
<td>(23) PRINT(LASTNAME,FIRSTNAME)</td>
<td></td>
</tr>
<tr>
<td>(24) NXT</td>
<td></td>
</tr>
<tr>
<td>(25) JUMP (20)</td>
<td></td>
</tr>
<tr>
<td>(26) END</td>
<td></td>
</tr>
</tbody>
</table>

Text continued from page 55:

& (5) LASTNAME = "J?????????????"
& (6) AGE > 25
& (7) AGE < 30
& (8) SEX = "m"
"Has he had a raise lately?"
(9) READ(LASTNAME, FIRSTNAME)
(10) READ(LASTRAISE)
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part of future selection criteria. Alternatively, these flags might be used to save carry or overflow information during parallel arithmetic routines. Indeed, combining these program variables with further comparison sequences makes possible a whole list of parallel associative routines like:

MAXIMUM
MINIMUM
NEXT GREATER THAN
NEXT LESS THAN
ADD or SUBTRACT constant
ADD or SUBTRACT fields
STRING SEARCH (pattern matching)
SORT on any field.

Figure 3 demonstrates the method of flagging responding words, table 1 shows a complete information processing example with parallel update, and the use of disjunctive sets.

Responder Resolution

When it becomes necessary to get information out of the words rather than just updating them in place, some form of arbitration is required to handle cases of multiple responders. It is useful to have a query function to tell if there are any responding words. "Is anybody in there?" Any demons sitting down and asleep would not answer, and any amount of simultaneous yes replies would still be interpretable. In fact, any answer at all, except total silence, indicates there is at least one responder. A single, readable bit line on which each word ORs its tag (responder = 1) would tell the central processor whether or not any active words were left. (With some analog hardware we might even count the number of responders by measuring the intensity of the answer.)

It is not acceptable to walk to the mouth of the cave and yell inside, "I want the name of anyone who speaks French." If only one standing demon meets this requirement, the answer you hear will be true, but in general you may expect to be greeted with an unintelligible mixture of voices. To handle the problem, a priority list can be implemented at the hardware level. All words in the system are daisy-chained together to one word arbitrarily defined as having the highest priority. When an associative read is executed, a small amount of time is allowed for the chain to select the highest priority responder, and that responder alone is enabled to place its requested field(s) on the data in bus to the processor. With a companion function, Next, which turns off the first responder, information may be extracted serially from each active word without addresses and without conflict.

Without addressing, we are able to do the following: select via content those words we want (in parallel); process them in place (in parallel); and read out their information (serially).

Entering data into an associative memory initially is a serial operation, so provision is often made for random access addressing. With absolute fixed addresses, associative memory may be quickly loaded from secondary storage or main memory through DMA (direct memory access) or block transfers. Random access reads and writes are both allowed. To save address space when using this addressable associative memory, the memory may be arranged into banks occupying the same locations. Random access memory requests affect only the addressed memory section whose bank is selected; associative instructions ignore bank information and activate the whole memory.

Given the addressing order now placed on the memory, an alternative to the priority list responder resolution hardware is available. The tags of words sequential in address space may be blocked into groups and led to the central processor as data from special input ports or memory locations. The processor can then scan the bits in order for 1s (responders). Since tag N represents word N in the associative mem-

Figure 3: Multiwriting allows the user to write data into all locations that are responding at the same time.

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Memory. VP-570 RAM Expansion Board adds 4K bytes of memory. Jumper locates RAM in any 4K block of up to 32K of memory. On-board memory protect switch. $95.

EPROM Programmer. VP-565 EPROM Programmer Board comes complete with software to program, copy and verify 5-volt 2716 EPROMs—comparable to units costing much more than the VP-565 and VIP put together! Programming voltages generated on board. ZIF PROM socket included. $99.

EPROM Interface. VP-560 EPROM Interface Board locates two 5-volt 2716 EPROMs (4K bytes total) anywhere in 32K of memory. VIP RAM can be re-allocated. $34.

ASCII Keyboard** Fully encoded, 128-character ASCII encoded alpha-numeric keyboard. 58 light touch keys including 2 user defined keys! Selectable upper and lower case. Handsomely styled. Under $50.

Auxiliary Keypads. Program your VIP for 2-player interaction games! 16-key keypad VP-580 with cable ($15) connects to sockets provided on VP-590 Color Board or VP 585 Keyboard Interface Card ($10).

Tiny BASIC** VP-700 Expanded Tiny BASIC Board puts this high-level language on your VIP. BASIC stored in 4K of ROM. Ready for immediate use—no loading necessary. This expanded BASIC includes the standard Tiny BASIC commands plus 12 additional—including color and sound control! Requires external ASCII encoded alpha-numeric keyboard. $38.

COSMAC VIP lets you add computer power a board at a time.

With these new easy-to-buy options, the versatile RCA COSMAC VIP (CDP18S711) means even more excitement. More challenges in graphics, games and control functions. For everyone, from youngster to serious hobbyist. And the basic VIP computer system starts at just $249* assembled and ready to operate.

Simple but powerful—not just a toy.

Built around an RCA COSMAC microprocessor, the VIP includes 2K of RAM. ROM monitor. Audio tone with a built-in speaker. Plus 8-bit input and 8-bit output port to interface relays, sensors or other peripherals. It's easy to program and operate. Powerful CHIP-8 interpretive language gets you into programming the first evening. Complete documentation provided.

Take the first step now. Check your local computer store or electronics parts house. Or contact RCA VIP Marketing, New Holland Avenue, Lancaster, PA 17604. Phone (717) 291-5848.

* Suggested retail price, does not include video monitor or cassette recorder.
** Available 1st Quarter, 1979.
ory, an absolute word address can be derived and information read random access style.

The accessing of data via address makes this second responder resolution technique nonassociative, but it is sometimes used to avoid the extensive hardware of the priority list.

**The Real Time Pinch**

When the first generation of computers was being built, hardware was critically expensive, and the von Neumann architecture—a general purpose design which truly minimizes hardware through serial processing was not seriously questioned. With the plummeting cost of electronic parts, minimizing hardware has become less important to the designer. The desire to maximize throughput, particularly in multiuser situations, has led to the introduction of parallel processing at all architectural levels with the concomitant increase in hardware complexity—from multiprocessor systems, to machines incorporating multiple independent I/O (input/output) channels, down to distributed processing logic, as in an associative memory. The concept of a general purpose parallel computer is quite hazy, so the thrust has been to build specialized hardware for the von Neumann machine to deal with the parallel components of computing as they are recognized.

Some products for associative processing are commercially available. On the high end, STARAN is a very expensive associative machine from Goodyear Aerospace, and may be the only machine of its kind for sale. On only a slightly less grand level, there are a few 16 bit or smaller CAMS (integrated circuit associative memory integrated circuits), which even in quantities of 100 carry a price tag of about $1.50+ per bit. They are fast parts, some with speeds in the 10 to 40 ns range. IBM also uses such fast, and small associative memories in the virtual memory hardware of the 360/67 for quick address lookup. But associative memory for a large computer subsystem need not be nearly so fast, nor could it be tolerable at such a price. Cost, in the world of electronics, is not necessarily a function of complexity, but of volume.

Unfortunately, large manufacturers must usually see millions of projected sales before entering the marketplace with anything really new. Big businesses, meanwhile, cannot afford to walk away from years of accumulated software on their present machines, no matter how cumbersome. Software is expensive to create and maintain, so big installation inertia will keep sales volume at a trickle. Yet given the ubiquity of sorting, searching, merging, updating, and linking in such business systems, it is no small irony that a judiciously used associative memory subsystem could in many cases greatly reduce software complexity, and therefore expense (not to even mention greatly increase program speed).

To review, costs will not come down, nor viable products become available until expected sales volume goes way up, and at $1.50 per bit... The cycle, representative of large scale business, may perhaps be broken at the new grass roots level—the home, small business, or research system where inertia is at a minimum. An add-in associative memory can be designed with off-the-shelf integrated circuits and random access memories for a cost to memory ratio of only 2 or 3 to 1. This memory design is discussed in part 2 (May 1979 BYTE).

**BIBLIOGRAPHY**


Horizon Disk Capacity Keeps Growing

The Horizon is now capable of 720K bytes on-line! The Horizon can connect to four double density 5¼" single-sided disk drives. Each of those drives can access 180K bytes of information. A four drive system accesses 720K bytes! That’s capacity you don’t usually find in a microcomputer, but there’s even more to come! The North Star disk controller board is designed so that two-sided disk drives may be added as soon as they become available from North Star.

Existing Horizons will accommodate the new two-sided drives so North Star owners can simply add additional drives to up-grade their system. Each two-sided drive will access 360K bytes! That means the maximum on-line disk storage for the Horizon will increase to over 1.4 million bytes!

New Cabinet for Disk Drives

North Star additional disk drives are now available with the same high quality wood cover as the Horizon computer! The Additional Drive Cabinet (ADC) is designed to accept either one or two drives for the Horizon or for mounting North Star Micro Disk System drives. Like the Horizon, the ADC is available with either wood or blue metal cover. Included is a new power supply capable of powering one or two drives. The ADC is $129 in kit form. Assembled, with one drive the ADC is $599, with two drives $999.

Pascal Now Available for Horizon

The much-heralded Pascal language is now being offered for use with the North Star Horizon computer. North Star, with the co-operation of the University of California at San Diego, is now delivering a Pascal Program Development system. North Star Pascal is ideally suited for developing large programs because of features such as: long variable names, block-structured control statements, and compilation.

North Star Pascal is available on 5¼" diskettes for use with the Horizon or Micro Disk System. North Star Pascal will operate with either the Z80 or 8080 microprocessor.

Pascal, including documentation, is available in either single or double density versions for $49.

An auxiliary Pascal diskette, containing an 8080/280 assembler and some additional Pascal utilities, is available for $29. Complete Information is available at your local retail computer store.

First Double Density, Now Double Memory

The new North Star 32K RAM board (RAM-32) has doubled the memory density of the popular Horizon computer. Available either with the Horizon or other S-100 bus computers, the RAM-32 runs at full speed—no wait states—with the 4 MHz Z80A microprocessor (as well as with slower Z80 and 8080 processors). Addressability of the RAM-32 is switch-selectable in four 8K regions.

North Star RAM features like bank-switching and parity checking are standard. The parity checking capability means that the RAM-32 is constantly diagnosing itself. That’s a plus for your system. The fact that parity checking is a North Star RAM-32 standard is a plus for your pocketbook! There is no extra charge for this important capability.

A Horizon with 48K of RAM can be configured by using one North Star 16K RAM board and a RAM-32. Need more memory? 56K can be configured by using two RAM-32 boards with one 8K region switched off.

NORTH STAR MDS, ZPB, FPB FOR OTHER S-100 COMPUTERS

Upgrade your system with these North Star products—available for any S-100 computer: Micro Disk System—a complete 5¼" floppy disk system, Z80 Processor Board, or the Hardware Floating Point Board.

Horizon and RAM board prices are:

<table>
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<td>RAM-16</td>
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A typical Horizon configuration: CRT, Horizon computer, Additional Drive Cabinet (ADC).
Motorola 6809 Card Folding

A useful item of documentation furnished with the Motorola 6809 microprocessor is the MC6809 Microprocessor Instruction Set Summary card. Printed on heavy stock, it contains vital information for the programmer in condensed form. This combination of heavy stock and condensed information gives this document an information density of 4.72 x 10⁷ characters per slug, a figure imaginable only with advanced technology.

Users who peruse the card, however, might have difficulty in refolding it to its original compact configuration. Therefore we present here helpful instructions to refold the card.

The first step is to differentiate between the pages of the card. Luckily, this is much easier than integrating between the pages, or even reading between the lines. Here we employ the convention of using letters of the English alphabet. Upper case is preferred for clarity, but lower case may be employed if you are coding a word processing system.

Having identified the pages, you are now ready to begin the actual folding process. Grasp the bottom page J. Fold it up on top of page I. Now take page I, and fold along the F-G seam so that the back side of page I contacts the back side of page D. Take care that page J does not become unfolded from I.

Take heart, we’re almost through. Grasp the top edge of page G and fold along the C-D seam so that the front side of page G contacts the back side of page A. Moving quickly now, fold the front side of page C to the front side of page B. Take the A-G aggregate, and fold the whole thing back onto page E. The folding process should now be complete, and the card returned to its original state.

User options at this point include: placing the card in your pocket, placing the card in a desk drawer, or binding the card with a paper clip.

Note please, that these instructions are based on preliminary folding information provided by Motorola. It is possible that actual production sample of the card will have a different foldout specification.

In addition to its unique topological properties, the card will be of interest because of the information printed on it. Included are addressing mode summaries, operation descriptions, register bit assignments, vectors and stacking order, and miscellaneous data…RS

NE Computerized Bulletin Board

We have received an announcement from the New England Computerized Bulletin Board System informing us that they have been in operation since December 1977. In order to connect to the CBBS, a terminal with a modem or acoustic coupler and a phone line is necessary. The procedure is as follows: set your terminal to 300, or 110 bps (30 or 10 characters per second) full duplex. Dial (617) 963-8310 and wait for the carrier. Place the phone in the acoustic coupler and hit carriage return on your terminal a few times. The CBBS will then respond and take you the rest of the way.
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Street ___________________________
City/State/Zip _______________________

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At one time or another, each of us lets our imagination wander; perhaps to places familiar to us, or places we have never been and can only dream about exploring. Often, my imagination leads me to the questions: "What does our sun look like from neighboring stars?" and "What do our familiar constellations look like from other points of view?" Have you ever wished that you could travel anywhere in the universe whenever you wanted to? With the help of computers and graphics displays we can begin to answer some of these questions and have fun exploring what we know about the galaxy at the same time.

Getting Started

Several things are needed to simulate the stars in our galaxy; an algorithm that will allow us to shift our position with respect to the Earth based coordinate system; actual or hypothetical coordinates of stars; and a display device on which to plot the resulting star maps. The first version of this program was written four years ago and run on an IBM 1130 computer. Output was in the form of a printer plot. 50 stars were entered, using data on the 50 brightest stars in our sky. Since positions given in star catalogs are in celestial (spherical) coordinates, right ascension (RA) corresponding to longitude (0 to 23 hours), declination (DEC) corresponding to latitude (−90 to +90 degrees), and distance in light years were entered directly into a disk file. The program then performed the necessary conversions to get values in radians. Figure 1 shows the celestial coordinate system.
The author wishes to thank TRC Photographic Specialists of Omaha NE for their help.

Coordinate Transformations

In order to display the stars as they would appear from another point in space, their coordinates must be converted to a manageable form. Shifting the origin of the coordinate system appears to be the easiest way to obtain the desired results. Declination and right ascension must be converted to radians first:

\[
\begin{align*}
RA &= RA \times 0.261799 \\
DEC &= DEC \times 0.01745
\end{align*}
\]

where RA and DEC represent right ascension and declination, respectively. Then the celestial coordinates can be converted to rectangular coordinates:

\[
\begin{align*}
X &= R \times \cos (DEC) \times \cos (RA) \\
Y &= R \times \cos (DEC) \times \sin (RA) \\
Z &= R \times \sin (DEC)
\end{align*}
\]

The resulting rectangular coordinates are in units of light years, because of the variable R (distance). The coordinates may be kept in three arrays for easy manipulation.

Next, the origin must be shifted to the new point of view. The celestial coordinates of the destination or new origin are given by the user of the program (through console input) and converted to rectangular coordinates with the same set of equations used above. To shift the origin, the following three equations should be used:

\[
\begin{align*}
X' &= X - X_0 \\
Y' &= Y - Y_0 \\
and \quad Z' &= Z - Z_0
\end{align*}
\]

where \( X_0, Y_0, \) and \( Z_0 \) are the rectangular coordinates of the new origin; \( X, Y, \) and \( Z \) are the old coordinates of a star in the three arrays; and \( X', Y', \) and \( Z' \) are the resulting shifted coordinates.

To display the stars, the rectangular coordinates must be converted back to celestial coordinates:

\[
\begin{align*}
(R')^2 &= (X')^2 + (Y')^2 + (Z')^2, \\
\text{RA}' &= \arctan \left( \frac{Y'}{Z'} \right), \\
\text{DEC}' &= \arcsin \left( \frac{Z'}{R'} \right).
\end{align*}
\]

It is also necessary to multiply by the appropriate scale factors to be compatible with the screen or window dimensions of the display device. The current version of the program displays the stars in the form of a Miller projection, as shown in figure 2. This produces a distorted view on the top and bottom of the display but does show the entire sky. An alternate format magnifies the window to display only a 50 by 50 degree frame. This gives the impression of looking out the window of a spaceship, but makes navigation difficult.

In order to shift the window, we must introduce some new variables to indicate in the program which rotations are required. This can most easily be accomplished by altering the equations used for shifting the origin:

\[
\text{Text continued on page 70}
\]
At this time I wish to introduce myself. I am PERRY POLLOCK, the owner, manufacturer and designer of the products advertised in this issue of this fine magazine. In the issues to come, I will be introducing more powerful interfaces for the various popular computers.

To take advantage of this opportunity, I would like to tell you a little about my beliefs, aims and policies. Starting out as a hobbyist, I realize your needs, concerns and most of all the requirements of a good, well designed and fairly priced interfaces for your computer. It is my goal to supply you with the most for your investment and the highest quality possible.

All the products are designed by me. They are first drawn out and logically analyzed. Then they are wire wrapped and tested. When I am satisfied that it functions well, then I will etch a sample printed circuit board, then and only then, will I commit the design to a mass production run.

All the parts used in our products are of the highest quality. The manuals are written so you can understand all the phases of construction and operation. How many times have we bought a product and it lacked for a good, understandable manual, or has it had so many flaws that we could swear that we were re-designing the product. ALL OF THIS IS IN THE PAST. These products are not offered unless they are right!!!!

Another one of my aims is to let you know who you are dealing with. How many times have we ordered a product and wondered who we were really dealing with. Then... if we had problems, how difficult was it to contact them? Because of all this, I have chosen to publish a picture of myself (I'm not vain, really) and a picture of my wife Korrine (pictured below). I am available 24 HOURS A DAY. I have a telephone answering service that will put your call through to me anytime day or night, or if you wish you can call me at home. (602) 886-5037. If you have a problem, question or just want to talk, give me a call.

I have many exciting new products under development. It will be an exciting year and I hope you will enjoy the interfaces designed for you and I. I know these interfaces have made my computer more enjoyable for me and hopefully for you.

Sincerely,

Perry and Korrine Pollock
Your fellow computerists
WORLD POWER SYSTEMS, INC.

P.S.: My guarantee... If you are not satisfied with the product, return it to your dealer or me for a full refund within 5 days of purchase.
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- HIGH QUALITY: The highest quality parts are used. P.C. Board is with plated through holes, solder mask, silk screen legend and gold plated contacts.
- OUTPUT ARRANGEMENT: All outputs terminate at the top of the card via a 26 contacts. Standard 26 pin IDC connectors mate with each port. RS-232, current loop at each serial port and full data lines at the parallel port connection. Operation is asynchronous mode, but can be configured for synchronous operation by minor re-configuration.
- FULL DOCUMENTATION: A complete manual of operation and construction is included. Easy construction and 3 hours is the estimated construction time. Just plug in, set the switches and enjoy all the different configured software. NO MORE changing the software to match your I/O board. Just set the board and enjoy.

Kit

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...galaxy to what it actually looks like. The stars listed should be enough to produce interesting patterns in a reasonable amount of home computer time. Names (popular or scientific) are rough approximations in English alphabet. An asterisk represents fictitious "fill-out" stars to represent extragalactic objects.

Table 2: Star coordinates taken from star atlases and catalogues. Besides using real stars, the author also input 300 "imitation" stars to fill out the galaxy to what it actually looks like. The stars listed should be enough to produce interesting patterns in a reasonable amount of home computer time. Names (popular or scientific) are rough approximations in English alphabet. An asterisk represents fictitious "fill-out" stars to represent extragalactic objects.

Table 2 continued on next page.

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<tr>
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<td>100.0</td>
<td>3.1</td>
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</table>

Table 2 continued on next page.

<table>
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<tr>
<th>Number of Stars</th>
<th>IBM-1130</th>
<th>8080/BASIC</th>
<th>8080/ASM</th>
<th>IBM 370/158</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>4 minutes</td>
<td>10 seconds</td>
<td>0.5 seconds</td>
<td>0.1 seconds</td>
</tr>
<tr>
<td>100</td>
<td>6 minutes</td>
<td>100 seconds</td>
<td>5.0 seconds</td>
<td>0.3 seconds</td>
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<td>8 minutes</td>
<td>400 seconds</td>
<td>20.0 seconds</td>
<td>1.0 seconds</td>
</tr>
</tbody>
</table>

Table 1: Execution times of one iteration of the program with various numbers of stars. Times include plot or display device data transfer rates.

Text continued from page 67

where:

\[
X' = (X - X_0) (\cos \phi) (\cos \theta) + (Y - Y_0) (\sin \theta) (\cos \phi) + (Z - Z_0) (\sin \phi)
\]

\[
Y' = (Y - Y_0) (\cos \theta) - (X - X_0) (\sin \theta)
\]

\[
Z' = (Z - Z_0) (\cos \phi) - (X - X_0) (\cos \theta) (\sin \phi) - (Y - Y_0) (\sin \theta) (\sin \phi)
\]

will become:

\[
X = X - X_0,
\]

\[
Y = Y - Y_0,
\]

and

\[
Z = Z - Z_0.
\]

Also, when converting back to celestial coordinates, scale factors must be introduced to produce a 50 by 50 degree field of view. The user may wish to experiment with other window formats.

Expanding the Model

Looking at the sky from various points of view in space is interesting, but I have found that animation really shows the power of the simulation technique, and of animated graphics. With the coordinates of over 400 stars (100 real stars and 300 that add the general shape of the Milky Way spiral arms of our own galaxy), we can begin the exploration of our universe. Unfortunately, 400 stars do not make a galaxy, or even a small

About the Author

Mark Dahmke is currently employed by the University of Nebraska Computer Network as a programmer/analyst in the Academic Computing Services section. He is also a senior computer science major. At home Mark owns an 8080 based system with 32 K bytes of memory and a floppy disk drive. His work involves graphics, electronics, writing and systems programming.
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Table 2, continued:

D.LEO
Z.LEO
M. LEO
R.D sea

sea

TH. sea
SHAULA
E. sea
K.SCO
D.SCO
G.SCO
POLLUX
CASTOR
E.GEM
GEM
D.GEM
Y.CAS
A. CAS
B.CAS
D. CAS
E.CAS
D. TAURUS
TAU
HYADES
E. TAU
E URSAE MAJ
DUBHE
N. UMA
MIZAR
D.UMA
B. UMA
Y.UMA
B CRUCIS
A CRUCIS
E CANIS MAJ
ACRUX
E. CARINA
B. CARINA
A.TRIA
MIRFAK
Y.VEL
ALHENA
KAUS. AUST
ALWAZOR
MURZIM
D. VEL
ALNITAK
B. AURIGAE
PEACOCK
POLARIS
Y. UMI
N.UMI
D. UMI
E. UMI
TH. UMI
A.OPH
NUNKI
A.AND
ALPHARD
AL NA'IR
SU HAIL
B. PER ALGOL
A.ARI
B. GRUS
B. CETI
B. UMI
I. CARINA
TH CENT.
D. PUPPIS
Y1. AND.
ALPHECCA
Y. CYGNUS
B.AND
Y. ORA
N. CMA
A. PHE
E.PEG
A. PEG
N.OPH
Y. CRV

72

11.217
10.250
09.850
15.900
16.883
17.567
17.500
16.783
17.650
15.938
16.883
07.705
07.523
06.700
06.217
07.300
00.900
37.833
00.108
01.400
01.867
05.383
05.633
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04.450
12.863
11.000
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12.233
10.980
11.867
12.746
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09.217
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08.133
36.583
18.350
07.100
06.342
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01.530
01.620
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09.100
03.082
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22.650
00.683
14.850
09.267
14.067
08.033
02.033
15.550
20.333
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00.400
21.700
23.033
17.125
12.217

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021.000
023.567
026.167
-28.500
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-42.967
- 37 .067
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-39.000
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360.0
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44.0
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300.0
300.0
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45.0
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100.0
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350.0
300.0
300.0
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100.0
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88.0
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325.0
220.0
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100.0
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160.0
650.0
300.0
70.0
400.0
84 .0
160.0
470.0
500.0
700.0
650.0
550.0
750.0
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200.0
91 .0
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100.0
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270.0
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100.0
76.0
130.0

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3.6
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1.6
.9
1.7
1.8
1.8
1.9
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1.9
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2.1
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4 .7
5.7
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2.3
2.3
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2.3
2.4
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2.5
2.6
2.6
2.8

fraction of it, but with a little imagination
(which was all we had in the first place) we
can mentally fill the gaps in the model. The
current version of the simulation runs on an
IBM 370-158 with a 2250 graphics display
unit. The 2250 has a resolution of 4096 by
4096 points. With a slight modification to
the program, it will run in a continuous
loop, starting with a direction vector and
velocity in light years per iteration. The
effect is that of a space craft with almost
unlimited velocity . With a fast processor, the
impression of speed is dramatic. Velocities
of ·10,000 light years per second have been
simulated . There are no relativistic effects,
but it might be interesting to add the nec­
essary equations- especially if color graphics
are avai lable. The Doppler shi fts would be
most striking. The stars in the direction of
travel would be intensely blue, while those
receding from the observer would be a deep
red.
Adding More Stars
As my desire to travel outward increased,
soon reali zed that I would have to have
something to travel to. Additions to the
mode l included the Andromeda galaxy
(approxim ately 1.5 million light years away),
the Magellanic clouds (our nearest inter­
gal ac tic neighbors} and severa l other extra­
galactic objects. One problem with adding
more stars is that the execution time goes up
proportionately. When experimenting with
computer based simul ations, this soon be­
com es apparent. Note that in listing 1, the
algorithms have been optimized to the
ext re me, to cut down on the execution time.
Comparison Les ts were run on several sys­
tems with the results shown in table 1.
The IBM-1130 was slowed down by its
printer, used to generate a printer plot of
the star map. The 8080 is almost fast enough
to compete with the 370, if it didn't have to
do the floating point calculations in software.
A floating point hardware board would
probably decrease the ti mes given for the
8080 by a factor of 10. The 370 is a multi­
programming system- running several other
programs a l th e same time. Thus, the simula­
tion has to compete with other programs
and is also slowed down by competition for
peripheral devices such as video terminals,
the 2250 graphics display, printers, and card
readers .
Implementation
The details of implementation depend on
the computer, display device, and language
used. The original IBM-1130 version used a
printer plot because that was the o nl y out­


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put device available. Since the available memory was limited (8 K words), the program was written to make heavy use of disk files for storage of the starting coordinates and intermediate results. The last phase of the program scanned the disk file containing the shifted coordinates and produced a printer plot.

The second version ran on an IBM/360-65 and plotted on a Tektronix 4013 graphics display terminal. Although neither of these first two versions was animated, single star maps could be obtained.

The 2250 version required considerably more programming effort. Since the 2250 is a high speed device, true animation was finally possible. The 2250 refreshes its display from a core buffer loaded from the processor. Coordinates are plotted and mapped into the buffer; subroutine EXEC is then called and the entire buffer is sent to the display. Unfortunately the buffer must be cleared before another iteration can take place—but clearing the buffer also clears the screen. The solution is to maintain two separate buffers. One can be displayed on the screen while the other is being cleared and loaded. If this is not done, the display will flicker with a duty cycle of about 10 percent on, 90 percent off, since the calculation time is greater than the intermediate display time.

Sample Output

Photo 1 is a side view of our galaxy from 90,987 light years. As you can see, the model is not accurate because the middle of the galaxy is almost empty. Also, the large bright spot on the right side of the galaxy represents the tight group of 100 stars that form our local constellations. At the bottom of the screen distance, right ascension, declination, and velocity have been displayed for reference. The minus sign on the distance means that the direction of travel is opposite the direction the right ascension/declination vector. Photo 2 is a view of our galaxy from -5983 light years. Photo 3 shows the sky from Earth (note the Big Dipper in the upper center, Leo just above and right of center, and the Milky Way down the left and across the middle). Photo 4 shows our local constellations from 2937 light years, against the background of the Milky Way. Photo 5 is another side view of the Milky Way from one million light years (viewed with the 50 by 50 degree window). The two small objects just below and to the right of the galaxy are the large and small Magellanic Clouds. They are approximately 100,000 light years from the Milky Way.
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- Times to 59 min. 59.99 sec. with auto reset
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- Three stopwatches in one: single event, split (cumulative) and timer (sequential timing)
- Uses 3 penlite batteries
- Size: 4.5" x 2.15" x .90"

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**Jumbo 6-Digit Clock Kit**
- Bright .300 ft. common cathode display
- Uses MM5314 clock chip
- Switches for hours, minutes and hold functions
- Hours easily viewable to 20 feet
- Simulated walnut case
- 115 VAC operation
- 12 or 24 hour operation
- Includes all components, case and wall transformer
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- 115 VAC operation
- 12 or 24 hour operation
- Includes all components, case and wall transformer
- Size: 6-3/4" x 3-1/8" x 1-3/4"
C PLOT POINTS HERE, USING THE APPROPRIATE SUBROUTINE CALLS FOR THE
AVAILABLE DISPLAY DEVICE.

DO 1 I = 1, 400
READ (5, 100) CRA, CDEC, CDIST

C FIRST, CONVERT CRA, AND CDEC TO RADIANS
CRA = CRA * .261799
CDEC = CDEC * .9745

10 FORMAT (3(10F7.3))

1 CONTINUE

10 DIST = DIST + VEL

C NOW COMPUTE THE NEW LOCATION IN SPACE FROM RA, DEC, DIST.
AXY = DIST * COS (CDEC)
AY = AXY * SIN (CRA)
AZ = DIST * SIN (CDEC)

C NOW ENTER THE INNER DO LOOP WHERE THE SHIFTED COORDINATES

C NOW ADVANCE THE DISTANCE COUNTER BY ADDING THE VELOCITY FOR ONE
C ITERATION.

DO 20 I = 1, 400
XP = FX(I) - AX
YP = FY(I) - AY
ZP = FZ(I) - AZ
NRA = ATAN (YP / XP)
IF (XP .LT. 0.) NRA = NRA + 12.
IF ((XP .GT. 0.) .AND. (YP .LT. 0)) NRA = NRA + 24.

C TEST FOR QUADRANTS MESSED UP BY THE ARCWTANGENT FUNCTION.
IF (XP .LT. 0.) NRA = NRA + 12.
IF (XP .GT. 0.) AND. (YP .LT. 0) NRA = NRA + 24.

C TEST FOR SCREEN LIMITS.
IF (NRA .GT. 24.) NRA = NRA - 24.
IF (NRA .LT. 0.) NRA = NRA + 24.

C CIGNAL POINTS HERE, USING THE APPROPRIATE SUBROUTINE CALLS FOR THE
C AVAILABLE DISPLAY DEVICE.

CALL P POINT (-NRA, NDEC)

C CLEAR SCREEN; PREPARE FOR NEXT ITERATION.

C TEST FOR CONSOLE INPUT; CHANGES IN DIRECTION, VELOCITY, SCREEN
C WINDOW FRAMING, ETC.

GO TO 10

STOP END

Listing 1: Generalized FORTRAN version of galaxy simulation. This program
can be converted almost directly into BASIC. Note: for those people not
having an arccos function: arccos function: arccos (x) = arctan (x / sqrt (1-x^2)).
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- COMPLETE WITH CABINET: Has attractive sloping cabinet
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- EASY CONNECTION: Plugs into TRS-80 expansion port edge card rear of keyboard or between keyboard and expansion interface
- 2-EDGE CONNECTORS: 2-additional expansion 40 pin edge connectors
- NEEDS NO SOFTWARE: Operates from OUT and IN statements from BASIC or machine code statements. Example: (Out 5, 1-turn on switch 5. Out 5, 2-turn off switch 5, etc.)
- COMPLETE MANUAL AND SAMPLE PROGRAMS: Comes with comprehensive manual

Model MCC-K (kit) $129.95
Model MCC-A (assem.) $159.95

EPROM PROGRAMMER +3
- SELF CONTAINED: Comes housed in an attractive cabinet with self contained power supply
- PROGRAMS: This unit programs the popular 2708, 2716 Eproms. Personality modules for other Eproms will be available at a later date
- FIRMWARE: On board firmware so that no software need be written or entered into your CPU system. The firmware can be shut off when not in use. Firmware resides at FF000. The firmware in and out of system is controlled from a switch on front panel
- 3-ADDRESSABLE ROM LOCATIONS: The Eprom Programmer has three sockets on front panel which are addressable to any location by dip switch. In addition each ROM location can be shut off or turned on by switches located on the front panel
- MONITOR: A monitor is supplied within the firmware for performing several functions. Move memory, debug, verify, program from memory, program from TTY input, etc
- EASY CONNECTION: The Eprom Programmer is attached with ease. For the TRS-80 users, the unit plugs into the rear of the keyboard or between the keyboard and expansion interface. Included with the unit are two additional 40 pin edge connectors for interfacing to other interfaces. For the S-100 users, a molded connection cable is supplied and it is inserted into one of the connectors on your mother board. Plug it in and it is ready to use
- FULLY BUFFERED: add address and data lines are fully buffered
- OTHER FEATURES: Other features include status lights for which ROM selected, switch enable for programming, pulse (burn) indicator, firmware select/deselect switch, on and off

Model EPR-80K (kit) $129.95
Model EPR-80A (assem.) $159.95

SERIAL PARALLEL I/O MODULE
THIS POWERFUL INTERFACE MODULE ALLOWS THE TRS-80 COMPUTER OWNER TO COMMUNICATE OVER 8 SEPARATE RS-232 OR PARALLEL CHANNELS. ALL SELECTABLE FROM A SIMPLE COMMAND IN LEVEL-II OR DISK BASIC OR MACHINE CODE. NOW YOU CAN INTERFACE PRINTERS, TAPE READERS, OTHER RS-232 OR CURRENT LOOP SERIAL DEVICES OR ANY PARALLEL DEVICE.

- 8-SERIAL INPUT/OUTPUT PORTS: Fully buffered
- 8-PARALLEL INPUT/OUTPUT PORTS: Fully buffered
- EASY CONNECTION: Connects to the expansion port edge card connector between keyboard and expansion interface or direct to rear of the TRS-80 keyboard
- DIP SWITCH: All ports, baud rate, parity, etc all set by dip switches
- ON BOARD FIRMWARE: No software driver routine needed for operation of the module
- RS-232, CURRENT LOOP: All 8 channels can be selected for RS-232 or current loop
- BAUD RATE SELECTION: All channels dip switch selectable for individual baud rates from 110 to 9600 baud
- COMPLETE DOCUMENTATION: Complete instruction manual. Just plug in and set the switches and you are able to communicate with the outside world. This module also includes 2 additional 40 pin edge connectors for connection of other interfaces

Model MS10-K $129.95
Model MS10-A (assem.) $149.95

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1161 North El Dorado Place, Tucson, Arizona 85715
24 Hours Order Phone No: 602-886-2537
(Dealers: Write or phone for information)
STOCKING DISTRIBUTOR FOR SOUTHERN CALIFORNIA CONTACT: CALIFORNIA DIGITAL 213-679-9001
WATCH FOR MODULE "50"

*Trademark: Radio Shack

Circle 390 on inquiry card.
3 POWERFUL INTERFACES
FOR THE TRS-80* AND S-100 BUS

**TRS-80 TO S-100 BUS CABLE ADAPTER**

- **FULL INTERFACE**: Contained within the cable assembly, is a small enclosure. This enclosure contains all the logic to convert your TRS-80 to be compatible with the S-100 bus system.
- **FULL BUFFERING**: All address, data and signal lines are fully buffered.
- **EASY CONNECTION**: It is easy to connect. Just plug the one end of the cable into one slot on your S-100 system and plug the other end into the rear of the TRS-80 keyboard or between the expansion interface. Turn on and go.
- **TWO EDGE CONNECTORS**: Two additional 40 pin port edge connectors are provided for other connection of expansion interfaces.
- **POWER**: All power is derived from the S-100 bus structure. Since the TRS-80 will not support other devices hooked to its power supply, it is a must that your S-100 supply 8-10 volts D.C. Logic card contained within the cable has onboard 5 volt regulator. Current requirements is 375 ma. Unit has separate terminal for exterior connection of DC power requirement if it is to be supplied outside the S-100 bus system.
- **FULL OPERATION MANUAL**: Not much need for a manual, but we have prepared one with full principal of operation, etc.

Model CAB-80K (kit) $99.95
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- **FULLY SELF CONTAINED POWER SUPPLY**. (10 AMP)
- **BUS TERMINATION**: Bus termination and conditioning for no cross talk or noise etc.
- **S-100 SIGNALS**: All required S-100 signals are generated by on board logic and is fully compatible with the TRS-80.
- **COMPLETE**: Comes complete with cabinet, card guides, on off switch and sockets. Nothing else to buy.
- **STAND ALONE**: This system can stand alone or can operate with the TRS-80. All input, output, address and signal lines fully buffered between TRS-80 and S-100 BUS system.
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Model RSB-K (kit) $249.95
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**S-100 EPROM PROGRAMMER +3**

*All the same features of the TRS-80 model. Comes complete with interface cable, S-100 plug-in card. Totally self-contained power supply, plus many other extras.

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Model EPR-100A (assem.) $159.95

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*Trademark Radio Shack*
Other Possibilities

Computer enthusiasts who are also interested in astronomy or physics might want to experiment with the Doppler shift effect mentioned earlier—requiring a color graphics display. Also, giving the stars colors related to their surface temperatures might be interesting. Another possibility would be the addition of magnitude (brightness). The IBM-1130 version calculated magnitudes and used different printer characters to indicate stars, but the 2250 does not have a programmable intensity control.

Another interesting possibility lies in the three-dimensional nature of the model. If two images were plotted side by side on the screen at slightly different viewing angles, a pair of stereoscopic viewing glasses would permit a truly three-dimensional view. I have experimented with the stereo three-dimensional effect by placing similar Gould hard copy plots side by side. The sense of depth produced gives one a feeling of vertigo.

Since the model is animated, navigation experiments are possible. Perhaps the algorithms presented here could be written into a game program producing the ultimate celestial exploration game.

GLOSSARY

Buffer: Temporary storage area in main memory, usually used to prepare or receive data from input or output devices.

Declination: The angle from the celestial equator to the star. Equivalent to latitude (−90 to 90 degrees).

Doppler shift: Apparent changes in frequency due to direction of travel and speed. For example, if you are moving towards an object that is emitting light, the frequency of the observed light is higher. The reverse is true for the opposite direction of travel.

Extragalactic objects: Objects outside the domain of a galaxy.

Light year: The distance light will travel in one year at 186,284 miles per second (300,000 kilometers per second)—about 5,870,000,000,000 miles.

Magnitude: The brightness of a star. Each unit of magnitude signifies a difference in brightness factor of 2.512.

Right ascension: The arc measured along the equator, from 0 hours to the base of the star's vertical declination circle.
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DIGITAL RESEARCH

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- MAC — 8080 Macro Assembler. Full Intel macro definition. Pseudo Ops include RPC, IRP, REPT, TITLE, PAGE, and MCLIB. Z-80 library included. Produces Intel absolute hex output plus symbols file for use by SID (see below) $100/$15
- SID — 8080 symbolic debugger. Full trace, pass count and break-point program testing system with back-trace and histogram utilities. Produces absolute hex output with symbols and display of memory labels and equated values. $65/$15
- TEXT — Text formatter to create paginated, page-numbered and justified copy from source text files, directly to disk or printer. $85/$15
- DESPOOL — Program to permit simultaneous printing of data from disk while user executes another program from the console. $50/$1

MICROSOFT

- Disk Extended BASIC* — New version, ANSI compatible with long variable names, WHILE/WEND, chaining, variable length file records. $300/$25
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- MACRO-80 — 8080/280 Macro Assembler. Intel and Zilog mnemonics supported. Relocatable linkable output. Loader, Library Manager and Cross Reference List utilities included. $149/$15
- MACRO-80 plus FORTRAN subroutine library available. Library includes ABS, SIGN, EXP, DLOG, SQRT, DQ, ATAN, DATAN etc. $219/$15
- EDIT-80 — Very fast random access text editor for text with or without line numbers. Global and intra-line commands supported. File compare utility included. $89/$15
- Z-TEL — Text editing language. Expression evaluation iteration and conditional branching ability. Registers available for text and commands. Macro command strings can be saved on disk for re-use. $69/$20
- ASM Macro Assembler — Mnemonics per Intel with Z-80 extensions. Macro capabilities with absolute Intel hex or relocatable linkable output modules. $69/$20
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- Z-BUG debugger — Trace, breakpoint tester. Supports decimal, octal and hex modes. Disassassembler to ASM mnemonic set. Emulation technique permits full tracing and breakpoint support through ROM. $60/$20

SOFTWARE SYSTEMS

- CBASIC Disk Extended BASIC — Non-interactive BASIC with pseudo-code compiler and runtime interpreter. Supports full file control, chaining, integer and extended precision variables etc. Version 1 users can receive Version 2 and new manual for $45 with return of original diskette. Standard CP/M and TRS-80 CP/M versions available. $95/$15
- TOP Text Output Processor — Creates page-numbered, justified documents from source text files. Available only as part of A3 or A3+ package. $99/$20
- SUPER BASIC — Sub-set of Xitan Disk BASIC with extensive arithmetic and string features but without random access data file support. Available optionally with features to support VBD Xitan video output board. $249/$40
- A3 package includes Z-TEL, TOP, ASM and Super BASIC. $408/$40
- A3+ package includes Disk BASIC, Z-TEL, TOP, ASM, Z-BUG and LINKER. $595/$20

MICROPRO

- Super Sort I — Sort, merge, extract utility as absolute executeable program or linkable module in Microsoft format. Sorts fixed or variable records with data in binary, BCD, Packed Decimal, EBCDIC, ASCII, floating, fixed point, exponential, field justified, etc. etc. etc. Available on files per record. $225/$25
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- Super Sort Ill — As II without SELECT/EXCLUDE. $150/$25
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- Corresponder — Mail list system, supporting form letter generation with personalized greetings. Reference fields permit sorting and extraction by name, address fields or reference data using Super Sort. Requires CBASIC. $95/$25
- BASIC/S — Microsoft BASIC with Super Sort Capability $400/$25
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- COBOL/S — Microsoft COBOL-80 with Super-Sort capability $800/$25

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- Accounts Payable — Provides aged statements of accounts by vendor with check writing for selected invoices. Can be used alone or with General Ledger and/or with NAD. Requires CBASIC. $900/$20

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- Word Master Text Editor — In one mode has super-set of CP/M's ED commands including global searching and replacing, forward and backwards in file. In video mode, provides full screen editor for users with serial addressable.E-tensor terminal. $150/$25
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STRUCTURED SYSTEMS GROUP

- General Ledger — Interactive and flexible system providing proof and report outputs. Customization of COA created interactively. Multiple branch accounting centers. Extensive checking performed at data entry for proof, COA correctness etc. Journal entries may be batched prior to posting. Closing procedure automatically backs up input files. All reports can be tailored as necessary. Requires CBASIC. $995/$20
- Accounts Receivable — Open item system with output for internal aged reports and customer-oriented statement and billing purposes. On-Line Enquiry permits information for Customer Service and Credit departments. Interface to General Ledger provided if both systems used. Requires CBASIC. $750/$20
- Accounts Payable — Provides aged statements of accounts by vendor with check writing for selected invoices. Can be used alone or with General Ledger and/or with NAD. Requires CBASIC. $900/$20
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QSOFT — Fast sort/merge program for files with fixed record length, variable field length information. Up to five ascending or descending keys. Full back-up of input files created. Parameter file created, optionally with interactive program which requires CBASIC. Parameter file may be generated with CP/M assembler utility .................................................. $95/$20

OTHER

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DISZILOG — As DISINTEL to Zilog/Mostek mnemonic files. Runs on Z80 only. Standard CP/M and TRS-80 CP/M versions available .............................................. $65/$10

ZASM Assembler — Disk-based assembler for Zilog/Mostek mnemonic Z-80 code. Creates output in absolute Intel hex. Requires Z-80 to operate .............................................. $45/$10

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Marsport, Here I Come

Delmer D Hinrichs
2116 S E 377th Av
Washougal WA 98671

The Three-Dimensional Celestial

Introduction

The motion of a freely falling body in a gravity field has many interesting characteristics. One of the better methods of showing this is with a simulation, in this case written for the Hewlett-Packard HP-67 or HP-97 programmable calculator.

Lunar lander simulation programs, in which the application of thrust is used to counteract gravity, have become quite popular. Extending the lunar lander concept to two dimensions allows study of the motion of bodies in orbit. Further extension to three dimensions, as in this program, makes it possible to investigate orbital plane changes. Since Mars has a much stronger gravity field than the moon, the effect of gravity is accentuated.

Running the Program

This program is designed as a three-dimensional Mars lander so you can exercise your three-dimensional visualization of space. With a limited fuel supply you can pilot a spaceship from its initial orbit around a spherical simulation of Mars to a soft landing at a designated target site on Mars' surface. The initial orbit does not pass over the target site. The three-dimensional trajectory of the spaceship is calculated as a series of segments under your control.

Realistic features of the program include:

- True inverse square law gravity acts upon the estimated midpoint of each trajectory segment.
- The thrust of the spaceship's rocket engine simulates the use of a hydrogen-oxygen fuel, with an exhaust velocity of 4 km/s.
- The spaceship loses mass as fuel is used; with less total mass, the spaceship accelerates more rapidly for the same fuel usage rate.
- If the limited fuel supply is exhausted, the spaceship automatically free-falls to impact on the surface of Mars.
- After impact with or landing on Mars' surface, the actual landing position, velocity, and remaining fuel are interpolated from the segment-end conditions immediately before and after impact. Also, the distance along the spherical surface of Mars from the impact site to the target site is calculated.

To avoid some pilot errors, there are data entry checks: the maximum fuel usage rate is limited to 100 kg/s. The maximum segment duration is limited to 60 seconds. If an attempt is made to burn more fuel than actually remains, only the actual remaining fuel is burned.
One difficult part of landing the spaceship with this program is to correctly interpret exactly where the spaceship is and where it is going at all times; that is, to visualize its movement in three dimensions. To make this as easy as possible, the position is displayed as the spaceship's altitude from Mars' spherical surface, plus two position angles, $\phi$ and $\theta$, as shown in figure 1. The coordinate system is fixed with the origin at the center of Mars, and both position angles equal 0 at the designated target landing site. If Mars is considered as a globe like the Earth, then angle $\phi$ is degrees of longitude and angle $\theta$ is degrees of latitude. The X,Y plane intersects Mars' surface along its equator. Therefore, angle $\phi$ is in the X,Y plane, and angle $\theta$ is from the X,Y plane. Then Z and $-Z$ are the north and south poles, respectively. The maximum range of angle $\phi$ is $\pm (0^\circ \text{ to } 180^\circ)$, while the maximum range of angle $\theta$ is $\pm (0^\circ \text{ to } 90^\circ)$. Note that when angle $\theta$ is exactly $\pm 90^\circ$, angle $\phi$ is indeterminate.

Similarly, the spaceship's velocity is displayed as a magnitude and two velocity angles, $\phi$ and $\theta$. The velocity vector is parallel to the vector from the origin to a position with the same angles. Thus if velocity angles $\phi$ and $\theta$ are both 0, the spaceship's velocity is parallel to the X axis, and toward more positive X values, regardless of the spaceship's position.

Now that we know where we are and where we're going, let us check out the spaceship's operation, summarized in table 1. We must first decide on the initialization method we want to use. To start with a relatively easy landing problem, use the fixed initialization on the Three-Dimensional Mars Lander program card (program listing 1); this always puts the spaceship in the same position and at the same velocity in a nearly circular orbit. When landing from this fixed initialization becomes too easy, use one of the random initialization routines of program listing 2; these put the spaceship at a random altitude (107 to 3,607 km), in a

---

**Mechanics Simulation for the HP 67/97**

### Table 1: Operating instructions for the optional random initialization program and for the Three-Dimensional Mars Lander program.

<table>
<thead>
<tr>
<th>Step</th>
<th>Instructions</th>
<th>Input</th>
<th>Keys</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Prepare for Three-Dimensional Mars landing—Use either:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) Fixed initialization:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1) Load Three-Dimensional Mars Lander program;</td>
<td></td>
<td></td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>(2) Initialize;</td>
<td></td>
<td>E</td>
<td>Status</td>
<td></td>
</tr>
<tr>
<td>(3) Go to step 2.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b) Random initialization:</td>
<td></td>
<td></td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>(1) Load Random Initialization Program;</td>
<td></td>
<td>x</td>
<td>Status</td>
<td></td>
</tr>
<tr>
<td>(2) Optionally, enter a random seed;</td>
<td></td>
<td>.</td>
<td>Status</td>
<td></td>
</tr>
<tr>
<td>(3) Optionally, spin for a random seed, wait for a few seconds, then stop;</td>
<td></td>
<td>R/S</td>
<td>Status</td>
<td></td>
</tr>
<tr>
<td>(4) Initialize for a random circular orbit, or for a random elliptical orbit;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(5) Load Three-Dimensional Mars Lander</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Optionally, reset segment duration, t seconds.</td>
<td></td>
<td>C</td>
<td>t/2</td>
</tr>
<tr>
<td>3</td>
<td>Enter either a free-fall or a rocket burn:</td>
<td></td>
<td>A</td>
<td>Status</td>
</tr>
<tr>
<td>(a) Free-fall n segments of t seconds each;</td>
<td></td>
<td>n</td>
<td>Status</td>
<td></td>
</tr>
<tr>
<td>(b) Rocket burn for one segment of t seconds;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1) Angle of thrust $\phi$, degrees;</td>
<td></td>
<td>$\phi$</td>
<td>ENTER</td>
<td>Status</td>
</tr>
<tr>
<td>(2) Angle of thrust $\theta$, degrees;</td>
<td></td>
<td>$\theta$</td>
<td>ENTER</td>
<td>Status</td>
</tr>
<tr>
<td>(3) Fuel usage rate, kg/s; (0 thru 100)</td>
<td></td>
<td>kg/s</td>
<td>B</td>
<td>Status</td>
</tr>
<tr>
<td>4</td>
<td>To calculate next trajectory segment, go to Step 2.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes**

- When fuel is gone, there is a print/pause of 10000, then the spaceship free-falls to impact.
- After Mars impact, there is a print/pause of 3393, then the landing status is displayed.
- Status is a double stack review of:

<table>
<thead>
<tr>
<th>Stack</th>
<th>Register</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Segment time, seconds (after landing, impact-to-target distance, km);</td>
<td>T</td>
</tr>
<tr>
<td>(b) Position angle $\phi$, degrees;</td>
<td>Z</td>
</tr>
<tr>
<td>(c) Position angle $\theta$, degrees;</td>
<td>Y</td>
</tr>
<tr>
<td>(d) Ship's altitude, km (after landing, vertical error of estimated position);</td>
<td>X</td>
</tr>
<tr>
<td>(e) Remaining fuel supply, kg;</td>
<td>T</td>
</tr>
<tr>
<td>(f) Velocity angle $\phi$, degrees;</td>
<td>Z</td>
</tr>
<tr>
<td>(g) Velocity angle $\theta$, degrees;</td>
<td>Y</td>
</tr>
<tr>
<td>(h) Ship's velocity, km/s.</td>
<td>X</td>
</tr>
</tbody>
</table>

- Any status display may be repeated by pressing D.

---

April 1979 © BYTE Publications Inc
random three-dimensional direction from Mars, and going in a random direction. The circular initialization puts the horizontal spaceship in a circular orbit. The elliptical initialization puts the spaceship at a random location on an orbit of random ellipticity. Some of these elliptical orbits may eventually terminate on Mars if not modified.

To repeat the same initial conditions with the random orbits, enter the same random seed prior to initialization. For an unpredictable initial status, use the SPIN routine, which increments the random seed until it is manually stopped. Repeated pressing of the C or E keys gives a different initial status each time.

After initialization, the user may change the segment duration (segment time stays as set until reset), then decide whether to free-fall or to make a rocket burn for each segment. Any number of segments of free-fall may be calculated automatically, without intermediate status displays. It is best not to free-fall too many segments at a time initially. Rocket burns are made one segment at a time by specifying the three-dimensional thrust angles and the fuel usage rate for each segment. At a fuel usage rate of 100 kg/s, the initial acceleration rate is about 0.45 g, gradually increasing to about 4 g as fuel is used up (gs are units of acceleration: at the Earth's surface, the acceleration of gravity is 1 g, or 9.81 m/s²). Of course, lower fuel usage rates will give lower acceleration rates. To reverse the direction of a vector in three dimensions (to reduce velocity), add ±180° to velocity angle φ and change the sign of velocity angle θ to get the required thrust angles. (See figure 1 to help visualize this.) Segment duration, thrust angles, and fuel usage rate may be decimal numbers; the number of segments of free-fall must be an integer.

With the fixed initialization, the spaceship starts at position angles of φ = 45° and θ = 35.264° (see figure 1). If the spaceship were over the Earth instead of over Mars, this would correspond to a position about 175 km north of Baghdad, in Iraq. The designated landing site is at position angles of φ = 0° and θ = 0°, or (on the Earth) on the equator and on the Greenwich meridian, due south of Ghana off the Atlantic coast of Africa. Initially, the orbit of the spaceship is horizontal and it is heading due west. If it were over the Earth, the orbit would not cross the equator until just off the east coast of South

---

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Figure 2: Simplified flow diagram for the Three-Dimensional Mars Lander program.
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Listing 1: Mars Lander program for the HP 67/97 programmable calculator. Clear flags, set for DEG, and set display to FIX 3 before recording program. User entry points are capitalized in comments.

<table>
<thead>
<tr>
<th>Location</th>
<th>Program Steps</th>
<th>Commentary</th>
</tr>
</thead>
<tbody>
<tr>
<td>001</td>
<td>(LBL B) EEX 2 X&lt;Y? X&lt;&gt;Y RI</td>
<td>ROCKET BURN: Check fuel usage rate, calculate mass loss.</td>
</tr>
<tr>
<td>007</td>
<td>RCL A X RCL 7 -</td>
<td>Fuel gone?</td>
</tr>
<tr>
<td>011</td>
<td>CHS RCL 9 X&lt;Y X&lt;Y?</td>
<td>Update ship's mass and velocity for burn.</td>
</tr>
<tr>
<td>015</td>
<td>GSB B R1 STO 7</td>
<td></td>
</tr>
<tr>
<td>018</td>
<td>LST X LN 4</td>
<td></td>
</tr>
<tr>
<td>022</td>
<td>GSB a 1</td>
<td></td>
</tr>
<tr>
<td>024</td>
<td>LBL A ST 1</td>
<td></td>
</tr>
<tr>
<td>026</td>
<td>LBL 0 GSB d CF 0</td>
<td></td>
</tr>
<tr>
<td>029</td>
<td>GSB d X^2 RCL A X&lt;&gt;Y</td>
<td></td>
</tr>
<tr>
<td>033</td>
<td>- RCL D GSB a P=S</td>
<td></td>
</tr>
<tr>
<td>037</td>
<td>RCL 4 + R1 RCL 6</td>
<td></td>
</tr>
<tr>
<td>041</td>
<td>+ R1 RCL 5 + R1</td>
<td></td>
</tr>
<tr>
<td>046</td>
<td>P=S SF 0 GSB b</td>
<td></td>
</tr>
<tr>
<td>049</td>
<td>RCL E X&lt;&gt;Y? X&lt;&gt;Y? GTO 7</td>
<td></td>
</tr>
<tr>
<td>053</td>
<td>- RCL 8 GSB 4</td>
<td></td>
</tr>
<tr>
<td>056</td>
<td>F? 1 GTO 0 RCL 0</td>
<td></td>
</tr>
<tr>
<td>059</td>
<td>X&lt;&gt;I DSZ? GTO 0</td>
<td></td>
</tr>
<tr>
<td>062</td>
<td>LBL D GSB 2 RCL E</td>
<td></td>
</tr>
<tr>
<td>065</td>
<td>RCL 7 RCL 9 RI STK</td>
<td></td>
</tr>
<tr>
<td>068</td>
<td>GSB d GSB c STK RTN</td>
<td></td>
</tr>
<tr>
<td>072</td>
<td>LBL a X P-R R1 X&lt;&gt;Y</td>
<td></td>
</tr>
<tr>
<td>081</td>
<td>P=R STO - 4 R1 STO - 5</td>
<td></td>
</tr>
<tr>
<td>085</td>
<td>R1 STO - 6</td>
<td></td>
</tr>
<tr>
<td>087</td>
<td>LBL c RCL 6 RCL 5</td>
<td></td>
</tr>
<tr>
<td>090</td>
<td>RCL 4 RTN</td>
<td></td>
</tr>
<tr>
<td>092</td>
<td>LBL b RCL B X</td>
<td></td>
</tr>
<tr>
<td>095</td>
<td>RCL 1 + F? 0</td>
<td></td>
</tr>
<tr>
<td>098</td>
<td>STO R1 RCL B X</td>
<td></td>
</tr>
<tr>
<td>102</td>
<td>RCL 3 + F? 0</td>
<td></td>
</tr>
<tr>
<td>105</td>
<td>STO 3 R1 RCL B X</td>
<td></td>
</tr>
<tr>
<td>109</td>
<td>RCL 2 + F? 0</td>
<td></td>
</tr>
<tr>
<td>112</td>
<td>STO 2 R1</td>
<td></td>
</tr>
<tr>
<td>114</td>
<td>LBL c R-P R1 X&lt;&gt;Y R1 RTN</td>
<td></td>
</tr>
<tr>
<td>120</td>
<td>R-P LBL 4 7 X&lt;&gt;1 STO</td>
<td></td>
</tr>
</tbody>
</table>

Listing 1 continued on next page.
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Listing 1, continued:

125 \( \text{LBL} \ B \) \( \text{RCL} \ (i) \) \( \text{P} \mapsto \text{S} \) \( \text{STO} \ (i) \)
129 \( \text{P} \mapsto \text{S} \) \( \text{DSZ?} \) \( \text{GTO} \ B \) \( \text{RTN} \)
133 \( \text{LBL} \ 2 \) \( \text{RCL} \ 3 \) \( \text{RCL} \ 2 \)
136 \( \text{RCL} \ 1 \) \( \text{GTO} \ c \)
138 \( \text{LBL} \ 7 \) \( -X- \) \( - \) \( X=0? \)
142 \( \text{GTO} \ 6 \) \( \text{STO} \ - \ 8 \)
144 \( \text{STO} / 8 \) \( 7 \) \( \text{ST} \ 1 \)
147 \( \text{LBL} \ 5 \) \( \text{P} \mapsto \text{S} \) \( \text{RCL} \ (i) \) \( \text{P} \mapsto \text{S} \)
151 \( \text{RCL} \ (i) \) \( - \) \( \text{RCL} \ 8 \) \( \div \)
155 \( \text{STO} - (i) \) \( \text{DSZ?} \) \( \text{GTO} \ 5 \)
158 \( \text{LBL} \ 6 \) \( \text{GSB} \ 2 \) \( \text{R} \) \( \text{I} \) \( \text{COS} \)
162 \( X \mapsto Y \) \( \text{COS} \) \( X \) \( \text{COS}^{-1} \)
166 \( 5 \) \( 9 \) \( - \) \( 2 \) \( 2 \) \( X \)
172 \( X \neq 0? \) \( \text{GTO} \ 3 \) \( \text{RCL} \ 2 \) \( \text{STO} \ - \ 8 \)
175 \( \text{RCL} \ 3 \) \( \text{R} \mapsto \text{P} \) \( \text{LCL} \ 3 \)
178 \( \text{STO} \ A \) \( \text{GTO} \ D \)
180 \( \text{LBL} \ 9 \) \( \text{SF} \ 1 \) \( X \) \( X \neq Y? \) \( \text{RTN} \)
185 \( \text{LBL} \ E \) \( \text{CF} \ 1 \) \( \text{CL} \ \text{REG} \)
188 \( 3 \) \( 3 \) \( 9 \) \( 3 \) \( \text{STO} \ 5 \)
193 \( 4 \) \( 3 \) \( \text{EEX} \) \( 3 \)
197 \( \text{STO} \ D \) \( \text{EEX} \) \( 4 \) \( \text{STO} \ 9 \)
201 \( 9 \) \( X \) \( \text{STO} \ 7 \) \( \text{GSB} \ c \)
205 \( \div \) \( \text{STO} \ 1 \) \( \text{STO} \ 2 \)
208 \( \text{STO} \ 3 \) \( 2 \) \( \text{STO} \ 4 \)
211 \( \text{CHS} \) \( \text{STO} \ 5 \) \( \text{GSB} \ 4 \)
214 \( \text{GTO} \ D \)
215 \( \text{LBL} \ C \) \( 6 \) \( 0 \) \( X \neq Y? \) \( X \mapsto Y \)
220 \( \text{STO} \ A \) \( 2 \) \( \div \) \( \text{STO} \ B \) \( \text{RTN} \)

Listing 2: Optional random initialization for Mars Lander. Clear flags, set for DEG, and set display to FIX 3 before recording program. User entry points are capitalized in comments.

<table>
<thead>
<tr>
<th>Location</th>
<th>Program Steps</th>
<th>Commentary</th>
</tr>
</thead>
<tbody>
<tr>
<td>001</td>
<td>( \text{LBL} \ C ) ( \text{SF} \ 2 )</td>
<td>CIRCULAR: Set for random circular orbit.</td>
</tr>
<tr>
<td>003</td>
<td>( \text{LBL} \ E ) ( 6 ) ( 0 ) ( \text{STO} \ A ) ( 2 )</td>
<td>ELLIPTICAL: Set segment time, gravity constant, Mars radius,</td>
</tr>
<tr>
<td>008</td>
<td>( \div ) ( \text{STO} \ B ) ( 4 ) ( 3 ) ( \text{EEX} ) ( 3 )</td>
<td>ship's mass, ship's random radius ( \phi ) and ( \theta ).</td>
</tr>
<tr>
<td>014</td>
<td>( \text{STO} \ D ) ( 3 ) ( 3 ) ( 9 ) ( 3 )</td>
<td></td>
</tr>
<tr>
<td>019</td>
<td>( \text{STO} \ E ) ( 9 ) ( \text{EEX} ) ( 4 )</td>
<td></td>
</tr>
</tbody>
</table>

Listing 2 continued on page 98.
More BYTE BOOKS in your future...
THE BYTE BOOK OF COMPUTER MUSIC combines the best computer music articles from past issues of BYTE Magazine with exciting new material—all written for the computer experimenter interested in this fascinating field.

You will enjoy Hal Chamberlin’s "A Sampling of Techniques for Computer Performance of Music", which shows how you can create four-part melodies on your computer. For the budget minded, "A $19 Music Interface" contains practical tutorial information—and organ fans will enjoy reading "Electronic Organ Chips For Use in Computer Music Synthesis".

New material includes "Polyphony Made Easy" and "A Terrain Reader". The first describes a handy circuit that allows you to enter more than one note at a time into your computer from a musical keyboard. The "Terrain Reader" is a remarkable program that creates random music based on land terrain maps.

Other articles range from flights of fancy about the reproductive systems of pianos to Fast Fourier transform programs written in BASIC and 6800 machine language, multi-computer music systems, Walsh Functions, and much more.

For the first time, material difficult to obtain has been collected into one convenient, easy to read book. An ardent do-it-yourselfer or armchair musicologist will find this book to be a useful addition to the library.

SUPERWUMPUS is an exciting computer game incorporating the original structure of the WUMPUS game along with added features to make it even more fascinating. The original game was described in the book What To Do After You Hit Return, published by the People's Computer Company. Programmed in both 6800 assembly language and BASIC, SUPERWUMPUS is not only addictively fun, but also provides a splendid tutorial on setting up unusual data structures (the tunnel and cave system of SUPERWUMPUS forms a dodecahedron). This is a PAPERBYTE™ book.

TINY ASSEMBLER 6800, Version 3.1 is an enhancement of Jack Emmerichs' successful Tiny Assembler. The original version (3.0) was described first in the April and May 1977 issues of BYTE magazine, and later in the PAPERBYTE™ book TINY ASSEMBLER 6800 Version 3.0.

In September 1977, BYTE magazine published an article entitled, "Expanding The Tiny Assembler". This provided a detailed description of the enhancements incorporated into Version 3.1, such as the addition of a "begin" statement, a "virtual symbol table", and a larger subset of the Motorola 6800 assembly language.

All the above articles, plus an updated version of the user's guide, the source, object and PAPERBYTE™ bar code formats of both Version 3.0 and 3.1 make this book the most complete documentation possible for Jack Emmerichs' Tiny Assembler.

A walk through this book brings you into Ciarcia's Circuit Cellar for a detailed look at the marvelous projects which you do useful things with your microcomputer. A collection of more than a year's worth of the popular series in BYTE magazine, Ciarcia's Circuit Cellar includes the six winners of BYTE's On-going Monitor Box (BOMB) award, voted by the readers themselves as the best articles of the month: Control the World (September 1977), Memory Mapped IO (November 1977), Program Your Next ROM in BASIC (March 1978), Tune In and Turn On (April 1978), Talk To Me (June 1978), and Let Your Fingers Do the Talking (August 1978).

Each article is a complete tutorial giving all the details needed to construct each project. Using amusing anecdotes to introduce the articles and an easy-going style, Steve presents each project so that even a neophyte need not be afraid to try it.
BASEX, a new compact, compiled language for microcomputers, has many of the best features of BASIC and the 8080 assembly language—and it can be run on any of the 8080 style microprocessors: 8080, Z-80, or 8085. This is a PAPERBYTE™ book.

Subroutines in the BASEX operating system typically execute programs up to five times faster than equivalent programs in a BASIC interpreter—while requiring about half the memory space. In addition, BASEX has most of the powerful features of good BASIC interpreters including array variables, text strings, arithmetic operations on signed 16 bit integers, and versatile I/O communication functions. And since the two languages, BASEX and BASIC, are so similar, it is possible to easily translate programs using integer arithmetic data from BASIC into BASEX.

The author, Paul Warme, has also included a BASEX Loader program which is capable of relocating programs anywhere in memory.

PROGRAMMING TECHNIQUES is a series of BYTE BOOKS concerned with the art and science of computer programming. It is a collection of the best articles from BYTE magazine and new material collected just for this series. Each volume of the series provides the personal computer user with background information to write and maintain programs effectively.

The first volume in the Programming Techniques series is entitled PROGRAM DESIGN. It discusses in detail the theory of program design. The purpose of the book is to provide the personal computer user with the techniques needed to design efficient, effective, maintainable programs. Included is information concerning structured program design, modular programming techniques, program logic design, and examples of some of the more common traps the casual as well as the experienced programmer may fall into. In addition, details on various aspects of the actual program functions, such as hashed tables and binary tree processing, are included.

SIMULATION is the second volume in the Programming Techniques series. The chapters deal with various aspects of specific types of simulation. Both theoretical and practical applications are included. Particularly stressed is simulation of motion, including wave motion and flying objects. The realm of artificial intelligence is explored, along with simulating robot motion with the microcomputer. Finally, tips on how to simulate electronic circuits on the computer are detailed.

RA6800ML: AN M6800 RELOCATABLE MACRO ASSEMBLER is a two pass assembler for the Motorola 6800 microprocessor. It is designed to run on a minimum system of 16 K bytes of memory, a system console (such as a Teletype terminal), a system monitor (such as Motorola MIKBUG read only memory program or the ICOM Floppy Disk Operating System), and some form of mass file storage (dual cassette recorders or a floppy disk).

The Assembler can produce a program listing, a sorted Symbol Table listing and relocatable object code. The object code is loaded and linked with other assembled modules using the Linking Loader LINK68. (Refer to PAPERBYTE™ publication LINK68: AN M6800 LINKING LOADER for details.)

There is a complete description of the 6800 Assembly language and its components, including outlines of the instruction and address formats, pseudo instructions and macro facilities. Each major routine of the Assembler is described in detail, complete with flow charts and a cross reference showing all calling and called-by routines, pointers, flags, and temporary variables.

In addition, details on interfacing and using the Assembler, error messages generated by the Assembler, the Assembler and sample I/O driver source code listings, and PAPERBYTE™ bar code representation of the Assembler's relocatable object file are all included. This book provides the necessary background for coding programs in the 6800 assembly language, and for understanding the innermost operations of the Assembler.
LINK68: AN M6800 LINKING LOADER is a one pass linking loader which allows separately translated relocatable object modules to be loaded and linked together to form a single executable load module, and to relocate modules in memory. It produces a load map and a load module in Motorola MIKBUG loader format. The Linking Loader requires 2 K bytes of memory, a system console (such as a Teletype terminal), a system monitor (for instance, Motorola MIKBUG read only memory program or the ICOM Floppy Disk Operating System), and some form of mass file storage (dual cassette recorders or a floppy disk).

It was the express purpose of the authors of this book to provide everything necessary for the user to easily learn about the system. In addition to the source code and PAPERBYTE™ bar code listings, there is a detailed description of the major routines of the Linking Loader, including flow charts. While implementing the system, the user has an opportunity to learn about the nature of linking loader design as well as simply acquiring a useful software tool.

ISBN 0-931718-09-0
Authors: Robert D. Grappel & Jack E. Hemenway
Pages: 72
Price: $8.00
Winter 1979

MONDEB: AN ADVANCED M6800 MONITOR-DEBUGGER has all the general features of Motorola's MIKBUG monitor as well as numerous other capabilities. Ease of use was a prime design consideration. The other goal was to achieve minimum memory requirements while retaining maximum versatility. The result is an extremely versatile program. The size of the entire MONDEB is less than 3 K.

Some of the command capabilities of MONDEB include displaying and setting the contents of registers, setting interrupts for debugging, testing a programmable memory range for bad memory locations, changing the display and input base of numbers, displaying the contents of memory, searching for a specified string, copying a range of bytes from one location in memory to another, and defining the location to which control will transfer upon receipt of an interrupt. This is a PAPERBYTE™ book.

ISBN 0-931718-06-6
Author: Don Peters
Pages: 88
Price: $5.00

BAR CODE LOADER. The purpose of this pamphlet is to present the decoding algorithm which was designed by Ken Budnick of Micro-Scan Associates at the request of BYTE Publications, Inc., for the PAPERBYTE™ bar code representation of executable code. The text of this pamphlet was written by Ken, and contains the general algorithm description in flow chart form plus detailed assemblies of program code for 6800, 6502 and 8080 processors. Individuals with computers based on these processors can use the software directly. Individuals with other processors can use the provided functional specifications and detail examples to create equivalent programs.

ISBN 0-931718-07-4
Author: Ken Budnick
Pages: 32
Price: $2.00

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Available now on KCS cassette for $39.95. Requires 9K minimum, no source listing included. Soon to come is a version for the FLEX™ disk operating system.

Graph based on benchmarks listed in October 1977 issue of KiloBaud™ magazine.
Listing 2, continued from page 92:

023 STO 7 3 + 5 EEX 3

Convert position to X, Y, Z, and store.

029 STO 8 GSB 0 STO + 8 GSB 1

033 3 6 0 X GSB 1

036 1 8 0 X

042 RCL 8 P→R R↓ X=Y R↑

047 P→R STO 1 R↓ STO 2

Calculate circular orbit velocity.

051 R↓ STO 3

053 RCL D RCL 8 + √X

random X, Y, Z velocity for an orbit

057 STO 9 GSB 1 STO 4

horizontal at the ship's

060 RCL 1 X GSB 1

position,

063 STO 5 RCL 2 X +

adjust X, Y, Z velocity.

067 CHS RCL 3 + STO 6

Circular orbit?

071 RCL 5 RCL 4 GSB 2

If elliptical orbit,

074 RCL 9 ÷ STO ÷ 4

make random

077 STO ÷ 5 STO ÷ 6 F? 2

X, Y, Z velocity adjustment.

080 GTO 5 GSB 1 2 ÷

084 STO ÷ 4 GSB 1 2 ÷

088 STO ÷ 5 GSB 1 2 ÷

092 STO ÷ 6 LBL 5 7

Shift data from primary to

096 ST 1 LBL 3 RCL (ii)

secondary registers.

098 pcs STO (ii) pcs DSZ?

DISPLAY: Show segment time,

102 GTO 3

ship's position,

103 lbl d RCL 3 RCL 2

fuel,

106 RCL 1 GSB 2 RCL E

and velocity.

109 - RCL A R↓ STK

Subroutine: Randomize position and velocity.

113 RCL 7 EEK 4 STO 9

117 - RCL 6 RCL 5

120 RCL 4 GSB 2 STK RTN

Subroutine: Random number generator.

124 LBL 1 1 GSB 0 + 5

129 - RTN

Subroutine: Rectangular to spherical.

131 LBL 0 RCL 0 π +

135 X² FRAC STO 0 X RTN

140 LBL 2 R→P R↓ X=Y R↑

145 R→P RTN

147 LBL A CL REG 1 CHS

151 ST 1 CHS STO + 0

SPIN: A random seed randomizer.

154 GTO (ii)

SEED: To store user's random seed.

155 LBL B STO 0 RTN
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Table 2: Demonstration of the Three-Dimensional Mars Lander program’s operation. Note that the thrust from the rocket burn is directly opposite to the initial velocity.

**Table 2:** Demonstration of the Three-Dimensional Mars Lander program's operation. Note that the thrust from the rocket burn is directly opposite to the initial velocity.

Text continued from page 86:

America. Follow the demonstration example in table 2 to help to understand the spaceship control, and the status displays. The HP-97 prints status displays.

A good landing is within 100 m (0.100 km) of the target site, with a near-vertical descent ($\phi = \pm 180^\circ$, and $\theta = 0^\circ$, for velocity angles), and at an impact velocity of less than 1 m/s (0.001 km/s). There is plenty of fuel on board to make a good landing at the target site from even a “worst case” random orbit. The initial mass ratio is 9 to 1.

Note that the display reads in kilometers and in km/s; in the normal FIX 3 display format, you can read down to the nearest meter and m/s. When near to landing, it is helpful to change the display to FIX 6, so that you can read down to the nearest millimeter and mm/s. Also note that during descent, the spaceship’s position is given in degrees, and on Mars’ surface, one degree is about 60 km.

### Celestial Mechanics

Celestial orbits of a relatively light body around a massive primary may be represented by the conic sections: circle, ellipse, parabola, and hyperbola, all formed by the intersection of a plane with a cone at various angles. In this program we are concerned only with circular and elliptical orbits, since parabolas and hyperbolas represent non-repeating, or one pass orbits.

In a circular orbit, the orbiting body always has the same velocity and the same distance from the primary. The attraction of gravity is exactly balanced by the centrifugal force at all times. Both the body’s potential energy (a result of altitude) and its kinetic energy (a result of velocity) are constant.

An elliptical orbit is far more common; a circular orbit is really just a special case of an elliptical orbit. In an elliptical orbit, the body’s velocity and its distance from the primary are continually varying. While the body’s potential energy varies with its alti-
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tude, and its kinetic energy varies with its velocity, its total energy remains constant. Its energy is merely oscillating between kinetic and potential forms.

If we are in a spaceship, how do we change altitude with a minimum energy usage (ie: minimum fuel usage)? Under some special circumstances, this is fairly straightforward. For example, to go from one circular orbit to another circular orbit in the same plane — but at a different altitude — the minimum-fuel-usage maneuver is known as a *Hohmann transfer*. It is simply an ellipse tangent to both circular orbits. A Hohmann transfer is made in three stages:

1. Thrust along the current direction of motion (or against it) until the velocity has increased (or decreased) enough to form an elliptical orbit that reaches just up (or down) to the desired new circular orbit altitude;
2. Wait in elliptical transfer orbit until the new altitude has been reached on the opposite side of the primary from the start;
3. Thrust along the current direction of motion (or against it) until the orbit has been circularized at the new altitude. Note that the direction of this second thrust must be opposite to the initial direction of thrust (since we are now on the opposite side of the primary), though both increase (or decrease) the spaceship's velocity.

But how can we use this method to land on the surface of the primary? Just perform a Hohmann transfer to zero altitude, then stop! Of course, this assumes that the landing trajectory is tangent to the surface, and that we stop instantly. While this is theoretically the most efficient way to land from orbit, we can't quite actually do it this way; we have to leave some room to slow down and stop and a little extra for maneuvering room. However, the closer we can approach this theoretical minimum-fuel-usage landing, the lower the actual fuel usage will be.

*To repeat:* for a minimum-fuel-usage landing from orbit, an initial rocket burn is made when the spaceship is on the opposite side of the primary from the landing site to slow down enough to pass over the landing site at a low altitude; then free-fall until near to the target site. At the last possible moment, again make a rocket burn (or series of rocket burns) to stop orbital velocity, and to land vertically on the surface at the target site. Note that Mars' very thin atmosphere is ignored.

But what do we do when the landing site is *not* in the plane of the orbit? Just change the plane of the orbit so that the landing site is in the plane of the orbit. This can create two complications:

1. Since orbital velocity around Mars is fairly high, it takes a lot of fuel to change the plane of the orbit;
2. In general, the heading of the spaceship in orbit is continually changing. But what is the proper heading to make the plane of the orbit pass through the landing site?

The answer to (1) is, literally, roundabout. If the plane change is very great, it will save fuel to first do a Hohmann transfer to a higher altitude so that the spaceship's velocity will be lower, before changing the plane of the orbit. Then come back down on another elliptical orbit to a low altitude over the target landing site. In answer to (2), there are two planes that the spaceship's orbit can be in, that also pass through the target site, where the heading does not change: the equator, and the Greenwich meridian. If we approach the target site along the equator or along the Greenwich meridian, there is no problem of constantly changing headings.

Note that any free-fall orbit is planar (that is, flat), and that the plane of the orbit always passes through the center of the primary. Therefore the orbit's path on the surface of the primary is always a *great circle*. (A great circle is formed by the intersection of the primary's surface with a plane passing through the center of the primary.) It passes over the equator twice for each complete orbit, and over the Greenwich meridian (or its extension, position angle $\phi = \pm 180^\circ$) twice for each complete orbit.

**Program Organization**

To squeeze this rather complex program into the 224 program steps available in the Hewlett-Packard HP-67/97, considerable use was made of subroutines, as shown in program listing 1. Note that subroutines may have two entry points. To translate this program to other systems, remember that the HP-67/97 uses RPN (reverse Polish notation) on a 4 register stack. Therefore function symbols follow data entry, the same as though you were doing the calculation manually. Flags and conditional tests skip the following program step if the test is false.

The more important equations used for calculating the random initialization, the
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Table 3: Random initialization, spaceship trajectory, and impact status calculations. The trajectory and impact equations do not give exact velocity and impact data, but do give good approximations. The calculated values increase in accuracy as segment duration and velocity decrease and as radius increases. While the equations are shown in their simplest linear form, calculations are actually carried out in three dimensions, using rectangular or spherical coordinates. Note that the initial conditions for one segment were the final conditions for the previous segment.

Table 4: Polar-to-rectangular and rectangular-to-polar coordinate conversions.
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Figure 3: Interpolation of the spaceship's landing status. Figure 3a is a cross-section showing the spaceship's last trajectory segment. Figure 3b is a view from above showing impact position and miss distance.

Table 5: Register, label, and flag usage for the Three-Dimensional Mars Lander program.

<table>
<thead>
<tr>
<th>Registers</th>
<th>Secondary</th>
<th>Labels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>Secondary</td>
<td>Labels</td>
</tr>
<tr>
<td>0</td>
<td>Temporary Loop Count</td>
<td>S0 –</td>
</tr>
<tr>
<td>1 x</td>
<td>New Position</td>
<td>S1 x</td>
</tr>
<tr>
<td>2 y</td>
<td>Initial Position</td>
<td>S2 y</td>
</tr>
<tr>
<td>3 z</td>
<td>Position</td>
<td>S3 z</td>
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<tr>
<td>4 x</td>
<td>New Velocity</td>
<td>S4 x</td>
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<td>5 y</td>
<td>Initial Velocity</td>
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<td>6 z</td>
<td>Velocity</td>
<td>S6 z</td>
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<td>7 Ship's Mass</td>
<td>S7 Ship's Mass</td>
<td>7 Mars Surface Impact</td>
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<td>8 Last Altitude</td>
<td>S8 –</td>
<td>c Rectangular to Spherical</td>
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<td>9 10,000</td>
<td>S9 –</td>
<td>d Recall Velocity</td>
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<td>A</td>
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<td>B</td>
<td>t/2</td>
<td>–</td>
</tr>
<tr>
<td>C</td>
<td>–</td>
<td>0 On, Store New Position</td>
</tr>
<tr>
<td>D</td>
<td>Gravity Constant</td>
<td>1 On, Out of Fuel</td>
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<tr>
<td>E</td>
<td>Mars' Radius</td>
<td>2 –</td>
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<tr>
<td>I</td>
<td>Loop Count</td>
<td>3 –</td>
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APPENDIX A


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Confidence 2 Curve Integration 2
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The program operation is shown most clearly in figure 2. At the beginning of calculations for each segment, the same position, velocity, and fuel data are in both the primary and the secondary registers. During the rocket burn and free-fall calculations, only the data in the primary registers is progressively updated. After all trajectory calculations for the segment have been made, the secondary registers still contain the initial segment data, while the primary registers now contain the final segment data. Then there is a test for Mars impact during the segment; if impact has occurred, initial and final segment data are used to interpolate impact status; if impact has not occurred, primary register data is copied into the secondary registers in preparation for calculation of the next segment. If the program is still in a loop of free-fall segment calculations, the next segment is calculated; otherwise, the current status data is displayed and the program halts.

The impact interpolation method is shown in figure 3. The calculated impact-to-target distance is correct only for the hemisphere of Mars that is centered upon the designated target site. If the landing is within a square about 240 meters on a side centered upon the designated target site, roundoff in the cosine function causes a calculated miss distance of 0. If you are this close, Mars' surface may be considered as flat, and a simpler alternate miss distance calculation is used.

Conclusions

This program may be considered primarily a game program, or as primarily a celestial mechanics simulation program. In either case, as you learn how to control the spaceship for better landings using less fuel, you will also be learning more about the intuitive "feel" of celestial mechanics, and will gain a greater appreciation of some of the problems of space flight.

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This APL/Z80 expression inputs a list of values (list B), computes the average of all the items in the list, then prints out the average. In other languages, this expression may require at least one loop and perhaps 10 statements.

\((- \times (A / B)) ÷ p A \times B\)

In other languages, this expression usually takes two loops and 15 to 20 statements.

Example

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\(\text{mean} \quad \text{variance} \quad \text{standard deviation} \)

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Example

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\(-A \times (A \times A)\)

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Part 1 of this article described the five basic functions which must be performed to implement the Standard Data Encryption Algorithm:

- permutation operations,
- table lookup,
- circular rotation,
- byte exchange, and
- modulo 2 addition.

Of course, there are many iterations of these functions in the encryption and decryption process.

Design Approach

When I began the design, I knew that there were many possible approaches. However, I also knew that the one hard constraint I faced was the amount of memory available on the basic KIM-1 computer. This constraint was the determining factor in the design, and, as a consequence, in the efficiency and speed of the implementation. In order to determine how much memory I would have for the program, I began to estimate the amount of storage I would need to hold all of the tables I needed. My preliminary estimate was that for each entry in each permutation table I would need one byte (I actually needed slightly more, as you will see). This assumption meant that I would need 312 bytes — almost one third of the memory available to me. I next looked at the Select S1 thru S8 function. There are eight separate tables with 64 entries each. However, since each table entry required only four bits instead of eight (the entries range from hexadecimal 0 to F), I knew that if I was clever I could get away with half a byte per entry. I would still need 256 bytes for these tables, of course. So before I even started on the program, one half my available memory was committed.

The impact of the above results became clear when I looked at the memory requirements for subkeys K1 thru K16. Each subkey would require 6 to 8 bytes (depending on how data was represented), giving a possible total storage requirement of 128 bytes. Since I would be left with only about 128 bytes for the program (and I didn’t think that was enough) I made the decision to generate each subkey as I needed it.

Module Design Difficulties

The actual design of the individual modules went through several iterations. My primary problem was that the optimization of the overall program meant that the design of each module was intimately involved with the design of other modules—not usually a good design approach. A revision of any module usually resulted in several iterations of changes to other modules. An example of this coupling is the following:

- efficient design of the Select S1 thru S8 module requires inputs to be available as 8 bytes of 6 bits each.
- in order to generate the input as required above, the subkey and the results of the Select E permutation must be represented as 8 bytes of 6 bits each.
- the design of the module which performed the permutation function had to be modified and reoptimized to allow for less than 8 bits per byte in the result.
I am sure that many readers have encountered the same type of difficulty in developing relatively complex software which must be optimized for speed, space, or both. It was a frustrating experience because of the many revisions required.

**Data Movement**

One of the first tasks in designing this program, or any program, was the definition of the data structures and the data transfers which will occur. The basic data elements to be manipulated are:

- 8 bytes of plaintext input (PT)
- 8 bytes of key (KEY)
- 8 bytes of subkey (SUBKEY)
- 8 bytes for Ci and Di (CD)
- 8 bytes of storage for intermediate results (TEMP).

Text continued on page 114.
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Table 8 depicts the data transformations and data transfers that occur. The first item shows that the plaintext data is permuted by the initial permutation and stored in the bytes originally occupied by the plaintext data.

Figure 7: Flowchart of module which performs the permutation function TFORM.

For each of the transformations which occur, table 9 shows the format of both the data input and the results of the operation. Each rectangular box represents one byte. As an example, consider the transformation Permed Choice 2 (PC-2). The input is Ci (28 bits) and Di (28 bits) and the output is stored as 8 blocks of 6 bits each. The label CD (to the left) shows the source data, and subkey shows the destination of the results of the permutation.

Permutation Module: TFORM

At this point I can begin the detailed explanation of the major modules. The module where most of the work is done (and where most of the time is spent) is TFORM. Steps 1, 2, 3, 4, 7, and 9 of table 8 depict the permutation functions performed. The operation of this module is similar in each case; only the input parameters are different. The primary input parameters to TFORM are: source data address, destination address for results, and permutation table address. For example, to perform the permutation shown in step 4 of table 8, TFORM would get the source address of PT (right), the destination address of TEMP, and the table address of the Select E permutation.

A general flowchart of TFORM is shown in figure 7. It provides a top level description of the operation for those readers who want to program the function on different machines.

The first task is to update the input parameters used by the routine. In addition to the parameters described above, the routine also needs the number of elements in the permutation table (PCOUNT), the number of bytes in the result of the permutation (WCOUNT), and the number of bits in each result byte (BCOUNT).

Here's how the permutation is done. The first element of the permutation table is obtained. This element tells which bit of the input is the first bit of the result, as follows: referring to figure 8, bits 0, 1, and 2 refer to the byte of the source data to be used; bits 3, 4, 5 and 6 refer to a mask number to be used to isolate the proper bit. At this point, an example might help. Figure 9 shows how the first bit of Permute P is obtained. The first bit of the result is bit 16 of the input – this corresponds to byte 1 of the input.

Figure 8: Format of elements of permutation table.
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After completion of all bit permutation operations using all table elements, the result bytes are taken from the stack and placed at the proper destination address.

This routine, as well as others, makes extensive use of the 6502 indirect, indexed mode of addressing. It is a particularly powerful technique for sequencing through many tables, as this program does.

Before leaving the description of this routine, I should explain one problem I had with the permutation table for Permuted Choice 1. For the results of each permutation except Permuted Choice 1, there are either 6 or 8 bits in each byte. Table 9 shows that two bytes of the result have only 4 bits. To achieve consistency in the code for TFORM, I added eight elements to the permutation table of Permuted Choice 1. They force these extra bits to 0, using mask 0, and allow all bytes of the result to have eight bits.

Select S1 thru S8 Module

As described before, the Select S1 thru S8 function transforms groups of six bits into groups of four bits according to tables S1 thru S8. Table 9 shows that each group of six bits is contained in one byte of source data. Figure 10 shows the organization of the data for the tables S1 thru S8.

In order to transform each 6 bit source group into the proper 4 bit result group, you must generate an index into the segment containing the S1 thru S8 data. As seen in

---

**Figure 9:** Example of permutation operation being used to obtain first bit of Permute P result.

**Figure 10:** Table organization for Select S1 through S8 data.
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Let's examine how to map the last byte of the source data using $S_8$. Figure 11 shows that the low order 6 bits from the source byte are used to select a byte from the 64 bytes in the $S_7$, $S_8$ segment. To access the correct 64 byte segment ($S_7$, $S_8$) we force the two high order bits to 11. The resulting byte is used as an index into the table. If you mask the high 4 bit word of the accessed byte (which also contains $S_7$ data), the proper $S_8$ data is selected. Of course, the table data must be properly ordered within $S_8$, but that's fairly easy.

In order to carry out the other transformations, you proceed in a similar fashion. The only changes would be the two high order bits used to index the proper segment of the table, and whether you mask the low or high nibble.

A general flowchart of this module is provided in figure 12.

**ROTATE Module**

As I said before, I decided to generate each subkey as I needed it. To generate subkeys $K_1$ thru $K_{16}$, it is necessary to perform left rotations of $C_i$ and $D_i$ and then perform Permutated Choice 2 as shown in part 1. The number of left shifts is determined by using the iteration count, LOOPCT, as an index into the table SHIFTM. This module is relatively straightforward except for the problem caused by the half byte boundary shown in figure 13.

A second problem arises in the case of decryption. In this case, the subkeys must be generated in reverse order (i.e.: $K_{16}$ thru $K_1$). In order to generate them properly, the rotation of $C_i$ and $D_i$ is done by right shifting and by using the SHIFTM table in reverse sequence and by performing Permutated Choice 2 before the right rotation is done. This may seem strange, but I gave it a great deal of thought to make sure it was right. It is the simplest way that I could devise to do the decryption correctly, and it works!

**What's Left?**

The only remaining module is the one which swaps two groups of four bytes each. This module is called SWAP, and it performs the swap function and block transform function discussed in Part 1.

**Put Them All Together**

The main module, DES is really a master controller for the other modules. It initializes the parameters used by TFORM, performs the appropriate modulo 2 additions shown in table 8, makes sure that subkeys are properly generated during encryption and decryption, and maintains the iteration count. Figure 14 is a general flowchart for this module.
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The only particular point worth noting is that the parameters used by TFORM to perform the proper permutation are stored sequentially in the order used. The order of the information in the table DATA is:

Initial Permutation data
Permuted Choice 1 data
Permuted Choice 2 data
Select E data
Permute P data

Once the Initial Permutation and Permuted Choice 1 are performed, the DES routine sequences TFORM thru Permuted Choice 2, Select E, and Permute P, for 16 iterations. Then TFORM performs the inverse Initial Permutation to complete the encrypt or decrypt operation.

Using the Program

The Standard Data Encryption Algorithm program is written as a subroutine which can be called at hexadecimal address 0176. In order to use the routine, three things must be supplied: mode, plaintext, and key. The mode byte (location 0000) is set to 00 for encryption or FF for decryption. The plaintext is 8 bytes of data (locations 0001 thru 0008) which is to be encrypted or decrypted. The key is eight random bytes provided by you (locations 0009 thru 0010) to control the algorithm. The encrypted (or decrypted) result is returned to locations 0001 thru 0008.

A call to DES uses 12 bytes of stack storage. If your other programs use the stack, you should take care to avoid overwriting the main routine. Many of the page zero locations used by DES may be used for other purposes between calls. These hexadecimal locations are 0011 thru 002C and 0038 thru 0040. A memory map of the entire program is shown in figure 15.

When the encryption key is loaded, you should make sure that the bits are nearly as random as possible, since it is the randomness of the key which makes it difficult for an outsider to decrypt the cipher. If you attempt to load ASCII characters as key, it is likely that the most significant bit of each byte will be zero. This will substantially reduce the strength of the algorithm. An alternate way to handle the key is as 16 ASCII characters, with random contents in the four low order bits. The four low order bits of these characters can be compacted to form the eight bytes of key which the algorithm requires.

Text continued on page 124.
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Figure 14: Flowchart of the main routine for the Standard Data Encryption Algorithm.
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Timing Analysis

One of my primary objectives in programming the Standard Data Encryption Algorithm was to determine the efficiency of the 6502 processor in handling a task which requires lots of bit manipulation. In order to determine the efficiency of the implementation, I calculated the approx-

Table 10: 6502 instructions which could be used to in line code the permutation function. Fastest time to permute one bit requires 12 cycles and 8 bytes of memory.

<table>
<thead>
<tr>
<th>Key</th>
<th>Plain</th>
<th>Cipher</th>
</tr>
</thead>
<tbody>
<tr>
<td>7CA11065A1A6E57</td>
<td>01A106D039776742</td>
<td>609F5BD0D0A26BD33B</td>
</tr>
<tr>
<td>0131D9691D0C1376E</td>
<td>5CD54CA83DEF57DA</td>
<td>7A389D1035B0271</td>
</tr>
<tr>
<td>07A1133EA4AB2666</td>
<td>0244380EF67172</td>
<td>868F5B51AB499A</td>
</tr>
<tr>
<td>38496742C02319E</td>
<td>51A5B52BDF4A00</td>
<td>71B876E01F19B2A</td>
</tr>
<tr>
<td>048915843FEB3B6</td>
<td>42D43B659577FA2</td>
<td>AF37FB421F0C495</td>
</tr>
<tr>
<td>011338F76D43F2CE</td>
<td>059B5E0561C43A</td>
<td>86A5DF9F10E05D59</td>
</tr>
<tr>
<td>0170F15746BFB35E</td>
<td>0756D8E0774761D</td>
<td>0CD3DA020201D09</td>
</tr>
<tr>
<td>43295F1ADEB3E73E</td>
<td>72514BB2D0F864A</td>
<td>EAB7682C7DB9B7A</td>
</tr>
<tr>
<td>07A137045DA2A16</td>
<td>38D193903372802</td>
<td>DF64A815CA01AF</td>
</tr>
<tr>
<td>04887040C2D032F</td>
<td>2695F838EA5606A</td>
<td>5C513B0C888608B</td>
</tr>
<tr>
<td>370D68B516C7546</td>
<td>164D5E40F275232</td>
<td>02A2F6A4E3F04AB7</td>
</tr>
<tr>
<td>1F08260D1AC2465E</td>
<td>6806E1E79F55C6CA</td>
<td>EF13F5E35F0A575</td>
</tr>
<tr>
<td>5849234A1B0A67</td>
<td>00480DE0F9178062</td>
<td>86FB0D0B7D04056</td>
</tr>
<tr>
<td>025816E64C2980</td>
<td>48030660EE76206F</td>
<td>AF90165B202936</td>
</tr>
<tr>
<td>49793EBC6392359F</td>
<td>437540B680F3CAF</td>
<td>6F8F1B2A5FCF0D656</td>
</tr>
<tr>
<td>4FB0561515AB7A3</td>
<td>072D4A30770751</td>
<td>2F2F0E89BAA7CA1AC</td>
</tr>
<tr>
<td>49E5D604CA2290E</td>
<td>02F6578117F12A</td>
<td>5A88061CC063CE0A</td>
</tr>
<tr>
<td>01831DDC048266</td>
<td>1D058C518F728C2</td>
<td>5FAC038ED12B2E1</td>
</tr>
<tr>
<td>1C581F13924FEF</td>
<td>30553286D0F295A</td>
<td>63FA0DD34D9F793</td>
</tr>
</tbody>
</table>

Table 11: Sample test words for the Standard Data Encryption Algorithm.
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imate number of machine cycles spent in each module during one encryption cycle. The cycle times which I used for each instruction were taken from the data provided by MOS for the 6502. My calculations revealed the following times:

DE5 (Main) Routine — 4300 cycles
Rotate — 1900 cycles
Select S1-S8 — 7500 cycles
TFORM — 146000 cycles

This indicates that over 90 percent of the time is spent in the module TFORM. These calculations also indicate that the total encryption time is approximately 160 ms; assuming the 1 μs cycle time of the K1M-1. In order to verify these calculations, I timed a loop which performed 256 encryption operations. The observed execution time was 164 ms. Not bad for a rough estimate. Maximum throughput would be about 390 bps.

Next wondered what maximum throughput could be achieved, given unlimited memory. The two most obvious changes to make were to perform subkey generation only once, and to optimize TFORM. Table 10 shows the basic instructions which could be used to code the basic permutation functions, such as Permute P in line. It also shows the number of machine cycles required and the number of bytes of memory required. These changes would reduce the number of cycles spent in TFORM to about 16900. The time for one encryption cycle would be reduced to about 31 ms, and maximum throughput would increase to 2000 bps. Memory requirements would increase to about 3500 bytes.

It is clear that although the 6502 can perform at a reasonable rate, its instruction set is not well suited to high speed implementation of the Standard Data Encryption Algorithm. If bit test instructions were available, similar to those of the Zilog Z-80, it would theoretically be possible to reduce the time spent in TFORM by 50 percent. It would then make sense to speed up the other routines. I would not be surprised if throughputs of 8,000 to 10,000 bps were possible.

Conclusions

I have demonstrated that the Standard Data Encryption Algorithm can be implemented on the basic K1M-1 with reasonable performance. However, it is clear that the instruction sets available for most processors are not well suited to an efficient implementation of the algorithm. It is also clear that the basic functions necessary to perform the algorithm (i.e.: bit permutations) are not well suited to implementation in software. I have shown that an increase in memory to about 3500 bytes will allow the throughput to be increased from 390 bps to about 2000 bps.

I have attempted to present a coherent description of the Standard Data Encryption Algorithm for those readers who may be interested in reprogramming it. Table 11 provides a set of test words to verify your implementation. These test words are part of those available from National Bureau of Standards Special Publication 500-20.

The coding of my encryption program is provided in listing 1. For anyone interested in obtaining a K1M compatible cassette with the Standard Data Encryption Algorithm program, several driver routines for Teletype and keypad, a shortened version of the program, and complete documentation, send $6 to R Meushaw, 4188 Brittany Dr, Ellicott City MD 21043.

Listing 1: The DES program implemented on the basic K1M-1 module.

```
Listing 1 continued on next page.
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REFERENCES


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Two years ago we wrote a piece on the most startling product of the decade. The first personal computer. It actually brought the miracle of computing power within reach of small businesses. At less than $1000, it was even affordable for home use.

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If you're thinking about a Home Computer, make sure it's not just a game
Continued below:

**Listing 1, continued:**

0130 B9 41 05 L5 LOAD DATA,Y LOAD NEW DATA INTO ZERO
0140 95 39 00 STA INFO,X PAGE AREA (INFO).
0142 89 DEY
0143 0A DEX
0144 15 F7 BPL L5 STORE #00 BITS PER WORD IN
0146 A5 3F L6 LOAD COUNT BIT
0148 03 2A STA BITCOUNT
014A A4 3E L7 LDY PCOUNT GET ELEMENT OF PERMUTATION
014C 81 3C LDA (PERMUT) Y
014E HA TAX PUT COPY IN X
014F 29 07 AND #07 AND PROPER WORD
0150 89 TAX IN Y
0152 8A TAXX
0153 4A TAX AND ISOLATE BIT
0154 4A LSR AND MASK # I PUT IT IN
0155 4A TXS
0156 A3 TAX LOAD SOURCE WORD
0157 B1 3B LDA (SOURCE) Y
0159 35 2F AND MASK: X ISOLATE PROPER BIT
015B 1C IF BIT IS 1 GET IT INTO
015C 69 FF CARRY AND MOVE INTO
015E 26 2B ROL HOLD
015F 69 FF DEC PCOUNT
0161 A5 2B LDY HOLD
0162 C6 3E DEC PCOUNT GET 'HOLD' JUST IN CASE
0164 3A 04 BMI EXIT MOVE INDEX TO NEXT PERMUTE
0166 C6 2A BMI EXIT ARRAY ELEMENT EXIT IF DONE
0168 60 DF DEC BITCOUNT IF MORE BITS IN WORD
0169 60 DF BPL L7 KEEP GOING
016A 4D HPL EXIT IF
016B 4D LFH PULL WORD FROM STACK
016C 4F 08 LDR H COUNT CONTINUE UNTIL DONE
016D 60 L8 PUT COPY IN Y
016F 60 L8 PULL FROM STACK
0170 91 3A LSR (DEST) Y
0172 58 AND PLACE IN PROPER
0173 10 FA DESTINATION WORD
0175 60 BPL L8 BPL CONTINUE UNTIL DONE

**DESI (MAIN) SUBROUTINE**

0176 08 DES CLD CLEAR DECIMAL MODE
0177 A9 FF LDA FF INITIALIZE DATA POINTER
0179 85 2C STA POINT
017B A9 0F LDA #0F INITIALIZE LOOP COUNT
017D 05 2A STA LOOPCT FOR 16 ITERATIONS
017F 20 33 01 JSR TFORM PERFORM 'PC-1'
0181 FF 05 2C JSR TFORM PERFORM 'PC-1', FOR
0183 87 0B 08 JSR TFORM ENCRYPT CYCLE, GET
0185 20 67 00 JSR TFORM SUBKEY BY ROTATING
0187 20 33 01 JSR TFORM CC(1) AND CC(3) THEN
0189 20 33 01 JSR TFORM PERFORM 'PC-2', FOR
018B 80 36 JSR TFORM DECRYPT CYCLE,
018D 33 01 SKP3 JSR TFORM REVISE THIS
018F 20 33 01 JSR TFORM JSR TFORM
0191 20 33 01 JSR TFORM PERFORM 'SELECT-E'
0193 FF 05 JSR TFORM PERFORM 'MOD 2', FOR
0195 FF 05 2C JSR TFORM SUBKEY AND
0197 FF 05 2C JSR TFORM SUBKEY (X)
0199 20 33 01 JSR TFORM PERMUTED (PT)(RIGHT)
019B 20 33 01 JSR TFORM SET BITS 0-7 TO ZERO
019D FF 05 2C JSR TFORM FOR SELECT 51-58
019F FF 05 2C JSR TFORM DEX
01A1 15 FF BPL L16
01A3 15 FF BPL L16
01A5 10 FA JSR SELECT PERFORM 'SELECT' 51-58

**DESI (SUBROUTINE)

0067 08 DES CLD CLEAR DECIMAL MODE
0069 09 FF LDA FF INITIALIZE DATA POINTER
006B 85 2C STA POINT
006D 05 2C LDA #0F INITIALIZE LOOP COUNT
006F 05 2A STA LOOPCT FOR 16 ITERATIONS
0071 FF 05 2C JSR TFORM PERFORM 'PC-1'
0073 FF 05 2C JSR TFORM PERFORM 'PC-1', FOR
0075 FF 05 2C JSR TFORM ENCRYPT CYCLE, GET
0077 FF 05 2C JSR TFORM SUBKEY BY ROTATING
0079 FF 05 2C JSR TFORM CC(1) AND CC(3) THEN
007B FF 05 2C JSR TFORM PERFORM 'PC-2', FOR
007D FF 05 2C JSR TFORM DECRYPT CYCLE,
007F FF 05 2C JSR TFORM REVISE THIS
0081 FF 05 2C JSR TFORM JSR TFORM
0083 FF 05 2C JSR TFORM PERFORM 'SELECT-E'
0085 FF 05 2C JSR TFORM PERFORM 'MOD 2', FOR
0087 FF 05 2C JSR TFORM SUBKEY AND
0089 FF 05 2C JSR TFORM SUBKEY (X)
008B FF 05 2C JSR TFORM PERMUTED (PT)(RIGHT)
008D FF 05 2C JSR TFORM SET BITS 0-7 TO ZERO
008F FF 05 2C JSR TFORM FOR SELECT 51-58
0091 FF 05 2C JSR TFORM DEX
0093 FF 05 2C JSR TFORM BPL L16
0095 FF 05 2C JSR TFORM BPL L16
0097 FF 05 2C JSR TFORM JSR SELECT PERFORM 'SELECT' 51-58

0067 08 DES CLD CLEAR DECIMAL MODE
0069 09 FF LDA FF INITIALIZE DATA POINTER
006B 85 2C STA POINT
006D 05 2C LDA #0F INITIALIZE LOOP COUNT
006F 05 2A STA LOOPCT FOR 16 ITERATIONS
0071 FF 05 2C JSR TFORM PERFORM 'PC-1'
0073 FF 05 2C JSR TFORM PERFORM 'PC-1', FOR
0075 FF 05 2C JSR TFORM ENCRYPT CYCLE, GET
0077 FF 05 2C JSR TFORM SUBKEY BY ROTATING
0079 FF 05 2C JSR TFORM CC(1) AND CC(3) THEN
007B FF 05 2C JSR TFORM PERFORM 'PC-2', FOR
007D FF 05 2C JSR TFORM DECRYPT CYCLE,
007F FF 05 2C JSR TFORM REVISE THIS
0081 FF 05 2C JSR TFORM JSR TFORM
0083 FF 05 2C JSR TFORM PERFORM 'SELECT-E'
0085 FF 05 2C JSR TFORM PERFORM 'MOD 2', FOR
0087 FF 05 2C JSR TFORM SUBKEY AND
0089 FF 05 2C JSR TFORM SUBKEY (X)
008B FF 05 2C JSR TFORM PERMUTED (PT)(RIGHT)
008D FF 05 2C JSR TFORM SET BITS 0-7 TO ZERO
008F FF 05 2C JSR TFORM FOR SELECT 51-58
0091 FF 05 2C JSR TFORM DEX
0093 FF 05 2C JSR TFORM BPL L16
0095 FF 05 2C JSR TFORM BPL L16
0097 FF 05 2C JSR TFORM JSR SELECT PERFORM 'SELECT' 51-58

Continued below:
Listing 7 continued on next page.
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THE REASON
YOU BOUGHT
YOUR COMPUTER.

Circle 151 on inquiry card.
How many times have you waited in a line? Do you always get to a supermarket checkout counter without having to wait? Is the pump at the gas station always open and ready for you as you drive into the service area? It's difficult to imagine anyone going anywhere and not having to wait in a line.

Since we're computer oriented, let's define a waiting line by its proper name—that is, a queue. A queue is a waiting line controlled by some service mechanism. A customer enters a queue at the tail of the queue, waits in line until he or she arrives at the head of the queue, is serviced at the head of the queue, and, finally, leaves the queue. At the supermarket a customer pushes a cart to one of the lines formed at the checkout area and waits in a line until finally arriving at the cash register at the head of that line. After checking out the purchases, that customer leaves the queue.

Queue Examples

Other examples of queues can be found in many areas of our everyday lives. The supermarket checkout queue is a commercial type of queuing system. Other commercial queues include the bank teller queue, the barbershop queue, the gas station queue, etc. The field of transportation is not without its share of queues: traffic lights, turnpike toll booths, airport runways, loading and unloading docks are but a few examples.

Of course, we have personal queues. How about that shelf of books you're planning to read some day?

Let's Have Order

A queue is defined as a waiting line, and since a waiting line has both a beginning (tail) and an end (head), a queue must also have both these properties.

The head and tail idea implies that customers entering (being inserted) or leaving (being deleted) must follow a definite ordering scheme as members of the queue. This ordering scheme is defined as the dispatching discipline of the queue.

The usual dispatching discipline of a queue is known as first in first out or FIFO. An orderly queue exhibits this scheme. The first person entering the queue is the first person to receive service, and the last person entering the queue is the last person to receive service. Any person entering after the first but before the last must spend some time waiting in the queue before service may be rendered.

The first in first out discipline is but one of many ordering schemes that queues follow. Other servicing disciplines include last in first out (eg: a stack of dishes), a priority queue, and shortest line first or longest line first (these are multiple queuing systems and will be discussed later).

Queue Representation

How can we represent a queue as part of a computer program? The following piece of BASIC coding (a one-dimensional array) could be used to represent a queue in a computer program:

```
10 DIM Q(100).
```

A queue is nothing more than a special purpose one-dimensional array. Just as the ordinary one-dimensional array is represented as a single row or a single column structure \( n \) locations long or deep, the queue can be represented as a single row structure \( n \) locations long.

Over and Under

When an array is dimensioned to 100 locations, the program cannot access the
Wondering which memory is best for you?

Base 2 offers the following products to the S-100 market at the industry's lowest prices:

**8K Static Memory Board**
This 8K board is available in two versions. The 8KS-B operates at 450ns for use with 8080 and 8080A microprocessor systems and Z-80 systems operating at 2MHz. The 8KS-Z operates at 250ns and is suitable for use with Z-80 systems operating at 4MHz. Both kits feature factory fresh 2102's (low power on 8KS-B) and includes sockets for all IC's. Support logic is low power Schottky to minimize power consumption. Address and data lines are fully buffered and 4K bank addressing is DIP switch selectable. Memory Protect/Unprotect, selectable wait states and battery backup are also designed into the board. Circuit boards are solder masked and silk-screened for ease of construction. These kits are the best memory value on the market! Available from stock...

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Circle 22 on inquiry card.
Listing 1: Simple BASIC simulation of a row queue. Pseudorandom number generation is done to ensure that the queue simulation works correctly as described in the text. A sample run of the program is also shown.

```
1000 DIM Q(5)
1001 REM INITIALIZE QUEUE TO EMPTY STATE
1002 REM
1010 FOR J2 = 1 TO 5
1020 Q(J2) = -9
1030 NEXT J2
1031 REM INITIALIZE TAIL TO HEAD OF QUEUE
1032 REM
1040 T = 5
1041 REM START OF MAIN SIMULATION LOOP
1042 REM
1050 FOR J2 = 1 TO 15
1051 REM GENERATE A RANDOM NUMBER TO DETERMINE
1052 REM AN INSERTION WHEN N <= 5
1053 REM A DELETION WHEN N >= 6
1054 REM
1060 N = INT ( RND (1) * 10 ) + 1
1070 PRINT "NUMBER"; N;
1080 IF N <= 5 GOSUB 1170
1090 IF N >= 6 GOSUB 1240
1091 REM PRINT QUEUE CONTENTS
1092 REM PRINT TAIL POINTER VALUE
1093 REM
1100 PRINT "QUEUE";
1110 FOR J3 = 1 TO 5
1120 PRINT Q(J3);
1130 NEXT J3
1140 PRINT "TAIL"; T
1141 REM END OF MAIN SIMULATION LOOP
1142 REM
1150 NEXT J2
1160 STOP
1161 REM INSERTION ROUTINE
1162 REM
1164 REM WHEN T = 0 QUEUE IS FULL, I.E. OVERFLOW
1165 REM ELSE, INSERT N AT TAIL AND DECREMENT TAIL
```

104th or -36th location. These integer values are not within the boundaries of the dimensioning statement. If the program attempts to address out of range locations during execution of the program, an overflow or underflow condition occurs. Overflow occurs when a location greater than that given in the dimensioning statement is addressed. Likewise, underflow occurs when a negative subscript is given as an addressing value.

Some BASIC interpreters allow for addressing location 0 of an array. If an array is dimensioned to 100 locations, the actual number of legally addressable locations is 101 (counting location 0 as the first available location).

The program listings in this article do not take advantage of this extra available array location. The first available location is always array location 1, and the last available location is equal to the integer value given in the dimensioning statement.

Let's get back to overflow and underflow as these conditions apply to queues. If we assume that our queueing program will not address a location above or below those given in the dimensioning statement, overflow and underflow take on a somewhat different meaning.

A queue overflow occurs when the program attempts to insert an item into our queue and the queue is filled to its capacity. Underflow in a queue structure occurs when the program attempts to delete an item from the queue but there are no items in the queue.

Queue Operations

Items in an ordinary one-dimensional array can have many operations performed
on them. A program can insert items anywhere within the array, and items can be removed from any legal location within the array. Items can be examined and left in place or moved to any location within an array.

A queue can have only two operations performed upon its items. The first of these allowable operations is the insertion of an item into the queue. This insertion can be done only at the tail of the queue. The second operation allows for deletion. Deletion is done only at the head of the queue.

The Simple Row Queue

The program shown in listing 1 is a simulation of a row queue (see figure 1). The mechanics of a row queue follow the definitions we have seen so far.

The row queue has its tail at location 1 of array Q, while its head is at location 5 of array Q. The choice of these locations for tail and head is arbitrary. I chose this scheme

Figure 1: Simple row queue. This type of queue has a stationary "head" and a moving "tail." As data items are deleted from the head, all of the data items in the queue are moved toward the head, and the tail pointer is decremented by 1. As more data is entered into the queue at the tail, the location of the tail pointer is incremented by one location.

Listing 1, continued:

1166 REM
1170 IF T = 0 GOTO 1220
1180 PRINT "INSERTION";
1190 QC(T) = N
1200 T = T - 1
1210 RETURN
1220 PRINT "OVERFLOW";
1230 RETURN
1231 REM
1232 REM DELETION ROUTINE
1233 REM
1234 REM WHEN T = 5 QUEUE IS EMPTY, I.E., UNDERFLOW
1235 REM ELSE, DELETE N AT HEAD OF QUEUE
1236 REM AND MOVE REMAINING ITEMS TOWARD HEAD
1237 REM
1240 IF T = 5 GOTO 1350
1250 PRINT "DELETION";
1260 T = T + 1
1270 FOR J4 = 5 TO T STEP -1
1280 IF J4 = 1 GOTO 1350
1290 J5 = J4 - 1
1300 QC(J4) = QC(J5)
1310 NEXT J4
1320 RETURN
1330 QC(1) = -9
1340 RETURN
1350 PRINT "UNDERFLOW";
1360 RETURN
1370 END

RUN
NUMBER= 7 UNDERFLOW QUEUE=-9 -9 -9 -9 -9 TAIL= 5
NUMBER= 3 INSERTION QUEUE=-9 -9 -9 -9 3 TAIL= 4
NUMBER= 7 DELETION QUEUE=-9 -9 -9 -9 -9 TAIL= 5
NUMBER= 4 INSERTION QUEUE=-9 -9 -9 -9 4 TAIL= 4
NUMBER= 1 INSERTION QUEUE=-9 -9 -9 -9 4 TAIL= 3
NUMBER= 5 INSERTION QUEUE=-9 -9 3 1 4 TAIL= 2
NUMBER= 2 INSERTION QUEUE=-9 2 3 1 4 TAIL= 1
NUMBER= 5 INSERTION QUEUE= 5 2 3 1 4 TAIL= 0
NUMBER= 2 OVERFLOW QUEUE= 5 2 3 1 4 TAIL= 0
NUMBER= 8 DELETION QUEUE= 5 2 3 1 4 TAIL= 1
NUMBER= 7 DELETION QUEUE=-9 -9 3 2 3 TAIL= 2
NUMBER= 8 DELETION QUEUE=-9 -9 3 5 2 TAIL= 3
NUMBER= 3 INSERTION QUEUE=-9 3 3 5 2 TAIL= 2
NUMBER= 4 INSERTION QUEUE=-9 3 3 5 2 TAIL= 1
NUMBER= 9 DELETION QUEUE=-9 -9 4 3 5 TAIL= 2
Figure 2: Circular queue in three states of use. Figure 2a is an empty queue, in which the head pointer and the tail pointer point to the same location in the queue. Figure 2b shows a partially filled circular queue. The tail pointer moves ahead of the head pointer as data items are added to the queue. As an item is deleted, the head pointer moves towards the tail pointer. Figure 2c shows a full queue. In this state the tail pointer has caught up with the head pointer. Note that one location in the queue will be left empty. If this were not done, the next item added to the queue would make the head and tail pointers point to the same location, which would seem to indicate that the queue was empty.

because it is easier to output the queue during execution of the program in a normal left-to-right reading fashion.

The head (service facility area) of the queue of listing 1 is always at location Q(S). The tail of the queue (the location in the queue where items will be inserted) moves from location 5 toward location 0 of array Q as items are inserted into the queue. When items are deleted, the tail of the queue moves from its present value toward location 5.

The tail of the row queue is indicated by a tail pointer (variable T). When T is 5 the queue is empty: that is, there are no items in the queue. When T is 0 the queue is filled to its capacity and no insertions can be made without causing an overflow condition.

To simulate the action of a queue properly, listing 1 generates pseudorandom numbers to determine queue insertion or deletion. The importance of randomness in proper queue operation is explained later.

Before you execute the program in listing 1, run through its operations with pencil and paper. This approach will show you how the program will run before the actual operation is simulated by the computer. This method will also clarify the mechanics of a simple row queue operation.

The Circular Queue

A major disadvantage of our simple row queue is the fact that items must be moved toward the head of the queue after each deletion. [Editor's Note: This is not true for all implementations of a row queue. Often, the pointers indicating the head and tail of the row queue are moved instead of all the data inside the queue. . . . RGAC] The loop in line numbers 1370 through 1400 of listing 1 accomplishes this move. If we're trying to represent a queue simulation in a computer program, why not use some programming techniques to take advantage of decreasing execution time and thereby eliminate some of the unwieldy code?

The circular queue, figure 2, is also represented as a special purpose one-dimensional array. The simple row queue has a pointer to keep track of the location where the next item insertion was to take place. The circular queue also has this tail pointer.

The difference between the row and circular queue lies in the addition of another pointer to indicate the location of the head of the queue. The simple row queue always has its head at the last available location of the array Q. The circular queue structure can have its head anywhere within the queue.

Circular Queue Representation

The circular queue operates in the same manner as the simple row queue. Items are still inserted into the location given as the tail point location of array Q.
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Circle 278 on inquiry card.
Listing 2: BASIC listing for a circular queue simulation. Lines 1900 through 2100 are the insertion routine; lines 2110 through 2270 are the deletion routine. A sample run of the program is shown at the end of the listing.

```
1000 DIM Q(5)
1001 REM
1002 REM INITIALIZE QUEUE TO EMPTY STATE
1003 REM
1010 FOR J2 = 1 TO 5
1020 Q(J2) = -9
1030 NEXT J2
1031 REM INITIALIZE HEAD AND TAIL POINTERS
1032 REM HEAD OF QUEUE LOCATION
1033 REM
1040 H = 5
1050 T = 5
1051 REM START OF MAIN SIMULATION LOOP
1052 REM
1060 FOR J3 = 1 TO 10
1062 REM GENERATE A RANDOM NUMBER TO DETERMINE
1063 REM AN INSERTION WHEN N <= 5
1064 REM A DELETION WHEN N > 6
1065 REM
1070 N = INT ( RND (1) * 10 ) + 1
1080 IF N <= 5 GOSUB 1900
1090 IF N > 6 GOSUB 2110
1091 REM PRINT QUEUE CONTENTS
1092 REM PRINT TAIL AND HEAD POINTER VALUES
1093 REM
1100 FOR J4 = 1 TO 5
1110 PRINT Q(J4); 
1120 NEXT J4
1130 PRINT " TAIL AT"; T; " HEAD AT"; H
1131 REM END OF MAIN SIMULATION LOOP
1132 REM
1140 NEXT J3
1150 STOP
1151 REM
1152 REM INSERTION ROUTINE
1153 REM
1154 REM CHECK TAIL AND HEAD POINTER VALUES
1155 REM
1160 IF H = T GOTO 1970
1170 IF H < T GOTO 2030
1180 IF T >= H GOTO 2030
1190 IF H = 5 GOTO 2080
1200 REM
1201 REM INSERT ITEM AT Q(H)
1202 REM SINCE QUEUE IS EMPTY
1203 REM
1210 Q(S) = N
1220 T = 4
1230 GOTO 2050
1240 IF T <= 0 GOTO 2000
1250 REM
1251 REM RESET POINTERS TO HEAD OF QUEUE
1252 REM
1260 H = 5
1270 T = 5
1280 REM
1290 REM CHECK IF Q(T) EMPTY FOR POSSIBLE INSERT
1300 REM
1310 IF Q(T) <= -9 GOTO 2080
1320 IF T <= -9 GOTO 2000
1330 REM
1340 REM END OF PROGRAM
1350 REM
1360 STOP
```

The major difference is in the way which
the program controls the head location of
the queue. A new variable called H (for head
pointer) points to the array location which
holds the item ready for deletion.

An item is inserted into the queue at the
location pointed to by the tail pointer. After
this insertion, the pointer is moved by one
location in readiness for another insertion.
When an item is deleted, the head pointer
comes into play. In the simple row queue,
the head is always at the last available loca­
tion. In the circular queue, the head of the
queue is defined by the value of the head
pointer variable H. After an item is deleted,
the head pointer is moved one location
toward the value of the tail pointer. In this
structure, data items remain stationary; only
the pointers vary, indicating relative positions
of the tail and the head of the queue.

This queue structure is clearly advan­
tageous when we’re dealing with long
 queues. If a row queue is fil led to its capac­
ty and an item is dele ted, every remain ing
item has to be moved one at a time toward
the stationary head of the row queue. The
circular queue moves the head pointer by
only one location, thereby cutting progr a m
execution time.

The tradeoff is time versus space. The
circular queue program is longer than the
simple row queue; however, the time to
execute the circular queue routine is shorter
since the majority of code execution in the
simple row queue is during the moving of
the items after a delete operation.

In the circular queue, the tail pointer
chases the head pointer during insertions.
During deletions, the head pointer chases
the tail pointer.

When the circular queue is filled to
capacity, the head and tail pointers are at
adjacent locations. No more items may be
inserted simply because there is no more
available space to fit an item into the queue.
An overflow condition occurs if an insertion
is attempted on a filled queue.

An underflow occurs when the queue is
empty and a deletion is attempted. An
empty circular queue is one in which the tail
and the head pointers are at the same loca­
tion in the array Q.

The program given in listing 2 simulates
a circular queue. Again, a pencil and paper
method of initial execution may prove help­
ful. After the mechanics of this structure are
understood, then execute the program.

This completes our discussion of two
different types of queues and their represen­
tation in a computer. In part 2 we will
consider queues in the world around us
and fit them into the structures already
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Circle 326 on inquiry card.
Listing 2, continued:

2021 REM
2022 REM NORMAL TAIL INSERTION
2023 REM
2030 Q(T) = N
2040 T = T - 1
2050 PRINT "="
2060 PRINT "ARRIVAL"
2070 RETURN
2080 PRINT "="
2090 PRINT "OVERFLOW"
2100 RETURN
2101 REM
2102 REM DELETION ROUTINE
2103 REM
2104 REM CHECK POINTER VALUES FOR POSSIBLE DELETE
2105 REM
2110 IF H = T GOTO 2150
2120 IF H > 0 GOTO 2190
2130 H = 5
2140 GOTO 2180
2150 IF H =< 0 GOTO 2180
2160 H = 5
2170 T = 5
2171 REM
2172 REM DELETE FROM Q(H) IF Q(H) HAS AN ITEM
2173 REM ELSE, QUEUE IS EMPTY, I.E. UNDERFLOW
2174 REM
2180 IF Q(H) = -9 GOTO 2240
2190 Q(H) = -9
2200 H = H-1
2201 REM
2202 REM RESET POINTERS FOR NEXT DELETE
2203 REM
2210 IF H =< 0 GOTO 2260
2220 H = 5
2230 RETURN
2240 PRINT "="
2245 PRINT "UNDERFLOW"
2260 RETURN
2270 END

RUN

ARRIVAL
-9 -9 -9 -9 3 TAIL AT 4 HEAD AT 5

ARRIVAL
-9 -9 -9 2 3 TAIL AT 3 HEAD AT 5

ARRIVAL
-9 -9 4 2 3 TAIL AT 2 HEAD AT 5
-9 -9 4 2 -9 TAIL AT 2 HEAD AT 4

ARRIVAL
-9 5 4 2 -9 TAIL AT 1 HEAD AT 4

ARRIVAL
3 5 4 2 -9 TAIL AT 0 HEAD AT 4

ARRIVAL
3 5 4 2 1 TAIL AT 4 HEAD AT 4

OVERFLOW
3 5 4 -9 1 TAIL AT 4 HEAD AT 3

ARRIVAL
3 5 4 3 1 TAIL AT 3 HEAD AT 3
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<th>Unkit</th>
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<td>Econoram XII*</td>
<td>16K X 8</td>
<td>S-100</td>
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Cryptography

Part 2: Using the Pocket

As mentioned in part 1 of this article (March 1979 BYTE, page 56), a field cipher is a technique for encoding plaintext so that it can be easily decoded with pencil and paper (or calculator) in the field, so to speak. The calculator program of listing 1 when used with the procedures described offers the user an effective field cipher capability. Unlike most field cipher machines, which perform substitution only, the program Crypto (listing 1) offers both transposition and substitution. The transposition operation is mandatory and provides the main strength of the cipher. Substitution may be added for further protection if desired. The basic principles of operation are first described, including detailed instructions for usage. Following this, a discussion of program organization is given.

Since Crypto performs both transposition and (optionally) substitution, a transposition table and substitution key are involved in the processing of each character. It is convenient to define a few terms:

| Na | alphabet size (no practical limit); |
| Nc | number of characters in message (300 maximum); |
| J  | plaintext character position (1, 2, ..., Nc); |
| M  | ciphertext character position (1, 2, ..., Nc); |
| P  | plaintext character (A, B, C, ...); |
| C  | ciphertext character (A, B, C, ...); |
| K  | key value used in substitution process. |

The program uses a random number generator which must be initialized with a seed, R0, and two parameters, A1 and A2. These three numbers plus the character count are entered into the stack, after which A is depressed. One more number completes the entry, after which R/S is depressed. The
in the Field

Calculator

demonstration numerical key is: R0 = 0.5; A1 = 1.625; and A2 = 3.125.

Transposition Only Mode

The character manipulations for transposition only are illustrated in table 8. The top two rows, an index row and a plaintext character row, are concerned with plaintext. The bottom two rows are ciphertext index and ciphertext. Each time Crypto is cycled, a pair of integers is displayed in the format:

J.M

... and are interpreted in the enciphering operation as “plaintext character at position J goes to ciphertext position M.” Number J is simply indexed every cycle (1, 2, . . ., Ne). Crypto produces the M values randomly in the range 1 to Ne with no repetitions (transposition table). For the cycle illustrated in table 8, the display shows 6.002, which requires that the B from J = 6 be moved to M = 2. By this means the plaintext characters are reordered in a random fashion to form the ciphertext.

The deciphering operation works in an obviously reverse fashion. The displayed J.M is read as “ciphertext character at position M goes to plaintext position J.” Thus in table 8 6.002 would return the B from ciphertext position 2 to the correct plaintext position 6.

Mixed Alphabet Generation

If the optional substitution operation is to be added to the transposition operation, numerical equivalence for each character of the alphabet must be established. In the discussion which followed the Vigenère Tableau method (March 1979 BYTE, page 57, table 3), an ordered alphabet was used in which the numerical values ran, in order, from 0 to one less than the alphabet size (Ne-1).

In the work which follows, two changes are made. The numerical equivalents are moved

<table>
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<tr>
<th>Location</th>
<th>Keys</th>
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<tr>
<td>01</td>
<td>ILBLA</td>
</tr>
<tr>
<td>07</td>
<td>ST02</td>
</tr>
<tr>
<td>13</td>
<td>R/S</td>
</tr>
<tr>
<td>19</td>
<td>hCF1</td>
</tr>
<tr>
<td>25</td>
<td>2</td>
</tr>
<tr>
<td>31</td>
<td>ILBL1</td>
</tr>
<tr>
<td>37</td>
<td>IGSBE</td>
</tr>
<tr>
<td>43</td>
<td>hINT</td>
</tr>
<tr>
<td>49</td>
<td>hSTI</td>
</tr>
<tr>
<td>55</td>
<td>x</td>
</tr>
<tr>
<td>61</td>
<td>RCL(i)</td>
</tr>
<tr>
<td>67</td>
<td>gx&gt;y?</td>
</tr>
<tr>
<td>73</td>
<td>GTO5</td>
</tr>
<tr>
<td>79</td>
<td>9</td>
</tr>
<tr>
<td>85</td>
<td>IBL3</td>
</tr>
<tr>
<td>91</td>
<td>IBL5</td>
</tr>
<tr>
<td>97</td>
<td>STO:7</td>
</tr>
<tr>
<td>103</td>
<td>RCLE</td>
</tr>
<tr>
<td>109</td>
<td>GTOB</td>
</tr>
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<td>STO:7</td>
</tr>
<tr>
<td>121</td>
<td>hRCI</td>
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<td>ILN</td>
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<td>+</td>
</tr>
<tr>
<td>139</td>
<td>RCL6</td>
</tr>
</tbody>
</table>

Listing 1 continued on page 152.

Entries:

A = A0, A1, A2, Ne  
R/S: Na  
Na=0 transposition only,  
Na=0 transposition and substitution  
+a encrypt  
-a decrypter  

Registers:

<table>
<thead>
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<th>Register</th>
<th>Value</th>
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</thead>
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<tr>
<td>D</td>
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</tr>
<tr>
<td>1</td>
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</tr>
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<td>2</td>
<td>A2</td>
</tr>
<tr>
<td>3</td>
<td>S</td>
</tr>
<tr>
<td>4</td>
<td>Na</td>
</tr>
<tr>
<td>5</td>
<td>utility</td>
</tr>
<tr>
<td>6</td>
<td>J</td>
</tr>
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<td>8</td>
<td>utility</td>
</tr>
<tr>
<td>9</td>
<td>R</td>
</tr>
<tr>
<td>50-59</td>
<td>M-field bit storage</td>
</tr>
<tr>
<td>A</td>
<td>R2j</td>
</tr>
<tr>
<td>B</td>
<td>not used</td>
</tr>
<tr>
<td>C</td>
<td>Na</td>
</tr>
<tr>
<td>D</td>
<td>not used</td>
</tr>
<tr>
<td>E</td>
<td>229</td>
</tr>
</tbody>
</table>

Listing 1: Crypto program written for the HP 67. This program performs encryption and decryption functions by transposition and substitution as described in the text. The value of Na must be less than or equal to 300 and the value of Na must not exceed 999. Flag F0 has two states: true for decipherer and false for encrypter mode. Flag F1 is true when only transposition mode is wanted and false when the dual transposition and substitution mode is used. Flag F2 is used in the random number generation loop.
to the range of 1 to the alphabet size for user convenience only. Secondly, a mixed alphabet is recommended, such as that shown in table 9. This type of alphabet is no harder to use and offers an increase in security over the ordered alphabet.

Generation of such an alphabet is trivial. Columns 1 and 3 are prepared first. Program Crypto is then run in the transposition only mode with a character count equal to the alphabet size. The M values generated are copied into column 2; the J index corresponds to column 3. The data thus formed in columns 1 and 2 permits column 4 to be filled in. Table 9 allows convenient alphabetic-to-numeric conversions (columns 1, 2) and numeric-to-alphabetic (columns 3, 4).

Dual Mode Operation

Table 10 illustrates the situation in which substitution is done in addition to transposition. Note that a plaintext numerical value row has been added to the plaintext section and a ciphertext numerical value row has been inserted into the ciphertext section. The $\overline{P_j}$ row is filled by use of columns 1 and 2 of table 9. Each Crypto cycle now has two parts. In the first part the machine halts with $J.M$ in the display, as before. The user then enters the plaintext value ($\overline{P_j}$) value (11 for I in this case) from the plaintext value row and depresses R/S. The machine will perform the appropriate addition (modulo Na) and halt showing:

$$J.M \overline{C_m}.$$ 

For the table 10 example the display would show:

7.002024.

The user then places 24 in position 2 of the ciphertext value ($\overline{C_m}$) row and depresses R/S for the next cycle. Columns 3 and 4 of table 9 may be used later to convert the character values to equivalent characters $C_m$.

In the deciphering operation one starts with the ciphertext and obtains the $C_m$ values from table 9. During the $J.M$ halt in the Crypto cycle the user enters $\overline{C_m}$ (24 from position 2 in the 7.002 example) and depresses R/S. The subtraction operation (modulo Na) is performed and the result is shown as:

$$J.M \overline{P_j};$$

which would be:

7.002011.

This directs that 11 be placed at position 7 of the $\overline{P_j}$ row which is thus filled and later converted to character equivalents to complete the deciphering operation.

In actual usage a single index row may serve for both $J$ and $M$. However, one may wish to record $M$ of the displayed $J.M$ pair as a record of the transposition operations.

Detailed Instructions and Examples

Tables 11 and 12 give detailed instructions for the use of Crypto in the transposition only mode. Tables 13 and 14 give instructions for operation in the dual (transposition and substitution) mode.

These tables contain 10 character examples using the demonstration message and demonstration key. The complete demonstration message processed by transposition only (table 11) using the demonstration key, becomes:

$$(A: 0.5, 1.625, 3.125, 40 R/S: 0)$$

$$(E B A E Y \quad E C N T M)$$

$$(I P D E O \quad R R Y P P)$$
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</tr>
</tbody>
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1. Prepare table as example table 11b shows and enter plaintext Pj.
2. Switch calculator to RUN and ON.
3. Load program.
4. Input data R0, A1, A2, Nc. Follow each entry except the last with ENT1. Press A.
5. Input data 0.
6. Depress R/S to start program.
7. Calculator will stop with a number in the form J.M. Copy plaintext character at position J to ciphertext position M.
9. Repeat the steps 7 and 8 loop. Pressing R/S after character Nc will cause the ERROR sign to flash. When flashing stops, press R/S one time.
10. If program is to be restarted, return to step 4.

Encipherment Example

<table>
<thead>
<tr>
<th>J.M</th>
<th>01</th>
<th>02</th>
<th>03</th>
<th>04</th>
<th>05</th>
<th>06</th>
<th>07</th>
<th>08</th>
<th>09</th>
<th>10</th>
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</thead>
<tbody>
<tr>
<td>Pj</td>
<td>M</td>
<td>A</td>
<td>Y</td>
<td>U</td>
<td>P</td>
<td>B</td>
<td>I</td>
<td>D</td>
<td>P</td>
<td>R</td>
</tr>
<tr>
<td>Cm</td>
<td>A</td>
<td>B</td>
<td>M</td>
<td>P</td>
<td>D</td>
<td>I</td>
<td>P</td>
<td>R</td>
<td>U</td>
<td>Y</td>
</tr>
</tbody>
</table>

Table 11: Crypto instructions for enciphering in the transposition only mode. The key is A:0.5, 1.625, 3.125, 10 R/S: 0.

1. Prepare table as example table 12b shows and enter ciphertext Cm.
2. Switch calculator to RUN and ON.
3. Load program.
4. Input data R0, A1, A2, Nc. Follow each entry except the last with ENT1. Press A.
5. Input data 0.
6. Depress R/S to start program.
7. Calculator will stop with a number in the form J.M. Copy ciphertext character at position M to plaintext position J.
9. Repeat the steps 7 and 8 loop. Pressing R/S after character Nc will cause the ERROR sign to flash. When flashing stops, press R/S one time.
10. If program is to be restarted, return to step 4.

Decipherment Example

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<td>B</td>
<td>I</td>
<td>D</td>
<td>P</td>
<td>R</td>
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</table>

Table 12: Crypto instructions for deciphering in the transposition only mode. The key is A:0.5, 1.625, 3.125, 10 R/S: 0.

1. Prepare table as example table 13b shows. Enter plaintext Pj and, using alphabet table, enter Pj values.
2. Switch calculator to RUN and ON.
3. Load program.
4. Input data R0, A1, A2, Nc. Follow each entry except the last with ENT1. Press A.
5. Input data 0.
6. Press R/S to start program.
7. Calculator will stop with a number in the form J.M. At index J select and enter Pj and press R/S.
8. Calculator will stop with a number in the form J.M Cm. At index M in table enter Cm from display.
10. Repeat the steps 7, 8 and 9 loop. Pressing R/S after character Nc flashes the ERROR sign. When flashing stops, press R/S one time.
11. Using alphabet table convert Cm to Cm to obtain ciphertext.
12. If program is to be restarted, return to step 4.

Encipherment Example

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<tr>
<th>J.M</th>
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<th>04</th>
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<td>P</td>
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<td>Y</td>
<td>M</td>
<td>P</td>
<td>I</td>
<td>Z</td>
<td>X</td>
<td>M</td>
<td>G</td>
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</tbody>
</table>

Table 13: Crypto instructions for enciphering in the dual transposition and substitution mode. The sample table used for enciphering is shown in table 13b. The key is A:0.5, 1.625, 3.125, 10 R/S: 26; table 9 used.

Text continued from page 146:

The same message enciphered in the dual mode (table 13) becomes:

(A: 0.5, 1.625, 3.125, 40 R/S: 26)

S I H I U J I F Y Y
I M P A I X R V X Z
S A V V W P A R T U
S G I W M V F F B G.

In the dual mode operation a conversion operation may be saved at each end of the system by using the numerical Cm data directly as the cryptogram. The disadvantage to this is that the number of characters to be transmitted is doubled. In some circumstances transmission of numerals may be preferred over alphabetic characters in spite of the expanded volume.

Use of Nulls

Many procedures may be followed which will aid in protecting the cipher. One of these is the use of nulls. This procedure is very simple to use and actually speeds up the enciphering and deciphering process as discussed in the text box on search strategy. To use this technique, specify a message character length (Ne) to program Crypto which is larger than the actual message length. For example, consider a message of length 100 and an Ne value specification of, say, 125. Crypto is used in the normal way until all 100 message characters are processed into the ciphertext. At this point the 125 character ciphertext contains 25 (scattered) blank spaces. Fill these blank spaces with characters chosen by you at random. When finished, the cryptogram will contain 25 totally irrelevant characters randomly located in the ciphertext.

The nulls present no problem to the decipherer since Crypto will point that person to genuine data for the first 100 processing cycles; after that the nulls are indicated. It might be wise to clearly delineate the end of a message by appending some prearranged terminal symbol to the plaintext. The speed of operation may be greatly increased by use of nulls since this keeps the mean processor time low, as discussed in the text box on search strategy. The longer messages should definitely use nulls to speed up the process. The use of nulls is clearly advantageous, since this presents the cryptanalyst with some additional possibilities that must be sorted out. Make sure that the nulls you supply blend well with the genuine ciphertext. Do not attempt, for example, to bal-
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Listing 1, continued from page 145:

145  GTOfa  ENT1  1  --  RCLO  RCLC
151  X  HINT  h30  GTOfe  +  GTOld
157  gLBLfe  CH5  RCLC  +  +  gLBLld
163  RCLC  gX>Y?  CLX  --  1  +
169  EEX  6  +  RCL5  +  DSP6
175  R/S  gLBLfa  1  STO-3  RCL3  h 1/x
181  1  STO+6  6  RCL3  gX>Y?  GTO1
187  GTO2  fLBLfE  hSF2  RCLA  gLBLfe  RCL1
193  +  RCL2  hy*  gFRAC  STOA  hF2
199  GTOfe  X  HINT  RCL0  RCL1  +
205  RCL2  hy*  gFRAC  ST06  RCLA  --
211  h 1/x  hR1  hRTN

Listing 2: Keygen program written for the HP 67. This program generates numerical keys from alphabetic phrases for program Crypto. When using this program, the user needs to know both the key base and the number of the key within the key sequence produced. A detailed description of how to operate program Keygen is given in table 15.

<table>
<thead>
<tr>
<th>Location</th>
<th>Keys</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>fLBLD  ENT1  EEX  1  0</td>
</tr>
<tr>
<td>7</td>
<td>fIX  DSP4  STO6  STO7  STO3  CLX</td>
</tr>
<tr>
<td>13</td>
<td>RCL8  EEX  3  x  gFRAC  3  -</td>
</tr>
<tr>
<td>25</td>
<td>7  5  x  +  STO8  RCL6</td>
</tr>
<tr>
<td>31</td>
<td>EEX  6  x  gFRAC  3  -</td>
</tr>
<tr>
<td>37</td>
<td>7  5  x  RCLA  +  STOC</td>
</tr>
<tr>
<td>43</td>
<td>hRTN  fLBLfE  STO8  fLBL9  RCL9  RCL8</td>
</tr>
<tr>
<td>49</td>
<td>gX&gt;Y?  GTO8  RCL6  fLBL9  RCL9  RCL8</td>
</tr>
<tr>
<td>55</td>
<td>STO9  fLBL8  RCL8  RCL9  --  1</td>
</tr>
<tr>
<td>61</td>
<td>-  fX=0?  GTO7  hSTI  fLBL8  gGSBfd</td>
</tr>
<tr>
<td>67</td>
<td>IDSZ  GTO6  fLBL7  RCL8  STO9  gGSBfd</td>
</tr>
<tr>
<td>73</td>
<td>RCL7  RCL9  +  R/S  RCL6  --</td>
</tr>
<tr>
<td>79</td>
<td>7  5  x  RCLA  +  R/S</td>
</tr>
<tr>
<td>85</td>
<td>RCLD  3  -  7  5  x</td>
</tr>
<tr>
<td>91</td>
<td>RCLA  +  R/S  1  STO+8  GTO9</td>
</tr>
<tr>
<td>97</td>
<td>gLBLfe  RCL7  RCLB  +  RCLC  hy*</td>
</tr>
<tr>
<td>103</td>
<td>gFRAC  STO7  RCLD  RCLB  +  RCLC</td>
</tr>
<tr>
<td>109</td>
<td>hy*  gFRAC  ST06  RCLB  +  RCLC</td>
</tr>
<tr>
<td>115</td>
<td>hy*  gFRAC  STO6  RCL2  --  h 1/x</td>
</tr>
<tr>
<td>121</td>
<td>hRTN</td>
</tr>
</tbody>
</table>

The 15 nulls are distributed randomly throughout the ciphertext. The reader may verify the operation by deciphering this cryptogram. Note that the first null pointed to will be on plaintext character 46, which is the start of the junk region.

In addition to the use of nulls, other precautions may be taken to protect the cipher. The beginning and end of a message can represent sources of vulnerability. Standard or easily guessed salutations and signatures can be of great help to the cryptanalyst. One counter to this is to insert a few nonsense words at the beginning and end of each message using prearranged delineation flags. There is also the division method, which involves starting the message from some point near the middle, going to the end and then picking up the start. This buries the head and tail of the message somewhere in the middle of the cryptographic process.

The key of program Crypto is the 3 number group (R0, A1, A2). Program Keygen (listing 2) provides for convenient generation of thousands of keys from an easily remembered keyphrase. There is absolutely no excuse for using a given key more than once. In dual mode operation use one key for the mixed alphabet transposition table (table 9) and a different key for the Crypto enciphering operation. (By the way, do not be overly impressed by the added complexity of the dual mode cipher. In this business, complexity and security are not necessarily correlated. The transposition mode represents a very effective cipher in spite of its simplicity of operation. Don't be afraid to use it.) The limited speed, storage and I/O (input/output) facilities of today's pocket
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<table>
<thead>
<tr>
<th>DISPLAY</th>
<th>SPECIFICATIONS</th>
<th>INTERFACE</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCREEN CAPACITY, CHARACTERS</td>
<td>DATA FORMAT</td>
<td>7 serial, asynchronous</td>
</tr>
<tr>
<td>CHARACTERS PER LINE</td>
<td>DATA BITS</td>
<td>1, 0 or deleted</td>
</tr>
<tr>
<td>NUMBER OF LINES</td>
<td>DATA BIT R</td>
<td>Odd, even or deleted</td>
</tr>
<tr>
<td>SCREEn</td>
<td>PARITY</td>
<td>with error displayed as</td>
</tr>
<tr>
<td>TUBE SIZE/DIAGONAL</td>
<td>STOP BITS</td>
<td>DLE</td>
</tr>
<tr>
<td>VIEWING AREA</td>
<td>DATA TRANSFER RATE</td>
<td>1 or 2</td>
</tr>
<tr>
<td>CHARACTER SIZE</td>
<td></td>
<td>50, 75, 110, 134.5, 150,</td>
</tr>
<tr>
<td>REFRESH RATE</td>
<td></td>
<td>300, 600, 1200, 1800,</td>
</tr>
<tr>
<td>SCAN METHOD</td>
<td></td>
<td>2000, 2400, 3600, 4800,</td>
</tr>
<tr>
<td>CHARACTER GENERATION</td>
<td></td>
<td>7200, 9600 baud</td>
</tr>
<tr>
<td>MEMORY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TYPE</td>
<td>INVERSE VIDEO</td>
<td>Operator or software</td>
</tr>
<tr>
<td>CAPACITY</td>
<td>TRANSMIT MODES</td>
<td>selectable</td>
</tr>
<tr>
<td>OPERATOR CONTROLS</td>
<td>DATA ENTRY</td>
<td>Half or full duplex (switch</td>
</tr>
<tr>
<td>POWER ON/OFF SWITCH</td>
<td>END OF LINE BELL</td>
<td>selectable</td>
</tr>
<tr>
<td>BRIGHTNESS CONTROL</td>
<td>CURSOR POSITIONING</td>
<td>X, Y</td>
</tr>
<tr>
<td>POWER REQUIREMENTS</td>
<td>DISPLAYABLE CHARACTERS</td>
<td>Load and read</td>
</tr>
<tr>
<td>Model 501 - 115 volts, 60 Hz,</td>
<td>CURSOR CONTROLS</td>
<td>126 (including space)</td>
</tr>
<tr>
<td>Model 502 - 230 volts, 50 Hz,</td>
<td>AUTOMATIC ROLL UP</td>
<td>Up, down, left, right,</td>
</tr>
<tr>
<td></td>
<td>AUTO CARRIAGE RETURN AND LINE FEED</td>
<td>home, return</td>
</tr>
<tr>
<td></td>
<td>MONITOR MODE</td>
<td>Switch selectable</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Special &quot;Monitor&quot; Mode</td>
</tr>
<tr>
<td></td>
<td></td>
<td>allows display of control</td>
</tr>
<tr>
<td></td>
<td></td>
<td>codes (first two columns of</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ASCII Code Chart)</td>
</tr>
</tbody>
</table>

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calculators are compensated for in Crypto by putting the user to work. Because of the manual cooperation required, one quickly learns to keep messages brief. Thus the tendency to keep traffic volume down is, in a lefthanded sort of way, an aid in protecting the cipher.

Program Organization

Extensive use is made of a pseudorandom number generator for producing a sequence \( R_n \) where:

\[
0 \leq R_n < 1. \quad (4)
\]

The algorithm used is:

\[
R_{n+1} = \text{FRAC} \left( (R_n + A_1)^{A_2} \right). \quad (5)
\]

Term \((n+1)\) of the sequence is obtained from term \(n\) by addition of a constant \(A_1\), raising the sum to the power \(A_2\) (another constant parameter), then taking the fractional part of this result as \(R_{n+1}\). The following seed and parameter value ranges have been used successfully:

\[
0 \leq R_0 < 1 \quad \text{(seed)}
\]

\[
1.25 \leq A_1 \leq 2
\]

\[
1.25 \leq A_2 \leq 5.
\]

Changes in any of these three values by 0.0001 or more will produce rapidly diverging series. At the higher \(A_2\) values much smaller changes in \(R_0\) and \(A_1\) will suffice.

\[
0 \leq R_0 < 1 \quad \text{(seed)}
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\]

\[
1.25 \leq A_1 \leq 2
\]

\[
1.25 \leq A_2 \leq 5.
\]
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- Underlining
- Bold face

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NV-II VDM NEC Spinwriter $275.
NR-II REX NEC Spinwriter $300.
NI-II VIO NEC Spinwriter $300.
SSH SOL Helios/TTY $250.
DSH SOL Helios/Diablo $300.

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In place of the old keyphrase PATRICIA ZLOTNIK, three keystream generator numbers \((R_0, A_1, A_2)\) now become the key. The demonstration values are chosen as:

\[(0.5, 1.625, 3.125). \tag{7}\]

This move from keyphrase to numerical key required by automation is undesirable. A word or phrase is much more easily remembered than a sequence of digits. In order to humanize this process, the program Keygen is written which accepts a keyphrase and produces any number of machine-oriented keys \((R_0, A_1, A_2)\).

The ideal sequence generator would provide an infinite sequence of \(R_n\) values, each value being statistically independent of all other values. In practice the sequence must eventually repeat. There is a finite number of digits in the representation of \(R_n\) so there is a finite number of different \(R_n\) values that may be produced. Since \(R_n + 1\) is a function only of \(R_n\), once a value is produced that has appeared before, a computational cycle is entered which cannot be broken and a periodic sequence results. This can create serious cryptographic vulnerability problems, especially if the sequence repeats during the processing of a message. Other shortcomings of sequence generators, such as correlation tendencies or biases, can also be exploited by the cryptanalyst.

Protection against looping is provided in Crypto using a technique ascribed by D E Knuth and J Gait to R W Floyd. See especially problem numbers 6 and 7 in Section 3.1 of the Knuth book in the bibliography. Floyd’s algorithm requires that a second sequence generator be used, which is cycled twice for every cycle of the first generator. The values of \(R_n\) and \(R_{2n}\) are compared. As Knuth shows, equality will always be reached before cycling begins. After each cycle of \(R_n\) comparison is made with \(R_{2n}\), and, if equality is detected, Crypto halts (at step 211). If this occurs (very, very unlikely), pick another \((R_0, A_1, A_2)\) key and try again. The author has tested many keys selected at random and found sequence lengths much longer than required for any message, even in the worst cases. The demonstration key \((0.5, 1.625, 3.125)\), for example, has a nonrepeating sequence length which lies between 18,303 and 24,403, after which cycling takes place with a period of 6101.

### Transposition Operation

The operating principles of program Crypto can be explained with the aid of

### Search Strategy

The method of generation of the random integer \(R\) for selection of M-field cells (phase A, figure 1) does not preclude repetition in the random number sequence. That is, on a given pass an M cell can be pointed to that which has already been used. The bits in the special registers are used to represent M-field cells, bit off meaning cell open and bit on meaning cell already used. Access to and control of these bits currently involves arithmetic rather than logical operations, and processor time becomes an important consideration.

In the phase A portion of figure 1, repeated trials are made to find an open cell. Up to \(T\) such trials are permitted before phase B is entered as a slow but sure last resort solution. Timing runs indicate that one phase A trial requires 4.375 seconds of processor time. Hence we define a time cost \(C_a\) as:

\[C_a = 4.375 \text{ seconds}. \tag{8}\]

This is the time required to test one isolated bit in one of the ten special registers.

In phase B an exhaustive search is made of each bit in the M-field. The overhead is lower here and it takes only 1.533 seconds to search each cell. However, the mean cell number searched until the specified empty cell is found will be roughly half the number of characters in the message \((Nc/2)\). Hence the mean cost of the phase B operation \(C_b\), is:

\[C_b = 1.533\left(\frac{N_c}{2}\right) = 0.767 N_c. \tag{9}\]

Note that the phase B cost increases with the number of characters in the message. For long messages, the cost of phase B becomes much greater than the cost of phase A. We seek now a strategy which minimizes the mean overall time cost \((C_o)\) for an M cell selection in the transposition table generation. (The substitution operation takes a very short time to complete.)

If the number of open cells is \(S\) then the probability of success \(P_s\) per phase A trial is simply:

\[P_s = \frac{S}{N_c}. \tag{10}\]

On a given phase A pass, let the first success be on trial \(K\). The probability of this is:

\[(1-P_s)^{K-1}P_s;\]

and the total cost of this phase A operation is:

\[(K)(C_a).\]

The probability that \(T\) consecutive failures will occur in phase A (and hence require use of phase B) is:

\[(1-P_s)^T.\]

The cost when this occurs is:

\[(T C_a + C_b).\]

Putting these results together, the mean overall cost for a transposition table entry calculation becomes:
Using the identity:

\[ \sum_{N=0}^{K-1} N X^N = X \left[ \frac{X^{K-1}}{X-1} - \frac{X^K - 1}{(X-1)^2} \right] \]  

allows equation 11 to be reduced to:

\[ Co = Ca \left[ \frac{1 - (1 - Ps)^T}{Ps} \right] + Cb \left[ 1 - Ps \right]^T. \]  

The function \( Co \) is monotonic in \( T \) and behaves as indicated in figure 2. When \( T \) is equal to 0, no phase A trials are made and the cost is simply the phase B cost (\( Cb \)). As \( T \) increases without limit (success in phase A is forced to prevent use of phase B) the mean overall cost has an asymptote of \( Ca/Ps \). If this value is smaller than the cost of phase B (\( Cb \)), the lowest mean cost (time) is achieved with the penalty that some calculations may never finish.

As the encryption (or decryption) progresses, \( S \) becomes smaller and eventually the critical point is reached when the value of the asymptote \( Ca/Ps \) equals the cost of phase B (\( Cb \)). Using equations (8), (9) and (10), this critical value \( (Sc) \) is seen to be:

\[ Sc = (Nc) \left( \frac{Ca}{Cb} \right) = \frac{(Nc) \left( \frac{Ca}{0.767 \ Nc} \right)}{0.767 \ Nc} = 5.7; \]  

which simply says that when the number of empty cells reaches approximately 6, phase A operation is too expensive (in time) because the probability of success is too low. The strategy at this point is to cut out phase A completely and go directly to phase B. The parameter \( T \) controls the exchange of maximum processor time for a transposition table calculation to the mean processor time. Increasing \( T \) results in lower mean times and longer maximum times.

Figure 2 shows that, for sufficiently large values of \( T \), the mean time \( (Co) \) becomes inversely proportional to the probability of success in phase A (\( Ps \)) and hence the number of open cells (\( S \)). One way of keeping the probability of success (\( Ps \)) high and the mean cost (\( Co \)) low is to pick a number for \( Nc \) (message length) which is greater than the actual message length. The program is then used only to process all the legitimate message characters. The remaining spaces are filled with randomly selected characters (nulls). By this artifice, the number of available cells (\( S \)) is not permitted to run down to its critical value. Use of this technique is detailed in the main text.

The 2 phase approach of figure 1 has real value even if faster computation is at hand. Random tests of isolated M cells will always be faster than the contiguous M-field search required in phase B. Hence the optimization strategy will always be able to contribute to computational efficiency. Additionally, the pseudorandom nature of the transposition table calculations helps isolate the resulting cryptogram from the key stream generator, hence strengthening the cipher.

**Key Generation**

Those concerned with field ciphers generally concede that the basic method of operation cannot be kept secret. The security of the cipher, therefore, rests in the key. In some of the examples given in part 1 of figure 1. The ten special registers S0-S9 of the HP 67 are reserved for up to 300 ciphertext character position indicators (M-field). A bit is reset (0) if the corresponding position is open and can accept a ciphertext character. Conversely, the bit is set (1) if that M-field position has been filled in a previous transposition operation.

The transposition operation of figure 1 is comprised of two phases, A and B. Upon entry to phase A the sequence generator is cycled and a random integer number \( R \) in the range 0 to \( Nc - 1 \) is generated. Position \( R \) is then tested in the M-field and if the \( R \)th position is open the bit is set and phase B is bypassed. If the position is already filled, additional tries via loop A are executed. If an open position is not found in T trials, phase B is entered.

Phase B is demanding of processor time, but success here is guaranteed. A count \( S \) is kept of the number of open spaces remaining in the M-field. The sequence generator is cycled and random integer number \( R \) is generated in the range 0 to \( S - 1 \). The entire M-field is then searched and the open positions are counted until the \( R \)th one is reached. When this happens the corresponding bit in the M-field is set and phase B is complete.

Following phases A and B an M value is computed and the transposition pair \( J,M \) is displayed with the program halted. The transposition portion of the program is now complete.

**Substitution Operation**

In dual mode operation the user would at this point enter \( \overline{Pj} \) (encipher) or \( \overline{Cm} \) (decipher) and press R/S to restart the program. The necessary residue arithmetic would be done as shown in table 10 and the program would again halt showing either:

\[ J,M \overline{Cm} \text{ (encipher)} \]

or

\[ J,M \overline{Pj} \text{ (decipher)}. \]

The substitution key is generated from the \( R_n \) register of the Floyd algorithm; the sequence generator is not cycled for this operation. In the transposition only mode, this whole process is bypassed as indicated in figure 1.

**Throughput Optimization Strategy**

After this information is disposed of by the user, the program is restarted. If the number of open spaces in the M-field is Q
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this article, the keys were easily remembered keyphrases such as ROYAL NEW ZEALAND NAVY, PHYSICAL EXAMINATION, and our own PATRICIA ZLOTNIK. In program Crypto the key becomes the 3 number group \((R_0, A_1, A_2)\) such as \((0.5, 1.625, 3.125)\).

Since keyphrases are more easily remembered than a sequence of digits, program Keygen has been written to permit the use of keyphrases for the generation of keys for program Crypto. One part of the program key is a 10 digit integer which we may call the key base. Once this base number is entered into Keygen, a number of keys may be generated. Each key triplet is identified by a key number \(N\). If a different key base is used, a different sequence of \((R_0, A_1, A_2)\) keys will be generated. If Keygen is employed, the user needs to know both the key base used to produce the sequence of keys and the number of the key within the sequence.

A convenient way of relating keyphrase to key base is to number the normal alphabet using 2 digit numbers. That is: \(A = 01, B = 02, C = 03, \ldots, X = 24, Y = 25, Z = 26\). Now simply associate each letter with the second digit of its corresponding numerical value. Ten characters are selected from the keyphrase and their digit-for-character equivalences form the key base. For example, calling once more upon our friend from the main text yields:

\[
\begin{array}{cccc}
N & R_0 & A_1 & A_2 \\
1 & 0.6233 & 1.7175 & 2.8561 \\
2 & 0.4283 & 1.7423 & 2.6784 \\
3 & 0.6564 & 1.7579 & 3.5444 \\
4 & 0.3809 & 1.8209 & 3.8895 \\
5 & 0.6771 & 1.9392 & 4.8296 \\
6 & 0.6119 & 1.9619 & 3.9956 \\
7 & 0.7612 & 1.7418 & 2.3276 \\
8 & 0.7039 & 1.9241 & 3.4082 \\
9 & 0.9190 & 1.7517 & 2.4218 \\
10 & 0.9546 & 1.3436 & 3.4242 \\
\end{array}
\]

A little imagination in the use of Keygen should make it possible never to have to repeat the use of a key. For example, in a multiple-user environment, each user could be assigned a unique block of key numbers. These would be used in some form of rotation that could be restarted after a new key base is invoked. All users must know the key base by prearrangement. The key number, however, could be contained in the cryptogram. If certain groups are set aside by prearrangement as control groups, the key number information could be contained in these characters.

For example, let the third group of each cryptogram be a control group and assume the same alphabetic-numeric equivalence described in the keyphrase-key base relationship. Let the center character of the third group indicate mode: even number for transposition only, odd number for dual mode. The first two characters of this group could represent mixed alphabet key number for dual mode or would be nulls in the transposition only mode. The last two characters could represent the encipherment operation key number. The control group JNGTI, for example, signals dual mode, indicates key number 4 for mixed alphabet generation, and shows that key number 9 was used in encipherment. The control group is inserted into the cryptogram after encipherment and removed before decipherment.

or less, phase A is skipped and phase B is entered directly. Otherwise the program loops back and enters phase A. This strategy and the choices of \(T\) and \(Q\) are designed to minimize the mean processing time (details are in the text box on search strategy). Coincidentally this approach presents the cryptanalyst with a highly nonlinear, multivalued barrier from the cryptogram back to the key \((R_0, A_1, A_2)\). On some passes \(R_n\) is cycled only once. At the other extreme it is also possible that \(R_n\) is cycled \(T\) times in phase A and one time in phase B for a total of \(T + 1\) cycles of the \(R_n\) generator. The luck of the draw nature of the transposition algorithm can produce some dramatic changes in the flow of events arising from very minor situation differences, such as adding or subtracting one character from the plaintext. This algorithm has some interesting trapdoor or one way properties.

General Remarks

With the notable exception of Vernam's onetime key, all cryptographic systems are considered to be vulnerable to cryptanalytic attack. As a consequence any proposed cryptographic technique must be evaluated for degree of security before being used. The adversary roles of the cryptographer and the cryptanalyst have existed for centuries. Mathematical proofs of security (usually based on the impossibility of testing the vast number of combinations offered) have lured innumerable amateurs and a few professionals over the years into positions that later proved embarrassing to the people who formulated the proofs. These proofs of invulnerability were destroyed by competent cryptanalysts who accepted the futility of exhaustive searches and instead searched for other means to break the system. The question of security, which is the very core of cryptography, encompasses many disciplines and occupies the full-time efforts of thousands of talented people worldwide. Part III of the Shannon paper and sections VI and VII of the Diffie and Hellman paper are highly recommended for background in this area (see bibliography).

Standard evaluation methods of secrecy systems involve cryptanalytic attacks on the system. The ciphertext only attack is the weakest test, since the analyst is given only ciphertext with which to work. Systems which fail this test are rated as very weak. The known plaintext attack allows the analyst access to corresponding portions of plaintext and ciphertext. The most severe test is the chosen plaintext attack, in which...
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Table 15 gives detailed user instructions for program Keygen. An error halt at program location 120 (very unlikely) indicates that a looping condition has been detected in the Keygen random number generator. The largest permissible key number value for this key base is one less than the difference between the contents of register 8 and register 1. Either stay within this limitation or change the key base. As a precaution, one could generate the highest numbered key to be used when a new key base is invoked to insure that there are no looping problems within Keygen. As mentioned before, it is very unlikely that this condition will ever be encountered. The 3 sequence generator cycles required by the Floyd algorithm serve double duty in Keygen. 1. Prepare table as example table 14b shows. Enter ciphertext Cm and, using alphabet table, enter Cm values. 2. Switch calculator to RUN and ON. 3. Load program. 4. Input data Rn, A1, A2, Nc. Follow each entry except the last with ENT+ Press A. 5. Input data Na, follow Na with CHS (that is enter -Na). 6. Press R/S to start program. 7. Calculator will stop with J.M in display. At index M, select Cm and enter. Press R/S. 8. Calculator will stop with a number in the form J.M Pj. At index J in table enter Pj from display. 9. Press R/S and return to step 7.

Evaluation of Crypto

In the qualitative discussion which follows, a known plaintext attack will be ended.
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Figure 2: Graph showing the variation in the mean cost with respect to the number of trials allowed to take place to find an empty cell.

assumed as the testing vehicle. The reason for making transposition mandatory in Crypto may be demonstrated by considering a known plaintext attack on a substitution cipher. In such a cipher, character positions remain unaltered in the cryptogram. The ciphertext character values are the modulo sums of key and plaintext values. The known plaintext attack removes the plaintext value cover to reveal the key generator values. The analyst then attempts to determine the generator parameter settings by use of the known sequence of generator key numbers. In a straight substitution cipher the security load is carried entirely by the keystream generator. Gait indicates that shift register generators produce very poor ciphers, especially the linear congruential generators which are in common use (see bibliography).

No claim for greatness is made for the generator used in Crypto as defined in equation (5). We have ignored Knuth's admonition not to select a random generator at random. While this algorithm appears to be satisfactory, there would be no hesitation in replacement by a better algorithm that fits into the available coding space.

The sequence generator and the organizational logic of Crypto (figure 1) work together against the cryptanalyst. Consider a transposition only cipher and a known plaintext attack. The characters of the plaintext are scattered throughout the cryptogram. The ciphertext character values are the modulo sums of key and plaintext values. The known plaintext attack removes the plaintext value cover to reveal the key generator values. The analyst then attempts to determine the generator parameter settings by use of the known sequence of
capability results if Crypto is used according to the instructions given.

The author wishes to express his thanks to Dr J C Buchta and Dr S B Akers, Jr, both of the General Electric Company, for many interesting comments and criticisms.

BIBLIOGRAPHY


9. Gaines, Helen F, Cryptanalysis, A Study of Ciphers and Their Solutions, Dover, New York, 1956. (Formerly published under the title, Elementary Cryptanalysis.)
I’ve written a fairly short and simple program (about 220 bytes) to play Life on an 8080 based system. You need only two pages of memory for the program and the playing board. When this was originally written, I had only 1 K bytes of memory in my Altair, so this version is a simple one. A few extensions are suggested, but they are not necessary to enjoy Life.

The playing board is a 16 by 16 grid taking one page (256 bytes) of memory. Only the two least significant bits of each byte are used, and the leftmost column and top row are used as a border. If you don’t use the border, the top of the board is next to the bottom, and the right edge is next to the left edge.

The board is arranged as shown in figure 1. The number in each box is its address in memory. It is initialized by first setting all locations to 00. Next, hexadecimal locations 00 through 0F (the top row) and 10, 20, 30 . . . E0, F0 (left column) are set to hexadecimal FF. Each cell with FF is a border cell and is ignored by the rest of the program. The function of the border will become clear later.

The initial pattern must be loaded by some other loader program or through your front panel. You simply draw the first generation on a sheet of graph paper numbered as in figure 1, then set the address of each line cell to hexadecimal 01.

Each byte looks like figure 2. Note that only the two least significant bits of each byte are used. Bit zero is a 1 if that cell is alive this generation. If it will be alive next generation, bit one is also a 1. To make the next generation into this generation, we need only shift each memory location to the right.

The program is written to be simple—not efficient or fast—and consists of six main routines that are called repeatedly for each cell (see listing 1). Subroutine NCOUNT, for example, is called about 1,900 times each generation.

The first routine, BDINIT, initializes the board (clears it and sets up border) and then jumps to your loader to get the initial pattern. After you have loaded an initial pattern, you will want to write it out on your terminal before the next generation is computed. This is done by routine WRITE. The border characters are written as a slash and the live cells as a star.

Before a line is written, it is scanned for live characters. If none are alive, a slash and a carriage return are output, and the next line is checked. This saves the computer the task of writing a line of blanks and can save considerable time in writing out small patterns.

Now we have the board set up and the initial pattern loaded and checked. The computer is ready to calculate the next generation. Since the status of a cell (alive or dead next generation) depends only on the number of live neighbors, the program simply goes from one cell to the next counting the number of live neigh-

\[
\begin{array}{cccccccccccccccc}
00 & 01 & 02 & 03 & 04 & 05 & 06 & 07 & 08 & 09 & 0A & 0B & 0C & 0D & 0E & 0F \\
10 & 11 & 12 & 13 & 14 & 15 & 16 & 17 & 18 & 19 & 1A & 1B & 1C & 1D & 1E & 1F \\
20 & & & & & & & & & & & & & & \\
30 & & & & & & & & & & & & & & \\
40 & & & & & & & & & & & & & & \\
50 & & & & & & & & & & & & & & \\
70 & 71 & 72 & 73 & 74 & 75 & 76 & 77 & 78 & 79 & 7A & 7B & 7C & 7D & 7E & 7F \\
80 & & & & & & & & & & & & & & \\
90 & & & & & & & & & & & & & & \\
A0 & & & & & & & & & & & & & & \\
B0 & & & & & & & & & & & & & & \\
C0 & & & & & & & & & & & & & & \\
D0 & D1 & D2 & & & & & & & & & & & & \\
E0 & E1 & E2 & E3 & E4 & & & & & & & & & & & \\
F0 & F1 & F2 & F3 & F4 & F5 & F6 & F7 & F8 & F9 & FA & FB & FC & FD & FE & FF
\end{array}
\]

Figure 1: Layout of the Life board in memory. The number of each box is its address. The shaded boxes are border cells.
bors. For example, if we are looking at the cell at location hexadecimal 68, we would check cells 57 thru 59, 67, 69 and 77 thru 79. This is done by subroutine VALCK. When the routine is exited, register E holds the number of live neighboring cells.

Next subroutine ESET is called. This routine sets the next generation bit if register E equals 3, clears it if register E equals 0, 1, 4, 5, 6, 7, or 8 and sets it equal to the present generation if register E equals 2. The only variation from this procedure concerns the border cells. They are treated as dead cells when counting neighbors. If we are pointing to a border cell when VALCK is called, the routine is exited before any tests are performed. To initialize the board, begin at BDINIT. After you have loaded the first generation, enter at WRITE, and your work is done.

Listing 1: The board initialization routine (BDINIT) sets the entire board (figure 1) to 00. Next the border cells are set to FF. A jump is then made to the loader program to get the initial pattern. Subroutine WRITE displays the board on the video display. Border characters are written as a slash, live cells as a star. If your display doesn’t scroll on a carriage return, you will have to change this routine. The next generation is calculated by subroutine MOVE by calling VALCK and ESET for each cell. After MOVE is done, routine UPDATE is entered and the board is output. Update rotates each nonborder cell to the right. The next generation bit moves into the present generation bit. VALCK is called by the main MOVE routine. MOVE sets register pair BC to the address of the current cell. The HL registers look at its neighbors. NCOUNT checks the cell addressed by register pair HL. If that cell is alive, register E is incremented. This routine is called repeatedly by VALCK which sets up the HL register pair before calling. ESET sets the next generation bit based on the contents of register E. ESET is called after VALCK and determines the number of live neighbors.
Listing 1, continued:

```
0A29  FF  RST 7  Output routine.
0A2A  00  NOP  
0A2B  00  NOP  
0A2C  00  NOP  
0A2D  3E  2F  MVI A,2F  Write a slash (/).
0A2F  FF  RST 7  Clear accumulator.
0A30  AF  TEST INR L  Point to next cell.
0A31  B6  ORA M  If alive value is nonzero.
0A32  0D  DCR C  Decrement character counter.
0A33  C2  31 0A  JNZ TEST  If not done with live to test.
0A37  B7  ORA A  Set flags.
0A38  C4  42 0A  CNZ WRITLIN  If register A nonzero, there are live cells.
0A3B  2C  INR L  
0A3C  CA  65 0A  JZ MOVE  Compute next move if done writing board.
0A3F  C3  25 0A  JMP WRITE  
0A42  6B  WRITLIN MOV L,E  Address of start of line.
0A43  0E  0F  MVI C,0F  Restore character counter.
0A45  2C  INR L  Point to first nonborder cell.
0A46  7E  MOV A,M  
0A47  FE  01  CPI 01  
0A49  CA  57 0A  JZ ALIVE  Jump if cell is alive.
0A4C  FE  FF  CPI FF  
0A4E  CA  5D 0A  JZ SLASH  Jump if border cell.
0A51  3E  20  MVI A,""  Must be dead cell.
0A53  FF  RST 7  Write dead cell.
0A54  C3  60 0A  JMP OVER  Living cell.
0A57  3E  2A  ALIVE MVI A,""  Dead cell or border.
0A59  FF  RST 7  
0A5A  C3  60 0A  JMP OVER  Decrement character counter.
0A5D  3E  2F  SLASH MVI A,""  
0A60  0D  OVER DCR C  Jump if not done with line.
0A61  C2  45 0A  JNZ NEXT  
0A65  0E  11  MOVE MVI C,11  Address of first nonborder cell.
0A67  26  09  MOV H,09  Page of board.
0A69  44  MOV B,H  Page of board.
0A6A  CD  8A 0A  NXCELL CAL VALCK  E returns number of living neighbors.
0A6D  CD  BD 0A  CAL ESET  Set next generation bit of current cell.
0A70  OC  INR C  Point to next cell.
0A71  CA  77 0A  JMP UPDATE  Go to update routine if done with board.
0A74  C3  6A 0A  JMP NXCELL  If not done go to next cell.
0A77  2E  0A  UPDATE MVI L,0A  First nonborder cell.
0A79  7E  LOOP MOV A,M  Get cell from memory.
0A7A  FF  CPI FF  Border cell?
0A7C  CA  83 0A  JZ BRDR  Then don’t rotate.
0A7F  1F  RAR  Rotate next generation into this generation.
0A80  E6  01  ANI 01  Clear unused bits.
0A82  77  MOV M,A  Put it back.
0A83  2C  BRDR INR L  Point to next cell.
0A84  C2  79 0A  JNZ LOOP  Do next cell.
0A87  C3  22 0A  JMP WRITE  
0A8A  1E  00  VALCK MVI E,00  E counts number of living around cell.
0A8C  DA  LXDX B  Get current cell.
0A8D  FE  FF  CPI FF  Is this a border?
0A8F  C8  RZ  Skip all tests.
0A80  79  MOV A,C  
0A89  DB  11  SUI 11  Address of cell above and left of current cell.
0A93  6F  MOV L,A  Put new address in register L.
0A94  CD  B5 0A  CAL NCOUNT  Test it.
0A97  2C  INR L  Point to neighbor above current cell.
0A98  CD  B5 0A  CAL NCOUNT  Test it.
0A9B  2C  INR L  Neighbor above and right of current cell.
0A9C  CD  B5 0A  CAL NCOUNT  Test it.
0A9F  6B  MOV L,C  Cell to the left of current cell.
0AA0  2D  DCR L  Test it.
0AA1  CD  B5 0A  CAL NCOUNT  Cell to right of current cell.
0AA4  2C  INR L  Test it.
0AA6  CD  B5 0A  CAL NCOUNT  Cell below and right of current cell.
0AA8  79  MOV A,C  Cell below and left of current cell.
0AAC  C6  0F  ADI 0F  
0AAC  6F  MOV L,A  
0AAD  CD  B5 0A  CAL NCOUNT  Test it.
0AED  2C  INR L  Cell below current cell.
0AEB  CD  B5 0A  CAL NCOUNT  Test it.
0AFB  2C  INR L  Cell below and right of current cell.
0A97  7E  MOV A,M  Get cell from memory.
0A98  1F  CPI FF  Border cell?
0A9A  D0  RZ  Return if so.
0A9B  1C  RNC  Return if dead cell.
0A9C  C9  INR E  Count if alive.
```
Possible Improvements

In this program the time needed to compute the next generation is insignificant compared to the time needed to write out and observe the pattern. I feel that any effort to speed up execution just isn't worth the trouble.

The first routine you should add would be a better way to load the initial pattern. If you have cursor control (up-down, right-left), it should be easy to add a fast, easy loader. A 16 by 16 grid is small for doing any serious experimenting on. Many interesting patterns run into the border; or if you don't use the border, the left edge interferes with the right and top interferes with bottom. You will have to use the dual addition instructions and complement arithmetic in VALCK, because adjacent cells won't always be on the same page.

I am interested in hearing about any improvements to this program or about any interesting patterns you may discover. Have fun!
An Easy Way
to Calculate Sines and Cosines

Robert Grappel
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Lexington MA 02173

The instruction set of a typical 8 bit processor can be quite confining at times. Any task requiring more than simple integer addition and subtraction can become a nuisance. There are reference books from which multiplication and division routines can be obtained, and square root and other functions can be built by using expansion, iteration, or other well-known methods. Implementing these algorithms on a microprocessor uses much space and programming time. Trigonometric functions are among this class of difficult functions. However, if one can tolerate accuracy of one part in 100, and allow about 1 ms per computation, the routine described in this article will provide sine and cosine values in a very simple 40 byte routine. I have coded it for a Motorola M6800 processor but it could easily be converted to any other processor.

Theory

The algorithm is based on two trigonometric identities:

\[
\sin(\theta + s) = \sin(\theta)\cos(s) + \cos(\theta)\sin(s)
\]

\[
\cos(\theta + s) = \cos(\theta)\cos(s) - \sin(\theta)\sin(s)
\]

where \( \theta \) is the angle we are interested in and \( s \) is a small step in angle added to \( \theta \). If we make the step small enough, we can approximate \( \sin(s) \) and \( \cos(s) \) as follows:

\[
\sin(s) = s \\
\cos(s) = 1
\]

Combining these four equations we get:

\[
\sin(\theta + s) = \sin(\theta) + s \cos(\theta) - s \sin(\theta)
\]

Solving for sine and substituting into the cosine formula:

\[
\cos(\theta + s) = (1 + s^2)\cos(\theta) - s \sin(\theta)
\]

Since \( s \) is very small, we can neglect \( s^2 \) and write:

\[
\cos(\theta + s) = \cos(\theta) - s \sin(\theta)
\]

Given that we have values for \( \sin(\theta) \) and \( \cos(\theta) \) at some point, we can get to any other angle by stepping through the two approximations, first computing \( \sin(\theta + s) \) and then using that to compute \( \cos(\theta + s) \). We choose to start at \( \theta \) equal to zero, and set \( \cos(\theta) \) to the largest positive value that can

<table>
<thead>
<tr>
<th>Location</th>
<th>Op Code</th>
<th>Operand</th>
<th>Label</th>
<th>Assembly Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td></td>
<td></td>
<td>THETA</td>
<td>RMB 1 *ARGUMENT TO FUNCTION</td>
</tr>
<tr>
<td>0001</td>
<td></td>
<td></td>
<td>SINE</td>
<td>RMB 1 *SINE OF THETA</td>
</tr>
<tr>
<td>0002</td>
<td></td>
<td></td>
<td>COSINE</td>
<td>RMB 1 *COSINE OF THETA</td>
</tr>
<tr>
<td>0003</td>
<td>B6</td>
<td>7E</td>
<td>START</td>
<td>LDA A #126 *BEGIN INITIALIZATION</td>
</tr>
<tr>
<td>0005</td>
<td>B7</td>
<td>0002</td>
<td></td>
<td>STA A COSINE</td>
</tr>
<tr>
<td>0008</td>
<td>7F</td>
<td>0001</td>
<td></td>
<td>CLR SINE</td>
</tr>
<tr>
<td>000B</td>
<td>B6</td>
<td>0000</td>
<td></td>
<td>LDA A THETA</td>
</tr>
<tr>
<td>000E</td>
<td>F6</td>
<td>0002</td>
<td></td>
<td>LDA B COSINE *COMPUTE NEW SINE</td>
</tr>
<tr>
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<td>57</td>
<td></td>
<td>CYCLE</td>
<td>ASR B</td>
</tr>
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<td>57</td>
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<td>ASR B</td>
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<td>ASR B</td>
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<td>ASR B</td>
</tr>
<tr>
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<td>F8</td>
<td>0001</td>
<td></td>
<td>ADD B SINE</td>
</tr>
<tr>
<td>0018</td>
<td>F7</td>
<td>0001</td>
<td></td>
<td>STA B SINE</td>
</tr>
<tr>
<td>001B</td>
<td>57</td>
<td></td>
<td></td>
<td>ASR B *COMPUTE NEW COSINE</td>
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<td></td>
<td></td>
<td>ASR B</td>
</tr>
<tr>
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<td>57</td>
<td></td>
<td></td>
<td>ASR B</td>
</tr>
<tr>
<td>001E</td>
<td>57</td>
<td></td>
<td></td>
<td>ASR B</td>
</tr>
<tr>
<td>001F</td>
<td>F0</td>
<td>0002</td>
<td></td>
<td>SUB B COSINE</td>
</tr>
<tr>
<td>0022</td>
<td>50</td>
<td></td>
<td></td>
<td>NEG B</td>
</tr>
<tr>
<td>0023</td>
<td>F7</td>
<td>0002</td>
<td></td>
<td>STA B COSINE</td>
</tr>
<tr>
<td>0026</td>
<td>4A</td>
<td></td>
<td></td>
<td>DEC A</td>
</tr>
<tr>
<td>0027</td>
<td>2C</td>
<td>EB</td>
<td></td>
<td>BGE CYCLE *LOOP UNTIL DONE</td>
</tr>
<tr>
<td>0029</td>
<td>39</td>
<td></td>
<td></td>
<td>RTS</td>
</tr>
</tbody>
</table>

Listing 1: 6800 routine for computing sines and cosines over the range 0 to \( \pi/2 \) radians (0 to 90 degrees).
be stored as a signed byte without causing overflow when negated and decremented. Hence $\cos(0) = 126$. Similarly the $\sin(0) = 0$. The step size is chosen to be 0.0625 radian or about 3.58°. The step size must be a binary fraction so that all the multiplication involved in the equations can be performed by arithmetic shifts. If more accuracy is needed, the step size is easily reduced by introducing more shifts into the algorithm.

**Program**

The assembly code program for the Motorola 6800 version of the routine is shown in listing 1. When called with the angle stored in variable THETA, it returns the sine and cosine of that angle. The accuracy is quite good for angles less than $\pi/2$ radians (90 degrees). For angles larger than $\pi/2$ radians, other trigonometric identities can be used:

$$
\sin(\theta) = \cos(\pi/2 - \theta) = \sin(\pi - \theta) \\
\cos(\theta) = \sin(\pi/2 - \theta) = (-\cos(\pi - \theta))
$$

Thus, the sine and cosine of any angle can be computed from the values over the range 0 to $\pi/2$ radians. These identities can be coded quite easily.

All the other trigonometric functions can be computed from the values of sine and cosine. All that is needed is an integer division routine such as the following:

$$
\csc(\theta) = 126/\sin(\theta) \\
\sec(\theta) = 126/\cos(\theta) \\
\tan(\theta) = \sin(\theta)/\cos(\theta) \\
\cot(\theta) = \cos(\theta)/\sin(\theta)
$$

Be careful of overflows and division by zero problems.

This algorithm can perform other tricks. It can generate continuous sine waves of any desired amplitude, period, or phase. Coupled with a digital to analog converter, it could form part of a modem or synthesizer. It could simulate mixers, AM or FM modulators, keyers, etc.

The maximum frequency it can generate depends on the processor cycle time. A 6800 processor running with a 1 MHz clock could generate a 200 Hz sine wave since there are about 50 machine cycles per step, and about 100 steps per wave. Increasing the step size to 0.125 radians would increase the maximum frequency to about 500 Hz. A step size of 0.25 radians would yield a maximum frequency of nearly 1050 Hz.

I hope that this algorithm will help programmers solve problems involving trigonometric functions, and that applications for microcomputers will expand into new areas where these functions are useful.

---

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Circle 90 on inquiry card.
Listing 1: TI-59 calculator program for the digital circuit simulator.

The program in listing 1 was developed for a TI-59 calculator to allow simulation or testing of combinational logic circuits. The circuit elements allowed and their identification numbers are:

<table>
<thead>
<tr>
<th>Number</th>
<th>Type</th>
</tr>
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<tbody>
<tr>
<td>20</td>
<td>AND</td>
</tr>
<tr>
<td>30</td>
<td>OR</td>
</tr>
<tr>
<td>40</td>
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</tr>
<tr>
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<td>NOR</td>
</tr>
<tr>
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<td>NOT</td>
</tr>
<tr>
<td>70</td>
<td>XOR</td>
</tr>
<tr>
<td>80</td>
<td>SR latch</td>
</tr>
</tbody>
</table>

Registers 11 through 25 are used to store the input values to the circuit. The circuit elements themselves are stored in registers 31 through 99. A code word is stored in each register that defines its inputs and its function. The format used is:

XXYYZZ.V,

where:

- XX = Input Device 1
- YY = Input Device 2
- ZZ = Device Identification Number
- V = Output of this device (0 or 1).

```
<table>
<thead>
<tr>
<th>Number</th>
<th>Label</th>
<th>Type</th>
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<td>HDP</td>
<td>45</td>
</tr>
<tr>
<td>030</td>
<td>FCL</td>
<td>43</td>
</tr>
<tr>
<td>031</td>
<td>END</td>
<td>29</td>
</tr>
<tr>
<td>032</td>
<td>END</td>
<td>24</td>
</tr>
<tr>
<td>033</td>
<td>END</td>
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<td>034</td>
<td>STF</td>
<td>37</td>
</tr>
<tr>
<td>035</td>
<td>STD</td>
<td>42</td>
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<td>036</td>
<td>STF</td>
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<td>HDP</td>
<td>68</td>
</tr>
<tr>
<td>039</td>
<td>HDP</td>
<td>71</td>
</tr>
</tbody>
</table>

Listing 1 continued on opposite page.

---

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---

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April 1979 BYTE Publications Inc
Note that the complete code must be entered for each device. Therefore, for the NOT device the same input number is entered for both XX and YY.

The minus sign is used as a code to indicate that a device has been asserted. At the start of each run the machine automatically sets all registers to a positive value. After the run is completed, each register should have a minus sign. The output value is given by the first digit to the right of the decimal point.

The circuit itself is set up on the machine by storing the appropriate values in registers 31 and greater. Devices are assigned registers consecutively starting with 31, in any order desired. However, the program runs faster with consecutive assignments. A 0 stored in a register tells the calculator that all devices have been processed. Therefore, you must be certain that no register numbers are skipped and that the last valid register is followed with a register containing 0.

The input values are stored into registers 11 through 25 by the following coding:

| logical 0 | store -1.0 |
| logical 1 | store -1.1 |

An alternate, and more convenient, method is available for registers 11 through 18. Just enter the logical value, 0 or 1, and press one of the keys A to D or A' to D' in accordance with the following assignment table:

<table>
<thead>
<tr>
<th>A</th>
<th>A'</th>
<th>B</th>
<th>B'</th>
<th>C</th>
<th>C'</th>
<th>D</th>
<th>D'</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>15</td>
<td>12</td>
<td>16</td>
<td>13</td>
<td>17</td>
<td>14</td>
<td>18</td>
</tr>
</tbody>
</table>

Listing 1, continued:

| 119 | 10 | 10 | 173 | 77 | 227 | 01 | 1 |
| 120 | 44 | SUM | 174 | 38 | 228 | 94 | 1 |
| 121 | 10 | 10 | 175 | 22 | 229 | 64 | F |
| 122 | 63 | EX+ | 177 | 65 | 230 | 10 | 10 |
| 123 | 10 | 10 | 178 | 01 | 1 |
| 124 | 50 | INT | 179 | 00 | 1 |
| 125 | 22 | INV | 180 | 94 | 1 |
| 126 | 67 | INT | 181 | 95 |
| 127 | 28 | LDG | 182 | 42 | 231 | 61 | GTO |
| 128 | 78 | LBL | 183 | 30 | 232 | 61 | GTO |
| 129 | 39 | DLS | 184 | 01 | 1 |
| 130 | 22 | INV | 185 | 00 | 1 |
| 131 | 06 | STF | 186 | 00 | 1 |
| 132 | 00 | 00 | 187 | 49 | 234 | 18 | K
| 133 | 63 | EX+ | 188 | 42 | 235 | 87 | K
| 134 | 10 | 10 | 190 | 27 | 236 | 06 | 1 |
| 135 | 03 | 03 | 191 | 43 | 237 | 99 | 32 |
| 136 | 00 | 00 | 192 | 27 | 238 | 99 | 32 |
| 137 | 42 | STD | 193 | 59 | 239 | 29 | 23 |
| 138 | 10 | 10 | 194 | 26 |
| 139 | 76 | LBL | 195 | 44 | 240 | 91 | F |
| 140 | 35 | 35 | 196 | 27 |
| 141 | 43 | PCL | 197 | 42 |
| 142 | 10 | 10 | 198 | 26 |
| 143 | 89 | + | 199 | 26 |
| 144 | 01 | 01 | 200 | 77 |
| 145 | 95 | 95 | 201 | 38 |
| 146 | 66 | PRG | 202 | 22 |
| 147 | 10 | 10 | 203 | 65 |
| 148 | 10 | 10 | 204 | 01 |
| 149 | 79 | RC+ | 205 | 00 |
| 150 | 10 | 10 | 206 | 00 |
| 151 | 57 | EQ | 207 | 00 |
| 152 | 33 | LBL | 208 | 96 |
| 153 | 22 | INV | 209 | 94 |
| 154 | 77 | GE | 210 | 42 |
| 155 | 35 | 25 | 211 | 29 |
| 156 | 55 | 55 | 212 | 40 |
| 157 | 01 | 01 | 213 | 27 |
| 158 | 00 | 00 | 214 | 05 |
| 159 | 00 | 00 | 215 | 01 |
| 160 | 00 | 00 | 216 | 95 |
| 161 | 00 | 00 | 217 | 95 |
| 162 | 82 | STD | 218 | 59 |
| 163 | 37 | 37 | 219 | 09 |
| 164 | 56 | INT | 220 | 42 |
| 165 | 32 | INV | 221 | 71 |
| 166 | 44 | SUM | 222 | 35 |
| 167 | 27 | 27 | 223 | 43 |
| 168 | 10 | 10 | 224 | 59 |
| 169 | 42 | STD | 225 | 29 |
| 170 | 26 | 26 | 226 | 42 |
| 171 | 73 | RC+ | 227 | 74 |
| 172 | 26 | 26 | 228 | 16 |

The DS-80 features full compatibility with the proposed IEEE S-100 standard and all current S-100 CPUs. New improved circuit design enhances performance. The DS-80 offers random access video digitization of up to 256 X 256 spatial resolution and 64 levels of grey scale, plus controls for brightness, contrast and width. It is versatile enough to handle any video processing task—from U.P.C. codes (above) and blood cell counting to computer portraiture and character recognition. The DS-80 comes fully assembled, tested and burned in. Included is portrait software compatible with the Vector Graphic High Resolution Graphics Display Board.

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Therefore, circuits with feedback (like the crossed-NOR flip flop) cannot be directly simulated. Note that the program runs faster in natural order of circuit evaluation.

This program uses some of the more advanced programming features of the TI-59 calculator, such as indirect addressing and flag operations. However, the program is straightforward and should be fairly easy to understand for most novice programmers.

The advantage of the simulator, of course, is the ease of setting up and quickly changing any reasonable circuit. No power supply is required and no purchasing of components is required until the circuit is thoroughly acceptable on the simulator.

The program is stored on both edges of one card. The data on a particular circuit can be stored on a card by pressing "3 2nd Write."
EYTE's Bits

Another Life

I've discovered a fourth glider and two new oscillators for Jonathan Millen's "One-Dimensional Life" (December 1978 BYTE, page 68). The new glider has period 5; it evolves from hexadecimal location 65F. My first new oscillator can be made by starting with either 394F or 22 cells in a row—it has period 13. The other oscillator, with period 21, has the ancestor 12157.

Paul Heckbert
4 Ames St, H303
Cambridge MA 02139•

Call For Papers: Sixth Data Communications Symposium

The Sixth Data Communications Symposium, scheduled for November 27 thru 29 in Pacific Grove CA, will concentrate on the design of systems for network user services. Original research and development papers are being solicited for topics related either to the application of specific technical issues that arise from the application nature of a data communication system, or to the application of general technical problems that are directly applicable to the planning, analysis, and design of the systems across the boundary between applications. Four copies of a completed paper and a 500 word summary should be sent no later than April 1 to Dr Wushow Chou, North Carolina State University, Computer Studies Program, POB S490, Raleigh NC 27650. Include name, address, phone number, and affiliation. All papers will be refereed and authors of selected papers will be notified by June 1, 1979. All papers accepted for presentation will be published in the conference proceedings.●

Data Transfer

It is practical to transfer programs directly from one microcomputer to another computer over the telephone without intermediate storage by using readily available equipment. Specifically, I have read TRS-80 BASIC programs into the CSU-Long Beach PDP 11/45 operating under RSTS. The terminal used was a 33 ASR Teletypewriter with an AJ 260 acoustic coupler. The Small Systems Hardware RS-232 interface unit was used to output from the TRS-80.

Many terminals have an auxiliary or similar connector for attaching other RS-232 devices to the terminal. The trick is to connect pin 3 of the TRS-80 RS-232 output to pin 2 of this plug. (Normally, pin 3 would be connected to pin 3 of the auxiliary connector if the terminal is to be used as a printer. The other pins connections remain the same but probably only pin 7 is needed.) After establishing contact with the PDP 11/45 an LLIST command to the TRS-80 causes it to output directly to the PDP 11/45. In my case, the PDP 11/45 checked each statement as it was entered and could send back error messages to the Teletype. Since the operation was full duplex without echo this did not interfere with the data transmission from the TRS-80. If a half duplex system is used it is essential that there be no turn-around on the line during transmission since the TRS-80 does not stop until the end of the LLIST. The program is immediately executable on the PDP 11/45.

A 10,000 byte program was transmitted in 17 minutes at 110 baud. Obviously a higher rate could be used to speed up the process.

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The Power of the HP-67 Programmable Calculator, Part 2

Listing 1: A simultaneous equations program which can solve systems of up to nine equations in nine unknowns. Listing 2 explains how to run this program.

Example Program

Last month I described the features and performance of the Hewlett-Packard HP-67 and HP-97 programmable calculators. This month I conclude with a practical application program. I have chosen for an example a program which uses the more powerful HP-67 operations. Likewise, I have chosen to write a program which will provide the solution to a general set of simultaneous equations, traditionally one of the most laborious mathematical solutions to obtain, yet one of the most useful solutions in electrical engineering.

The HP Math Pac contains a program to solve four simultaneous equations in four unknowns by Gaussian elimination, and the Standard Pac contains a program to solve three simultaneous equations in three unknowns by matrix operations. The program shown in Listing 1 solves any system of up to nine simultaneous equations in nine unknowns by the method of "Gaussian elimination using the largest pivots." (Because of its efficiency, the Gaussian elimination pivot method is a popular method for solving simultaneous equations. The term "pivot" refers to the $(r, c)$, a diagonal element of the coefficient matrix during the $r$th step of the process. This method is discussed in a number of numerical methods books. See also the reference at the end of this article. . .CM) The primary utility of this program would be in calculator aided design.

When the analysis of an electronic system is based upon a linear model, the unknown quantities will usually appear only to the first power, and the coefficients in the equations will usually be constants. Such a set of $n$ equations relating $n$ unknowns can be expressed in the form:

$$A_1X_1 + A_2X_2 + \ldots + A_nX_n = Y_1$$

Equation 2:

$$B_1X_1 + B_2X_2 + \ldots + B_nX_n = Y_2$$

Equation 3:

$$C_1X_1 + C_2X_2 + \ldots + C_nX_n = Y_3$$

Equation $n$:

$$m_1X_1 + m_2X_2 + \ldots + m_nX_n = Y_n$$
in which each X is an unknown quantity, the m terms are the coefficients of the unknowns and the Y terms are the right-hand sides of the equations.

The Gaussian Elimination Pivot Method

To solve a general system of simultaneous equations by Gaussian elimination using the largest pivots, perform the following steps:

1. Inspect the coefficient (\(A_1, B_1, \ldots, m_1\)) of the first term (\(X_1\)) in each of the system equations. The equation having the largest coefficient (in absolute value) of the first term is taken as the first pivotal equation.

2. Divide the first pivotal equation, equation 1(1), by the coefficient \(A_1\) of its first term \(X_1\). The result will be a new equation, equation 1A(1), in which the coefficient of the first term is 1. (The digit enclosed by parentheses in each equation label indicates the number of the system to which the equation belongs.)

3. Multiply equation 1A(1) by the coefficient \(B_1\) of the first term \(X_1\) of the second equation, equation 2(1), to obtain the new equation, equation 1B(1).

4. Subtract equation 1B(1) from the second equation, equation 2(1), to eliminate the first term of equation 2(1). The resulting equation will be one of the equations in a new system with \(n-1\) equations in \(n-1\) unknowns.

5. Repeat steps 3 and 4 with each of the remaining equations in the original system. The set of equations, for which the first term has been eliminated, forms a new system having \(n-1\) equations with \(X_2, X_3, \ldots, X_n\) as unknowns.

6. Inspect the coefficient of the first term in each of the new system’s equations. The equation having the largest coefficient (in absolute value) of the first term is taken as the next pivotal equation.

7. Divide the new pivotal equation by the coefficient of its first term. The result will be a new A equation in which the coefficient of the first term is 1.

8. Multiply the new A equation by the

Listing 1 continued on next page.
Listing 1, continued:

<table>
<thead>
<tr>
<th>NO.</th>
<th>PROGRAM CODES</th>
<th>DEFINITIONS AND REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>110</td>
<td>22 09</td>
<td>GOTO 9</td>
</tr>
<tr>
<td>111</td>
<td>22 09</td>
<td>GOTO 9</td>
</tr>
<tr>
<td>112</td>
<td>22 09</td>
<td>GOTO 9</td>
</tr>
<tr>
<td>113</td>
<td>22 09</td>
<td>GOTO 9</td>
</tr>
<tr>
<td>114</td>
<td>22 09</td>
<td>GOTO 9</td>
</tr>
<tr>
<td>115</td>
<td>22 09</td>
<td>GOTO 9</td>
</tr>
<tr>
<td>116</td>
<td>22 09</td>
<td>GOTO 9</td>
</tr>
<tr>
<td>117</td>
<td>22 09</td>
<td>GOTO 9</td>
</tr>
<tr>
<td>118</td>
<td>22 09</td>
<td>GOTO 9</td>
</tr>
</tbody>
</table>

Continuation Worksheet

In electronics engineering, the system of simultaneous equations could be the result of writing the mesh equations for a circuit such as that shown in figure 1. The nine mesh equations for this circuit are listed in table 1.

The system of nine simultaneous equations for the circuit are shown in standard form in table 2. The first pivotal equation is equation 1. The unknowns in a system of mesh equations are the currents. The right side of each equation is a summation of the voltage sources in the mesh represented by the equation.

The instructions for running the simultaneous equations program in listing 1 are shown in listing 2. Using the system of nine coefficients of the first term of the second system equation to obtain a new B equation.

9. Subtract the new B equation from the second system equation to eliminate the first term of the second system equation. The resulting equation will be one of the equations in a new system which has one less unknown than the system being processed.

10. Repeat steps 8 and 9 with each of the remaining equations in the system being processed. The resulting set of equations, from which the first term has, again, been eliminated, forms a new system of equations having one less unknown and one less equation than the preceding system.

11. Repeat steps 6 thru 10 until a final set is obtained which consists of the single equation:

\[ ZX_n = Y_n. \]

Being the only equation in the system, it must, of course, be the pivotal equation. When this pivotal equation is divided by the coefficient of its first term, the value of \( X_n \) will be known.

12. The value for \( X_n \) must then be substituted into the \((n-1)\)A equation and the equation must be solved for \( X_{n-1} \).

13. The values which have been obtained for \( X_n \) and \( X_{n-1} \) must then be substituted into the \((n-2)\)A equation and the equation solved for \( X_{n-2} \).

14. Continue in this manner until the 1A equation is solved for \( X_1 \) of the original system of equations after substituting the values obtained for all other unknowns.

15. The solution should be checked by substituting the values obtained for the unknowns into each equation of the original system, performing the indicated multiplications, additions and subtractions, and comparing the left side of the equation to the right side. They should be reasonably close to equality.
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equations (table 2) in a sample run of the program, listing 3 shows the contents of the registers at various points in the program, and listing 4 summarizes the original coefficients of the equations plus the calculated currents.

A "check" program and its instructions are shown in listings 5 and 6. Note that the quantity obtained for the left side of the equation may not be exactly equal to the right side due to round off approximations.

The "simultaneous equations" program of listing 1 calculates the values of the unknowns for any system containing no more than nine equations. The program is listed on calculator program worksheets upon which the addresses of program memory are preprinted. In addition, the program worksheets have labeled columns for listing the symbolic key codes, the numeric codes at various points in the program, and a column for comments.

The first page of the set of program worksheets contains pre labeled blocks which allow other useful information about the program to be stored. For example, the first section of listing 1 contains the following information about the simultaneous equations program in abbreviated form:

A. Registers

1. Registers R0 thru R9 and RS0 thru RS9 are used to store constants in a sequence that is reversed from the order in which they appear in the equations of each system. Note: Processing the first system (n equations) yields a system of n-1 equations; processing the second system (n-1 equations) yields a system of n-2 equations; ..., processing the nth system (1 equation) yields Xn.

2. Register A is used to store the number of equations in the original system of simultaneous equations.

3. Register B is used as a pointer for the registers R0 thru R9; register C is used as a pointer for the registers RS0 thru RS9. Registers B and C are decremented in a manner which allows constants to be indirectly recalled from the primary and secondary storage registers so that, using these constants, mathematical operations may be performed upon each equation of each system.

4. Register D starts at 1 and counts the number of pivotal equations that have been divided by their first term. When D=A, all pivotal equations have been processed, and Xn has been computed.

5. Register E starts at D+1 and counts the number of equations in each system that have been processed. When all equations of a system have been processed, E=A and the display calls for the next pivotal equation.

6. Register I takes care of miscellaneous temporary storage.

B. Labels

The main program has two parts which are actually subdivided into several smaller programs. Furthermore, most of the subprograms contain one or more subroutines which are used to conserve program steps.

Table 1: The nine equations for the circuit shown in figure 1.

| Mesh 1 | 40 + 111 - 212 - 313 + 014 + 015 + 017 + 018 + 019 = 0 |
| Mesh 2 | 2(12 - 11) + 412 + 612 - 141 - 612 - 131 = 0 |
| Mesh 3 | 3(13 - 11) + 612 - 1912 + 7(13 - 12) = 0 |
| Mesh 4 | 514 - 12 + 814 + 914 - 1014 + 1114 - 1512 = 0 |
| Mesh 5 | 714 - 13 + 1014 - 141 + 1114 - 1512 = 0 |
| Mesh 6 | 914 - 12 + 1214 + 1314 - 1514 + 1414 - 1512 = 0 |
| Mesh 7 | 1114 - 13 + 1414 - 151 + 1514 + 1512 = 0 |
| Mesh 8 | 1314 - 12 + 1614 + 1714 + 1814 - 1512 = 0 |
| Mesh 9 | 1514 - 12 + 1814 - 1914 = 0 |

Table 2: The nine simultaneous equations for the circuit in figure 1, shown here in standard form (ie: with the variables arranged in order for each equation).

| Equation 1 | 611 - 212 - 313 + 014 + 015 + 017 + 018 + 019 = 40 |
| Equation 2 | -211 + 171 - 013 - 514 + 015 + 017 + 018 + 019 = 0 |
| Equation 3 | -311 - 612 + 1613 + 014 - 715 + 016 + 017 + 018 + 019 = 0 |
| Equation 4 | -011 - 512 - 013 + 3214 + 1015 - 816 + 017 + 018 + 019 = 0 |
| Equation 5 | 011 + 012 - 711 - 1013 + 2814 + 015 + 1117 + 018 + 019 = 0 |
| Equation 6 | 011 + 012 + 013 - 813 + 015 + 4816 - 1417 - 1318 + 019 = 0 |
| Equation 7 | 011 + 012 - 013 + 014 - 1116 - 1417 - 1318 + 019 = 0 |
| Equation 8 | 011 + 012 + 013 + 014 + 015 - 1316 + 017 + 6418 + 1819 = 0 |
| Equation 9 | 011 + 012 + 013 + 014 + 015 + 016 - 1517 - 1818 + 5219 = 0 |
Only during the National Computer Conference will you have an opportunity to experience personal computing to the fullest. And that's why the 1979 Personal Computing Festival, June 4-7 in New York's Sheraton Center Hotel, formerly the Americana, is different. As a conference within a conference, it will give you the chance to explore the complete spectrum of information processing while concentrating on those aspects of personal computing you won't want to miss...including equipment, applications, ideas, and new developments that have created excitement throughout the entire computing community.

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### Listing 2: Detailed instructions for running the simultaneous equations program in listing 1.

#### Program Title: Simultaneous Equations

#### Application: Solves Systems of up to 9 equations

<table>
<thead>
<tr>
<th>Program Name</th>
<th>Bob Arp</th>
<th>DATE</th>
<th>12-16-76</th>
</tr>
</thead>
</table>

#### Instructions and Remarks

<table>
<thead>
<tr>
<th>Step No.</th>
<th>Instructions and Remarks</th>
<th>Inputs</th>
<th>Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Turn calculator on.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Place W/PRGM-RUN switch in RUN position.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Insert side 1 of program card labeled &quot;Simultaneous Equations&quot;.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>When card appears in the display, insert side 2.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Key in number of equations in the system.</td>
<td>n</td>
<td>n</td>
</tr>
<tr>
<td>6.</td>
<td>Press A.</td>
<td>START</td>
<td>A</td>
</tr>
<tr>
<td>7.</td>
<td>The &quot;1.00000 00&quot; which appears in the display calls for the coefficient of the first pivotal equation to be stored on the primary registers. Store A(1) in Rn, A2(1) in Rn-1,...,An(1) in R1 and T1(1) in R0. Coefficients which are zero need not be stored. The &quot;(1)&quot; refers to the first system.</td>
<td>0.00000 00</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>Press B.</td>
<td>DIVIDE</td>
<td>B</td>
</tr>
<tr>
<td>9.</td>
<td>When card appears in the display insert side 1 of card IA(1), where &quot;(1)&quot; is the number of the current pivotal equation (and system) being processed.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td>When card appears again, insert side 2 of card IA(1).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11.</td>
<td>Store the coefficients of the second equation of the first system in the primary registers. Store B1(1) in Rn, B2(1) in Rn-1,...,Bn(1) in R1 and T2(1) in R0.</td>
<td>0.00000 1A(1)</td>
<td></td>
</tr>
<tr>
<td>12.</td>
<td>Press C.</td>
<td>MULT/SUB.</td>
<td>0</td>
</tr>
<tr>
<td>13.</td>
<td>When flashing decimal point appears, record the absolute value of the coefficient for the first term of each equation, w, of the new system, 2, as it appears in the display. If the coefficient is missed while the decimal point is flashing, it may be recalled by pressing R CL after step 15, before proceeding with step 16.</td>
<td>m(w)[2] Displayed for 5 seconds with flashing decimal point.</td>
<td></td>
</tr>
<tr>
<td>14.</td>
<td>When card appears in the display, insert side 1 of card w(2).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15.</td>
<td>When card appears in the display again, insert side 2 of card w(2).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16.</td>
<td>Insert side 2 of card IA(1).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17.</td>
<td>When card appears in the display press C L A.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18.</td>
<td>Store the next equation of the current system, 1, in the primary registers. Store m(x) in Rn, m(x) in Rn-1,...,mn(x) in R1 and T(x) in R0, where x is the number of the equation in system 1 currently being processed.</td>
<td>0.00000 00</td>
<td></td>
</tr>
</tbody>
</table>

#### Listing 2 continued on next page.

1. Subprogram A: initiates the first part of the main program.
2. Subprogram B: divides pivotal equations by their first term and outputs an A equation.
3. Subprogram C: multiplies A equations by the coefficient of the first term of each succeeding system equation, subtracts the results of the multiplication from that equation and outputs the equations of a new system.
4. Subprogram D: initiates the second part of the main program.
5. Subprogram E: operating upon the A equations, computes X1 thru X(n-1) by multiplying the previously computed X values by their constants and subtracting the results from the right side of the A equation.
6. Subroutine a: initializes B and C registers every time B is pressed after a new pivotal equation is stored in the primary registers and every time C is pressed after a new equation is stored in the primary registers.
7. Subroutine b: clears registers R0 thru R9 to 0.
8. Subroutine c: recalls R0 thru R9 to 0.
9. Loops d, 0, 2, 4: these loops allow the same mathematical operation to be performed many times within the same subroutine.
10. Routine 1: compares the contents of D to the contents of A and transfers execution to routine 9 when D=A.
12. Routine 5: stores the address of the first coefficient of each equation of the new system being generated in register I, then recalls the coefficient, stores its absolute value in I, and finally displays the absolute value of the coefficient for 5 seconds.
13. Routine 6: increments E register and decrements D register in the second part of the main program.
14. Routine 7: displays the number of the unknown X which has been computed in a continuous loop until R/S is pressed.
15. Routine 8: calls for the next pivotal equation by displaying its number.
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3. Speed Sensor
4. Flow Sensor
5. 2 Temperature Sensors
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8. Installation Manual

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**Listing 2, continued:**

<table>
<thead>
<tr>
<th>STEP NO.</th>
<th>INSTRUCTIONS AND REMARKS</th>
<th>INPUTS</th>
<th>OUTPUTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>19.</td>
<td>GO TO step 12 until the digit &quot;2,00000 00&quot; appears in the display, calling for the second pivotal equation. A new pivotal equation must be stored in the primary registers each time the program halts automatically and displays a digit, z, indicating the desired pivotal equation. When the pivotal equation digit is displayed, the decimal point will not be flashin;g, nor will the digit be displayed in a continuous loop. The digit, z, is also the number of the system being processed. The first pivotal equation must be stored by using the keyboard. Subsequent pivotal equations are stored by inserting a data card.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20.</td>
<td>The new pivotal equation is that equation of the new system, Z, for which the largest (in absolute value) first term has been observed. This equation, as are the other equations of the new system, Z, is stored on a magnetic card.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21.</td>
<td>Insert side 2 of the card which contains the new pivotal equation.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22.</td>
<td>When card appears in the display, press CLX.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23.</td>
<td>Press f P2S.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24.</td>
<td>Press B.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25.</td>
<td>When card appears in the display, insert side 1 of card 1(A).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26.</td>
<td>When card appears again, insert side 2 of card 1(A).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27.</td>
<td>Press f P2S.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28.</td>
<td>Insert side 2 of card w(Z). (Card w(Z) no longer needed, where w is the equation of the system, Z, currently being processed, as are the other equations of the system, Z, stored on a magnetic card.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29.</td>
<td>When card appears in the display, press CLX.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30.</td>
<td>Press f P2S.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>31.</td>
<td>Press C.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>32.</td>
<td>When flashing decimal point appears, record the absolute value of the coefficient for the first term of each equation, w, of the system being created. If the coefficient is missed while the decimal point is flashing, it may be recalled by pressing h ROL after step 36, before proceeding with step 35.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>33.</td>
<td>When card appears in the display, insert side 1 of card (w(Z+1)).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>34.</td>
<td>When card appears in the display again, insert side 2 of card (w(Z+1)).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35.</td>
<td>Insert side 2 of card 1(A).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>36.</td>
<td>When card appears in the display press CLX.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>37.</td>
<td>GO TO step 29 until a new digit &quot;2,00000 00&quot; appears in the display, calling for the next pivotal equation.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>38.</td>
<td>When the new digit &quot;2,00000 00&quot; appears in the display, GO TO step 21. Eventually, the digit &quot;w,00000 00&quot; will appear in the display. The nth pivotal equation is the only equation...</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The instructions to be used while running the simultaneous equations program, shown in listing 2, are listed on calculator run worksheets. These worksheets list the manual steps which must be followed to obtain the solution to the system of equations, inputs you must supply to the calculator by pressing keys or inserting cards, and outputs from the calculator in the display or on cards.

Although it might appear that many magnetic cards are needed to run the program, note that cards containing the equations of a system are no longer needed after the equations have been processed with the pivotal equation of the system. Therefore, these cards may then be used to record the equations of another system.

These instructions are self-explanatory (I hope), therefore, I will allow them to speak for themselves. Please note, however, that the instructions contain loops that refer you to steps previously accomplished. Remember that n pivotal equations must be processed and each equation contained in a pivotal's system must be processed with the pivotal equation.

As a further aid in understanding both the program and the HP-67, listing 3 shows what is stored in each register after selected program steps. The calculator register worksheets illustrated in these figures are a valuable debugging tool and serve as explicit program documentation.

All of the forms shown in this article, except the one shown in listing 4, may be used with any HP-67 (and with other calculators as well) program. The form shown in listing 4 has been prepared specifically for simultaneous equations. This worksheet can be used to list the constants of the original system of equations, to record the first terms of each of the other systems as they appear in the display so that the pivotal equations may be easily spotted, and finally, to record the value of each unknown.
Conclusion

With the help of special forms designed for the occasion, the powerful repertoire of the HP-67 (and the HP-97) has been examined; yet I have taken from you none of the pleasures in store as you begin your adventures with this versatile calculator.

The example program presented will be an added attraction to those anticipating the purchase of an HP-67, as well as to those fortunate who already possess one. When you look at the price tag on the HP-67, compare its cost to the cost of computer time and memory which would be necessary to run similar programs. In addition, think of the programs you could run on the HP-67 which might never be run otherwise.

Listing 2, continued:

<table>
<thead>
<tr>
<th>STEP NO.</th>
<th>INSTRUCTIONS AND REMARKS</th>
<th>INPUTS</th>
<th>OUTPUTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>39</td>
<td>Press S.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>The &quot;n-1.00000 00&quot; displayed with flashing decimal in a continuous loop indicates that Xn-1 has been computed and is stored in RSO.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>Press R/S.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>Press D.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>43</td>
<td>Insert side 2 of card IA(n-I).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>When crd appears in the display, press CLX.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>Press E.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>46</td>
<td>The &quot;n-1.00000 00&quot; displayed with flashing decimal in a continuous loop indicates that Xn-1 has been computed and is stored in R11 (Xn is now stored in R1).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>47</td>
<td>Press R/S.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>Insert side 2 of card IA(n-I).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>49</td>
<td>When crd appears in the display, press CLX.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>Press E.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>51</td>
<td>The &quot;1.00000 00&quot; displayed with flashing decimal in a continuous loop indicated that XI has been computed and is stored in Rn.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>52</td>
<td>Press R/S.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>53</td>
<td>Recall each X value from the primary registers by pressing R1 through R5.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Listing 3: Selected register worksheets for the sample program discussed in the text. These sheets illustrate the contents of the registers at various key points in the program.

<table>
<thead>
<tr>
<th>PROGRAM TITLE: 6 Equation Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>APPLICATION: Calculator-Aided Design</td>
</tr>
<tr>
<td>PROGRAMMER: Bob Arp</td>
</tr>
<tr>
<td>DATA CARD LABEL: None</td>
</tr>
<tr>
<td>LAST PROGRAM STEP: 010</td>
</tr>
<tr>
<td>NEXT PROGRAM STEP: 011</td>
</tr>
<tr>
<td>EQUATION: EQUATION 1</td>
</tr>
<tr>
<td>COUNTERS AND CONSTANTS</td>
</tr>
<tr>
<td>REG CONTENTS</td>
</tr>
<tr>
<td>R0 0.00000</td>
</tr>
<tr>
<td>R1 0.00000</td>
</tr>
<tr>
<td>R2 0.00000</td>
</tr>
<tr>
<td>R3 0.00000</td>
</tr>
<tr>
<td>R4 0.00000</td>
</tr>
<tr>
<td>R5 0.00000</td>
</tr>
<tr>
<td>R6 0.00000</td>
</tr>
<tr>
<td>R7 0.00000</td>
</tr>
<tr>
<td>R8 0.00000</td>
</tr>
<tr>
<td>R9 0.00000</td>
</tr>
</tbody>
</table>

REFERENCES


Listings 3, 4, 5 and 6 are continued on pages 186 and 188.

Listing 3 continued on next page.

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Listing 3, continued:

Heating systems are shown along with the solution.

Listing 4: A special simultaneous equations worksheet showing the constants of the original nine equations of the sample problem discussed in the text. The first terms of each of the intermediate systems are shown along with the solution.
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Listing 5: Instructions for running the program in listing 6 which checks the solutions obtained by the program in listing 1.

Listing 6: A program which accepts the coefficients calculated by listing 1 and checks them for accuracy.
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BASIC Cross-Reference Table Generator

William and Alice Englander
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A standard compiler feature for high level languages like COBOL and PL/I is a cross-reference of the source program. In the simplest case, each named element in the program is listed in a report with the line numbers of all statements containing that element. Words which have special meanings in the language being cross-referenced, such as READ or IF, are ignored.

Features of more sophisticated cross-reference facilities include placing the elements in alphabetical order, showing the statement number in which an element is defined separate from its references, defining the use of the element as a sending or receiving field and cross-referencing both data elements and procedural elements (statement labels).

As we began program development in BASIC on our microprocessor, we discovered the pleasures of using BASIC, but were surprised to find that cross-references of our BASIC programs could not be produced with any of our regular system software. In addition, our survey of the literature did not turn up any BASIC cross-reference programs.

A cross-reference can be an extremely useful programming aid. When you are debugging a program, it allows you to quickly find each statement which deals with a particular variable. For example, if the program is looping you can look at each reference of the loop control variable to ensure that it has been initialized, that it is being incremented, and that a check for the upper limit is being made. A cross-reference is

Text continued on page 192.
Listing 1: An example program with a cross-reference table generated by the BASIC cross-reference generator program.

About the Authors

William and Alice Englander have a programming and consulting firm in the San Diego area. While most of their program development is done on customers' large scale computers, they also do work for customers on their IMSAI 8080 disk based system. They are both computer systems instructors at National University.
handy when you need to make a program change, too. You can quickly see what names have already been used if you need to define a new variable. And you can double check your planned changes against uses of the existing variables, which may enable you to use existing ones instead of having to define new ones.

In BASIC, a cross-reference listing can be especially useful in helping you to verify that you have used correct names in your code. Since BASIC sets up variables for you without requiring explicit definitions, you can accidentally miss a variable name and cause some elusive program problems. A quick look at the cross-reference would alert you right away since you would see both the correct name and the improperly coded name.

Our BASIC cross-reference program was written using C-BASIC on an IMSAI 8080 disk based system running under CP/M. Depending on your configuration, enhancements could probably be made which would speed up the processing time. A typical program and cross-reference table is shown in listing 1 on the preceding page.

The Nybbles Library is an inexpensive means for BYTE readers to share some interesting but specialized forms of software. These programs are written by readers with small computers and printer facilities, and are therefore designed for particular systems. The algorithms and programming techniques can be used by readers with similar equipment, or can serve as an inspiration for improvisation on computers of different characteristics.

Potential authors of such programs should send us a self-addressed stamped envelope, with a request for a copy of our Guidelines for Nybbles Authors. Payment for Nybbles items is based on sales and length of the item. Rates are set at the time of acceptance.

Nybbles Library programs are sent in listing form, printed on 8.5 by 11 inch paper on both sides. The Nybbles Library programs are punched with three holes for collection in loose leaf binders, and come in an attractive folder which serves as a cover. This month the BASIC Cross-Reference Table Generator has been added to the Nybbles Library. You can order a personal copy of this program (BYTE Nybbles Library Document #105) for $3.75 postpaid ($1.05 overseas postpaid) by filling out the coupon on the preceding page.

Motor Source Error

A list of stepping motor sources in "A Stepping Motor Primer, Part 1: Theory of Operation," by Paul Giacomo (February 1979 BYTE, page 90) was incomplete. We omitted Superior Electric Co., 383G Middle St, Bristol CT 06010, a major manufacturer of stepping motors.

Polyphony Made Accurate

Perusal of my copy of the January 1979 BYTE, containing my article "Polyphony Made Easy," reveals two errors in the schematic on page 106.

First the trivial one: the counters are incorrectly labeled as 7473 (in fact, both are called IC10a). They are, in reality, 7493s.

Second, the multiplexers - all nine of them - have a pinout error. Instead of "B A C" along the bottom of each one (input address), they should read "A B C," with the pin numbers changed accordingly to "11 to 9."

These are not crippling errors - anyone who's reasonably familiar with TTL (transistor-transistor logic) would spot the first one immediately, and the second would cause scrambled key codes but would sooner or later be figured out.

Steven K Roberts
129 N Galt Av
Louisville KY 40206

Finishing the Job

The Programming Quickie "Single Stepping the 8080 Processor" (January 1979 BYTE, page 179) has one small bug in it. A line of code was left out of the program listing on page 180. The last line of the program should read: 118A JMP FINI C37D10.
32 Bit Microprocessors Are Rumored. While Zilog and Motorola are struggling to get their 16 bit microprocessor-ICs into production, Texas Instruments and Intel have been delivering theirs for some time. Now rumors abound that both TI and Intel will show prototype 32 bit processors by the end of the year and may be in production by the end of 1980 or the beginning of 1981.

Tremendous Growth of Personal Computer Systems Predicted for 1979. Mike Shea, marketing director for Atari, who recently brought two personal computer systems to the market, predicts a four to sixfold increase in personal computer sales for this year. He feels that between 200,000 and 300,000 personal computer systems will be sold this year, compared to 50,000 last year, and said that in the future Atari will pay less attention to developing new game consoles and instead concentrate on bringing out new software for existing units.

Fairchild Camera & Instruments predicts that 4.6 million programmable video games will be sold this year, worldwide, compared to 2.1 million in 1978. Further, they predict that 18 million cartridges, worth $110 million, will be sold, compared to 5.7 million, worth $18 million, last year.

Nonvideo games growth should prove even more dynamic, according to industry pundits. Sales should reach $290 million in 1979, and possibly $500 million in 1980.

Lear Seigler Shipped 40,000 Video Terminals in 1978. The Data Products division of Lear Seigler announced that in 1978 they shipped 40,000 video display terminals. This was more than they shipped in their six previous years of doing business. LS is predicting an increase in video display sales in 1979 of 25 to 30 percent.

Centronix Reports 20 Percent of Its Printers Go to Personal Computer Makers. Centronix, the leading maker of dot matrix printers, predicts that about 20 percent of its 1979 business will be from Tandy (Radio Shack TRS-80) and from Apple Inc. At the beginning of the year they were shipping 1700 printers per month to Tandy (in other words, 20,400 per year). Centronix is getting set to introduce a high density dot matrix printer and a word processing impact printer to compete with Diablo and Queene.

Computer Stores Becoming Big Business. Computer stores are becoming mass merchandisers, judging by an order recently placed with Perkin-Elmer Corp. Their terminal division announced that Micro-Age, a chain of five computer stores in Arizona and Texas, placed an order with them for 2000 of their new Bantam video display terminals. That's a far cry from the garage-type computer store operations of just a year or two ago.

Battle Shaping Up in 32K EROM. In February 1978 Texas Instruments introduced its TMS 2532 4K by 8 EROM (erasable read only memory), with full production promised for April or May. This meant that they were well ahead of all the other integrated circuit manufacturers. They accepted orders for the device at $54 in 100 price lots. Intel introduced their 2732 erasable read only memory in November. Needless to say, the pinouts were different and a heated debate developed in the JEDEC committee over which would be the standard. TI hoped their 10 month lead would favor them. However, they encountered production problems and only started to deliver samples by year-end. Intel, in the meantime, is in production and has already lined up at least one second source. TI is promising production quantities by April. The unit price on the Intel part is currently $140. The 2732 also uses the same pinout as the 2716 and 2708 EROMs.

HP May Be Developing Personal Computer System. Hewlett-Packard is rumored to be developing a new personal computer system at its Corvallis Oregon Consumer Products division. HP has been selling a desktop computer with BASIC in read only memory and an IEEE-488 interface for a few years now. It is expected that the system will be a scaled down version of this system, that it will have a base price of $1000, and that it will be on the market this fall.

Tandy Developing New Computer. Tandy is rumored to be in development of a second generation Radio Shack TRS-80, possibly with color capability. Tandy, which has a 200,000 square foot plant and staff of 700 making the TRS-80, is supposedly looking for an outside manufacturer of the new system. Tandy also plans to develop many new software packages for introduction this year.

Magnavox Files Suit on Microprocessor Video Game Patents. Magnavox, the originator of video games played on home TV receivers, has filed suit against several manufacturers of programmable TV video games; among them...
are Fairchild, Bally, Sears Roebuck and Montgomery Ward. Magnavox has won previous suits on dedicated, non-programmable video games. Some industry experts feel that if Magnavox is successful in this suit, the next step might be to try to license makers of personal computers that connect to home TV receivers.

DEC Forms Retail Products Group. Digital Equipment Corporation, the largest manufacturer of minicomputers, has formed a retail products group. Its initial objective is planning for expansion based on its successful experience with a retail store, which opened last August in Manchester NH. Located in a shopping mall, the store sells small computer systems starting at less than $10,000.

Flat Panel Displays Getting Closer to Production. Last month I reported on a flat panel terminal display being readied for production by General Telephone and Electronics. Several other companies have also announced that they have display panels in development. However, none appear near to replacing the present video displays, such as that of GT&E. Nonetheless, they are worth reviewing.

Datascreen Corp, of Mountain View CA, will soon start sampling a 40 character LCD (liquid crystal display) panel (5 by 10 dots) which works off 5 V and consumes 250 mW.

Westinghouse has already demonstrated a 180 by 180 line LCD panel for TV use. Hitachi has shown a 120 line panel. Neither, however, is near production.

Electroluminescent type panel samples are already available from Sharp. A 480 character display using a 7 by 9 dot matrix, with complete drive electronics, is currently available for $2500. A 240 by 320 dot graphics panel will be available next year.

ISSCC Gives Preview of New Technology Coming. The annual International Solid State Circuits Conference, held in Philadelphia, February 14 to 16, saw the presentation of new hardware technology still in the research and development stage. These devices will not be on the market for at least a year yet, and most are still 2 to 3 years off. But all are real and coming. Here's a partial list of some of those presented at the ISSCC:

From Intel: a self-refreshing dynamic 4 K programmable memory with 200 ns access, an NMOS 4 K static programmable memory with 25 ns access, a 16 K HMOS static programmable memory with 45 ns access, a 5 V only 16 K dynamic programmable memory with 100 ns access and an analog I/O (input/output) microprocessor with on board erasable read only memory.

From Texas Instruments: a simple 1 transistor cell.

From Nippon Telephone and Telegraph: a 128 K bit read only memory and a megabit full wafer MOS programmable memory with 350 ns access.

From Hitachi: a 1 K programmable memory with 5 ns access.

The Robots Are Taking Over. There are already about 20,000 robots at work in US factories. But this is just the beginning. Japan and several European countries are already ahead of the US in introducing manufacturing robots and automation under computer control.

Automation experts claim that in most manufacturing situations a product spends 95 percent of its time moving and waiting. Time is money. Hence, automation can cut this wasted time tremendously, effecting considerable savings.

Zilog Reports $18 million in Sales. Zilog, the creator and maker of the Z-80 processor, has reported sales for 1978 of $18 million. The company, which started in late 1975, and brought the Z-80 to the market in 1976, operated in the red in 1976 and 1977. A company spokesman said that in 1978 they were "at breakeven."

The Altair May Live Again. When Pertec bought MITS and its Altair line of PC system in 1977, they deserted the hobbyists who made the Altair a success. Pertec tried to change the Altair into a small business computer system. Things did not go too well. Pertec moved MITS from Albuquerque to California and then Pertec stopped making Altairs in June 1978. Pertec now is going to resurrect the Altair and start producing it again, in a new plant it is building in Albuquerque (of all places). Pertec plans to market it to small business users and not to personal computer users.

Computers Produce $350 Million Trade Surplus. It seems that all we read about in the newspapers are trade deficits. Well, last year the US exported $350 million in computer gear. Canada was the biggest purchaser ($12 million), and Japan was second ($10 million). Actually the US exported $406 million but imported $56 million in computer gear.

IBM Keeps Growing and Growing. When microcomputers came out and skyrocketed in popularity, many pundits predicted that IBM's domination of the computer business was coming to an end. However, that is not what has
happened. Today IBM has a larger backlog of orders than ever before. Their current backlog is more than four times the computing power it has ever shipped. Delivery time on its new 303X large computers is now over two years, and IBM has orders for about 13,000 of these machines, which replace large 370s.

Paper Newspapers and Mail May Soon Be a Thing of the Past. The groundwork for a digital electronic mail system is now in the works. Imagine having your newspapers, magazines, bills, etc., delivered to you directly via your personal computer system, and likewise being able to write letters (with on-line text editing, naturally) and then transmit them at the press of a button. It is already used in some large corporations and government agencies. But during the 1980s, this technology will explode into business offices and homes. It is rumored that TI, HP and IBM are developing personal computer systems specifically for these emerging applications.

Further, last December Xerox filed a petition with the FCC to develop a digital mail/communication system using microwave. It would provide for document distribution, data communication, etc., at rates up to 256 K bytes, which is far greater than current telephone systems and even than Bell's new T-carrier system now being installed. Xerox claims they will be able to deliver documents at less cost than the U.S. mail. Each office desk would be equipped with a keyboard, video display, disk and processor; and would be able to do word processing, sorting, etc., in addition to mail handling. The mail handling naturally would be controlled by computer and hence include automatic addressing, priority routing, multipoint delivery, automatic transmission of previously stored messages, scan messages, etc.

GT&E is setting up a group to test market (in early 1980) a system to transmit data via telephone lines onto modified TV receivers in homes and offices. The system will be similar to the Viewdata systems currently under test by the British Postal System. GT&E is also negotiating for Viewdata licenses. ITT, TI and RCA reportedly are doing the same. TI, however, is currently testing a home information system in Salt Lake City that sends data over regular broadcast channels.

Also getting into the business is the US Postal Service, which last fall asked the US Postal Rate Commission for authority to offer an on-line service called Electronic Computer Originated Mail (ECOM). ECOM is expected to start this year. The sender writes a "letter" on a terminal and sends it via telephone to the post office, who routes it to the destination post office where it is printed and delivered in the conventional way. This will be used mostly for mailing bills, overdue notices, etc.

This communications revolution will be boosted by the new Advanced Communications Service (ACS) for which AT&T recently received approval. ACS will lower data transmission costs and increase service. It will lower costs via shared communications facilities and make possible interfacing of incompatible terminals and computers and provide user selectable communications capabilities.

A few personal computer groups have already started a simple system called PCNET. The leading PCNET activity is run by the CACHE group (Chicago Area Computer Hobbyist Exchange). Other PCNET groups are functioning in the San Francisco, LA and Atlanta areas. The PCNET uses modems and telephone lines for communication. A writeup on PCNET appeared in the November 1978 BYTE.

Another personal computer approach has been taken by AMRAD (Amateur Radio Research and Development Corp) in McLean VA. They have established a bulletin board type system using telephone and 2 meter radio telephone.
Continued from page 6:

Another cause for possibility of losing files is just plain lack of experience with the system involved. A friend of mine who works at Digital Equipment Corporation tells the tale of how he once forgot which of several operating systems he was working on—and deleted a whole slew of files thanks to a “feature” known as wild card operations. Such operations are shortcuts to allow more than one file name to match the file name specified to the operating system. This friend’s problem came from the fact that one PDP-11 operating system had a wild card specification that in another operating system was a unique specification.

There are more than just wild card opportunities for not understanding or forgetting how the operating system software works. There are many ways in which the user of any small computer can interfere in disk filing operations so that the file will be lost, or a whole disk file directory will be lost. For example, all it takes is the simple removal of the disk from the drive or resetting of the computer while an operation is being performed. Thus the fundamental rule of small computer and big computer use is “don’t touch the computer during a disk (or tape or any other filing) operation.”

But when you introduce the possibility of physical errors due to imperfect media, the whole problem gets complicated, and sometimes such a simplistic rule has to be violated. My problem may have resulted from the facts that I have been using one floppy disk for three months solidly and that I was updating a file one stormy winter day. Because floppy disk media are contact media, they are indeed subject to wear. Whether it was wear or the wile of Peterborough Flicker And Flash division of New Hampshire Public Service, on the day of the disaster I got a little message from the physical I/O disk drivers which support the operating system.

It was an ominous message, for several reasons. First, it occurred during a “krunch” operation which is the UCSD Pascal system’s disk file compression program. Second, it occurred after the last file had been moved, so it was most likely during a directory write operation. Third, it was one of those frustrating situations where an apparently infinite retry loop was involved, with one error message coming every 15 or 20 seconds. So, I violated the rule stated above and reset the computer.

That was the end. The directory was no longer valid, I had no alternate directory, and I had not the foggiest idea ahead of time about what to do to fix this situation. The
directory included maybe 20 or 30 Pascal programs which I had written during the preceding month or so, including a really useful one called "littleblackbook." Well, in my experience using computers, the best course of action following such a disaster has always been to sit back and contemplate what has happened, to avoid compounding the problem with hastily conceived actions.

One thing was obvious. Only the directory had gotten zapped. This was confirmed by the use of some of the utility functions built into the UCSD Pascal system software: in the Filer portion of the system, one can scan for bad blocks on a disk, then enter a fixup routine to try and recover most of the data. The bad block was obviously in the directory, due to its physical location on the disk and that in using another copy of the system no directory could be found among the remaining data on the damaged disk. Knowing this, plus the fact that the files in the UCSD are stored contiguously on the disk, I knew that all the actual data was out there and that I just could not get at it through the normal directory methods.

But, if I could read the disk without the benefit of paying attention to such niceties as file structures, I would be able in principle to recover from this problem by writing a relatively simple program. Well, I proceeded to do exactly that. Since most of my data was in the form of programs, my first step was to write a program which would search arbitrary disk blocks in sequence from a starting block to the end of the disk. As each block was read by the program, I printed a confirmation message giving the current block number.

In this search, the program would look for the key word PROGRAM which begins every program’s text file. When found, I would print out the first 20 characters of the file starting at the word PROGRAM. This would give me a physical block address directory of all the Pascal programs on the damaged disk. The program entitled Recover found in listing 1 accomplished this end for me, using the low level I/O procedures of UCSD Pascal called UNITREAD, UNITBUSY and UNITCLEAR. Output was directed to the screen and to the printer using the usual techniques of the 83/P implementation of UCSD Pascal: a control P character is intercepted from the keyboard to toggle on and off the output to the Diablo Hytype II printer I have on the system.

Once I had this printed directory of physical blocks which had the word "PRO-
I proceeded to modify and extend Recover until I had a second Pascal program called Grabber which would physically grab the good data from the damaged disk and write it on the new system disk as a file called A.TEXT. Grabber starts at a block address obtained by Recover’s listing and transfers all data to the new file. This continues until a block is found containing the magical key word END, which marks the last line of every Pascal program in the system.

The text of Grabber is found in listing 2 accompanying this editorial. It has a couple of minor technical points worth noting. First, the UCSD Pascal system editor program tries to keep integral lines of text (marked by carriage return codes) within one block of 512 bytes of data. Since lines vary in size there is usually a segment of null data at the end of each block. Second, the UCSD Pascal system uses a form of data compression to eliminate redundant spaces at the beginning of each line of text in a file, so the first two bytes physically following a carriage return character are often (but not always) not text at all but codes indicating line compression. Thus in converting the file, the conversion program Grabber had to ignore all nonprinting characters except carriage returns and various combinations of characters following a carriage return.

The end result of running Grabber is always a file called A.TEXT, which I can then change to a name appropriate for the program being recovered. In this way, the new system disk could be restored with the contents of any program I wanted to use from the old disk. Now, of course, the old disk will never be modified in any way until I have recovered all the data I want from it.

The final version of the Grabber program as I wrote it is shown in listing 2a. It is still not perfect, for there are various strange combinations of carriage return and indentation codes which crop up when a file is recovered in this manner. It only handles the most common states of indentation codes. The exceptions are relatively benign, in that they get turned into arbitrary characters at the beginning of lines. These characters can in turn be edited out of the file after the grabber has completed its operation. Verification of the success of this strategy has been provided by several programs which compile and run as expected after transfer to new files using Grabber.

As for new operating procedures, I have now started to make a more regular practice of backing up files on my system disk. It turns out that there is no particular difficulty in transferring the entire contents of a
disk from one drive to another using the UCSD Pascal system's filer program. So, readers who wish to learn from my little fiasco should consider taking the time at least once per day to copy all the files on their main disk to a backup disk as a little bit of logical insurance against a serious filing system problem which may or may not ever happen. This is an important practice even if all you are using your computer for is fun and games, for every program that is ever written takes time and energy to create and type into a computer.

Listing 1: The first stage in the process of recovery from the directory zeroing disaster was to write an exploratory Pascal program called Recovery. The zapping of course only applied to the current system disk, copied from the master supplied with the system. Thus it was possible to make a new system disk for the purposes of compiling programs such as this one.

```pascal
[Program to scan blocks on disk for text string "PROGRAM"]

PROGRAM recovery;
CONST
   disk = 5;
VAR
   blocknr,i,j : INTEGER;
   anychar : CHAR;
   buffer : PACKED ARRAY[0..511] OF CHAR;
PROCEDURE initialize;
BEGIN
   WRITELN('Enter starting block number for scan');
   READLN(blocknr);
   FOR j := 0 TO 511 DO buffer[j] := ' ';
END (initialize);

PROCEDURE findprogram;
BEGIN
   WRITELN('Checking Block #',blocknr);
   UNITREAD(disk,buff,512,blocknr,0);
   UNITWAIT(disk);
   j := 0;
   WHILE j < 480 DO
      BEGIN
         IF (buffer[j+40] = 'P') AND
             (buffer[j+3] = 'R') AND
             (buffer[j+2] = 'O') AND
             (buffer[j+3] = 'M') AND
             (buffer[j+4] = 'A') AND
             (buffer[j+5] = 'R') AND
             (buffer[j+6] = 'M')
            THEN
               BEGIN
                  FOR i := j TO j+20 DO WRITE(buffer[i]);
                  WRITELN();
                  j := 505
               END;
      END;
END (findprogram);
BEGIN (recovery)
   initialize;
   repeat
      findprogram
      until blocknr > 1100;
   END (recovery);
```

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Listing 2: The second stage in the process of recovery was a modification and extension of the first program, now renamed Grabber. Once the earlier version of the program had printed out a rough listing of block numbers and names of programs, the program shown at (a) was created to transfer these files from the bad disk to a good disk. At (b) is shown an example run for recovery of a Pascal program of some 5 blocks in length.

```
LISTING 2: The second stage in the process of recovery was a modification and extension of the first program, now renamed Grabber. Once the earlier version of the program had printed out a rough listing of block numbers and names of programs, the program shown at (a) was created to transfer these files from the bad disk to a good disk. At (b) is shown an example run for recovery of a Pascal program of some 5 blocks in length.

{program to copy physical IO files to "A.TEXT" text file}

PROGRAM grabtext;
CONST
   carrIagereturn = 13 [decimal integer equivalent of ASCII <CR>];
   indentcode = 16 [decimal integer equivalent of ASCII <DLE>];
   disk = 5 [physical unit address of right-hand floppy drive];
VAR
   blockcount,blocknr,i,j,k : INTEGER;
   onecounter,anychar : CHAR;
   buffer : PACKED ARRAY[0..511] OF CHAR;
   filename : STRING[32];
   ifoundareturn : (no,yes,spacecount);
   theoutput : FILE OF CHAR;

PROCEDURE initialize;
   BEGIN
      blockcount := -1;
      ifoundareturn := no;
      READLN(blocknr);
      filename := 'A.TEXT';
      WRITELN('Output will be to the file "A.TEXT"');
      WRITELN('Do you approve?');
      READ(KEYBOARD,anychar);
      IF anychar <> 'y' THEN
         WRITELN('When you have figured out what you want to do, ');
         WRITELN('try me again');
      blocknr := 9999 (to force premature end of program)
      END;
      Rewrite (theoutput,filename)
      END [initialize];

PROCEDURE makenormal;
   BEGIN [simply transfer if printing character]
      IF { (k >= ORD(' '))
      AND (k <= ORD(' ')) }
      THEN
         WRITE (theoutput,onecharacter);
         ifoundareturn := no {-> first state}
      END [makenormal];

PROCEDURE transferblock;
   BEGIN
      {first grab the block from the bad disk}
      WRITELN('Transferring Block #',blocknr);
      UNITCLEAR(disk);
      UNITREAD(disk,bufffer,512,blocknr,0);
      UNITWAIT(disk);
      {then transfer the block to output file}
      FOR j := 0 TO 511 DO
         ONECHARACTER := buffer[j];
         IF j = 0 THEN
            BEGIN
               IF { (buffer[j-3]='E') AND
               (buffer[j-2]='N') AND
               (buffer[j-1]='D') AND
               (onecharacter = 'E') }
               THEN
                  BEGIN
                     WRITELN('I found END in block #',blocknr);
                     blocknr := 2000
                     END;
      END [ansible];

Listing 2a continued on opposite page.
Listing 2a, continued:

Legal possibilities are as follows
... <any><any> ... <any>
... <CR><CR> ...
... <CR><DLE><n><any> ...
... <CR><DLE><n><DLE><n> ...
... <DLE><n><any> ...

k := ORD(onecharacter);
CASE ifoundreturn OF
no:
  IF k <> acarriagereturn THEN
    makenormal
  ELSE
    WRITE(theoutput,onecharacter);
    ifoundreturn := yes [--> next state]
    END [IF...ELSE...];
yes:
  BEGIN
    IF k=indentcode THEN
      BEGIN
        WRITE(theoutput,onecharacter);
        ifoundreturn := spacecount [--> next state]
      END [CASE];
      END [FOR];
      blocknr := blocknr + 1
    END [transferblock];
BEGIN [grabber]
  initialize;
  IF blocknr < 1103 THEN REPEAT
    [put an upper limit on number of blocks to transfer]
    blockcount := blockcount + 1;
    IF blockcount < 1 THEN
      BEGIN
        WRITEUN("Enter number of blocks to do");
        READLN(blockcount);
        IF blockcount = 0 THEN blocknr := 9999;
        IF blockcount > 20 THEN blockcount := 20
      END;
    IF blocknr < 1103 THEN transferblock
    UNTIL blocknr > 1102;
  CLOSE(theoutput, LOCK)
END.

Enter starting block number to grab from right drive 259
Output will be to the file "A.TEXT"
Do you approve?
Y
Enter number of blocks to do
5
Transferring Block #259
Transferring Block #260
Transferring Block #261
Transferring Block #262
I found END. in block #262

---

Historical Correction

Regarding Keith S Reid-Green's article "The History of Computers: The IBM 704" (January 1979 BYTE, page 190), the magnetic core storage unit, shown in photo 1, is the IBM 737. It had a capacity of 4096 36 bit words. The 32 K core storage, referred to in the article, is the IBM 738 and did contain a minor amount of solid state logic.

The IBM 711 (photo 3) could read any of 80 card columns, selectable by a plugboard whose access is shown under the identification tag. Only 72 of those 80 columns could be read at any one time, however. Also the Q bit of the multiplier-quotient register was used in multiply to contain bits of partial product during shifts.

I am sure that all of us "old-timers" who worked on the 704 appreciate your nostalgic look backward to the early days of this industry.

Warren G Tisdale
Rt 6 Box 348N
Raleigh NC 27612

Commander in Chief Generalized

Regarding the program Commander in Chief, presented in December 1978 BYTE, page 192, there are several minor errors: location 093 should read \texttt{G} instead of \texttt{8}; and \texttt{PGM} should be inserted at location 041. To get different games each time, one need only enter any number before pressing \texttt{E}. The program can be modified in the following manner to remove the necessity of entering a new seed number for each game:

128 \texttt{G}
129 \texttt{LNX}
130 \texttt{RLL}
131 \texttt{9}
132 \texttt{CM'S}
133 \texttt{STO}
134 \texttt{9}
135 \texttt{CLR}
136 \texttt{1/A}
137 \texttt{R/S}

Dennis Grundler
818 E 22nd St
Marysville CA 95901

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April 1979 © BYTE Publications Inc
April 3-5, Specifications of Reliable Software, Hyatt Regency Hotel, Cambridge MA. This conference is sponsored by the IEEE Computer Society. Contact Douglas T Ross, Softech Inc, 460 Totten Pond Rd, Waltham MA 02154, (617) 890-6900.

April 5-6, Computers in Ophthalmology, St Louis MO. This is a course in application of computers to ophthalmic patient care and clinical research. Sessions dealing with data bases, automated patient testing, artificial intelligence, and image processing are being planned. Contact Robert Greenfield, DSc, Biomedical Computer Laboratory, Washington University School of Medicine, 700 S Euclid Av, St Louis MO 63110.

April 9-11, Computer Contract Negotiation, Atlanta GA. This 3 day course is designed to give participants sound answers to the complex ramifications of preparing and negotiating computer contracts. Contract Brandon Consulting Group Inc, 505 Park Av, NY NY 10022.

April 9-11, Data Processing Operations Management, Miami FL. This seminar will emphasize the management skill and techniques applicable to the data processing operations function. The curriculum is designed toward practical, applied management techniques to provide a sounder understanding of the ways of managing data processing operations more effectively. Contact The University of Chicago, Center for Continuing Education, 1307 E 60th St, Chicago IL 60637.

April 9-12, Interface '79, McCormick Pt, Chicago IL. This is the seventh annual conference and exposition on data communications and computers. Contact The Interface Group, 160 Speen St, Framingham MA 01701.

April 16-20, Data Communication Systems and Networks, George Washington University, Washington DC. This course is designed for systems analysts, engineers, managers, and others who need a better working knowledge of data communication systems. The course will be of particular value to those who are currently planning, designing or implementing a computer that involves data communications. The objective of the course is to provide participants with an understanding of the basic principles and current techniques involved in computer to computer and terminal to computer communications and networking. Contact Continuing Engineering Education, George Washington University, Washington DC 20052.

April 18-20, Understanding and Using Computer Graphics, Dallas TX. This course is for people who are now using or making decisions about using computer graphics and its role in their organization. It will describe computer graphics; show how installing computer graphics can be justified; explain what hardware and software systems are available and give costs and performance comparisons. Contact Frost and Sullivan, 106 Fulton St, NY NY 10038.

April 23-26, Middle Eastern Electronic Communications Show and Conference, Bahrain Exhibition Ctr, Bahrain. The exhibition will consist of companies marketing communication systems, products, and services. Contact Gerry Dobson, McCormick, Arabian Exhibition Management, 11 Manchester Sq, London W1 M 5AB.

April 23-27, PASCAL Programming for Mini and Microcomputers, Ramada Inn, Woburn MA. This course covers a general approach to the use of high level languages in small computers, including an intensive course in PASCAL programming, and an introduction to structured programming techniques. Contact Institute for Advanced Professional Studies, One Gateway Center, Newton MA 02158.

April 23-27, High Speed Computer Organization: Super Machines and Low Cost Systems, Holiday Inn, Westwood CA. For computer designers, system architects, project leaders and managers involved in the implementation, application and evaluation of high speed computing systems. The course provides a thorough understanding of the principles of high speed computer organization and their use in cost effective systems. Several commercial and paper high speed computers are presented and compared. Contact UCLA Extension, 10995 Lc Conte Av, Los Angeles CA 90024.


April 30-May 2, First Annual International Conference on Computer Capacity Management (ICCCM), Washington DC. Individuals involved in computer capacity management will present papers on research, experiments and other activities concerned with the importance, requirements and benefits of capacity management in today's data processing environment. Contact Market Communications, 2275 E Bayside Rd, Palo Alto CA 94303.

May 11-13, The West Coast Computer Fair, San Francisco Civic Auditorium. This is a conference and exposition on personal computers for home, business, and industry. Contact Computer Faire, ROB 1579, Palo Alto CA 94302, (415) 851-7075.

May 21-25, Systems Analysis Workshop, Chicago IL. This workshop will teach systems analysts and others needing systems analysis skills to use a practical set of tools and techniques to evaluate user requests and document requirements for new data processing systems. Contact Brandon Systems Institute, 4720 Montgomery Ln, Bethesda MD 20014.

June 6-8, Eighth Annual Conference of the MUMPS Users Group, Marriott Hotel, Atlanta GA. Papers will be presented on all aspects of MUMPS development, implementation, and use. Contact Judith Faulkner, Program Committee, Department of Psychiatry, Clinical Sciences Center, 600 Highland Av, Madison WI 53792.

June 6-8, Twelfth Annual Association of Small College Computer Users in Education Conference, Denison University, Granville OH. Sessions will include the presentation of papers and demonstrations of the educational use of microcomputers, computer textbook surveys, discussions with authors of computer texts, administrative uses of computers in small colleges, and a tutorial on microprocessors. Contact Douglas Hughes, Computer Center, Denison University, Granville OH 43055, (614) 587-0810.

June 6-8, Computer Contract Negotiation, NY NY. This 3 day course is designed to give participants sound answers to the complex ramifications of preparing and negotiating computer contracts. Contact Brandon Consulting Group Inc, 505 Park Av, NY NY 10022.

June 19-21, International Microcomputers/Minicomputers/Microprocessors '79, Palais des Expositions, Geneva Switzerland. The 1979 conference program will probe advances in systems and equipment with emphasis on practical applications and uses of minicomputers and microcomputers as well as the techniques important to their development. Contact Industrial & Scientific Conferences Management Inc, 222 W Adams St, Chicago IL 60606.


June 27-29, Machine Processing of Remotely Sensed Data, Purdue University, W Lafayette IN. The symposium will focus upon the theory, implementation and novel applications of machine processing of remotely sensed data. Contact Purdue University, Laboratory for Applications of Remote Sensing, 1220 Potter Dr, W Lafayette IN 47906.
**TRS-80 Complete System**

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**C-10 Cassettes**

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<th>Description</th>
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<td>TRS-80 Complete System</td>
<td>$628.20</td>
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<tr>
<td>Level II-4K RAM</td>
<td>$889.20</td>
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<tr>
<td>TRS-80 Complete System</td>
<td>$269.10</td>
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<td>Level II-16K RAM</td>
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<td>Expansion Interface</td>
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<td>BASF 6106</td>
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<tr>
<td>Centronics 779 Printer</td>
<td>$995.00</td>
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<tr>
<td>Centronics 101 Printer</td>
<td>$445.00</td>
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<td>Anadex DP-8000 Printer</td>
<td>$975.00</td>
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St Louis Area Computer Club

The St Louis Area Computer Club meets at 7 PM on the first Thursday of the month at the Thornhill Branch of the St Louis County Library on Fee Fee Rd north of Olive Rd. The meetings are open to the public. Club dues are $5 which includes a newsletter. Contact SLACC, POB 28924, St Louis MO 63132.

Glitch Kickers Computer Club

The Glitch Kickers Computer Club has recently formed in Des Moines IA and is looking for new members. The club is open to anyone, whether you have a computer or are just interested in learning about computers. The club plans to work in several areas, among them education, writing software and starting a personal computer network. The club meets the first and third Saturday of each month at 2 PM. The meeting place is the Computer Emporium, 3711 Douglas, Des Moines IA. For further information, call (515) 279-8861.

Commodore PET 2001 User Group

PET User Group is an organization for people interested in the Commodore PET 2001 computer. Their purpose is to share and exchange applications, programs, and hardware expansion techniques; and to provide general user feedback. The first year membership is $5 and will include six issues of the PET User Notes. Write Gene Beals, POB 371, Montgomeryville PA 18936.

Delaware Club Develops Home Heater Control

Jodie Hobson, president of the Delaware Users of Microprocessor Systems, writes to tell us that his club is interested in both hardware and software and they are combining both in the development of a home heating control as a club project. The club meets the first Monday of each month at the University of Delaware. Contact Jodie at 318 B Chapel Av, Claymont DE 19703 or call (302) 792-2319.

New Mexico Computer Society

Dick Franzen, president of the NMCS (New Mexico Computer Society), has written to inform us of the existence of his club. NMCS promotes the understanding and use of computer technology in all areas of our society. They have a
diverse membership including high school and college students; housewives; electronic and computer technicians; and various professional and business people. Apple II users in the club, regardless of their level of understanding or expertise, is encouraged to attend one of the meetings. The club's interest groups include: TRS-80 basic programming, TRS-80 advanced programming, TRS-80 business applications, M6800, software, personal programmable calculators, and computer technology. NMC meets quarterly; however, each of the interest groups has its own meeting schedule which is published in their monthly newsletter, the Bit Stream. For more information, write or call Dick at POB 26544, Albuquerque NM 87125; (505) 292-1572. 

MicroComputer Investors Association

The January 1979 issue of The MicroComputer Investor, the Journal of the MicroComputer Investors Association, continues to reflect admirably upon the activities of the association. In this issue there are 18 articles within the journal’s 214 pages. Each article deals with utilizing microcomputers to make or manage investments. The association is professional and non-profit in nature. Dues are currently $30 per year. Membership in the association carries with it the requirement for each member to submit one article per year for publishing in the association's journal. Persons desiring to become members of the MicroComputer Investors Association should send a self-addressed stamped envelope to J Williams, 902 Anderson Dr, Fredericksburg VA 22401.

Caterpillar Computer Club

The members of the Caterpillar Computer Club are interested in home built as well as prepackaged systems to be used in home applications or civic interest applications. Some instrumentation is club owned and may be loaned out. They meet the first Thursday of each month at 7 PM in the Caterpillar Administration Building, 100 NE Adams, Peoria IL 61629. Contact Robert Miller, club president, 1539 Moss, Peoria IL 61606.

Publication for Apple II Owners

Apple Pugetsound Program Library Exchange (A.P.P.L.E.) is an association of approximately 400 members throughout the United States. Each month they publish a magazine called Call – A.P.P.L.E., which contains information on the Apple II’s capabilities, utility, programs and general tidbits of useful facts. Volume I has been compiled into a bound edition consisting of all the articles published in 1978. For further information about obtaining the magazine or Volume I, contact Call – A.P.P.L.E., 6708 39th Av SW, Seattle WA 98136.

Newsletter for Computer CT-1 Speech Synthesizer

Computer Consultants, manufacturers of the computer CT-1 speech synthesizer, have announced the first issue of The Word from Computer, a user newsletter. The Word is a 16 page newsletter designed to open up two way communication between Computer Consultants and users of the CT-1 speech synthesizer and other interested parties. It contains items of interest about CT-1 applications, new software, new hardware, software fixes, software written by users, technical manual updates, and more. The premier issue of The Word is free to all who write for a copy. Five issues will be included with the purchase of each CT-1 speech synthesizer. Additional copies of The Word will cost $0.10 each and may be obtained by writing to the company at 1730 21st St, Suite A, Santa Monica CA 90404.

Attention: Phoenix AZ Computer Users

A new computer club is forming in the metropolitan Phoenix area. For more information, call or write Marc Tessler, 3520 W Dunlap Av, #105, Phoenix AZ 85021, (602) 249-6224.

Attention: Long Island Computer Enthusiasts

Aileen Harrison, treasurer and secretary of the Long Island Computer Association, has written a newsletter that meets at 8 PM on the third Friday of the month at New York Institute of Technology, Route 25A, Old Westbury NY, building 500, room 508. One hour before the regular meeting the 6800 users group meets at the same location and every second Friday of the month the 8080 user group meets. The club is entering its fourth year and has approximately 140 members. The meetings consist of various programs such as "show and tell," tutorials, hardware lectures, language lectures, group discussions by members, computer manufacturer presentations, and presentations by computer stores describing the products they market. The dues are $10 per year and every paid member gets a free raffle chance each month on some "goody." Also paid members are entitled to borrow USCD Pascal disks and users manual on a monthly first come first serve basis. Members receive a copy of the monthly meeting notice. For more information, contact Aileen at 36 Irene Lane E, Plainview NY 11803.

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Write on your check or money order for the full amount due, including all sales tax, and send to: MicroGraphics Software Inc. 859 Merchandise Mart Plaza, Chicago, IL 60607.
Hey, how about some support for the 1802? It is no longer an obscure processor used by few of us. Many personal computers utilize this chip—the RCA VIP, Quest Super Elf, Netronics Elf II, many homebrew systems, and others. An 1802 recently went up in an OSCAR satellite! Much software is available to 1802 users, including debug and monitor routines, video games, Tiny BASIC, and general purpose programs available from the many 1802 based clubs.

Writing one’s own software is simple, due to the unique COSMAC architecture. The processor contains sixteen 16 bit general purpose registers that can be used to hold data and memory addresses to point to stacks, subroutines, etc. The program counter can be changed to any one of these under program control, facilitating the use of subroutines.

What about hardware? The 1802 is completely static and CMOS, resulting in very low power dissipation, an important consideration when designing battery operated systems. It is available in two voltage versions: 4 to 6 V and 4 to 12 V. There is also an on chip direct memory access controller that simplifies loading of programmable memory, since this can be done in hardware without the need for a bootstrap read only memory. Memory interface is simple and straightforward, because no bizarre data multiplexing is performed; sequential high and low order bytes of the memory address are strobed onto an 8 bit bus by two timing pulses. Once decoded, the address is used just as any other 16 bit address bus. Hardware single step is also easily implemented. I/O (input/output) is especially simple, due to three binary encoded output lines that can be controlled by the processor to select one of eight input and output devices directly. Also available are four flag lines that can be tested by the processor to determine a course of action. These features, coupled with the simple 93 instruction set and RCA support chips make software and hardware development painless (and sometimes even fun).

We avid 1802 fans are no longer a tiny minority, and would like some support from BYTE, a magazine that many of us subscribe to for the purpose of discovering the latest in the computer world. The 6800 and 8080A are good processors, but there are others on the market.

In addition, please go a little heavier on hardware. Also, I would like to see an article on the very basics (no pun intended!) of Pascal. I’ve read and reread the previous pieces, but I still can’t make heads nor tails out of a Pascal listing.

Other than these few gripes, I enjoy your magazine, and look forward to its arrival every month.

Ivan Dzombak
621 Spring St
Latrobe PA 15650

[Authors take note! Our articles come from our readers. Let’s see some more information on the 1802—RAC.

CANCELLER AND HAPPY?

Recently I took advantage of your offer to receive one free issue of BYTE by filling for a subscription and canceling after receiving the first issue. Although I did cancel the subscription upon receiving the first free issue, I do wish to compliment you on the quality of BYTE. I canceled not because I did not think BYTE is a good buy for the hobbyist, but because it made it clear to me just how big the hobby is! As an active amateur radio operator in the process of designing and building some new major pieces of hardware, I decided that I had better get more of that work out of the way before I delve into computers too deeply.

I expect to return to BYTE in about a year or so—a short time before I begin any extensive home computer experimentation. That first issue of BYTE has convinced me that it will provide the means for coming up to speed on the subject.
define the dividing line between expected use of published software and theft.

I'm polling editors and the major computing magazines, hoping they will help me define some of these issues. I'd appreciate getting your views on this thorny subject. Besides being editor of Dr Dobb's Journal, I'm getting a master's degree at Stanford in journalism—this quarter I'm taking a course in the law school entitled "Communications Law." I will be talking (and in fact, am already talking) with lawyers and legal scholars on this subject—frankly, they're more confused than anybody else. One consensus among the legal people I've talked to is this: the dividing line between expected use and theft is money.

When you publish software, what do you expect will happen to it? An interested computerist will adopt or adapt the program for his or her own use? A club will play around with it? Another magazine—nonprofit, for instance like mine—will reprint it? When do your hackers rise over use of software originally printed in a magazine? When does it become unfair?

What I want to do is gather comments from people like you and combine them with advice and facts from legal scholars. After which, I will write an article attempting to pull this data together and make sense of it. Hopefully, the article will be the first of many others in which people in the field will try to arrive at some working conclusions.

I look forward to hearing from you.

Suzanne Rodriguez
Dr Dobb's Journal
POB E
1263 El Camino Real
Menlo Park CA 94025

When we publish software, it is subject to copyright, the only meaningful form of protection. Just as we would expect someone to formally ask permission to reprint an article published in BYTE magazine, we would expect similar respect from anyone going beyond the bounds of fair use with respect to program copies taken from our products. In short, when we publish a program with copyright protection, whether as part of a book or as part of an article, we would expect anyone copying and distributing such a program to write requesting permission to do so. We are not averse to giving permissions with credit, and no publisher with a long-term view would, in my opinion, have a blanket policy against granting such permissions.

If anyone were to widely reproduce copies of our products without our permission, chances are we would find out about it, and we would not hesitate to examine the effects and our options in such a situation. There is a matter of our own concern, which can be compromised by indiscriminate reproduction of our products even if there is no monetary gain to be had by the person or persons engaging in such unauthorized reproduction.

As for software publishing, when we buy a program for reproduction in book form, or as a simple listing plus documentation (often accompanied by machine-readable code), we treat it in the same way as we treat the ideas of an author writing a conventional article or book. We are buying the embodiment of those ideas in a particular written or program form, not the ideas or concepts which constitute the program or work of writing. Because of the rampant confusion in the software area, our typical contract with authors of software explicitly states that we are buying an exclusive license to the software reproductions in book form, with the rights to license the software in other ways to manufacturers or media distributors retained by the author. The act of sale of the book or listing copy is then, in our view, totally analogous to the act of sale of such items as a photograph recording, a book about some subject, a video recording, or other relatively conventionally published work. This act of sale carries with it an implied zone of fair use reproduction possibilities, but is in no way a license to widespread reproduction whether it is done commercially or by some "nonprofit" entity.

Basicallly, there should be a software publishing analogue of the ASCAP or BMI organizations of the music world, but the field is too young at present. There are a number of questions to be answered as history unfolds in this field but, contrary to your letter's viewpoint, there are historical precedents which can certainly be examined and applied to the new concept of computer programs as works of authorship and original composition.

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IBM Emulation Information Needed

As an avid BYTE reader, I have, as a last resort, turned to you to request some assistance. I am looking for a software house that can supply the communications software for effecting IBM 3780 and Teletype emulation using a standard mini/micro system. There are a number of manufacturers (ADDS, Datapoint, SYCOR) who have such emulators available when one purchases or leases their equipment; however, I do not wish to be tied down to any one manufacturer. The software is proprietary and cannot be used on the standard systems. Can you supply any leads in this area?

George J Lehmann
Data Processing Consultant
163 S Sycamore Ave
Hollywood CA 90036

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Suzanne Rodriguez
Dr Dobb's Journal
POB E
1263 El Camino Real
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Basicallly, there should be a software publishing analogue of the ASCAP or BMI organizations of the music world, but the field is too young at present. There are a number of questions to be answered as history unfolds in this field but, contrary to your letter's viewpoint, there are historical precedents which can certainly be examined and applied to the new concept of computer programs as works of authorship and original composition.

---

IBM Emulation Information Needed

As an avid BYTE reader, I have, as a last resort, turned to you to request some assistance. I am looking for a software house that can supply the communications software for effecting IBM 3780 and Teletype emulation using a standard mini/micro system. There are a number of manufacturers (ADDS, Datapoint, SYCOR) who have such emulators available when one purchases or leases their equipment; however, I do not wish to be tied down to any one manufacturer. The software is proprietary and cannot be used on the standard systems. Can you supply any leads in this area?

George J Lehmann
Data Processing Consultant
163 S Sycamore Ave
Hollywood CA 90036

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THE SHAPE OF LIFE

I liked the articles on Life in the December 1978 BYTE.

An area of Life that I find particularly fascinating is the behavior of Life forms in universes other than the flat twodimensional universe. For example, in cylindrical or torus shaped universes it is possible for various kinds of stable "shock waves" to exist. These consist of complete loops around the universe and travel at the velocity of light, or twice as fast as a space ship. The simplest forms look like combs and can leave various kinds of debris behind or simply empty space. Another class of objects not found in the flat universes are "universal oscillators" that can exist in finite universes of the torus type and which engulf the entire universe.

To investigate these kinds of Life forms I wrote a program in COSMAC 1802 machine language that runs on the RCA VIP Computer. The geometry of the universe can be selected by the user. Speed is very desirable if you are trying to determine the fate of a particular pattern and I spent considerable effort to maximize the program speed. The program calculates about five generations per second for an almost full universe up to 25 generations per second for an almost empty one. The actual speed can be set to a lower value by the user and this is useful for examining a pattern in detail or for designing new patterns.

To make the program generally useful I added pattern storage and pattern editing features. Those users who are interested in obtaining copies of the program can write to ARESCO, POB 43, Audubon PA 19407.

Brian Astle
22 Fieldston Rd
Princeton NJ 08540

KUDOS

After reading so many complaints (and suffering from the same problem myself) about vendors of computer peripherals, I'd like to salute one of the "good guys" of the industry. We're always quick to condemn, but how many of us take the time to give praise when someone's worked hard to earn it???

I nominate for "The Good Guy of the Month Award" Warren Rosenkrantz, superstar of V R Data Corporation in Fairport PA. After dealing with several other rather questionable firms, I received a flyer from V R Data congratulating me on the purchase of my Radio Shack TRS-80 and listing several peripherals at very attractive prices. I investigated and, to make a long story short, began what I hope to be a long and rewarding business relationship.

Warren and his staff exhibited a willingness to help a fledgling computerist. They brought back that old, forgotten trait that makes good businessmen great--the customer comes first. Sure, like everyone else in this mad industry, we had problems such as printer modifications that didn't work and the disk drive that gave weird results. However, Mr Rosenkrantz spent considerable time and effort to correct these problems and, together, I think we both learned a lot. He's also very knowledgeable in the field of electronics and is quickly becoming a pro on the TRS-80. What do you expect from a guy who starts work at 5:30 AM and sometimes doesn't quit until after 10 PM? I reiterate that praise is something earned--and Warren Rosenkrantz of V R Data Corporation has certainly earned praise from this very satisfied customer.

Clifford W Coughlin
30 S Kirklyn Av
Upper Darby PA 19082

"THUS & SO" IMPLEMENTATION

In the December 1978 BYTE Carl Helmers, comparing BASIC to Pascal, made the point that:

In BASIC I would have to reference a procedure in the program with a number artificially created for that purpose. I might say GOSUB 10000, for example, when I really mean to call and execute a thus-and-so procedure.

Good point! Because of this lack of expressiveness in ordinary BASIC the Canon model BX-1 allows statements such as GOSUB "Thus&so". Elsewhere in the program the same alphanumeric literal appears as a label, identified as such by the keyword FLAG. Note that, due to using quotes, it is possible to use upper and lower case, special characters, spaces and even graphic characters. It is not necessary to begin with a letter or to avoid keywords of the language. The BX-1 does, however, limit the length of the label to eight characters.

GOTO may be used in the same way. Furthermore, the BX-1 executes statements such as ON A$ GOTO "YES", "NO", "MAYBE", "HELP!". If A$ matches any of the literal strings shown, then a branch to the location so labeled will occur. If there is no match, execution continues with the next statement. The statement form except with GOSUB is also in the BX-1 language.

As far as I am aware, the observation of Mr Helmers is correct for all other BASIC implementations.

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An Introduction to Microprogramming

Many computer users have not been exposed to the subject of microprogramming although it was introduced more than 25 years ago. With the advent of microprogrammed microprocessors, though, more and more people are gaining access to the world of microprogramming. The purpose of this article is to provide an introduction to the subject.

The word *microprogramming* was introduced in 1951 by M V Wilkes to describe a method of implementing the control circuits of a digital computer that differed from the conventional hardwired logic approach. The actions of a microprogrammed processor during the execution of an instruction are determined by a program in high speed memory called the control store. The data paths, memory units, and arithmetic and logic circuits of the processor are directly controlled by bits in a microinstruction held in the control store. Each machine instruction results in the execution of one or more microinstructions.

Conventional versus Microprogrammable Architectures

Figure 1 is a functional block diagram of a conventional bus structured computer. The memory unit is used to hold both data and machine instructions. The arithmetic and logic unit (ALU) performs arithmetic and logic functions such as addition, logical AND, etc. The input and output (IO) control unit communicates with the external world. Data is passed between memory and the arithmetic and logic unit by a bus system. The IO, arithmetic and logic unit, memory, and bus circuits are controlled by hardwired logic to generate the necessary signals to fetch, decode and execute machine instructions.

A microprogrammed architecture is presented in figure 2. This functional diagram is similar to figure 1 except for the control unit. The conventional control unit has been replaced with a programmable control unit. Each step of the machine level instruction fetch and each step of a machine instruction execution is controlled by a microinstruction. The microinstructions are held in the control store. The control store is a high-speed memory which is usually independent of main memory. The address control unit determines which microinstruction will be fetched and executed next. Several addressing methods are discussed later in this article. The microinstruction register (MIR) holds the current microinstruction being executed. The microinstruction in the register is decoded by the decode logic which generates signals to control IO, arithmetic and logic unit, memory and bus according to the actions specified in the microinstruction.

The decode and address control circuits of the microprogrammable architecture are
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much simpler than the control circuits used to implement the full instruction set of the conventional machine. However, the simplicity of the elementary hardwired microcontroller is partially offset by the addition of a new element: the control store. A significant part of the cost of a microprogrammed computer also lies in the set of microprograms which must be developed and debugged to simulate a full virtual machine instruction set. As a result, the costs of the two types of computer architecture are probably comparable.

The microprogrammable central processor is often referred to as the host machine because many different virtual machines can be superimposed on it by changing the control store. By implementing different microprograms in the control store the hardware seems to change from the viewpoint of the virtual machine software. For this reason, a microprogrammable computer is said to emulate the architecture of a particular virtual machine.

This emulation technique is a powerful tool. It enables the same basic hardware to implement the instruction sets of many different computers. For the homebrew computer builder who goes this route, a basic 8 bit microprogrammed machine acting as the host might be programmed to emulate any one of the existing 8 bit microprocessors. The same host machine might even be used to emulate an IBM 370 so that some widely available public domain software could be utilized. Potential microprogrammers should be warned, however, that creating the microprogram for such an emulation is not a trivial undertaking.

Microinstruction Formats

There are two microinstruction formats: horizontal and vertical. Most machines use a combination of these two. In a horizontal system, each bit in the microinstruction controls one data path or function in the machine. Figure 3 shows the input side of one bus in a hypothetical machine containing several registers. The A, B, MA, MD, PC, IR and I registers may be logically switched onto this bus, which might then route the data to one input of the arithmetic and logic unit.

Figure 4 shows a portion of a possible horizontal microinstruction format to control the data paths of figure 3. Seven bits are reserved in each microinstruction to indicate which, if any, registers are to be switched onto the bus. If all these bits are 0, no data is put on the bus and the bus carries a value of 0. If any of the seven bits of the current microinstruction is 1, the corresponding register is put on the bus. To avoid conflicts, only one bit position in the 7 bit bus field may be logical 1 at any given time. Depending on the electronics of the bus structure, switching more than one register onto the bus at the same time may damage the hardware or simply give unpredictable results.
A vertical microinstruction format groups similar functions into operation codes called micro-orders. A micro-order for the bus input of figure 3 is given in figure 5. Since only one binary code can exist in the 3 bit field, it is not possible to put more than one register on the bus at a time. The vertical microinstruction format is more compact than a corresponding horizontal format.

Each microinstruction typically contains bits to control all computer functions. In a microinstruction, the two inputs of the arithmetic and logic unit and the destination of the output would be specified. The main memory read and write functions are specified by microinstruction bits. Bits for testing register quantities are also provided along with bits to cause jumps and subroutine calls in the microprogram. "No operation" may be specified if a particular bus or function is not used for a microprogram step.

Control Store Addressing

The control store is much like a conventional memory. In cases of machines where user microprogramming is not allowed, a read only memory is used to contain the standard virtual machine instruction set. If the manufacturer supplies microinstructions to emulate more than one machine, or if user microprogramming is allowed, a programmable memory called a writable control store is used. If users are allowed to add instructions but not alter the basic instruction set, part of control store will be read only memory for the basic instruction set and part will be writable control store for additional instructions.

Homebrew computer people who choose to do microprogramming will most likely implement a writablecontrolstore and hardware to load it. Another alternative is to use inexpensive high-speed programmable read only memory to store microinstructions.

One control store addressing technique often used is to execute microinstructions in sequence. This technique is typically used with the vertical microprogramming format. A microinstruction counter, which is similar to a program counter or instruction counter in a virtual machine environment, is used to step through the microprogram. A microinstruction may contain a jump command which is indicated by a certain bit pattern in one of the micro-orders. With this technique the jump address is contained in the microinstruction in place of certain other micro-orders; thus, not all operations can be specified in a microinstruction that specifies a jump function.

Another addressing technique uses a field in each microinstruction to specify the address of the next microinstruction to be executed. Horizontal microcoding formats typically use this technique. This method requires additional bits in each microinstruction that the sequencing method does not need.

Executing Virtual Machine Instructions

Executing a virtual machine instruction typically begins with the microprogrammed instruction fetch. The instruction fetch is performed by a microprogram routine which sends the virtual machine program counter contents to a memory address register, cycles memory and puts the instruction which comes back from memory into the instruction register (IR). This instruction has a virtual machine op code which indicates which operation should be performed. To emulate the instruction, the proper microprogram in control store must be selected and executed. For example, if the op code 4 means ADD and the ADD microprogram begins in control store location 100, the next microinstruction fetched after loading the ADD instruction into the instruction register should be fetched from location 100.

One method of providing the proper mapping between op code and control store address is by an indirect jump through the instruction register op code field. When the op code indirect jump is specified (by a specific bit pattern in the current microinstruction), normal control store addressing is suspended and the op code gives the address of the next microinstruction to be fetched and executed. If a 4 bit op code is used, an op code indirect jump would cause the next microinstruction to be fetched from a control store location from 0 thru 15, depending on the op code value. The first 16 locations of the control store would contain jump instructions to the microprograms for each of the 16 op codes. If the ADD instruction is op code 4 and the ADD microprogram is at location 100, control store location 4 would contain a microinstruction specifying a jump to location 100 (see figure 6).

A second method for relating op codes to microprograms is the use of a read only memory mapper. A special read only memory contains the beginning address of microprograms which emulate each virtual machine instruction. When the mapper is invoked, the op code in the instruction register is used to address the read only memory which looks up the proper address of the microprogram to emulate the virtual machine instruction indicated by the op code (see figure 7).
This method is used in such machines as the HP 2100 minicomputer. A memory mapper is not flexible enough to be used in a computer where the virtual machine instruction set is altered dynamically. To change the virtual machine instruction set easily, a new mapper must be invoked. The read only memory mapper is most useful for manufacturers who supply a fixed set of microprograms that emulate only one virtual machine.

In both mapping techniques, a table of beginning addresses of microprograms is kept—one in control store and one in an independent read only memory. These tables are referred to as jump tables.

Hybrid Systems

Some of the flexibility of a microprogrammed processor is lost when certain functions are not controlled entirely by micro-instructions. For example, input/output on the HP 2100 minicomputer is handled in hardware and merely initiated and synchronized by microcode. As more control functions are performed in hardware and the ability to use different instruction formats is hampered, the number of different virtual machine instruction sets that can be easily emulated decreases. On the other hand, if certain control functions are handled by hardware and the machine level instruction format is relatively fixed, a virtual machine instruction set may be emulated efficiently.

The hybrid combination of microprogramming with some custom hardware is used in most general purpose computers. Functions which cannot be handled easily in microcode, such as isolating specific instruction register bits, are delegated to hardware. The flexibility of microcode is still available for instruction sets that take advantage of the hardware functions.

Advantages and Disadvantages

There are several advantages to a microprogrammable architecture. For computer designers, the choice of the virtual machine instruction set may be postponed longer than with a conventional architecture, allowing hardware and software design to overlap and influence each other. Instructions may be added after the computer has been designed, built and marketed. As examples of this, the HP 2100 minicomputer's floating point option is implemented entirely in microcode, and the DEC LSI-11 floating point feature is achieved by plugging in an extra control store read only memory.

It is also possible with a microprogrammed machine to market a line of computers with similar instruction sets even though the actual hardware of less expensive machines may be very different from the more complex models. The IBM 360 computer uses 32 bit words and 16 general purpose registers. Some of the smaller IBM 360s have less than 16 registers and 32 bit data paths but are

![Figure 6: Mapping an op code into a microprogram routine by means of a table of indirect jumps. Here the op code 4 picks the fifth jump in the table, causing the microprogram to execute the ADD routine.](image)

![Figure 7: Another way to map microroutines: the instruction register op code field is used to address a special read only memory that points to the proper microprogram routine. Here the example of figure 6 is illustrated using a read only memory mapper.](image)
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Microprogrammed to appear like full-sized 360s. Such microcoded versions are, of course, slower than the more expensive models.

Some manufacturers allow the user to add special instructions to their machine by use of microprogramming. Functions or portions of routines that are executed frequently in the user's system are good candidates for implementation in microcode. Microcode routines run faster than similar routines executed in main memory.

One disadvantage of allowing user microprogramming is the possibility of altering the standard instruction set. This could eliminate compatibility with other machines of the same model and decrease the reliability of the system's software. Since manufacturers sell both hardware and software, user microprogramming is usually not provided because of the compatibility factor. The design of microprogramming by the user seems presently limited to special applications and people who design their own computers from the ground up.

### Studying Microprogramming

Studying the microprogramming user's manual for one or more user microprogrammable machines will provide much information about microprogramming. Another source (although heavy reading) of information is a copy of IBM's patents on the system 360. If a microprogrammable machine is available, writing some simple microprograms will provide a lot of insight. If no microprogrammable machine is available, the microprogrammable architecture of a real or hypothetical machine can be simulated on a conventional machine. A simulator usually will not provide insight into the hardware timing problems that can be encountered on a real machine, but it can be used to try out microcoding ideas.

It is possible that a microprocessor system could be converted to support user microprogramming. The National IMP-16 and Raytheon RP-16 both use read only memory to control bit-sliced register and arithmetic and logic units. It is possible that a programmable read only memory or a writable control store could be substituted for the standard read only memory if timing problems could be overcome and if the control logic in the standard read only memory circuits can be simulated.

Another possibility is the use of a transistor-transistor logic (TTL) bipolar microcontroller integrated circuit. This chip is typically a 4 bit slice in some microprogrammed central processor's data paths. Putting four 4 bit microcontrollers together
with a control store and address control logic implements the central processor of a 16 bit computer. This technique is being used for the next generation of high performance minicomputers and is a plausible way for the homebrew computer designer to implement a microcoded machine.

Although this type of project would allow more people to work with microprogramming, it seems to be a sizable engineering problem. Is anyone interested?

Conclusion

Microprogramming offers something for both hardware and software proponents. The software fan can approach microprogramming from the programming viewpoint. Since the microprograms in control store must be efficient for the machine to run quickly, the design and programming of microcode is a challenging activity. Micro-assemblers and microcode editing and debugging programs should also appeal to the software person. The design and implementation of a microprogrammed machine should similarly interest the hardware enthusiast. A microprogrammable machine that resembles a new design may be used to test, at least partially, a new hardware design. Microprogramming should interest and challenge many computer experimenters.

REFERENCES


Editor’s Note: BYTE is looking for more articles on the subject of homebrew computers with microprogrammed instruction sets. This is one of the most advanced state of the art techniques in computer science, yet it should be possible for individuals and clubs to do significant work in this area. . . . CH
Daniel Chester  
Dept of Computer Sciences  
University of Texas at Austin  
Austin TX 78712

Editor's Note:  
Although prices have been significantly reduced since this article was written in 1976, the ideas presented are still quite valid. The learning experience involved with designing and building any type of interface is invaluable...RGAC

A digital display consists of a decimal point and seven line segments. If the decimal point and line segments are numbered as shown in figure 1, each display pattern represents eight bits of information. Only 21 of the 256 possible patterns are used by calculators. After a few hours of experimenting, I found, surprisingly, that most letters of the alphabet are included among the remaining 235 patterns. Although far from ideal, it is possible to display a large, recognizable character set on 7 segment digital readouts. The character set that I came up with is shown in table 1. One of the shortcomings of this set is that some letters are upper case and others are lower case. This inconvenience is unavoidable, except for a few letters like C, G, and U. Some letters, like K and X, are impossible to display others, like M, V and W, are just difficult. For these letters, and the other symbols in the character set, I chose patterns that are in some sense “close” to the desired
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Figure 2: Sample message written in 7 segment display code.

Figure 3: Block diagram of an alphanumeric display panel.

ones. Even with these imperfections, however, this display code is quite readable, as is shown by the sentences in figure 2.

A simple 8 character alphanumeric display panel can be made from eight single digit readouts and eight shift registers. Each shift register corresponds to a different line segment in the digital displays. All the bits in register 1 are connected in parallel to segment one in each of the readouts, and the other registers are connected in similar fashion to the other segments as shown in figure 3. When an 8 bit pattern is fed into the registers via their left shift inputs and the registers are shifted, the appropriate display character appears on the rightmost readout. As more characters are entered in this way, they progress, ticker tape fashion, across the display panel until they disappear at the left end of the display. To make this display panel compatible with other computers besides your own, you can use a 256 word by 8 bit read only memory to convert from ASCII code to the display code required by this panel. To extend the panel, just add more readouts and more shift registers so as to extend the original eight registers.

The most practical form of alphanumeric input is the ASCII encoded keyboard, but the digital display code makes possible a computer terminal the size of a pocket calculator. Alphabetical characters could be entered by drawing them with a stylus on a pattern of eight metal sensing areas arranged as shown in figure 1. A small number of digital readouts would display the output.
Call for Papers: Third International Conference on Computer Software and Applications

Papers are being solicited for the Third International Conference on Computer Software and Applications (COMPSAC 79). Sponsored by the IEEE Computer Society, COMPSAC 79 will bring together computer practitioners, users, and researchers to share their ideas, experiences, and requirements for applications software, management techniques, and software development support, including automated techniques. The conference will be held November 5 thru 8 at the Palmer House, Chicago IL. Some of the areas where papers are invited include: software development methodology, software management, database management systems, data communication and computer networking, computers and biomedicine, business office automation, industrial and design automation, application oriented languages, software testing and tools, and legal implication of electronic data processing technology. Papers should range in length between 1000 and 5000 words. The submission deadline is June 1, 1979. For additional information, contact Dr. William Smith, executive director, Toll Electronic Switching and Operator Services Division, Bell Laboratories, Naperville IL 60540.

Call for Papers: Twelfth Annual Microprogramming Workshop

The Twelfth Annual Microprogramming Workshop to be held November 18 thru 21, 1979 at the Hershey Motor Lodge Convention Center, Hershey PA will provide a forum for practical and theoretical aspects of firmware and related areas. Authors in industry and academia are encouraged to submit papers for formal presentation. Topics for consideration at the workshop include, but are not limited to: directly executable (intermediate) languages; language oriented architectures; emulation; microprogrammable host machines; on chip microprogramming; microprogramming experience; microprogramming languages; firmware development methodology; support tools for microprogramming; database support; operating systems and security kernel support; and signal processing. Formal sessions will be enhanced by informal discussions in a workshop atmosphere. Papers should be submitted in triplicate by June 1, 1979 to Richard A. Belgard, MICRO-12 program chairman, Data General Corp, 62 Alexander Dr, Research Triangle Park NC 27709.

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Label and File Program
Andrew A Carpenter
POB 841
Gordonsville VA 22942

I occasionally need to order a part that I cannot obtain at my local vendor. Thus, I wrote a parts order program for this purpose on my SwTPC computer. The program generates two letters and two address labels. I keep one letter for my file.

Lines 8 and 2100 erase the screen and place the cursor in the upper left hand portion of my CT-1024 terminal. The program starts off by asking if a vendor's name and address is needed. If not, the program jumps to the letter form at line 2100. The user keys in the information prompted by lines 2110 thru 2245. If only one line is needed for parts, a carriage return may be entered when prompted for the second part (lines 2220 thru 2245).

If an address is required, the user is prompted to enter the first letter in the manufacturer's name. The letter B will list lines 250 thru 278 on the PR-40 (Bell and Howell) printer. The command LIST #7 on lines 50 thru 110 lists the lines noted on the number 7 output device. In this case, the output device is the printer. Lines 200 thru 2000 are reserved for vendor's names and addresses. They may be changed to suit the user's requirements. Lines 50 thru 150 select the various sections of the address file.

Listing 1: Parts order program written for the SwTPC 6800 computer.

0008 PRINT CHR$(16); CHR$(22)
0010 PRINT "PARTS ORDER"
0012 INPUT "NEED AN ADDRESS (Y/N)?",8$
0015 IF 8$- "N" GOTO 2100
0020 PRINT "FILES ARE LISTED A-Z"
0030 INPUT "WHICH FILE ARE YOU SEARCHING FOR?",A$
0050 IF A$="A" LIST #7, 200,248
0055 IF A$="B" LIST #7, 250,278
0060 IF A$="C" LIST #7, 280,298
0065 IF A$="D" LIST #7, 300,318
0070 IF A$="E" LIST #7, 350,378
0075 IF A$="F" LIST #7, 450,498
0110 IF AS="M" LIST #7, 500,610
0155 PRINT #7, "TV SERVICE"
2170 INPUT "DATE'',ES 2510 PRINT #7, "---------------"
2190 INPUT "MFR" $ 
2210 INPUT "MODE ,L & EQUIP TYPE ",GS 2520 PRINT #7, AS+LS
2220 INPUT "QUAN & PART NO . ",1$ 2540 PRINT #7, C$+N$
2230 INPUT "PART DESCRIP",H$ 2550 PRINT #7, " ---------------"
2235 PRINT 2560 PRINT #7, "A.A . CARPENTER, TV 
2240 INPUT "QUAN & PART NO. " , OS SERVICE"
2245 INPUT "PART DESCRIP",P$ 2570 PRINT #7, "BOX 841"
2260 FOR I=1TO2 2580 PRINT #7, "GORDONSVILLE, VA.
2270 PRINT #7, "", " "
2280 PRINT #7, TAB(20); ""A.A. CARPENTER"
2290 PRINT #7, TAB(20); ""SERVICE"
2300 PRINT #7, TAB(20); ""GORDONSVILLE, VA."
2310 PRINT #7, 
2320 PRINT #7, TAB(20);E$ 
2330 PRINT #7, 
2340 PRINT #7, 
2350 PRINT #7, AS+LS 
2353 PRINT #7, B$+M$ 
2355 PRINT #7, C$+N$ 
2358 PRINT #7, 
2363 PRINT #7, "GENTLEMEN:" 
2365 PRINT #7, 
2370 PRINT #7, "PLEASE SEND C.O.D. THE 
2380 PRINT #7, "FOR A ".F$; " MODEL ".G$; 
2390 PRINT #7, 
2400 PRINT #7, I$; " ";H$ 
2405 PRINT #7, O$; " ";P$ 
2410 PRINT #7, 
2420 PRINT #7, "THANK YOU . 
2430 PRINT #7, 
2440 PRINT #7, TAB(20);"YOUR TRULY," 
2460 PRINT #7, 
2470 PRINT #7, 
2480 PRINT #7, TAB(20);"A.A. CARPENTER" 
2490 PRINT #7, 
2500 NEXT I 
2505 PRINT #7, " "
2510 PRINT #7, " "
2520 PRINT #7, AS+LS 
2530 PRINT #7, B$+M$ 
2540 PRINT #7, C$+N$ 
2550 PRINT #7, " "
2560 PRINT #7, "A.A. CARPENTER, TV 
2570 PRINT #7, "BOX 841"
2580 PRINT #7, "GORDONSVILLE, VA.
2590 PRINT #7, " "
2600 END

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Until I read Steve Ciarcia's article "Having a 'Private Affair' with your Computer" in April 1977 BYTE, page 18, I had not envisaged my 6800 or my 8080 as the basis of a timesharing system. Then I asked myself, "Why not? Why shouldn't a microprocessor be capable of supporting a timesharing system?" I subsequently had the opportunity at the ONLINE conference held in London England on May 14 1977 to see Robert Uiterwyk's 6800 based multi-user system. This prompted me to search back through the literature (especially that of the time when timesharing systems were first being introduced) to check on the problems their designers encountered and their solutions. This article is the outcome. It does not set out to specify in detail how a timesharing system can be established, but it does deal with the main problems involved. Perhaps it will provide a starting point for readers' systems development.

Requirements

Timesharing has been defined in many different ways. For our purpose it will be taken to mean the concurrent, effective utilization of computer resources by several users, possibly at remote terminals. It will imply multiprogramming, possibly multiprocessing; in general, multiple access to system resources.

The key requirement in any multiprogramming or timesharing system is that programs and data should not be bound, that is, converted into hardware dependent form, until the moment of execution. This requirement has many implications and may involve many problems, some of which have been solved in different ways with varying degrees of success. This article examines what is perhaps the main problem: relocating programs and data in a multiprogramming environment. The related problems of scheduling and priority systems, memory addressing algorithms and resource allocation are also discussed briefly.

The Problem

A timesharing system should be designed to execute user programs in such a way as to provide reasonable service and to satisfy each user's requirements. This means that each user should believe that he has all the benefits of a dedicated computer. It is the basic philosophy of timesharing and leads directly to the concept of virtual machines linked to physical computer resources through address mapping tables.

Typically, individual user programs are allowed exclusive use of the computer resources in some order of priority for short periods. They are stopped after a certain time, frequently before completion, to allow other user programs to be given their exclusive use of resources. They are continued at some future time from the point where they were stopped, in either the same memory area or a memory area different from the one they were allocated when first allowed to run.

To be able to continue a program in this way, the system must have facilities to preserve the status of a program when it is
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stopped and to restore it when it is resumed. That is to say, at the point in time when one user's program is stopped and another user's program is resumed, the instantaneous description of the former program must be saved and the description of the latter restored. These instantaneous descriptions are typically referred to as the current "state" of the user program. The state of a program typically contains such information as the contents of the accumulators, program counter, and condition code register. The state word might also contain pointers to the address mapping tables which determine the correspondence between virtual and physical addresses.

To explain this process in more detail, it is necessary to examine the factors which make multiprogramming possible and to study a typical system in operation.

### Multiprogramming Requirements

Technically, there are a number of considerations which decide whether it is possible to run programs together. In the book *Computer Timesharing* (see references), Popell specifies a minimum of five:

- A supervisory program referred to as executive, monitor, or supervisor.
- An interrupt processing system.
- Memory protection facilities to prevent one program from destroying others.
- Dynamic program and data relocatability so that the same routine can be reentrant. That is, the routine can be used, unmodified, in different memory locations at different times.
- Direct access facilities, or at least the facility for the convenient addressing of peripheral equipment. (For personal computers the floppy disk is the typical example of a direct access device.)

Typically, user programs to be run are stored in auxiliary memory, usually disk, readily accessible so that the supervisory program can switch them into main memory when their times to operate arrive. Each program is allocated the required area in main memory and that area is protected by either hardware or software, from interference by other programs. Any instruction attempting to address an area outside the allocated memory block is trapped and prompts an error message.

A system of priorities is usually implemented. The supervisory program permits the execution of the program with the highest priority until such time as it is suspended for some reason. Priorities are usually determined by a scheduling algorithm which is used by the supervisory program to keep a record of the status of each user program. Table 1 lists all the possible states of a program at a particular point in time.

If, by bringing a program into its area in main memory, there is a storage conflict, the program with the lower priority status must be restored to its place in auxiliary memory. This process is variously called swapping, switching, push-pull or roll out-roll in.

The most common cause of program suspension is a peripheral operation such as I/O. But there are others such as a machine or program error or the lowering of priorities. Until suspended, however, user programs run for periods of time determined by the scheduling algorithm. At the end of each program's appropriate time slice (or when it changes status) the supervisory program determines which user program is to be run next. The state of the program which is to be suspended (contents of accumulators, index registers, condition code register, etc) will then be saved either in a supervisor's stack or dumped to auxiliary memory.

The supervisory program then retrieves the next user program from auxiliary storage, together with that program's old state. It loads this program into main memory, processes it, restores it, proceeds to the next user program and so on, until it returns to the first user program to give it a second burst of processing (if required). Then it continues the cycle. It can be seen that the quintessential function of the supervisory program in a timesharing system is scheduling.

### Scheduling

On early machines, programs were assembled into the part or parts of main memory they were to occupy during run time in much the same way as they are on microcomputers today. If a large program required too much memory, it was necessary to assemble the program in sections, transferring each section as it was completed to auxiliary storage and restoring it (if nec-
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The effect of these routines is to provide multiprogramming facilities which enable
many users to initiate programs and to schedule them through the system according to their relative predetermined priorities.

The simplest system is based on a circular queue for "round robin" scheduling. Each program accepted into the system is assigned a fixed time slice and processor operation is switched from one program to another in round robin fashion until each program is completed. In this arrangement, only one active user program is in main memory at one time. Other active programs are held on disk.

In other systems several user programs may reside in main memory simultaneously. The operational switching between them is controlled by a clock which is used to generate an interrupt to signal the processor that a certain time period has elapsed. The scheduling algorithm is then entered every time a clock interrupt occurs. If it is found that the program in main memory has exhausted its time slice or has changed its status, that program is swapped for the next program in the queue.

Most sophisticated installations of any size find the need to operate a system of queues. The appropriate queue to be serviced by the processor at any particular time will be selected according to priority and program type by the scheduling algorithm. Programs are initiated, or released for processing by being selected from the tops of the various queues which are formed in accordance with the particular installation's design philosophy. In addition to systems of queues, the supervisory program normally has to deal with systems of priorities. Again, what determines these priorities will be a matter of design philosophy. Various criteria are used in practice. Usually it is possible for the system itself to cause priorities to be modified while programs are being queued. Such modifications are especially desirable in real time systems because one program might be continually bypassed; or because a deadline is approaching and the program concerned is not being serviced.

From time to time it may be that a program being queued will have to take precedence over a program being serviced. Downgrading of priorities happens often in scheduling systems. To facilitate this, some operating systems provide a roll in-roll out facility which enables the supervisory program to make a request for processing time on behalf of a higher priority program in the queue. This will result in a lower priority program being rolled out to enable the new program to be processed. Programs rolled out in this way are written into temporary storage along with their current status. When changing circumstances permit the reloading of the program in memory it is swapped back into the active queue.
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of programs temporarily suspended, the supervisory program will automatically roll in these programs and they will restart from where they left off.

It may be that the exact locations in memory which such programs and their data were using are no longer available. To deal with this situation, operating systems provide the facility to relocate programs dynamically.

Scheduling Methods

To summarize the discussion so far, there are basically two methods of scheduling:
- Simple swapping systems with only one program at a time residing in main memory for a fixed unit of time in accordance with a system of priorities.
- Elaborate systems which overcome the disadvantage of only one user program in main memory at a time with consequent waste of time due to switching.

This necessity of switching programs into and out of main memory at speeds approaching the internal clock rate leads to further problems which can only be solved with additional hardware and software facilities. In particular, since a given user program does not always get loaded into the same place in memory it leads to addressing problems.

Addressing Techniques

In most systems, individual programmers will have to write their programs without knowing which other programs, if any, will share main memory with theirs. The implication must be that they will need to use symbolic addresses that will be converted to absolute addresses at some time by the supervisory program when allocating memory space and peripherals to the various programs. This necessity has led to the present timesharing philosophy which requires the conceptual separation of absolute storage addresses from the logical system addresses.

In a multiprogramming system, resources are not normally allocated to programs until execution time. Since the physical resources allocated may be different during each time slice, it is essential that the run time representation of programs should be in hardware independent form. This means that the addresses in particular should be virtual addresses. Physical addresses will be represented by an address mapping table which will be updated whenever programs are moved from main memory to temporary storage and vice versa.

As Wegner points out, the structure of the address mapping table will depend not
only on the relation between the virtual address space and the physical address space, but also upon the hardware facilities available for performing address mapping. For example, in “Addressing Structures” (see references) Gammage recalls that the need for dynamic program relocation was met on second generation machines by the provision of a single base register, the contents of which were added to a virtual address generated within the program to map it into an actual main storage address.

The major drawback here was that the program had to be moved between main storage and temporary storage as a single unit (a wasteful process where large programs are involved). It also meant that no program could be larger than the available main memory space.

To overcome these problems, more elaborate addressing structures were devised. These structures reflected the hierarchical organization of problem oriented programs and the need in real time systems to provide for the organization of sets of independent, multiprogrammed jobs. To give the facility of dynamic program relocation, for example, some machines were fitted with special hardware. IBM built upon the addressing system of the IBM 360, which allowed only two levels of addressing, and provided a third level. They did this by providing two sets of additional base registers, one set to act in the same way as the base registers of the IBM 360 (being accessible to the programmer). The other set, sometimes known as segment registers, accessible only to the supervisory program, are used in allocating storage.

Gammage outlines three such schemes, but suggests that because these schemes use variable length segments as the basic unit for storage swapping, they are very inefficient in terms of storage utilization. Their inefficiencies cannot be overcome completely unless a full paging system is employed, using fixed length units for swapping.

Paging

Most modern machines provide some kind of virtual memory structure if they are to be used for multiprogramming. This addressing space may be provided by hardware or created interpretively by software. Most modern systems also interpose an address mapping structure between virtual and physical addresses.

Typically, the virtual address of a word in memory consists of two parts. The first refers to a page number (a fixed size block of main memory). The second refers to a location within the block. In operation, secondary memory is connected to these
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Dynamic Relocation

Let us spell out the need for dynamic relocation in a timesharing system. In general, a program consists of instructions and data, blocks through high speed I/O devices that permit programs to be swapped directly from disk into any one of the main memory blocks without interfering with processor operation. This process is known as direct memory access and allows execution of one user program in one block of memory while programs are being swapped to and from another block.

Main memory is similarly divided into physical pages, each capable of handling one page of a program or block of data. Program pages, although the same size as main memory pages, will not necessarily be contiguous in main memory and may well occupy different main memory pages at different times. One of the functions of the supervisory program in a paging environment is to form and keep up to date a page table which establishes a mapping of the program and data pages into physical pages. By this means, the address of a page within a program is transformed via the page table into an absolute memory location.

In practice, to achieve dynamic relocation, it is necessary to extend the instruction address to include a segment number as well as a page and location number and to leave the binding of address parameters until run time. The segment number is then used to access a segment table belonging to the user whose program is running at that instant. The reference in the segment table is to the page table which in turn maps onto the physical page and through this to the physical address.

This scheme can be very clumsy and take too long, unless the machine is fitted with additional registers which permit the development of an associative memory. The associative memory combines the segment and page numbers, so that only one interrogation is required to find the number of the physical page containing the appropriate address. Systems in which page registers are designed to be accessed associatively operate various page turning algorithms which determine:

- Whether certain pages are in memory,
- Whether pages are to be preserved or overlaid,
- How recently pages have been used so that, if need be, they can be disposed of when new pages are brought into memory.

These systems are the basis of the virtual memory concept which in turn provides the means for dynamic relocation.
While being executed it will contain references to intermediate results. These will need to be mapped or translated into references to specific parts of the machine (machine addresses, device numbers, etc.). This can be accomplished at three different times:

- During compilation, assembly, or translation into machine code. The result is an absolute program which will be assigned to the same memory locations and use the same peripherals each time it is run, assuming they are available. (This is the most common scheme for user programs in typical personal computers.)
- When the program is loaded. Most machines have a relocating loader which enables programs to be re-located statically.
- During execution, using dynamic relocation.

In multiprogramming it is difficult, if not impossible, to allocate memory concurrently to two or more independently written programs if they are absolute programs. The allocation method requires that the particular combination of programs to be run at any one time and their storage requirements are known in advance. This is information that is not always available when the programs are written.

If the absolute addresses are left untranslated by the assembler or compiler and translated by a relocating loader into actual addresses only when the program is loaded for execution, the particular combination of programs to be loaded together can be decided just prior to loading. This method is known as static relocation. Using static relocation it is possible, with a relocating loader, to allocate memory to a program each time it is executed, provided:

- The program can be separated into a data part and a procedure part.
- The procedure part is never modified during execution.
- The data part, including the contents of registers at the time of interrupt, contains no absolute memory addresses.
- When the program is interrupted, the data part is dumped onto auxiliary storage.

These four conditions are not difficult to achieve. Nevertheless, the relocation of an interrupted program by this method has a number of significant drawbacks, which are summarized by Denning in his article "Virtual Memory" (see references).

In dynamic relocation, the translation of virtual addresses to main memory addresses ...
is delayed until the last possible moment (until access to memory is required in running the program). Because the program contains no absolute addresses, it is independent of the actual memory allocation it receives. This means that it can be interrupted at any time and subsequently reloaded into a different part of memory without modification. This desirable facility can only be achieved at the expense of additional hardware and more complex instruction formats. This is desirable since instructions in general must now hold untranslated addresses in a form appropriate to the relocation technique adopted.

There is also the related problem of storage protection (the need to prevent user programs from interfering with each other while being processed). The usual solution to this problem is to allow them to operate in well defined areas of memory only (unrestricted access to all parts of memory being reserved for the supervisory program only). Frequently the technique used to achieve dynamic relocation can also be used to effect storage protection.

Conclusion

Many programs running concurrently in a multiprogramming environment typically require far larger total memory space than is available in a particular system. The virtual memory concept and dynamic relocation techniques outlined here have solved many of the problems of managing and optimizing the use of large, hierarchical memories. These techniques are often seen in large computer systems and can be adapted (in principle) for use in microcomputer timesharing systems.

REFERENCES

## BUSINESS APPLICATION SOFTWARE

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A Binary Guessing Game

Calculator Pattern Recognition

Humans and animals do not as a rule behave at random: instinct and past experience play too important a role. In the computer, a good pseudorandom string of digits isn't hard to produce, but to get genuinely unpredictable output is tremendously difficult.

This article introduces pattern recognition and gives a sample program that recognizes patterns with better than random accuracy. The program is in game format to add to the fun, but it can be easily adapted to other purposes.

We will look only at binary patterns (ie: sequences of Os and 1s). This is not a limitation, since any string of symbols can be encoded into a corresponding binary sequence using a suitable conversion code such as ASCII, and, of course, neurons and flip flops are binary devices. (One could encode the text of this article up to this point in binary, and attempt to predict the rest of what we are going to say; if you want to try, good luck!)

Consider the string:

\[ 1010110 \]

What is the next digit?

There is no correct answer, and in fact, there is no "best" answer. A lot depends on what kind of system generated the string. \[ \text{Recent mathematical work has shown that, in general, there can be no "best" element following a given string of elements; that indeed any element can be shown to be the correct successor to any given string... CM.} \]

If the string were generated by an algorithm with almost no "memory" of the immediate past, but with a possible bias toward 0 or 1 (such as a roulette wheel), a good strategy would be to note the majority of 1s appearing and to bet on 1 in the future, regardless of what the last digit was. On the other hand, a human producing a pattern may tend to repeat sequences made in the past, even if an attempt is made to avoid them.

It is useful to define the term "depth" at this point to mean the longest recent sequence of digits that a program will consider. The basic pattern recognition algorithm we have developed simply looks at the last few digits in a string, checks to see what choice followed that sequence previously, and guesses that the same choice will follow this time.

As a specific example, consider the above binary string. A depth 0 algorithm does not look back at all; it has no memory. It simply guesses that the next digit will be the same as the present one (a 1 in the previous example). A depth 1 program checks back to the previous time that a 1 occurred (the sixth digit in our example), and, since it is followed by a 0, makes the prediction 0. A depth 2 routine searches for the previous occurrence of 01, and a depth 3 for 101.

The program listed in this article performs the procedure described above precisely, to depth 3. (Special circumstances which require further processing are discussed below.) All this is not difficult when you have plenty of program and memory space. Implementing it on the HP-25 calculator requires considerable economization, though. If readers with calculators have need of "bit packing and manipulation" it would be worth their while to spend a few hours puzzling out the logic involved, but for applications and gaming, this isn't necessary.

Now that you know the algorithm, it is possible to defeat it in a competition by taking advantage of its weakness (an over-reliance on past patterns). For a simple depth N program, it is possible to generate a pattern of length \(2^{N+1}\) that varies in such a fashion that the program is constantly one step behind and never gets a right answer. A depth 0 routine, which just guesses that the most recent digit will be repeated again, is fooled by the simple string 1010101010... A depth 1 program will fail when it meets 1100110011001100... that is, the pattern 1100 repeated continuously. A pattern that will defeat depth 2 is 11101000. This combination is not unique,
but once such a pattern is found and used, the program will always guess incorrectly. We won't mention a pattern to defeat our depth 3 program, but one can be found fairly easily now that you know how it works.

The program is about evenly matched with human opponents. It is very difficult for a human to win decisively (i.e., to get more than 15 points ahead) without analyzing the logic of the program. Don't spoil your friends' fun: let them play without first explaining how it works.

Unfortunately we seem to have spoiled the fun by explaining most of the game's logic in this article. If the reader will change step 9 to "4," and step 44 to "7," the program will acquire new evasive tactics: it is now designed to outthink the readers of this article! It will also recognize much longer patterns, although it takes a bit longer to learn them. Readers can still foil the program in this mode, but the task is considerably more difficult.

Several questions of interest remain unanswered. First, what is the optimum depth for a machine to look when attempting to outguess a human? How much does it depend on who is playing? (Do 6 year olds tend to generate simpler patterns than adults?) Are there other algorithms better equipped to tackle human opponents? Are deeper or more complex programs also more interesting? What about a base 3 number guessing game such as "rock paper scissors," or a more intriguing video display? What is it that makes artificial intelligence (AI) programs so interesting in general? Psychologists and software experimenters might consider working on some of these problems.

Implementation on Other Systems

Our program should be convertible for use on most programmable calculators with conditional branching and several memory registers. It will not work without extensive revision on some microcomputers because it requires at least 8 digit accuracy.

Watch the $10^x$ function; it must be absolutely, not approximately, accurate for integers in the range between $x = +4$ and $x = -4$. If it is not, write a routine to correct it.

Some calculators like the SR-52 do not have the required INT and FRAC functions, but these functions can be easily programmed.

Note that there is an implicit "GO TO 00, R/S" at the end of the program, since this is what the calculator does when it runs past step 49.

### Instructions for Running the Binary Guessing Game

<table>
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<th>Comments</th>
<th>Data</th>
<th>Keys</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Key in program.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Set display digits.</td>
<td></td>
<td>FIX 0</td>
</tr>
<tr>
<td>3</td>
<td>Initialize</td>
<td></td>
<td>PRGM</td>
</tr>
<tr>
<td>4</td>
<td>Key in values.</td>
<td>10</td>
<td>STO 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11.1001</td>
<td>STO 4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>STO 7</td>
</tr>
<tr>
<td>5</td>
<td>Clear stack.</td>
<td></td>
<td>STK</td>
</tr>
<tr>
<td>6</td>
<td>Start program.</td>
<td></td>
<td>R/S</td>
</tr>
<tr>
<td>7</td>
<td>Program stops with score displayed, for opponent's guess. Enter 1 or 0.</td>
<td>1 or 0</td>
<td>R/S</td>
</tr>
<tr>
<td>8</td>
<td>HP 25 displays its guess, then the cumulative score: + for opponent, - for HP-25.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Go to step 7.</td>
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Notes: The advanced program described in the article also uses the above instructions. If you convert back to the regular version after running the advanced version, the contents of several memory registers will cause problems. To avoid this, start over at step 3 above. After changing the two steps necessary for the advanced program, remember to return to 00 to run the program. The advanced program will guess 0 for several times until it learns your style. To avoid this, try 123.0123 STO 4.
Languages Forum is a feature which is intended as an interactive dialog about the design and implementation of languages for personal computing. Statements and opinions submitted to this forum can be on any subject relevant to its purpose of fostering discussion and communication among BYTE readers on the subject of languages. We ask that all correspondents supply their full names and addresses to be printed with their commentaries.

Languages Forum

Note: We received the following letter detailing several possible changes to the BASIC language. Readers might try implementing them on their own systems if they do not already have these instructions available... RGAC.

Amended BASIC

Robert Paul Bass II
4827 N 63 Ln
Phoenix AZ 85033

Having been an avid programmer for many years, I've seen many ways for "Mr Murphy" to add some of his handiwork to programs. In order to accommodate some of the beginning programmers, I felt that a new version of BASIC that incorporated some of Mr Murphy's ideas would be appropriate to help explain away some of those mistakes that we all make at some time or another. Here I present some of the new statements and functions that I would like to see in this new version of BASIC.

Assignment

10 LET A ≠ 4*G
   Set A to any value not equal to the expression.

20 LET B ≈ 19/T
   Set B approximately equal to the expression.

These are also handy for generating data to test routines that need data close to a particular value, or if any value but one can be used in a program.

IF-MAYBE

100 IF G = 17.4 MAYBE 210

Advanced implementations of this statement could have nested conditions, ie:

110 IF G ≠ A*2 MAYBE 210
   THEN AGAIN 300
   OR PERHAPS 405

Modified FOR - NEXT

200 FOR N = 0 TO ABOUT 100
   •
   •
   •
   300 NEXT N

This statement is used when one isn't absolutely sure how many times to execute a loop.

MISPRINT and MISREAD

320 MISREAD A$
330 MISPRINT B,$

These are the standard input/output (IO) statements, except that they have a built-in glitch generator to produce those inexplicable characters that appear in everybody's output. Caution must be exercised when both of these statements are used in one program because it is possible that the errors could cancel out.

COMEFROM

350 COMEFROM 100

This is great for debugging programs as it allows the programmer to trace back where he should have been going.

FUZZ Function

400 FUZZ = 39

This function tells the actual monitor program that executes the BASIC program how picky it will be regarding errors. If FUZZ=0, the program will execute correctly regardless of how many errors there are in the program. If FUZZ=99, the entire system will crash on the smallest logical or even syntactical error.

FORGET

440 FORGET 450-560

This would be used to indicate which statements should be ignored.

DIMENSIONLESS

10 DIMENSIONLESS A,B,C,D,E,F,G,H,I,J,K,L....

This was designed for the theoretical mathematicians working on problems involving points, those zero dimensioned beasts. Systems using this statement should have plenty of memory, since an infinite number of DIMENSIONLESS statements are allowed (and usually needed) so that the programmer can define lines, planes and spaces.

BLINK

500 BLINK 10

This is used primarily in demonstration
programs where a visitor can see the front panel lights of the computer. When executing this statement, the lights will blink in a fashion guaranteed to impress anyone who doesn’t know too much about computers. With appropriate interfaces, this could be used with your Christmas tree lights next winter.

GLITCH

530 GLITCH

This is the most invaluable statement that the up and coming programmer can use. It will randomly choose a location in memory or in the internal registers and will change one bit of that word.

SLOWDOWN

650 SLOWDOWN

Pascal versus BASIC: Round 2 Includes FORTRAN

Lawrence C Andrews
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Baltimore MD 21234

The article “Pascal versus BASIC: An Exercise,” by Allan M Schwartz (August 1978 BYTE, page 168) is a typical example of a language chauvinist using a language ineptly and then pointing to the faults in the code he has written as inherent properties of the language.

The function GCD (page 172) that he has written (leaving aside the BASIC version) has several faults, to wit:

1) X and Y are not declared in the Pascal version.
2) The FORTRAN version will develop an infinite loop if X or Y equals zero (no comment there excludes X, Y greater than zero).
3) The FORTRAN version never defines the functional value of GCD and so will not even compile in a good compiler.
4) There sure are a lot of GOTOs and statement numbers in his program; in particular, statement 180 is totally useless. GOTO 180 should be GOTO 120.
5) There is no reason to have any GOTOs. It could be written as in listing 1.
6) If you don’t mind downward branching GOTOs (generally considered to be harmless) function GCD can be written as shown in listing 2.

As in Pascal the flow is clear and flowcharting is simple (Warnier-Orr diagrams are still better). I don’t run down Pascal but I fail to see why Schwartz runs down FORTRAN just because he writes a pidgin dialect ineptly. In FORTRAN, as in Pascal, “Go to statements can fog the otherwise clear logic of a routine,” as Schwartz states in his article. FORTRAN 77 with IF . . . THEN . . . ELSE statements, and zero trip counts on DO loops, removes most of Schwartz’s FORTRAN objection. Anyone can write a bad program in any language. Pascal is no exception to that statement.

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Listing 1: The GCD function written in FORTRAN with no GOTO statements.

```
INTEGER FUNCTION GCD (X,Y)
    INTEGER X,Y, A, B, LIM
    C. . . X,Y .GT. 0
    A = X
    B = Y
    LIM = MAXO (A,P)
    DO 1000 I = 1, LIM
    IF (A .GT. B) A = A- B
    IF (B .GT. A) B = B- A
    GCD = A
    IF (A .EQ. B) RETURN
    1000 CONTINUE
    RETURN
```

Listing 2: A much shorter version of the GCD function using one downward branching GOTO statement.

```
DO 1000 I = 1, LIM
IF (A .GT. B) A = A- B
IF (B .GT. A) B = B- A
GCD = A
IF (A .EQ. B) GO TO 2000
1000 CONTINUE
2000 GCD = A
RETURN
END
```

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Note on an Easy Programming System

Mike Brown
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I have just completed reading Joseph Weisbecker's article "An Easy Programming System" (December 1978 BYTE, page 108). I was quite favorably impressed—with one minor exception. The random number facility does not seem to be very good, but could be improved with one minor modification. Regardless of what pseudorandom number generator is used, the idea is to provide a sample from a uniform distribution in the range of [0..KK]. The technique of simply using a mask is clearly not satisfactory. If, for example, KK = 02, the range of pseudorandom numbers is [0..2]. However, by using the mask, the possible numbers obtained are 0 and 2. It is not possible to get a 1.

There are several ways around this problem. The simplest is the rejection method in which new pseudorandom numbers are generated until one is found to be small enough. Since most pseudorandom number generation routines I have seen are fairly quick, this method would probably be satisfactory as long as KK is reasonably large.

My suggestion is a refinement of the rejection method, which will work fairly well even as KK gets small:

- Determine high order 1 bit position in KK (p). Form mask with bits 7 thru (p+1) off and bits p thru 0 on (m).
- Generate pseudorandom number in range of [0..255] (r).
- r² = r x m.
- If r² > KK, go to second step. Otherwise r is the required pseudorandom number.

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Peter D. Robertson
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After scanning your August 1978 BYTE, some amusing images came to mind. One was a landscape wherein 10,000 programmers sat in front of their terminals, each one saying, "Gee, if I only had Pascal, I could do this a lot easier than in lousy old BASIC. I really need Pascal." Another image was of Niklaus himself, saying, "Isn't it amazing how many fools there are who ignored Euler, but are wholeheartedly supporting Pascal?" Yet neither language has any real input/output (I/O) or was meant for any real machine. Euler was, after all, the more serious effort. Pascal is only a teaching toy.

This is how I see the programming language controversy in the world of personal computing. First of all, Pascal belongs to a class of highly structured, strongly typed languages. This means that it is hard to use. All variables must be explicitly typed, and control structures must follow a rigid syntax, or else the program is garbage. For well-documented, widely distributed programs, this is "good programming practice." For personal computing, this is useless. Secondly, Pascal is difficult to learn. I spent six months studying Pascal intensively, but even so, there are a number of subtleties and nuances of the language which escape me today. Yet it took only two weeks to master BASIC. Thirdly, Pascal was not meant to be debugged. Pascal is so good that every program you write is supposed to be correct. You just type it in, compile it, run it and move on to the next program. If it doesn't work, then hopefully your computer has PDB, the Pascal debugger program, to help you sort things out. Whereas in BASIC, every statement is (or should be) checked for errors when it is entered, not when it is interpreted. For run time errors, most BASICS allow you to print the values of variables and execute statements selectively, changing them as needed, rather than having to recompile every time.

In short, I don't see how Pascal can ever extinguish BASIC as the language of choice for personal computing. For industrial systems programming, sure, but not for personal applications. Pascal is, after all, only a

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programming language, whereas BASIC is an entire programming system. If you want to write something neat and elegant, use Pascal, but expect to spend a lot of time on it. If you want to get the job done, however, maybe BASIC isn’t so bad.

How To Define an OS Which Does Not Need a Wizard

James E Jones
123 NE 2nd
Moore OK 73160

I have noted a trend towards microcomputer operating systems which allow programs to be written without worrying about peculiar device interfaces. Nothing could please me more. IO and interrupt programming are the worst part of the transfer from large to micro. There is one disaster that must be avoided, though: the user’s interface with it, when it comes, will resemble OS/360 or 370 "JCL" (Job Control Language).

Other than the DD statement, JCL mainly presents tolerable nuisances. Indeed, it once made a perverse sort of sense. JCL is 360 macroassembler with a "///" at the beginning of each statement, and in the times when everybody used assembler and had to know the sordid details of the DCB, it was actually convenient. But in my experience, most people use high level languages now. (I’m from an academic background and probably biased. For purposes of argument, I’ll even admit that FORTRAN and COBOL are high level languages.) These people, who enjoy the advantages of such languages when programming, are saddled with large amounts of machine dependent trivia when JCL time comes. Maybe it’s not like having to write your own CCWs, but the user must still be concerned with many device peculiarities. (Don’t tell me that’s what procedures are for. Users must always fill in anything not foreseen by the procedure writer, who can’t have much foresight in such cases.) Processes that are easy to think in terms of become cumbersome to write or maybe impossible.

The worst part is that in the name of upward compatibility, the user is forever stuck with it.

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**Editorial Note:** Buried within this letter are numerous references to acronyms which every OS/370 Job Control Language (JCL) hacker must deal with in everyday life. Being lazy, and rationalizing on the grounds of not perpetuating the mistakes we leave the text as is, filled with references to JCL, DD statements, CCWs, DCBs, and all the other incantations of the wizards of OS...CH/
A Fix for the Dazzler

The New Jersey Institute of Technology purchased a Cromemco Dazzler as a kit which was constructed by a student during the summer of 1977. Plugging the unit into our S-100 bus computer system, we found that it produced pretty pictures on a video monitor. But an unfortunate side effect was that our terminal printed garbage while the Dazzler was operating. An investigation revealed a pulse on the SOUT line during the time the direct memory access (DMA) transfer was taking place. Cromemco was informed of this by letter and their response was... "your serial I/O (input/output) board cannot tolerate DMA." But the problem is deeper than tolerance of an I/O board. Our S-100 system uses a Z-80 processor rather than an Intel 8080. During direct memory access on the 8080, the PHLD (S-100 pin 74) is asserted by the peripheral and is answered with PHLDA (S-100 pin 26). The PHLDA signal appears at the leading edge of φ1 and the address bus and data bus are floated (put in three-state output condition) at φ2. Thus there is a period of time between PHLDA and the floating of the buses.

During direct memory access of the Z-80, the PHLD signal is asserted by the peripheral and is answered with PHLDA. The appearance of PHLDA signals that the address bus and data bus are floated (put in three-state output condition) at φ2. Thus there is a period of time between PHLDA and the floating of the buses.

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Figure 1: Portion of Cromemco Dazzler circuitry which is used to control direct memory access to system memory.

The information in this technical forum was also sent by the author to the newsletter of the Amateur Computer Group of New Jersey.

Figure 2: Addition to the Cromemco Dazzler circuit to eliminate problem-causing pulses on the author's Z-80 5-100 bus system. The fix eliminates spurious SOUT pulses that can cause garbage to be printed out on the system printer when the Dazzler is operating.

PHLDA signal. This is done by removing IC57 (a 7495), bending pin 12 straight out and reinserting IC57. This removes the effect of pin 12's output from the circuit. A signal must be supplied from pin 11 of IC57. Unfortunately, for simplicity, buffering must be used to be consistent with TTL loading rules. Fortunately, an uncommitted socket exists on board #2. A 7407, a hex noninverting buffer with open collector output, can be mounted in this socket along with the pull up resistor. The additional integrated circuit is connected as in figure 1.
Where Do New Products Items Come From?

The information printed in the new products pages of BYTE is obtained from "new product" or "press release" copy sent by the promoters of new products. If in our judgment the information might be of interest to the personal computing experimenters and homebrewers who read BYTE, we print it in some form. We openly solicit releases and photos from manufacturers and suppliers to this marketplace. 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.

Camac Interface Board for Integrated Circuit Pluggable Wire Wrap Use

Camac interface boards for integrated circuit pluggable wire wrap applications are now available from Garry Manufacturing Co., 1010 Jersey Av, New Brunswick NJ 08902. The new boards are "plug compatible with the Camac standard instrumentation bus. They provide 38 universal rows of 64 socket terminals per row, with ground and voltage terminals between every other row, spaced .300 inch (.76 cm). The boards will accommodate up to 125 16 pin integrated circuits or an equivalent mix of larger integrated circuits.

The new boards are available at $2 to $3 per integrated circuit position.

Products for the PET

PET Shack Software House, POB 966, Mishawaka IN 46544 has available a line of products for the Commodore PET. Their products include a complete set of schematics of all the boards in the PET plus parts layout and identification; a complete disassembled listing of all seven read only memories plus identified entry points and machine language monitor program listing; and a multitude of software on cassette. The schematics are priced at $35 and the read only memory routines are $19.95.

Instrument Enclosures for Designers and Manufacturers

This S series of sloped top panels and the V series of vertical front panels provide a wide range of uses. Vertical and sloping panels are finished brushed and clear anodized. Covers are finished in hard scratch resist, baked-on black textured enamel. Rubber feet and hardware are provided. All models are of flanged construction, using .063 inch (.16 cm) 14 gauge tempered aluminum. A pre-punching option on all models is available with instructions upon request. Pricing ranges from $4.43 to $17.90 each in quantities of one to four. For more information contact AAK Corp, POB 7, Methuen MA 01844.
The Computer Book by Fred Lee is an introductory reference for readers, student and nontechnician alike, who wish to improve their understanding of the digital world. This 365 page self-teaching workbook format guide is presented in a clear, straightforward style. In addition to text on each page, the top third of each page graphically represents a memory location which includes memory and address registers to be filled in by the reader so he or she goes through the same logical steps that a computer would follow while running a program. A sampling of the contents includes: number systems and codes, vacuum cleaners and circuits, the instruction set, programming, thumbs-on experience, assembly language, high level language, microprocessors, and microcomputers. The book is priced at $28 and is available from Artech House, 610 Washington St, Dedham MA 02026.

Teach Yourself How to Use BASIC

BASIC For Home Computers is a self-contained book for learning BASIC. The authors have used Microsoft BASIC for the MITS Altair computer; however, BASIC learned in this book will apply to any computer that understands a similar version of BASIC. This self-instructional book shows you how to read, write and understand BASIC. The material is presented in short numbered sections called frames, each of which teaches something new about BASIC and either asks a question or tells you to write a program.

Answers are given, and numerous applications and games are included. The book is priced at $4.95 and is published by John Wiley and Sons Inc, 605 Third Av, New York NY 10016.

Superior Electric Offers Free Stepping Motor Control Catalog

This 28 page catalog covers 16 new Slo-Syn stepping motor controls. It includes new translator and preset indexer modules, power supply modules, open chassis and buffered translators, open chassis preset indexers and completely packaged translators, preset indexers and buffered translators. Controllers drive at rates up to 5000 steps per second (1.8" steps) or 10,000 half steps per second (0.9" steps).

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 SOFTWARE

Software Patch for SwTPC 8 K BASIC
Adds Disk Data File Capability

A software patch that adds disk data file commands and functions to SwTPC's 8 K byte BASIC has been announced by PerCom Data Company Inc, 4021 Windsor, Garland TX 75042. SwTPC 8 K byte BASIC is for microcomputers that use the 6800 processor.

The software patch is overlaid after 8 K byte BASIC has been loaded in memory. This may be done either manually or from a PerCom disk which includes the patch and a loader program. The modified BASIC takes up 10 K bytes of memory. The patch permits up to four data files to be active concurrently and files may be formatted and updated in place. Formatted files may be accessed randomly.

In addition to OPEN, CLOSE, LOAD and SAVE commands, the program features special instructions that simplify data manipulation. The software patch includes nine commands and functions.

A listing of the patch program and user instruction manual sells for $10. A listing, manual and disk recording of the patch and patch loader sells for $15.

Circle 593 on inquiry card.

6800 Compiler

Written in 6800 assembly language, this 3 pass compiler (on floppy disk) provides a disk based high level language for microcomputers with at least 16 K bytes of programmable memory. The new language, called STRUBAL (Structured Basic Language), features fully relocatable and linkable code. Versions of the compiler are available for iCOM FDOs-II, Smoke Signal Broadcasting DOS68 and SwTPC Flex.

The software supports a full set of scientific functions, one-dimensional and two-dimensional arrays, three data types (16 bit integer, 10 digit floating point and variable length strings), structured programming forms, string functions, embedded assembly language in the source program and common and dummy sections. Line numbers are not required in source programs. Subroutines may be separately compiled or assembled and called by named parameters.

The price of STRUBAL is $99.95, which includes a user's manual. For further information contact Hemenway Associates Inc, 151 Tremont St, Suite 8P, Boston MA 02111.

Circle 594 on inquiry card.

Heurikon Introduces BASIC and Disk Operating System

The Heurikon Corp, 700 W Badger Rd, Madison WI 53713, has announced the addition of Heurikon BASIC and disk operating system (DOS) to its line of MLZ-80 microcomputer products. Heurikon BASIC and DOS is a multilevel system offering two levels of concurrent operation and a disk operating system with file management. The system provides both edit and real time program areas which run concurrently. Real time programs run independently from the keyboard and program editing functions. A real time program is given highest operating priority and may be started automatically in response to external stimuli. Edit area programs will be interrupted to service real time operations. When the real time program completes a task, control is returned to the interrupted point in the edit program. New programs may be developed and tested in edit while the real time program continues to monitor external events. Heurikon BASIC and DOS file management architecture allows any number of variable length files to be cataloged on the disk.

This system is available configured to run on the Heurikon MLZ-80 microcomputer system, which is fully compatible with Intel's SBC Multibus. It can be provided on disk or in erasable programmable read only memory.

Circle 595 on inquiry card.

Language Family Designed for Z-80 Computers

Designated PLZ, this family of system programming languages is implemented as a set of disk based programs that run in the RIO operating system of Zilog's Z-80 computers. Linkage to other languages such as BASIC, COBOL and FORTRAN is straightforward. PLZ permits a systematic combination of high level machine-independent modules with low level machine-dependent modules within the same program.

The high level modules utilize the procedure oriented PLZ/SYS language. PLZ/SYS blends elements of such languages as Pascal, ALGOL, PL/I and C to provide a medium for expressing algorithms in a high level, structured fashion. PLZ/SYS requires minimal run time support.

A structured assembly language, PLZ/ASM, provides all of the low level programming capabilities necessary for the user to manage such processor resources as registers, memory, accesses and input/output (IO) operations. Initial PLZ program implementation consists of the PLZ/SYS compiler, PLZCCG code generator, Zinterp Interpreter, PLInk linker, PLZ/ASM translation filter, and PLZ IO package.

For more information contact Zilog, 10340 Bubb Rd, Cupertino CA 95014

Circle 596 on inquiry card.

Software Package for 8080 and Z-80 Microcomputers

The SOS (single user operating system) package provides the user with a step between the Opus stand-alone high level languages and the Tempos multitasking operating systems. The SOS package includes Opus/Three, the high level compiler/interpreter from ASI; Texted, an easy to use, line oriented text editor; Assembl, an 8080 assembler; Files, a diskette file manipulator; and Utilities 1, a package of 12 utilities programs.

Full upward compatibility has been retained to allow the user of SOS to access data and programs developed at lower levels; all may be used under the TEMPOs operating system as well. All floppy disks and serial device input/output (IO) is handled by SOS; a system generation routine lets the user define IO drivers as required.

The recommended hardware configuration includes an 8080 or Z-80 processor, 32 K bytes of programmable memory, one or two floppy disk drives, and terminals as required. The system typically resides in less than 10 K bytes of programmable memory.

The package is priced at $585 and the user's manual set may be purchased separately for $20, which is credited toward purchase of the SOS package. For more information contact Administrative Systems Inc, 222 Milwaukee, Suite 102, Denver CO 80206.

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V-TE April

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BYTE April 1979 261
Discus I is a full-size floppy disk memory for S-100 systems using the 8080 processor. The Discus I is sold as a complete system, assembled and tested, with all required hardware and software. Hardware included in the Discus I system includes a Shugart 800R full-size disk drive fully mounted in a custom, all metal cabinet with an independent power supply; a Disk Jockey I S-100 controller with a capacity for seven additional disk drives; and all necessary cables and connectors.

The controller offers an on board serial input and output (IO) port to which all system software has been interfaced. The IO routines can then be modified with the included system software at the user's convenience.

Software included features an integrated Disk/Ate system containing most utilities: disk operating system, file management, system debugger, text editor, batch processor and SOSO assemblers. The fully assembled and tested memory board operates from a single 5 V power supply and is available in versions with either 250 ns or 500 ns access time.

The SME6808 is an 8 K byte by 8 bit low power static programmable memory board for microcomputer systems which utilize the M6800 bus structure. The fully assembled and tested memory board is capable of generating zero to four wait states. The eraseable read only memory section is addressable on any 4 K byte boundary in memory. Either 250 ns or 500 ns access time.

Memory Board for S-100 Bus

The module is organized as two 4 K byte arrays which can be independently located at any 4 K byte boundary in the 64 K byte addressing range of the system. Base address selection for each array is made via on board jumpers. Switches provided on the board allow selection of a read only mode of operation for each of the 4 K byte arrays. This permits the user to simulate read only memory for software development applications, or to protect data from being overwritten during program execution.

Slow memory circuitry can be provided with the SME6808 module. This option permits the 500 ns board to be used in applications with high speed processors or protects investments in memory as high speed processors are added to existing systems.

The price of the 500 ns board is $324.95; the 250 ns version sells for $399.95. Slow memory circuitry is available for either version at an additional cost of $10. Ultra low power modules are also available. Contact American Technologies, POB 23001, Rochester NY 14692.

Memory Board with Vector Jump

The MB-8A memory board, which uses 2708 erasable read only memories, is fully buffered, has reverse voltage protection, and includes vector jump capabilities which enable the user to jump to any 256 bit location on the board.

Features of the new board include magic mapping, which automatically disables any socket with no read only memory installed, allowing the use of additional programmable memory. The board does not require the use of a front panel. Just reset and go. The MB-8A is plug compatible with all S-100 bus mainframes and has dual-in-line package (DIP) switch selection of eight wait states.

The price of the MB-8A is $95 from SSM, 2116 Walsh Av, Santa Clara CA 95050.

Memory Board for 6800

PCE Electronics has announced the 16/4+1 erasable read only memory and programmable memory board for the S-100 bus. This board features accommodations for up to 16 2708 1 K word by 8 bit erasable read only memory integrated circuits, addressable in four separate 4 K byte blocks. Any block may be addressed on any 4 K byte boundary in memory and any of the 16 erasable read only memory sockets may be disabled. The eraseable read only memory section is capable of generating zero to four wait states.

The programmable memory section of the 16/4+1 utilizes eight 21L02 1 K by 1 bit static programmable memories. The 1 K byte block of programmable memory is addressable on any 1 K byte boundary in memory. Either 250 ns or 450 ns programmable memories are available with the board.

Other features of the board include complete buffering, solder mask, silk screened component location diagram, sockets for all integrated circuits and complete documentation.

The price for the board in kit form is $130, or $155 for an assembled and tested board. The 250 ns programmable memory circuit is $5. For more information contact PCE Electronics, 4782 Dewey Dr, Fair Oaks CA 95628.

Contact Thinker Toys, 120 11th St, Berkeley CA 94710.
IA Expands S-100 Line

Video Display Board
Featuring a full 128 upper/lower case ASCII character set stored in a 1K buffer memory. Easy to read 16 line x 64 character format can be displayed on an inexpensive video monitor or a modified TV set. Includes a TTY software driver. Add our powerful K 2 FDOs to create a versatile operator console.

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K2 Operating System
Power full disk software in the DEC tradition. Includes Text Editor (TED), File Package (FIP), Debugger (NDT), Assembler (ASMBLE), HEXBIN, 1 COPY, System Generator (SYSGEN). Command syntax follows Digital's OS-8 RT/11 format. First in a family of high level software. Soon to be released, FORTRAN & Pascal Compilers.

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Ithaca Audio is now stocking the Mostek 4115 add-on RAM for S-100’s Expandoram. Buy their basic board, 32K of RAM from us and SAVE.

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Circle 190 on inquiry card.
Add Hard Copy to Your S-100 System

This new Selectric input and output (IO) writer interface, called Typeaway, offers an easy, economical way to add hard copy capabilities to an S-100 system. Typeaway is a complete package of everything required to interface a model 731 or 735 IO writer to an S-100 computer. The total package includes: a single S-100 compatible printed circuit board with solenoid drivers; IO ports; complete software in programmable read only memory; all the cable and connectors needed to connect a Selectric to Typeaway, including a 50 pin A connector; and a versatile DC power supply.

Typeaway can be adapted to work with any factory version of a Selectric IO writer. Software supplied in two 1702A programmable read only memories is all that is necessary to operate a Selectric 10 writer as either an input or output device. All control functions and code conversions are programmed in the board's firmware.

The tested and assembled version is priced at $350 and a kit version sells for $275. For further information contact Micromation Inc, 524 Union St, San Francisco CA 94133.

Circle 570 on inquiry card.

S-100 Expansion for Commodore's PET Computer

Forethought Products, POB 8066, Coburg OR 97401 has announced a PET to S-100 interface and motherboard named Betsi. Betsi is a single circuit board that contains all the necessary logic to interface S-100 boards to the PET.

The board attaches directly to PET's memory expansion connector and provides both interface logic and four S-100 slots on a single compact circuit board, Betsi operates with any S-100 power supply and doesn’t interfere with use of PET's parallel or IEEE ports.

In addition to its compatibility with most available S-100 boards, Betsi has an on board dynamic memory controller which allows it to be expanded to 32 K bytes with a single S-100 card.

The kit (which includes one S-100 connector) is priced at $119. $165 is the price for the assembled and tested board (which includes four S-100 connectors).

Circle 606 on inquiry card.

DEC VT-52 Compatible Video

The Elite 3052A video terminal is a buffered VT-52 compatible terminal with a single page video memory. It offers formatting capability, eight levels of screen enhancements, and a detached keyboard.

The terminal displays 1920 alphanumeric characters in a 24 line, 80 character format and offers a series of features for VT-52 users that includes: an unmatched range of operating modes; host control of block transmit function in local or remote environment; communications flexibility through switch selectable EIA or 20 mA current loop interfaces; buffered support of host-to-printer data transfers; ten user function keys; 8 level video, which requires no memory address space; and 15 data transmission rates, up to 9600 bps, selectable from keyboard.

The Elite 3052A is priced at $1700 in single quantities and $1360 in quantities of 100. Write to Datamedia Corp, 7300 N Crescent Blvd, Pennsauken NJ 08110.

Circle 607 on inquiry card.
SMART FOXY KIT $199.95

OPTIONAL: • Sockets $10.00 • 2K Memory $30.00 • 4K Memory $60.00 • Video Driver Eprom $20.00 • Text Editor Eprom (Includes Video Driver $75.00)

S-100 Plug-In • Parallel Keyboard Port
On board 4K Screen Memory (Optional). On board Eprom (Optional) for Video Driver or Text Editor Software.

Up and Down Scrolling through Video Memory
Reverse Video, Blinking Characters.

Display: 128 ASCII Characters 64 X 32 or 32 X 16 Screen format (Jumper Selectable). 7 by 11 Dot Matrix Characters.

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15 MHZ DUAL TRACE PORTABLE SCOPE

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MODEL MS-215

• Battery or A.C. Operated • External and Internal Trigger
• Time Base—.1 m Sec./Div. Into 21 Calibrated Ranges •
3% Accuracy • Input Impedance 1 M Ohms • Complete
with Input Cables, Battery and Charger.

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Plugs into Slot of Mother Board
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**12 Volt 2000000000000000000000000 Amp Power Supply** $6.34

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RCA Cosmac Super Elf Computer $106.95

Compare features before you decide to buy any other computer. There is no other computer on the market today that has all the desirable features of the Super Elf for so little money. The Super Elf is a small single board computer that can do many big things. It is an excellent computer for training and for learning programming with its machine language and yet it is easily expanded with additional memory, Tiny Basic, ASCII Keyboard, character generator, etc.

The Super Elf includes a ROM monitor for program loading, editing and execution with SINGLE STEP for program debugging. It is packed with features not included in others at the same price. With SINGLE STEP you can use the microprocessor to do your own assembly programming. With auto isolate program bugs quickly, then follow with

24 key HX keyboard includes 16 HEX keys

Super Expansion Board with

This is truly an outstanding value! This board has been designed to let you choose how you want it worked. The Super Expansion Board comes with 4K of low power RAM full addressable anywhere in 64K with built-in memory protection and a capability interface. Provisions have been made for all other options on the same board and it fits neatly into the hardwired cabinet alongside the Super Elf. The board includes slot for EPROM (2708, 2728, 2764 or 2716) and is fully socketed. EPROM can be used for future personalizing and other purposes.

A 1K Super ROM Monitor $15.95 is available as an on board option in 2708 EPROM which has been programmed with a program loader editor and error checking. The 4K monitor is a full ASCII cassette and can be used with or without a cassette interface. The cassette interface is a direct expansion or an ASCII interface. It includes register save and readout, clock move capability and video graphics with blinking cursor. Great points can be used with the register save feature to isolate program bugs quickly, then follow with single step. The Super Monitor is written with subroutines allowing users to take advantage of monitor functions simply by calling them up.

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$3.95 Beautiful wood grain case w/ bezel $11.75

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IM6563 1.50 2102A-2L 1.60

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THE HAZELTINE 1400 Video Display Terminal is designed to optimize interactive real-time operations. The interface is capable of either local or remote connection through an EIA RS232C interface at baud rates that are switch selectable up to 9600 baud.

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- 64 Displayable Characters
- 24 Lines; 12 inch Screen
- 60 Characters per Line
- Self-Diagnostic Test

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- 64 Displayable Characters
- 24 Lines; 12 inch Screen
- 60 Characters per Line
- Self-Diagnostic Test

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Selectronic, 3100 H Carson, Los Angeles. Shipping to the East Coast at pric. $33. Combined TRS-80 interface and power supply available. Documentation will be supplied to those individuals who want to do their own custom interfacing. Sorry, but credit cards will not be accepted on this purchase.

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**BYL April 1979 271**
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POWER TRANSFORMERS (WITH MOUNTING BRACKETS)

<table>
<thead>
<tr>
<th>ITEM NO.</th>
<th>USED IN</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>2×9A</td>
<td>2×1.5A</td>
<td>3½”×3½”×3½”</td>
<td>19.95</td>
</tr>
<tr>
<td>T2</td>
<td>2</td>
<td>0V, 110V, 120V</td>
<td>2×13.5A</td>
<td>2×3.5A</td>
<td>3½”×3½”×3½”</td>
<td>25.95</td>
</tr>
<tr>
<td>T3</td>
<td>3</td>
<td>0V, 110V, 120V</td>
<td>2×10A</td>
<td>2×2.5A</td>
<td>3½”×3½”×3½”</td>
<td>27.95</td>
</tr>
<tr>
<td>T4</td>
<td>4</td>
<td>0V, 110V, 120V</td>
<td>2×4.5A</td>
<td>2×4.5A</td>
<td>3½”×3½”×3½”</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 NO.</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>UNIT PRICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>KIT 1</td>
<td>16 CARDS SOURCE</td>
<td>18A</td>
<td>2.5A</td>
<td>2.5A</td>
<td>12”×6”×4½”</td>
<td>46.95</td>
<td></td>
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</tr>
<tr>
<td>KIT 2</td>
<td>SYSTEM SOURCE</td>
<td>25A</td>
<td>3A</td>
<td>3A</td>
<td>12”×6”×4½”</td>
<td>54.95</td>
<td></td>
<td></td>
</tr>
<tr>
<td>KIT 3</td>
<td>DISC SYSTEM</td>
<td>18A</td>
<td>2A</td>
<td>2A</td>
<td>14”×6”×4½”</td>
<td>62.95</td>
<td></td>
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</tr>
<tr>
<td>KIT 4</td>
<td>DISC SOURCE</td>
<td>8A</td>
<td>1A</td>
<td>8A</td>
<td>16”×6”×4½”</td>
<td>44.95</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

EACH KIT INCLUDES: TRANSFORMER, CAPACITORS, RESIS., BRIDGE RECTIFIERS, FUSE & HOLDER, TERMINAL BLOCK, ALUM. CHASSIS PLATE, ALL NEC. MTG. PARTS AND INSTRUCTIONS.

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- Bank Selectable
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- Power 8VDC, ±16VDC, 5 Watts
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- Uses Popular 4116 RAMS
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CSC logic probes are the ultimate tool for troubleshooting and testing. These hand-held units present an overall overview of circuits without the need for detailed analysis. Simply look at the unit and most of the power leads to disturb the power supply, let logic levels and pulses down through digital circuits. Even stretch and check for easy pulse detection. Instant recognition of high, open, low levels, open circuits and nodes. Simple, dual-level detection LED's tell it quickly, correctly.

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  Accuracy: ±0.5% + 0.5

Hardware and optional Kit includes:
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Hickok's exciting new LX 303, 11 digit Mini-Multimeter with high quality components, one year guarantee and rugged Corgal case offers features previously found only in expensive units... at a price under $75.00! So why wait any longer? The amazing LX 303 is here, NOW! Another American made test equipment breakthrough from Hickok.

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SOLID STATE SALES... Announces a Breakthrough in Computer Technology

A PICTURE MAY BE TAKEN BY OUR CAMERA, STORED IN A COMPUTER IN REAL TIME AND THEN DISPLAYED ON A CRT AT AN AFFORDABLE PRICE

VIDEO COMPUTER PROCESSING SYSTEM

OUR VP1 VIDEO SYSTEM CONSISTS OF THE FOLLOWING KITS:

- CCD 202C SOLID STATE VIDEO CAMERA KIT (CASE INCLUDED) $399
- VP-1 COMPUTER/VIDEO INTERFACE KIT (3 BOARDS) $595
- ASSEMBLED 8K MEMORY BOARD (OPTIONAL) $235

THIS VIDEO COMPUTER KIT CAN WORK WITH THE GE, REDICON, OR ANY OTHER 128 x 128 SENSOR CAMERA

THE CAMERA WILL TAKE BETWEEN 15 AND 100 FRAMES/SECOND. THE CAMERA CONNECTS TO THE PROCESSOR WITH SEVEN LINES. THIS INCLUDES VIDEO AND TIMING SIGNALS

APPLICATIONS

- CONTINUOUS SURVEILLANCE
- INSPECTION OF MOVING PARTS WITH PROPER STROBING
- VISUAL GRAPHIC INPUT TO A COMPUTER
- CHARACTER OR PATTERN RECOGNITION
- PICTURES MAY BE TAKEN DIRECTLY FROM A TV WITHOUT ELECTRICAL CONNECTIONS
- THE INTERFACE KIT MAY BE USED SEPARATELY AS A 128 x 128 16 LEVEL GRAPHIC DISPLAY

THIS REMARKABLE VP-1 COMPUTER INTERFACE KIT HAS THE FOLLOWING:

FEATURES

- IT PRODUCES COMPOSITE VIDEO OUTPUT IN A 128 x 128 MATRIX FROM A DIRECT MONITOR CONNECTION USING 8K OF MEMORY
- THE SYSTEM USES A STANDARD $100 BUSS
- WILL NOT TIE UP COMPUTER SOFTWARE WHEN NOT Addressed
- IT DISPLAYS CONTINUOUSLY WHEN NOT Addressed
- IT MAY PRODUCE PSEUDO COLOR AND/OR GRAY LEVELS (UP TO 16 GRAY LEVELS, 4 BIT BINARY)

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### Printed Circuit Board

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### Transistor Specials

- 7402: 200-240V, 100-240V $1.95
- 7403: 200-240V, 100-240V $1.95
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- 7406: 200-240V, 100-240V $1.95

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### Solid State Power Rectifiers

- 7402: $1.95
- 7403: $1.95
- 7404: $1.95
- 7405: $1.95
- 7406: $1.95

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### Silicon Solar Cells

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- 12 x 12 x 24 x $3.50
- 12 x 12 x 24 x $3.50

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BYE April 1979 277

Circle 340 on inquiry card.
For sale: TI TM990/100M-1 microcomputer board with TIBUG monitor in read only memory, 256 words of programmable memory, TM990/103 microterminal, TM990/511 extender board and all documentation. It is a great little machine. I just don't have time to build a system around it. List price is now $2950. It's yours for $550 postage paid. W H Ganoe, 1634 E Drachman, Tucson, AZ 85719.

For Sale: Like new 33ASR. Purchased new and seldom used, 3850. 101C data set (110 bps modem) very nice, $300. COO to interface 33ASR with 101C, $100. All three $1000. Joe Turster, POB 147, Corona MI 48817, (517) 743-4607 after 6 PM.

School sale to raise money. Two Mohawk Data Sciences super compact card readers model 2CCR 6002 (6 2/3 cards per second), two A Bar code videojet ink-jet printers model 9600 (250 characters per second, with parallel interface). Both appear to be working and are hardly used. Also selling three Micro Systems Inc Micro 810 computers. They are microprogrammable, 270 ns, with teleprinterwriter interface and a combined total of 16 K core memory. The Berkeley High School Technology Club is selling these to raise money for projects. Any reasonable offer considered. Contact Eric Martinson, 2206 B Jefferson Av, Berkeley CA 94703, (415) 849-2633.


Help. For ND-B12/BR-2412 users. Is there any existing users group for the ND-B12 or BR-2412 microcomputer, or are there any other individual users of these orphaned systems who would like to communicate for mutual support? Write or phone: Bill Hunt, 237 South Blvd, Oak Park IL 60302, (312) 366-0194.

For Sale: Altair 8800 microcomputer with 28 K memory; has 3 P+5 cassette user tape systems board, VDM, 16 K read only memory board with monitor, 1 K board for stack, and keyboard. $1400. Larry Belmontes Jr, 1762 Yale St, Corpus Christi TX 78416, (512) 885-2684.

Wanted: Drawings, schematics and pin out data to interface a 8080 Inc. Model 303 Key-Cassette to a microcomputer. Will pay for documentation. Jim Cook, 11451 Olson Dr, Garden Grove CA 92641.

For Sale: Prolag read only memory programmer with UV light eraser. Program, copy, read, or edit 1702 UV read only memories. Excellent condition in attractive case. Cost $200. Sell for $640. Bill Fujitusa, 1506 Sandcastles Dr, Corone del Mar, CA 92625.

For Trade: Texas Instruments Silent 700 portable terminal, model number 725. Perfect working condition and clean. Want to trade for used DECwriter II or video type terminal. Will consider all offers. Mark Jay Hunt, 3040 Vista Monte Dr, San Jose CA 95118, (408) 265-7799 nights.

For Sale: Digital Group 2-80 system; 34 K; four Plidkeys; keyboard; monitor; dress cabinets for all; softwe (Mesa-V BASIC, Business BASIC, Assembler, Startrack, Chess, etc). Must sell - any reasonable offer accepted. John Case, 6703 Timberhill, San Antonio TX 78238, (210) 681-7504.

For Sale: TV camera parts; 7735A Vidicon tube brand new; 30 K; 16 mm lens $10; deflection and focus coil $18; video amplifier $5; and other miscellaneous goodies. Schematics available. Everything have for $45 plus shipping. S Stoddard, 12 Kathy Dr, Poquoson VA 23662, (804) 868-7682.

For Sale: Disk and tape drives from GE-116 computer system plus disk packs and other parts. Also Teletype ASR33, $500; Dura MACH-10 needs considerable work or good for parts, $100; Atari 270B board, $100; XY plotter with 10 by 15 inch (754.4 by 315.4 cm) plotting bed, $200; 72 CPS paper tape reader, $25; 3M microfilm viewer/primer, $100. Will consider trade. SASE for more information. Dan Bailey, 18 Shaver Rd, Concord NH 03301.

For Trade: BBDT FORTRAN MTS disk version for 1000 COBOL or MTS timing BASIC. Manuals included. K R Roberts, 10560 Main St, Suite 518, Fairfax VA 22030, (703) 379-7396, (703) 591-6008, (703) 691-2777.

For Sale: January thru December 1978 BYTE (volume 3) complete, mint condition, unopened. These 12 issues are yours for $15 (includes fourth class shipping). Send check or money order to John Burnet, 10324 S Prospect Av, Chicago IL 60643.

For Sale: Two Solid State Music 4K Static programmable memory boards from a working (and lovable) Altair 8800, asking $80 each or both for $150. Also have a working Digital Group TVC-F video interface and audio cassette tool. It lists for $195, but it's yours for $130. Dar Moras, 4334 N Quincy, Kansas City MO 64117.


For Sale: Three S D Sales 4K static programmable memory boards, fully operational, with all documentation, data read, data read on PDBIN! All three shipped promptly for certificated funds of $180 (that's less than 1.5¢ per byte!). W Howards, 1222 Krampe St, Denver CO 80224, (303) 756-4052.

Kim Users: Powerful console input monitor (CIM) lets you enter, edit, and execute programs from ASCII encoded keyboard on BASIC KIM. CIM modes are: address, program, text, data, increment, decrement, and execute. Complete documentation included for $150 postage paid. Add $5 for CIM documentation. E R Kistkis, POB 2175, Seal Beach, CA 90740.


For Sale: Panasonic 8 1/2 inch diagonal black and white video monitor with UHF type connectors. $50 or best offer. Charles Baumer, 5055 W Drummond Pl, Chicago IL 60639, (312) 637-0414.


For Sale: Partially assembled SwTTC CT-64 terminal kit. Keyboard and video terminal complete and working with sockets for all integrated circuits. $750. Allan J Hope, RR 2, Norwalk IA 50211, (161) 492-3220.
Circle 296 on inquiry card.

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Scrolling, Full Cursor, Bell, 8X8 matrix, 256 addressable characters 110-1,520 baud, 1200 ft. reels 111 megabyte capacity.

This terminal has been purchased by many agencies, universities & companies. Fully stand-alone, it is the only dual font terminal of any kind for the 8080 or 2-80 owner to read and write standard IBM NRZI format tapes as well as ASCII tapes with the Ampex Model TMX tape drive described below. Controller is sold only with tape drive, comes complete with controller cables to CPU and software listing in 8080 assembly language (specify 2MHz or 4MHz system.)

-Ampex TMX tape drive (used) with Version I Controller... $1,500.00

**NEW TAPE DRIVE CONTROLLER for Microcomputer:**
POS Version II tape drive controller is now available, permitting the 8080 or 2-80 owner to read and write standard IBM NRZI format tapes as well as ASCII tapes with the Ampex Model TMX tape drive described below. Controller is sold only with tape drive, comes complete with controller cables to CPU and software listing in 8080 assembly language (specify 2MHz or 4MHz system.)

-Controller & cable for mCPU, assembled & tested... $750.00

**DIGITAL CASSETTE DRIVE** (from GTE/IS Terminal): 1800 baud, 1200 ft. reels, (11 megabyte capacity.) Drive is like new & comes with 8-bit CPU controller diagram (requires only 1 I/C) & mCPU interface instructions: Power (125W), Performance (3600rpm) and cost effectiveness (10 MB and controller for $750.00). For PDP-11, LSI-11

AND... 8-100 machines

**Daisy Wheel Printers...**

-**DIABLO HYTYPE** Model 1200 Printer Mechanism: used, complete and operational. Requires power supply, case & mCPU interface. 15 day return privilege - no other warranties. LIMITED QUANTITY! ...

-Controller & cable for printer Main Logic PCB... $100.00

-Controller & cable for mCPU, assembled & tested... $750.00

-Controller & cable for mCPU, assembled & tested...

-**NEW BREAKTHROUGH!!!**

BYTE April 1979 279

Circle 298 on inquiry card.
### Content Overview

The document appears to be a list of companies, their locations, and possibly some product information. It seems to be a section from a larger document, possibly a catalog or a directory. The presence of page numbers suggests it might be a part of a book or a magazine. The text is scattered, and it's difficult to extract a clear structure without further context.

### Extracted Data

#### Table Content

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### Additional Notes

- The document seems to be a catalog or a list of companies, possibly related to technology or electronics.
- The content is fragmented and does not form a coherent paragraph or section.

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Structured Systems Group
5204 Claremont Oakland, California 94618 (415) 547-1567

* Complete prices will vary with equipment and software selected. Required: 8080 or Z-80 based computer running a CP/M or CP/M-compatible disk-based operating system. Your retailer or SSG can advise on specifics. (CP/M is a product of Digital Research.)

Circle 353 on inquiry card.
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The C3 Series is the only computer system with the three most popular processors — the 6502A, 68000 and Z-80. This allows you to take maximum advantage of the Ohio Scientific software library and the tremendous number of programs offered by independent suppliers and publishers. And all C3’s have provisions for the next generation of 16 bit micros via their 16 bit data BUS. 20 address bits, and unused processor select codes. This means you’ll be able to plug a CPU expander card with two or more 16 bit micros right in to your existing C3 computer.

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The three most popular computer languages including three types of BASIC plus FORTRAN and COBOL with more languages on the way. And, of course, complete assembler, editor, debugger and run time packages for each of the system’s microprocessors.

**Applications Software for Small Business Users.**

Ready made factory supported small business software including Accounts Receivable, Payables, Cash Receipts, Disbursements, General Ledger, Balance Sheet, P & L Statements, Payroll, Personnel files, Inventory and Order Entry as stand alone packages or integrated systems. A complete word processor system with full editing and output formatting including justification, proportional spacing and hyphenation that can compete directly with dedicated word processor systems.

There are specialized applications packages for specific businesses, plus the vast general library of standard BASIC, FORTRAN and COBOL software. OS-DMS, the new software star. Ohio Scientific has developed a remarkable new Information Management system which provides end user intelligence far beyond what you would expect from even the most powerful minisystems. Basically, it allows end users to store any collection of information under a Data Base Manager and then instantly obtain information, lists, reports, statistical analysis and even answers to conventional “English” questions pertinent to information in the Data Base. OS-DMS allows many applications to be computerized without any programming!

The new “GT” option heralds the new era of sub-microsecond microcomputers.

Ohio Scientific now offers the 6502C microprocessor with 150 nanosecond main memory as the GT option on all C3 Series products. This system performs a memory to register ADD in 600 nanoseconds and a JUMP (65K byte range) in 900 nanoseconds. The system performs an average of 1.5 million instructions per second executing typical end user applications software (and that’s a mix of 8, 16 and 24 bit instructions!)

**Mini-system Expansion Ability.**

C3 systems offer the greatest expansion capability in the microcomputer industry, including a full line of over 40 expansion accessories. The maximum configuration is 768K bytes RAM, four 80 million byte Winchester hard disks, 16 communications ports, real time clock, line printer, word processing printer and numerous control interfaces.

**Prices you have to take seriously.**

The C3 systems have phenomenal performance-to-cost ratios. The C3-S1 with 32K static RAM, dual 8” floppies, RS-232 port, BASIC and DOS has a suggested retail price of under $3600. 80 megabyte disk based systems start at under $12,000. Our OS-CPI/M software package with BASIC, FORTRAN and COBOL is only $600. The OS-DMS nucleus package has a suggested retail price of only $300, and other options are comparably priced.

To get the full story on the C3 systems and what they can do for you, contact your local Ohio Scientific dealer or call the factory at (216) 562-3101.

C3-B wins Award of Merit at WESCON ’78 as the outstanding microcomputer application for Small Business.