JUNE 1978 VOLUME 3, Number 6

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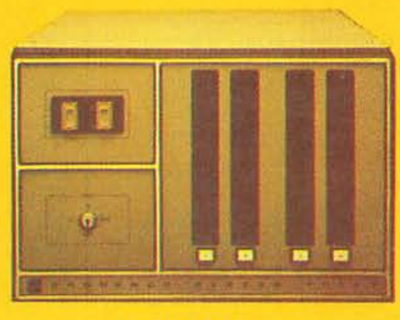

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BYTE June 1978
Volume 3 Number 6

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About the Cover:

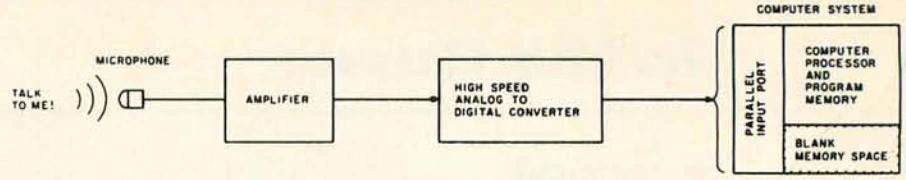
Robert Tinney's cover painting this month was inspired by the article, **A Theatrical Lighting Graphics Package** by William Hemsath, James Seawright, Emmanuel Ghent and Mimi Garrard. While Cyrano soliloquizes, the technical director in the wings keeps track of the lights with the aid of an ingenious graphics system. For more information see page 153.

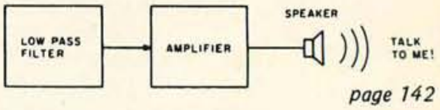
In This BYTE

Last month, Larry Weinstein described the hardware for a programmable character generator. This month, read **A Programmable Character Generator Part 2: Software** and find out how to program your own special characters for APL programming, music graphics, and so on. *page 14*

Many computer experimenters buy surplus integrated circuits and have the sometimes tedious job of testing them to see if they work. Mark Thorson offers an elegant way around this problem with **A Programmable IC Tester.** For relatively little expense, readers can now construct a black box that will put virtually any TTL integrated circuit through its paces quickly and accurately. *page 28*

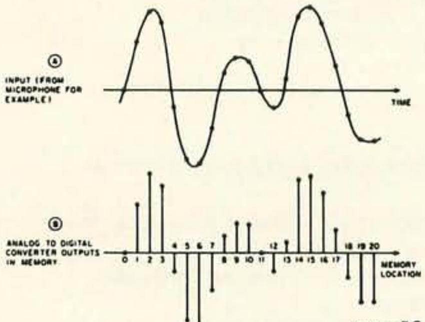
Since the introduction of the computer over 30 years ago, we have been forced to use difficult, archaic, near alien languages in order to communicate our wishes to the machine. The development of a system which understands the human language has been slow in coming. Now, Harry Tennant takes the naturally "speaking" machine out of the realm of science fiction and places it right in the lap of the home experimenter. But don't you need a huge machine to do that sort of thing, you *protest*? Read **Natural Language Processing and Small Systems** and discover the answer for yourself. *page 38*





page 142

Speech recognition is a key component of any software and hardware design for interesting systems ranging from mobile robots to the interactive and responsive house. To provide some background information on the complexities of the subject, Bill Georgiou has written an article entitled **Give an Ear to Your Computer.** *page 56*



page 56

Craig A Pearce reviews two programmable calculators from Hewlett-Packard in **The HP-67 and HP-97: Hewlett-Packard's Personal Computers** and describes Pinball Wizard, a simulation game he wrote to show off the two units. *page 112*

Dr William H Norton discusses the potential impact of using microcomputers on computer curricula in **Notes on Teaching with Microcomputers.** His own experiences using the KIM-1 microprocessor for one of his own courses at Marycrest College, Davenport IA, illustrate their practicality, ease of use, and positive effect. Just as hand calculators revolutionized many types of instruction, so too will micros eventually be used to enhance computer education. *page 138*

If you would like your computer to compose music for you, read Tom O'Haver's **More Music for the 6502.** There you will find a simple way to use the complicated sounding technique of first order stochastic control to create your own software sonatas and FIFO fugues. *page 140*

Would you like to try your hand at speech synthesis on your computer? Steve Ciarcia shows you how to make use of your programmable memory to store and play back digitized speech in **Talk to Me! Add a Voice to Your Computer for $35.** *page 142*

An unusual and creative use of microcomputers and video displays is described in **A Theatrical Lighting Graphics Package** by William Hemsath, James Seawright, Emmanuel Ghent and Mimi Garrard. The authors' system consists of a simple modification to a Processor Technology VDM-1 video display enabling it to simultaneously display five graphs of theatre lighting intensity versus time. *page 153*

In part 2 of **GRAPH: A System for Television Graphics** authors John Webster and John Young complete their discussion of a package for use with videotape studio equipment in educational audio visual contexts.

page 158

Does your computer have high fiedelity? We don't mean to imply that it lacks character if it doesn't, but as Tom O'Haver shows in his article on **Audio Processing with a Microcomputer** it is possible to use the capabilities of a personal computer to do some interesting real time audio processing tasks such as reverberation, phlanging and "fuzz." *page 166*

The fixed disk may soon become a fixture in personal computing, and the ability to store 30 megabytes of memory on line will have a major effect on the way we look at software. Read **A Look at Shugart's New Fixed Disk Drive** by Senior Editor Chris Morgan. *page 174*

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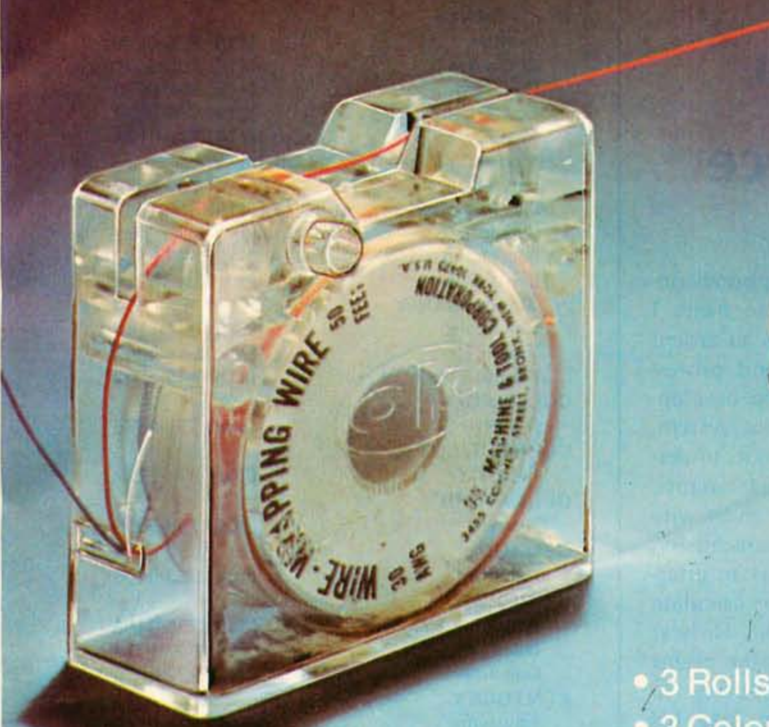

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Editorial

Memory: The Growth of a Resource

By Carl Helmers

Once upon a time, I had a telephone conversation with a gentleman whose name I cannot recall. This gentleman was an ardent experimenter, both personally and professionally, and was working on the development of a personal microprocessor system. He knew electronics inside and out, understood the principles of integrated circuits, could predict whether or not a given wire would have to be analyzed as a transmission line or could be treated simply as an interconnection, and knew how to calculate worst case conditions in a circuit. He was getting into microprocessors with the intent of learning enough about computing to enable him to incorporate them into his designs. I must have talked to him shortly after he had begun his project, but certainly before it had been completed to the state of a "working" processor. Given this background, he was able to come up with the statement, "Nobody will ever need more than 1 K bytes of memory for the personal computer. To use any more would indicate a lack of efficiency in the design."

I don't believe that this gentleman still holds this opinion, especially if he has proceeded into the world of programming and using a computer.

Then a little bit later in my experiences, I was having a conversation with a friend of over a decade's acquaintance concerning various topics of small computer design and utilization. Now this friend of mine has had a quite thorough background not in engineering, but in systems software, and is quite familiar with the process of allocating memory on a large system in lumps of 100 K bytes or more if the occasion arises. He's lately been enamored of the concept of interpretive languages with dynamic symbol

Continued on page 120

Articles Policy

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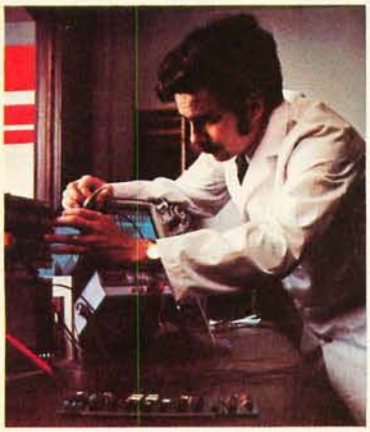

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Letters

THE IMPORTANCE OF COLOR GRAPHICS

The editorial about the importance of color graphics (October 1977 BYTE) touched on some issues that go much deeper than most people suspect. The story about the professional who asked, "Why would anyone ever want a personal computer?" has several variations that further illustrate the misunderstandings that can arise. For example, there is the listener to a computer based music system who asks, "Isn't that just a fancy new kind of record player?" Aside from obvious acoustic differences (our system plays real organ pipes—talk about hi fi!), the answer is, "Yes, if all you do is listen." But that's not the purpose of the system at all —it's meant to be manipulated, to be used by creative experimenters, that is, by artists.

Photo 1.

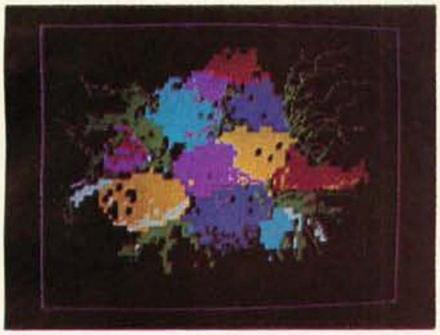
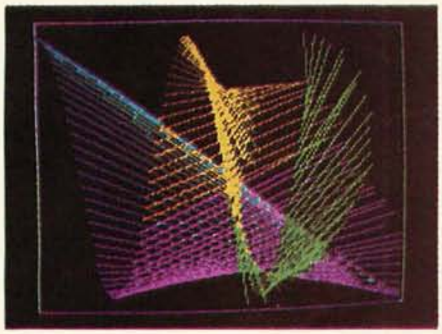
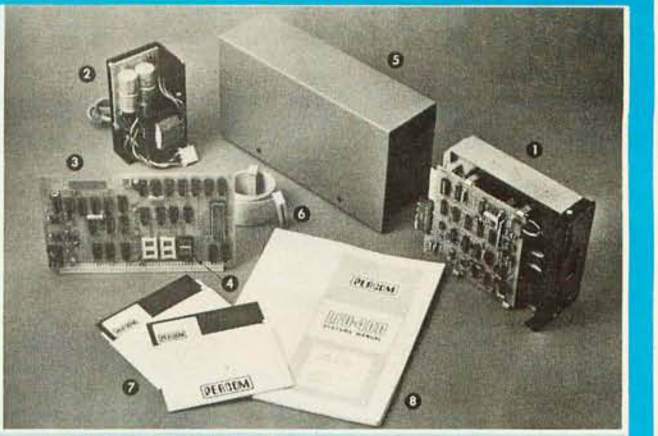


Photo 2.



A good example of the consequence of this creative viewpoint is the work of a high school physics teacher (Mike

Continued on page 98



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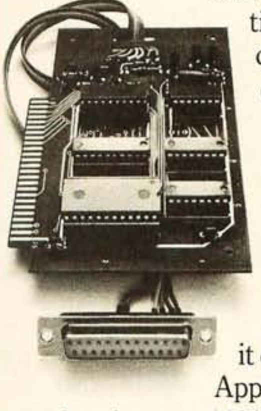

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A Programmable Character Generator

Part 2: Software

Larry Weinstein
Objective Design Inc
POB 20325
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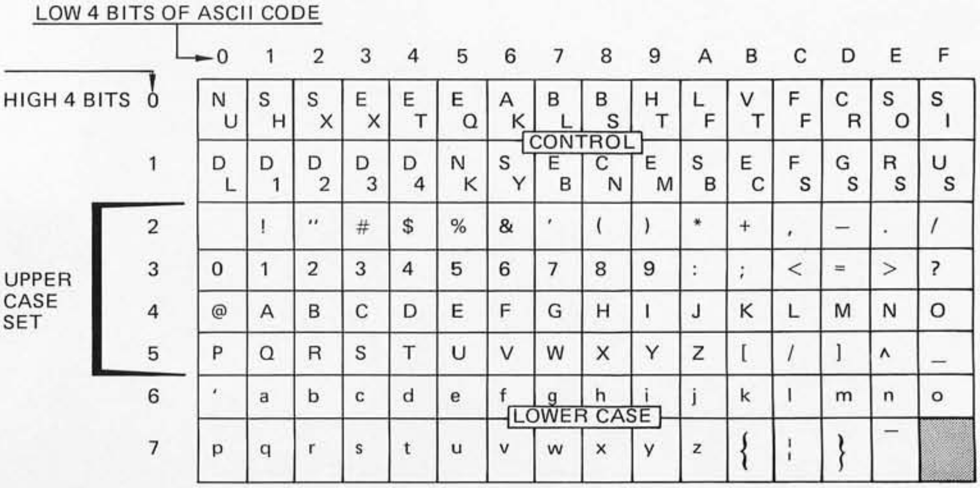
In part 1 last month (page 79), we saw that a programmable memory could be substituted for the character generator read only memory in a video display to create and use special character sets for special computer applications. With a small amount of additional software overhead, it is also possible to control high resolution screen graphics. The techniques for using the programmable character generator are detailed this month, and examples are presented.

Modes of Operation

Each character to be portrayed by a typical video display generator is represented by an 8 bit binary code, labeled B0 to B7. B7 often is not used for character selection, but rather serves a special hardware function: to key in reverse video, in the Processor Technology VDM-1, for example. The remaining seven bits are used to select from the 128 possible ASCII characters. These 128 characters are shown in figure 1. The programmable character generator allows the user to substitute, for some or all of these, characters created by the user (see figure 2). In each case the 7 bit code is used as an address in the character memory.

Programmable character generator circuitry selects the character data according to information present in the code itself and the operation mode. There are five such modes: fixed normal, fixed graphics, command, programmed, and automatic (part 1 of this article gave details on the selection process). In fixed normal, the programmable memory is never accessed. For the fixed graphics, command, and programmed modes, there is a simple connection between the character code and the programmable memory locations used to describe the characters.

Figure 1: The ASCII character set. The seven bits of the ASCII code indicate which of the 128 possible characters will be generated. The data used for producing these characters is usually stored in a character generator read only memory.



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1	DL	D1	D2	D3	D4	NK	SY	EB	CN	EM	SB	EC	FS	GS	RS	US
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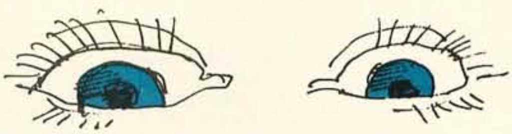

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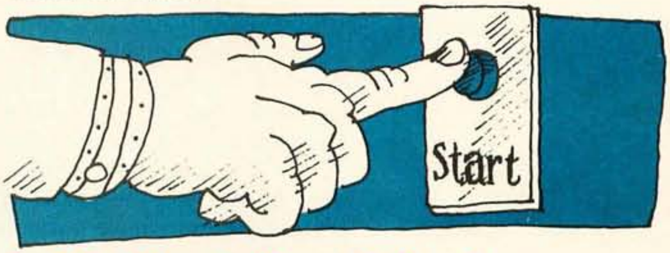

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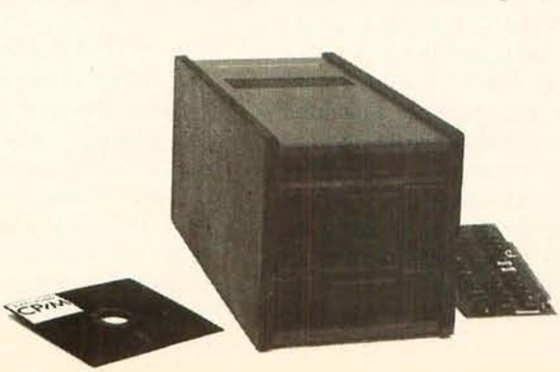

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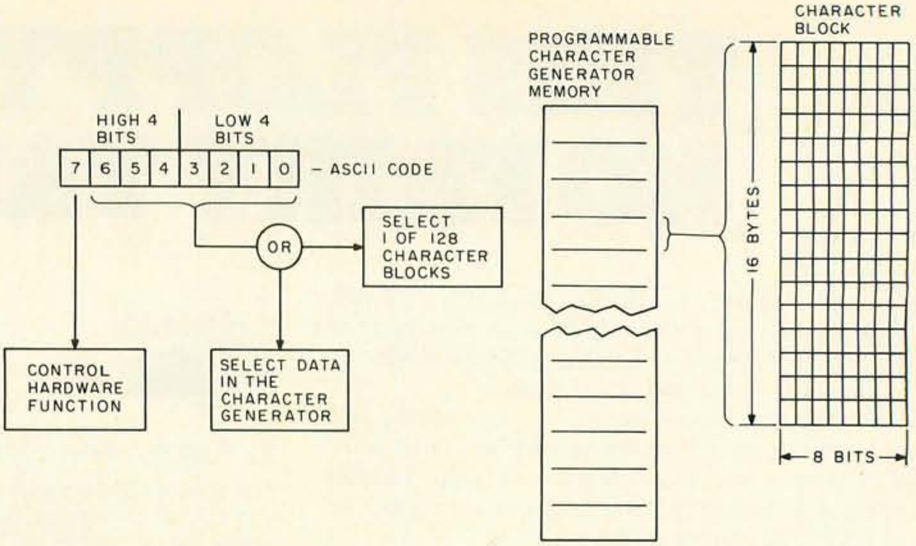

Figure 2: Decoding the code byte. The highest order bit of the 8 bit code is used for control hardware functions (such as reverse video). The remaining seven bits select character blocks in the character generator read only memory, the programmable character generator, or both (depending on what mode of operation is being used). Each data block consists of 16 bytes with eight bits. The 1s and 0s are converted to screen dots and spaces by the hardware.

The programmable memory is divided into 128 blocks of 16 bytes each, proceeding from low to high memory address. The seven code bits, from hexadecimal 00 to 7F, locate the block of 16 bytes used to describe the character. This is expressed by the simple formula for the address in memory of the first byte of a character block:

Address = Base address + [16 × code]

where "base address" is the lowest address of the programmable character generator memory, and "code" is interpreted as a number.

Each byte represents one row of the screen dots that form the character. Row 0 is the first byte (lowest address) in the block, and row 15 is the last byte (highest address). We are tempted at this point to say that row 0 appears at the top of a character space on the screen and row 15 at the bottom. But this is not always true, due to some hardware tricks in the various video display devices. For instance, in the Processor Technology VDM-1, row 15 is on the top, followed by row 0 and the other rows in order to 12. Since row 15 is always blank when generated by the character generator, this is not normally apparent. With programmable character generator characters, though, it will have an effect and must be dealt with in the hardware or software. We will assume, for now, that the rows are projected in numerical order.

The division of the programmable character generator's memory is slightly altered for the automatic mode (see figure 3). In this mode the 128 codes are split between the character generator and the programmable memory, with 64 characters being generated from each. The character generator produces all of those characters in what is normally known as the "upper case set." The remaining characters come from the programmable memory.

It is unfortunate that the split does not

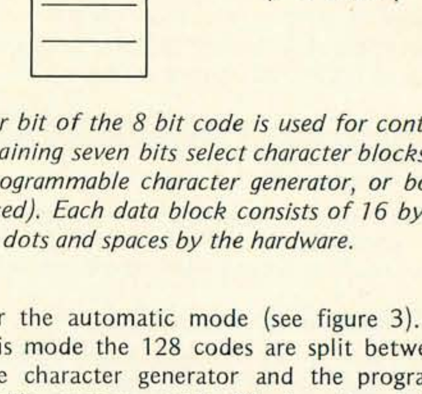

Figure 3: Automatic mode. In this mode, the upper case characters come from the existing character generator while the control character and lower case codes automatically reference 64 special characters in the programmable character generator memory. This is probably the most convenient mode of operation for many applications, since the normal upper case character set is available along with the special graphics characters.

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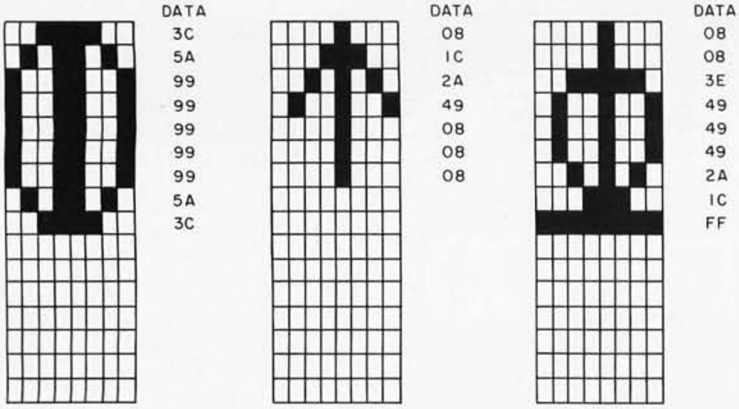

Figure 4: Some arbitrary special characters. The 16 bytes that form a character are projected onto a 16 by 8 grid, each bit corresponding to one space. The programmer can choose any combination of 1s and 0s to create filled and empty spaces, respectively.

take place in the center of the code numbers, as can be seen from the ASCII chart in figure 1. In order to neatly separate the programmable memory into special character and general purpose groups, the codes normally located in the top 512 locations can be moved to the second 512 spaces. In this case the low address 1 K of memory is devoted to special characters and the upper 1 K is free for system use. Automatic mode is probably the most convenient, since the normal character set used by most software is available, along with 64 special characters.

Photo 1: An APL character set generated by the programmable character generator.

Creating the Characters

The 16 bytes which form a character are chosen in a straightforward manner. The bytes are projected onto a simple 16 by 8 grid, where each bit equals one space. The spaces are roughly equivalent to dot spaces on the screen. The programmer constructs characters from filled spaces in the grid. When converted to data bytes, the filled spaces are 1s and the empty spaces are 0s (see figure 4).

In many cases, the circuitry in the video display device allows only a subset of the 16 rows to appear. Also, the eighth bit in each row is often left unused, although this can generally be "corrected" by an alteration. It is not necessary to dig through video display device schematics to learn which rows and columns are projected. A study of character generator characters on the screen plus some trial and error work with the programmable character generator will quickly reveal character limits.

The horizontal to vertical ratio of screen dot size is not 1:1 in most cases. For this reason, a grid composed of square spaces will not accurately portray the characters. The ratio of vertical to horizontal screen dot size can be calculated by:

$$\text{Size} = (\text{V dots}/\text{H dots})(4/3)$$

where 4/3 is the standard screen aspect ratio and V and H dots are the number of dots across the screen vertically and horizontally, respectively. For example, if each character is drawn on a 12 by 8 grid with a video display of 16 rows by 64 characters per row, one has:

$$\begin{aligned}\text{V/H size} &= \frac{(16)(12)}{(64)(8)}\left(\frac{4}{3}\right)\\ &= \left(\frac{192}{512}\right)\left(\frac{4}{3}\right)\\ &= \frac{8}{15}\\ &\approx \frac{1}{2}\end{aligned}$$

The grid should then be drawn with the vertical dimension of each space twice as large as the horizontal one.

Character Set Examples

There has been a great deal of interest lately in APL for microcomputers. The two great stumbling blocks have been writing the interpreter and displaying the unique APL character set. With the programmable character generator, producing the special character set is a trivial task (see photo 1).

Several of the characters are plotted here

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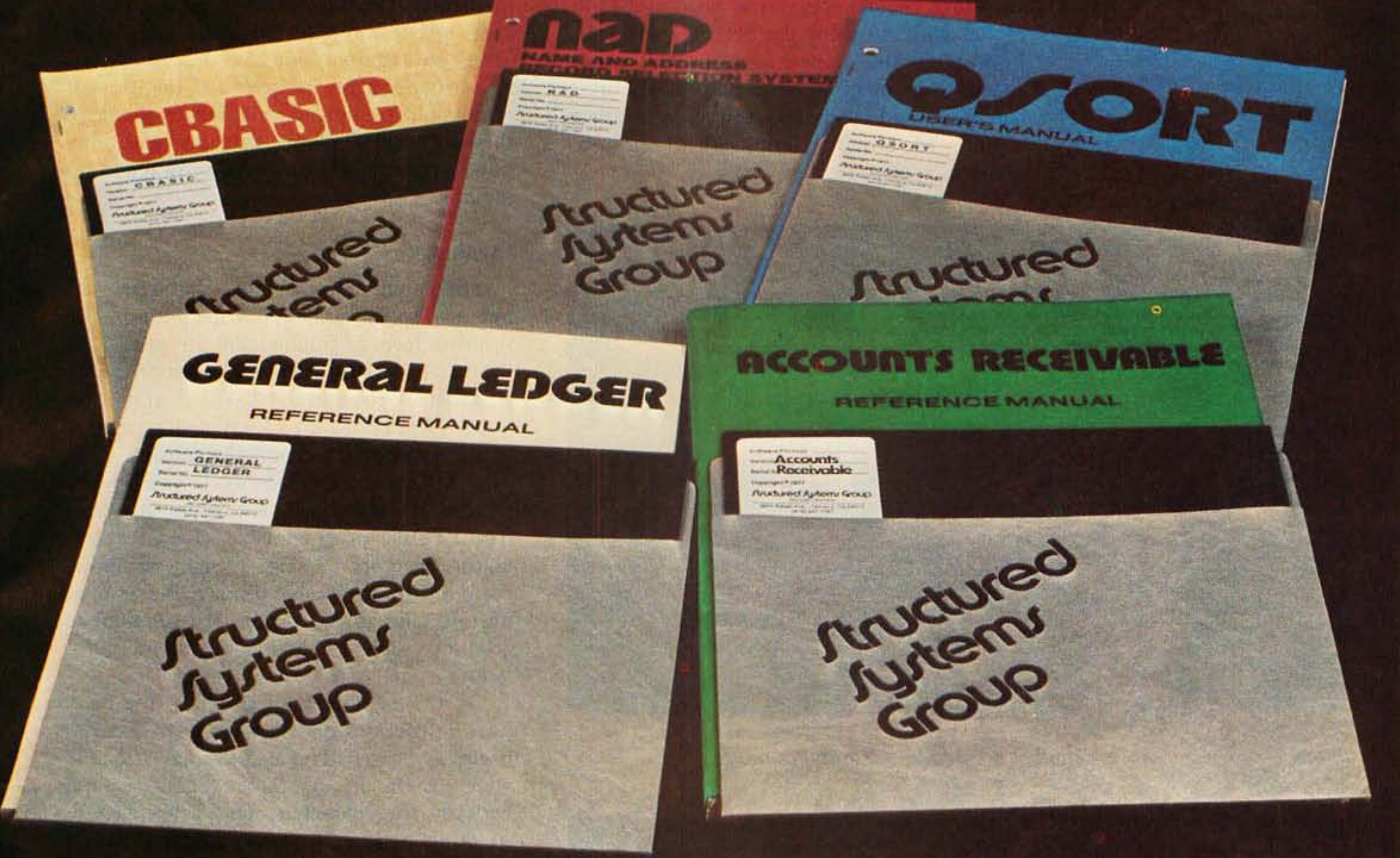

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with a simple grid. The automatic mode is used for the entire alphabet since the upper case character set is still needed. Placement in the programmable character generator's memory determines the keyboard code (and therefore, which keys) the characters will match with, so using the SHIFT and CTRL keys with the upper case set will cause special characters to be displayed. The user can easily add labels to a key set to produce a full APL terminal (minus all of the programming, of course).

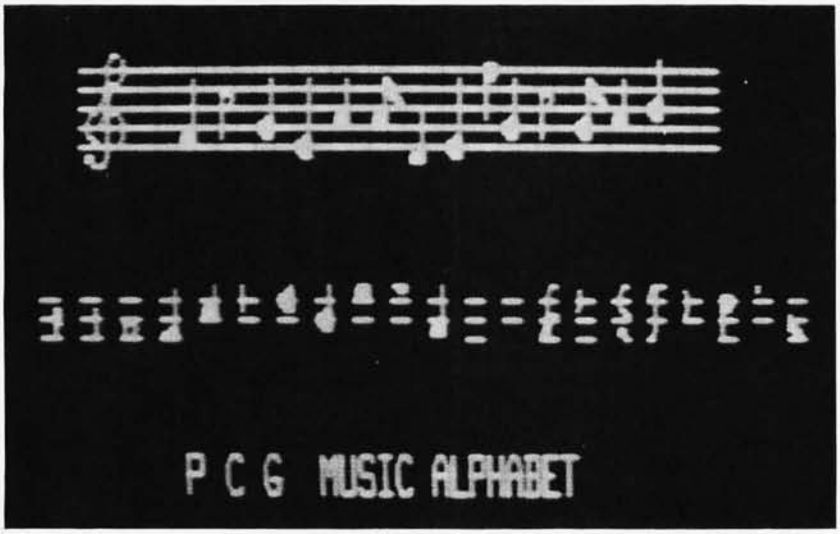

Photo 2: A special music alphabet created in the graphics mode.

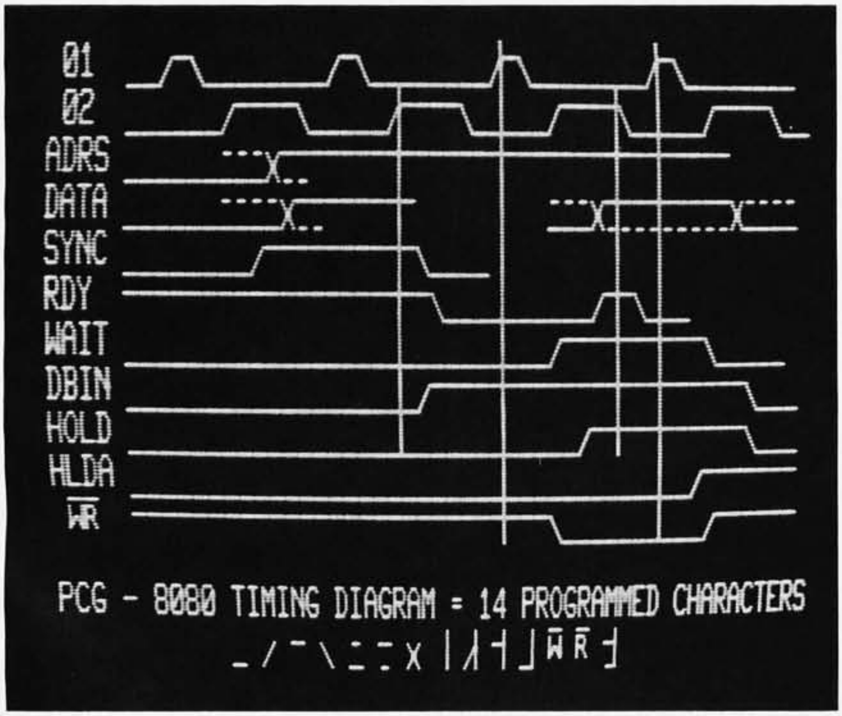

Photo 3: Timing diagram created in the automatic mode of the programmable character generator.

From this example, it should be obvious that any character set that will fit on the 9 by 7 (or larger, to 16 by 8) matrix used by the character generator can be generated. Also, multiple character sets can be stored in memory and swapped in as needed. In cases where more than 128 different characters are required, but all characters do not have to appear on the screen at one time, it is possible to dynamically create them. In this instance, a subset, possibly with only one element, of the set is swapped as required.

Graphics

The ability to create character sets implies some graphics capabilities. The simplest form of graphics will use an unusual character set, but still be handled as an alphabet. A good example is a set of musical notes (see photo 2). Each character is a single note, projected on the musical staff. The software overhead to create such a picture is very small, taking up less than half of the programmable character generator memory. Using a high resolution point by point graphic display, the amount of time and software overhead required to generate such a picture might be much larger.

At the next level of graphics, the hardware restrictions on the video display device begin to tighten. The ideal display is one in which there are no forced blank sections between the characters. This will enable us to build pictures from individual character elements. The next example is a timing diagram (see photo 3). In this case it is one for the 8080. The video display device used forces a single blank dot column between characters, which goes almost unnoticed. The diagram uses very few characters, but repeats them many times. Those who are applications oriented should note that storing this picture, or any picture constructed from this character set, requires only 1 K bytes for the screen memory and less than 256 bytes for the characters. Even a system with limited mass storage could hold all of the 8080 timing diagrams and information on the signals.

The bar graph picture in photo 4 is similar. However, its hardware restriction is mainly in the vertical direction. In this case it is best to eliminate the blanks between rows of characters as much as possible. Finally in the logic set (photo 5), the restrictions are tight in both horizontal and vertical directions. It should be remembered that while the human eye is capable of noticing even the smallest flaw in a picture, the human brain will "inte-

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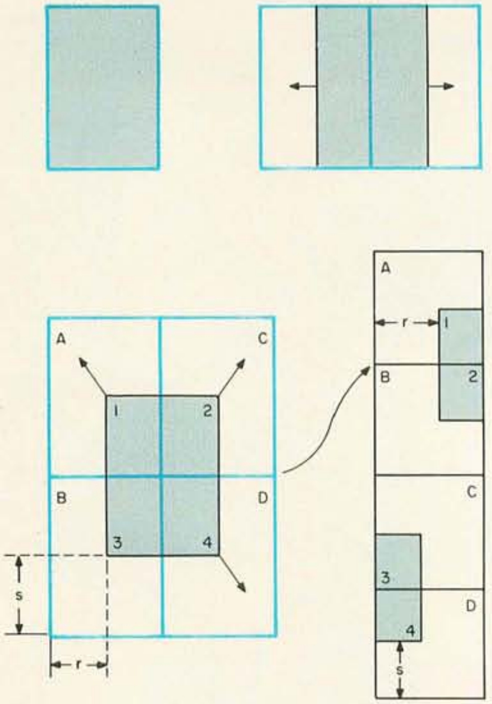

Figure 5: Dynamic generation. The user can cause a special character (such as a spaceship) to move smoothly across the screen by using the technique of dynamic generation. During its travel, the character can overlap up to four screen locations (the character is shown in color). Although the total number of characters needed to portray parts of the ship as it moves across the screen is quite large, only a maximum of four are needed at any time. These characters are generated by mapping the image onto the programmable character generator memory, with the mapping function determined by the screen position.

grate" the available information and make up for most imperfections.

Dynamic Generation

The previous examples have utilized a simple character set with frequently repeated elements. Now let us consider a case where this is not sufficient. We have a figure (it could be a spaceship) which must move smoothly across the screen. Assuming it is the same size as a single letter, it may overlap as many as four screen spaces at one time (see figure 5). Although the total number of different characters used to portray parts of the ship as it moves on the screen is quite large, only four are needed at one time. The total information on the screen appearance of the ship is contained in a single picture, requiring perhaps 8 to 12 bytes. The trick then is to dynamically create the one, two, or four characters needed at any one time from the basic ship picture bytes. This is done by mapping the image onto the programmable character generator's memory, with the mapping function determined by the screen position. For a changing object that also moves across the screen, it is only necessary to maintain different sets of picture "masters" from which to perform the mapping. If pictures larger than a single character space are required, they can be created by a repetition of the same process.

The applications of the programmable character generator are as varied and numerous as the characters it creates. Once its use is mastered, there is virtually no character set or graphic that cannot be portrayed with very low overhead in cost, memory, and programming effort. The examples I've shown in these two articles are but the first doodlings I've done with a flexible and powerful kind of display hardware. Users of this technique will find their displays limited only by imagination.■

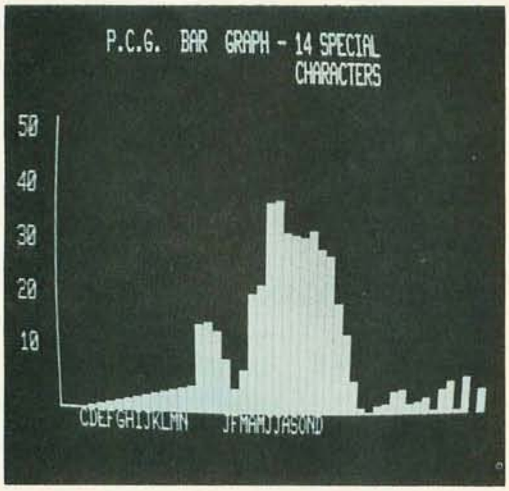

Photo 4: Bar graph created by the programmable character generator.

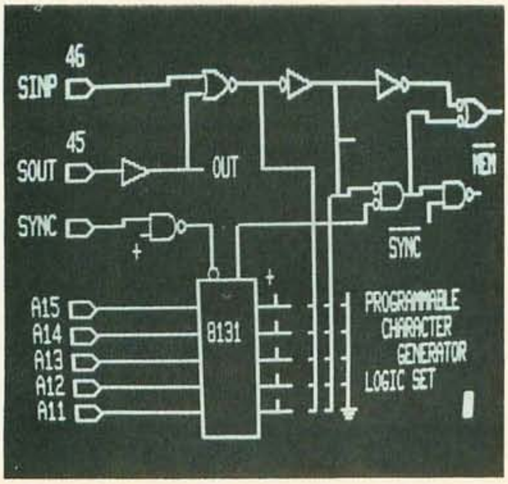

Photo 5: A logic diagram generated with the programmable character generator.

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Basic systems for personal computing

If you are just getting into personal computing and are looking for a starter system, you have two choices: a computer kit with RAM memory only or a fully assembled computer with BASIC-in-ROM. From reading this magazine and talking to computer buffs it should be obvious that it is desirable to have a computer capable of communicating in the programming language BASIC. This language allows you to instruct the computer in English-like phrases and to use any of the thousands of standard programs written in BASIC (there are probably several in this magazine).

If you purchase a (RAM-only) computer kit you will have to buy additional RAM (4K to 8K), a terminal, and cassette interface for a total cost of about $1000 to run BASIC after you get the kit together and working. Your reward for this endeavor will be a wait of about 15 minutes every time you turn the computer on just to load BASIC into the machine!

Your other alternative is a BASIC-in-ROM computer. These machines have BASIC built in so that it is there whenever the computer is turned on. BASIC-in-ROM computers are also usually fully assembled and cost far less than the RAM-only kits because they are mass-produced by the thousands.

But, you must be careful when selecting a BASIC-in-ROM computer. Some models do not have full-feature BASIC. Instead they have Tiny BASIC or 4K BASIC which cannot run most of the standard BASIC programs available. Still others have other shortcomings such as a small calculator-style keyboard which makes program entry difficult, or most important, lack of expansion capability, preventing the computer from growing with you.

Ohio Scientific offers you a line of expandable computers with full-feature 8K BASIC-in-ROM. They all come fully assembled and tested, but give you the option of economizing by supplying the simple things — power supply, keyboard and TV, if desired, so *that you* get the most computer power for your dollar.

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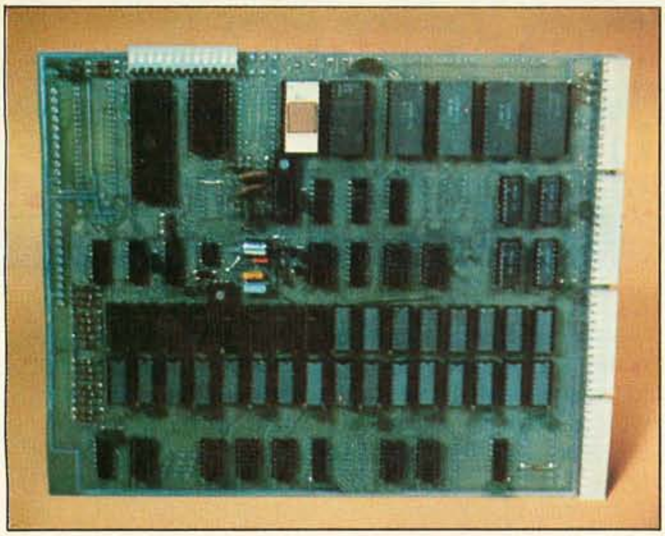
Having the fastest full-feature BASIC ROMs certainly isn't the only criterion necessary for a superior computer system, but it sure helps. Ohio Scientific offers all the other features necessary, including a full line of computer accessories complete with 15 accessory boards available in over 40 configurations. Many Ohio Scientific accessories are so innovative that no one else in the industry has them — such as dual port memory boards, multi-processing CPU's and big disks.

Ohio Scientific has other unique features for the personal computerist. For instance, there is Ohio Scientific's *Small Systems Journal*, published bi-monthly, a full magazine aimed specifically at the owners of Ohio Scientific computers. If you are looking for a personal computer, be sure to look carefully at Ohio Scientific. We think you will find that we have the system for you.



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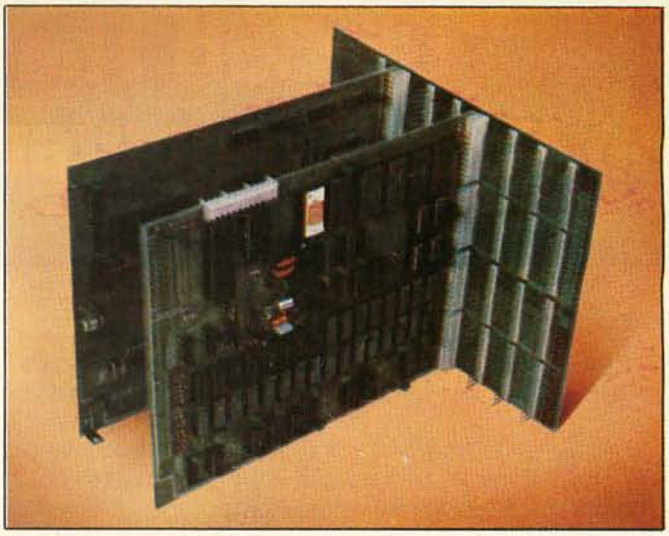

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We knew that all operating system commands and features should be an integral part of this BASIC language so we put them right in the BASIC itself. This means that all OS features can be accessed in the immediate or command mode and as part of BASIC programs. All syntax such as file names can be literal strings or BASIC variables.

We started with some simple but powerful extensions to BASIC to make the business system programmer happy—like $L, $R, INPUT #(D), and PRINT #(D). $L and $R are PRINT subcommands which automatically output numeric data in dollars and whole cents in neat columns just like "PRINT USING" only simpler and quicker.

The optional # specifier in LIST, INPUT and PRINT statements allows the user to route I/O directly to the console, 16 RS-232 ports, a cassette port, RS-232 and parallel printer ports and word processing printers, not to mention video displays and parallel keyboards.

We then added a continuous memory file system—the real achievement of OS-65U. This file system has no tracks, sectors or records. The user simply allocates storage capacity to each file when he creates it. (On a CD-74 Hard Disk this can be over 72,000,000 bytes or characters.) The user can then directly address every entry in the file with no awareness of any block, sector or track structures. Data files can simultaneously contain strings and pure numeric data. Files can be accessed sequentially *and* randomly.

Data files are handled with standard syntax including OPEN "File", CLOSE (File), PRINT % (File) and INPUT % (File) and the very special INDEX (File). INDEX is a special BASIC variable/function which specifies the file address of the next entry to be input or output to that file. If you leave it alone, it operates sequentially. However, you can change it at any time to force a random access. This remarkable function can be on either side of a BASIC equation and can take on any value within the storage range of an opened file. For example, all of the following are legal in OS-65U:

```
INDEX (1)  =  INDEX(1)  +  10  (Causes 10 characters to be skipped)
        B  =  INDEX (1)  (Sets B = current index)
INDEX (3)  =  INDEX(8)  /2 (Equates two file positions, useful in sorts and merges)
INDEX (5)  =  A*50  (Sets up a random access on an array with 50 character elements)
```

Where (N) is a channel number or shorthand notation for an open file, and is assigned by the OPEN command.

This may seem exotic but it is really super simple and incredibly powerful. Besides your files always automatically revert to simple sequential operation if you choose to ignore indexes.

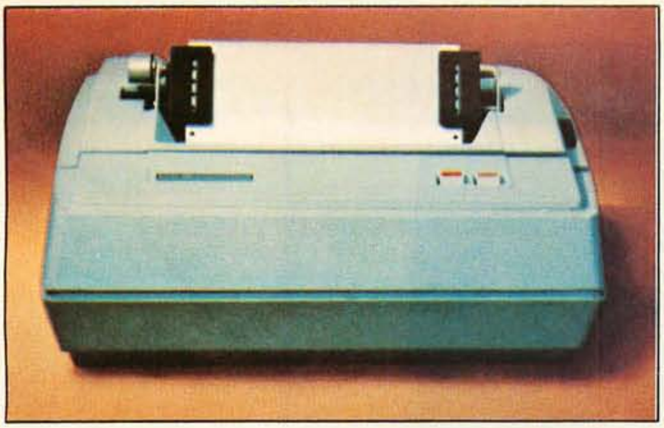
And, finally, for those of you who would really hate to give up plain old sequential files, we added a FIND command. FIND searches for up to a 32 character string with optional "don't care" characters and will automatically scan any file from the beginning or other specified index. The FIND command is implemented in straight line page zero 6502 code (the fastest programming technique on the fastest micro) and searches files at over 250,000 bits per second.

Only three statements are needed to support a sequential file in a BASIC program; only four to support a random file. A mere seven statements are required to use an indexed sequential file system as part of a program!

A Benchmark: A Challenger III equipped with a CD-74 running OS-65U can access any account entry in a 500 account one million byte randomly ordered ledger file by an alphabetic key string up to 32 characters long in less than 40 milliseconds (typically) using a simple two level ISAM file structure supported by a total program only 10 statements long. That's performance!

OS-65U also hosts multilevel passwords, elaborate error checking, programmable error recovery and end user niceties like warnings and automatic recovery when an "off" or non-existent peripheral is accessed. Programs and files in OS-65U can be fully secured so that they cannot be listed, copied or even accessed if desired.

OS-65U is available now for use on any Ohio Scientific floppy or hard disk based computer with 32K of RAM or more. At $199, it's quite possibly the best computer investment you'll ever make.



The Challenger III System

- Designed for small business computing.
- Uses the 510 triple processor CPU Board, runs 6502, 6800, 8080 and Z-80 programs.
- Available with up to 1 Megabyte of RAM memory; high reliability static RAM is standard; low-cost dynamic RAM is optional.
- Single- or dual-drive floppy disks store 250,000 characters per surface — 3 to 4 times the storage of mini-floppies.
- Supports our ultra-fast 6-digit BASIC (see "BASIC Timing Comparisons," Kilobaud, Oct. 1977, p. 23, where Ohio Scientific out-benchmarks all of our competitors) and our new super-fast 9-digit business BASIC.
- Powerful operating systems support all standard I/O ports including multiple terminals, line printers, video display and disk.
- Disk supports: sequential, random and index sequential files.
- Applications software, including:

  WP-1, a powerful disk-based Word Processor.

  DMS, a unique data-base management system which supports continuous disk addressing of up to 250,000 characters per file.

  Complete business packages including Accounts Receivable, Accounts Payable, Ledger, Payroll, Inventory and Taxes.
- Two factory-supported terminal options and two factory-supported line printer options.
- Optional 74-Megabyte hard disk for $6000. Reel-to-reel mag tape coming soon.
- Optional 16-user operating system with time share and distributed processing capabilities.
- Optional rack mounting and rack enclosures.
- Leasing programs and maintenance contracts available through many dealers. Optional nationwide field service coming soon.
- Challenger III systems have extremely high performance-to-cost ratios. For example, a system complete with triple processor CPU, 32K bytes of static RAM, a serial I/O port, dual drive floppy disks (500K bytes of on-line storage), fully assembled, plus DOS, BASIC and a demonstration program library costs $3590 fully assembled.

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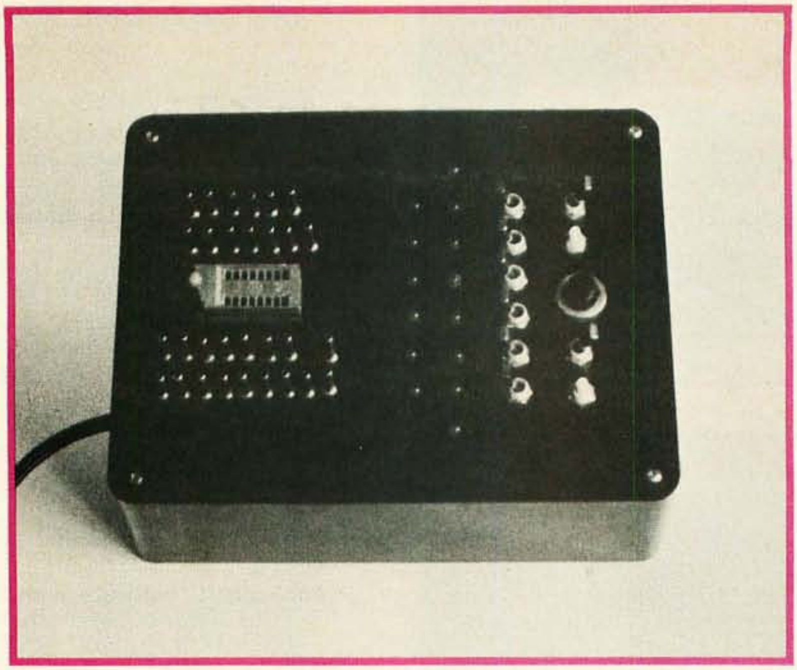

Photo 1: The prototype for the author's IC tester. The LEDs shown were not included in the final design of figure 1.

A Programmable IC Tester

Mark Thorson
1505 Spruce St
Berkeley CA 94709

The high cost of digital components can be significantly reduced by the construction of this simple test instrument. While components of questionable reliability have long been available for a fraction of their value, the experimenter has been unable to take full advantage of them for lack of an adequate means of component testing. This circuit, however, now offers such a means for the rapid and accurate screening of bargain components.

Conventional component testing generally takes the form of either building a prototype circuit and substituting devices until it works, or setting up a rig of lights and switches and testing each gate or flip flop on the chip individually. Although these procedures are sufficient for the construction of trivial circuits employing a small number of integrated circuits, neither is exacting enough nor fast enough to provide the quantity or quality of parts required for a well stocked electronics lab. The main weakness of both approaches is their failure to check the devices in question under *all* possible conditions of data. As an example, consider the 7400 quad NAND gate with the failure condition of an internal short between the input on pin 4 and the output on pin 3. If this device is either tested in a circuit employing the quad NAND gate without using the input on pin 4, or tested in a rig in which each gate is tested individually, then the device will be passed without the failure conditions ever having been met. To be certain of testing all possible failure modes of this device, all 256 possible data conditions on the eight device inputs must be checked, a prohibitive requirement for manual testing.

To this end, the circuit shown in figure 1 has been designed to provide an automatic, instantaneous and exhaustive test of most SSI and MSI components. [SSI (small scale integration) refers to gates, inverters, flip flops, etc, while MSI (medium scale integration) refers to counters, latches, shift registers, etc.] The circuit operates by sending eight lines of input data to the device under test (DUT) and receiving six lines of output. Upon depression of

About the Author

Mark Thorson is currently an undergraduate at the University of California at Berkeley majoring in neurobiology, and has been working with digital logic since sixth grade. (Early efforts involved discrete components and incandescent lamps.)

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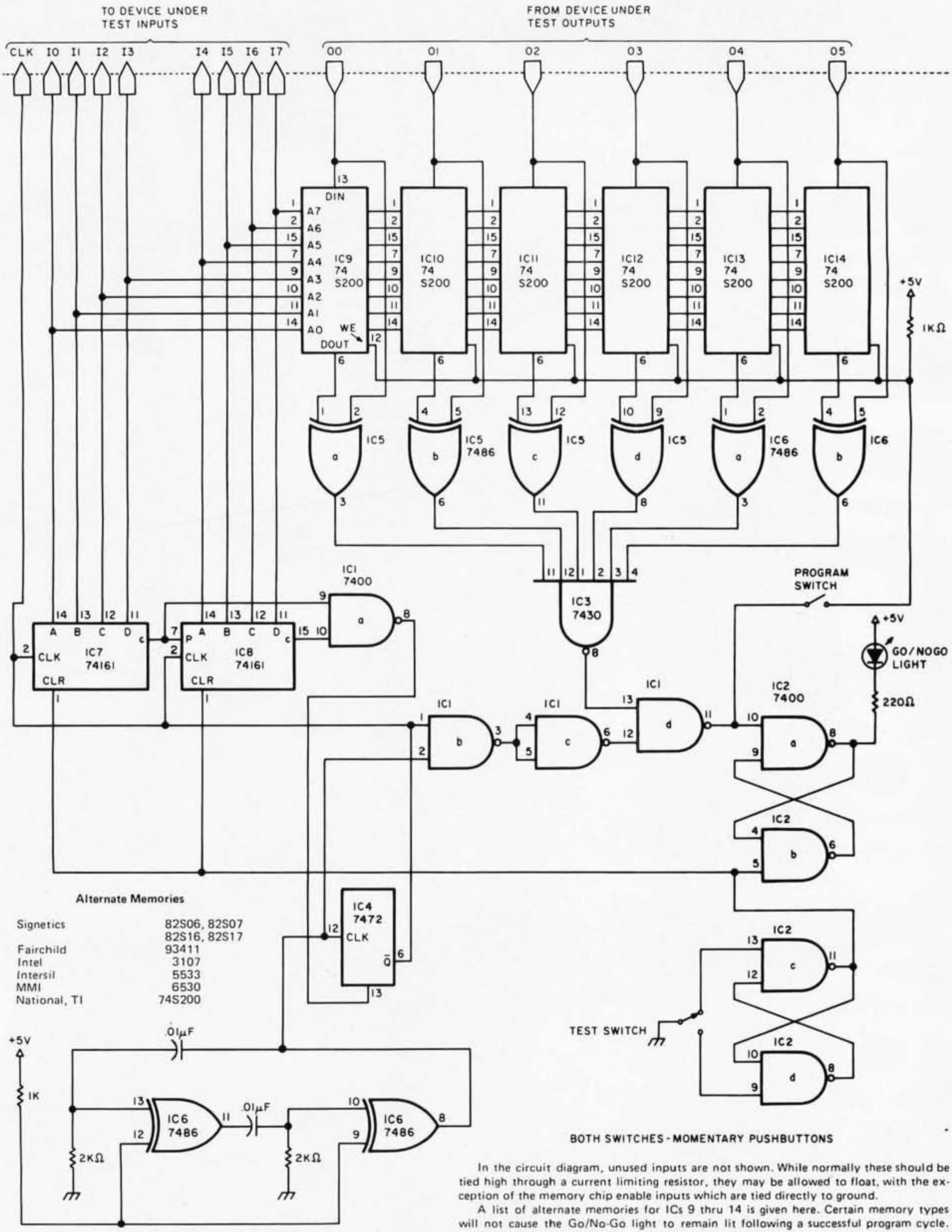

Alternate Memories

Signetics	82S06, 82S07 82S16, 82S17
Fairchild	93411
Intel	3107
Intersil	5533
MMI	6530
National, TI	74S200

In the circuit diagram, unused inputs are not shown. While normally these should be tied high through a current limiting resistor, they may be allowed to float, with the exception of the memory chip enable inputs which are tied directly to ground.

A list of alternate memories for ICs 9 thru 14 is given here. Certain memory types will not cause the Go/No-Go light to remain lit following a successful program cycle. This is because some memories lock out their data outputs while being written into. This can be remedied by running a test cycle after the program cycle. The Go/No-Go light will remain lit following the test of a known good device if the data in the memories is accurate.

Figure 1: The author's automatic integrated circuit tester. The unit is connected by probes to the inputs of the integrated circuit under test (up to eight inputs can be accommodated). 256 different combinations of logic levels are sent to the integrated circuit, and a running comparison of up to six data outputs from the device is made with a set of results stored in memory for another integrated circuit of the same type that is known to be good. Any deviation from the accepted pattern causes an LED to be lit. The unit is capable of testing both combinatorial ICs, such as logic gates, and sequential ICs, such as flip flops. A learn mode allows the tester to store the characteristics of virtually any TTL integrated circuit in memory for testing.

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Number	Type	+5 V Pin	Gnd Pin
IC 1	7400	14	7
IC 2	7400	14	7
IC 3	7430	14	7
IC 4	7472	14	7
IC 5	7486	14	7
IC 6	7486	14	7
IC 7	74161	16	8
IC 8	74161	16	8
IC 9 thru IC 14	74S200 (or equivalent)	16	8

Table 1: Power wiring table for figure 1. See figure 1 for alternate memory ICs for IC9 thru 14.

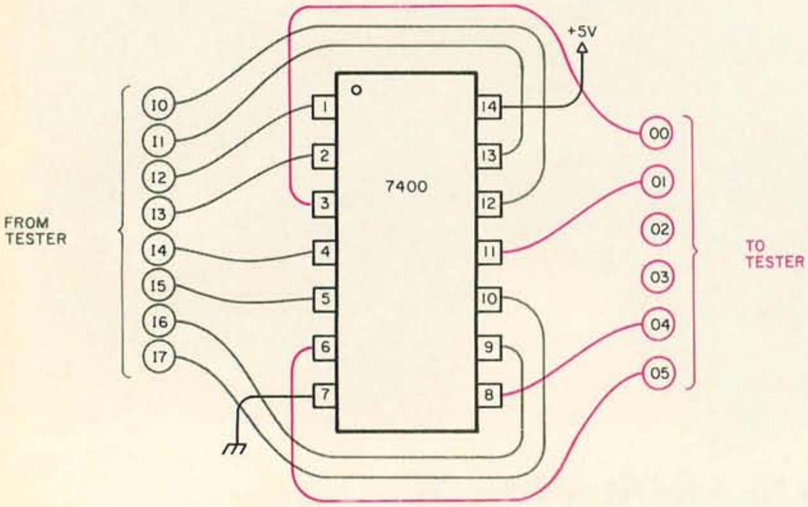

Figure 2: One method of hooking the tester up to a 7400 TTL integrated circuit.

the Test button, the binary counter driving the DUT input lines is cleared and the flip flop driving the Go/No-Go light is set. Upon release, the counter increments through all 256 input conditions to the DUT. Between counts, the data on the six DUT output lines is compared with the data stored in memory, and if any mismatch occurs, the Go/No-Go flip flop is cleared. Once the counter reaches its terminal count, the clear input to the clock oscillator flip flop is driven low, thereby inhibiting further counts until the Test button is hit again. At this time, if the Go/No-Go light has remained lit, the component has passed the test. Programming is accomplished by holding the Program button down during a test cycle of a known good device. During this time, data on the DUT outputs is loaded into memory between counts on the DUT input lines. Once the PROGRAM button is released, data in the memory is protected by a pull-up resistor on its read/write line.

Combinatorial integrated circuits, that is, integrated circuits such as gates or comparators which do not contain storage elements such as flip flops, are tested by connecting all device inputs to lines I_0 to I_7 and all device outputs to lines O_0 to O_5. Any ordering of the connections is satisfactory, because the tester will run through all possible input conditions despite the arrangement used. Sequential integrated circuits, however, require special consideration due to their internal data states. A device such as the 74161 4 bit binary counter, for example, will require its clock input to change at least 32 times faster than its clear input to insure the completion of a full counting cycle before being cleared. To aid in the testing of sequential integrated circuits with several clear, preset, inhibit, and other combinatorial inputs, the clock input has been provided which toggles twice as fast as I_0. This input is useful for connecting to the clock input of counters, flip flops, and shift registers, but should not be used with combinatorial devices or the combinatorial inputs of sequential devices.

As an example of the use of the tester, consider again the 7400 quad NAND gate. This device has a total of eight data inputs and four data outputs to be connected. An example of one possible configuration of the connections is shown in figure 2. It should be noted that two DUT outputs are allowed to float. This is permissible, because the same data will be present during a test cycle as when the tester is programmed. It is also acceptable to use less than eight DUT inputs, because the tester will still run through all possible data conditions on the remaining inputs. Once the proper connections have been made, the tester is programmed by inserting a known good device into the DUT socket and holding the Program button down while momentarily depressing the Test button. If the tester has accurately stored the characteristic output of the device, the Go/No-Go light will remain lit following the release of the Test button. The Program button may now be released and tests performed by inserting a questionable device and depressing the Test button. If the Go/No-Go light remains lit upon release of the Test button, the device has passed.

As an example of the testing of a sequential device, consider the 74161 4 bit binary counter. An example of one possible configuration of its connections is shown in figure 3. Unlike the case of the quad NAND gate, the ordering of the DUT input connections is very important. Combinatorial inputs such as clear, load, and inhibit are

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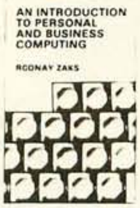

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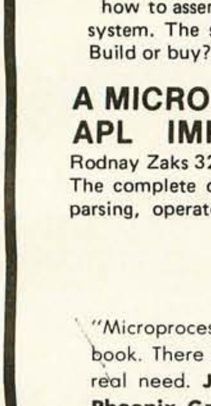

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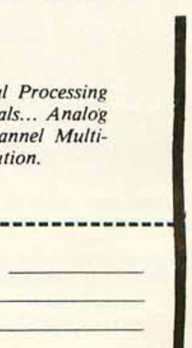

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put on the more slowly toggling lines I_4 to I_7, and the sequential inputs are put on the faster lines I_0 to I_3. This example also illustrates the use of the clock line for the clock. It should be noted that there is a minimum separation of four lines between the clock and any combinatorial input. As previously stated, this is necessary to allow the counter to complete a full counting cycle. Strictly speaking, the presetting inputs to the counter are also combinatorial inputs, but they do not interfere with the counting cycle, so they may be placed within four lines of the clock. They are, however, synchronous inputs and as such may not be placed on a DUT input line which toggles faster than the clock. Also, while the ordering of the DUT inputs is important (for reasons just explained), there are no restrictions whatsoever on the ordering of the DUT output connections. Connections between the integrated circuit tester and the DUT socket should be made via banana plugs, matrix switches, or other forms of connection which readily permit modification. The DUT socket itself should be a zero insertion force (ZIF) type socket (Textool or equivalent).

Expansion of the testing capacity of the unit can be achieved by extending the counter length or the memory size, but it has been my experience that the combination of eight inputs and six outputs has proven ideal for testing most standard TTL components. In my first prototype (see photo 1), a single step feature was provided by switching in a debounced pushbutton switch in place of the oscillator, and placing LED indicator lights on the DUT inputs and on the memory data outputs. This made it possible to examine the memory once it had been programmed and verify that the tester was really doing what it was supposed to do. This feature was also necessary because the original version had to be programmed manually, but the 10 to 15 minutes required to program the tester for even a device as simple as a quad NAND gate made the advantages of autoprogrammability quite apparent. Nevertheless, the single step feature may prove useful to the hobbyist who may wish to use this instrument as a logic analyzer. Other features that may prove useful would be the addition of low power TTL buffers on the DUT outputs to permit testing of CMOS integrated circuits, miniaturized construction for portable operation, and installation of an ammeter in series with the DUT socket power input pin to provide a measure of power dissipation.■

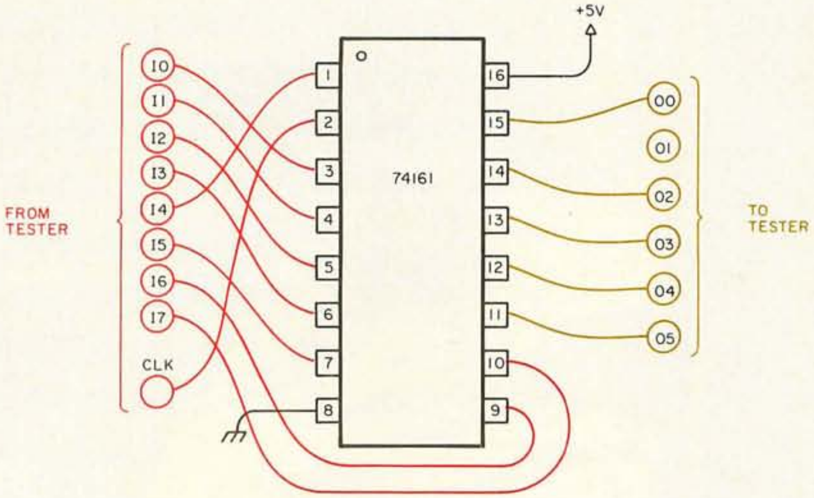
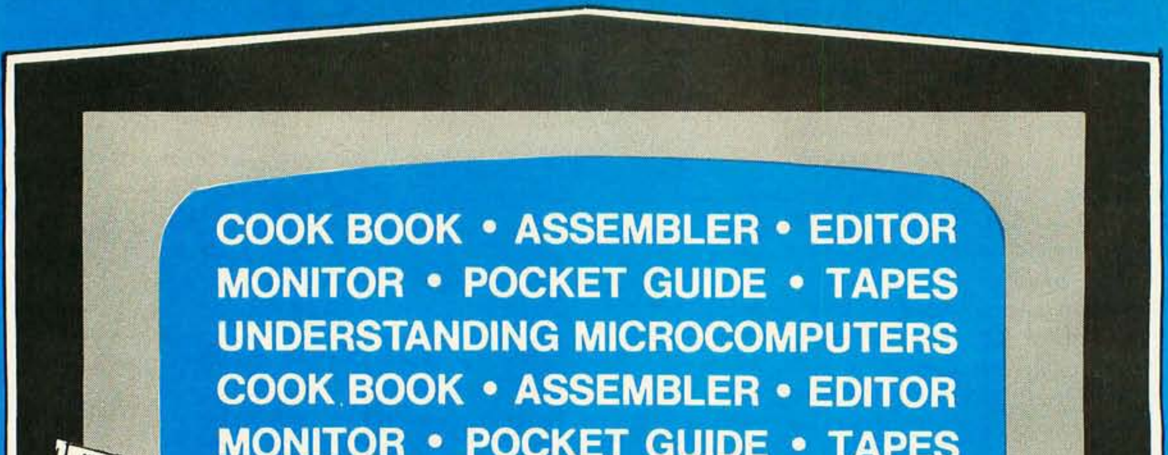
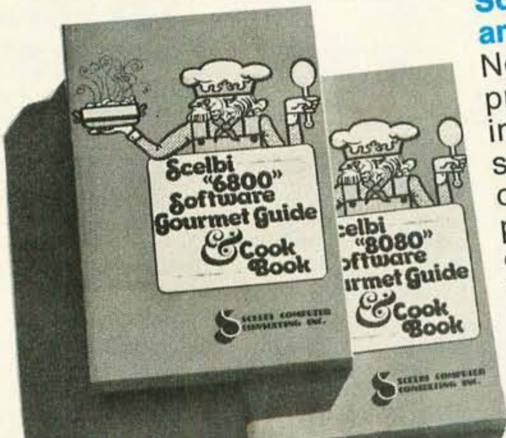


Figure 3: Tester hookup for a TTL 74161 integrated circuit. Note the use of the clock line coming from the tester. This is to ensure that the integrated circuit receives clock signals of the proper speed relative to the other test input lines.





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Natural Language Processing and Small Systems

Harry Tennant
1001 W Oregon #1
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Introduction

What can possibly be said about the use of natural languages, that is the languages people use, with small systems? Where research is done on natural language processing, it is done on the largest computers available. To many computer scientists, the problem of enabling computers to understand natural languages at a reasonable level of competence is beyond the current technology. Consider what are probably the two best natural language processors yet produced by computer scientists: William Woods' LUNAR system which answered questions about rocks brought back from the moon, and Terry Winograd's system which manipulated blocks on a table in response to English commands; both are quite large programs. LUNAR uses one task with 256 K 36 bit words to discover the meaning of the user's query, then uses another task of 256 K words to answer the question. One question could take from three to 20 seconds to answer. Winograd's system did not need the quantity of data that Woods' system needed, but it still required 60 K words of 36 bits to operate in its limited world, consisting of a few blocks on a table. These are just two examples of the many natural language processing projects which have been conducted in recent years. These two (from the early 1970s) and nearly all the others since then share the property that they are large projects done on large machines using large amounts of memory. So what can possibly be said about natural language processing and small systems?

The small system user is severely limited: he or she has comparatively little memory to work with, few languages to choose from (and those languages are not particularly suited to the needs of natural language processing), and usually few aids to software development, such as secondary storage, editing facilities, and debugging facilities. But among small systems users, there is a growing interest in the application areas of artificial intelligence: intelligent game playing, math, science and engineering aids, robotics, and natural language processing. In this article the general problems of computer based understanding of natural language are discussed briefly, and a few techniques that can be used on small systems to do a limited amount of natural language processing are presented.

Attempts have been made since nearly the dawn of computer history to make it possible for computers to understand the languages of people. It began as translation between natural languages, for example, from Russian to English. That kind of work was not successful. Later, research moved into the areas of natural language query of data bases and the study of the structure of human thought and memory through the modelling of human language behavior on computers. This is the work that is being done today. It looks promising, but it is still too early to tell if the work will actually provide users with the ability to communicate their thoughts to computers as efficiently as humans communicate with one another.

Natural Language Understanding on Computers

A conversation between two humans could proceed something like this:

Sam: Joe, how's your micro coming?
Joe: OK. I've moved on to the video cards.
Sam: When did you finish the cassette interface?
Joe: Last week. It took long enough for the chip to come.
Sam: Yeah, that's why I always deal with the fastest companies.
Joe: What do you think of the new video timing generator?
Sam: It will save some board space and maybe some money, too.

We do not know much about Joe and Sam, but we do know from this conversation that they both know something about microprocessors. We know that Joe is building one and that Sam knows quite a bit about it. When asked how his micro is coming, Joe thought of his computer, the problems he's had on it, the last section that he has been working on, the sections that have already been built . . . in other words, a great deal of information about his computer came to mind. Joe then thought of what Sam knew of the computer, and chose a relevant piece of information that Joe thought Sam did not know, and said that he was working on the video section. Now, Sam knows a lot about the computer, too. He is thinking about it just as Joe is. And so the conversation proceeds. Both Joe and Sam know a great deal about the computer. Both know about the problems of building a microprocessor, parts availability, etc. Their conversation is short, it uses few words, but it manipulates very large information structures in each of their minds as the conversation takes place. The conversation is not just a trickle of words between Joe and Sam, but it is mainly an activity inside their brains involving a great deal of information. The trickle of words is not what is really going on, it just triggers what is going on. The real activity is happening in the minds of Joe and Sam.

Now, what about a conversation with a computer? If it were to happen as the conversation above did, the computer would need to know a lot about the microcomputer that is being built. In other words, the computer would need knowledge very much like Joe's and Sam's. It would have to have some way of representing information about microcomputers: what they are made of; how they are built; the particular microcomputer being discussed; its state of completion; and so on. In addition to this, there must be some way for the computer to discover what the words in the conversation are referring to. How does it know that the conversation is about microcomputers, for instance? The word "micro" could refer to a microbiology program. As if that were not enough, let's say that the computer did interpret the first question correctly, did have information about the microcomputer, and decided on something to tell the questioner. It then has the task of presenting the information to the questioner in a form that he will understand. Add to this problem that humans converse on a wide range of topics, and learn about new topics without even trying, and the problem of enabling a computer to converse like a human becomes a large problem indeed. A full solution to the problem is a long way off, and quite possibly will require hardware beyond what is available today (a HAL 9000, perhaps?). But there are many steps toward natural language processing that can be done without a HAL 9000 and without 30 years of research and development.

As mentioned above, there are three main problem areas in natural language processing:

1. Representation of knowledge
2. Associating words with ideas
3. Presenting ideas

The problem of presentation of ideas by a computer will not be considered explicitly. Representation of knowledge and associating words with ideas will be considered in the next sections.

Representation of Knowledge

Before we approach the problem of representing knowledge on a computer, it may help to decide how to represent knowledge on a piece of paper. The first thing to decide is exactly what we want to represent.

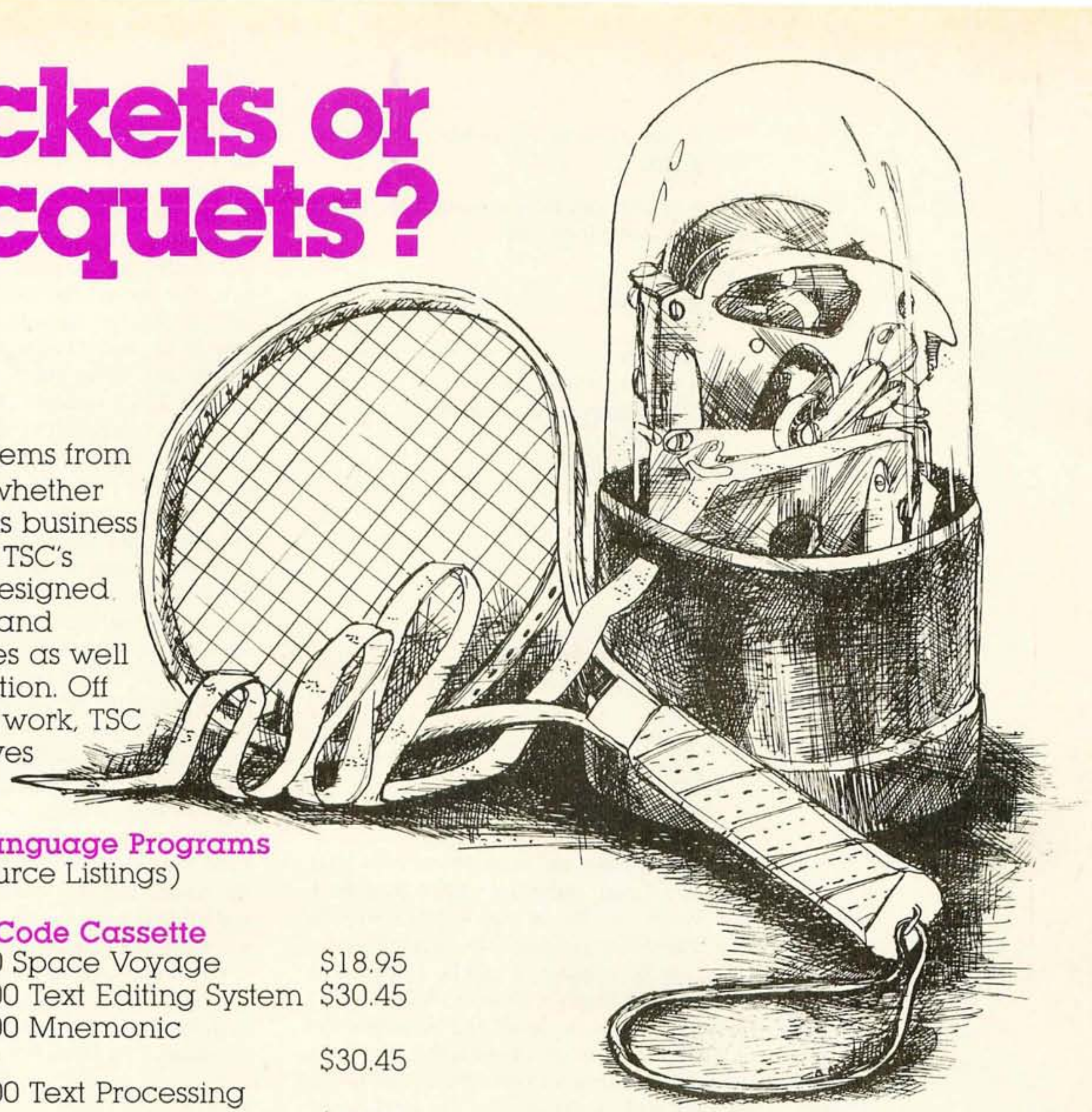
Consider the microcomputer systems in figure 1. If we want to be able to converse with a computer about such systems, we need some way of storing what is known about them. Some of the things we know about System 1 are:

1. It has an 8080 microprocessor.
2. It has 1 K of read only memory.
3. It has 2 K of programmable memory.
4. Its only output is lights.
5. Its only input is a keyboard.

We know the following about System 2:

1. It has an 8080 microprocessor.
2. It has 1 K of read only memory and 1 K of programmable memory.
3. It has a scale as an input device (it is a digital scale).
4. It has a small keyboard as input.

Rackets or Racquets?



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5. It has as output a display of decimal digits.

The system can be represented hierarchically (in outline form) as:

System 1
1. Processor
   8080
2. Memory
   1 K read only memory
   2 K programmable memory
3. Output
   Lights
4. Input
   Keyboard

System 2
1. Processor
   8080
2. Memory
   1 K read only memory
   1 K programmable memory
3. Input
   Scale
   Keyboard
4. Output
   Decimal display

Now suppose we want to use this data base to answer questions about System 1 and System 2. (Note that a data base like this could be extended to include many other similar systems. It can be extended to as many as memory will allow. But, consider how trivial it is in detail and breadth compared to a human's knowledge. For this reason, one cannot expect the computer to respond with anything like the intelligence of a human. The relevant questions are 1) is there enough data in the data base to make it worth doing and, 2) is the English interface to the data good enough to warrant making it.) When asked what the processor is for System 1, we consult our outline of System 1, look under "Processor," and reply that it is an 8080. When asked what the output for System 2 is, we consult the outline for System 2, look under the output to find "Decimal display," and we return that. When asked about the inputs to System 2, we respond that they are a scale and a keyboard. But note that a more complicated problem arises if we ask what kind of processor is in the system that uses the scale. First we must find all systems that use scales (we may not even realize that a scale is an input device). For all the systems using scales, we must then find what their processors are, and return that information. This is not a problem if we have only two systems, as in the example. But if we had many systems whose outline descriptions filled many sheets of paper, searching all the descriptions for the ones that use scales could be a major effort. One of the advantages of natural language is that items can be referred to by their descriptions instead of their names. We referred to System 2 not by its name, but by its description, ie: the system that uses a scale. Because this is such an important feature of natural language, it is very important to be able to deal with it. One way of doing so is to make a new set of outlines for each of the items mentioned in the original outlines. For example:

8080
1. Processor in
   1. System 1
   2. System 2

1 K Read only memory
1. Memory in
   1. System 1
   2. System 2

1 K Programmable memory
1. Memory in
   1. System 2

2 K Programmable memory
1. Memory in
   1. System 1

Lights
1. Output of
   1. System 1

Scale
1. Input of
   1. System 2

Keyboard
1. Input of
   1. System 1
   2. System 2

Decimal display
1. Output of
   1. System 2

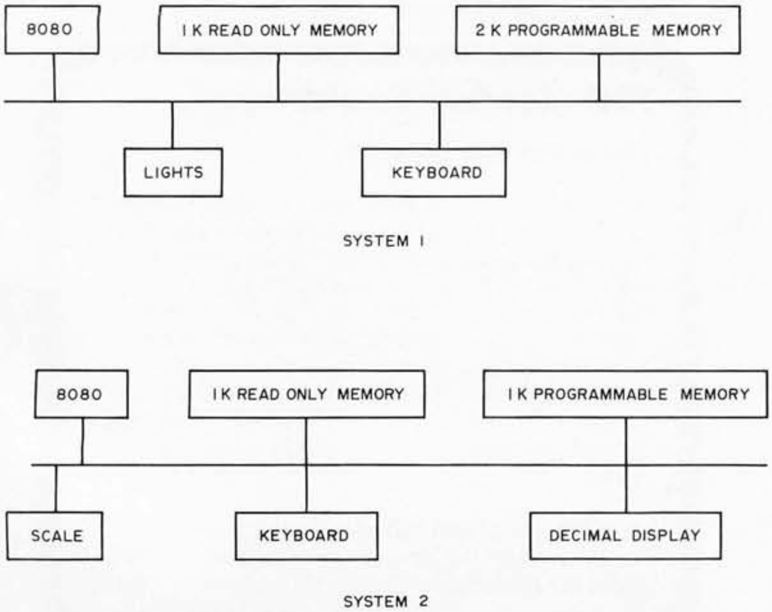

Figure 1: System 1 and System 2 diagrammed as components connected to a common bus.

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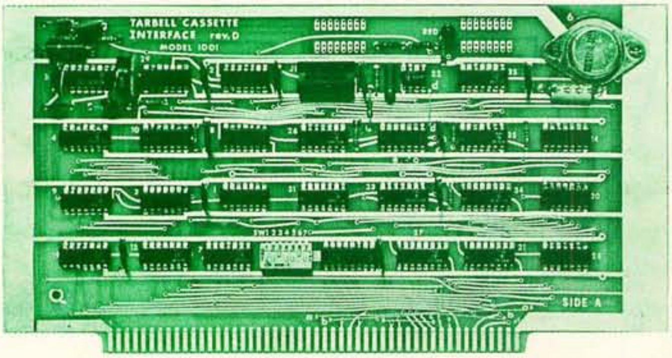

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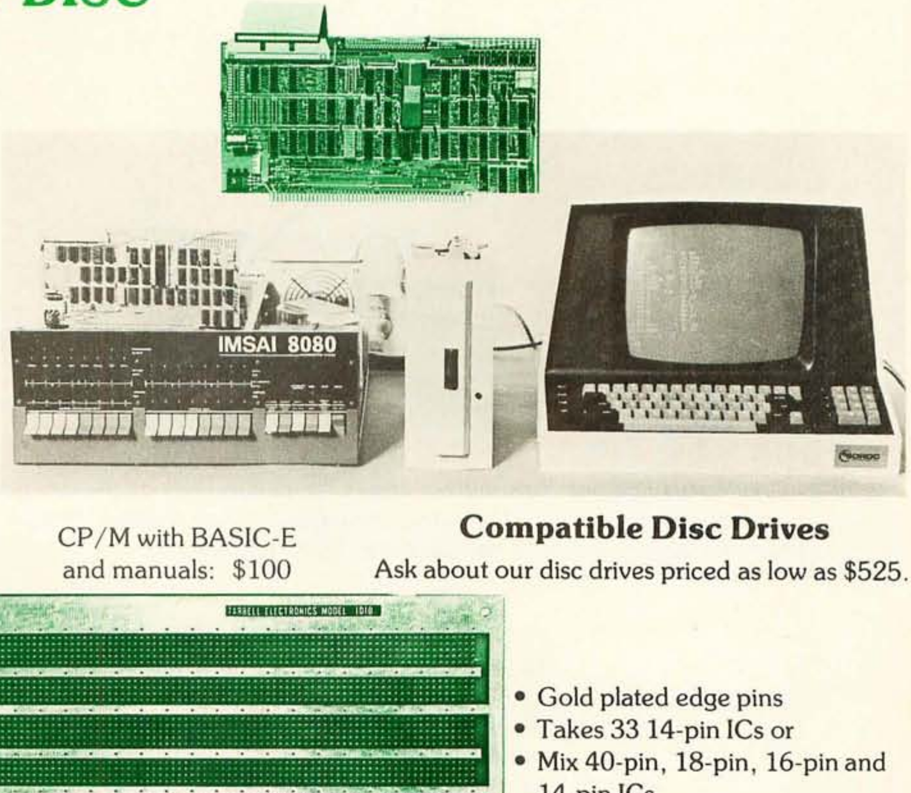

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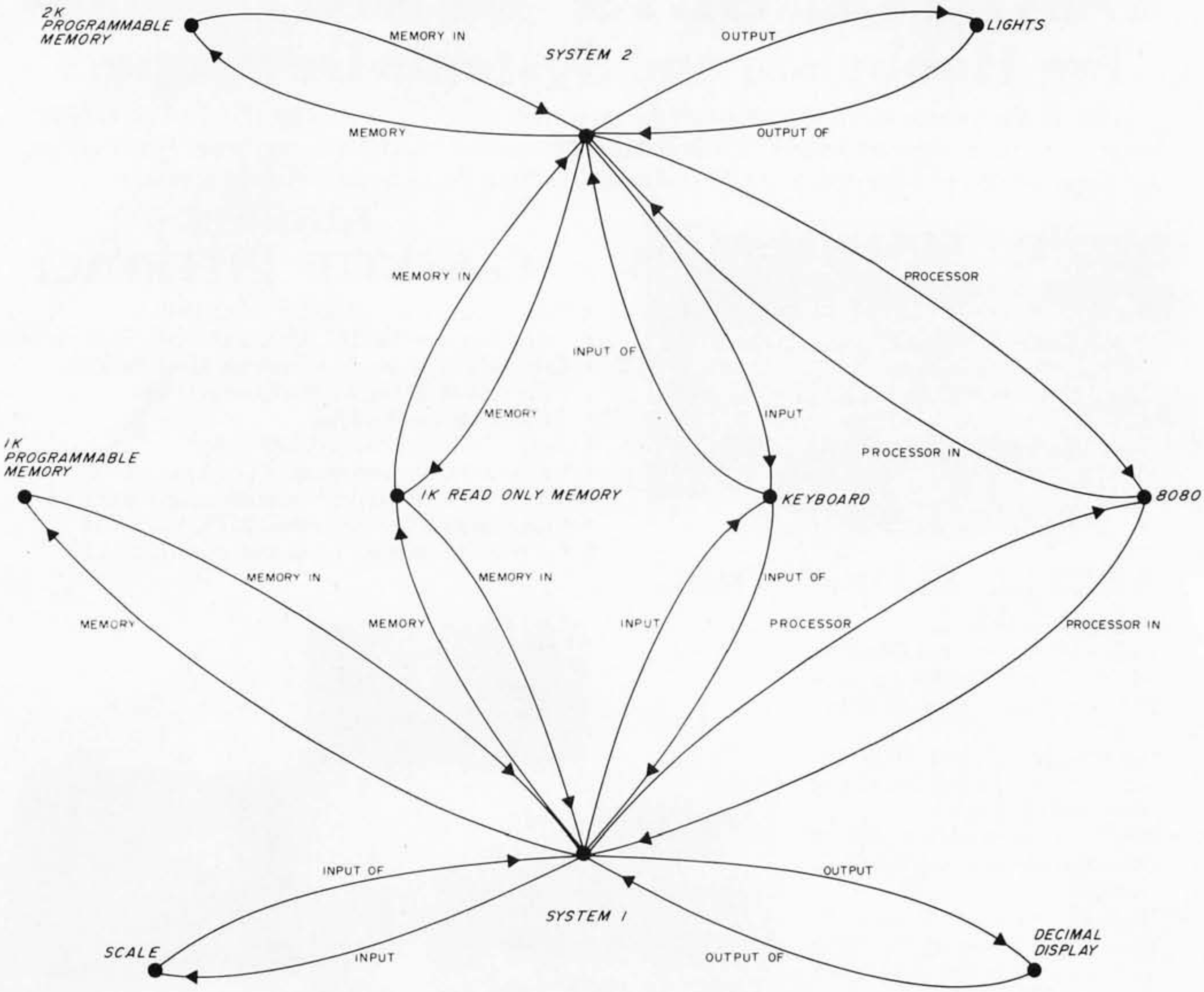

Figure 2: Simple semantic net. This net represents the connections of the components of System 1 and System 2. Each component is represented by a node. The nodes are related to one another through labelled links. Notice that the names chosen for the links and nodes are largely at the discretion of the net designer.

Now, think again about representing a large number of systems in this way. It will take more memory, but it will provide access to items such as scale or 8080. If a hundred systems are represented on sheets of paper, we would probably have an index or table of contents to direct us to the appropriate page to find the outline we seek, thus speeding up the response. I have not forgotten that in many small systems the trade-offs between memory and processing time often are in favor of saving memory space. What is presented here is intended to illustrate the trade-offs, not to make the decisions for the user.

It is easier to see this type of representation when it is presented in graphic form. The representation used in figure 2 is called a semantic net. Each outline is represented by a node and the relationships between nodes are represented by directed labelled arcs. The idea of a semantic net is that nodes are entities and arcs are relations between entities. The net shown in figure 2 is not the way most natural language researchers would represent the information about our two systems. For example, "System 2" is the name of something, it is not the thing itself. An 8080 is a part of the thing whose name is "System 1," and that thing that is called an 8080 has the function of "Processor" in the thing called "System 1." A diagram of representation like this is shown in figure 3. It is more explicit and more correct than the representation of figure 2, but is harder to build, more difficult to interpret, and requires more memory to represent.

Semantic nets, in whatever form one

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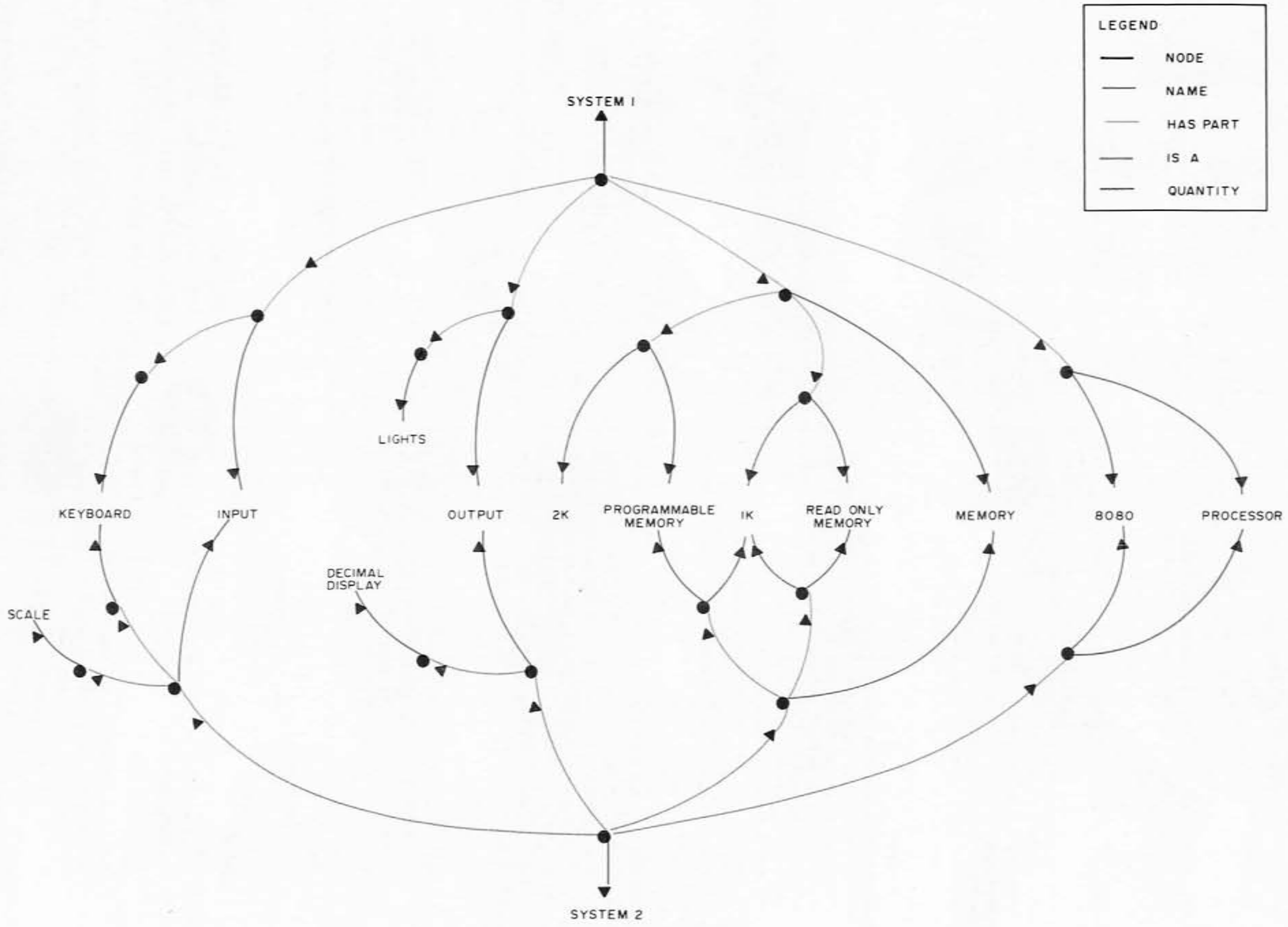


Figure 3: More complex semantic net. This semantic net represents the same systems as the net in figure 2, but in a more detailed fashion. In this net, each node represents an entity. For example, one of the parts of System 2 is an entity called the MEMORY. It is composed of two parts, the entity called the READ ONLY MEMORY and the entity called the PROGRAMMABLE MEMORY. As in the other semantic net, there is some flexibility in what to call the links and nodes. For example, "IS A" suggests that the 8080 is a member of the category of things called PROCESSORS. One could also say that a READ ONLY MEMORY is a member of a category of things called MEMORY, *but in this net, READ ONLY MEMORY is represented as a part of a thing* named MEMORY. *A fine distinction, but it may be significant when the net is interpreted by a program. Notice that reverse links (ie: NAME OF, PART OF, QUANTITY OF, EXAMPLE OF) are not shown.*

prefers, are a flexible and easily accessed way to represent knowledge. They simulate associative memory, as humans seem to have. But how are they represented on a computer? The answer to this comes in three parts:

1. Outlines can be represented by lists.
2. Lists can be represented on computers.
3. The index or table of contents to outlines can be represented as a hashed table.

Nodes can be represented in lists by having alternate elements be arc labels and related nodes. We must first reduce each multiple word node name and arc label to single word names, then just list them as follows:

8080	(Processor-in (System1 System2))
System 1	(Processor (8080) Memory (1 K Read only memory, 1 K Programmable memory) Output (Lights) Input (Keyboard))
Keyboard	(Input-of (System1 System2))

Most natural language projects are written in LISP because of its ability to handle list processing better than most other languages. Lists are represented in LISP in the following way: A list is composed of cells. Each cell has two parts, as shown in figure 4a. The two parts are called the CAR and the CDR of the cell. Each entity (node in the semantic net) is represented by a unique cell. A list of words would be represented by a string of cells. The CAR of each cell points to a node cell and the CDR points to the next cell in the string. The CDR of the last word has an end of list marker in it. A list of words ("The power surge exploded my 8080 chip") is shown in figure 4b.

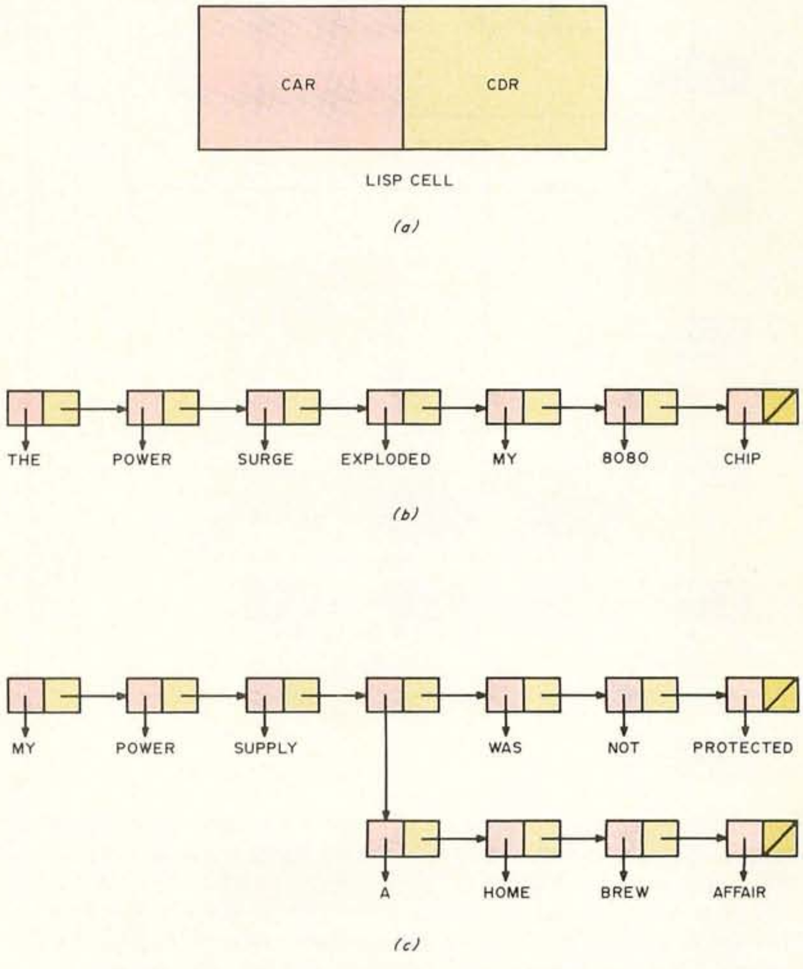
A list can be represented within another list by having a CAR point to the first element of the inside list, instead of pointing to a node cell. A list within a list (My power supply (a home brew affair) was not protected) is shown in figure 4c.

The index table for finding node names is provided automatically in LISP. The table is called the OBLIST or OBARRAY and the lists are called PROPERTY LISTS. If you do not happen to have LISP, the index table can be built as a hashed table of node cells with associated pointers to the property list associated with that name. A diagram representative of the whole configuration is shown in figure 5.

If the cell is a node cell, the CAR points to a location where the name of the cell (the character string) is held. The CDR points to another cell which is the beginning of the property list of the node. In cells that are not node cells, CARs and CDRs are both just addresses that point to other cells. (One exception is the cells that represent the relationships between nodes. These will also be on the OBLIST as "node cells," but their CDRs will contain end of list markers instead of pointers to property lists.) In LISP, a special bit is set to designate whether a cell is a node cell (called an ATOM in LISP) or just a regular cell. The amount of memory that needs to be addressed by the CAR and CDR of each cell determines the number of bytes that each cell must be composed of.

Associating Words with Ideas

The process of understanding natural languages certainly has something to do with



(a)

(b)

(c)

Figure 4: LISP cells. In (a) a LISP cell is shown. In an actual implementation there may be some additional bits in the CAR and CDR to carry information about how the cell is used (whether it is an atom, for instance). In (b) the list of words (THE POWER SURGE EXPLODED MY 8080 CHIP) is shown as a string of cells. The pointers that point to the words are actually pointing to the cells that represent those words (see figure 5). In (c) the cell representation of an embedded list is shown. The list is (MY POWER SUPPLY (A HOME BREW AFFAIR) WAS NOT PROTECTED).

associating words with ideas. It should be stressed from the beginning, however, that when humans understand something it is a process that uses much more than just word definitions. The process of understanding in humans involves interpreting the words they hear or see with the various meanings for those words, all viewed in the context of the current conversation, the environment of the conversationalists, and other factors. For example, the sentence, "I'll take a pancake," can be assumed to mean very different things depending on whether it is heard in Uncle John's Pancake House, or in a store that sells fans for relay racks (a pancake fan), or if it is said at a cosmetic counter (pancake makeup). The various conflicting meanings of "pancake" do not even occur to the people in question. A waitress would be unique indeed if she asked her customer if she preferred the pancake on a plate or on her face!

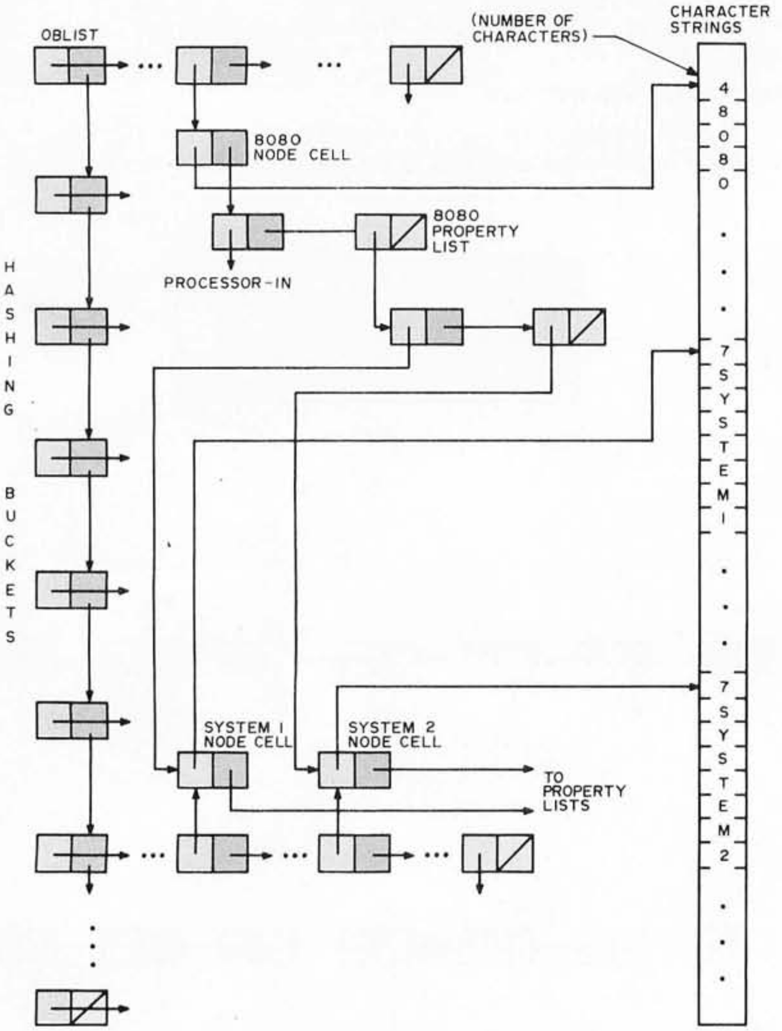


Figure 5: Representation of atoms. Each node in the system is represented by a unique cell, here called a node cell. In this figure the node cells for three nodes are shown, for 8080, SYSTEM1, and SYSTEM2. The CAR of each node cell points to a place in memory where the character string of the name of the cell is stored. The CDR of each node cell points to the property list of the node. The property list of the 8080 node is shown. The pointers to words shown in figure 4 are actually pointers to the node cells of the words. All node cells are chained together by the OBLIST. The character string names of the nodes are stored in a part of memory that has not been divided into cells. The CARs of the node cells point to an address that specifies the number of the characters that follow that are included in the character string of the name of the node. Links have cells on the OBLIST, just as nodes do. The only difference is that links do not need property lists. The pointer to Processor-in would actually be a pointer to the cell that represents Processor-in.

The problem of multiple meanings, contexts and other details of understanding will be ignored for the time being. In a small system there are limits to what can be done linguistically (in this respect, all contemporary systems seem small!). But a step toward natural language can be taken, however small. The goal we will assume is that an inexperienced user will be able to address the natural language processor in language that the user is most fluent in, and that the language processor will respond in a manner that the user finds appropriate.

We will be considering a situation in which natural language is being used as an interface language between a user and either procedures or data in a computer. The user types a sentence and the computer interprets the sentence and does what it is understood (by the computer) to mean. For example, say the computer holds a data base about various microprocessor systems like the one that was described above. The user asks questions about the systems and the computer provides answers.

Keywords

The simplest method of interpreting a sentence is to look for particular words, called keywords. If a keyword is found, a response is output. For our system, a useful set of keywords would be the names of all the nodes in the semantic net. For a response the system could print the property list which represents how that node is related to other nodes in the net. For example:

```
User: Tell me all about system1
Computer: System1
   Processor
      8080
   Memory
      1 K Read only memory
      1 K Programmable memory
   Output
      Lights
   Input
      Keyboard
User: What information do you have on lights
Computer: Lights
   Output-of
      System1
```

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.33mfd 35V	4.7mfd 25V
.47mfd 35V	6.8mfd 25V
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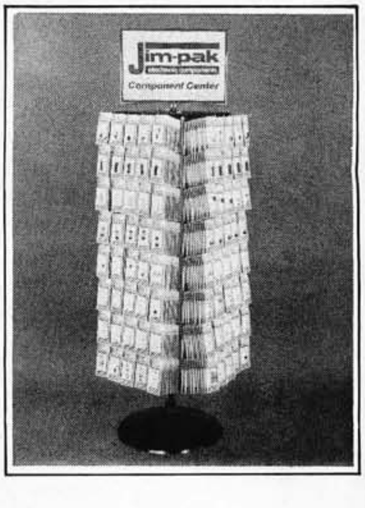

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for the questions asked. Major improvements can be had by a few simple changes, however. First, what would happen to "Tell me what you know about keyboards"? The language processor would not recognize keyboards as the same as "keyboard", so no information would be found. The easiest way around this problem is to strip the Ss off all the node names when building the semantic net, then strip them off all the words input by the user. However, this procedure runs into problems for words that end in S, like "process". Another problem is words ending in "es", like "processes". Actually, there are algorithms for analyzing word endings that correctly reduce words to their roots for nearly all the special cases like these.

The whole problem of word endings can be avoided by using a universal character. A universal character is one that matches all other characters. If # were a universal character, the node names could be written as "light#" and "process#". These would match "light" and "lights", "process" and "processes". Tricks like this can help, but may produce problems by also matching "lightning" and "lighter", "processor" and "processing". Therefore, universal characters must be used with care.

Another improvement deals with nodes that have multiple word names. A user would probably ask about "system 1" instead of "system1". Multiple word names can be handled by more property lists, one for each first word in multiple word names. These property lists would contain a list of the words of the multiple word name, followed by the corresponding node name in the semantic net. For example, system1 and system2 could be referred to by:

```
System (Mult-wrd-names ((1) System1 (One)
System1 (2) System2)).
```

This property list signals the language processor that "system 1", "system one" and "system1" are all to be interpreted as "system1". Also, "system 2" means the same as "system2".

The same mechanism can be used to allow synonyms. System 1 may be affectionately known as the "Bit Byter", "Old Smokey" (for its power supply problems), or "Zapper". These names can be interpreted as the same as "system1" with the following property lists:

```
Bit (mult-wrd-names ((Byter) System1))
Old (Mult-wrd-names ((Smokey) System1))
Zapper (Mult-wrd-names (() System1)).
```

Just as universal characters can be used, universal words and phrases can simplify specifying a large set of synonyms. For example, the multiple word name (President # Washington) would match all phrases that begin with "President" and end with "Washington". This would match (President Washington), (President George Washington), (President G Washington and also (President Ford never met George Washington).

A relevant question is: What good is putting the keyword in the middle of a sentence? Why not just have the user type keywords and forget about the rest of the sentence? There probably are few if any good reasons for trying to create an illusion of natural language understanding in this way other than that it is a fun trick.

Nodes and Links

The keyword approach to natural language processing is imprecise, and so it is prone to many errors and misinterpretations. There is an approach that is somewhat more precise, and allows correct interpretation of much more complex sentences without being much more complicated. This method involves identifying both node names and link names from the semantic net, then combining them to print only the parts of the semantic net desired by the user. The link names in our example are processor, memory, input, output, processor in, memory in, input of, and output of. There will usually be many fewer link names than node names. A user's sentence is processed by collecting node names, then link names, as in:

```
Give me the Old Smokey processor and
output.
```

Using a previously mentioned definition this is seen by the processor as:

```
xxx xxx xxxx system1 processor  xxx  output
             (node)  (link)           (link)
```

to which the appropriate response is:

```
System1
   Processor
      8080
   Output
      Lights.
```

The response is formed by searching the property list of the node mentioned for each link named. Then the node name, the link name, and the names of the nodes pointed to by the link are printed in outline format.

If link names are found to the left of node names in the sentence, the inverse link

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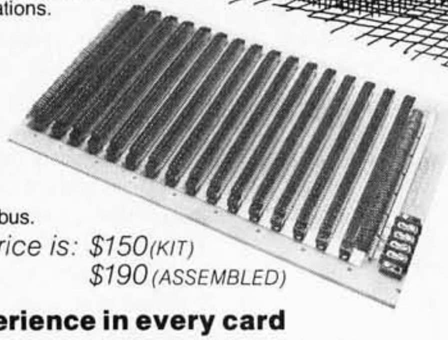

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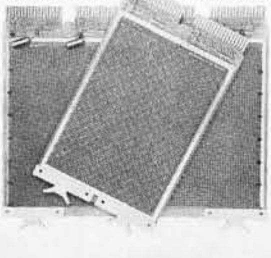

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® Trademark of Digital Equipment Corporation names must be substituted. For example,

```
What are the input of and processor in system 2
```

is seen as:

```
xxxxx xxx xxx  input-of xxx processor-in system2
               (link)         (link)        (node).
```

The reverse links are used, and the sentence is reinterpreted as:

```
system2  input  processor.
```

The property list of system2 is checked for input and processor links and the following is printed:

```
System2
   Input
      Scale
      Keyboard
   Processor
      8080.
```

This process is diagrammed in figure 6. This technique will allow quite complicated sentences to be interpreted if synonyms are chosen judiciously for nodes and links. Users on a natural language processing system tend to use very short and incomplete sentences if they can, which is also allowed with this system.

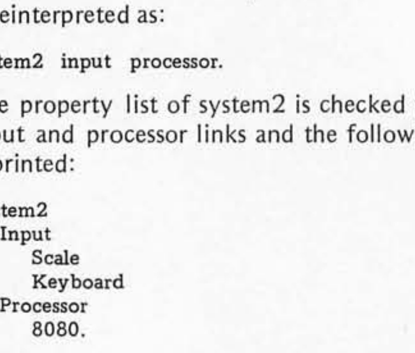

Figure 6: Node and link interpretation. This simplified method of interpreting which nodes and links mentioned in a sentence should be associated will often assume the proper interpretation to the input sentence. However, node and link names and synonyms must be chosen with care. A more successful method requires greater attention to words other than those in node and link names, particularly conjunctions, prepositions and relative pronouns.

Conclusions

There is naturally a lot that keyword based systems cannot do that humans can. For instance, keyword systems cannot understand pronouns, or when to use different word meanings (like pancake). Humans have little trouble using these. The difference is, of course, in all the information that keyword systems throw out when they disregard all words that are not keywords. Also, words carry with them more than just a definition. Most words say things about the words that are surrounding them. The word "the" says that the word to its right is either a noun or a noun modifier. In the system described above, the keyword "input of" tells us that either some kind of input device has preceded this phrase in the sentence, or a reference to a system will follow it ("what is the input of system 2"), or both ("a keyboard is input of system 2").

Natural language research today has moved far beyond the realm of keyword analysis to use not only knowledge about words, but knowledge about the things and events that the words refer to, and knowledge about the way text and conversations are structured. In a data base like the microcomputer data base used here, the system would retain information about the components that every system would probably have, the probable uses of systems, more detailed information about each of the components, and so on. The information that a human uses when discussing microcomputers would be collected and added to the knowledge base to be used when the computer is discussing microcomputers. This information is grouped into collections and the collections are associated with the concepts they describe.

It is nearly impossible to discuss how well such a system can work. We do not yet have any kind of scale for measuring natural language performance if it falls into the subhuman range. The only really useful measure is whether or not it does what it is supposed to. Unfortunately, that too is difficult to ascertain. I have implemented a system like the link and node system described here, but it was quite a bit more complex. It attempted to account for every word in the sentence in order to

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prevent misinterpretations. It handled pronouns fairly successfully and was good at identifying items by their description. It responded to the user in full sentences and in outline form. It also required a large system to run on, primarily because it had a fairly large data base. With all this, it still usually took a new user several examples before he could communicate with the system in a useful way.

With this experience, what do I think natural language systems can do on small systems? The question is vague, so the answer is vague: a little bit, but not too much. That not-very-helpful answer means that one must decide why he or she wants a natural language processor, then consider the techniques described in this article to decide if they will meet his or her needs. These techniques must then be compared to nonnatural language techniques.

The benefit of the language understanding techniques described here is primarily based on the power of the semantic net representation. Semantic nets have one advantage over other representations in that concepts are associated in a way similar to the way they seem to be associated in human memory. An important aspect of using natural language as an interaction language between humans and computers is that, if it works, it allows the user to state his requests in the same way that he thinks about his requests. A user using natural language to interact with a computer is manipulating an enormous amount of information in his or her mind, encoding a small part of that knowledge into the words of the conversation, assuming that the listener (the computer) can use these few words to manipulate its large information structures. On a small system, the information structures that the computer has to manipulate can not be nearly as large as the human's. The words of the conversation can be associated with ideas, but not on the lavish scale of association available to humans. Finally, most of the words of the conversation are thrown away using the techniques that a small system can support. What natural language processing can be done on small systems? Not enough to be able to compare it to natural language processing in humans, but perhaps enough to allow a user to learn to communicate effectively with the computer in a way that is close to the way the human brain thinks: through associations and descriptions.■

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Give an Ear to Your Computer

A Speech Recognition Primer for Computer Experimenters

Bill Georgiou
Dept of EE
California State University
Sacramento CA 95819

You pick up the phone and slowly and clearly you pronounce into the microphone: "Number one two one three five five five one two one two verify." You listen as out of the earpiece an awkward but quite intelligible voice repeats what you just have said. Then you say "Dial number." The sounds of dialing follow, then a ringing in the distance and you find yourself talking to the directory assistance operator in Los Angeles. A sequel to 2001 with personal HALs? Not quite. Just plain old 1977 reality. A couple of cards in your computer and some programming can do it. Speech recognition and voice control have come a long way from the "Open Sesame!" of the Arabian tales. Its technical foundations were laid in the 1950s and 1960s. The microprocessor revolution has brought it within the reach of any computer experimenter, opening up a fascinating frontier of voice control and spoken communication between human and machine.

In the following pages I will try to give you an introduction to speech processing and pattern recognition. To demonstrate the principles involved, we will go into some details of the workings of a speech recognizer suitable for a small personal computer. I hope the material to be presented will be enough to give you an idea of what speech recognition is, how it is done and what are its present limitations. It is left to the reader to get excited, read the literature to find more about speech recognition and then buy, borrow or build a recognizer and start using it imaginatively.

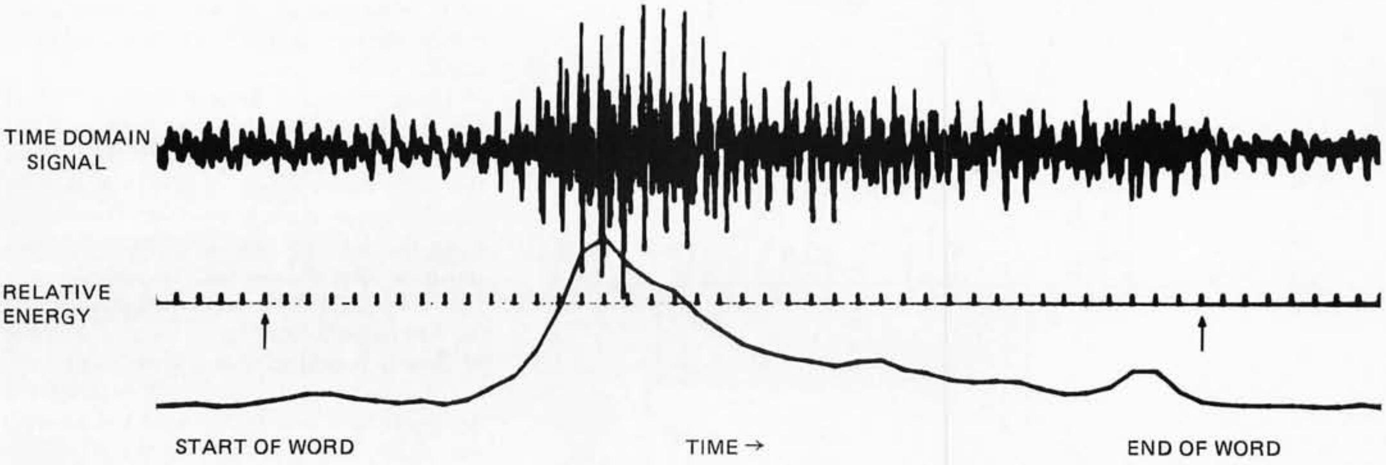

Figure 1: A time domain voice waveform and its energy. The top trace is the time domain signal for the word "three." The bottom trace is the energy in the above signal computed every 10 ms. Note that the signal before and after the word (arrows mark the beginning and end of the word) is not zero. This is due to background noise picked up by the microphone, in this case computer cooling fans and air conditioning noise.

The Speech Signal

If we connect a microphone to an oscilloscope and then speak into it, we will get a jittery trace similar to the one shown in figure 1. The vertical axis represents voltage, the output of the microphone. The horizontal axis is time and for this reason such a representation of speech is called a "time domain" representation.

You may ask can we use a time domain representation for speech recognition? It would be nice if we could because it is so easy to get; all we need is a microphone. The voltage in the output leads of the mike is, by definition, the time domain signal. Of course we would like to input this signal into our computer. Since it is an analog signal and our computer is a digital machine we will need an analog to digital converter (ADC). The analog to digital converter gives a binary number that corresponds to the amplitude of the signal at the particular time when the measurement is made. This process is called sampling. If we take and store equally spaced samples often enough so that the signal does not change very much between samples we will have a fairly accurate representation of the time domain signal in our computer's memory. Figure 2 shows such a situation, in which an arbitrary input waveform is sampled over some time interval, and the results of conversion are stored as values in successive memory locations.

It has been mathematically proven (the sampling theorem) that if we are to have an accurate representation of the signal, the sampling frequency should be at least twice the highest frequency in the signal. It is then called the Nyquist frequency and it is the lowest usable sampling frequency. One could sample at higher than Nyquist frequency but this would not give a more accurate representation of the signal. Instead there would be a lot more data words to deal with, an unwelcome situation. If we try to apply the Nyquist theorem to speech we are faced with the question: what is the highest frequency in speech? Well, for high fidelity sound a bandwidth of 20 to 20,000 Hz is necessary. This means that speech has frequencies up to this limit, perhaps even higher. On the other hand, telephone speech is band limited to 3200 Hz and it is still quite intelligible. Since in speech recognition we are interested in what has been said rather than the quality of the sound, if we limit the signal using a filter with a cutoff at 3200 Hz we will retain the information needed for recognition. Then we can use Nyquist's theorem to get a practical sampling rate since we will know that the highest frequency in the signal is 3200 Hz, due to the filter. Sampling at twice that frequency we will get 6400 samples

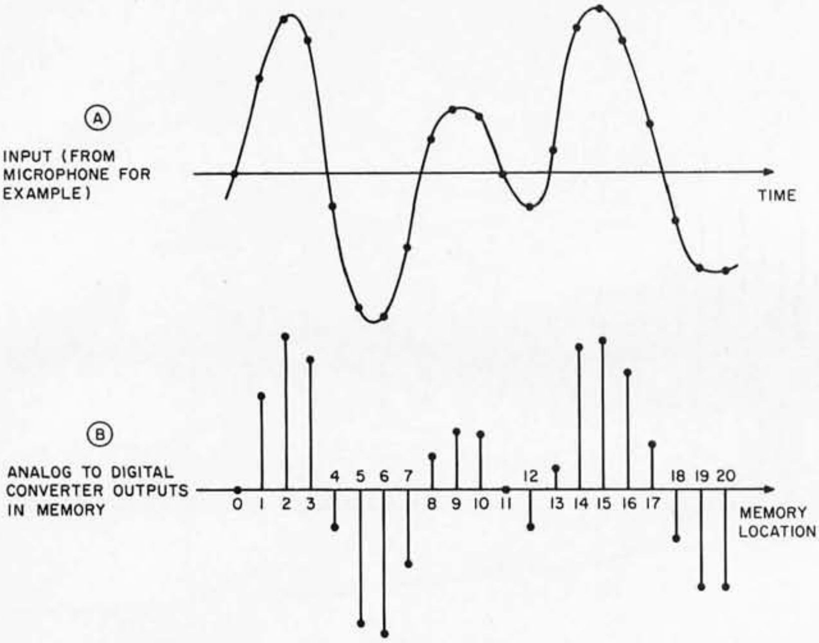

Figure 2: Sampling in the time domain. Waveform A is a time domain signal. If we sample it at equally spaced intervals we will retain the amplitude of the waveform at the dotted points and the signal will be zero between these points, as shown in waveform B. Although A and B look very different, if the sampling is done with a frequency higher than the Nyquist frequency (see text), both signals will contain exactly the same information.

per second of speech. Assuming our word length is eight bits which is about the minimum usable for speech and that the average word duration is about half a second, we will need 3.2 K bytes of memory space per word. If we had a 20 word vocabulary and we wished to store each word in main memory once to be used as reference, we would run out of memory space in any micro and most minis.

Using the time domain signal is out of the question because of the huge amounts of memory required to store it. This is not the only disadvantage of the time domain signal. Assuming we had enough memory to store the data, processing it would take too much processor time because every operation we would perform on the data would have to be performed to such a great number of data points. Real time operation (processing the signal as it occurs such that there is no appreciable time lag between the moment the signal ends and the time the recognizer decides which word has been said) would be out of the question. Yet real time operation is highly desirable in most situations in speech recognition. Another basic disadvantage of the time domain signal is its variability between different pronunciations of the same word. People do not repeat words exactly the same, down to the minute

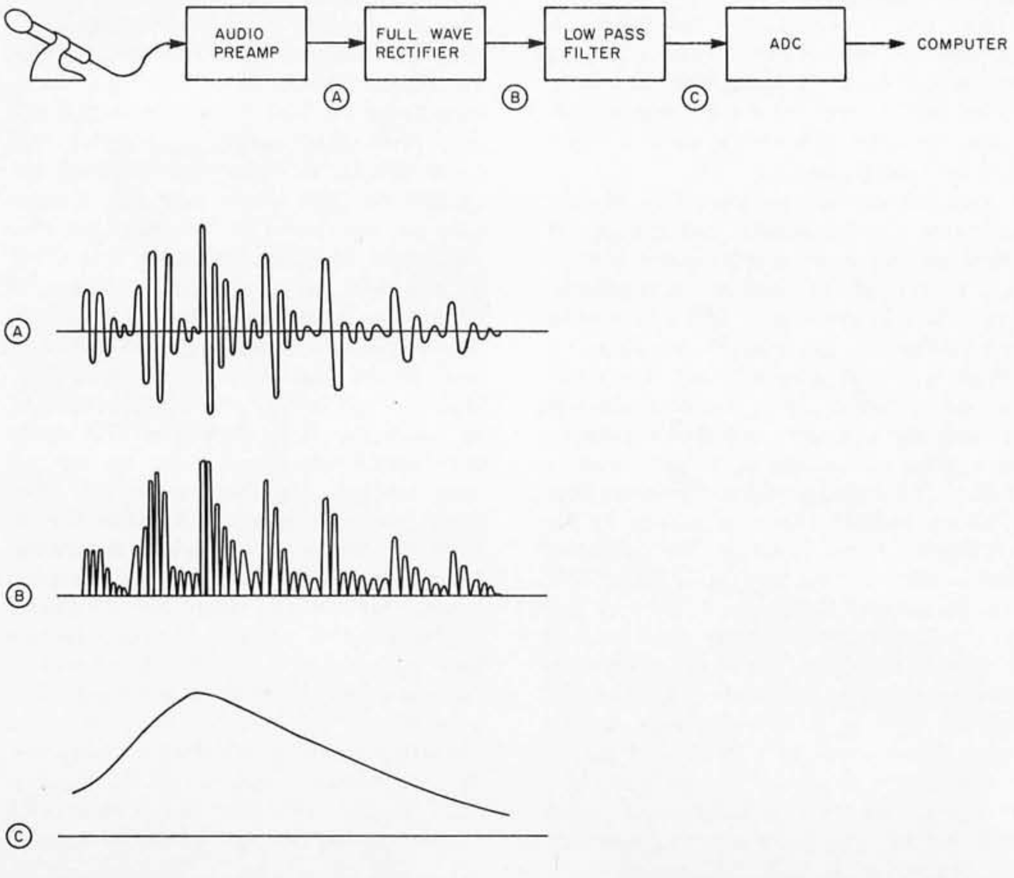

Figure 3: Rectifying the microphone signal at A we obtain signal B which contains a slowly varying DC component proportional to the volume of the signal and various high frequency components due to the formants. The low pass filter separates these and the analog to digital converter (ADC) sees only the volume signal.

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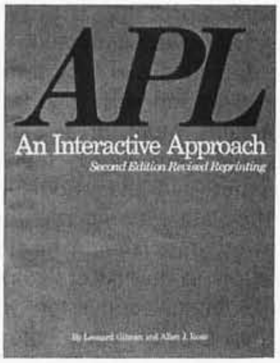

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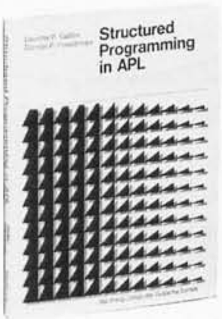

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details of amplitude. Quite the contrary; there is a tremendous amount of variation in the time domain signal even for the same person within several consecutive pronunciations of the same word.

In speech recognition we would like to transform the time domain signal into some other signal or representation with low data rate and which remains more or less invariant as long as the same word is pronounced. This is easier said than done. If we try to reduce the data rate we run the risk of throwing away important information. For example suppose that before going into the analog to digital converter we rectify the signal, then process it with a low pass filter. A block diagram of this operation is shown in figure 3 together with the resulting waveforms. Such an operation will extract the envelope (c) of the signal. The highest frequency of interest in the envelope is only about 50 Hz. This is due to constraints imposed by the mechanism that produces speech. We can thus set the low pass filter to 50 Hz and sample at 100 Hz, the Nyquist frequency. That gives us a very reasonable data rate, 100 words per second and well within the capabilities of all machines.

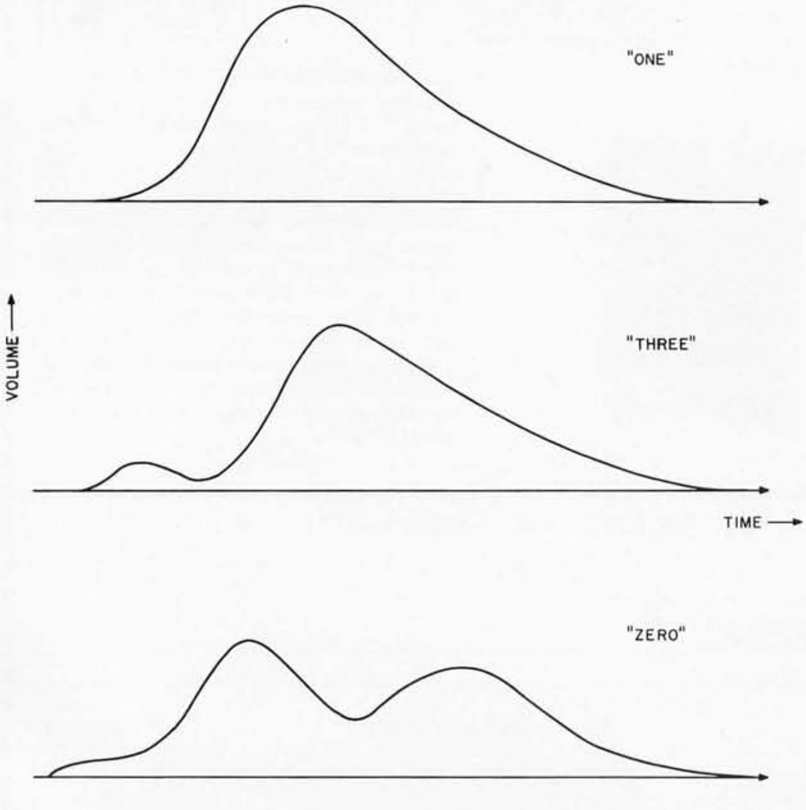

Figure 4: Amplitude envelopes of the words "one," "three," "zero." Note that "one" has one hump while "three" has two. The smaller one corresponds to "th" and the larger one to "ee." In "zero," "z" is the low amplitude area in the beginning. The dip corresponds to "r" and the humps to "e" and "o." Vowels always have high amplitude because they are produced with the mouth open and with strong excitation.

Yet, if we try to build a recognizer using only this information we would get very poor performance. The reason is that we have thrown away a lot if not most of the information in the speech wave in the process of rectification. The information that remains is quite variable between different pronunciations of the same word, further degrading recognition. But it is not totally useless. If we select a vocabulary of a few words carefully so their envelopes have distinct characteristics we may get usable performance out of a very simple recognizer. We could select for example the words "one," "three," "zero." Typical envelopes for those words are shown in figure 4. We note that the envelope for "one" consists of one hump. "Zero" has two humps and "three" has one main hump preceded by a small peak that corresponds to the sound "th." Based on these observations we can write a simple program that would examine the input data and decide which one of the three words has been said.

Feature Extraction

The process of extracting a set of slowly varying parameters that represent a word is called feature extraction. It has two objectives: First, as we have seen, it tries to reduce the amount of data necessary to process for recognition. This is a very important consideration for any practical implementation. Second (and extremely important), the features extracted must contain the relevant information in the signal. The speech signal conveys a lot of information about the sex, age, regional origin and emotional state of the speaker. Also it contains a lot of technical information incidental to speech production such as phasing and power spectra of the glottal pulses. All this information is related but not relevant to the meaning of the word pronounced. Ideally the features will contain as little as possible of this extraneous information.

A good feature extraction scheme will reduce the data rate in the recognizer by throwing away all the unnecessary information and retaining the information useful to the recognizer. The information pertaining to the meaning conveyed by speech is estimated to be from 15 to 30 bits per second, or about three orders of magnitude less than the data rate of the unprocessed speech signal. Practical feature extractors are not even close to the theoretical data

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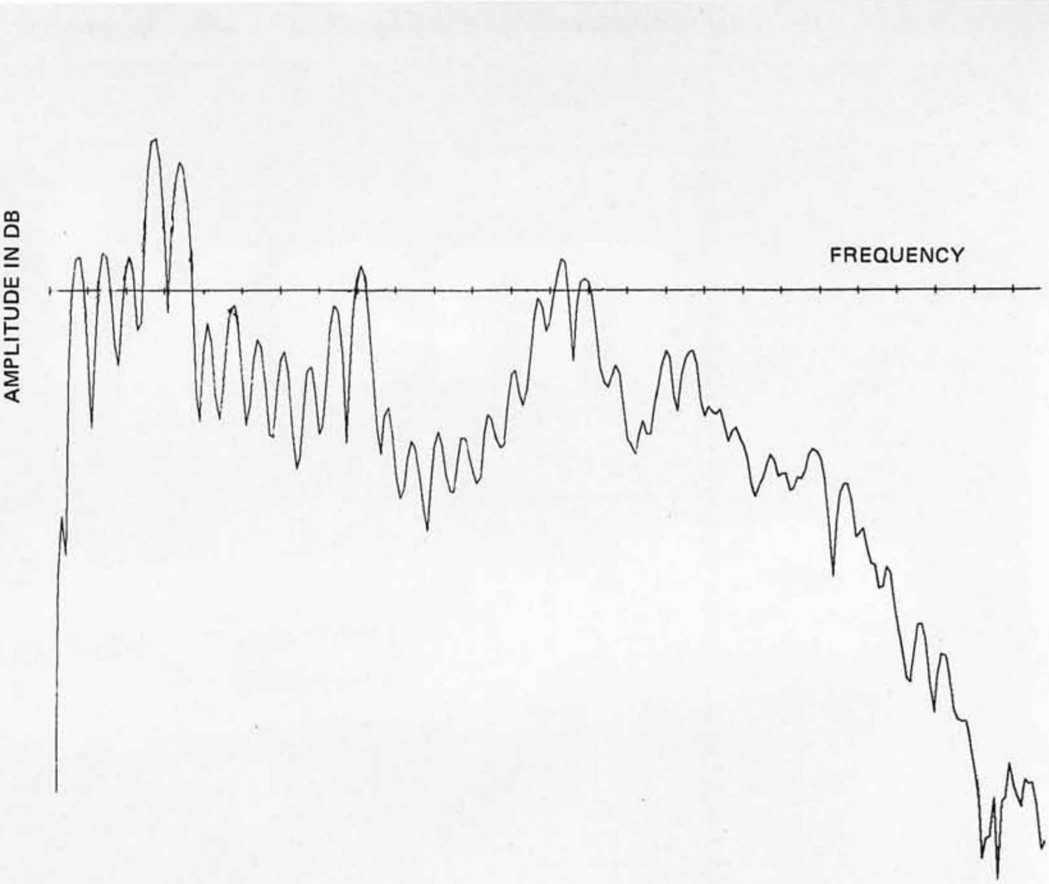

Figure 5: The frequency (logarithmic magnitude) spectrum of a 25 ms segment of speech. It covers the frequencies from 0 to 3.2 kHz. The major peaks correspond to the formant frequencies while the smaller, regularly spaced peaks are harmonics of the glottal frequency. In this case it is obvious that the sound is voiced both from the harmonics of glottal frequency which are highly visible and from the fact that the lower frequencies have more energy than the higher ones.

rate and, most important, they tend to throw away significant amounts of the useful information. An example of a very inept feature extractor is, of course, the envelope detector mentioned previously. But it does have the advantage of extreme simplicity.

In order to design more sophisticated feature extractors some knowledge about speech production is necessary. Knowledge about speech perception would also be very useful but at this point we have no concrete information as to how people are perceiving speech. In contrast, the mechanism that produces speech is well understood and rather simple. It has been previously explained in the August 1976 BYTE (page 16) in connection with speech synthesis. To summarize, speech is produced by exciting the vocal tract with either glottal pulses or noise while its shape is varied by controlling the position of the tongue and the jaws. Noise excitation produces unvoiced sounds. Glottal excitation produces voiced sounds, for example vowels. The movement of the articulators (tongue and jaws) changes the resonant frequencies of the vocal tract, called formants. It is well known that the first three formants, designated F1, F2, F3, carry most if not all meaning in speech together with timing considerations and type of voicing. The glottal frequency, although very important in speech synthesis because it carries information about the particular speaker, carries no information about meaning. This rather surprising fact is easy to ascertain in two ways: First, synthetic speech is equally well understood whether the pitch (another name for glottal frequency) varies according to rules or remains constant. Second, whispered speech, which does not contain any glottal excitation, is well understood.

It seems then that a good set of features for speech recognition would be the formant values. Information as to whether speech is voiced or unvoiced would be useful but not necessary. Unfortunately at this point it is not possible to experimentally either assert or refute this statement, simply because it is not possible to reliably and accurately extract the formants all the time. In addition, the best formant extraction methods known are at this point out of the reach of any imaginable personal computing machine. They involve digital signal processing methods which for real time process-

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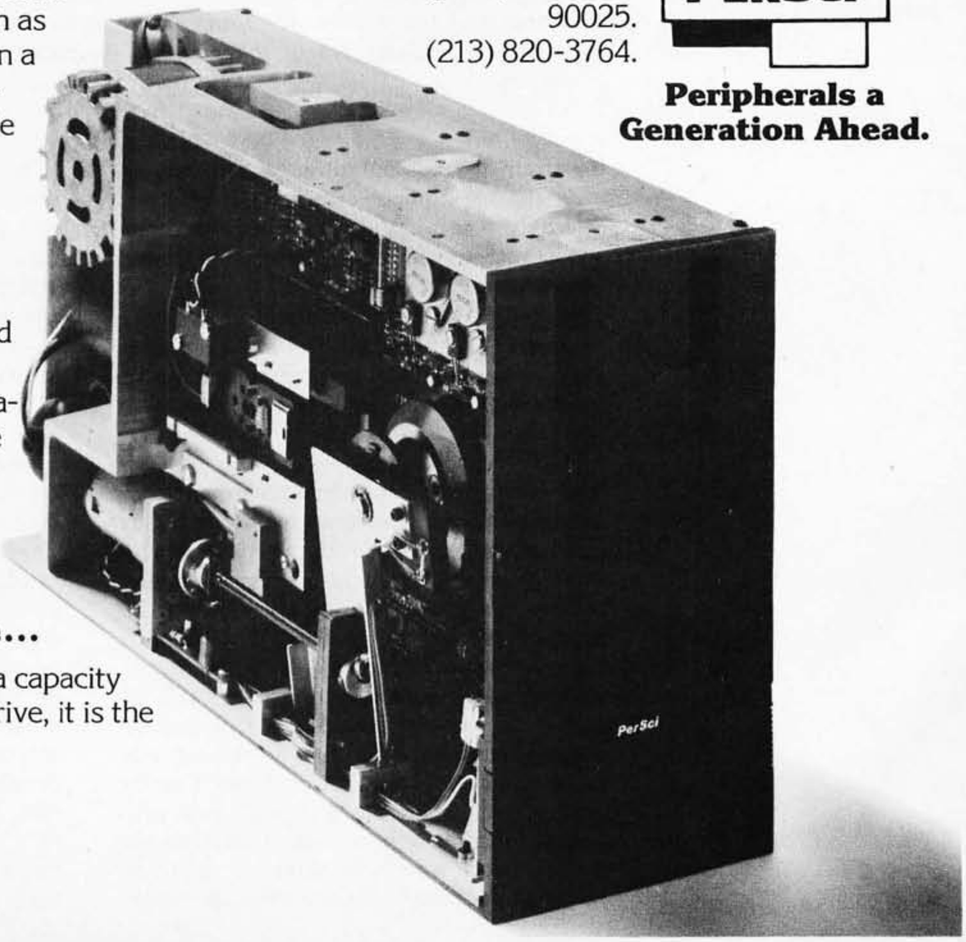

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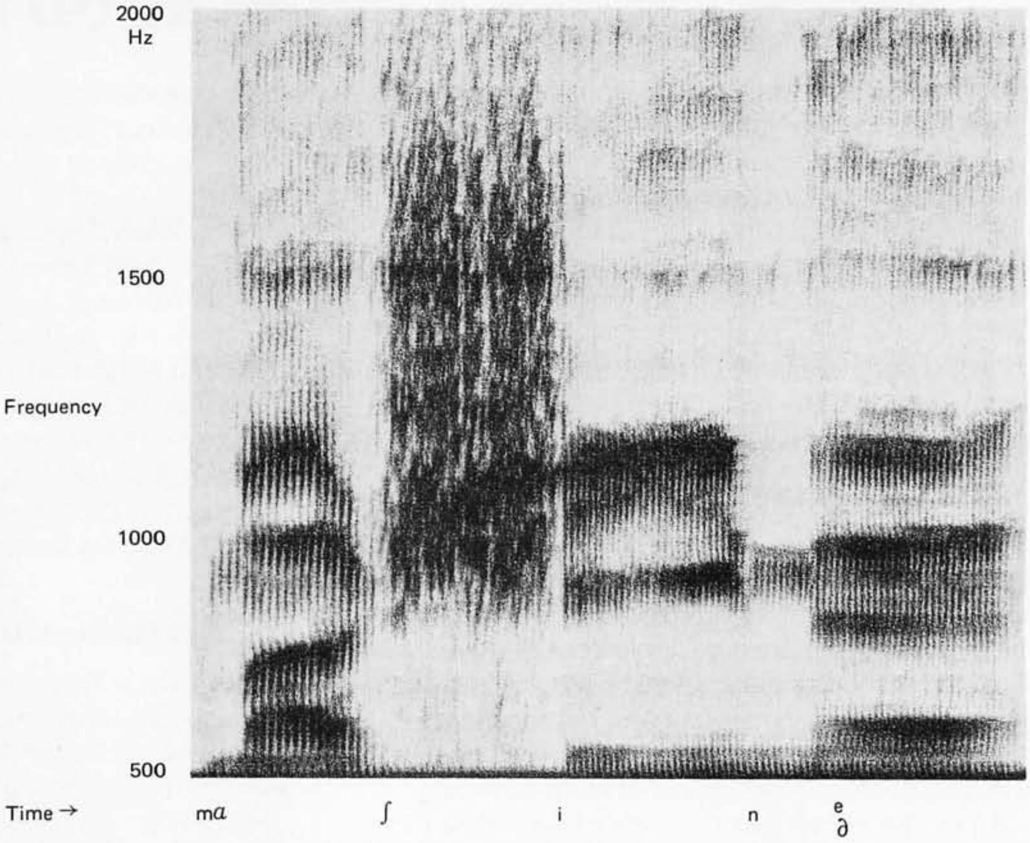

Figure 6: A typical Sonagram of an utterance. In a Sonagram the dark areas represent high intensity. This example represents the word "machine." The vertical (y) axis is frequency and the horizontal axis is time. The formants are seen as the dark bands that change with time. The large dark area about 1/5 of the way into the pattern corresponds to the sound of the "ch" in machine.

ing strain the computational capabilities of even the big number crunching computers. There is a lesson to be learned from the above analysis: Speech is intimately related to the resonances of a time varying resonator (the vocal tract) and perhaps it is more reasonable to expect to find better features in a frequency domain representation of speech rather than in a time domain one.

Frequency Domain Analysis

A usual frequency domain representation of a signal is its spectrum (amplitude versus frequency). It can be obtained from the time domain representation by applying what is called the Fourier Transform to it. Figure 5 shows the Fourier Transform of a speech signal 25 ms long. Note that in the time domain signal the horizontal axis of a plot is time whereas in the frequency domain representation the horizontal axis is frequency. A drawback of the Fourier Transform is that it is a digital signal processing method and as such it operates on the sampled waveform directly, requiring very fast computers for real time operation. If we are willing to settle for less accurate results, there exist analog methods which can give us spectral representations in real time using relatively simple hardware. An interesting spectral representation, based on analog methods, is the sound spectrogram or "Sonagram" obtained using a device called the "Sonagraph." This device has been in existence since the late 1940s and has been widely used in speech research. It gives a three-dimensional display of frequency in the y axis (vertical), time in the x axis (horizontal), and intensity on the z axis. The z axis is actually represented by shades of black since we are using two-dimensional paper. Figure 6 shows a Sonagram. The dark areas correspond to areas of high intensity and the evolution of formants can be observed as dark bands changing with time. The Sonagraph is a useful tool in speech research and it is mentioned here because it is widely referred to in the literature. It is of no value as a feature extractor to a practical speech recognizer because it is not a real time machine and because it costs thousands of dollars.

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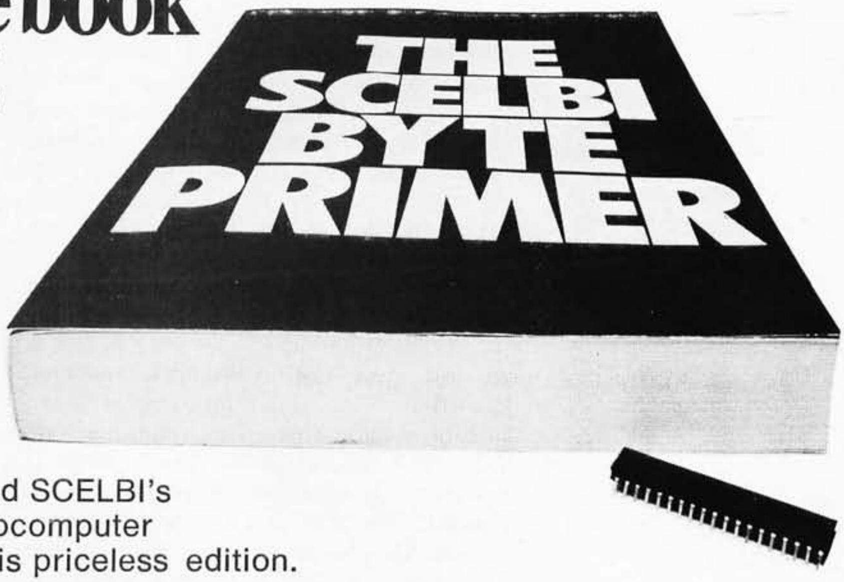

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Using Filter Banks for Feature Extraction

A less accurate yet simple and inexpensive method for obtaining a spectral representation is a filter bank. It is widely used in existing speech recognition machines, including the most successful commercial speech recognition system. As shown in figure 7, a filter bank consists of a number of bandpass filters, covering adjacent frequency bands. The output of each filter is full wave rectified, then smoothed and sampled by an analog to digital converter for computer input. The output of the converter for any given filter is related to the energy present in the frequencies of the filter's passband.

A filter bank is a useful tool for feature extraction. It should be obvious that the speech spectrum can change only as fast as we can move our articulators. The constraints here are about the same as in the case of volume changes mentioned before. That is, a bandwidth of about 50 Hz is sufficient to accurately represent spectral changes. This gives us a sampling frequency of 100 Hz. Assuming eight filters in our filter bank, we get 800 digital words per second of speech. If the converter is accurate to eight bits, the data rate is 6400 bits per second, quite reasonable for the degree of accuracy retained. What makes a filter bank even more exciting for feature extraction is that a number of parameters are available that can be manipulated to get various tradeoffs of data rate versus accuracy. Thus both simple and sophisticated systems can be built using the same type of hardware. The parameters available for experimentation are:

- Number of bandpass filters.
- Bandpass filter bandwidth and center frequency.
- Bandpass filter skirt (selectivity) characteristics.
- Amplitude compression.
- Smoothing cutoff frequency (sampling rate).

It should be obvious that the more filters we have, the more accurate the spectral representation. A filter acts as an averaging device over the frequency in its bandpass and thus it destroys local information. By increasing the number of filters and restricting their passbands this averaging is done over a smaller frequency range.

The bandwidth of the bandpass filters can be the same for all filters but usually it varies depending on the filter's center frequency. It has been shown that the ability of the ear to discriminate between closely spaced frequencies decreases when these closely spaced frequencies are high. Based on this observation, the bandwidth of the filters in a filter bank is rarely, if ever, the same. Instead it is set so that the higher the center frequency of the bandpass filter, the wider its bandwidth. The setting of a bandwidth for a given center frequency is done usually on the basis of experience in an effort to have enough filters covering the areas of greatest importance. Once a setting is decided upon, based on some criteria, experimentation may be required to optimize that particular filter bank. Another approach is to decide on some rule for setting the bandwidths. For example, a successful recognition system has been built using filter banks of third octave bandpass filters

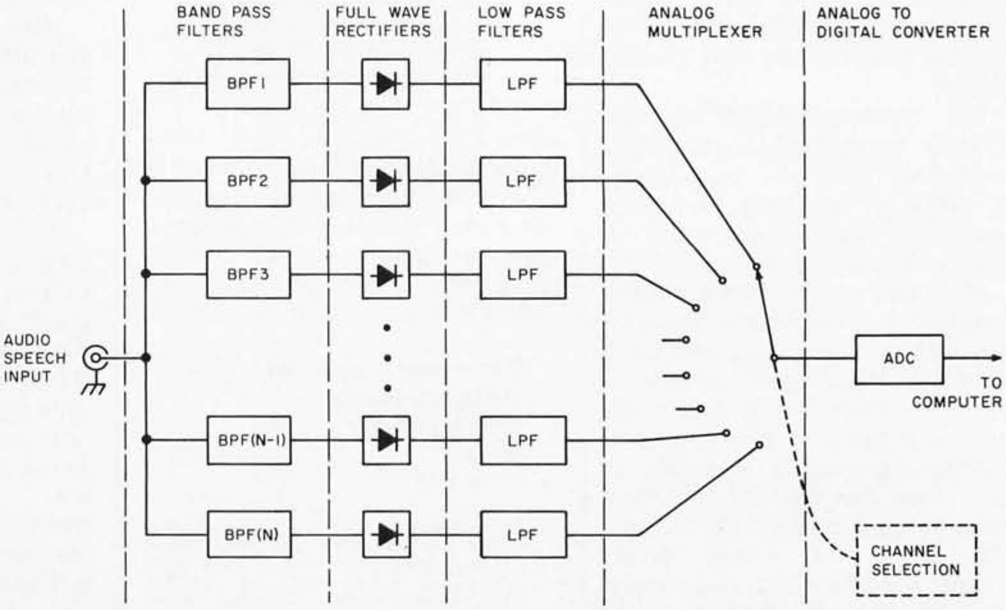
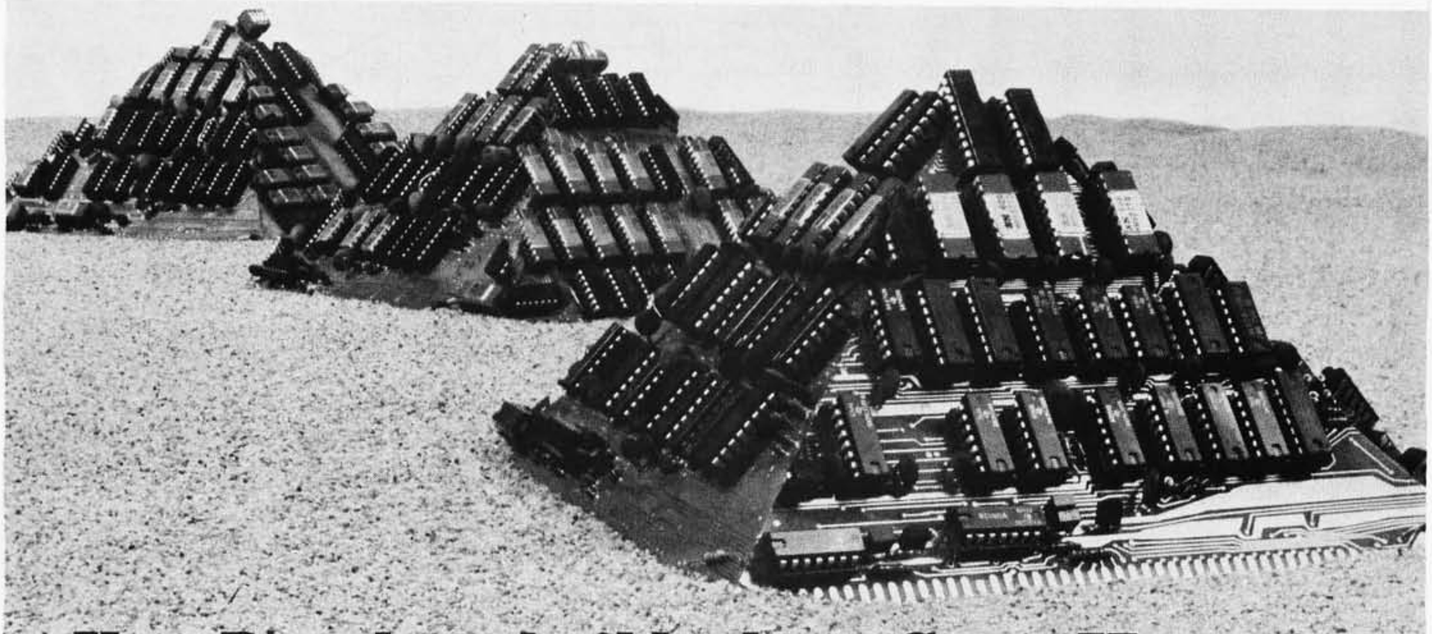


Figure 7: A filter bank feature extractor consists of a number of bandpass filters (BPF1 to BPF (N)) covering the range from about 100 to 10 kHz. The output of the filters is rectified and low pass filtered (LPF). Then it is multiplexed and digitized by the analog to digital converter for input into the computer.



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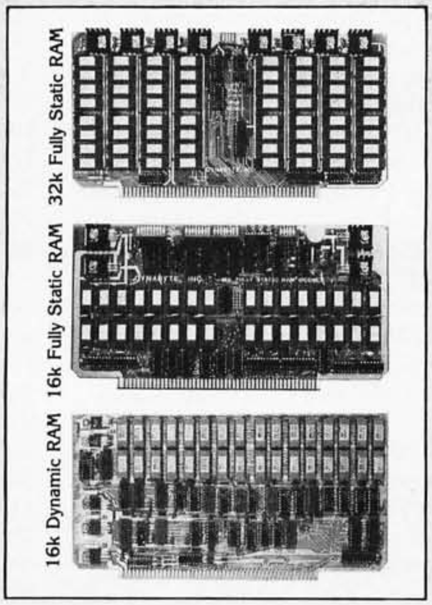

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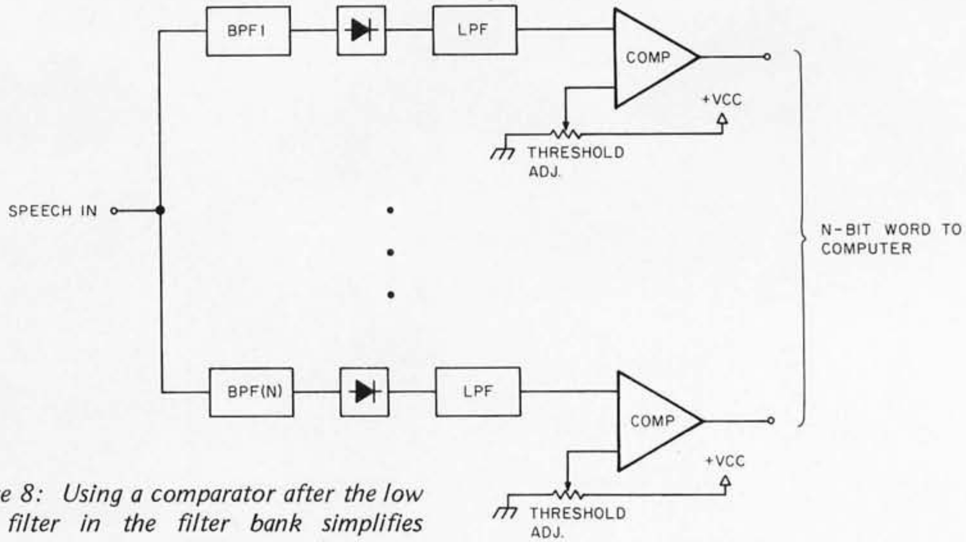

Figure 8: Using a comparator after the low pass filter in the filter bank simplifies hardware and reduces data rate at the cost of discarding useful information. The thresholds should be adjusted for the voice of each individual speaker. In addition, a good automatic gain control circuit should precede the filter bank to normalize the time domain signal.

covering the frequencies of 150 Hz to 10 kHz. Such filters are commercially available for audio work.

The skirt or cutoff characteristics of the filters in a filter bank is determined by the following factors:

- A steep skirt will give better frequency separation than a gently sloping one. It will also make for abrupt transitions from one filter to the other when a formant crosses the boundary. This is not necessarily bad but it might affect some systems. Both skirt types are used in practice.
- It is desirable that the filter exhibit linear phase shift in its passband. For a given filter order, that means that the skirts will be less steep than the case without phase restrictions. In general, this is not a serious consideration for a practical system.
- The cutoff characteristics depend on the order of the filter (the number of mathematical poles it has in its design equations). Higher order filters give steeper characteristics but require more poles and thus cost more.
- It is desirable that filters overlap at the three db points of their slopes.

The amplitude (volume) of the speech signal is dependent on two factors that cannot be controlled easily. These are the distance and orientation of the speaker with respect to the microphone and the loudness of the voice at any given time. Volume also varies constantly within a given word as we have already seen. This can result in a 50 db range for the amplitude of the speech signal. The dynamic range of an 8 bit converter which is most likely to be used in the environment of computer experimenters is 20 log (256) = 48.16 db. This seems sufficient but it will give severe quantization errors for low amplitude signals. The lower the amplitude of the signal, the fewer bits will be used to encode it, thus throwing a lot of the information out. A 12 bit analog to digital converter would help but it costs too much and it wastes memory space in an 8 bit machine because it takes a word and a half to store its output.

A different approach would be to use some form of amplitude compression before the analog to digital conversion. An audio automatic gain control circuit can be inserted between the audio source and the filter bank. It will limit the dynamic range of the signal by the amount of compression it offers, usually in the range of 20 to 40 db. Such an automatic gain control circuit (AGC) should have very fast attack. Its release time should be about two to three times the lowest glottal period expected. It should not be less than that because then it will tend to distort the signal by compressing between glottal pulses. Amplitude compression can also be applied after the rectifier smoothing filters by taking the logarithm of the signal at that point. The logarithm operation is suggested by the fact that our ears (and all of our body sensors) respond to stimuli intensity in a logarithmic fashion. This fact is utilized in every audio amplifier in the design of the volume control potentiometer which is made logarithmic so sound will

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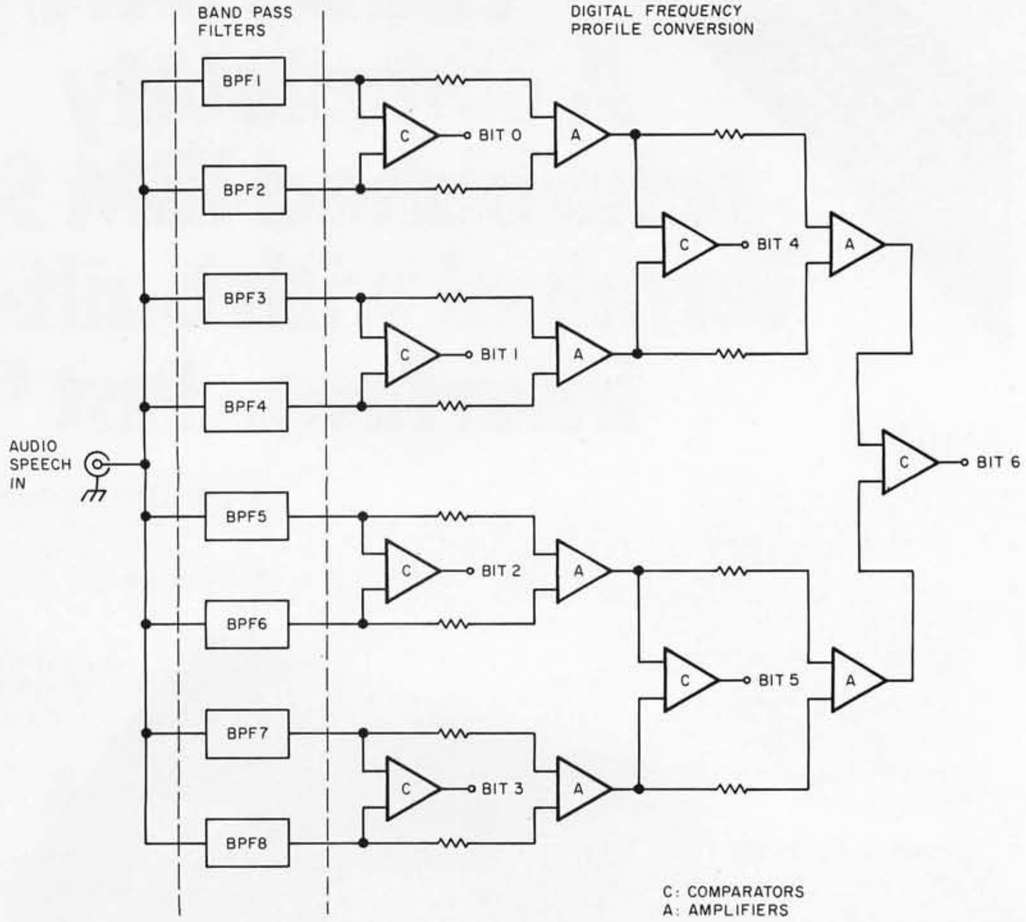

Figure 9: The differential comparator feature extractor detects which one of two adjacent bandpass filters has the highest energy. The output of each pair of filters is summed together and compared with the sum of the next pair of filters, yielding another, coarser comparison from the frequency viewpoint. In this example, the output of eight filters (we assume that the output of the blocks labeled BPF is the rectified and smoothed output of the bandpass filters) is encoded into a 7 bit digital word. The computer performs pattern recognition on time varying sequences of these 7 bit words.

seem to increase linearly with shaft rotation. The disadvantage of taking the logarithm of the smoothed signal is of course the number of required log circuits which is equal to the number of the filters in the filter bank. The logarithm can also be taken by having an analog to digital converter that converts logarithmically. There is such a product available from Precision Monolithics Inc. It is the DAC-76 companding digital to analog converter that can be used to build an 8 bit logarithmic analog to digital converter.

As a final note to amplitude processing we should mention a method used in a number of small systems. In its simplest form it consists of using in the place of the multiplexer and the analog to digital converter a number of comparators which change state when the input voltage exceeds a preset threshold as shown in figure 8. The output of the comparators forms an N bit binary word where N is the number of the filters in the filter bank. This gives a significant reduction in data rate and works for small vocabularies of the order of 8 to 12 words. It requires a good automatic gain control before the filter bank, and its major weakness is that the comparator thresholds have to be manually adjusted for each individual speaker. A variation of this method is used in a commercial recognizer made by Scope Electronics (US Patent #3,812,291). In that system the comparators are connected between two consecutive filter outputs to detect the slope or frequency profile. Figure 9 shows this differential comparator connection. Compared to the fixed threshold method it has the advantage that no adjustment for the individual talker is needed and the automatic gain control before the filter bank is not necessary. Its disadvantage is that it throws away more information than the fixed threshold method.

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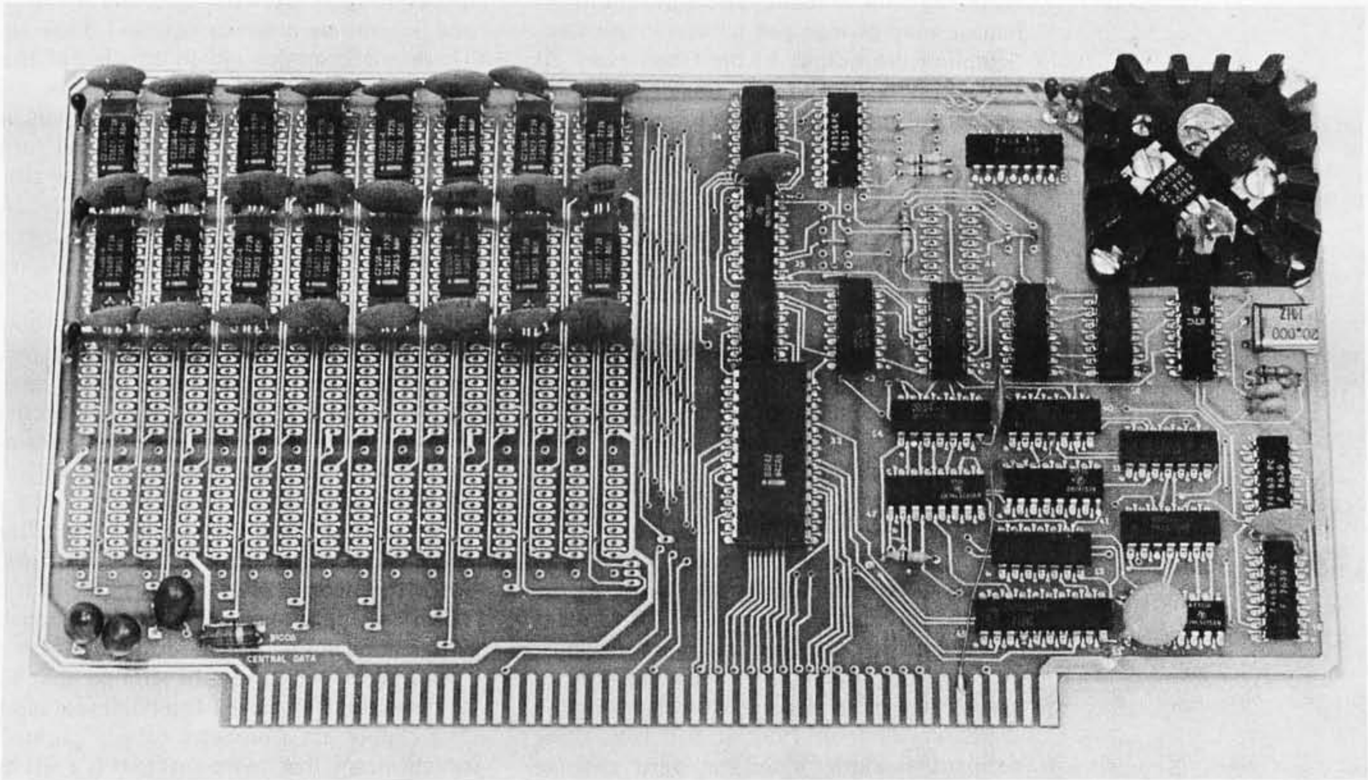

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The final parameter that can be adjusted in the filter bank feature extractor is the cutoff frequency of the smoothing filters. Reducing it reduces the data rate. Depending on the amount of reduction significant information may or may not be lost in this step. Sampling the output of the filters every 20 to 30 ms is tolerable in small vocabulary systems. The main consideration here is to find a combination of number of filters, analog to digital conversion quantization and sampling rate that will maximize the information retained and minimize the data rate of the pattern.

In summary, a filter bank offers a good yet inexpensive real time feature extractor which can be utilized in a speech recognition system. Properly used, it has performance similar to systems based on linear prediction residuals, a state of the art digital signal processing technique.

Zero Crossing Detectors

Another feature extraction technique that was popular for its simplicity in the early days of speech recognition is formant tracking using zero crossings. It is interesting to note that probably the first widely known speech recognizer capable of recognizing the digits was built in 1952 at Bell Labs using formant tracking based on zero crossing measurements. The contraption was grotesque by today's standards, using vacuum tubes as active elements and capacitors for memory. It was claimed that it achieved 97 percent recognition accuracy. Its formant tracker was based on two well known principles: First F1 and F2 formants span two different frequency ranges, that is F1 moves roughly between 200 and 1000 Hz and F2 moves between 800 and 3500 Hz. There are cases for which this is not true but for about 98 percent of the time this holds for any speaker, man or woman. Second, F1 and F2 of a given speaker for a given vowel remain about the same day after day of testing. (This is not true for the same vowel pronounced by different speakers and thus the machine has to be trained to a given speaker before it can recognize his or her speech.) This means that we could isolate the first two formants and they would be useful as features. Two bandpass filters centered around the respective formant regions would separate the formants except when they are in the overlapping area of 800 to 1000 Hz.

It turns out that when we highly amplify, then clip a signal to obtain the instances when the signal crosses zero, the problem is taken care of automatically. If the bandpass filters slope in the overlap region as shown in figure 10, F1 will always be stronger than F2 at the output of the F1 filter and vice versa. The clipper has a property called "capture" which means that any signal that is a few db or more stronger than another will swamp out the weaker signal and the output of the clipper will contain only the strong signal. This phenomenon occurs also in FM radio

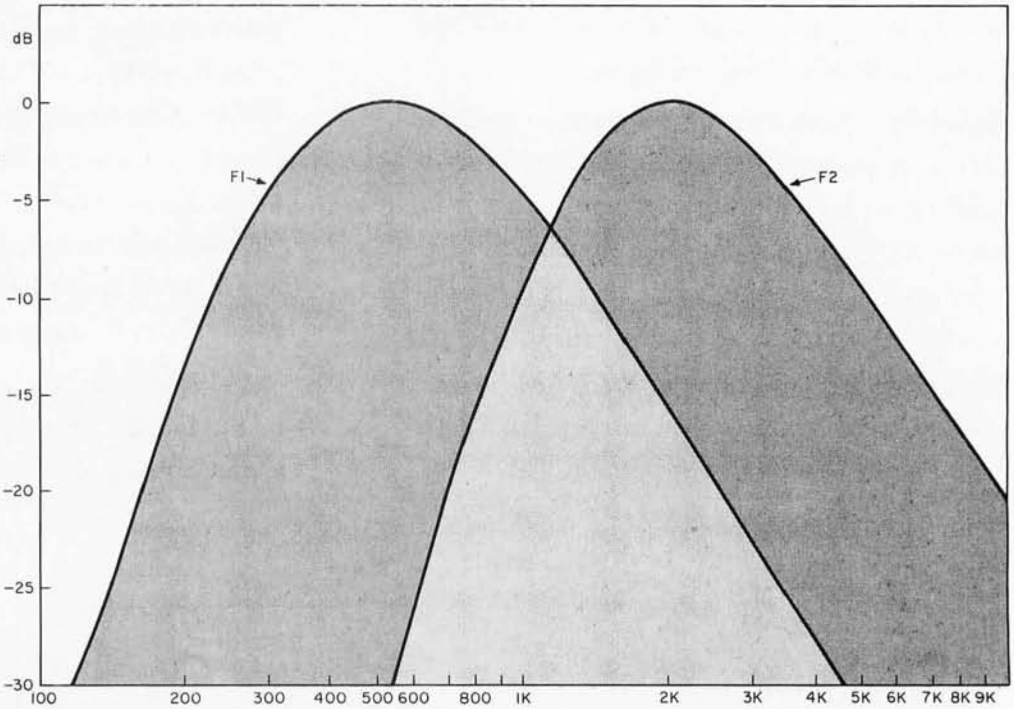

Figure 10: The frequency response of the two filters is designed to separate F1 and F2, when used in a zero crossing based formant detector. The filter characteristics overlap in the region of formant overlap but their slopes are designed to separate the two formants.

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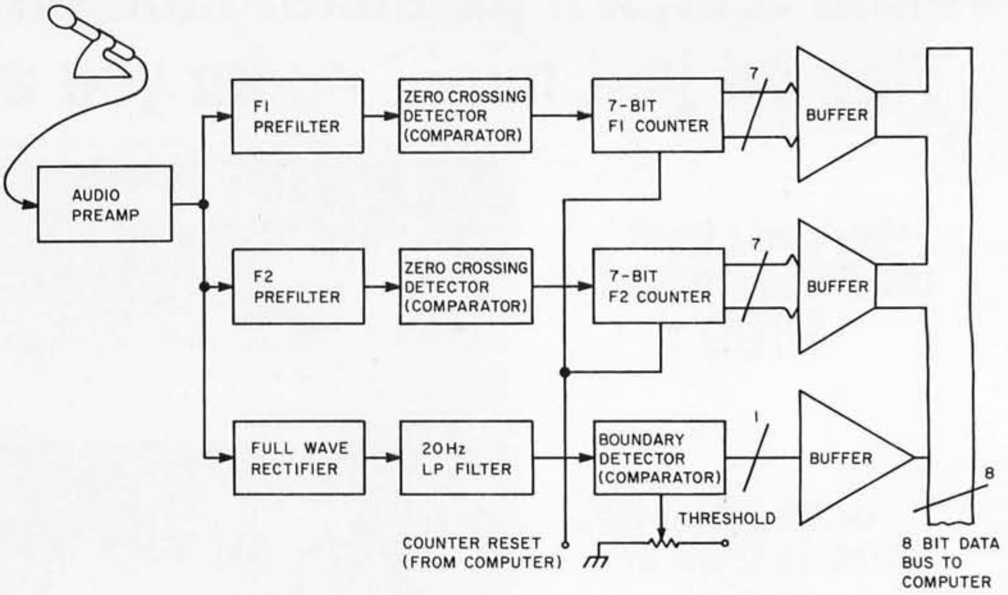

Figure 11: A zero crossing formant extractor. The zero crossing method of formant extraction uses two special bandpass filters to separate the formants. The output of the filters is passed through a zero crossing detector (a comparator whose threshold is set to zero) that puts out a logical "1" or a "0" depending on whether its input is positive or negative. The output is fed into a counter for each formant and the number of "0" to "1" transitions is counted for 20 ms. Then the counters are read by the computer and reset to start the next 20 ms counting period. An envelope detector (rectifier followed by a low pass filter) feeds a comparator whose threshold is set to detect word beginnings and endings.

reception with a limiting (clipping) intermediate frequency (IF) stage. It is one of the reasons FM was chosen for quality broadcasting, ie: it is not susceptible to interference from other weaker stations or interference from noise. Filtering and capture ensure that the output of the clipper contains only one frequency, the formant we are tracking. Determining what that frequency is requires nothing more than counting how many times the square wave output of the clipper crosses zero within a given interval, perhaps 20 ms. The data rate of the zero crossing formant extractor (see figure 11) is quite low, about 50 samples per second consisting of two 8 bit words per sample, a total of 800 bits per second.

In practice it works well with vowels, especially if there is no significant F1 and F2 overlap. Formant overlap and noise do affect its performance and thus limit its applicability. It is perhaps the simplest viable feature extractor that can be used and it does not contain any critical analog circuitry. One word of caution about the implementation, learned the hard way: an 8080 processor running with interrupts generated by the rising and falling edges of the clipped F1 and F2 signals is not fast enough to keep up with the pace in some cases and data is lost. Rather than trying an all software approach, I recommend that two hardware counters be used, read and reset by the computer every 20 ms. These counters are shown in figure 11.

Pattern Recognition

A set of features representing a word is a pattern corresponding to this word. Pattern recognition is the process by which, given an unknown pattern, we decide which word this pattern represents. An alternate term is pattern classification. A basic process of pattern recognition is template matching. The unknown pattern is compared to a number of reference patterns stored in memory and the differences between the unknown and the references are noted. Obviously the smallest difference indicates a best match and the unknown word is the word that corresponds to the reference pattern that gave the smallest difference.

There exist many ways to compare two patterns. Since features are represented by numbers, the most straightforward way is to compute the numerical difference between corresponding samples and then sum all those differences. That sum would be a measure of similarity between the patterns. There is a small precaution to be taken in practice when computing the sum of the differences. All differences should be positive. Otherwise when we sum them, negative differences will cancel positive ones and the

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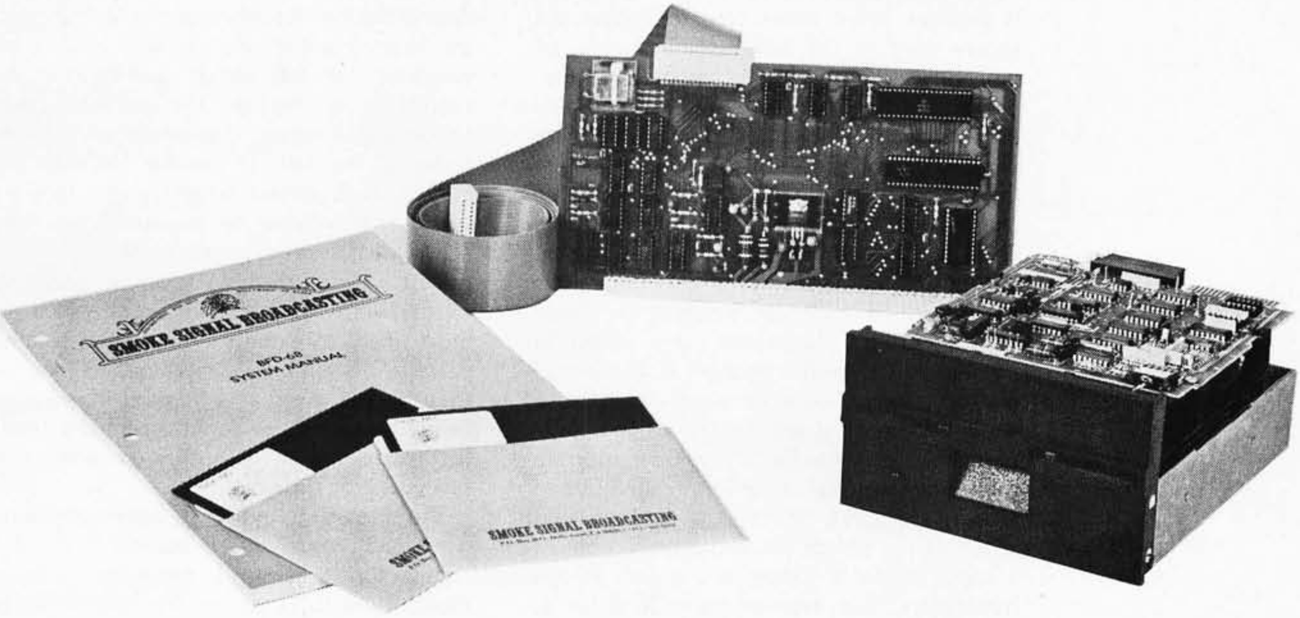

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effect would be a smaller total difference than is actually the case. To make sure that all differences are positive we can take the absolute value of the differences before we sum them. This is done simply by making any negative distances positive and leaving the positive ones alone. A fancy name for the absolute value of feature differences is "Chebyshev distance." "Euclidean distance" is another fancy name used to denote the square root of the sum of the squares of individual differences. The square of a number is always a positive number and this overcomes the problem of adding differences with different signs. Squaring takes much more time than finding the absolute value and it turns out it is no better than the absolute value as an indicator of degree of match.

Another pattern recognition technique not based on template matching is "linear discrimination." It is not very useful in practice but it excites people's mathematical instincts enough to write papers about it so we will mention it for the sake of completeness. If we view the features as dimensions in a multidimensional space (also called hyperspace), a pattern becomes a point in that space. If the points for all pronunciations of a word cluster together in a region of this hyperspace and regions corresponding to different words do not overlap, we can define hyperplanes that separate these regions. To classify a pattern then we can check to see if it is in a region enclosed by a given set of hyperplanes and keep checking until we find which region it corresponds to. If the regions cannot be separated by hyperplanes the feature space is not linearly separable which means that we can try to enclose the regions in sections of hyperplanes. It often turns out to be a matter of luck whether the feature space turns out to be even nonlinearly separable. The net result is that linear discrimination is often difficult if not impossible to use in practice.

Pattern recognition can also be achieved using a set of tests on a pattern to decide which word it represents. A simple example of that method is the rules used in the previously mentioned case of the volume signal to determine which one of the three words acceptable to the system has been pronounced. In a more complex system it is not very easy or accurate to do all the recognition by rule. Too many rules might be required and mistakes in the application of key rules might cause misrecognition or rejection. This last problem does not occur in template matching because each feature has equal say in the decision process; therefore a few bad features do not affect the result.

Rules can be used successfully together with template matching to speed up the matching procedure or to act as an additional accuracy check. For example, in a recognition system that accepts the digits 0 to 9, we might recognize a word as "six" by template matching but we may not be very sure that it is actually a "six": while the distance from the reference corresponding to "six" was the smallest it might also be too close to the threshold for a conclusive determination. Applying the rule that both the beginning and end of "six" have to be unvoiced we can either confirm our recognition or increase the suspicion that something is wrong, depending on the outcome of the test. In another situation we might check before template matching to see if the volume of the word has two approximately equal humps. If this test is passed we can then do template matching on the words "seven" and "zero" which are most likely to exhibit a 2 humped volume pattern. If template matching on one of these words gives a very good match well below threshold, we could accept it without further testing of the other patterns, thus saving testing time.

An interesting hybrid (template matching combined with discrimination by rule) recognition scheme is phonemic pattern recognition. It is based on the observation of phoneticians that human words are made up of a limited number of building blocks called phonemes. In English there are about 50 distinguishable phonemes. These phonemes were designated mainly by listening tests. Trying to automatically extract the phonemes is very difficult because our machines do not even approach the generalizing capabilities of the ear when it comes to speech. Proposals have been made to use from 200 to 700 basic units of speech for machine recognition in the hope that it will be easier to discriminate between those less general "phonemes." Reducing a word to a sequence of phonemes gives us a very low data rate pattern and simplifies pattern recognition, assuming of course that phoneme extraction is accurate. Phoneme extraction can be done using template matching, and recognition of a phonemic sequence can be done by rule.

Unfortunately in real life things are not that easy. The number of individual phonemes a machine can recognize depends on the type and number of features its preprocessor extracts. There exists no way to find out for sure what are the essential features that determine the phonemes for a given system except by tedious trial and error. In addition, coarticulation effects tend to change the pattern of phonemes depending on the phonemes that come before and after it. These effects can generate quite drastic

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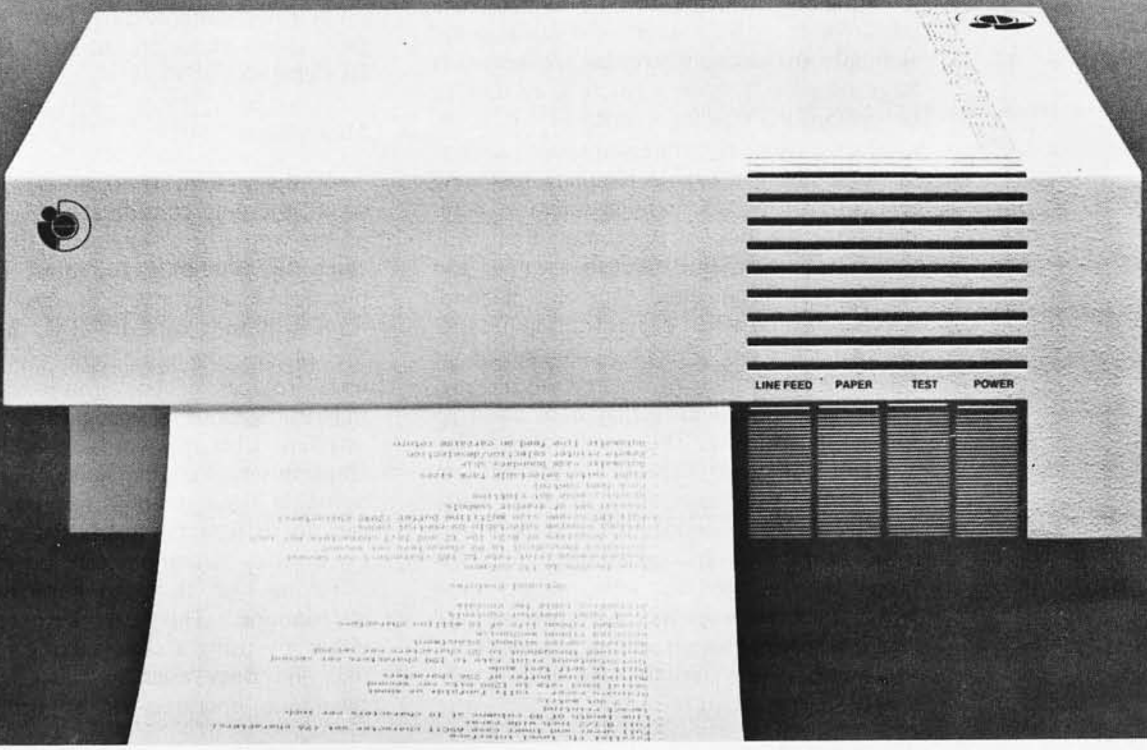

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changes in the pattern of a phoneme to the point that template matching is useless for recognition. In those cases some form of recognition by rule should be applied to separate the phonemes.

These problems are compounded by the fact that when we decide which phoneme represents a segment of speech we throw away all the features that make up the pattern for that speech segment. As a result, if our decision was mistaken for some reason, we have lost that portion of the speech pattern and even worse, we have substituted a potentially confusing phoneme. This is always a problem when we compress data too much. A piece of bad information can have very unpleasant consequences because due to the high compression factor there is not very much information available on which to base alternate decisions. A way around this problem would be to store the raw data until the final decision is made. If we are not confident in our decision for some reason we could go back and check the point of dispute. This is an example of the hypothesize and test method where on the basis of incomplete information a hypothesis is made as to what the word is and then the data is checked closely to either verify or reject the hypothesis. A disadvantage of this method is that it is time consuming computationally. The alternative to storing thousands of reference patterns in memory for template matching on a large vocabulary is cumbersome, to say the least. Finding a best match with templates when the vocabulary is big will take too much time even on very fast computers. Training the machine by storing reference patterns is still another disadvantage of template matching when the vocabulary is large because it takes a lot of user time to pronounce the training words.

Recognition of connected speech cannot be done using a simple template matching recognizer for two reasons that also complicate recognition of phonemes: First, it is very difficult to find word beginnings and endings in connected speech. Second, adjacent words affect pronunciation because of coarticulation. Practical recognizers at this time are limited to isolated word recognition and they require that each word be spoken individually. This is not as restrictive as it might seem because, with practice, words can be pronounced in sequence quite rapidly, up to 70 words per minute. Other usual restrictions on current pattern recognizers are the need for low ambient noise and a cooperative speaker. Cooperative here means a speaker who is willing to pronounce the words clearly, evenly, and with a conscious attempt at uniformity.

An Example of a Speech Recognizer

The basic components of any speech recognizer are the feature extractor and the pattern recognizer. The feature extractor is also called the "front end" or "preprocessor" and it is usually made up of analog circuits. The pattern recognizer nowadays is always a digital computer. We have seen an overview of what these two basic functions are, how they relate to the speech signal and how they are usually implemented. It is time now to give a block diagram of a speech recognition system using a particular method and go into greater detail about the functions and implementation of the various elements. I have chosen for this example a filter bank analyzer because I believe this particular approach will give the best results with the 8 bit microprocessors popular with computer amateurs. It is also a well known and proven approach, thus more likely to give consistent results than any other method. It is not the simplest possible approach and I expect to see a number of simple recognizers for personal computing machines based on zero crossing detection methods or combinations of zero crossing analysis and some sort of filtering. While it is possible that unusual feature extractors could give surprising results, the chances of something like that happening are very small. Speech recognition has a history about 30 years long and during that time many schemes have been tried, none of which gave better results in practical real time situations than the filterbank feature extractor.

Figure 12 is a block diagram of a complete filter bank feature extractor. Let us pay close attention to the specifics of its elements.

Microphone

If the system is to operate in a quiet room, the only consideration for the microphone would be a reasonably flat frequency response extending to about 8 kHz. In practice a quiet room is rarely the case. Radios, passing cars, the TV, the Teletype, the phone ringing, people talking are all usual sources of background noise which might trigger the recognition system or interfere with the words to be recognized. Once this background noise mixes with the desirable signal there is not very much we can do to separate them. The most benefit in a noisy situation can be derived by achieving high signal to noise ratio at the microphone. This can be accomplished either by using a close talking microphone like the ones used by aircraft pilots or telephone operators or by using a direc-

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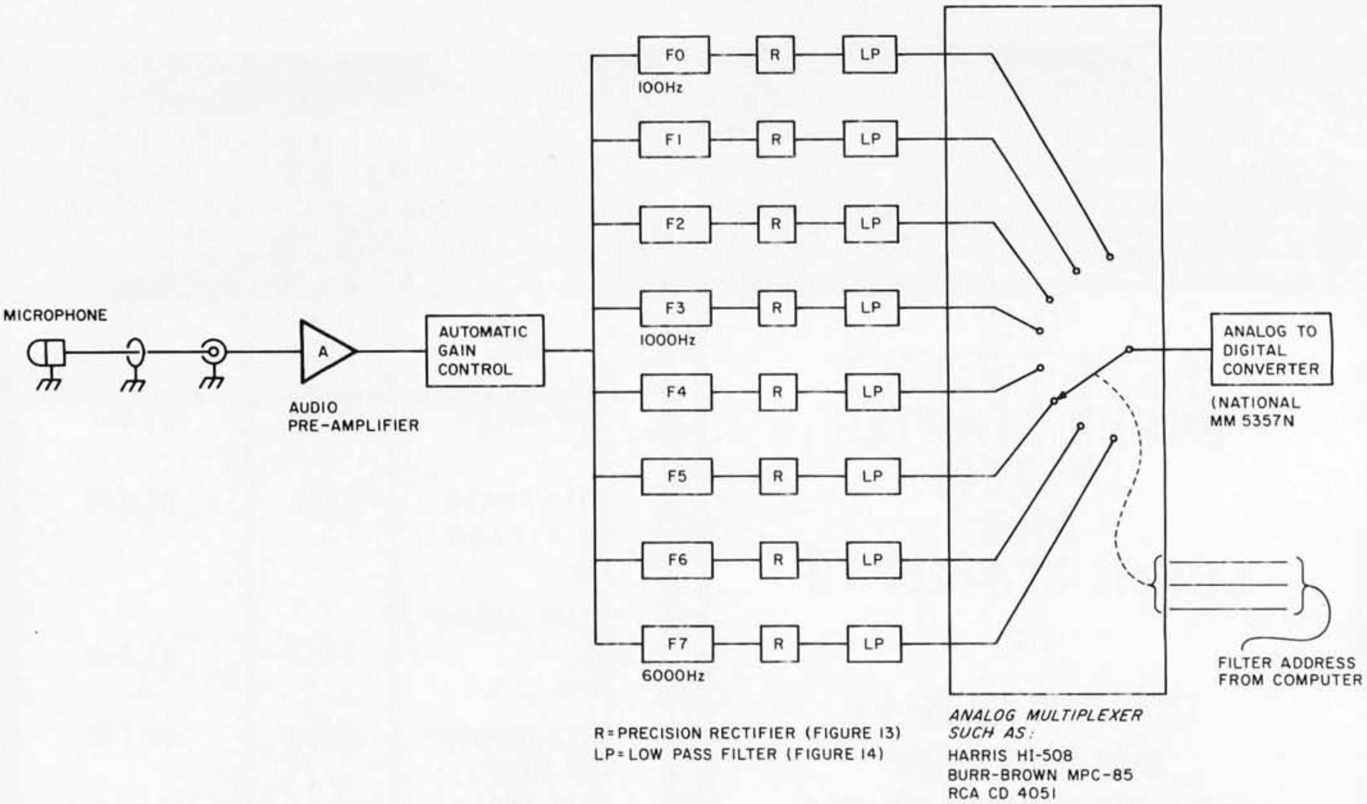

Figure 12: A detailed block diagram of a filter bank feature extractor. The output of the eight bandpass filters is sampled and digitized every 10 ms. Spectral information as well as word boundaries can be extracted from this set of data. See text for an extensive description of this particular implementation.

tional microphone. A directional microphone such as a cardioid will work best when the speaker is facing the noise source and there is no sound reflecting surface behind him. This last point is easy to overlook when using a directional mike so it is very important to remember that noise can get to the mike in its sensitive direction by reflection. A close talking mike depends basically on its distance from the speaker's mouth to separate between noise and speech and it is most helpful when the speaker moves unpredictably with respect to the noise source and when the environment is very noisy and reflective. The microphone should be positioned close to the mouth using a headphone strap or an eyeglass clip. This may or may not be a disadvantage depending on the application.

Audio Preamplifier

The audio preamplifier is quite straightforward in design being just a low level audio amplifier with flat frequency response unless it is used to equalize the response of the mike. There should be provisions to adjust its gain so that it can be matched to different mikes or background noise conditions. This is an infrequent adjustment and it should be hidden from the casual user. Changing the gain of the preamp affects the point at which the automatic gain control starts compressing and it should be done carefully.

Automatic Gain Control

As mentioned previously, the AGC should have very fast attack because in many instances the volume of speech increases very rapidly. Its release time should be 30 to 60 ms, fast enough to follow instances of quick decaying speech volume but not so fast that it will compress between glottal periods. If the AGC has a compression range of about 40 db it functions as amplitude normalizer so we do not have to do any normalization of the filter outputs in the computer.

Filter Bank

Eight filters were chosen for the filter bank simply because analog multiplexers are available with either 8 or 16 inputs and 16 filters are just too many. Another reason is that a workable system can be made with six filters as shown by George White (see references) and eight will certainly give adequate performance. There is a compromise made here between cost

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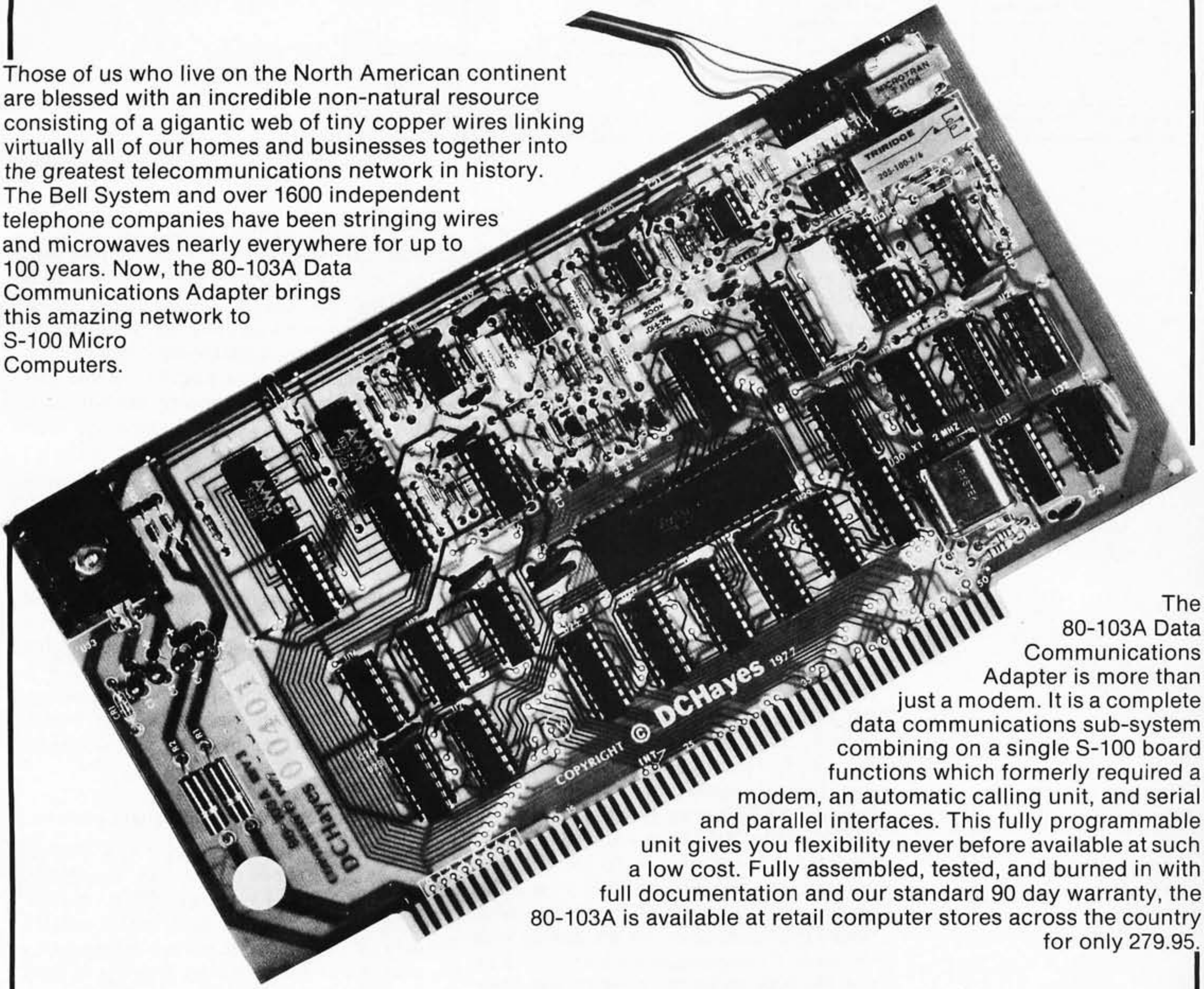

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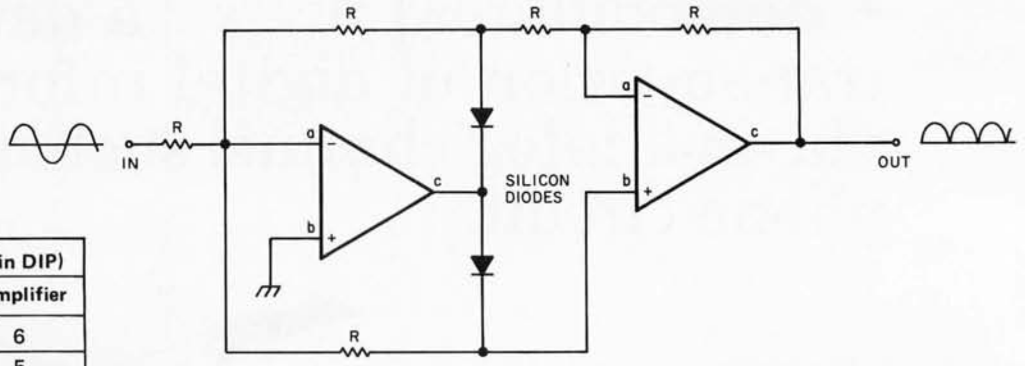
Figure 13: A precision full wave rectifier (R) used to rectify the output of each bandpass filter in figure 12.



R=10K A=1/2 558
(ALTERNATE AMPLIFIERS INCLUDE 741, 747, ETC.)

558 Dual Op Amp Wiring Table (8 Pin DIP)		
Pin	Amplifier A	Amplifier
a	2	6
b	3	5
c	1	7
Power: +12 V Pin 8 −12 V Pin 4		

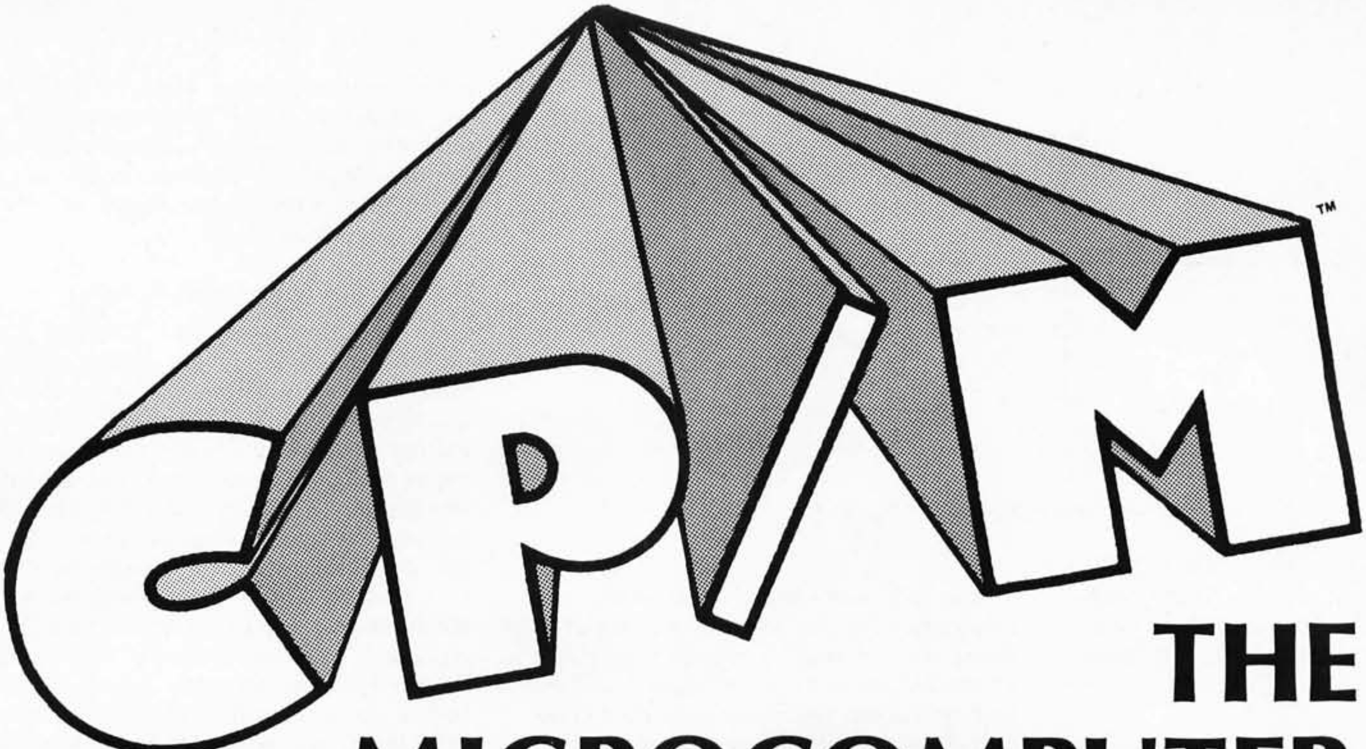
required storage and processing time on one hand and frequency resolution on the other. An interesting study will be to vary the number of filters in a given recognition system from let's say 1 to 16 and plot the recognition accuracy versus the number of filters. The center frequencies and the bandwidths given for the filters are merely an educated guess, based on knowledge of where the "action" is in the speech spectrum and on experimental results published so far. In a practical system some "tweaking" is highly recommended to achieve best results and to the true experimenter it should be irresistible anyway. The skirt characteristics of the filters should be from 24 to 48 db per octave. Steeper slopes require more poles in the filter which in turn require precision components so the desire for steeper slopes should be traded off with the realities of implementation. There are basically two approaches to implementing the filters: First hybrid active filters using the biquad configuration such as the National AF-100 or the Kinetics Technology FS-50 or the Burr-Brown UAF-31 can be used. They are quite easy to use but they have the disadvantage that they cost a lot. Second, one can build filters out of operational amplifiers. Since we are dealing with low audio frequencies, under 5 kHz, inexpensive 741 type op amps can be used as active elements. This will be less expensive than the previous approach but you will have to build the filters yourself, not necessarily the kind of trade-off everyone likes.

Rectifiers and Low Pass Filters

The use of relatively low level signals in the system makes the use of a precision rectifier after the bandpass filters mandatory. In precision rectifier circuits op amps are used to eliminate the forward voltage drop of the silicon diodes, that is 0.7 V, thus making the circuit behave like an ideal diode. Full wave rectification is desirable to give low ripple. A suitable precision rectifier circuit is shown in figure 13. A low pass filter is suggested to smooth the output of the rectifier. A 2 pole Butterworth filter with a cutoff frequency at about 20 Hz will work well and is shown in figure 14. Instead of the low pass filter we could use an integrator that is reset every time it is read by the analog to digital converter. The integrator output would be proportional to the average of the energy in the frequency band of the given filter during the period between reads. This of course is more complicated than using just a low pass filter and it is questionable whether it will give better results. It has been used in the past though and it is covered by a patent for use in vocoders.

Multiplexer and Analog to Digital Converter

There are several monolithic 8 channel analog multiplexers such as the Harris HI 508 or the Burr-Brown MPC-85 but the RCA CD4051 is the best choice, costing only $1 in single quantities compared to around $15 for the others. There is no need for a sample and hold because the preceding low pass filter assures that the signal does not change quickly. An excellent choice for the analog to digital converter is the National MM5357N which at $11.95 is three times cheaper than the competition. Making your own analog to digital converter from scratch using an 8 bit digital to analog converter could cost half as much assuming you do not count your time.



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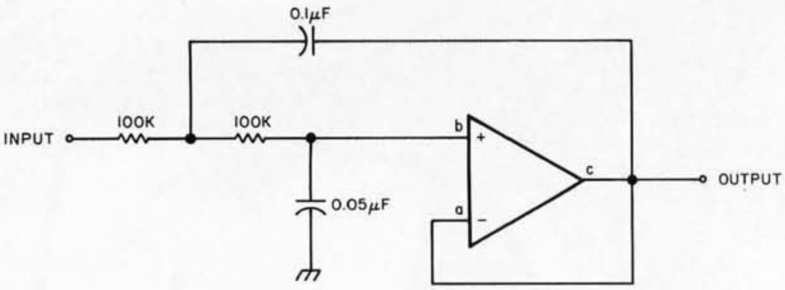

1/2 558 (SEE FIG. 13 FOR PINOUTS)

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Figure 14: A 2 pole 20 Hz low pass filter (LPF) suitable for smoothing rectified speech audio in figure 12.

You will notice that neither volume nor information as to whether the signal is voiced or unvoiced is explicitly extracted by the feature extractor of figure 12. These features are not lost. They are buried in the output of the filters. The sum of the filter outputs, for instance, at any sample point in time is the volume for that sample. A voiced sound has most of its energy under 1000 Hz and the opposite is true for unvoiced sounds. If we divide the sum of the outputs of the four higher frequency filters by the sum of the outputs of the four lower frequency filters we will get the ratio of the energy in the 1000 to 6000 Hz band to the energy in the 100 to 1000 Hz band. If this ratio is less than 1, the sound is voiced; otherwise it is unvoiced.

There are many ways of utilizing the features extracted by the filter bank feature extractor in a pattern recognizer. Actually this versatility is one of the desirable characteristics of the filter bank. Here I will describe only one possible approach to illustrate the various principles involved. Since all pattern recognition is done in software, experimentation in this area is easy and fun since you don't have to buy or build additional hardware to improve your recognizer. A pattern recognizer has two basic modes of operation: training and recognition. During training it performs the following functions:

- Word boundary detection (beginning and end).
- Pattern input and normalization.
- Reference pattern storage.

In the recognition mode, reference pattern storage is replaced by pattern matching (classification). Training is required to generate reference patterns for the words that form the vocabulary of the recognizer. When a different speaker wants to use the system, retraining is necessary to generate reference patterns for the new speaker's pronounciation of the words. Implicit in our discussion is the assumption that we limit our recognizer to isolated word recognition. Moreover, these words are to be drawn from a limited vocabulary of about 10 to 30 words in size.

Word Boundaries and Normalization

In operation, the word boundary detection module reads the output of the filter bank every 10 ms and stores it in a temporary storage area. To do this an input routine sequences the multiplexer, starts the analog to digital converter and reads the data into memory. A simple and usable means of detecting word beginnings and endings is to sum the output of the filters and compare it to a given threshold. If the energy exceeds the threshold, a word has begun. There is a precaution to be taken however when using volume for word boundary detection. Certain consonants called plosives or stops (p,t,k,b,d,g) are generated by building up pressure and then suddenly releasing it. While the pressure is being built up no sound is generated and this silence period or "stop gap" can last up to 150 ms. If this occurs in the middle of a word as in "ago" for example, the simple boundary detector will be fooled to think that two separate words occurred. This can be corrected easily by considering any "words" less than 200 ms apart to be parts of one word. Another problem arises when a noise pulse occurs without any word being said as in the case where something is dropped on the table. To prevent the word boundary detector from accepting such noise as a word, we define any sound with duration less than 150 ms as noise because words are not that short. These modifications will make the boundary detector quite successful for operation in a quiet room with a careful speaker. For any other situation considerable additional sophistication might be necessary. In a noisy environment the threshold for word detection has to be increased so that the detector will not trigger on background noise. But increasing the threshold will tend to chop off the low amplitude beginnings and endings of some words and this can affect recognition significantly. If the speaker is careless or he is physically strained when he speaks because, for example, he is lifting something heavy, breathing noises will tend to be considered as part of the word being said, further degrading recognition. In these situations a sophisticated boundary detector is very helpful in maintaining system performance. Once the beginning of a word is detected, the pattern input starts. Every 10 ms the output of the filters is sampled and stored in

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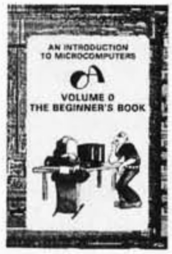

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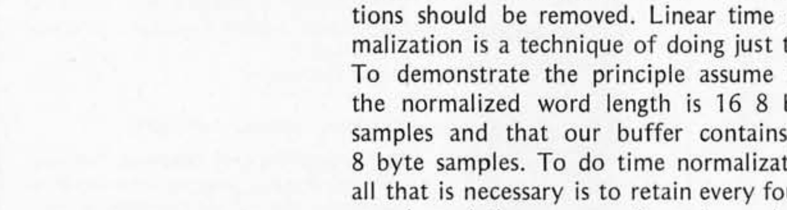
consecutive memory locations in the buffer area. The duration of the longest word can be expected to be less than 1.2 seconds, giving us a maximum of 120 samples to store in the buffer. Thus a 1 K buffer will be sufficient.

Upon detection of the end of the word, some form of time normalization is required before the next step. This need arises from the fact that people do not time their pronunciations the same every time. They may say "zero" one time and "zeroo" the next. Before we can do template matching, if we are to be successful, these timing variations should be removed. Linear time normalization is a technique of doing just that. To demonstrate the principle assume that the normalized word length is 16 8 byte samples and that our buffer contains 65 8 byte samples. To do time normalization, all that is necessary is to retain every fourth sample and throw away the rest, as shown in figure 15. If the number of samples in the buffer is not a multiple of 16 plus 1 (16 · N)+1, a number of rules can be implemented to resolve the problem. For example, if there are up to four less samples than (16 · N)+1, then samples in areas of high amplitude can be duplicated to reach a number of samples that is exactly (16 · N)+1. The assumption here is that in areas of high amplitude interesting things exist. It is not necessarily a correct assumption but it can give an idea of what can be done to adjust the length of the word without resorting to linear interpolation. Larger discrepancies can be treated similarly but duplication should occur throughout the word to avoid stretching only a part of it. Omission of samples can be used as well, to adjust the length. Insertions and deletions can be made in a number of locations in the word based on criteria other than local amplitude. For example, deletions in the beginning or ending of words, or slow spectral changes are other possibilities. The best guide as to what works for any given system is some experimentation with various techniques.

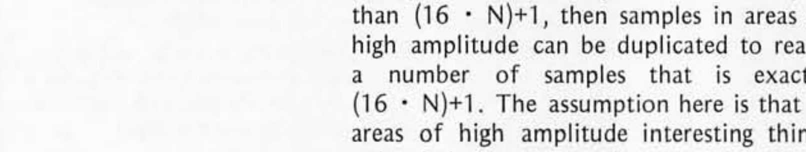
In usual practice, all words in a vocabulary for a given system are normalized to the same length, regardless of their actual length. It might be useful, though, if a large proportion of the words of the vocabulary are distinctly different in length from the rest, for example "yes," "no," "on," "off" compared to "television," "instrument," "telephone," to have two normalization lengths. An added benefit to the obvious savings in pattern storage memory would be a reduction in classification time because there is no point in trying to find a match between a long and a short word.

A more advanced form of time normalization is based on dynamic programming techniques. It is basically a systematic approach to stretching and compressing the unknown word in time until it best fits the reference pattern. It gives excellent results but it has two drawbacks: It is time consuming and it requires storing all the input samples for a given word as reference patterns. Despite its shortcomings, its superior performance makes it a very interesting technique. Its detailed analysis is not within the scope of this article.

The final phase of the processing of the unknown word depends on whether we are in the training mode or the recognition mode. In the training mode all that is necessary after time normalization is to store the resulting pattern in memory in an area designated for the word pronounced. To improve performance two or more reference patterns may be used for a given word to account for variations in pronunciation. For example the speaker may be required to pronounce each word in the vocabulary twice (although not one immediately after the other to avoid similarity as much as possible) so that two references will be generated and stored for each word. Variations of this scheme include making the speaker repeat a word until it is sufficiently different from the first reference or changing the second reference adaptively as the system is used. In the recognition mode the normalized unknown word is compared to



6 SAMPLES SELECTED ONE EVERY 4 INPUT SAMPLES
TO ACHIEVE LINEAR TIME NORMALIZATION



LAST SAMPLE IS DUPLICATED TWICE SO THAT ABOVE RULE
CAN BE APPLIED TO NORMALIZE LENGTH TO SIX SAMPLES

Figure 15: Linear time normalization compresses the stream of input samples to a fixed number of samples (in this case six) by selecting a sample at regular intervals. The resulting fixed length for all words facilitates feature matching for pattern recognition. Various techniques (such as duplicating samples) are used to make the number of inputs fit the selection rule.

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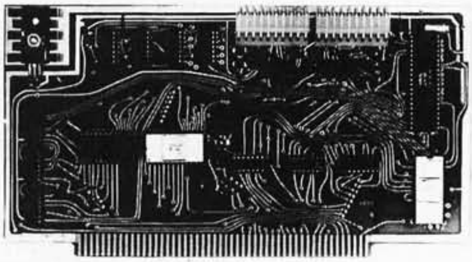

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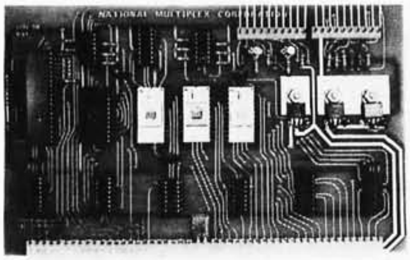

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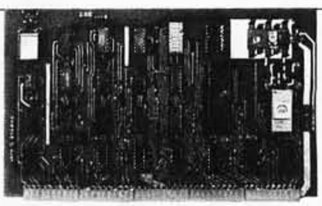

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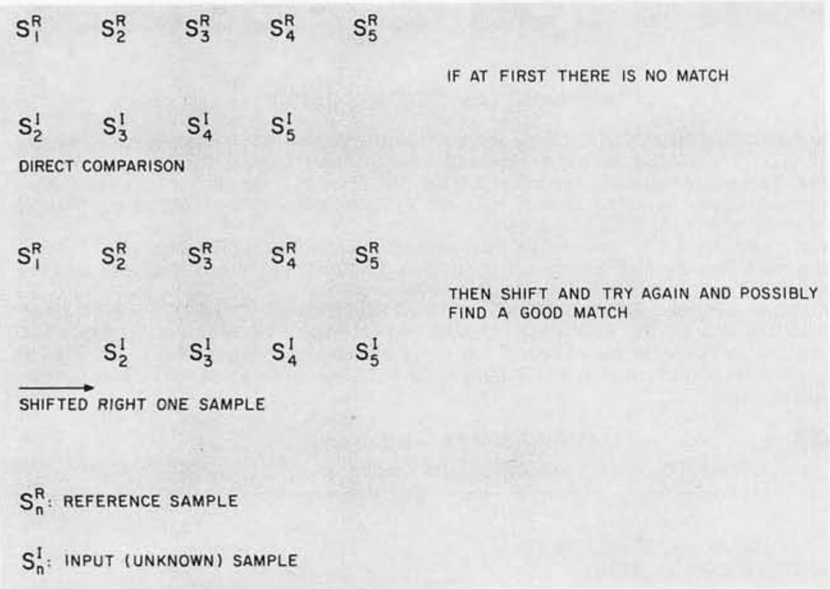

Figure 16: Shifting the unknown left and then right one position helps prevent mismatches due to missing ends or beginnings. In this case the right shift gave a good match. This test has been simplified to one parameter (S) which might be the output of one filter in a filter bank.

each reference pattern by computing the sum of the absolute values of the differences of the features. The smallest sum indicates the best match between the unknown and that reference. This alone is not sufficient for recognition because a word that does not belong to the vocabulary of the system will always give a best match because one of the reference patterns is bound to be more like it than the others. To avoid "recognizing" words that are not in the vocabulary, we impose the restriction that successful recognition requires that the smallest difference measure will be smaller than a given threshold. This threshold has to be found experimentally for any given vocabulary. If it is too high, it will allow for acceptance of words that are not part of the vocabulary. If it is too small, words that are in the vocabulary but not pronounced very close to the stored references will be rejected.

Word beginnings and endings usually have low amplitude and it is possible that the word boundary detector could chop them off. If that happens, it will most likely happen only occasionally and as a result there will be instances where the reference and unknown patterns are shifted with respect to each other in time. For this reason, if computer time is available, the unknown may be shifted to the right one position and the difference calculated and then to the left and the difference computed again as shown symbolically in figure 16. The smallest of the three differences thus computed is to be used as the indicator of match quality.

When a word is recognized it can be used directly to perform a function which could be, for example, the equivalent of pushing a key on a calculator. In some instances it is necessary or desirable that more than one word be used to perform a single function. For example the sequence of the words "light on" can perform the function of turning on the lights in a room. In these cases there should be a subroutine to check if the word sequence is correct. For example, the word "light" should be followed by the words "on" or "off." If the word "radio" follows, we know that either "radio" or "light" has been misrecognized. These syntactical constraints decrease the probability that an incorrectly recognized word will cause something undesirable to happen. This is due to the fact that for a sentence to be correct, all the words that form it have to be correct, at least syntactically. Syntactic constraints of course do not help when the words have the proper sequence but are still not correct. For example, if we are controlling a vehicle of sorts and we say "forward faster," if "faster" is recognized as "slower" the sentence will be syntactically correct but it will not do what we want.

Performance

The performance of a recognizer is evaluated on the basis of the percentage of the words it recognizes correctly out of the total pronounced. For a given recognizer the recognition score will vary from speaker to speaker, with the speaker's emotional condition and with the level of background noise, to mention some of the variables. Recognition scores quoted in articles and advertisements are likely to be the ones obtained with best conditions and they are not necessarily indicative of the performance of the recognizer under actual conditions. There exist three types of recognition errors: failure to recognize a given word, substitution (recognizing one word for another) and misrecognition (recognizing a word not in the vocabulary). The first type of error is in most cases merely an annoyance requiring that the user repeat the word. The last two types of error can cause problems because the recognizer will give a response which is wrong. Failure to recognize will occur when the recognition threshold (the maximum that the smallest difference sum can be to recognize a word) is set too low. Setting the threshold too high will result in misrecognition, as mentioned previously. Substitution becomes a problem when the vocabulary size is increased. To avoid substitution the vocabulary can be divided in two segments and a shift word used to switch between the two segments of the

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vocabulary. The shift word can be "shift" or "change" for example. This would correspond to the shift key on a typewriter or the function ("f") key on a calculator. The user will have to remember in what segment he currently is and when a word from the other vocabulary has to be pronounced he should preface it with the shift word. The system can provide the user with an indication such as an LED to remind him of the current segment. Using a number of different shift words it is possible to extend the technique to several segments of a large vocabulary.

Advanced Systems

The hottest areas in speech recognition today are feature extraction using digital speech processing and speech understanding systems. Unfortunately both are out of the reach of the capabilities of the usual amateur computing experimenter's machines. In addition they tend to be involved theoretically so we will only briefly mention them here. Digital speech processing involves operating directly on the sampled time domain waveform and as it was mentioned earlier it requires very fast computers. One of the most usual operations is the Fourier Transform. It is computed using a fast algorithm called the FFT for Fast Fourier Transform and the result is the spectrum of the signal as was shown in the example of figure 5 (actually figure 5 is the log of the magnitude of the spectrum). Its advantage over output of a filter bank is resolution and accuracy. A typical FFT derived speech spectrum is made up of 128 frequencies spanning the range from 0 to 5 kHz. The amplitude at each frequency is specified with 12 to 16 bit accuracy. Such performance is very difficult to achieve using analog components and certainly not economical. The output of the FFT can be used directly by making different measurements on it to extract features, such as the formants. IBM is using this approach in their research effort in speech recognition which, by the way, is very well funded, in the range of millions of dollars per year.

Another digital method for speech processing is "linear prediction." It is a method by which the impulse response of the vocal tract can be extracted from the speech signal. It is basically a time domain operation and it involves predicting the next sample of the waveform on the basis of a linear combination of the N previous samples. It can be used for formant extraction but it is at times quite sensitive to minor aspects of the input signal so it is not as reliable as might be desired. When it works it gives excellent results and therefore it has a lot of promise as a formant tracking tool. It has also been used in isolated word speech recognition by storing the vocal tract impulse response it generates as reference pattern and then comparing it with the impulse response of the unknown. It gave very good results in a vocabulary of 200 words. As it would be expected, this method yields results very similar to the filter bank approach because they are very similar in substance although totally different in implementation.

Formant extraction can also be achieved with "cepstral" analysis which is based on the Fast Fourier Transform. The cepstrum is the spectrum of the logarithm of a spectrum. These operations separate the impulse response of the vocal tract from the driving function. Its name is derived from the word spectrum spelled more or less backwards because the operations involved in obtaining it are very similar to spectral analysis of a time domain signal. It gives very good results when used for pitch extraction but when used for formant extraction it is not very reliable. It tends to fail in different ways than the linear prediction methods so perhaps the two methods combined will yield good results.

All these methods will become more commonly used as computer technology advances decrease the cost of very fast computers. Because of their accuracy (at least when the data is to their liking) these algorithms are bound to play a significant role in feature extraction of future recognizers.

Speech Understanding

Speech understanding systems differ from speech recognition systems in that they do not just recognize sequences of words but instead they use knowledge about the subject of discussion to check if the word sequences make sense. They use syntactical analysis as previously mentioned as well as context analysis to improve recognition. For example, a speech understanding system used to input the moves of a chess player to the computer (an experimental system doing just that has been built at Carnegie-Mellon University) checks the recognized sentences for syntax errors and then checks whether the sentence gives a legal chess move for the particular situation. Speech understanding systems are usually designed with a specific problem domain in mind for which the semantics are known. The US Defense Department's Advanced Research Project Agency (ARPA) has spent about $30 million on the development of a speech understanding system in the last five years. The results have not been too exciting, an indication that high performance speech recognizers are hard to build.

Commercial Systems

Threshold Technology Inc, Dialog Inc, Perception Technology and Scope Electronics all offer commercial speech recognition systems capable of recognizing isolated words from 16 to 32 word vocabularies. Of these, Threshold Technology is by far the most successful commercially and their systems are used in a variety of industrial applications, such as baggage handling in airports (the destination is spoken to the system which in turn routes the baggage) and quality control inspection (the inspector uses his or her hands to hold a micrometer and take measurements which then are spoken to the recognizer and entered in a computer for report generation). The Threshold Technology machine uses an LSI-11 and their feature extractor consists of a bank of 16 filters. It costs about $10,000. Threshold Technology claims 99.6 percent recognition rate and operation in noisy environments.

At the time of this writing (April 1977) Heuristics Inc has announced an Altair (S-100) compatible recognizer. It sells for $249 in kit form and a detailed description of its hardware appears in the May 1977 issue of *Popular Electronics*. It is a simple device consisting of three bandpass filters and a zero crossing detector. The filters cover the range of 150 Hz to 5 kHz. Their output is peak detected and averaged and then quantized with six bits resolution. They claim 90 percent correct recognition in a quiet environment with a cooperative speaker.

Addresses of Commercial Speech Recognition System Manufacturers

1. Threshold Technology Inc
   1829 Underwood Blvd
   Delran NJ 08075
2. Heuristics Inc
   900 N San Antonio Rd (Suite C-1)
   Los Altos CA 94022
3. Dialog Systems Inc
   639 Massachusetts Av
   Cambridge MA 02139
4. Scope Electronics Inc
   Reston VA 22070
5. Perception Technology Inc
   Winchester MA 01890

As a final remark, a note on recognizer performance is in order. It was mentioned before that quoted performance figures are usually the best obtained with a given system under ideal conditions. This optimistic approach reflects more than anything the difficulty of making a very good recognizer. People choose to present the best results because the bad results may look terrible and the average unimpressive. While recognition scores can be taken with a grain of salt, it would be a mistake to view speech recognizers in the same light. The correct approach is to see them as a challenge to find applications in which they are useful despite their present shortcomings. You certainly would not want to control your car with a recognizer that has a 90 percent recognition score. Yet I have seen a recognizer with an average 80 percent score do a very good job in controlling the electric wheelchair of a paralyzed patient. Think how important this is if you can only move your head and speak and the rest of the body is paralyzed totally.

I am sure that a great number of applications can be found for existing systems that I just haven't thought of yet, or that I would never imagine. Given the thousands of computer enthusiasts and their different backgrounds and the computer power they command, I wonder if there will be any stones left unturned in the applications area now that we can talk to our own speech recognizers.■

REFERENCES

1. Lindgren, Nilo, "Machine Recognition of Human Language," *IEEE Spectrum*, March and April 1965. A somewhat antique review of the field. This article covers history and some principles in rather nontechnical language.
2. Otten, Klaus, "Approaches to the Machine Recognition of Conversational Speech," *Advances in Computers*, vol 11, Academic Press, NY, 1971. Easily readable, a less antique review than Lindgren's.
3. White, George, "Speech Recognition: A Tutorial Overview," *IEEE Computer*, May 1976. A very up to date review, rather technical at points but quite readable.
4. Martin, Thomas: "Practical Applications of Voice Input to Machines," *Proceedings of the IEEE*, April 1976. The author is president of Threshold Technology and from that vantage point reviews the practical side of speech recognition.

The reference lists at the end of each of the above papers are good sources of additional information.

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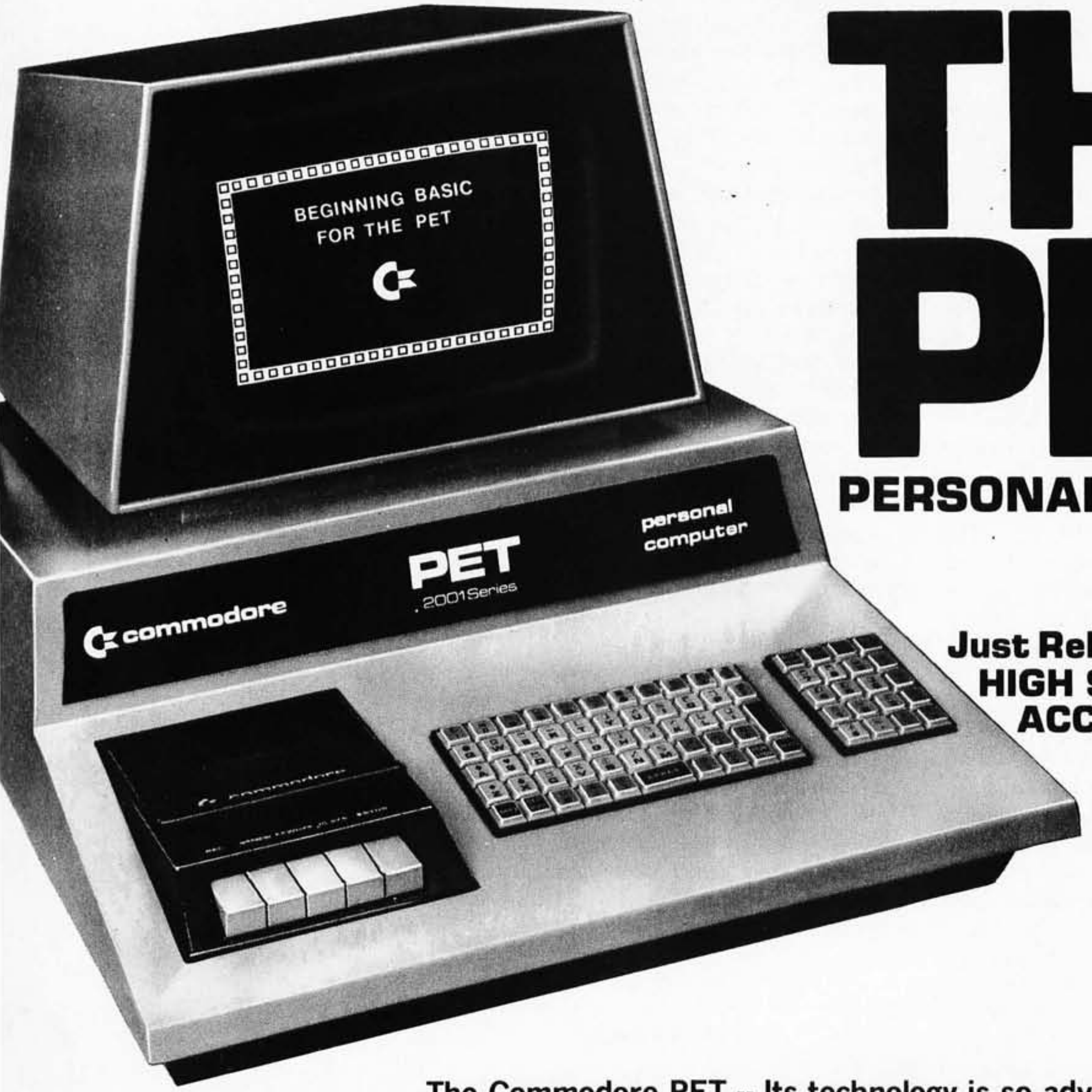

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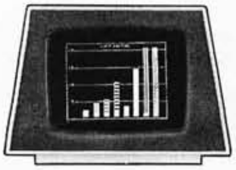
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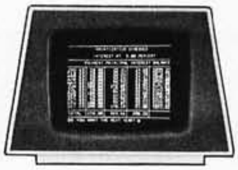
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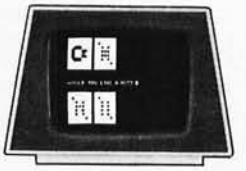
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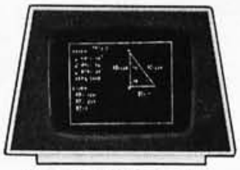
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Read Only Memory (operating system resident in the computer); 14K bytes
8K-BASIC interpreter program
4K-Operating system
1K-Diagnostic routine
1K-Machine language monitor

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9" enclosed, black & white, high resolution CRT
1000 character display, arranged 40 columns by 25 lines
8 x 8 dot matrix for characters and continuous graphics
Automatic scrolling from bottom of screen
Winking cursor with full motion control
Reverse field on all characters (white on black black on white)
64 standard ASCII characters; 64 graphic characters

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All 64 graphic and reverse field characters accessible from keyboard (with shift)
Screen Control: Clear and erase
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BYTE's Bugs

Caught Microprocessor Programming

John W Langner, 411 Monterey Blvd, Apt B, Hermosa Beach CA 90254, sent us a letter pointing out a relatively gross terminological faux pas which we allowed to stand in an article entitled "Take a Course in Microprogramming" by Richard Mac Millan on page 168 of the March 1978 BYTE. The terminological ambiguity of the "micro" in the common name for large scale integration computer processors comes from the fact that the term "microprogramming" is not the same as "programming a computer implemented with a microprocessor." The article should have been edited so that the term "microprogramming" never appeared in the course of its text; the title might better have been changed to "Take a Course in Microprocessor Programming."■

Bug Bug

In the March 1978 BYTE's Bugs (page 46) we reported on some bugs in figure 1a of David Allen's "A Floppy Disk Interface," January 1978 BYTE, page 61. One more item should be added to the list: disconnect the line presently going to pin 9 of IC3c (the NAND gate which feeds into the $\overline{CE}$ line of IC4). In its place run a line from pin 9 of IC3c to pin 4 of IC12b (the latter pin is also connected to pin 5 of IC3b). This change is necessary so that IC4 will be addressed when the QC and QD outputs of IC5 are at low and high levels, respectively. We thank Howard Oels of Phoenix AZ for discovering this bug in the bug.■

Moving Violation

The 6800 program relocator presented on page 197 of the November 1977 BYTE should more properly be called a move routine for use with self-relocatable code only, since it obviously will not fix the internal references of three byte jump instructions. Our thanks to Ed Smith of Ed Smith's Software Works for this information.■

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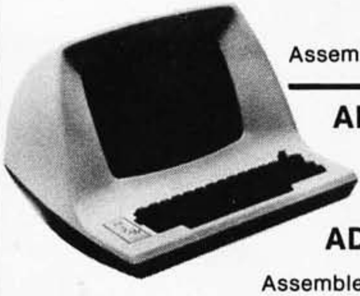

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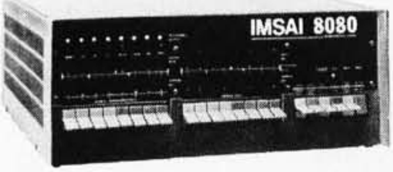

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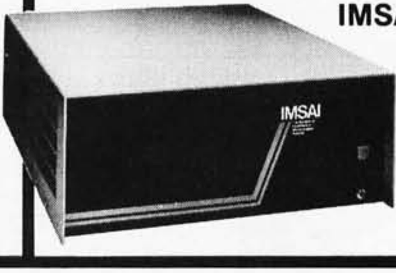

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____**Periodical Guide for Computerists,** January-December 1977, by E. Berg Publications. This is a comprehensive index of all the articles, book reviews, editorials, letters, record reviews, and miscellaneous small inserts and notes from the top 25 magazines in the field. Several thousand articles are grouped into over 60 subject categories that are listed alphabetically for easy reference. At the back is an author index, including the major areas of their expertise. An indispensable guide for anyone in the fields of personal computing, amateur radio, and electronics. 72 pp. $5.00.

____**Robots on Your Doorstep** by Nels Winkless and Iben Browning. "This book will amaze you, frighten you, nauseate you, excite you...it will probably make you think about things you have never contemplated before," states the introduction to this clever and well-written account of robots: past, present, and future. Intelligence, artificial intelligence, brain structure and simulation, and characteristics of robots are only a few of the areas explored. One chapter is devoted to the personal computer revolution and how it has brought robots into the amateur's workshop. 179 pp. $6.95.

____**Programming in PASCAL** by Peter Grogono. This book is an excellent introduction to one of the fastest growing programming languages today. The text is arranged as a tutorial containing both examples and exercises to increase reader proficiency in PASCAL. Besides sections on procedures and files, there is a chapter on dynamic data structures such as trees and linked lists. These concepts are put to use in an example bus service simulation. Other examples range from the Tower of Hanoi problem to circumscribing a circle about a triangle. **Programming in PASCAL** is sure to hold the reader's interest. 359 pp. $9.95.

____**Z80 Programming for Logic Design** by Adam Osborne, Jerry Kane, Russell Rector, and Susanna Jacobson. Here's the book we've all been waiting for! It's third in the series of Osborne's programming for logic design books (the 8080 and 6800 books). Written for both programmers and logic designers, it explains how an assembly language program can replace non-programmable logic devices—with direct reference to the Z80 microcomputer. 352 pp. $7.50.

There will be a one dollar price increase on July 1, 1978, so order now and save!

____**8080A/8085 Assembly Language Programming** by Lance A. Leventhal. This book provides an introduction to assembly language programming for the 8080A and the 8085 processors. Included are sections on the instruction sets for the two processors, assemblers, simple program examples, code conversion, tables and lists, subroutines, IO, interrupts, program design, and debugging. Many examples and illustrations are included to cover critical points. 467 pp. $7.50.

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____**How to Profit from your Personal Computer** by Ted G. Lewis. If you have wanted to use your personal computer in a profitable manner, and you feel you need some help planning programming techniques for common business applications, this book is for you. Enjoyable and readable, it contains suggestions for accounting, payroll handling, inventory management, and sorting mailing lists. Many terms and notations are explained. Sample programs in BASIC, the use of blueprints to design program structure, and a full glossary of terms are a few of this book's special features. 191 pp. $7.95.

____**Microcomputer Primer** by Mitchell Waite and Michael Pardee. Here's a microprocessor tutorial for readers having some electronics background. **Microcomputer Primer** concentrates on the hardware of microcomputers (although there are sections dealing with software) with chapters on basic computer concepts, hardware, programming, memories, and number systems. A full complement of photos and schematics accompanies the text. 224 pp. $7.95.

____**Programming a Microcomputer: 6502.** This informal, well-written book may be just what you need to enter the world of microcomputers. Caxton C. Foster uses the 6502 as a basis for discussing the techniques of writing programs. The chapters include simple, practical example programs for creating a Morse Code oscillator, combination lock, tune player, digital clock, and more. The emphasis is on clarity, and the many illustrations and flowcharts help get the author's points across. 231 pp. $9.95.

____**Programmable Calculators** by Charles J. Sippl and Roger J. Sippl. This large (526 pages) book is an exhaustive survey of the programmable calculator field covering its history and present status. Chapters deal with the basic calculator, advanced hand-held products, RPN (Reverse Polish Notation) versus algebraic notation, desktop calculators, and programming the programmable calculator. Examples and illustrations abound in this useful reference work. $14.95.

Here are two big packages of fascinating information and practical guidelines from the symposiums held at the 1977 and 1978 West Coast Computer Faires.

___**The First West Coast Computer Faire Conference Proceedings,** edited by Jim C. Warren, Jr., contains 336 pages covering such topics as: tutorials for the computer novice, human aspects of system design, robots (including the text of a talk by science fiction writer Fred Pohl), computers for the physically disabled, education, electronic mail, music with computers, hardware, software—the list goes on. $12.00.

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____**Fundamentals of Recordkeeping and Finance for the Small Business** by Robert C. Ragan, CPA, and Jack Zwick, Ph.D. Once you have your organization or business up and running, records must be kept. What should I keep, and how do I record them? This book on fundamentals will give you a helpful start. Section One deals with maintaining records, protecting assets, and providing a basis for planning. Section Two provides a starting point for owner-managers who want to sharpen their financial management skills. 196 pp. Only $10.00 in hardcover.

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BITS™ The Microcomputer Bookstore

Continued from page 11

Shore) who decided to feed the output from his orbital motion program into our music system (instead of data that represented conventional music). The results were very intriguing, and quite modernly musical. They helped us all see the power of allowing human imagination to work with objects that represent a new kind of clay or paint—in this case algorithms for solving differential equations! The designer of the music system (Jeff Lederer) had obviously developed a use of technology that was radically different from the fanciest of "record players."

The same ideas apply to color graphics. Photo 1 shows a very simple example of using an algorithm as a creative adjunct. The first slide shows a static use of the medium. The artist simply used a light pen to "paint" a bouquet of flowers on the screen of a Compucolor 8051. Photo 2 shows what happens when the computer is no longer static. In this case it uses two algorithms: one to draw nothing more than the simple elegance of a sine curve, the other to join the artist's light pen input to the computer's sine curve with vectors. Our feeling is that the second mode is great for people (including very young kids) who haven't yet developed the techniques needed for painting a bouquet of flowers or composing a two-dimensional space abstractly (which is what the sine function does in this context). From the point of view of technical competence, the first mode (static computer) is the more advanced one. The function of the second mode is to get the user thinking creatively so that he or she can eventually go beyond what the machine helped start.

Translating this idea into a general philosophy of "Why personal computing?" gives the unexpected but heartening answer: "To help people do things computers can never do."

Tom Dwyer
Margot Critchfield
325 N Craig St
Pittsburgh PA 15213

Tom Dwyer and Margot Critchfield's article, "Color Graphics on the Compucolor 8051," appeared on page 32 of BYTE May 1978.

TEXT EDITING DREAMS AND REALITIES WITH AN AM-100

This is in response to your March 1978 editorial. A friend of mine asked me two years ago to create a keyboard especially for him. He was at that time employed as a phototypesetter for the *Los Angeles Free Press.* As a result I got heavily involved in the discrepancies between the needs of a typesetter and the available [Singer-Friden-Burroughs-IBM-3%&†*($+&!&%] word processors! Therefore, your editorial on the desire for a truly sophisticated editor stirred some painful memories of TTS book codes, incompatible character sets and paper tape format, TTL logic, etc. The project never did "fly" right.

However, since that time I've come across (and purchased) a system that I am surprised you haven't given heavier mention of in your magazine. I am referring to the Alpha Microsystems AM-100. Let me explain why I feel it could result in the editor you are searching for.

The AM-100 processor is a two board realization designed to interface with a parallel operating 8080/Z-80 CPU on the Altair (S-100) bus. It uses the Western Digital WD-16 chip set, which is an extended version of the DEC LSI-11, but using special microcoding to create a more powerful instruction set. Using this, Mr Wilcox has made an operating system similar to UNIX, with some features of DECsystem 10. Included in the software bundled with the processor is the operating system (it supports eight users with full timesharing protocols), a powerful macro assembler, BASIC, LISP, and a system EDIT.PRG, all disk oriented. For a preliminary feel for what this means, read *Dr Dobb's Journal*, volume 2, number 1, page 3. The AM-100 system manuals comprise, at present, over 250 pages of closely packed information.

Robert Williams
President, Cheesy Operations
Micromouse Enterprises
POB 69
Hollywood CA 90028

IMPROVING RELATIVE ADDRESSING FOR THE 8080

I read with great pleasure Mr Gaskell's article on "Relative Addressing for the 8080" in the December 1977 BYTE. The approach to implementing the relative jumps was superb.

However, having been working with microcomputer applications for several years, I have learned that any program can be made shorter and faster with a little effort! Moreover, optimization in the case of the relative addressing routine is even more critical than usual since the code will be executed with incredible frequency if most of the jumps in a main program are relativized. The key to optimization is selecting a value for BIAS such that (BIAS+4) is a multiple of 256. The program section in both its original and optimized form is shown below. The optimized version saves two microseconds (at 2 MHz).

Gaskell's version

```
LXI D,-(BIAS+4)
DAD D
```

Lewis' version

```
MVI A,-(BIAS+4)/256
ADD H
MOV H,A
```

I would like to say that no further optimization is possible but the rule says, "any program can be made shorter and faster." Suppose we select BIAS = FEFC! Then −(BIAS+4) becomes 100 hexadecimal and the code becomes:

Lewis' version 2

```
INR H
```

This final version saves 7.5 microseconds over the original version! The routine is now completely optimal!

Jim Lewis
Micro Logic Corp
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with all attentive mind.

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'neath ROM's intent control.
It does what it's supposed to do.
(It has no other goal.)

Let's hear a cheer from ROM, my friends,
and celebrate its ends.
A servant so impeccable
is rare as teeth in hens.

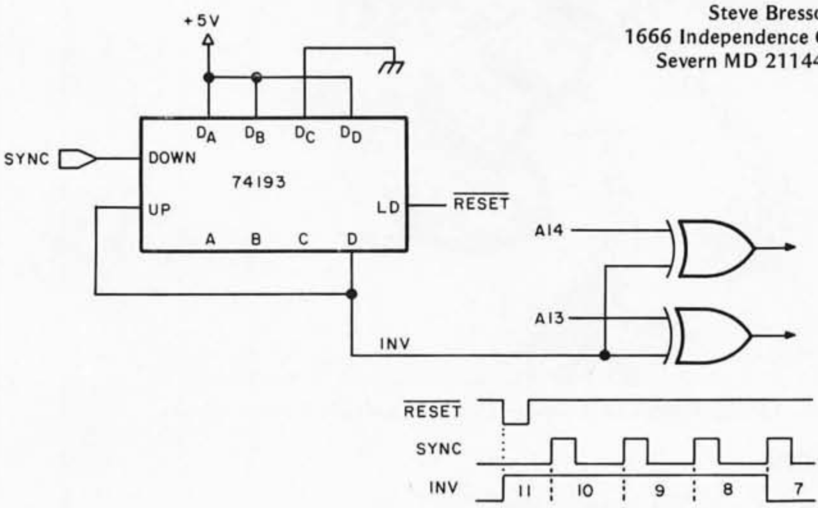
Bob Schweitzer
1501 Palm Av
Richmond CA 94805

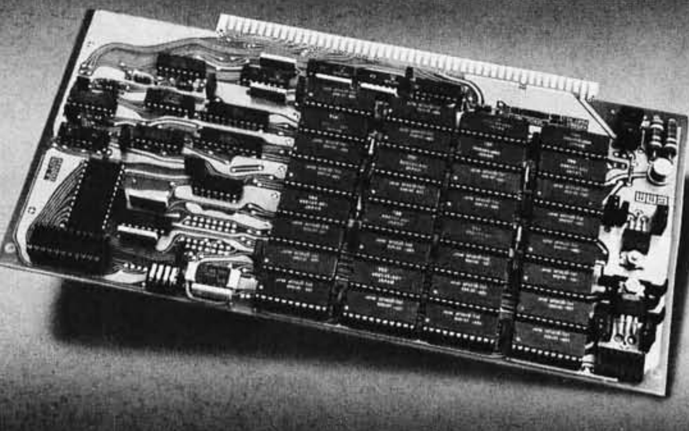
A BIT SIMPLER?

While I liked Frank Holman's idea in the March 1978 BYTE (page 185) of forcing the address bits high so that the 8080 resets to a location in high memory, the method could have been implemented in a slightly simpler fashion. The diagram below uses two fewer ICs.

Thus the 7404 and 7474 are eliminated. Also, the inverter in the original circuit could have been replaced by one of the EX-ORs in the 7486.

Steve Bresson
1666 Independence Ct
Severn MD 21144■





BYTE's Bits

ACM Seeks Nominations for Annual Grace Murray Hopper Award

The Association for Computing Machinery is seeking nominations for its Grace Murray Hopper Award, given each year to the outstanding young computer professional selected on the basis of a single recent major technical or service contribution to the computer industry. In order to qualify, candidates must have been 30 years of age or less at the time the qualifying contribution was made.

The award will be presented at the opening session of the association's Annual Conference on December 4 1978, in Washington DC. The award is in the amount of $1000, donated by the Univac Division of Sperry Rand, and is accompanied by a certificate.

While the award is given to the outstanding young "computer" professional, emphasis for the 1978 award will be placed on contributions in the fields of business data processing and personal computing. The committee felt that these fields have not been adequately rewarded for outstanding contributions in the past.

The last three winners of the Grace Murray Hopper Award were: Edward A Shortliffe, for his development of a program that consults with physicians about diagnosis and treatment of infection; Allen L Scherr, for his pioneering study in quantitative computer performance analysis; and George N Baird for the development and implementation of the U S Navy's COBOL compiler evaluation system.

Nominations, which may be made by the nominees themselves, should be sent to:

Richard G Canning
Chairman, ACM Grace Murray
Hopper Award Committee
925 Anza Av
Vista CA 92083

In order to be considered for the 1978 award, nominations should be received by Mr Canning no later than June 30 1978.

Please include the following information.

1. Name, address and phone number of the person making the nomination.
2. Name, address and phone number of the nominee.
3. A statement (200 to 500 words) on why the candidate deserves the award, describing the contribution.
4. The date of birth of the nominee and the date on which the qualifying work was completed.■

Carnegie-Mellon Sponsors a Workshop

Carnegie-Mellon University will sponsor an intensive five day microcomputer workshop June 5 thru 9 1978 on the CMU campus. The program will include hands on experience for those who have a serious interest in applying microprocessor systems to a practical problem. It is intended to provide a foundation of theoretical knowledge and practical experience about the capabilities and limitations of microcomputers and what it takes to apply them on the job.

The concepts and techniques introduced in class are implemented by more than 12 hours of hands on problem solving experience. The workshop format emphasizes opportunities to review and discuss the sample problems and their alternative solutions with the faculty and other class members.

For more information call Gerry Cohen at (412) 578-2207 or write Post College Professional Education, Carnegie Institute of Technology, Carnegie-Mellon University, Schenley Park, Pittsburgh PA 15213.■

Harvard University Announces International Computer Graphics Week

Harvard University has announced an international Computer Graphics Week July 23-28 1978, to be sponsored by the school's Laboratory for Computer Graphics and Spatial Analysis.

The event will focus on the Laboratory's International Users Conference on Computer Mapping Software and Data Bases: Application and Dissemination. At the conference over 100 speakers and numerous exhibits from the commercial, educational and governmental sectors will show how computer mapping is being used in city and regional planning, social services, public safety, transportation and engineering, ecology and the environment, energy, public health, marketing, research and development, management information systems and university research and instruction.

In addition there will be an in-depth review of currently available computer mapping software and data bases, as well as sessions on thematic map design principles and a hands-on workshop at the Harvard Laboratory. Among special features will be a session on software and data base distribution and marketing and an executive briefing seminar to discuss the relevance and projected impact of computer mapping in the commercial sector. For more information, contact Ira Alterman at the Center for Management Research, Executive Plaza, 850 Boylston St, Chestnut Hill MA 02167, (617) 738-5027.■

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To make ELF II easier to use, we've developed ELF II Tiny Basic. It lets you program ELF II with simple words you can type out on a keyboard such as PRINT, RUN and LOAD. ELF II responds by displaying answers on your printer, video monitor or TV screen.

Write And Run Programs The Very First Night!

The ELF II kit includes all components and everything you need to write and run your own programs plus the new Pixie Graphics chip that lets you display any 256 byte segment of memory on a video monitor or TV screen. No wonder ELF II is now being used as a trainer in many high schools and universities.

Easy instructions get you started right away, even if you've never used a computer before. The newly expanded ELF II Manual covers assembly, testing, programming, video graphics and games.

ELF II can be assembled in a single evening and you'll still have time to run programs including games, video graphics, etc. before going to bed!

SPECIFICATIONS

ELF II features and RCA COSMAC COS/MOS 8-bit microprocessor addressable to 64k bytes with DMA, interrupt, 16 registers, ALU, 256 byte RAM, full hex keyboard, two digit hex output display, 5 slot plug-in expansion bus (less connectors), stable crystal clock for timing purposes and a double-sided, plated-through PC board plus RCA 1861 video IC to display any segment of memory on a video monitor or TV screen.

EXPANSION OPTIONS

- **ELF II GIANT BOARD™** with casssette I/O, RS 232-C/TTY I/O, 8-bit P I/O, decoders for 14 separate I/O instructions and a system monitor/editor. Turns ELF II into the heart of a full-size system with massive computing power! $39.95 kit.
- **4k Static RAM.** Addressable to any 4k page to 64k. Uses low power 2102's. Chip select circuit allows original 256 bytes to be used. Fully buffered. Onboard 5 volt regulator. $89.95 kit.
- **Prototype (Kluge) Board** accepts up to 36 I.C.'s including 40, 24, 22, 18, 16, 14 pin. Space available for onboard regulator. $17.00.
- **Gold plated 86-pin connector.** $5.70.
- **ELF II Full ASCII Keyboard.** Upper and lower case. $64.95 kit.
- **5 amp Expansion Power Supply.** Powers the entire ELF II (Not required unless adding 4k RAM boards.) $34.95 kit.

All of the above PC boards plug directly into ELF II's expansion bus.

ELF II TINY BASIC

Communicate with ELF II in BASIC! ELF II Tiny BASIC is compatible with either ASCII keyboard and TV screen or standard teletype/video terminal utilizing RS 232-C or 20 mil TTY interface. Commands include SAVE and LOAD for storing programs on standard cassettes, a plot command to display graphic information and special commands for controlling ELF II I/O devices. 16-bit integer arithmetic, ±, x, ÷, (). 26 variables A-Z. Other commands include LET, IF/THEN, INPUT, PRINT, GO TO, GO SUB, RETURN, END, REM, CLEAR, LIST, RUN, PLOT, PEEK, POKE. Comes with maintenance documentation and excellent user's manual that allows even beginners to use ELF II for sophisticated applications. (4k memory required.) $14.95 on cassette tape.

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☐ $4.95 for Short Course on Microprocessor & Computer Programming.
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☐ $39.95 plus $2 p&h for ELF GIANT BOARD™ kit.
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National Bureau of Standards Symposia: Microcomputers

Current and future benefits of microcomputer technology will be weighed at the Symposium on Microcomputer Based Instrumentation, to be held at the National Bureau of Standards (NBS), Gaithersburg MD, on June 12 and 13 1978. Sessions in four major areas, each highlighted by an overview presentation, will focus, respectively, on microcomputer technology, applications to scientific instrumentation, microcomputer interface standards, and applications to industrial process control. This symposium, cosponsored by NBS, the Institute of Electrical and Electronics Engineers (IEEE) Computer Society, and the IEEE Group on Instrumentation and Measurement, will mark the opening of a series on Challenges in Science and Technology.

The symposia series, instituted by NBS Director Dr Ernest Ambler, is intended to encourage a cross-fertilization of ideas from many disciplines. Participating scientists of diverse backgrounds will jointly assess current trends and future needs. Each symposium will feature contributed or invited papers from within and outside the bureau.

Major papers at the June 12 and 13 symposium will include:

- Microcomputers for Biomedical and Clinical Applications
- Microprocessor Based Satellite Controlled Clock
- Fault Tolerance in Distributed Architectures
- Microcomputers in the Linear World
- Control of a 1 Gigahertz CCD Transient Digitizer
- Automating Analytical Instrumentation

For more information on sessions or schedules of the microcomputer symposium, contact Bradford M Smith, Room A130 Technology, National Bureau of Standards, Washington DC 20234, (301) 921-2381.

The second event in the series will be the Symposium on Atomic and Molecular Science and Technology, September 7 and 8 1978. For details contact Dr Stephen J Smith, Joint Institute for Laboratory Astrophysics (JILA), National Bureau of Standards, Boulder CO 80303, (303) 499-1000, extension 3631.

Tentatively scheduled for January 1979 is the third in the series, the Symposium on Mathematical Modeling. For details contact Dr J R Rosenblatt, NBS Applied Mathematics Division, Room A337 Administration, Washington DC 20234, (301) 921-2315.

Coordinating the Symposia on Challenges in Science and Technology is Dr Helmut Hellwig, NBS Time and Frequency Division, Boulder CO 80303, (303) 499-1000, extension 3277.■

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MUMPS Group to Meet in San Francisco

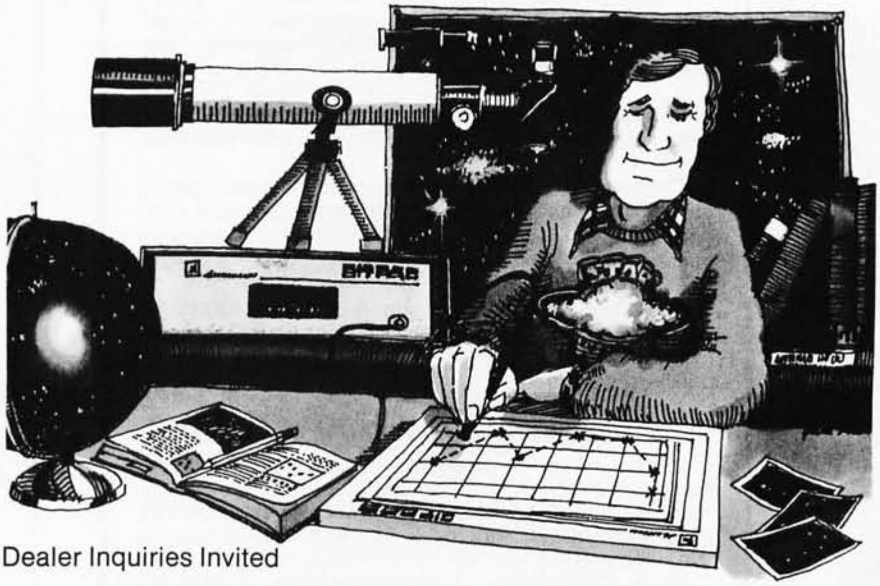
MUMPS Users' Group (MUG) will meet in San Francisco CA on June 7 thru 9 1978, at the Jack Tar Hotel. The conference includes all day tutorials on programming in MUMPS, ambulatory care information systems, technical aspects of ANSI Standard MUMPS, formal presentations of medical and nonmedical applications, panel and discussions on applications on computers in medicine. The conference is the same week as the NCC in Anaheim CA. For more information contact Pat Zimmerman, Dept of Biometry, Wearn Research Bldg, University Hospitals, Cleveland OH 44106.■

What Might Be Called CACHE's On Line Graffitti (COG)

In a recent phone conversation with Ward Christensen, confirmed by a copy of *The CACHE Flash* newsletter, I learned about an experiment called the Computerized Bulletin Board System. This system was implemented over a weekend by Ward and another member of CACHE, Randy Suess. It is an 8080 computer system, floppy disk and auto answer modem running 24 hours a day just to see what happens. According to its originators, all you do is call (312) 528-7141 with a 110 bps or 300 bps modem handy, connected to your terminal (or your computer emulating a terminal). When the tone is heard (assuming you don't find a busy signal because of all the other people reading this notice who are trying the same operation) you connect your modem and proceed with an interactive sequence. A session begins when you slowly type a series of isolated carriage returns (ASCII hexadecimal code 0D) which enable the system to determine the speed of your terminal. After that, the system provides the caller with interactive prompting about its various functions. The system has been running since early this year; according to Ward people have been calling and leaving messages from all over the country. It represents a practical implementation of some of the networking concepts which people are talking and writing about for use with personal computers. For those unfamiliar with the organization, CACHE is the Chicago Area Computer Hobbyist Exchange, located at POB 52, South Holland IL 60473, with meetings once a month on the third Sunday of the month. For more information call Dave Jaffe, (312) 849-1132.

Bulletin Board System

The interactive Bulletin Board system implemented by Ward Christensen and



Randy Suess produces this hard copy upon signing on. The entire system is interactive, so that all the instructions and prompting information a user needs can in principle be obtained by interacting with it. This text printout was obtained by answering "y" for yes to a number of the prompting queries. We only show a small excerpt of what can be a long and fascinating interactive communications session.

```
#1      TERMINAL NEED NULLS?  TYPE CTL-N WHILE THIS TYPES:

          ***   WELCOME TO WARD AND RANDY'S   ***
        ***  COMPUTERIZED BULLETIN BOARD SYSTEM  ***

-----> CONTROL CHARACTERS ACCEPTED BY THIS SYSTEM:

        DEL/RUBOUT  ERASES LAST CHAR. TYPED (AND ECHOS IT)
        CTL-C       CANCEL CURRENT PRINTING
        CTL-K       'KILLS' CURRENT FUNCTION, RETURNS TO MENU
        CTL-N       SEND 5 NULLS AFTER CR/LF
        CTL-R       RETYPES CURRENT INPUT LINE (AFTER DEL)
        CTL-S       STOP/START OUTPUT (FOR VIDEO TERMINAL)
        CTL-U       ERASE CURRENT INPUT LINE

----------------------   BULLETIN   ----------------------
     PROBLEMS WITH THE SYSTEM??
FOR HARDWARE CALL RANDY AT (312) 935-3356
FOR SOFTWARE CALL WARD  AT (312) 849-6279
----------------------   BULLETIN   ----------------------
)
----------------------   BULLETIN   ----------------------
MARCH CACHE MEETING, SUN. THE 19TH.  DETAILS IN MSG. 101
----------------------   BULLETIN   ----------------------
)

Y/N: IS THIS YOUR FIRST TIME ON THE SYSTEM?Y
Y/N: CAN YOUR TERMINAL RECEIVE LOWER CASE CHARACTERS?Y
File last updated 3/14/78

When you are asked a question, answer with Y for yes,
or N for no.
Are you using a video terminal (not a printer)?y
When the system is typing, you can use control-S to stop
the output to look at it, then again to continue.  This will
allow you to see what is sent before it scrolls off.

Want summary of system functions?y

The system has only three major functions:

    --> Entering messages
    --> Retrieving message summaries
    --> Retrieving messages


Want to know purpose of this system?y
It was conceived, financed, and is run by Ward Christensen
and Randy Suess for message communication between computer
hobbyists.  Typical message subjects include: 'something for
sale', 'need help with something', 'club meeting notice',
or just sharing ideas.  Feel free to leave a message on
any hobbyist computer related subject.

Want to know what hardware makes up the system?y
The hardware consists of:
  Vector/I mother board
  Card cage
  Vector Reset and Go Prom/Ram board
  IMSAI 8080 CPU board
  24K of various memory
  Tarbell floppy disk controller
  Innovex floppy disk
  DC Hayes modem board
  Polymorphic VTI video board
  SWTPC keyboard
  Processor Tech. 3P+S
  ASR-33 for message logging


Want a quick summary of what to do your first time?y
1.  S - Use the S function to retrieve message summaries
    *   Start with message 1
    *   Use control-S to stop/start output.
    *   Write down message numbers you want to see.
    *   Use control-K to kill the summary, return to menu
2.  R - Use R function to retrieve messages of interest.
3.  G - Use the G (Good bye) function when you are done.

Remember to use the H (Help) function for details.
WHAT IS YOUR FIRST NAME?new
WHAT IS YOUR LAST NAME?user

LOGGING NAME TO DISK...
FUNCTION: B,C,D,E,G,H,N,R,S,W, (OR ? IF NOT KNOWN)??

FUNCTIONS SUPPORTED:

B=PRINT BULLETIN
C=CASE SWITCH (UPPER/LOWER)
D=DUPLEX SWITCH (ECHO/NO ECHO)
E=ENTER MSG INTO SYSTEM
G=GOOD BYE (LEAVE SYSTEM)
H=HELP WITH FUNCTIONS
N=NULLS: SET 0 TO 9 AS REQUIRED
R=RETRIEVE MSG
S=SUMMARIZE MSGS
W=TYPE WELCOME


FUNCTION: B,C,D,E,G,H,N,R,S,W, (OR ? IF NOT KNOWN)?hh'U
?s
STARTING MESSAGE NUMBER (C/R TO RETURN TO MENU)?169
USE CTL-K TO ABORT, CTL-C TO SKIP, CTL-S TO PAUSE.

NO. SIZE --DATE-- --------FROM-------- ---------TO---------

169  16  3/19/78  WARD CHRISTENSEN      IMSAI OWNERS
```

■

Survey Contest Results

The 1978 BYTE Reader Survey, mailed to 5000 randomly selected addresses on our mailing list on January 15 1978, featured an informal incentive contest drawing from among those individuals who returned completed survey forms. The drawing was held on March 15 1978 in our offices, with the names of the three winners documented here:

> First Place (the first name drawn) was a $500 check sent to T L Balog of Cleveland OH.
>
> Second Place (awarded to the second two names drawn) was a $250 check sent to J Edward Potzler of Brookfield IL and another $250 check sent to Robin Sutton-Brown of Fresno CA.

We wish to thank all the individuals who participated in this survey for returning the filled out forms. The results are being tallied as this is written (March 29 1978) and are expected to be summarized in BYTE towards the end of this coming summer as well as being made available in more complete form as a report available on request.■

A Metamorphosis

Recently we received the first copy of a journal with which we have long been familiar under a previous name and format. The *PPC Journal* is the new format and name for the HP-65 Users Club publication formerly called *65 Notes.* (The group is not affiliated with Hewlett-Packard.) This publication is the work of Richard J Nelson, 2541 W Camden Pl, Santa Ana CA 92704. Quoting from fine print in the volume 5 number 1 issue, "The Club is a volunteer, non-profit, loosely organized, independent, worldwide group of Hewlett-Packard personal programmable calculator users. The official Club publication, *PPC Journal,* formerly *65 Notes,* disseminates user information related to applications, programs, programming techniques, problems, hardware, innovations, — any information related to the selection, care, use and application of Hewlett-Packard Personal Programmable Calculators."

The first issue of the new format contains 36 pages of material in a saddle stitched booklet form with three hole punching that enables the user to accumulate issues in an ordinary three ring binder. The materials in this issue include the following titles:

"Sampling Without Replacement"
"Calculator Wish List"
"Calculator Patents & Programs"
"Adjusting HP-97 Print Density"
"Uneven & Irregular Cash Flows"
"The Games of King & Hammurabi"
"Beginners' Programming Tricks"
"Calendar Algorithms"
"HP-67 Circuit Details"
"HP-67 Modifications"

If you are a user or prospective user of the calculator products of Hewlett-Packard, this grass roots user phenomenon (independent of HP) will provide valuable information not available from any other source. The price of the *PPC Journal* is $15 in the US, and membership is open to anyone anywhere in the world who uses HP calculators.■

Ask BYTE

SPECIFICATIONS SOURCES

Can you tell me where a beginning hacker can get transistor and integrated circuit specifications? Where I shop, one or two ratings are readily available, but more detailed characteristics under varying conditions are not.

James Howard
3600 Parker Av
Louisville KY 40212

Several mail order parts suppliers make available engineering documentation for the common integrated circuits. In our work at BYTE, the most frequently referenced books are those of Texas Instruments. This series of books includes one or two textbooks and manuals of specifications on subjects ranging from TTL integrated circuits to memory parts to optoelectronics to discrete transistors and linear integrated circuits. (These books are marketed by BITS Inc, 70 Main St, Peterborough NH 03458.) The next most frequently referenced compendium of technical specifications for integrated circuits is the set of documentation put out by National Semiconductor, but this set is much less readily available. For other manufacturers and parts not covered in these two libraries, we have to rely on a random collection of individual specification sheets, since books don't seem to be available.■

Clubs and Newsletters

Conducted by
David Wozmak

NCCN

The Northwest Computer Society Inc meets at the Pacific Science Center in Seattle on the first and third Thursday of each month at 7:30 PM. The first meeting of the month is usually more formal with a featured speaker or a demonstration. The second meeting of the month is less formal, with freewheeling discussion and problem solving. To contact the Northwest Computer Society write *Northwest Computer Club News*, POB 242, Renton WA 98055.

PET User Group

The newsletter of this Pennsylvania based group contains a veritable treasure trove of information and interesting facts about the Commodore PET. On the hardware side it has information about operating modems with PET, interfacing to an Altair (S-100) mother board, available peripherals, and more. In the software section there is a PET Errors and Bugs column, which offers solutions for the few bugs which have been found. There are also a number of columns by various contributors on the subject of PET programming.

PET User Notes is published six or more times a year by Gene Beals, PET User Group, POB 371, Montgomeryville PA 18936. Membership/subscription is $5 per year in the US and Canada, $10 in other countries.

APPLE

An Apple II users group has recently been formed in the Seattle Washington area, with membership open to all. The primary function of the group is the exchange of ideas and programs, which is accomplished through the medium of *Call Apple*, a monthly newsletter. For a sample copy of the newsletter and an application blank, send an SASE to APPLE, c/o Val J Golding, 6708 39th Av SW, Seattle WA 98136.

Theater Computer Users Group

The Theater Computer Users Group (TCUG) exists to provide a method of exchange of information about uses of computers in theater. The primary medium of communication is a periodic newsletter which is supported with a $4 fee. Topics of interest include special programs for specific theater jobs such as set design and inventory, cutting lists and ticket sales and special uses of hardware for things like stage lighting and management of production cuing. Other areas of interest include ticket sales, mailing list and patron records, actors/casting lists, volunteer crew management, financial records and a number of inventory and management functions.

Material in the newsletter includes comments from theater people, descriptions of programs and problems and analysis of new products that might have special uses in theater. Book reviews and reports of past or upcoming meetings of interest are also included. Contact Mike Firth, Theater Sources Inc, TCUG-TSI, 104 N St Mary, Dallas TX 75214, (214) 827-7734.

TRS-80 User Group of Eastern Massachusetts . . .

The TRS-80 Users Group of Eastern Mass was formed in January 1978 to link the growing numbers of users of the new Radio Shack TRS-80. With thousands of these Z-80 based systems delivered since October 1977 and new peripherals and software becoming available each month, the group expects to be a popular and useful clearinghouse and generator of activities concerning effective use of the TRS-80. Interested TRS-80 users are invited to attend meetings, held at 7:30 PM on the second Wednesday of each month. For further information, write TRS-80 Users Group of Eastern Mass, c/o Miller, 61 Lake Shore Rd, Natick MA 01760.

. . . and Wisconsin

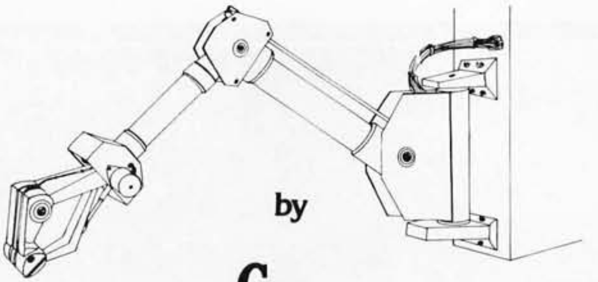
Hardware is the specialty of this group. Only the TRS-80, by Radio Shack, is dealt with. The aim of this group is to develop, jointly with members, hardware and interfaces to existing, lower cost peripheral units. Software will be handled via exchange. Hardware and software exchange pays a small royalty to developer. The newsletter *TRS-80 User Notes* is sent monthly. Membership cost is $17 the first year, $12 per year thereafter. For more information and a sample newsletter send a SASE to John P Marsh, 621 13th Av S, Onalaska WI 54650.

. . . and North Carolina

The TRS-80 Users Group of North Carolina has a newsletter which is packed with programs for such things as: biorhythms, math quiz, card games, wumpus, lunar lander, UFO and so on. There is also hardware information on the TRS-80. For more information contact R Gordon Lloyd, TRS-80 Users Group, 7554 Southgate Rd, Fayetteville NC 28304.

Computer Club of Western New York

The Computer Club of Western New York is an organization in the greater Buffalo area providing computer hobbyists, professionals and students the chance for hands on experience with the latest in microcomputers. The club presently has two Cromemco Z-80A microprocessors with up to 64 K core memory each, an 8 inch dual disk drive, tape cassette storage, a Teletype several CRTs, and is always adding more. Classes in BASIC, FORTRAN IV, assembly, and microcomputer engineering are held on a rotating basis.



Club meetings are on the first Tuesday of every month at 7 PM, and a newsletter is being planned. Dues are $20 for students, $25 for nonstudents, with group discounts available on both memberships and computer time. For more information, write Computer Club of Western New York, 3834 Main St, Eggertsville NY 14226.

BUSS

Edited by Charles Floto, *Buss* is the independent newsletter of Heath Company computers. It contains Heath product information and user reports. The contact address for BUSS is Charles Floto, 325 Pennsylvania Av SE, Washington DC 20003.

COM-3

COM-3 is a huge newsletter (approximately 45 pages) from Victoria AUSTRALIA. Edited by Timothy Mowchanuk, this newsletter covers just about everything from calculators to PROM data rewrites. The name COM-3 is taken from the first three letters of the words computer, community and communication, and symbolizes the growing interaction between these things. To contact COM-3 write to Timothy Mowchanuk, editor, c/o Essendon Grammar School, POB 138, Essendon, Victoria 3040, AUSTRALIA.

Alpha Micro Systems AM-100 User Group

A program exchange and monthly newsletter is being established for users, owners and persons interested in the Alpha Micro Systems AM-100 computer system.

The newsletter will contain descriptions of the programs that have been submitted by users. In addition, it is planned to include short announcements of programs that are in the process of being developed as well as other items of interest.

The distribution medium of the programs and their support files will be via floppy diskettes written in the IBM compatible AMOS format. For further information concerning membership and details of program submission contact Lefford F Lowden, 616 Long Pond Rd, Rochester NY 14612.

DG Users Group Formed

An independent users group has been formed to act as a clearinghouse for exchange of Digital Group information. The first issue of the group's newsletter features an evaluation of Micro Com software, an interface for a Selectric (hardware and software), a discussion of problems in expanding past 26 K, a flea market section, and so on. For information write to DG Users Group, POB 316, Woodmere NY 11598.

Tri-State Computer Club

The Tri-State Computer Club is a newly formed club with one main purpose in mind, to provide a common source of information and help to those interested in computers and other related equipment. Meetings are held every other Tuesday evening at 7:30 PM at 22 Beechurst Av. Anyone interested is invited to attend. For more information contact Randy Crowe at Rte 3, Box 84, Morgantown WV 26505 or phone (304) 292-1915 or (304) 292-9700.■

Programming Quickies

Those Calculating Romans

Laurence G Dishman
5525 Metropolitan Pky
Sterling Heights MI 48077

Remember learning about Roman numerals and all the fun you had with the ungainly numbers? Now you can let your computer have fun with them too! The program in listing 1 is a 4 function Roman numeral calculator that displays intermediate values in Arabic notation. A slash (/) preceding a Roman numeral is substituted for a bar above the numeral. The slash signifies multiplication by 1000. The program was written in North Star BASIC and uses the variables shown in table 1. Table 2 is a brief description of the program.

The examples in listing 2 are, of course, addition, subtraction, multiplication and division. The program prompting is reminiscent of many old mathematics texts which are arranged as conversations between teacher and pupil. One interesting aspect of the program is that if a nonstandard Roman expression is entered in addition mode and nothing is added to it, the result will be a Roman expression in standard form.

```
1 FILL 51207,01
10 DIM N$(40),N(40)
20 FOR P1=1 TO 40\N$(P1)=""\NEXT P1
30 PRINT TAB(28),"CENTURION"
40 FOR P1=1 TO 3\PRINT\NEXT P1
50 INPUT "      ENTER FUNCTION (A,S,M,D) :",F$
60 IF F$<>"A" THEN 180
70 PRINT TAB(10),"ENTER @=' FOR SUM."
80 S=0
90 PRINT TAB(10),"ADDEND ",
100 GOSUB 590
110 IF N$<>"=" THEN S=S+N1 ELSE 130
120 GOTO 90
130 PRINT TAB(10),S ," = ",
140 A=S
150 GOSUB 850
160 PRINT N$
170 GOTO 1920
180 IF F$<>"S" THEN 300
190 PRINT TAB(10),"MINUEND ",
200 S=0
210 GOSUB 590
220 S=N1
230 PRINT TAB(10),"SUBTRAHEND ",
240 GOSUB 590
250 A=S-N1
260 PRINT TAB(10),A," = ",
270 GOSUB 850
280 PRINT N$
290 GOTO 1920
300 IF F$<>"M" THEN 420
310 PRINT TAB(10),"FACTOR ",
320 S=0
330 GOSUB 590
340 S=N1
350 PRINT TAB(10),"FACTOR ",
360 GOSUB 590
370 A=S*N1
380 PRINT TAB(19),A," = ",
390 GOSUB 850
400 PRINT N$
410 GOTO 1920
420 IF F$<>"D" THEN 540
430 PRINT TAB(10),"DIVIDEND ",
440 S=0
450 GOSUB 590
460 S=N1
470 PRINT TAB(10),"DIVISOR ",
480 GOSUB 590
490 A=INT(S/N1)
500 PRINT TAB(10),A," = ",
510 GOSUB 850
520 PRINT N$
530 GOTO 1920
540 PRINT TAB(17),"ET TU BRUTE...THEN SYSTEM CRASHES"
550 GOTO 1920
560 GOTO 590
570 GOTO 750
580 GOTO 1290
590 INPUT "ENTER ROMAN NUMERAL :",N$
600 IF N$="=" THEN RETURN
610 FOR P1=1 TO 40\N(P1)=0\NEXT P1
```

Listing 1: Roman numeral mathematics program written in North Star BASIC. Listing 1 continues on pages 110-111.

Listing 1, continued:

```
620 N1=0
630 P=LEN(N$)
640 FOR P1=P TO 1 STEP -1
650 IF N$(P1)="/" THEN NEXT P1
660 GOSUB 750
670 NEXT P1
680 N1=N(P)
690 FOR P1=P-1 TO 1 STEP -1
700 IF N(P1+1)=0 THEN P2=P1+2 ELSE P2=P1+1
710 IF N(P1)>=N(P2) THEN N1=N1+N(P1) ELSE N1=N1-N(P1)
720 NEXT P1
730 PRINT TAB(15),N$," = ",N1
740 RETURN
750 IF N$(P1,P1)="I" THEN N(P1)=1
760 IF N$(P1,P1)="V" THEN N(P1)=5
770 IF N$(P1,P1)="X" THEN N(P1)=10
780 IF N$(P1,P1)="L" THEN N(P1)=50
790 IF N$(P1,P1)="C" THEN N(P1)=100
800 IF N$(P1,P1)="D" THEN N(P1)=500
810 IF N$(P1,P1)="M" THEN N(P1)=1000
820 IF P1=1 THEN RETURN
830 IF N$(P1-1,P1-1)="/" THEN N(P1)=N(P1)*1000
840 RETURN
850 N$="                                        "
860 P=1
870 IF A/1000000 < 1 THEN 920
880 N$(P,P+1)="/M"
890 A=A-1000000
900 P=P+2
910 GOTO 870
920 IF A/900000 < 1 THEN 960
930 N$(P,P+3)="/C/M"
940 A=A-900000
950 P=P+4
960 IF A/500000 < 1 THEN 1000
970 N$(P,P+1)="/D"
980 A=A-500000
990 P=P+2
1000 IF A/400000 < 1 THEN 1040
1010 N$(P,P+3)="/C/D"
1020 A=A-400000
1030 P=P+4
1040 IF A/100000 < 1 THEN 1090
1050 N$(P,P+1)="/C"
1060 A=A-100000
1070 P=P+2
1080 GOTO 1040
1090 IF A/90000 < 1 THEN 1130
1100 N$(P,P+3)="/X/C"
1110 A=A-90000
1120 P=P+4
1130 IF A/50000 < 1 THEN 1170
1140 N$(P,P+1)="/L"
1150 A=A-50000
1160 P=P+2
1170 IF A/40000 < 1 THEN 1210
1180 N$(P,P+3)="/X/L"
1190 A=A-40000
```

Table 1: Variables used in Roman mathematics program.

A	Intermediate Arabic value for later conversion to Roman
F$	Character value indicating function desired
N	Array holding the Arabic value of each Roman numeral in the expression
N$	Array holding the Roman numeral expression
N1	Returned Arabic number after conversion
P, P1, P2	Pointer variables
S	Intermediate Arabic value used in calculations

Table 2: Brief description of program broken down by line number.

Statement	Commentary
1	Switches from CRT to Printer mode in my system.
10-50	Inputs desired function.
60-530	Based on which function is desired, the computer calls for the inputting of a Roman expression and calls the appropriate subroutines. Then prints the values and answer.
540	If no legal function is inputted, the program aborts.
560-580	Were used for diagnostics during program preparation. May be omitted.
590-740	Input Roman expression and evaluates it back to front using the subroutine at 750.
750-840	Checks for value of Roman numeral then check to see if it is preceded by a slash. If so, muliplies by 1000.
850	Set the output array equal to 40 blanks.
860-1910	Is a common assembly line approach to assembling the standard Roman expression of the Arabic value calculated.
1920	Prints QED "It is finsihed."

Listing 1, continued:

```
1200 P=P+4
1210 IF A/10000 < 1 THEN 1260
1220 N$(P,P+1)="/X"
1230 A=A-10000
1240 P=P+2
1250 GOTO 1210
1260 IF A/9000 < 1 THEN 1300
1270 N$(P,P+2)="M/X"
1280 A=A-9000
1290 P=P+3
1300 IF A/5000 < 1 THEN 1340
1310 N$(P,P+1)="/V"
1320 A=A-5000
1330 P=P+2
1340 IF A/4000 < 1 THEN 1380
1350 N$(P,P+2)="M/V"
1360 A=A-4000
1370 P=P+3
1380 IF A/1000 < 1 THEN 1430
1390 N$(P)="M"
1400 A=A-1000
1410 P=P+1
1420 GOTO 1380
1430 IF A/900 < 1 THEN 1470
1440 N$(P,P+1)="CM"
1450 A=A-900
1460 P=P+2
1470 IF A/500 < 1 THEN 1510
1480 N$(P)="D"
1490 A=A-500
1500 P=P+1
1510 IF A/400 < 1 THEN 1550
1520 N$(P,P+1)="CD"
1530 A=A-400
1540 P=P+2
1550 IF A/100 < 1 THEN 1600
1560 N$(P)="C"
1570 A=A-100
1580 P=P+1
1590 GOTO 1550
1600 IF A/90 < 1 THEN 1640
1610 N$(P,P+1)="XC"
1620 A=A-90
1630 P=P+2
1640 IF A/50 < 1 THEN 1680
1650 N$(P)="L"
1660 A=A-50
1670 P=P+1
1680 IF A/40 < 1 THEN 1720
1690 N$(P,P+1)="XL"
1700 A=A-40
1710 P=P+2
1720 IF A/10 < 1 THEN 1770
1730 N$(P)="X"
1740 A=A-10
1750 P=P+1
1760 GOTO 1720
1770 IF A/9 < 1 THEN 1800
1780 N$(P,P+1)="IX"
1790 RETURN
1800 IF A/5 < 1 THEN 1840
1810 N$(P)="V"
1820 A=A-5
1830 P=P+1
1840 IF A/4 < 1 THEN 1870
1850 N$(P,P+1)="IV"
1860 RETURN
1870 IF A = 0 THEN RETURN
1880 N$(P)="I"
1890 A=A-1
1900 P=P+1
1910 GOTO 1870
1920 PRINT TAB(30),"QED"
READY
```

Listing 2: Examples of the four arithmetic functions which are arranged in the form of Roman mathematics texts.

```
                                          CENTURION


        ENTER FUNCTION (A,S,M,D) :A
               ENTER @=' FOR SUM.
               ADDEND ENTER ROMAN NUMERAL :/M/M/MMMCMLXIV
                   /M/M/MMMCMLXIV =  3002964
               ADDEND ENTER ROMAN NUMERAL :/C/C/CMMCCV
                   /C/C/CMMCCV =  302205
               ADDEND ENTER ROMAN NUMERAL :/MCII
                   /MCII =  1000102
               ADDEND ENTER ROMAN NUMERAL :=
                4305271 = /M/M/M/M/C/C/C/VCCLXXI
                                          QED
READY
RUN

                                          CENTURION


        ENTER FUNCTION (A,S,M,D) :S
               MINUEND ENTER ROMAN NUMERAL :MCMLXXVII
                   MCMLXXVII =  1977
               SUBTRAHEND ENTER ROMAN NUMERAL :CMXCIX
                   CMXCIX =  999
                978 = CMLXXVIII
                                          QED
READY
RUN

                                          CENTURION


        ENTER FUNCTION (A,S,M,D) :M
               FACTOR ENTER ROMAN NUMERAL :MDCXII
                   MDCXII =  1612
               FACTOR ENTER ROMAN NUMERAL :LVI
                   LVI =  56
                         90272 = /X/CCCLXXII
                                          QED
READY
RUN

                                          CENTURION


        ENTER FUNCTION (A,S,M,D) :D
               DIVIDEND ENTER ROMAN NUMERAL :/M/M/C/X/XM/XCCLVI
                   /M/M/C/X/XM/XCCLVI =  2129256
               DIVISOR ENTER ROMAN NUMERAL :DXIX
                   DXIX =  519
                4102 = M/VCII
                                          QED
READY
RUN

                                          CENTURION


        ENTER FUNCTION (A,S,M,D) :A
               ENTER @=' FOR SUM.
               ADDEND ENTER ROMAN NUMERAL :CMMMLXIX
                   CMMMLXIX =  2969
               ADDEND ENTER ROMAN NUMERAL :=
                2969 = MMCMLXIX
                                          QED ■
```

The HP-67 and HP-97

Hewlett-Packard's Personal Computers

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Photo 1: The Hewlett-Packard HP-67 programmable calculator. Magnetic cards containing programs are inserted into the slot on the side of the unit. (Photo courtesy Hewlett-Packard Co.)

Manufactured by Hewlett-Packard, the HP-97 and its software compatible younger brother the HP-67 are considered by many to be two of the best programmable calculators available.

The HP-97 costs $750, compared with $450 for the HP-67. Both feature a full complement of mathematical functions and statistical functions for two sets of variables; additional features include: Reverse Polish Notation; 26 data storage registers (one of which is used for indirect and relative addressing); register arithmetic; 224 program steps (all fully merged, with no 2 or 3 keystroke instructions); the ability to record programs or data on magnetic cards; a pause feature that opens the keyboard up for user input during a running program; and a smart card reader.

Smart Card Reader

One of the HP-67's most interesting features is its "smart" card reader. When a card is fed into the unit, the reader begins accepting 28 byte blocks of data from the cards. The first block tells the calculator if the card being read is a program card (which means the remaining bytes are to be read into program memory), or if the card contains numerical data that must be fed into the data registers. The card, if it is a program card, will also set the display mode (fixed, scientific, or engineering, zero through nine places showing), the trigonometry mode (degrees, radians or gradians) and the calculator's four user flags (on or off). If side 2 of the card (containing steps 113 through 224) is fed into the reader first, they will be placed in the correct position, just as if side 1 had been fed in first (containing steps 1 through 112). When a card like this exists (that is to say, a program is recorded with more than 112 steps, or more than one side of the card), the calculator displays the word "Crd" as a prompt to the user that the second side of the card is required.

The same holds true for the data card. Side 1 contains the contents of the 16 primary registers. If data is also present in the secondary ten registers, the user is again prompted with "Crd." The contents of these

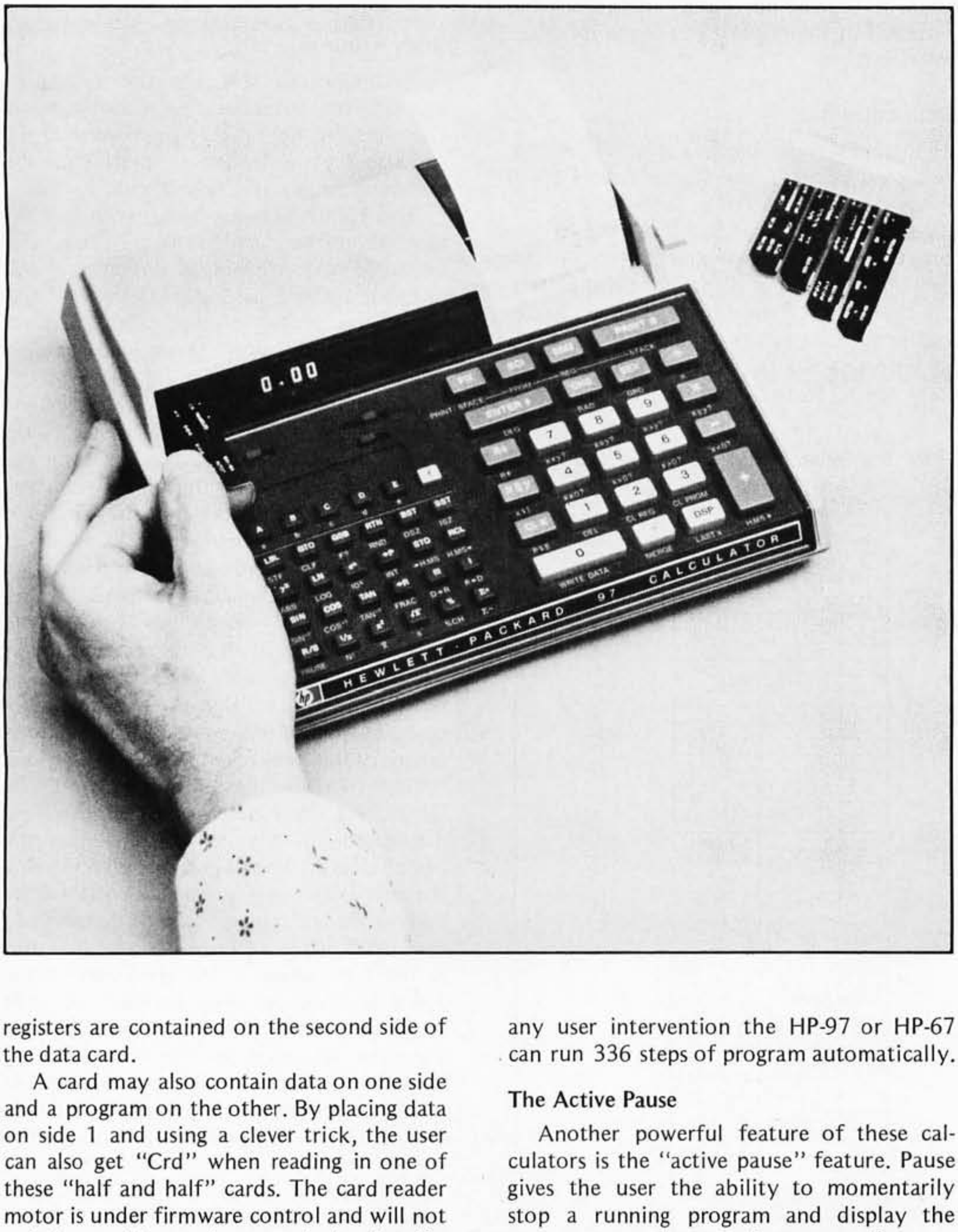


Photo 2: The Hewlett-Packard HP-97 programmable desk top calculator with printer. (Photo courtesy Hewlett-Packard Co.)

registers are contained on the second side of the data card.

A card may also contain data on one side and a program on the other. By placing data on side 1 and using a clever trick, the user can also get "Crd" when reading in one of these "half and half" cards. The card reader motor is under firmware control and will not switch on with a card present in the slot, if a program is running. However, the user does have the keyboard option of merging programs and data, or just feeding in 112 steps of program, under software control. Thus, with a 112 step card in the slot and a 224 step program running, all the user need do in order to feed in (overlay paging) those next 112 steps is to call for the keyboard active pause, which will cause the card reader to turn on and feed in that next card. Without any user intervention the HP-97 or HP-67 can run 336 steps of program automatically.

The Active Pause

Another powerful feature of these calculators is the "active pause" feature. Pause gives the user the ability to momentarily stop a running program and display the answer currently on the screen for one second or so. It also unlocks the keyboard for user use and accepts any cards fed in at this point.

Normally, pressing any key on an HP programmable calculator causes the program to halt immediately. This is not the case during the pause feature. When pausing, any key, including one of the ten user definable label keys, can be pressed and that function will be carried out. After this the pause will be extended an additional second, and the program will then continue. If a user definable key is pressed, that program is called as a subroutine (three levels of subroutining are available on the HP-97 and HP-67), and, if that subroutine ends with the "RTN" (return) command, program control is returned to the original pausing point in the main routine.

Data Entry Flag

In addition to being a general purpose, test clearable flag, the fourth flag (FLG 3) is also a data entry flag. When any of the digit keys is pressed, flag 3 switches to the on state. Thus the program, if so written, can sense the input of data, much like testing the status register on a full blown microcomputer, for keyboard input.

With this flag the user can define the ten keys for more than one function. A simple example is the programming of the formula distance=rate x time. Each of three keys can accept data input if the third flag is on; if the third flag is off, the key just pressed can calculate the unknown variable. This feature is indispensible when writing games.

Listing 1: Pinball Wizard, a game for the Hewlett-Packard HP-67 and HP-97 programmable calculators.

STEP	KEY ENTRY	KEY CODE	COMMENTS	STEP	KEY ENTRY	KEY CODE	COMMENTS
001	f FRAC	16 44			R↓	-31	
	f π	16-24			DSP 0	-63 00	
	X ≷ Y	-41	NOTE: * indicates the location of a label address.		RTN	24	
	f X=0?	16-43		060 *	LBL B	21 12	
	+	-55			RCL 1	36 01	
	f FRAC	16 44			f X=0?	16-43	
	STO E	35 15			GTO f a	22 16 11	
	5	05			1	01	
	0	00			STO - 1	35-45 01	
010	STO B	35 12			-	-45	
	1	01			PRINT X	-14	
	0	00			0	00	
	STO A	35 11			STO 0	36 00	
	X^2	53		070	5	05	
	STO C	35 13			STO 3	35 03	
	CLX	-51		*	LBL f b	21 16 12	
	STO 0	35 00			f CLF 0	16 22 00	
	STO 1	35 01			DSP 0	-63 00	
	STO 2	35 02			3	03	
020	GTO f a	22 16 11			STO 7	35 07	
*	LBL f e	21 16 15			EEX	-23	
	RCL E	36 15			3	03	
	9	09			STO 6	35 06	
	9	09		080 *	LBL f c	16 21 13	
	7	07			f CLF 3	16 22 03	
	x	-35			RCL 3	36 03	
	f FRAC	16 44			f X=0?	16-43	
	STO E	35 15			GTO f a	22 16 11	
	RTN	24			f PAUSE	16 51	
030 *	LBL A	21 11			f F? 3	16 23 03	
	2	02			f F? 3	16 23 03	
	STO + 1	35-55 01			GTO f c	22 16 13	
	.	-62			1	01	
	2	02		090	STO - 3	35-45 03	
	5	05			DSP 1	-63 01	
	STO - 2	35-45 02			X ≷ Y	-41	
	RCL 1	36 01		*	LBL f d	21 16 14	
	PRINT X	-14			GSB f e	23 16 15	
*	LBL f a	21 16 11			1	01	
040	2	02			2	02	
	CHS	-22			x	-35	
	STO I	35 46			f INT	16 34	
	RCL 0	36 00			3	03	
	5	05		100	-	-45	
	EEX	-23			f X=Y?	16-33	
	4	04			GTO f d	22 16 14	
	÷	-24			f X>0?	16-44	
	f INT	16 34			GTO E	22 15	
	STO + 1	35-55 01			f PAUSE	16 51	
050	RCL 0	36 00			f X=0?	16-43	
	f PAUSE	16 51			GTO 0	22 00	
	GTO (i)	22 45			f F? 3	16 23 03	
*	LBL C	21 13			f F? 3	16 23 03	
	DSP 2	-63 02		110	GTO 0	22 00	
	RCL 2	36 02			CHS	-22	
	f PAUSE	16 51			f X≠Y?	16-32	

REGISTERS

0 score	1 games	2 $$$	3 balls	4	5	6 bonus	7 targets	8	9
S0	S1	S2	S3	S4	S5	S6	S7	S8	S9

A 10 (constant)	B 50 (constant)	C 100 (constant)	D	E seed	I used

Other Features

Naturally the user has the ability to manually or automatically record data or programs on the 1 by 7 cm program cards. A write protect feature is available on the cards by clipping off the corners.

The HP-97 comes with its own built in thermal printer, and can print out the displayed value manually or during a running program without halting it. Because of the 7 level key buffer, a single print command will not even slow down the running program. Of course, the buffer works in the manual mode as well. The HP-97 can also list the contents of the 4 level Reverse Polish Notation (RPN) stack and give a complete program listing with line number, mnemonics, and an on and off switchable key code as well. There is even a trace mode of operation for program debugging or for keeping a detailed record of a manual operation. A "Normal" position is also available to keep a record of all numbers entered during a manual problem along with all the key mnemonics, but without the final answer, in case the user might want just a keystroke record of the steps taken.

The HP-67 is the pocket version of the HP-97. All the functions of the HP-97 are duplicated on the HP-67, including the print features. When a program with printing commands is run on some calculators, the commands are skipped over as though they were NOP when no printer is available. But in the same situation the HP-67 will pause for 5 seconds and blink the decimal point to show that a print statement is being executed. At this point the user can either stop the program and hand copy the answer displayed or just let the program run, since 5 seconds is usually enough time to get the answer written.

Although of no use on the HP-67, the paper spacing key is provided so that full control is possible when a HP-67 program is run on an HP-97.

Both machines come with huge manuals containing some of the clearest, most detailed documentation in the programmable calculator market. A standard "PAC" of blank and prerecorded program cards is also provided. These prerecorded cards cover dozens of various applications and include their own manual of several dozen more detailed pages. The latter gives programming tips and lists techniques about how certain of the prerecorded cards were written.

As with all of Hewlett-Packard's calculators, the units run on rechargable nickel cadmium batteries, or from AC through an adapter that recharges the batteries whether the machine is in use or not. A carrying case is also standard with the machines.

For all owners who join, an extensive users' library of contributed programs is available. A user can send a favorite brainchild and get free programs and blank magnetic cards in exchange. Even for those who do not write programs the library is of great importance, since dozens of widely different programming areas are covered.

HP-65, 67 and 97 owners receive free issues of *Keynotes,* a newsletter edited by Henry Horn. *Keynotes* keeps the user up to date about all the changes or corrections to the several PACs of preprogrammed cards available, as well as listing some of the newer programs submitted between library catalog updates.

Unsupported Features

As with the HP-65 (and later the Texas Instruments' SR-52), HP-67 and 97 users have managed to locate and use quite a number of features that Hewlett Packard had not originally intended to document.

Through the efforts of Louis Cargile, a member of PPC, an independently run users' group, the limited alphanumerics of the machines (both can form: r, C, o, d, E), have been brought under user control along with the ability to view internal registers, create moving marquee type displays, animation and dozens of other ingenious outputs. Even the hexadecimal representations for all the internal codes have been mapped and printed in *PPC Journal,* the newsletter of PPC. These codes include the six unused codes, formally unavailable to the user. (The HP-97 and 67 use 8 bit instructions, but only a total of 250 different commands, thus leaving six unused.)

One clever program by Cargile is called "Ida/Gerald/Ella." Through the use of an alphabetic overlay of the keys it allows the user to spell out mathematical functions and commands to the units and carry on a running dialogue with them.

Example Program

Of course, the proof of the ability of these machines lies in how intricate a program can be run on them. I offer a version of a program I wrote, called "Pinball Wizard," which duplicates many of the features on a standard pinball machine including dual flipper action, out hole bonus, and even an optional tilt feature for the wizards among you. It is playable on either the HP-67 or 97, but the keystrokes and codes shown in the program listing correspond to those of the HP-97. They can all be converted over to the HP-67 by using the manual's back pages, which list the various keystroke differences between the machines for example, the key sequence: f (a shift key) followed by FRAC (fractional truncation), will be converted to g frac on the 67.

As always, a card recorded on the 97 will show the corrected codes when read into a 67, and vice versa.

This article by no means explores all the intricate and complex programming capabilities of the HP-67 and HP-97, but I hope the reader now has a better idea of the sophistication these desk top wonders have to offer.

Note: PPC (not affiliated with the Hewlett-Packard Company) is an independently run users' group started for and by users of Hewlett-Packard programmable calculators. It is the largest calculator club in the world, with over 2500 members worldwide. The address is: PPC, Richard J Nelson, editor, *PPC Journal,* 2541 W Camden Pl, Santa Ana CA 92704.

Listing 1, continued:

STEP	KEY ENTRY	KEY CODE	COMMENTS
	GTO 0	22 00	
	2	02	
	CHS	-22	
	f X≠Y	16-32	
	GTO f d	22 16 14	
	GSB f e	23 16 15	
	3	03	
120	x	-35	
	f INT	16 34	
	f X=0?	16-43	
	GTO f b	22 16 12	
	GTO f d	22 16 14	
•	LBL E	21 15	
	STO I	35 46	
	GTO (i)	22 45	
•	LBL 0	21 00	
	8	08	
130	CHS	-22	
	STO I	35 46	
	RCL 0	36 00	
	f X≠0?	16-42	
	GTO 0	22 00	
	1	01	
	STO + 3	35-55 03	
	DSP 0	-63 00	
	GTO f c	22 16 13	
•	LBL 0	21 16	
140	1	01	
	f F? 0	16 23 00	
	2	02	
	STO x 6	35-35 06	
	RCL 0	36 00	
	f PAUSE	16 51	
	EEX	-23	
	3	03	
	STO - 6	35-45 06	
	STO + 0	35-55 00	
150	RCL 0	36 00	
	f PAUSE	16 51	
	RCL 6	36 06	
	f X≠0?	16-42	
	GTO (i)	22 45	
	R ↓	-31	
	f PAUSE	16 51	
	GTO f b	22 16 12	
•	LBL 9	21 09	
	f F? 0	16 23 00	
160	RCL A	36 11	
	f F? 0	16 23 00	
	x	-35	
•	LBL D	21 14	
	STO + 0	35-55 00	
	RCL I	36 46	
	RCL A	36 11	
	÷	-24	
	+	-55	
	f PAUSE	16 51	
170	f PAUSE	16 51	
	GTO f d	22 16 14	
•	LBL 1	21 01	
	f F? 0	16 23 00	
	GTO 1	22 01	
	f STF 0	16 21 00	
	DSP 9	-63 09	
	RCL A	36 11	
	GTO D	22 14	
•	LBL 1	21 01	
180	DSP 1	-63 01	
	f CLF 0	16 22 00	
	RCL A	36 11	
	GTO D	22 14	
•	LBL 3	21 03	
	RCL C	36 13	
	RCL A	36 11	
	GTO 3	22 03	
•	LBL 4	21 04	
	RCL 6	36 06	
190	2	02	
	5	05	
•	LBL 3	21 03	
	GSB f e	23 16 15	
	x	-35	
	1	01	
	+	-55	
	f INT	16 34	
	x	-35	
	GTO 9	22 09	
200 •	LBL 5	21 05	
	RCL B	36 12	
	GTO 9	22 09	
•	LBL 2	21 02	
•	LBL 6	21 06	
	EEX	-23	
	3	03	
	STO + 6	35-55 06	
	RCL C	36 13	
	GTO 9	22 09	
210 •	LBL 7	21 07	
	RCL A	36 11	
	f DSZ (i)	16 25 45	
	GTO 9	22 09	
	3	03	
	STO 7	35 07	
	1	01	
	STO + 3	35-55 03	
	RCL C	36 13	
	GTO 9	22 09	
220 •	LBL 8	21 08	
	RCL A	36 11	
	GTO D	22 14	

LABELS					FLAGS
A 25¢	B CREDIT	C RCL $	D used	E used	0 SPECIAL
a used	b used	c used	d used	e rnd# gener.	1 –
0 out hole	1 SPECIAL	2 roll over	3 thumpers	4 spin. gate	2 –
5 kick out	6 bonus adv.	7 drop targ.	8 slibg-shot	9 used	3 used

SET STATUS

FLAGS	ON	OFF
0	☐	☒
1	☐	☒
2	☐	☒
3	☐	☒

TRIG		DISP	
DEG	☒	FIX	☒
GRAD	☐	SCI	☐
RAD	☐	ENG	☐
		n	0

Pinball Wizard:
A Game for the HP-67 and HP-97

This program duplicates the play of standard pinball machines including features like out hole bonus points, "Special" for higher scoring, two thumper-bumpers, a spinner gate, three drop targets for a free ball, bonus advance roll overs, kick out holes, two flippers, and a tilt option for putting the ball into play in two out of three chances. The program is meant to be left running at all times, with all input from the user occuring during the active keyboard pause feature of the HP-67 or HP-97.

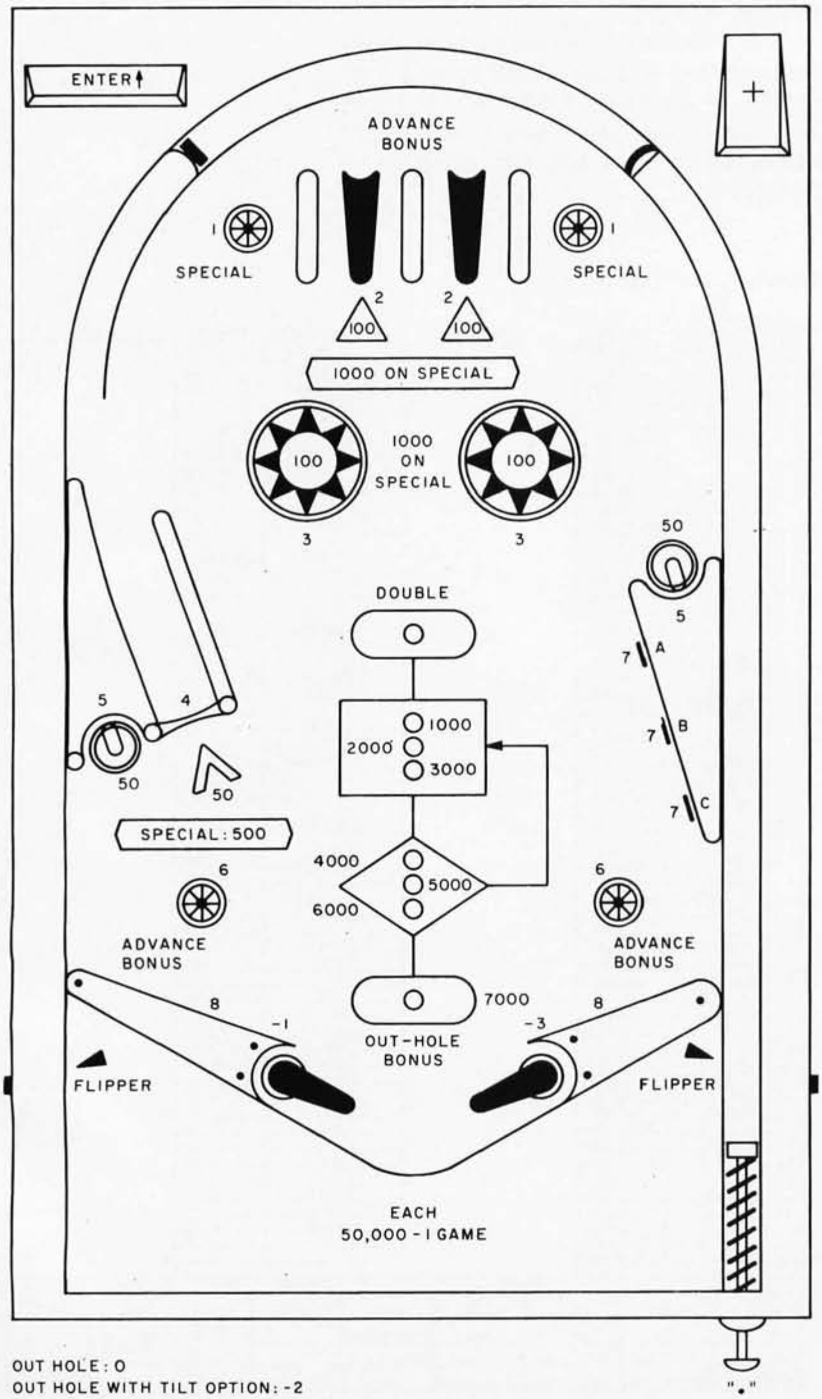


Figure 1: Model pinball machine layout used in the game of Pinball Wizard (see listings 1 and 2).

There are eight different scoring devices on the play field (see figure 1) and each device is given an identification number. When a score is made on a device, the display pauses twice, showing the amount of points just made to the left of the decimal point, and the device identification number to the right of the decimal point. The score to the left of the point is added to the player's total score, which will be displayed at the end of each round of play. The various devices are:

Device #1: Consists of two star roll overs (buttons) on the play field which, when hit, will add ten points to the player's score and switch on the "Special" scoring (which is indicated by turning on all the trailing zeroes after the device ID number). When this occurs, all devices so listed will score ten times higher than normal. Hitting device #1 repeatedly will alternately switch the Special scoring on and off.

Device #2: Consists of two top roll over lanes which score either 100 (or 1000 points if Special is lit), and advance the out hole bonus by 1000 points.

Device #3: Consists of two thumper (jet) bumpers. Each scores 100 points (or 1000 when Special is lit) whenever the "ball" strikes them. The ball can bounce between them up to ten times, so scores from 100 to 1000 (1000 to 10,000) can be made.

Device #4: This is a spinner gate that will score 50 (or 500 points for Special) each time it spins one turn. The gate can spin from one to 25 times.

Device #5: Consists of two kick out holes where the ball drops in, scores either 50 (or 500 points again depending on the state of Special), and is kicked back out.

Device #6: Consists of two bonus advance roll over stars and functions in the same manner as device number 2.

Device #7: Consists of three drop targets. Each time device 7 is hit, one target drops away and the player receives ten points added to his score. On the third hit, however, the player receives 100 points and is credited with a free ball. The targets are reset to try again. Special scoring increases the point value by ten times.

Device #8: Consists merely of two slingshot kickers giving a score of only ten points, whether or not Special is lit.

A "0" on the display means that the ball has rolled past the flippers and through the out hole. At this point the player's score so far is shown on the display and the out hole bonus points accumulated during the game are added onto the player's score, 1000 points at a time. The display pauses for viewing each time. At the end of this scoring, the final total is flashed once more and the display goes back to blinking the remaining number of balls (if any) in the game. If none remain, the final score is flashed. If Special was lit when the ball rolled out, the out hole bonus is doubled.

To shoot a ball, the player keys the decimal point (.) when the remaining number of balls left to play is flashed on the display.

Pressing key "A" adds two games to the "credit wheel" and deducts 25¢ from the player's cash register (no pun intended). The amount of money spent can be viewed by pressing key "C" during a pause at any time.

Pressing key "B" deducts a game from the credit wheel, and starts a new game.

Caveats

If a "–1" shows on the display, it means that the ball has reached the left flipper and requires the user to key in a "1" (pressing the left flipper button) in one second or the ball will roll out. Likewise, if a "–3" is displayed, the ball is at the right flipper, and requires an immediate input of the digit "3" from the user, or again the ball will roll out through the out hole.

When a "–2" appears on the display, it means the ball will miss both flippers, but the user has the option of keying in a "2" which effectly will "tilt" the machine, and, in two out of three cases, put the ball back in play. Be warned, however! If you should fail in the tilt attempt (that is, the machine has been tilted), you lose all collected bonus points and the next ball is immediately displayed, without a score review.

For each 50,000 points made, the player is credited with a free game. When a score over 50,000 is made, please refrain from pressing the "A" key.

Special note: If, on the first ball, before *any* score is made, you should lose the ball, it will be returned to you for reshooting, as in most pinball machines. (A failure at a tilt will not return the ball, however.)

Example of Play:

- Initialize game by inputting a seed number such that 0<seed<1. For this example, let's use 0.1541790869.
- Press: RTN R/S Display will flash "0."
- Obtain credit of two games and spend one quarter: press A . (A "2" will be displayed, confirming a credit of two games.)
- Start first game: press B . (A "1" is displayed to show that there is one game remaining. Next, 5 is flashed on the display to show that there are five balls left to shoot.)
- Shoot first ball: press · . See displayed:

50.5	(50 points on a kick out hole)
10.10000000	(10 points and Special is on)
1000.60000000	(device 6 advances bonus and gives player 1000 points)
–2.00000000	(a tilt option has come up)

Try tilting the machine by inputting a 2 from the keyboard during the pause window. A flashing 4 will be displayed to show that there are four balls remaining to shoot. The machine was tilted and all bonus points were lost.

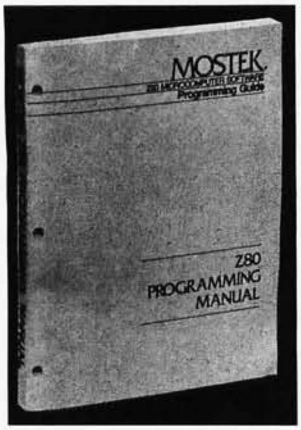
You can continue to play out this game in the same manner. Good luck.■

(Note: Pinball Wizard is reprinted with the permission of PPC.)

Listing 2: User instructions for Pinball Wizard.

STEP	INSTRUCTIONS	INPUT DATA/UNITS	KEYS		OUTPUT DATA/UNITS
1	Enter program				
2	Input seed (s) such that 0<(s)<1	seed	RTN	R/S	0 ‡
3	To obtain credit of 2 additional games (and				
	spend 25¢):		A		2 ***
	The number printed/paused, will show the				
	number of games the player has credit for.				
4	To start one game (which is deducted from the				
	credit register):		B		1 ***
	The first number printed/paused will be the				5 ‡
	remaining games left. The next number flashed				
	will be the remaining balls left to shoot.				
5	To shoot current ball, displayed, during a 1				
	second pause 'window':				
	Scoring begins as described in the program				
	description on the previous pages.				
6	When '-1' is displayed, to use the left flipper				
	during a 1 second pause 'window', input:		1		
	-OR-				
6	When '-3' is displayed, to use the right flipper				
	during a 1 second pause 'window', input:		3		
	-OR-				
6	When '-2' is displayed, to attempt to 'tilt'				
	the machine and chance putting the 'ball'				
	back in play, input:		2		
	If the tilt was successful, the scoring will				
	continue. If the machine 'tilted', the				
	remaining number of balls will be flashed				
	(if any) or the final score will be flash-				
	ed, if the game is over.				
7	To shoot any remaining balls, go to step 5.				
8	If no balls remain, to start a new game, go to				
	step 4.				
9	If no games remain on the 'credit wheel', go				
	to step 3.				
***	--Indicates a printed number, on the 97 or a				
	number paused for 5 seconds on the 67.				
‡	--Indicates a number flashed (paused for 1 sec.)				

Book Reviews



Z-80 Programming Manual (publication number MK78515)
MOSTEK
Carrollton TX 75006
300 pages
$7.50

Although much has been published about the differences between the Z-80 and the 8080, the *Z-80 Programming Manual* is the first reference I have found that gives a detailed description of all the Z-80 instructions. The bulk of the book consists of one or two pages of description for each instruction. The preface accurately notes that this book is for those with some programming experience. It will not teach you when to use a certain instruction; rather it will confirm exactly what an instruction does.

When this manual arrived I was struggling to use the block search instruction for the first time. The detailed explanation of the instruction sequence and a detailed example are a far cry from the terse description in the *Z-80 Technical Manual.* In contrast, the explicitness of MOSTEK's programming manual continues to the level of triviality required to work at machine level coding. One note points out that the instruction "EX AF, AF' " does indeed mean exchange registers A and F with registers A' and F'. MOSTEK states that this manual is the standard for Z-80 assembly language.

There is no description of hardware other than a brief outline of the architecture. The printing is only of fair quality and the book is not an eye catcher. However, for those programming in an isolated environment, with no one nearby to quibble on fine points, this book will prove to be a useful source.

If it is not available at your local computer store, it should be available from your nearest MOSTEK distributor.

David Clapp
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Wellsville PA 17365■

Motorola 6800 Microprocessor Course

Technical Training Department
Mail Stop 56-113
Motorola Semiconductor
5005 McDowell Rd
Phoenix AZ 85003
$25 (1-9 copies); $20 (more than 10)

The Motorola 6800 microprocessor course is the 3 ring notebook used at the 3 day seminars given by Motorola. For those of us who don't have $400 to spend on learning about the 6800 by attending the seminars, this $25 book is a reasonable alternative.

The first part of the book consists of sections on number systems, the 6800 processor, programmable and read only memory, the 6820 peripheral interface adapter, and a discussion of the six addressing modes used by the 6800. Following this is a section on assembler techniques and sections which contain various sample programs. This part of the manual, along with the 6800 programming manual, should get you up to speed on 6800 assembly language programming if you have background in another assembly language.

The remainder of the manual is concerned with hardware design. There is a section on system configuration followed by the data sheets on all the 6800 family chips, some other integrated circuits used in most systems, and a copy of the M6800 EXORciser users guide. Also included is an M6800 reference card and a pad of graph paper.

Who should buy this book? If you are seriously looking at a 6800 system or have a system and want to start assembly language work with it, this book contains a lot of good information. Also, if you plan to do your own hardware design, this book would be very helpful. Those people who already own a SwTPC system have most of this information in the documentation package which comes with the system.

Phil Hughes
POB 2847
Olympia WA 98507■

Continued from page 6

tables and reverse Polish operand notation for use on his personal computers. What surprised me to no end, though, was when I heard from him words to the effect that, "With this language we've developed no one would really ever need more than 16 K bytes of memory."

It sounded vaguely familiar, as if the engineer's statement had merely been updated by a hexadecimal order of magnitude. (Of course the particular system involved did use a floppy disk secondary storage medium, so the memory limit of 16 K obviously applied only to resident capacity.)

Reflecting on both of these incidents, it is obvious that memory as a resource has become quite inexpensive yet people do not fully realize quite how inexpensive it has really become. Both points of view are in a sense equally valid, but based upon an economic impression formed when memory was dear and had to be economized much more than is currently the case.

Ten years ago people were still seriously talking about the expense of semiconductor memory relative to the existing core memory technology. Would semiconductor memory really catch on? Could it be made for the same price of core? Core memory, as a technology, has in many respects gone the way of the buggy whips in the automobile era. Except for the limited contexts in which its nonvolatility is useful, I would be surprised to find any engineer seriously considering it for a new design in view of the cost savings to be attained by using semiconductor memory parts. Semiconductor memory is basically a mass production item by comparison with core. The number of delicate manual operations required is independent of the number of bits for the most part, depending only on the number of pins in the package; for core memory, virtually every bit required a manual operation of some form during assembly by stringing cores on wires in a complicated braided pattern. The mass production of memory using silicon technology has changed the whole attitude which is appropriate toward memory as a system resource.

In short the era of memory riches is now upon us. All it takes now to add 16 K bytes of dynamic memory to a system is eight integrated circuits at a price of about $50 per circuit in small quantities, and in another year the prices will be even lower as the parts progress further on the "learning curve" of semiconductor manufacturers. We find the single board microcomputer of contemporary "state of the art" design supplies enough sockets (both for read only and for volatile memory) to completely fill address space in a typical 8 bit microprocessor's design. And the trend toward lower cost will continue, of course, as the technology of the 64 K bit memory chip approaches marketability.

Reflecting this change in costs, the newer microprocessor designs are taking into account the need for additional memory address space so that more memory than 64 K bytes can be employed. The second generation 6800, 6502, 8080 and Z-80 machines are proving easy to saturate now that personal computers are using these processors as general purpose machines. As a result of this saturation, we find, for example, that the new Intel 8086 design is capable of addressing 20 bits worth of memory address space (more than one million bytes). As was strongly hinted at a recent IEEE Compcon session on microprocessor architecture, the new Zilog Z8000 may have some 23 bits worth of address space in its radical new design, allowing some eight million bytes of memory if one cares to implement it.

By this time, three years from now, I can almost expect the $50 memory chip to have 64 K bits capacity. The personal computer of 1981 and 1982 will have one processor, one video display and keyboard interface chip, one floppy disk controller chip, eight 64 K memory chips, and one read only memory chip with a kernel of systems software including a P-code interpreter. Based on information from various manufacturers, we can expect this dual minifloppy disk system with 64 K memory still to retail at around $2000 continuing the deflationary growth of the personal computer field. With a total of only about 12 integrated circuits, the electronics will certainly be simple enough. And returning to the theme which started this commentary, if you have 64 K available, I guarantee that as a user your programs and data will expand to fill the available memory.■

An APL Interpreter: Further Thoughts

Languages Forum

Tom Brightman
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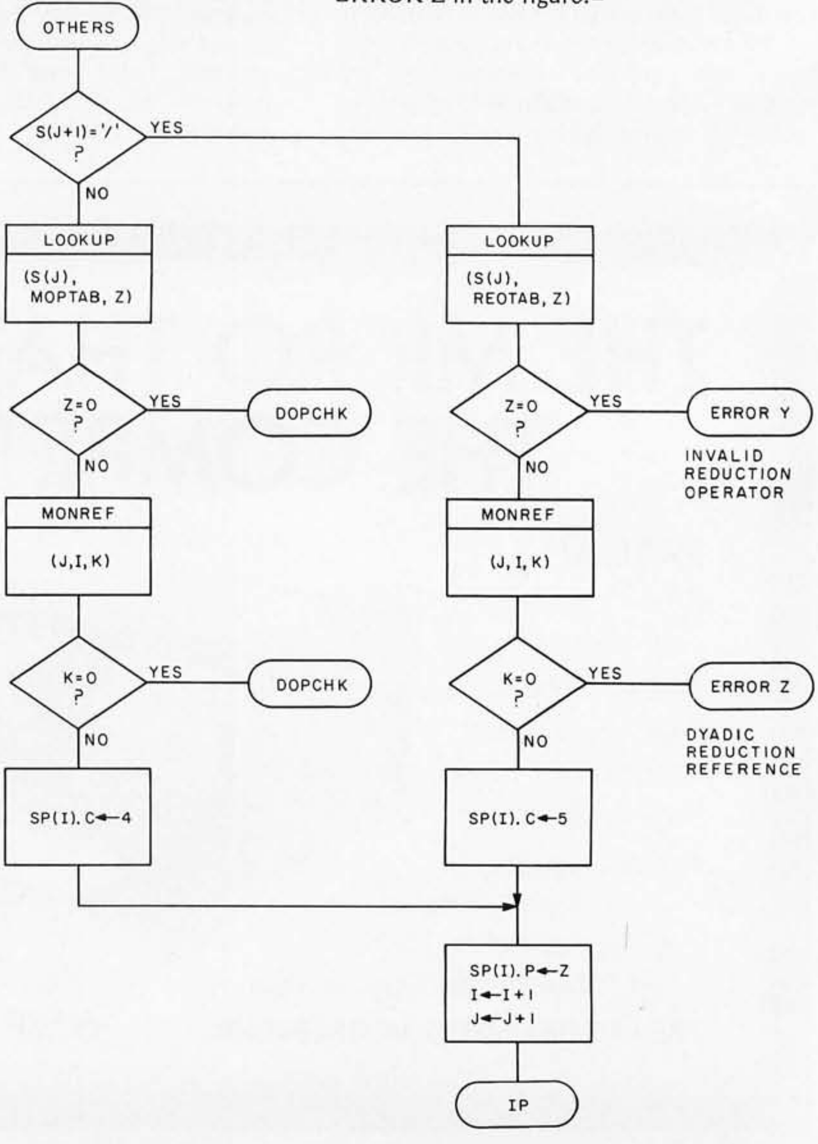
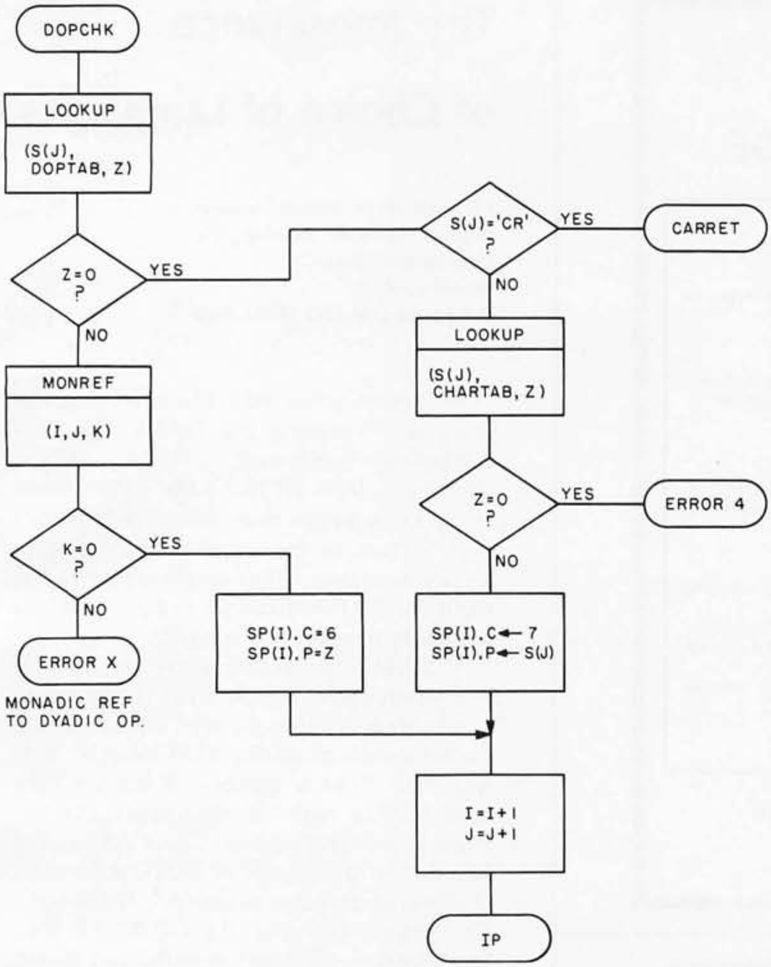
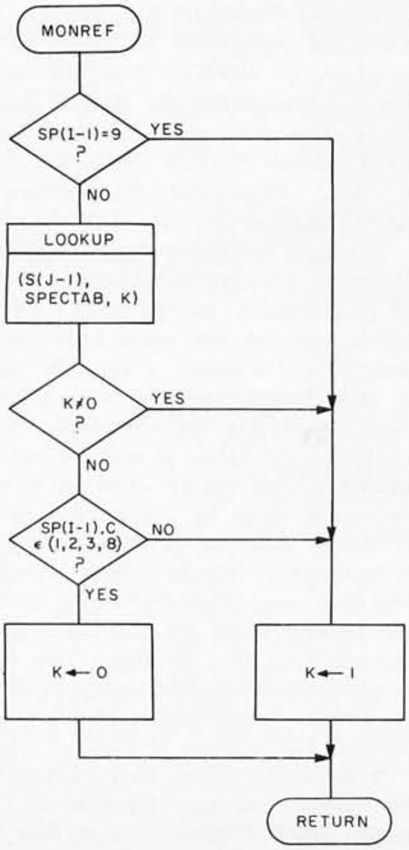
Here is a possible solution to the problem of resolving monadic, dyadic, and reduction operation references in Mike Wimble's article "An APL Interpreter For Microcomputers, Part 1," August 1977 BYTE, page 62. The subroutine MONREF has been added to perform context checking for operator references. MONREF returns its third call parameter = 0 for dyadic contexts and = 1 for monadic contexts.

Since most reductions are monadic, the logic enclosed requires reductions to occur in a monadic context. However, ceiling, floor, and log reductions could be meaningful (and legal) in a dyadic context. They can be implemented simply by checking for appropriate tokens at the point marked ERROR Z in the figure.■




DOPCHK
LOOKUP
(S(J), DOPTAB, Z)
Z=0 ?
YES
NO
MONREF
(I, J, K)
K=0 ?
YES
NO
ERROR X
MONADIC REF TO DYADIC OP.
S(J)='CR' ?
YES
CARRET
NO
LOOKUP
(S(J), CHARTAB, Z)
Z=0 ?
YES
ERROR 4
NO
SP(I).C=6 SP(I).P=Z
SP(I).C← 7 SP(I).P← S(J)
I=I+1 J=J+1
IP


MONREF
SP(I-1)=9 ?
YES
NO
LOOKUP
(S(J-1), SPECTAB, K)
K≠0 ?
YES
NO
SP(I-1).C ∈ (1,2,3,8) ?
NO
YES
K← 0
K← 1
RETURN

The Importance of Choice of Languages

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It is good to see that structured programming is permeating the field of personal computing. However, David Higgins (October 1977 BYTE, page 147) should really know better than to reduce Dijkstra's contribution to the art of programming to a statement that "(he) simply observed that the more GOTOs that were in a program, the less likely it was to run correctly."

I doubt whether the great man himself ever uttered such words. What he did say, in a celebrated letter to the editor of the *Communications of the ACM* (March 1969) was that "For a number of years I have been familiar with the observation that the quality of programmers is a decreasing function of the density of GOTO statements in the programs they produce." Please note, Mr Higgins, that with 11 GOTOs in your Bug Program, Dijkstra's remarks cast doubt, not upon the quality of your program, but upon you! There have been reams of correspondence around the world on the vexed question of GOTOs, most of which, I believe, was settled by Donald Knuth in his constructive article in the December 1974 edition of *ACM Computing Surveys*, entitled, "Structured Programming with GOTO Statements."

To leave the matter there would ignore Dijkstra's principal contribution to the art of programming. In 1972 in a paper which forms part of the book *Structured Programming* (Academic Press), he discusses at great length, and with deep insight, the methods of top down step-wise program construction. The principals which he described, and the set of primitive control functions which he advocated have had a profound influence on modern high level programming languages. What Warnier and Orr have done is simply to offer a notation for writing down the top down step-wise construction of a program. This *notation* is not unique. Michael Jackson's approach is similar, but his diagrams are rotated through 90°.

Finally, I believe your readers should be warned concerning the choice of language. David Higgins suggests that it does not matter. It does. He ought to be the first to admit that his Bug Program would have looked far better in ALGOL or PL/I, where the use of compound statements would have removed the necessity for his GOTOs, and would have resulted in a program rather closer to the Warnier-Orr diagram. When personal computers are offered with a richer selection of languages, the "structured" programmer would do well to select his or her language with due care.■

Toward a Common Pseudocode for Expression of Programs

Richard Wingerter
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I have been reading with interest the "flurry" of articles and correspondence concerning languages for small computers. I would like to pass on to readers some hints which I've picked up from literature that might be helpful in choosing a language, designing a language, or even using a language.

A large amount of work has been done in computer language design. One of the results of this work is the *Revised Report on the Algorithmic Language ALGOL 68* (A van Wijngaarden et al, Springer Verlag, New York, 1976). While we don't, of course, need to adopt all of their conclusions, ie: ALGOL 68, we might wish to consider several criteria they enumerate, especially if we design a language from scratch (as Glen Taylor suggested in November 1977 BYTE). They accepted the following aims:

1. Completeness and clarity of description
2. Orthogonal design
3. Security
4. Efficiency
5. Static mode checking
6. Mode independent parsing
7. Independent compilation
8. Loop optimization
9. Representations made possible in a minimal character set

In other words, a computer language should be simple and clear (1). It should be

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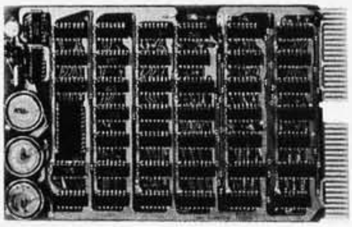


built on the smallest number of primitive concepts that can assure a powerful and expressive language, and those concepts should not overlap or cause "side effects" when combined (2). Syntactical and logic errors should be easy to find and should not propagate through the program (3). The compilation should not result in a kludge, nor should the compilation take too long (4). As much as possible, the data "types" should allow checking during compilation (5), and they should not be treated differently in similar constructs (6), ie: one ought not to have "Number 1 := Number 2" for integral values, but rather, "Move String 1 to String 2" for strings in the same language. Furthermore, the language should allow procedures (routines) to be compiled separately (7). The syntax should allow optimization of loops (8) and should allow for language to operate with a minimal character set (9), such as 64 character ASCII.

To these I might add that the syntax should suggest logical possibilities so that the programmer is not apt to forget to include things. To this end, the "*If . . . then . . . [else] . . . fi*" format is better than the limited "IF condition THEN statement" form, because in using the former, the programmer is reminded to think about the "else" possibility, which he might otherwise overlook. In other words, the language should support the programmer's thinking. *[Here the token "*fi*" is used as an "end-if" marker . . .* CH.*]*

It might seem, by now, that we should pitch all of our current languages, and possibly give up in despair. But I don't believe we will. Most of us are saddled with "outdated" languages with no real hope of ever getting away from them. However, it may be possible to have the best of both worlds.

The great boon in using a "good" computer language is that it permits us to think easily. Since we are using, say, BASIC to program our computers, we tend to fall out of the habit of thinking in English and into the habit of thinking in BASIC. But BASIC is not necessarily a good language to think in. It lacks good control structures and good data structures. One cannot easily express complex ideas with it. And yet, I must program in it and many other users probably do, too.

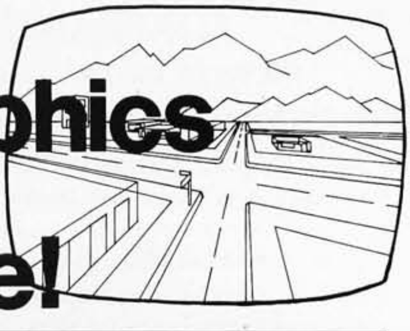
Actually, I don't program *in* it; I program "into" it from another language, one which is convenient to think in. And I believe that if we would think and communicate in a language or group of languages which are easy to think in, and program in whatever language was available, we could avoid being limited by our computer languages.

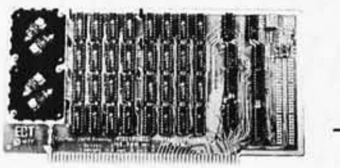
This would have many advantages. The basic ones would be that we could apply the latest techniques to our communication language much more easily than to implemented languages, and that we wouldn't need to develop any new language at all. We'd need only choose the language(s) we wish to use for thinking and communicating, and request that routines submitted for publication be in one of them. Or we could set criteria for the communication language and ask that submitted routines be translated into some language that meets the criteria.

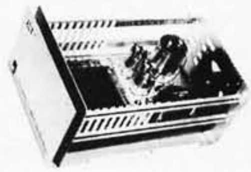
There would be one disadvantage to this method that I can foresee: it may be slower to work out and code a routine this way. Effectively, we would have to hand translate each procedure into whatever language we have implemented. But I should point out that some of this disadvantage would be mitigated by the gains due to faster design, less debugging, and easier communication of routines. My experience is that it may be worth the trouble, but this is no guarantee that everyone would find it so. I might note that "into" programming is recommended in its own right by Roy F Keller in "On Control Constructs for Constructing Programs" (*SIGPLAN Notices,* ACM Special Interest Group on Programming Languages, volume 12, #9, September 1977, pages 36 to 44), so I am not alone.

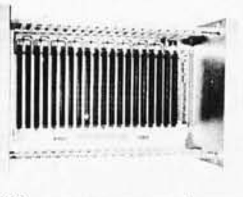
I hope that some readers might consider this approach, as it might be very helpful. Expecting people to throw away their BASIC, FORTRAN, or what have you, is not really practical, as we know from the experience of those with larger computers. But expecting them to communicate in a common language especially suited for that purpose is reasonable.■

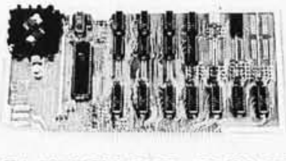
Languages Forum is a feature which is intended as an interactive dialog about the design and implementation of languages for personal computing. Statements and opinions submitted to this forum can be on any subject relevant to its purpose of fostering discussion and communication among BYTE readers on the subject of languages. We ask that all correspondents supply their full names and addresses to be printed with their commentaries. We also ask that correspondents supply their telephone numbers, which will be printed unless we are explicitly asked to omit them.











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Technical Forum

Big Disks Must Be Managed Properly

Charles A Rovira
2250 Grand Blvd #21
Montreal Quebec H4B 2W9
CANADA

As a data processing professional, I view the announcement of the new 10 to 100 megabyte disk drive memory sub-systems (*Electronics*, January 19 1978, volume 5, number 2, page 33) with mixed feelings.

This development will at last put true workable mass storage within the reach of countless users who could not otherwise avail themselves of this much needed capacity. The believably low $2000 price tag generates an enormous market potential. These new drives may cause an even larger revolution in data processing than the introduction of microprocessors; a revolution for the industry, by the elimination of high price tags and relief of software headaches caused by too much data and too little storage. Of course, the users benefit as a whole slew of new applications and data management tools present themselves at an affordable price.

A computer system that is easy to sell and easy to program is a software house's or original equipment manufacturer's dream. There is however a danger that this dream will turn a nightmare. My concern is based on two major points.

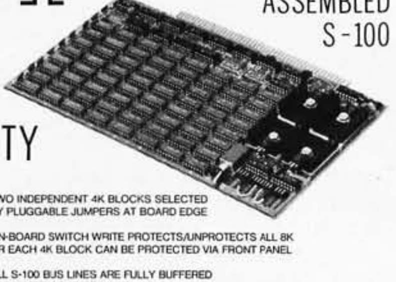
First are the limitations inherent in a fixed disk system. When a disk fails (as all do at some point, either through hardware fatigue or software and operator errors) there arises a problem of data recuperation. In removable disk systems, external backups can be made and remounted. Data loss is limited to entries made since the backup's creation. Start-up time is the time it takes to get the disk back on the drive and running. A fixed disk system calls for backup onto an external device, which can be a very slow process, or by 100 percent redundancy (namely, buying two drives and using one for backup purposes).

Due to the impracticality of copying ten to 100 megabytes of data on diskette or cassette, the only practical solution is redundancy. The problem is that the low cost of these drives will open whole new markets of unsophisticated users who will not see the need for buying two drives until they call to cancel orders or sue because they have lost valuable data. Nobody needs this kind of aggravation. In order to protect both the users and the industry, I think such drives should be designed with at least a backup surface for data recovery.

Second, a 100 megabyte drive is a 100 megabyte drive and the software must be treated as such. Inadequate disk management systems are inexcusable, since the necessary software tools already exist. These devices will have to be provided with the proper routines (ie: dynamic disk allocation, catalogs and catalog path file allocation, binary files, spool and random access files, hash/sequential and multikey indexed/sequential files (with keys in separate files) record oriented IO and cylindrical allocations in multisurface systems).

The most sensible solution is to take the standard routines and some diagnostic routines, put them in read only memory with a dedicated microprocessor (thereby making the device intelligent) and to offer the controllers with serial, parallel and DMA interfaces for the major bus configurations (that includes the Altair (S-100) bus). Even if these steps triple the price of the drive, they will still result in a vast improvement over present prices. These steps also will ensure the smooth and painless creation of new and lucrative markets as well as rapid acceptance by existing markets.

I hope the manufacturers will act on my recommendations as I write this not as criticism, but merely with a critical eye. The only problems which don't occur are the ones that are foreseen and prevented.■



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On Converting 60 Hz VDM-1s to 50 Hz Line Current

Timothy Mowchanuk
Editor of COM-3
Senior Chemistry Master
POB 268
Niddrie 3042 AUSTRALIA

I read Guy Burkill's letter in the June 1977 column of "Ask BYTE," page 60. The following is a modification to the Processor Technology VDM-1 board that may prove useful. (By the way, I have built two VDM-1 boards and they both work perfectly. I can strongly recommend them.)

Modify IC8 (93L16). Cut the land between pins 5 and 6, and connect pin 5 to ground (pins 3 and 4 of the same IC are handy). This will alter the field and line frequencies to suit 50 Hz main frequencies. The video levels may be inverted, but this can be changed using the switches on the VDM-1. The inversion problem depends on the particular TV standard and the method of input to the television. This modification will work with the PAL-D television system. It will not work with the French television standard. (PAL-D is the British standard.)

You may wish to publish this information for your foreign readers.■

The Need for Relocating Loaders

K P Pielmeier
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D-7014 Kornwestheim
W GERMANY

I would like to make some suggestions. Today most machine code programs for personal computers are produced for fixed memory assignment and are relocatable only after changing the source code and reassembling or recompiling. As program libraries grow, the drawback of reassembly becomes more and more obstructive.

It would be quite nice to have relocatable modules, and it would be even nicer to have one standard defined for any type of processor. (There are other ways to produce relocatable modules; see Borrmann's excellent "Relocatability and the Long Branch," page 26, in the October 1977 BYTE. This method produces programs which are slower and a little longer.) From my experience with IBM's linkage editor and loader I can say that this is a valuable tool: any translator (assembler or compiler) can produce its code in the required format and the code may be executed on any IBM system without change.

Of course I have a proposal at hand and I hope that it will not remain the only one, so that a satisfactory solution may be found. My suggestion is that a relocatable load module consist of four parts, which are:

1. The code part, which contains the machine instructions and the data. This part will need some changes in relocation.
2. The relocation directory part, which defines the points in the code part, which must be processed during relocation.
3. The entry point directory part, which defines the entry points in the code part, ie: the names and the addresses of items defined in this program which may be referenced by other programs.
4. The external reference directory part, which defines the external references in the code part, ie: the names of references in this program to items defined in other programs.

(If the names look like IBM, this is because I took them from there.)

I propose that each part should have the same format: a descriptor field and the part itself. As a minimum, the descriptor field should contain the identification of the part and its length.

To keep the loader program simple and small, I suggest that only one operation be allowed for relocation: one (and only one) constant will be added to all points designated by the relocation directory. This constant can be passed to the loader as a parameter and need not be defined in the relocation directory itself. To keep the

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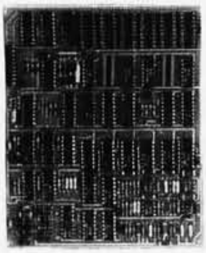
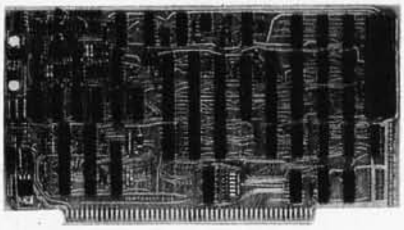
COMPUTER VOICE



M250



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relocation directory small, I suggest that it should consist simply of 1 byte entries, each of which describes the offset from the last relocation point to the next, with 255 (=FFH) as an "advance and do nothing" indication. The relocation points must be presented in ascending order. For the entry/external directories I will only suggest that they should contain the name and the relative address of each reference.

I don't think it is reasonable to adopt a load module format very close to any external storage medium (as is the case with IBM's convention). It is better to separate the task of reading into internal memory and processing, so that a change in the external medium will not affect the processing part.

Unfortunately I have no knowledge of any existing relocatable load module format for personal computers. I have neither a translator program producing relocatable modules nor a loader program.

I think that many people have similar ideas, and I would like to discuss them to find a good and widely accepted solution.■

Speeding Up MIKBUG IO Routines

T W Moore
Amateur Computer Club 6800 Library
24 College Rd
Maidenhead, Berkshire SL6 6BN
ENGLAND

The Motorola MIKBUG ROM is widely used by 6800 hackers. It contains two entry points, E1D1 and E1AC, which can be used by a user program as input or output routines; these routines use a single bit of a PIA and the data rate timing is determined by software and a programmable monostable (MC14536).

Because of the software nature of the timing, some jitter will be introduced in the output waveform and there will be a jitter component in the sampling point of the received waveform. This effectively results in a maximum data rate at which

MIKBUG can communicate with the outside world.

The jitter is caused by software loops in MIKBUG which wait for timeout of the monostable MC14536 but cannot quite catch the exact trailing edge of the monostable output. The following loop:

```
E1EF      DEL   TST   2,X  (7 cycles)
E1F1            BPL   DEL  (4 cycles)
```

senses bit 7 of the PIA in a loop and exits when bit 7 is a logic "1." In practice, the program exits anywhere between 7 and 18 machine cycles after the leading edge of the signal into pin 7, since bit 7 is only sampled every 11 machine cycles.

The input routine (E1AC) looks for a start bit by continually sensing bit 7 of side A of the PIA in a short loop, jumping out into the main routine when a logic zero is detected indicating a start bit. The main routine starts the programmable monostable which is sensed on bit 7 of side B of the PIA. The monostable effectively times out 1.5 T, where T is 1/data rate, 3.33 ms for a data rate of 300 bps. After this, the first bit of data is sensed and rotated into the accumulator via the carry bit. This procedure is repeated eight times for all eight bits separated by a delay routine (DEL above) which waits for the monostable to timeout.

The output routine works in a similar manner but then outputs data from the accumulator by rotating it into bit 0 of side A of the PIA.

The effective input and output data rates are therefore determined by the time interval between samples or program loops, and mostly dependent on the monostable pulse width. The actual time between input samples in MIKBUG is:

$$T_{mono} + 28.T_{cycle} + \begin{bmatrix}0\\11\end{bmatrix} .T_{cycle}$$

where T_{mono} is the monostable delay, T_{cycle} is the 6800 machine cycle time and $\begin{bmatrix}0\\11\end{bmatrix}$ is my notation for any number between 0 and 11.

The time between output samples is:

$$T_{mono} + 62.T_{cycle} + \begin{bmatrix}0\\11\end{bmatrix} .T_{cycle}$$

except for the width of the start bit which is:

$$T_{mono} + 56.T_{cycle} + \begin{bmatrix}0\\11\end{bmatrix} .T_{cycle}$$

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Up to two headings may be specified in a single Request, a capability that makes possible versatile cross-indexing within the data base.

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For easy installation, the **WHATSIT** programs are supplied in the widely available North Star BASIC, and can be installed without modification on any S-100 bus (8080 or Z-80) computer equipped with a North Star disc system and at least 24K bytes of random access memory (RAM). For other disc systems or non-compatible computers, the programs would require modification.

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Hardware compatibility: Any S-100 Bus (8080 or Z-80) computer with one North Star disc system and 24K of RAM (random access memory).
Language: North Star BASIC, Version 6 Release 3.
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Entry length: Up to 30 characters.

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A
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CREATION

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Assuming a 6800 machine cycle of 1 μs, there will be a peak to peak jitter component of 11 μs between bit samples. Unfortunately this jitter component is cumulative. If we refer the sample times of a waveform to the leading edge of the start bit, as most asynchronous devices operate, the trailing edge of the eighth bit can have a peak to peak jitter component of 88 μs. Similarly, the MIKBUG input routine can sample the eighth bit anywhere within a 116 μs window. These two figures are different since MIKBUG input routine adds an extra 39 μs of jitter sensing the start bit.

At low data rates, such as 300 bps, the jitter is comparatively small. If we take a maximum allowable jitter of 25 percent of data rate as a deterministic bound on reliable communications, then with a 1 μs cycle time (and no clock cycle stealing), the maximum data rate at which MIKBUG will operate without errors is $1/(4.88) \approx$ 2400 bps. In practice, the jitter adds with a Ganssian envelope distribution and operation at 4800 bps, which for noncritical applications such as video displays, is quite possible with a few errors appearing.

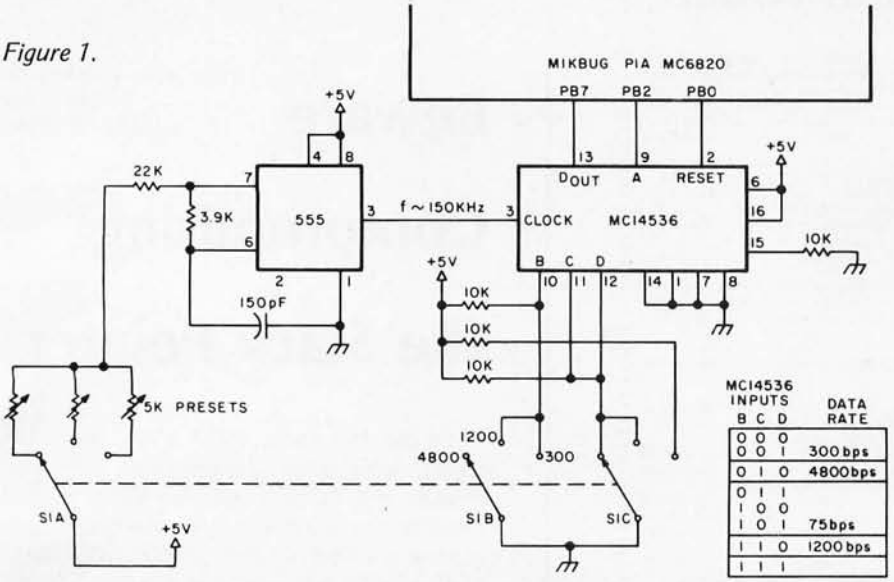
For more critical applications, such as cassette program storage, reducing the data rate to 1200 bps should allow enough margin for jitter introduced by the rest of the system. In fact, MIKBUG operates very reliably at 1200 bps and I have used it to load programs from standard cassettes such as 8 K BASIC without any errors.

It should also be mentioned that at these high external clock rates, the output data rates from MIKBUG will be different from the input data rate. This is because of the different number of machine cycles taken in the input and output routines. In fact, the output routine produces an extra delay of 34 μs between data edges. At 1200 bps this represents a disparity of 4 percent between input and output data rates.

A practical MIKBUG system configured for high speed would have say 4800 bps for video display output, 1200 bps for high speed cassette and 300 bps for standard Kansas City interface.

The circuit of figure 1 shows a typical configuration. Rather than switching the oscillator over such a wide range, the unused programming pins of the programmable monostable are used to give the required delays of 3.3 ms, 830 μs, and 200 μs. The oscillator shown is a separate 555 since this gives improved temperature stability, but is not essential. The oscillator frequency is around 50 kHz, but should be pulled slightly to compensate for the extra delays introduced by the 6800 cycle times.

Figure 1.



MC14536 INPUTS B C D	DATA RATE
0 0 0	
0 0 1	300 bps
0 1 0	4800 bps
0 1 1	
1 0 0	
1 0 1	75 bps
1 1 0	1200 bps
1 1 1	

■

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Beware Compromising the Stack Pointer

Tom Pittman
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San Jose CA 95153

In the November 1977 BYTE there are several articles on implementing real time clocks, and at least two of them suggest bringing the interrupts in on the NMI interrupt of the 6800 or 6502. I think your 6800 users should be warned that to do so *requires* (with no exceptions) a clean stack. This means *never* using the stack pointer for any other purpose.

I notice that SwTPC software is gaining wide acceptance in 6800 circles (especially among SwTPC users, naturally enough, but also elsewhere). By my count their 8 K BASIC (version 2.0) has no fewer than 13 places where the stack pointer is used to move a block of data. While this technique certainly works, it makes the software incompatible with interrupts such as those used by the various clock articles in the November BYTE. In two of these places the stack pointer is used to shift the user BASIC program over for line insertions and deletions, which tends to take a long time for large programs. This means that as you edit your BASIC program, little by little your real time clock will eat little holes in it, leaving debris which may cause the interpreter to self-destruct when you try to RUN. The SwTPC coresident editor and assembler does not even disable interrupts when fooling with the stack pointer, so *any* interrupt (NMI or IRQ) will compromise the data. I should remark here that the assembler part of this package appears to be a modified copy of the Motorola coresident assembler, and it is only the SwTPC modifications which compromise the stack.

The 6502 is less subject to such hazards because there is less temptation to use its 8 bit stack pointer for other purposes, and because its indirect addressing capabilities obviate the need for such machinations.

Both the 6800 and the 6502 are subject to a different hazard in the use of the NMI interrupt for a clock (or any other purpose, for that matter). This is the inherent conflict between the NMI and the other interrupts. You see, the NMI wins that conflict. In the case of an IRQ at the same time, this is not a

Circle 373 on inquiry card.

problem because the IRQ input to the CPU is level sensitive, and if the IRQ gets lost in the service of an NMI who cares? The interrupting device simply holds its level and when the NMI service is complete the IRQ is still waiting and gets its turn. But a software generated interrupt is a different matter. By the time this is decoded inside the processor, the program counter has already been incremented to point to the next instruction. But *it is not too late for an NMI to replace that interrupt.* When the NMI service completes, it returns to the next instruction *after* the SWI or BRK, just as if it were a NOP. This is true of both the 6800 and the 6502. I do not know it to be true of the Z-80, but it is a question worth asking.

What this means is that you cannot depend on SWI (or BRK) instructions in the same system that uses the NMI. Fortunately most present systems use these instructions for setting breakpoints in a program under test. If you want to be sure not to lose a breakpoint, put two in right next to each other; if you lose the first, the second will surely work. A few 6800 operating systems use the SWI as a monitor service call. Tough luck. The second byte of the service call (which identifies the monitor function to be performed) will occasionally be executed instead of being passed as data to the monitor.

By the way, in case you are thinking of a software fix like backing up the program counter, forget it. You have no way of knowing if a SWI got lost, or even if a SWI preceeds the instruction the NMI returns to. You could bail out if all service calls were identified by an illegal op code after the SWI (or *two* bytes after the BRK in a 6502). Otherwise hardware is required to fix the problem.■

Technical Forum is a feature intended as an interactive dialog on the technology of personal computing. The subject matter is open-ended, and the intent is to foster discussion and communication among readers of BYTE. We ask that all correspondents supply their full names and addresses to be printed with their commentaries. We also ask that correspondents supply their telephone numbers, which will be printed unless we are explicitly asked to omit them.

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Notes on Teaching with Microcomputers

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The microcomputer in a classroom is worth a thousand words. The visual demonstrations of computer function and design enable students to grasp ideas that would otherwise have to be abstract verbal constructs. The ability to help student understanding of computers reach a more profound level faster using microcomputer demonstrations opens up many possibilities for the instructor. The newness of microcomputers and probable future applications, such as energy conservation, lend interest to the subject for both student and teacher.

The Teaching Tool

We recently purchased a KIM-1 from MOS Technology for use in the computer science program at Marycrest College in Davenport IA. Our conventional computer facilities consist of a remote line to the IBM 360/65 at the University of Iowa about 60 miles away. The KIM-1 compensates for the remoteness of the IBM computer and opens new possibilities for computer use as well.

As a teaching tool the microcomputer has several strong advantages over the larger computer systems:

- It is portable enough to be moved into a classroom.
- It is small enough to be nonthreatening to students.
- Students can get actual hands-on experience programming it.
- Small schools can afford to purchase a microcomputer system.

A whole microcomputer system with basic language facilities can provide an excellent computer facility for many small school systems and colleges. In the future a microcomputer system with a modest amount of bubble memory may finally make computer assisted instruction (CAI) a reality. Thus educational uses for microcomputer technology look very promising.

Talking to a class about computers is really different when you have one in your hand. It is almost like adding another dimension to the teaching situation. The KIM-1 we are using has the added advantage that programs can be stepped through one instruction at a time. This allows registers, addresses, op codes and data to be inspected after each instruction. We have even displayed voltages on a DVM and oscilloscope. These activities make computing a visible reality for the student; that seems to be an important part of learning.

My goal in setting up the computer curriculum has been to make it practical and career oriented rather than a theoretical science. The term "software engineering" is closer to describing the intended approach than is traditional computer science. The microcomputer fits nicely into this scheme. It enables me to base teaching software techniques on known hardware mechanisms rather than on abstract mathematical theories. Hopefully this will increase the range of students who can become good programmers.

The Microcomputer as a Friend

Students seem to have gotten used to the idea of the calculator as a friend. Big computers with flashing lights and noisy IO devices are totally beyond the understanding of many students, especially those in the introductory courses. The microcomputer seems to fit in the same category as the calculator: it somehow has to be understandable because it is so small. This is a significant contribution toward overcoming student fear of technological monsters.

Not only is it less threatening for the beginning student, but it is a thrill to make it actually work for the more advanced student. We are using the microcomputer as the basis for a course in large computer organization. The basic architecture of micros is similar enough to large scale computers so that actual hands-on experience is applicable to understanding most computer systems. In addition, by the time the students currently enrolled in this course graduate, microcomputing jobs may be plentiful, enabling them to apply their microcomputer experience directly to a career situation. Either way the students come out ahead.

But Is It Affordable?

Current prices put microcomputers within the range of most school systems and colleges as well as affluent students. According to *Datamation* (January 1977) the University of California and Pasadena Polytechnic High School are among the first users of microsystems. Computer Power and Light Inc of Studio City CA is a new business engaged in selling microcomputer systems to schools. Schoolwork on home computer systems as we have seen in BYTE is now a reality.

Computer assisted instruction requires little computing power and lots of memory. The ideal solution might be a micro with a video display and a bubble memory module containing the course to be learned. Perhaps a micro could integrate the verbal material with a visual display on a television using video tape.

Thus microcomputers are an ideal tool for teaching students about computers and hold much promise for deeper involvement in education in the future. This means many more marketing and occupational opportunities in microprogramming.■

More Music for the 6502

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```
The following zero page locations must be loaded before execution:

     000E           BEAT            bass downbeat rate.  Typical value = 08.
     000F           MASK            determines largest table increment used.  Typical value = 0F.
     0012           TEMPO           determines duration of shortest note; controls tempo.
                                    Typical value = 0D.

Other labels used:

     0010           INCR            Table increment (harmonic number)
     0011           CNTRL           Inner loop counter (wraparound)
     0013           BCNTR           Downbeat counter
     0014           CNTRH           Outer loop counter
     0300           TABLE           Starting address of waveform table
     F900           DAC             Address of output port connected to DAC

     0200      A0 OO          LDY  0               y index is the note counter
     0202      98        NOTE TYA                  split y into upper and lower halves.
     0203      29 F0          AND  11110000
     0205      4A             LSR  A
     0206      4A             LSR  A
     0207      4A             LSR  A
     0208      4A             LSR  A
     0209      85 10          STA  INCR
     020B      98             TYA
     020C      29 0F          AND  00001111
     020E      25 10          AND  INCR            AND the two halves
     0210      65 10          ADC  INCR            and add to lower half.
     0212      25 0F          AND  MASK            MASK out upper half.
     0214      85 10          STA  INCR            Store result for use as table increment.
     0216      A2 00   RESET  LDX  0               X is waveform table pointer
     0218      A5 12          LDA  TEMPO           Reset tempo counter.
     021A      85 14          LDA  CNTRH
     021C      BD 00 03 LOOP  LDA  TABLE           Get Xth byte of table and send to DAC
     021F      8D 00 F9       STA  DAC
     0222      8A             TXA                  Add the table increment INCR to X.
     0223      18             CLC
     0224      65 10          ADC  INCR
     0226      AA             TAX
     0227      C6 11          DEC  CNTRL           Repeat until 256 X TEMPO table bytes are output
     0229      D0 06          BNE  RPEAT          (which constitutes one note)
     022B      C6 14          DEC  CNTRH
     022D      D0 ED          BNE  LOOP
     022F      F0 04          BEQ  NEXT
     0231      EA      RPEAT  NOP                  Waste as much time as it takes to decrement CNTRL.
     0232      18             CLC
     0233      90 E7          BCC  LOOP
     0235      C8      NEXT   INY                  Go on to next note.
     0236      C6 13          DEC  BEAT
     0238      D0 C8          BNE  NOTE
     023A      A5 0E          LDA  BEAT
     0231      85 13          STA  BCNTR
     0233      A9 01          LDA  #01
     0235      85 10          STA  INCR
     0237      18             CLC
     0238      90 D1          BCC  RESET
```

Listing 1: A program written for the 6502 which generates first order tone sequences. The program can reside in any 70 consecutive memory locations. It requires a 256 byte waveform table on page 03 and an 8 bit digital to analog converter address at F900. The program uses the X and Y registers and zero page locations 0E thru 14. This program was hand assembled and is reproduced here from the author's typed listing.

Here is a simple "music" composition and generation program which should provide some fun for the experimentally inclined. In September 1977 BYTE, page 12, Hal Taylor wrote about rules describing the style and structure of computer generated music. He described *zeroth order stochastic control,* in which the note sequences and durations are completely random. This sort of thing is very easily implemented with a microcomputer, and I suspect many of you have already done so just for fun, but the novelty wears off very quickly. More interesting is *first order control,* in which the pitches (or more precisely the transitions between pitches, or intervals) and rhythms are governed by some set of rules derived from conventional music (or from mathematics, poetry, etc, according to Hal Taylor).

The algorithm given here generates a monotonic tone sequence under first order control based on simple arithmetic and Boolean relations. The tone generation itself is done by the conventional sampled waveform approach with a stored waveform and variable table increment (see Hal Chamberlin's article cited at the end of this article for explanation). In the conventional technique, the table increments which determine the pitches are stored in a table, which forces the computer to play a predetermined tune. In the system described here, though, the table increments are calculated in real time by means of a simple pattern generating algorithm. The result is music which is "natural," at least from the computer's point of view, because the elements of the pattern algorithm are simple binary machine operations such as increment, shift, AND, OR and add. While you might not consider the results serious competition for the top ten, I think you will find that the computer's idea of music has many elements in common with our own.

The hardware requirements are minimal: an MOS Technology 6502 based computer with 1 K of programmable memory, a simple 8 bit latched output port, and an 8 bit digital to analog converter (DAC). A KIM-1, Ebka 6502, PAIA 8700, or an OSI 400 board should be able to run this program by simply changing the output instruction (locations 021F to 0221) to the address of your output port (F900 on my Ebka).

The complete program is given in the accompanying listing. It is written to occupy the first 70 bytes of page 02, but is relocatable without change. The 256 byte waveform table is on page 03. Page zero locations 0E to 14 are used. The pattern generating routine (hexadecimal addresses 0202 to 0213) produces a 4 bit integer table increment (INCR) from the value in the y index register, which is initialized to 0 and is incremented by 1 for each successive note (at location 0235). Then code at locations 0216 to 0234 generates the note with the duration determined by TEMPO. To add a rhythmic touch, locations 0236 to 0241 force the fundamental (lowest) frequency to be played every eight notes: a sort of bass drone effect.

The waveform table can be anything you like. Of the simple waveforms, a triangular wave sounds pleasant. Or you can use a more complex waveform such as the one given by Hal Chamberlin in his September 1977 BYTE article, page 62.

In addition to the waveform, several other variables can be changed for experimental purposes, including TEMPO, MASK, BEAT, and, most interestingly, the pattern generator itself. For example by changing the AND and ADC operations at 020E and 0210 to ORA, EOR, SBC, etc, a variety of other patterns can be generated.

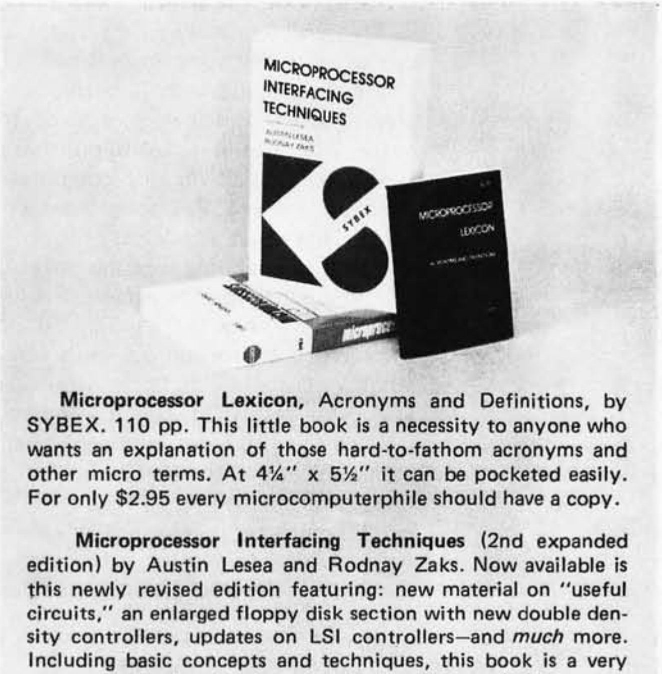
Note that, since only integer table increments are used, the pitches obtained will be a "natural" harmonic series resulting in a so-called "scale of just intonation" rather than the equally tempered scale more familiar in post 17th century Western music (see Olsen's book in the references). The difference is slight for the first few harmonics, so for that reason the harmonic numbers (table increments) are limited by the MASK applied at 020B.■

REFERENCES

1. Hal Taylor, "Scortos: Implementation of a Music Language," September 1977 BYTE, page 12.
2. Hal Chamberlin, "A Sampling of Techniques for the Computer Performance of Music," September 1977 BYTE, page 62.
3. H F Olson, *Music, Physics, and Engineering,* second edition, Dover, New York, 1967.

Harmonic Number	Note	Interval
1	C_2	––
2	C_3	Octave
3	G_3	Perfect 5th above C_3
4	C_4	Next octave
5	E_4	Major 3rd above C_4
6	G_4	Perfect 5th above C_4
7	B_4^b	Harmonic minor 7th
8	C_5	Next octave

Table 1: The harmonic series based on the note C_2. (C_2 is two octaves below middle C.)



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Steve Ciarcia
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"Talk to me! Talk to me!"

"OK! I'll talk to you if you need it that much!" Ken called out as he descended the stairs into my cellar workshop. "You sure you aren't going a little buggy?"

I looked up from the video monitor and parted the piles of cassette tapes and printouts. Ken was a good neighbor and I knew his comment was only in jest. I hit the carriage return and the speaker said, "Talk to me!"

Ken smiled when he realized I was just exercising the voice synthesizer option I had previously added to my system.

"This synthesizer is part of the reason I'm here this evening," he said.

"What's the problem?" I asked.

"No problem really. We just got a microcomputer in my company's R and D lab and I've been playing with it lately. It's pretty sophisticated and has plenty of memory space. What would it cost to put that type of synthesized voice on our computer? I can probably raise $50 among the technicians for it. They'd get a kick out of it."

"Well, depending on the manufacturer and the particular interface, they usually run from $400 to $800 and up." I looked at the startled expression on Ken's face. It was what I normally call "peripheral face," the look you get when you tell someone that it'll cost $1100 for a video terminal to communicate with the computer he just bought for $250.

"So much for that idea. How's the weather been lately?"

"Wait!" I interjected. "How much memory do you have on your lab microcomputer?"

"40 K, I believe. Why?"

"How much of a vocabulary do you need?"

"I suspect we'd only need the numbers 0 through 9 and a few letters. We want to monitor data and verbally record channel number and input value. But at that price it's far too expensive to justify."

"How about digitized speech? You probably have enough memory for that."

"What's that?"

"It's a process to record speech digitally. For all practical purposes it's like a tape recorder, but instead of magnetic tape for the storage medium it uses the computer's programmable memory. The tape recorder uses an analog storage method while the computer stores the information digitally."

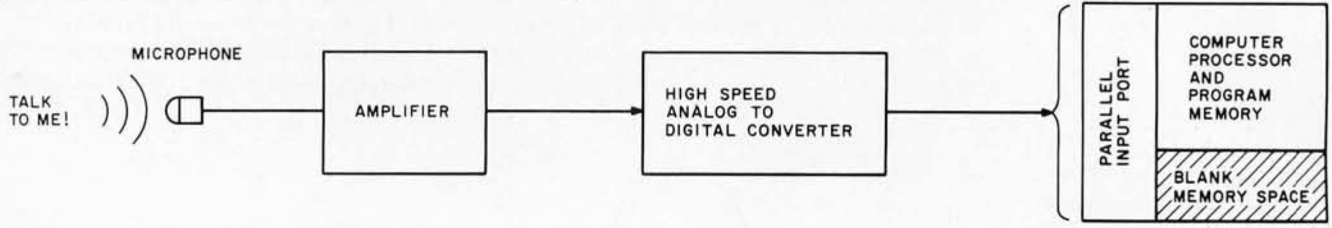
"If it's that simple why don't more people use it?"

"It's mostly because it's not very memory efficient. A voice synthesizer is an analog voltage generator that creates the speech phoneme sounds through a hard wired circuit. In its most advanced form a single 8 bit byte can be used to tell the synthesizer what discrete sound it should make. By sending it a series of byte codes, words can be made from the discrete sounds. That's the way my Votrax synthesizer works." I pulled out a pad to sketch my explanation. "In digitized speech the analog voice input is sampled very quickly with a high speed analog to digital converter, and the samples are stored in memory. To reconvert to analog or "say" the words, the stored digital data is sent to a digital to analog converter at the same rate and in the same order the samples were taken. The concept of digitized speech has been around for a long time, but up until recently the cost of a system dedicated to this was prohibitive. You already have the computer and enough memory for limited applications. All you need is the high speed analog to digital and digital to analog converters and the knowledge to do it."

"And what is that going to cost me, $500?" Ken was still skeptical.

I opened a drawer under the bench. It was my "junk box" (in my case one corner of my cellar is a junk *room*). I rummaged through the prototype boards from previous experiments and pulled out a particular one. "Ah, here we are. You remember a few months ago when I designed that 8 channel digital voltmeter (December 1977 BYTE, page 76, and January 1978 BYTE, page 37).

Figure 1a: Block diagram of a digital speech recording system. Speech is picked up as sound waves by the microphone and is amplified and processed through a high speed analog to digital converter which samples the analog sound waveform several thousand times a second. These samples are stored in the computer's programmable memory.



I needed it to troubleshoot this board. This is all you need for digitized speech." I tossed the board to Ken. "It contains a 100,000 sample per second 8 bit analog to digital converter and an equivalent speed digital to analog converter. And now the beauty part: It cost less than $35 to build."

"Great! Tell me how to use it. How much memory does it need? What kind of program does it use? Can you tell me how to use it so I can borrow it for work tomorrow?"

"Well, let's go over the concept in more detail. . . ."

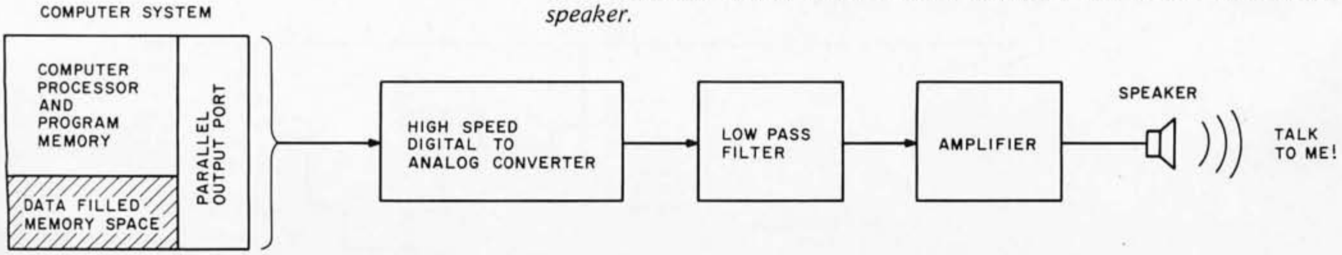
What is Digitized Speech?

Digitized speech is simply a standard data acquisition technique with a new definition. For years people have been using computers to scan analog to digital input converters and store the results in memory. Often, in high speed applications such as wind tunnels and nuclear experiments, the sample rates can exceed thousands of samples a second. In cases where the critical event is of short duration, these thousands of samples are stored directly into memory to increase system throughput capabilities. When the event has passed and sampling has stopped, the computer memory contains a record of that event in discretely timed intervals. The stored data is now available to be reduced, analyzed or listed. It's often listed in "slow motion." This technique employs an analog pen recorder and a digital to analog converter. Each sample is successively processed through a digital to analog converter at a slow rate to the pen recorder. The result is an expanded view of a short event.

An alternative method for utilizing this stored data is to play it back in real time. In this case the computer outputs the stored data to the digital to analog converter at the same rate the data is taken. The output of the converter would then exactly duplicate the values of the event previously recorded (at the times the samples were taken).

Digitized speech is a specific application of this type of data recording technique. Your voice, when applied to a microphone and amplifier, creates a fluctuating analog voltage that varies at the frequency rate of the sound. If this analog signal is applied to the input of a high speed (greater than 10,000 samples per second) analog to digital converter and stored in memory, the computer won't care whether the source is speech or a nuclear reaction. The analog fluctuations are "digitized" at discrete sampling intervals and stored (figure 1a). If the stored memory table is sent to a digital to analog converter at the same rate it was initially sampled, the speech is reproduced exactly. Of course there are trade-offs and limitations that have to be considered to produce a usable system (figure 1b). We will consider them in detail later.

Figure 1b: Block diagram of a digital speech playback system. Digital sample points stored by the system in figure 1a are converted by a high speed digital to analog converter into an analog speech waveform. A low pass filter is used to smooth the signal, which is then amplified and played back through a speaker.



A digitized speech system creates its output waveform by digital to analog conversion rather than by completely analog generation as in the case of a voice synthesizer. The major consideration that limits the usefulness of digital speech is the vast quantity of data which must be stored to reproduce a single spoken word.

Choosing the Correct Sampling Rate

The 8 channel digital voltmeter *mentioned* earlier has a maximum sampling rate of 25 conversions a second. A slow speed analog to digital converter of this type is of no value in this application. The normal human voice occupies a bandwidth of 4000 Hz, and taking

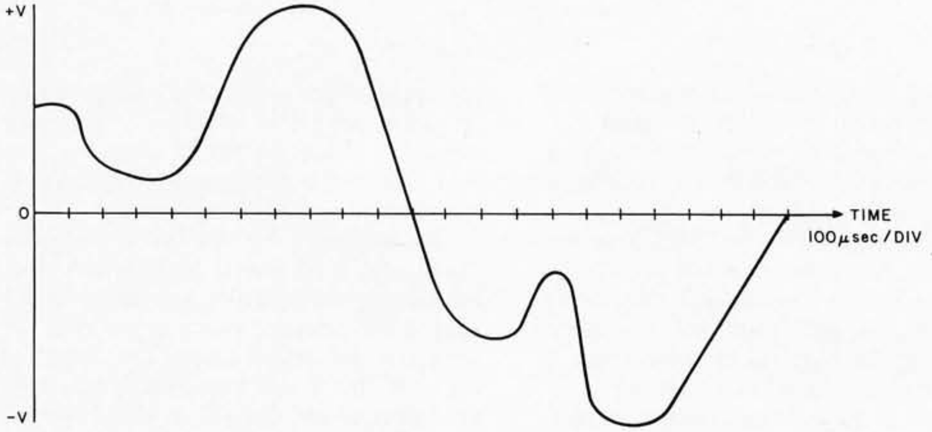


Figure 2a: A waveform (considerably simplified) which is characteristic of the voice.

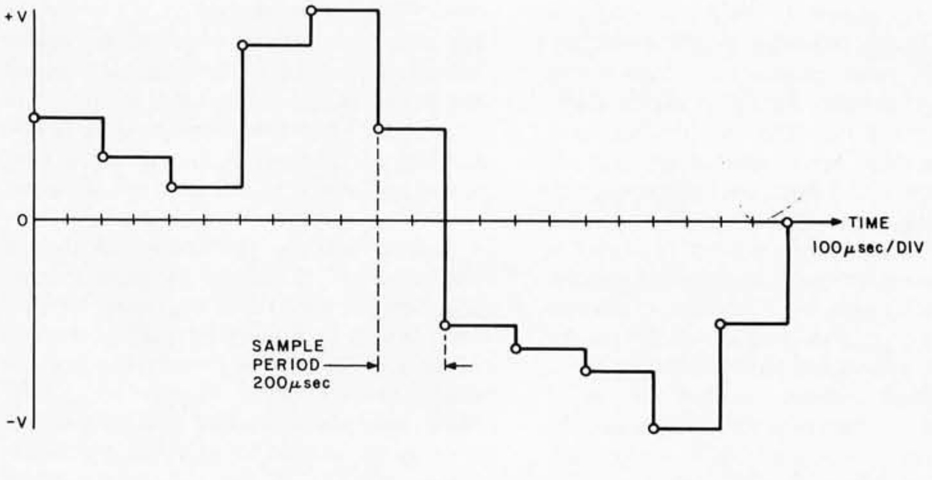


Figure 2b: Waveform in figure 2a after being processed through a digital to analog converter at a sample rate of 5000 samples per second.

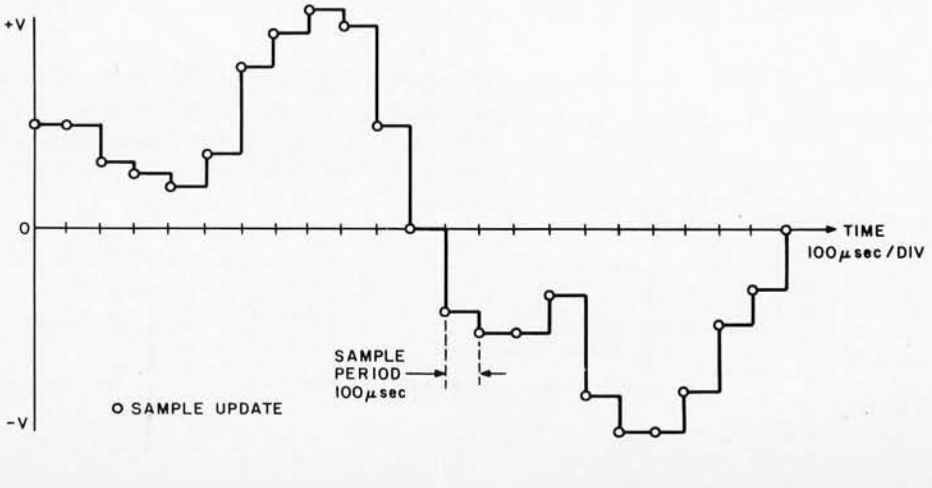


Figure 2c: Waveform in figure 2a after being processed through a digital to analog converter at a sample rate of 10,000 samples per second.

25 samples within a period of one second could not effectively record the event. At what sampling rate should audio speech be digitized?

There is a specific law used to determine this rate, called the Nyquist criterion. It states that, at the very minimum, the sampling rate of the digitizer must be twice the maximum frequency of the input sample. If human voice extends to 4 kHz, the minimum sample rate should be 8 kHz. This presumes that there is an ideal low pass filter on the output of the converter. Ideal filters are something like perpetual motion, impossible to attain. In reality the sampling rate should be three or four times the highest input frequency. This means that to digitize voice fully you need a sample rate of from 12 to 16 kHz.

It is easier to explain the digitization process visually. Figure 2 illustrates an expanded view of a typical speechlike waveform. Voice waveforms are complex: the majority of the voice sounds exist below 1500 Hz, but intonation and accent occupy the higher frequencies. It is these added harmonics and inflections that make one voice different from another, and capturing and recording them is an important consideration. The waveform in figure 2 has been digitized at two different rates for comparison. Figure 2a is the original waveform which consists of a fundamental frequency of approximatley 500 Hz and some added components of higher frequency. If this waveform is "digitized" or sampled at a 5000 samples per second rate and the stored values are sent to a digital to analog converter, the resultant waveform would be that shown in figure 2b. It is easy to see that only a vague representation of the original waveform would be recorded. Even though this output is filtered before being amplified, the higher frequency components of the original input would be lost. Increasing the sampling rate to 10,000 samples per second as in figure 2c gives a better record of the higher frequencies. The addition of a good low pass filter would eliminate the sharp transitions between samples.

Tradeoffs to be Considered

The benefits associated with the reduced cost of the voice input and output circuitry

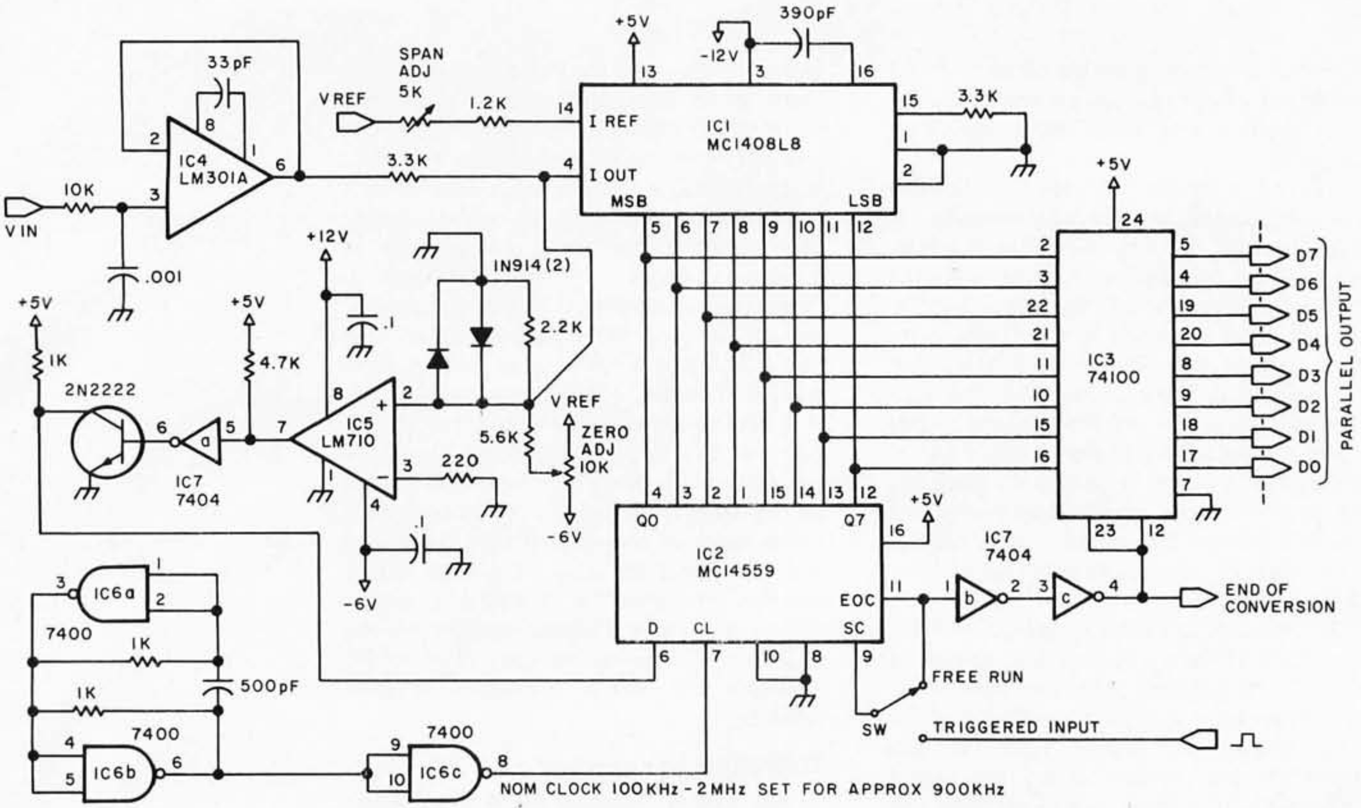


Figure 3a: An 8 bit successive approximation analog to digital converter.

are counteracted by the increased memory requirements. Digitized speech uses a lot of memory. In the previous example, if the voice input is sampled at 10,000 samples per second, the table in memory needed to store one second of data would be 10,000 bytes long (presuming an 8 bit analog to digital converter). If increased fidelity is required and the sampling rate is set for 16 kHz, the table would fill up at a rate of 16,000 bytes per second.

Obviously, systems like my own, which already have considerable amounts of programmable memory, would be easy to use for experimenting with digital speech. I do not recommend buying additional memory just to store a few words, but, if you have it, you'll be surprised at the results.

Building a Voice Digitizer

To experiment fully with digitized speech, it is necessary to have a high speed analog to digital converter to store the analog input and a high speed digital to analog converter to reconstruct the analog output.

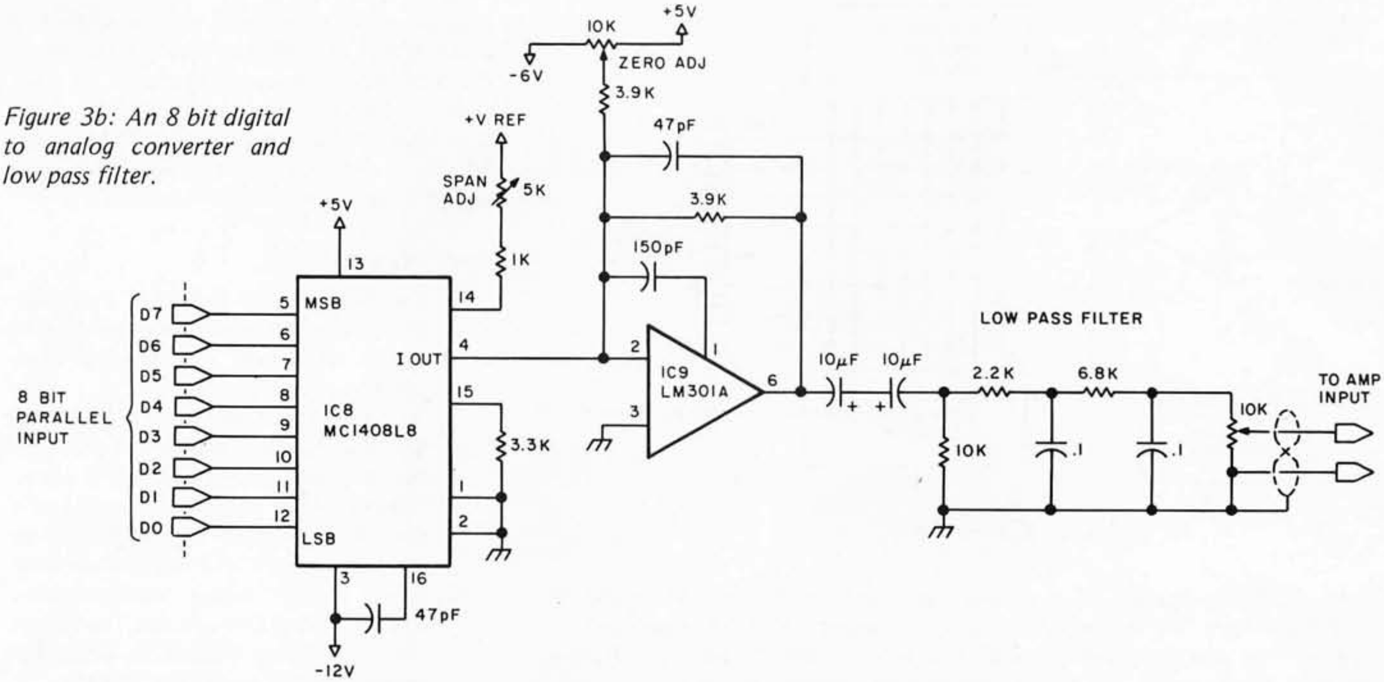
Figure 3a shows the schematic of an 8 bit analog to digital converter capable of sample rates in excess of 200,000 samples per second. With an 900 kHz clock rate it will run at a modest 100,000 samples per second. Figure 3b shows an 8 bit digital to analog converter and low pass filter with similar capabilities. The estimated total cost for parts is $35.

The analog to digital converter is a general purpose high speed 8 bit converter that can

Table 1: Power wiring table for figures 3a and 3b.

IC Number	Type	+5 V	Gnd	+12 V	−12 V	−6 V
IC1	MC1408L8	13	1		3	
IC2	MC14559	16	8			
IC3	74100	24	7			
IC4	LM301A			7		4
IC5	LM710			8		4
IC6	7400	14	7			
IC7	7404	14	7			
IC8	MC1408L8	13	1		3	
IC9	LM301A			7	4	

Figure 3b: An 8 bit digital to analog converter and low pass filter.

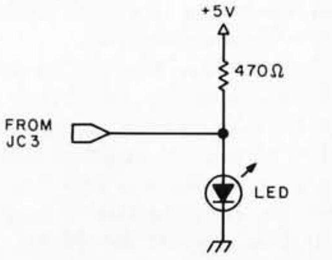


be used for any data acquisition application requiring high speed. The technique used to attain this speed is called successive approximation. The circular logic of successive approximation is best explained in a block diagram (see figure 4).

Initially, the output of the Successive Approximation Register (SAR) and mutually connected digital to analog converter is at a zero level. After a start conversion pulse, the register enables the output bits one at a time starting with the most significant bit (MSB). As each bit is enabled, the comparator gives an output signifying whether the amplitude of the input signal is greater than or less than the amplitude of the converter. If the converter output is greater, that particular bit is set equal to 0; if less than, it is set to 1. The register moves successively to the next least significant bit (retaining the setting on the previously tested bit or bits) and performs the same test. After all the bits of the converter have been tested, an EOC is output and then the conversion cycle is complete. The entire conversion period takes only nine clock cycles, and

Notes for Figures 3a, 3b and 3c:

1. All resistors are 1/4 W 5% unless otherwise indicated.
2. All capacitors are 100 V ceramic unless otherwise indicated.
3. With components shown, clock frequency is 900 kHz. This is 100,000 conversions per second in free run mode.
4. The following circuit can be added to each output pin of IC3 if a visual indicator is desired:
5. Clock rate is not critical. A slower clock of 100 kHz (about 9 K samples per second) may be quite adequate.



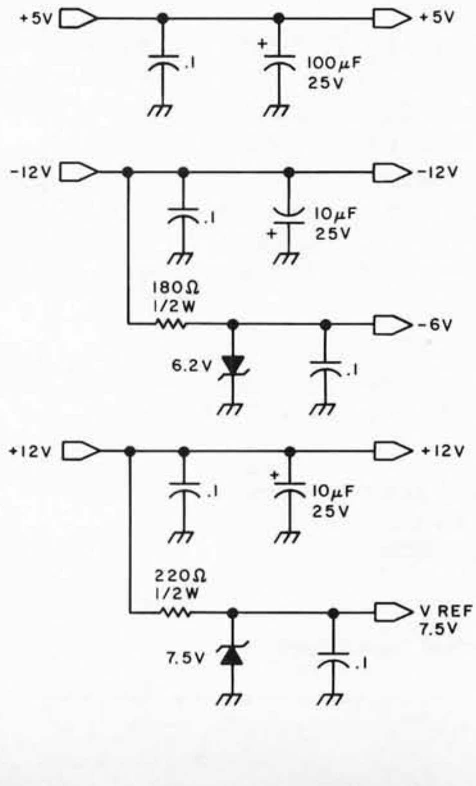


Figure 3c: Power supply circuitry for figures 3a and 3b.

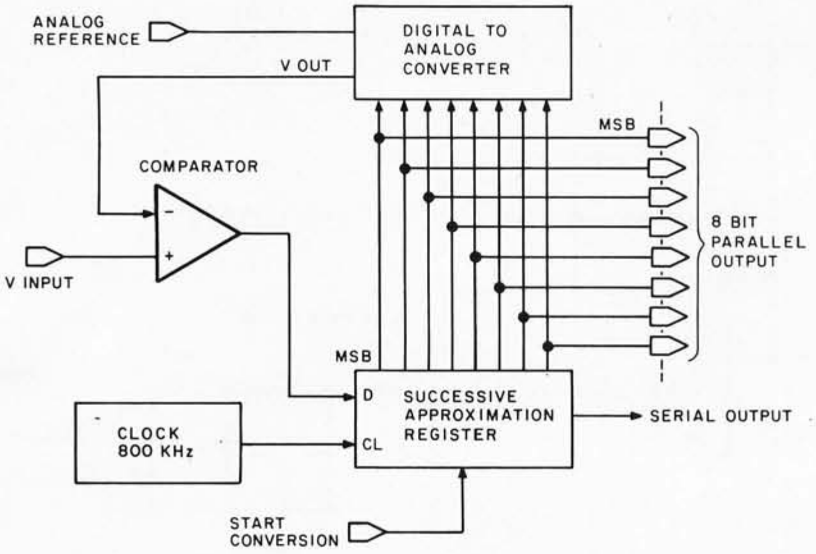


Figure 4: Block diagram of a typical successive approximation analog to digital converter. The device uses a digital to analog converter to perform its function. The successive approximation register is initially set to 0. After a start conversion pulse, the register enables the output bits one at a time, starting with the most significant bit (MSB). As each bit is enabled, the comparator gives an output signifying whether the amplitude of the input signal is greater than or less than the amplitude of the digital to analog converter. If the converter output is greater, the bit in question is set equal to 0. Otherwise it is set to 1. The process continues for the remaining bits until the conversion is complete.

another conversion begins on the next clock pulse when in free run mode. To retain the 8 bit value between conversions, an 8 bit register (IC3) has been added (see "Control the World," September 1977 BYTE, page 30, for a complete description of MC1408 digital to analog converter operation).

Assembly and Testing

1. Component types and values are chosen to allow high speed operation. Substitution of slower devices may compromise overall performance.
2. Assemble components on a prototype board as neatly as possible. Keep wires between components short and direct. The MC14559 is a CMOS device and it should be handled carefully. Sockets are suggested for all integrated circuits.
3. Check power supply voltage before inserting integrated circuits. Then insert clock oscillator IC6. The clock frequency should be around 900 kHz.
4. Insert the rest of the integrated circuits and ground the V input connection of IC4. Slowly rotate the zero adjust pot until the parallel output of IC3 reads binary 10000000. This output can be read either through a computer program which scans and displays this value or with LEDs attached to the output pins. In practice, the LEDs are easier in the long run.
5. Remove the short on V input and apply a voltage of +2 V. Adjust the span adjust pot until the displayed output is 11111111. The result of this procedure is an analog to digital converter with an input range of −2 to +2 V represented by binary 00000000 and 11111111 patterns respectively. 0 V is represented by 10000000. Any voltage span between + and −5 V can be set on this circuit using this method.
6. The digital to analog converter section should be assembled with the same care. Insert all ICs. With all parallel input pins at a logic zero level, adjust the zero pot until IC9 pin 6 reads 0 V.
7. With all parallel input pins at a logic 1 level, adjust the span pot until the output at IC9 pin 6 equals the +V setting of the analog to digital converter, or as in the example (2 V).
8. The low pass filter in the schematic is optimized for the speech samples in the text, but can be experimentally determined. The optimum cut off frequency of the low pass filter should be the sampling rate frequency. (ie: 10 kHz cut off for 10 kHz sample rate).

9. The easiest way to test the entire unit is to attach the analog to digital converter output to the digital to analog converter input. What goes in should come out! Since both units would be running continuously at the 100,000 samples per second rate, this will give the experimenter firsthand knowledge of the ultimate fidelity of the system. Don't expect miracles with an 8 bit unit; 12 bit units would be far superior, but 8 bit precision is more than adequate. A standard cassette recorder in the record mode serves as a handy amplifier. The amplified output is available at the earphone jack on most recorders.

Using the Interface with a Computer

Not everyone will want to add a voice to their home computer but the concept is none the less intriguing. Once you have built the analog to digital converter and digital to analog converter of figure 3 you are ready to digitize the spoken word. Listing 1 is a simple program that reads the analog to digital converter output and puts the values sequentially in a memory table. Hardware for the experiment should be arranged as in figure 1b. When the program is executed it will scan the input port containing the analog to digital converter information and will compare this value to hexadecimal A8 (when speech is started, the audio level will presumably exceed this trigger level). The amplifier should be adjusted to eliminate false triggering because of background noise.

When the input level is attained, the digitization process begins. The program sets the beginning address of the memory table and sequentially reads the input port and stores the value. The rate at which the sampling occurs is determined by the value of a constant, "SAMP." A value of hexadecimal 38 is approximately 3 kHz on my Z-80 system. When the table is filled, the program stops. All programs in this article, while written on a Z-80, use only 8080 instructions.

Once the table is filled with digital values corresponding to a voice input, we are ready for the next phase: voice output. The hardware is configured as in figure 1b, and the output program shown in listing 2 should be used. The same values as those of the input program should be used for START, END and SAMP. When the program is executed, the recorded data gives a speech output.

As with most computer experimenters, hearing is believing. To allow people to try out the concept without having to construct the analog to digital converter I have included a predigitized listing of a few words. This 2000 byte listing (listing 3), will say "Talk to me" when read out using the program of listing 2. Since I could not presume that everyone had the patience to hand load a 10,000 byte table with good fidelity, a compromise was in order. The sample rate on this table is only 3 kHz, but the speech will still be understandable. It should also be realized that since this example of digitized speech is actually recorded sounds, the words "Talk to me" will be in my voice. The fact that I have a fairly low voice allows understandable speech even at these very low sample rates.

Listing 1: An 8080 assembler program that reads the 8 bit parallel output of the analog to digital converter and stores the samples sequentially in memory. This assembly uses octal notation for machine codes.

```
120000                 0100 *
120000                 0110 *
120000                 0120 * VOICE TO MEMORY TABLE TEST PROGRAM *
120000                 0130 *          S.CIARCIA
120000                 0140 *
120000                 0150 *
120000                 0160 START  EQU  010000 MEMORY TABLE START HL ADDRESS
120000                 0170 END    EQU  110    MEMORY TABLE END H ADDRESS
120000                 0180 TRIG   EQU  250    INPUT START CONVERSION LEVEL
120000                 0190 IPORT  EQU  020    A/D INPUT PORT NUMBER
120000                 0200 SAMP   EQU  070    SAMPLE RATE TIME CONSTANT
120000                 0210 *
120000                 0220 *
120000                 0230 *
120000 333 020         0240 INP    IN   IPORT  READ A/D INPUT VALUE
120002 376 250         0250        CP   TRIG   COMP. INPUT TO CONVERT TRIGGER LEVEL
120004 302 000 120     0260        JP   NZ,INP LOOP AGAIN IF NOT SUFFICIENT LEVEL
120007 041 000 010     0270        LD   HL,START LOAD TABLE START ADDRESS
120012 333 020         0280 AGAIN  IN   IPORT  TAKE A SAMPLE
120014 167             0290        LD   (HL),A STORE SAMPLE IN MEMORY
120015 315 030 120     0300        CALL DELY   SAMPLE TIME DELAY
120020 043             0310        INC  HL
120021 174             0320        LD   A,H
120022 376 110         0330        CP   END    TEST TO SEE IF AT END OF TABLE
120024 302 012 120     0340        JP   NZ,AGAIN IF NOT TAKE ANOTHER SAMPLE
120027 166             0350        HALT
120030                 0360 *
120030                 0370 *
120030                 0380 * SAMPLE RATE TIMING LOOP *
120030 006 070         0390 DELY   LD   B,SAMP
120032 005             0400 DCR    DEC  B
120033 302 032 120     0410        JP   NZ,DCR
120036 311             0420        RET
```

Listing 2: An 8080 assembler program designed to output digital speech samples to the digital to analog converter at the correct rate. This assembly uses octal notation for machine codes.

```
120000                 0100 *
120000                 0110 *
120000                 0120 * MEMORY TABLE TO VOICE OUTPUT TEST PROGRAM *
120000                 0130 *                S.CIARCIA
120000                 0140 *
120000                 0150 *
120000                 0160 START  EQU  010000 MEMORY TABLE START HL ADDRESS
120000                 0170 END    EQU  012    MEMORY TABLE END H ADDRESS
120000                 0180 OPORT  EQU  022    D/A OUTPUT PORT NUMBER
120000                 0190 SAMP   EQU  070    SAMPLE RATE TIME CONSTANT
120000                 0200 *
120000                 0210 *
120000                 0220 *
120000 041 000 010     0230        LD   HL,START LOAD TABLE START ADDRESS
120003 176             0240 AGAIN  LD   A,(HL) TABLE VALUE TO ACCUMULATOR
120004 323 022         0250        OUT  OPORT,A OUTPUT BYTE TO D/A
120006 315 021 120     0260        CALL DELY   SAMPLE TIME DELAY
120011 043             0270        INC  HL
120012 174             0280        LD   A,H
120013 376 012         0290        CP   END    TEST TO SEE IF AT END OF TABLE
120015 302 003 120     0300        JP   NZ,AGAIN IF NOT OUTPUT THE NEXT SAMPLE
120020 166             0310        HALT
120021                 0320 *
120021                 0330 *
120021                 0340 * SAMPLE RATE TIMING LOOP *
120021 006 070         0350 DELY   LD   B,SAMP
120023 005             0360 DCR    DEC  B
120024 302 023 120     0370        JP   NZ,DCR
120027 311             0380        RET
```

Listing 3: A listing of the digital samples making up the phrase, "Talk to me" spoken by the author. This somewhat bandwidth limited signal allows interested readers to reproduce the message through an 8 bit digital to analog converter without having to build the analog to digital converter.

```
THE FOLLOWING LIST HAS THE ADDRESS LOCATION IN DECIMAL
ALL MEMORY BYTE VALUES ARE GIVEN IN OCTAL NOTATION
      32768      277   307   320   250   177   140   077   037   001   000
      32778      000   000   000   027   101   220   274   303   300   260
      32788      213   210   174   147   100   054   007   001   014   007
      32798      003   030   047   040   050   037   050   060   077   140
      32808      170   234   203   170   156   117   060   037   047   060
      32818      034   003   040   076   077   140   150   127   053   060
      32828      037   040   077   137   113   060   077   117   060   057
      32838      043   060   076   067   120   077   157   200   174   137
      32848      160   140   077   107   077   067   060   070   057   041
      32858      044   037   041   034   017   027   040   037   023   060
      32868      070   043   060   054   047   060   056   037   040   070
      32878      047   045   074   037   060   074   077   140   077   037
      32888      377   370   004   123   220   274   127   000   136   047
      32898      000   000   000   000   000   077   377   260   000   100
      32908      176   377   107   000   077   357   240   017   000   240
      32918      130   000   000   000   000   000   377   377   000   000
      32928      177   263   320   000   000   240   357   133   000   036
      32938      227   020   000   017   000   000   227   377   130   000
      32948      101   240   317   061   000   077   377   120   057   043
      32958      140   077   000   020   007   000   000   377   377   000
      32968      000   277   300   220   000   000   330   314   000   077
      32978      137   067   040   016   023   000   000   000   377   377
      32988      000   000   344   257   120   000   000   363   174   000
      32998      147   140   037   027   030   017   000   000   077   377
      33008      240   000   067   340   224   047   000   076   377   040
      33018      000   177   063   050   017   003   010   000   000   377
      33028      377   000   000   277   237   150   000   000   311   274
      33038      000   140   170   037   040   034   017   000   000   037
      33048      377   300   000   107   320   230   043   000   137   377
      33058      000   056   157   040   074   007   020   004   000   000
      33068      377   377   000   050   316   227   140   000   027   370
      33078      074   057   101   077   077   000   054   003   000   000
      33088      377   377   000   017   221   260   234   000   030   356
      33098      147   060   034   147   060   000   067   000   000   000
      33108      377   377   000   017   210   237   213   000   077   303
      33118      140   037   047   140   014   007   074   000   007   040
      33128      000   377   245   000   237   067   220   117   013   200
      33138      016   113   060   017   047   020   077   017   074   077
      33148      017   140   177   157   141   130   137   120   120   077
      33158      047   070   057   057   060   057   047   070   077   073
      33168      076   077   107   120   134   117   100   077   077   060
      33178      064   027   020   036   037   040   074   067   120   120
      33188      077   120   076   137   061   130   077   067   120   077
      33198      107   100   077   077   120   130   200   120   120   136
      33208      103   130   077   077   120   077   077   071   077   077
      33218      100   077   077   100   076   077   070   074   067   060
      33228      070   057   061   070   057   060   070   057   060   070
      33238      057   061   074   077   100   076   077   077   076   077
      33248      073   074   077   067   070   077   067   074   077   067
      33258      100   077   077   100   077   077   100   077   077   073
      33268      076   077   101   076   077   101   120   077   077   100
      33278      077   077   100   077   077   075   077   077   101   077
      33288      077   101   077   077   075   076   077   077   076   077
      33298      073   070   077   067   074   077   067   074   077   073
      33308      074   077   077   074   077   077   073   077   077   075
      33318      077   077   073   076   077   071   076   077   070   076
      33328      077   061   074   057   061   076   067   061   074   067
      33338      063   074   077   063   074   077   067   076   077   067
      33348      074   077   067   074   077   067   074   077   073   100
      33358      077   077   100   077   077   100   077   077   101   077
      33368      077   101   076   077   101   076   077   077   110   077
      33378      077   110   077   077   101   077   077   101   077   077
      33388      101   077   077   077   076   077   073   076   077   077
      33398      076   077   077   074   077   077   074   077   077   074
      33408      077   073   074   077   077   074   077   077   071   077
      33418      077   070   076   067   070   076   067   070   076   067
      33428      060   074   067   061   076   067   063   074   067   063
      33438      074   067   063   074   077   071   074   077   067   074
      33448      077   067   074   077   067   074   077   067   074   077
      33458      073   074   077   077   100   077   077   100   077   077
      33468      101   076   077   101   076   077   101   120   077   077
      33478      120   077   077   103   077   077   103   077   077   077
      33488      110   077   077   110   077   077   076   077   077   076
      33498      077   077   074   077   077   071   076   077   071   076
      33508      077   071   076   077   071   076   077   071   076   077
      33518      065   074   077   067   074   077   065   074   077   063
      33528      074   077   063   074   077   063   070   077   063   074
      33538      077   063   074   077   063   074   077   067   074   077
      33548      067   074   077   067   070   077   067   070   077   073
      33558      100   077   077   100   077   077   101   077   077   073
      33568      120   077   077   110   077   077   110   077   077   120
      33578      077   077   110   077   077   103   077   077   077   110
      33588      077   077   100   077   077   100   077   077   100   077
      33598      077   100   077   077   073   077   077   071   076   077
      33608      073   076   077   071   077   077   061   140   217   143
      33618      076   057   053   140   077   013   040   077   063   020
      33628      074   057   060   077   077   101   057   027   020   060
      33638      027   060   077   143   120   077   077   120   130   077
      33648      107   070   076   067   120   137   147   140   077   077
      33658      120   134   077   140   130   077   120   074   077   063
      33668      077   077   027   060   077   123   074   074   021   030
      33678      057   007   070   037   027   040   077   127   140   137
      33688      137   200   150   077   060   040   037   020   030   017
      33698      013   060   057   063   100   077   107   140   137   137
      33708      140   144   147   140   134   077   063   074   047   040
      33718      036   037   043   074   077   100   074   077   100   140
      33728      137   137   140   134   077   070   074   047   070   077
      33738      117   111   120   077   121   140   137   161   174   156
      33748      117   074   076   047   040   037   017   020   003   000
      33758      000   277   317   320   174   077   010   040   077   121
      33768      076   017   073   070   077   051   070   027   000   000
      33778      002   000   000   017   147   370   276   147   040   077
      33788      077   200   140   117   000   040   017   121   140   167
      33798      043   060   017   023   000   000   000   000   157   243
      33808      360   260   107   010   134   157   200   130   077   000
      33818      030   037   101   077   157   133   074   057   073   060
      33828      007   000   000   000   027   220   277   227   103   077
      33838      067   140   160   147   043   040   017   040   060   077
      33848      073   150   137   127   060   077   043   020   007   001
      33858      000   034   147   200   230   177   140   130   117   127
      33868      077   077   053   050   037   041   060   076   101   130
      33878      077   107   120   077   067   060   056   037   040   037
      33888      057   100   150   147   147   160   137   121   120   077
      33898      073   070   074   043   060   057   053   100   077   117
      33908      120   120   077   061   070   037   040   054   037   071
```

More Advanced Applications

I don't want you to finish this article and think that digitized speech is as limited as I have represented it so far. It is possible to totally simulate the capabilities of an analog speech synthesizer with more involved software. If you realize that the analog synthesizer works by connecting strings of distinctly independent phonemes, it is not hard to consider that the same can be true for the digital method. Each phoneme could be recorded separately and would occupy approximately 2 K bytes. As in the analog situation, a separate control program determines how these individual phonemes are to be connected together. Besides determining the type of phoneme to be used, the processor must also create the waveform. Such a system uses much more memory and takes considerably more processing time than something like the Votrax, but it is equally as versatile.■

Listing 3, continued:

```
33918      134   137   153   160   137   127   140   077   077   070
33928      074   047   060   070   057   074   077   117   121   134
33938      077   073   074   047   041   050   037   040   060   077
33948      120   160   157   133   140   077   077   100   077   057
33958      060   060   043   060   074   067   100   077   117   121
33968      077   077   061   064   037   040   050   037   041   076
33978      077   140   150   154   127   120   077   077   070   076
33988      057   040   060   047   060   076   077   120   134   137
33998      111   077   077   047   070   037   041   060   057   067
34008      120   137   143   144   154   137   120   077   077   071
34018      074   057   051   064   057   060   076   077   120   140
34028      077   103   076   076   057   060   037   041   040   057
34038      067   120   137   147   140   140   117   120   077   077
34048      063   070   057   047   070   057   061   074   077   117
34058      140   077   077   074   076   057   060   056   037   060
34068      057   067   120   137   137   140   140   117   107   120
34078      077   063   070   057   041   060   057   057   074   077
34088      107   120   077   077   100   076   057   060   056   037
34098      040   037   077   120   154   137   141   150   077   123
34108      120   077   063   060   037   040   060   076   057   076
34118      077   147   140   134   077   063   060   037   040   034
34128      007   001   020   077   140   230   176   167   120   137
34138      077   140   077   067   040   054   033   060   077   067
34148      100   077   147   140   140   077   063   060   037   040
34158      040   027   005   020   037   160   174   237   167   160
34168      137   077   120   077   077   040   056   007   041   074
34178      057   070   076   117   140   150   077   073   074   057
34188      047   050   037   023   020   034   027   170   177   207
34198      200   136   137   100   130   077   067   070   037   041
34208      060   067   061   074   077   105   140   137   117   076
34218      074   057   060   037   033   040   017   007   040   170
34228      163   201   174   137   140   077   077   077   074   076
34238      041   060   057   053   074   077   101   120   136   143
34248      120   077   067   060   070   047   041   057   027   040
34258      034   047   140   160   177   200   140   137   101   076
34268      077   067   070   057   033   060   057   063   074   077
34278      103   140   140   127   100   076   067   060   070   047
34288      040   054   037   040   070   077   140   170   157   141
34298      140   077   117   110   077   077   060   070   057   060
34308      077   067   074   077   117   121   130   077   063   070
34318      057   041   070   047   043   070   047   061   074   077
34328      121   160   176   141   120   077   077   100   077   067
34338      060   070   047   060   076   067   100   077   117   121
34348      120   077   063   070   047   043   070   057   061   060
34358      057   061   120   137   147   160   137   107   120   077
34368      077   074   076   057   060   057   047   060   077   077
34378      121   120   077   073   074   076   060   070   057   053
34388      070   057   061   074   077   133   160   154   127   120
34398      077   077   100   077   077   070   074   057   060   077
34408      077   120   120   077   071   070   074   060   070   057
34418      047   070   057   061   074   077   063   140   137   133
34428      140   130   077   100   077   077   071   077   077   063
34438      076   067   060   074   057   060   070   047   040   070
34448      077   140   140   156   137   130   077   077   100   077
34458      067   060   057   043   060   076   067   100   077   077
34468      100   077   077   063   076   057   060   070   067   061
34478      074   077   100   077   077   103   120   077   117   120
34488      077   077   107   077   077   075   076   077   067   074
34498      077   065   074   077   067   076   077   063   120   137
34508      123   140   136   107   100   077   067   070   074   057
34518      060   074   057   060   076   057   060   077   067   070
34528      076   067   070   076   077   100   077   077   107   077
34538      077   077   100   077   077   070   077   067   070   076
34548      063   070   076   057   070   076   067   100   077   067
34558      070   077   077   100   076   077   100   077   077   100
34568      076   077   073   077   077   077   100   077   073   074
34578      077   073   100   077   077   110   077   077   100   077
34588      077   077   077   077   077   100   077   077   110   077
34598      077   100   077   077   074   077   077   100   077   077
34608      101   077   077   075   076   077   065   074   077   063
34618      074   077   067   076   077   071   076   077   067   074
34628      067   061   070   077   061   074   077   063   074   077
34638      063   074   077   067   070   077   067   070   077   063
34648      070   077   067   074   077   077   100   077   077   101
34658      077   077   100   076   077   067   074   077   071   076
34668      077   077   076   077   077   100   077   077   100   077
34678      077   103   120   077   101   120   077   103   120   077
34688      077   120   077   077   100   077   077   100   077   077
34698      100   077   077   075   077   077   077   076   077   073
34708      074   077   067   074   077   073   074   077   071   074
34718      077   067   074   077   063   070   076   053   070   077
34728      063   070   077   067   074   077   067   074   077   067
34738      074   077   067   070   077   067   070   076   067   070
34748      076   077   070   076   077   100   077   077   073   077
34758      077   073   074   077   073   076   077   077   120   077
34768      077   110   077   077   101   077   077   103   120   077
34778      103   110   077   077   110   077   077   110   077   077
34788      100   077   077   100   077   077   075   077   077   075
34798      076   077   075   076   077   073   076   077   073   074
34808      077   067   070   077   067   074   077   073   155   014
```

Next month: Keyboard Function Decoder.

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A Theatrical Lighting Graphics Package

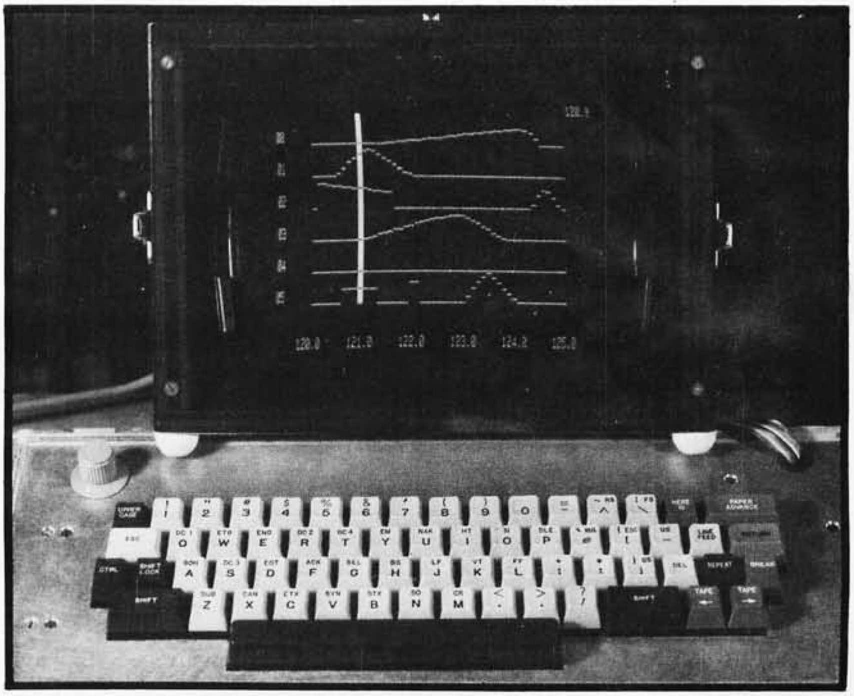
We recently developed an 8080 based composition and control system for theatrical lighting. This led us to the need for a way of displaying several time functions at once for examination and editing. Our system already made use of the Processor Technology VDM-1 display module, but the existing character set made it necessary to devote the entire screen to the display of one function in order to have useful resolution. Several functions could of course be superimposed, but this was awkward to program and left much to be desired in visual clarity.

Our first thought was to obtain a special read only memory integrated circuit to replace the control characters in the ASCII set with special characters consisting of a single scan line each, but the expense of this approach seemed impractical. Still, the improvement in resolution with such a character set was just what we needed, so we looked for other ways to modify the VDM-1 circuitry to achieve this; the results are detailed below.

Photo 1 shows our modified terminal with a typical display. Six functions of time are shown, each representing the brightness of a group of theatrical lights over a 5 second time span. The brightness values are stored in memory as full 8 bit values and are scaled to the 26 possible display values. Two adjacent rows of 13 scan lines each make up the 26 line display for each function. A cursor indicates current time. The various timing marks, channel designations, cursor time value, etc, show that the normal text display mode of the VDM-1 is unimpaired.

Photos 2a and 2b show a comparison between two variations of the basic display. Photo 2a shows the straight graphic mode with the cursor at a point in time and the value at that point shown in reverse video.

Photo 1: The authors' theatre lighting control graphics package in action. Six functions of time are shown displayed on a Processor Technology VDM-1 video display. Each function represents the brightness of a group of theatrical lights over a 5 second time span.



About The Authors

William Hemsath was formerly chief of electronic design with Robert Moog's music synthesizer company and is presently a design engineer and software specialist with Cornell University's Department of Psychology. James Seawright is Director of Visual Arts at Princeton University as well as the creator of electronically controlled sculpture. His wife Mimi Garrard has studied with Alwin Nikolais and is currently head of the Mimi Garrard Dance Company, a well known New York dance ensemble. She has been active in the design of new types of theatre lighting systems. Emmanuel Ghent is a composer in residence at Bell Labs and exponent of the GROOVE system, a computer driven electronic music studio, developed by Bell Labs.

Photos 2a and 2b: Two variations of the basic display. Photo 2a shows the straight graphics mode with the cursor at a point in time and the value at that point shown in reverse video. Photo 2b shows the numeric mode in which the cursor is replaced by the numerical value of the lighting intensity.

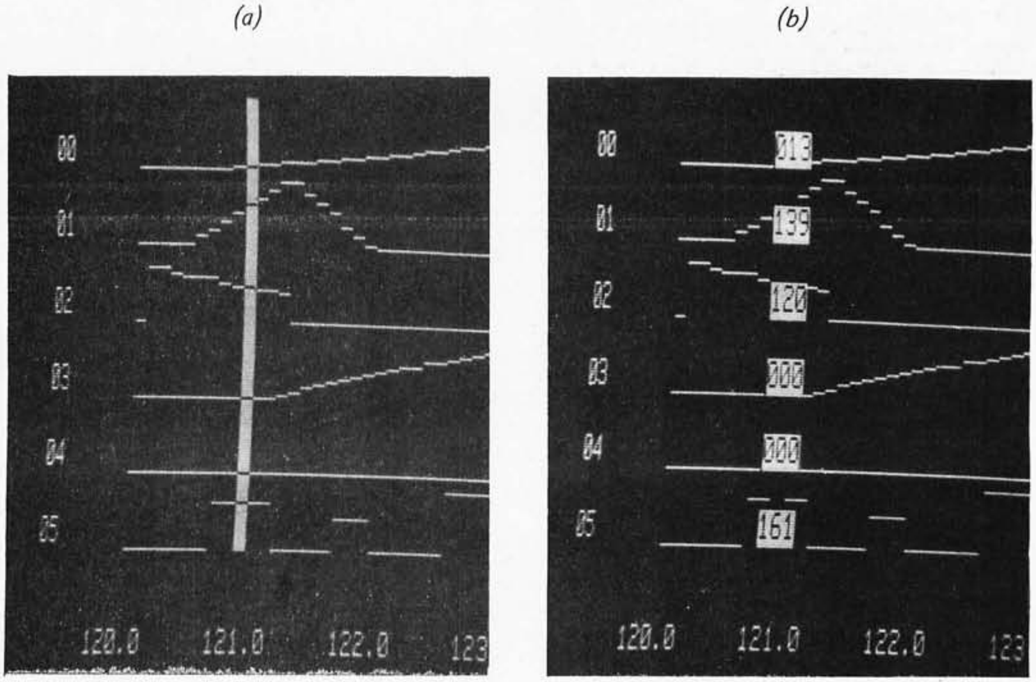


Photo 3: Installation of the authors' custom modification to the VDM-1 board. A small strip of breadboard containing the circuitry in figure 2 is mounted with spacers on the back of the VDM-1 board.

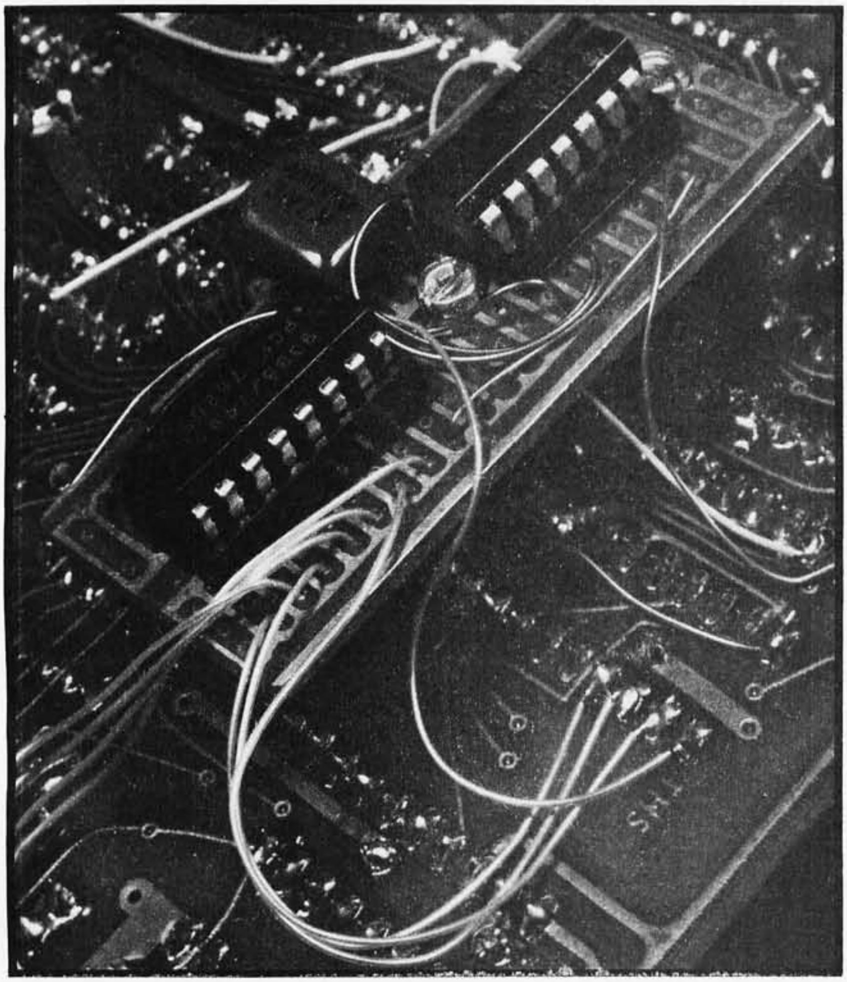


Photo 2b shows the numeric mode in which the cursor is replaced by a block containing the actual stored value from 0 to 255 for greater accuracy in reading or editing.

Before considering the modifications in detail, let's take a look at the operation of the VDM-1, referring to the partial schematic shown in figure 1. Character generation is accomplished as follows: Characters in the current line of the display are fetched in sequence from the screen memory and latched in two 4 bit registers, IC5 and IC6. A scan divider, IC2, counts through the 13 scan line values of each text line. These two sets of data are presented to the character generator read only memory, IC4, which outputs the correct pattern of seven dots for each scan line of every character. This pattern is parallel loaded into a shift register, IC3, when clocked by LOAD CLOCK, and clocked out serially by DOT CLOCK as the video output signal. Various gates and latches provide for blanking of certain characters or cursor blinking.

Since we didn't want to impair the normal display of letters, numbers, or frequently used punctuation marks, we decided to use the control characters to override the operation of the shift register and to supply a single line of dots, only once in the generation of a given character and on the scan line we want. One way of doing this is shown in figure 2. A new 7485 4 bit comparator (ICA) looks for agreement between the low order bits of a character and the current scan line value. In order to limit this to control characters only, IC11, the control character

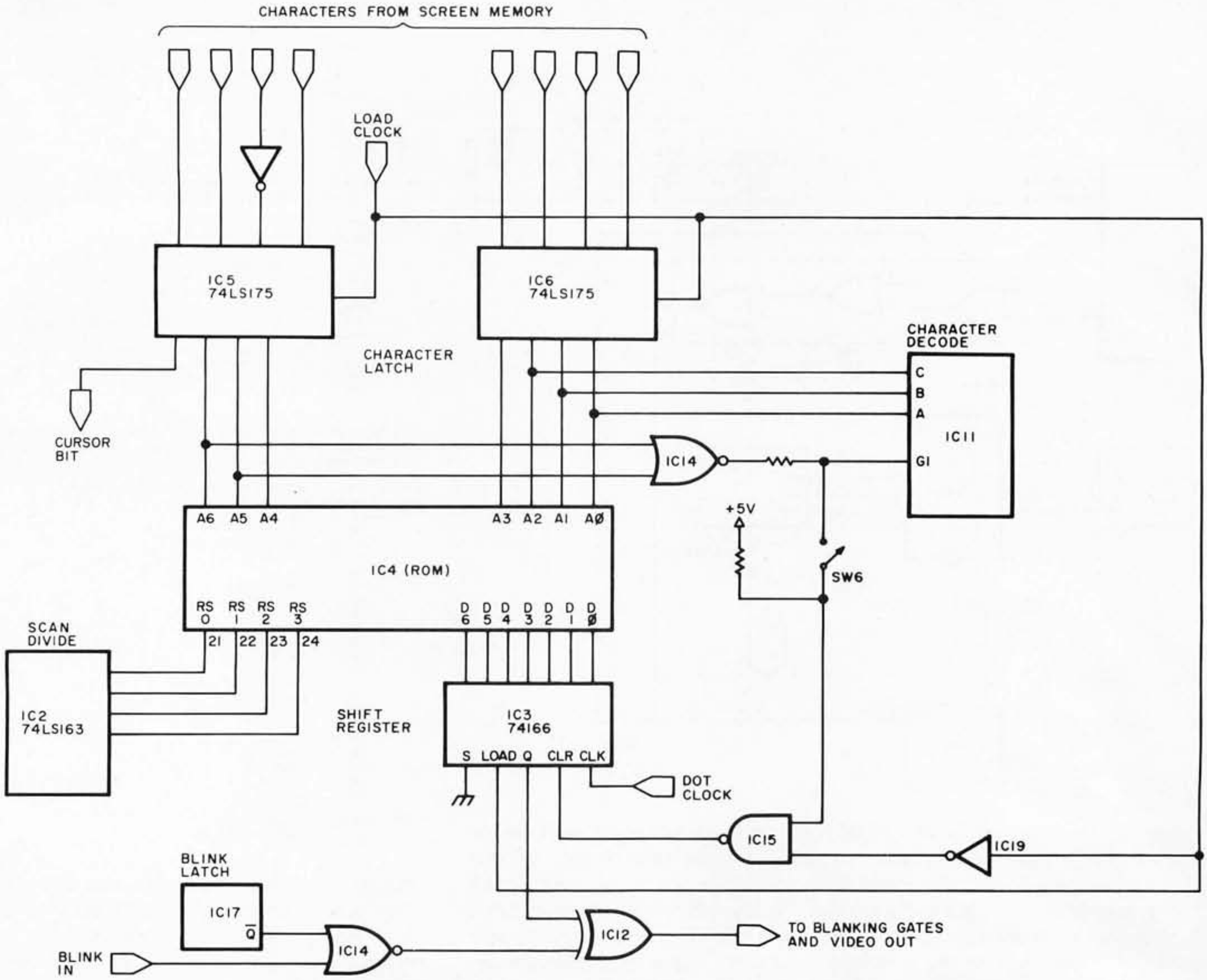
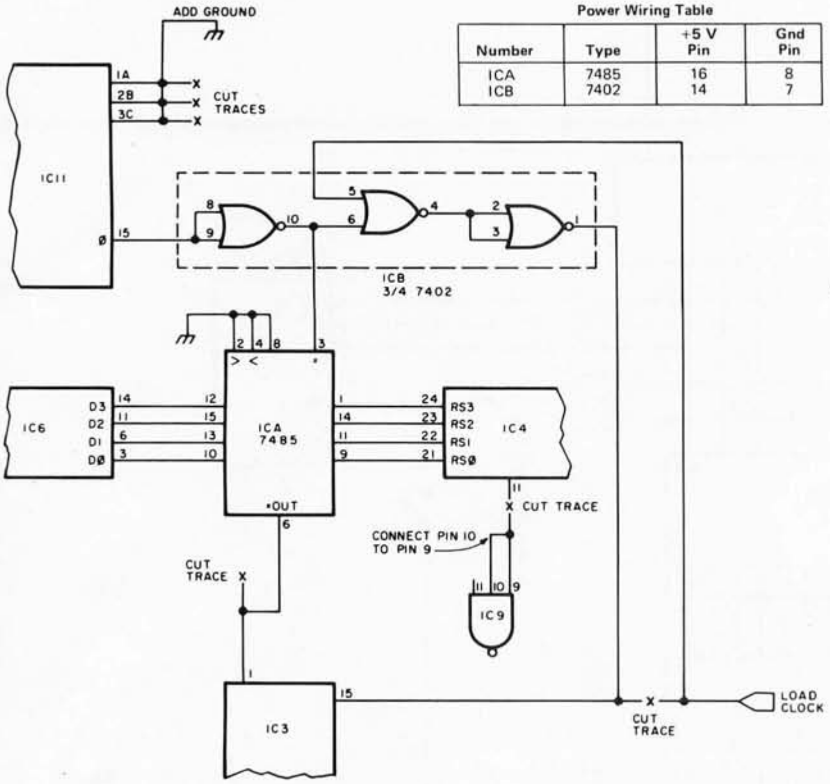


Figure 1: Partial schematic of the Processor Technology VDM-1 video display driver circuitry. Character generation is done by fetching the characters in the current line of the display in sequence from the screen memory in the form of 8 bit ASCII characters and latching them into two 4 bit registers, IC5 and IC6. This data and the scan line data from IC2 are presented to character generator IC4, a read only memory circuit. The latter outputs the correct pattern of seven dots for each scan line of every character; this information is routed through shift register IC3 to become the video output signal.

decoder, is modified to force a low state on the 0 output whenever the control character detector gate output goes high. (Control character blanking must be enabled with switch 6.) This modification will disable the automatic blanking from carriage return (CR) to end of line and from vertical tab (VT) to end of page, but if you're writing your own software this won't matter. Next, the control-character-low signal is inverted to enable the equals input of the 7485, and is ANDed with LOAD CLOCK in order to disable the shift register load when control characters are present. The comparator output supplies either a low (control character present, but not the one for the scan line where we are now) or a high (control character present and the right one for this scan line) to the serial input of the shift register. The video output will then appear as a blank or a line of dots, accordingly, when clocked out by DOT CLOCK. (The first circuit modification we tried fed the output of the comparator directly into the video line. This allowed the single scan line character to appear one character position too early. By sending the signal through the shift register it is delayed by one character position and appears in its proper place in the display.) The shift register serial input is normally



Power Wiring Table

Number	Type	+5 V Pin	Gnd Pin
ICA	7485	16	8
ICB	7402	14	7

Figure 2: Modification to the VDM-1 circuitry enabling the software to generate single lines of dots when required for the theatre light control graphics package. The special display consists of two sets of adjacent parallel lines totalling 26 lines used to display lighting intensities as functions of time. Control characters are used to activate the new circuitry and produce a single line of dots only once in the generation of a given character and on the desired scan line. The new 7485 comparator (ICA) compares the low order bits of a character with the current scan line value and supplies either a low logic level output (indicating that a control character is present, but not the one for the current scan line), or a high level (control character present which is the correct one for the present scan line). The video output then appears as a blank line or a line of dots, respectively. Normal operation of the VDM-I is not affected by these modifications.

```
;THE A REGISTER CONTAINS THE NUMBER OF THE LINE TO BE DISPLAYED
;THE BC REGISTER PAIR POINTS TO THE UPPER CHARACTER POSTION

BAR:    MOV     L,A
        MVI     H,0      ;HL CONTAINS LINE NUMBER
        DAD     H        ;TABLE CONTAINS DOUBLE BYTES
        LXI     D,TABLE  ;GET ADDRESS OF LOOKUP TABLE
        DAD     D        ;HL POINTS TO ENTRY IN TABLE
        MOV     A,M      ;GET FIRST CONTROL CHARACTER
        STAX    B        ;PUT IN THE UPPER CHARACTER POSITION
        INX     H        ;POINT TO SECOND CONTROL CHARACTER
        MOV     A,M      ;GET IT
        LXI     H,64.    ;LOWER CHARACTER POSITION IS
        DAD     B        ;64 CHARACTERS BEYOND UPPER ONE
        MOV     M,A      ;STORE LOWER CHARACTER
        RET

;THE FIRST ENTRY IN THE TABLE IS THE CONTROL CHARACTER FOR THE
;UPPER CHARACTER POSITION IN THE DISPLAY. THE SECOND ENTRY IS
;FOR THE LOWER POSITION.

TABLE:  DB      01H,04H ;BOTTOM LINE (01 IS BLANK)
        DB      01H,05H
        DB      01H,06H
        DB      01H,07H
        DB      01H,08H
        DB      01H,09H
        DB      01H,0AH
        DB      01H,0BH
        DB      01H,0CH
        DB      01H,0DH
        DB      01H,0EH
        DB      01H,0FH
        DB      01H,00H
        DB      04H,01H
        DB      05H,01H
        DB      06H,01H
        DB      07H,01H
        DB      08H,01H
        DB      09H,01H
        DB      0AH,01H
        DB      0BH,01H
        DB      0CH,01H
        DB      0DH,01H
        DB      0EH,01H
        DB      0FH,01H
        DB      00H,01H ;TOP LINE
```

Listing 1: Display software used with the theatrical lighting graphics package. TABLE is a lookup table containing 26 pairs of control characters that turn on the proper line in a vertical pair of character positions.

low, grounded in the unmodified VDM-1. When we don't have control characters in the character latch it will still be low, and LOAD CLOCK will get through to parallel load the shift register with the read only memory output, for normal text display.

The additional circuitry may be mounted on a small strip of breadboard and attached by spacers to the back of the board, as shown in photo 3. Between the first and second columns of ICs near the top of the board, just above the read only memory socket, are several small areas where ground is on one side and no traces on the other. Small holes for spacers may carefully be drilled at this location.

Programming

The scan divider starts with a count of 0 (top line of character) and counts down (0, F, E, etc), until it reaches a count of 4 (bottom line of character). It is then reset and counts down again for the next text line of characters. This means that characters 01, 02, and 03 will never appear as bars on the display since the scan counter never generates these codes and the comparator can never detect them. Character 04 will light up the bottom line in a character position. Character 05 will light up the next line up, and so on. Character 0F will light up the line below the top line, and 00 the top line.

In our display software we use a lookup table containing 26 pairs of control characters to turn on the proper line in a vertical pair of character positions (note that the lower character position is 64 locations after the upper character position). Listing 1 shows the display routine we use. ■

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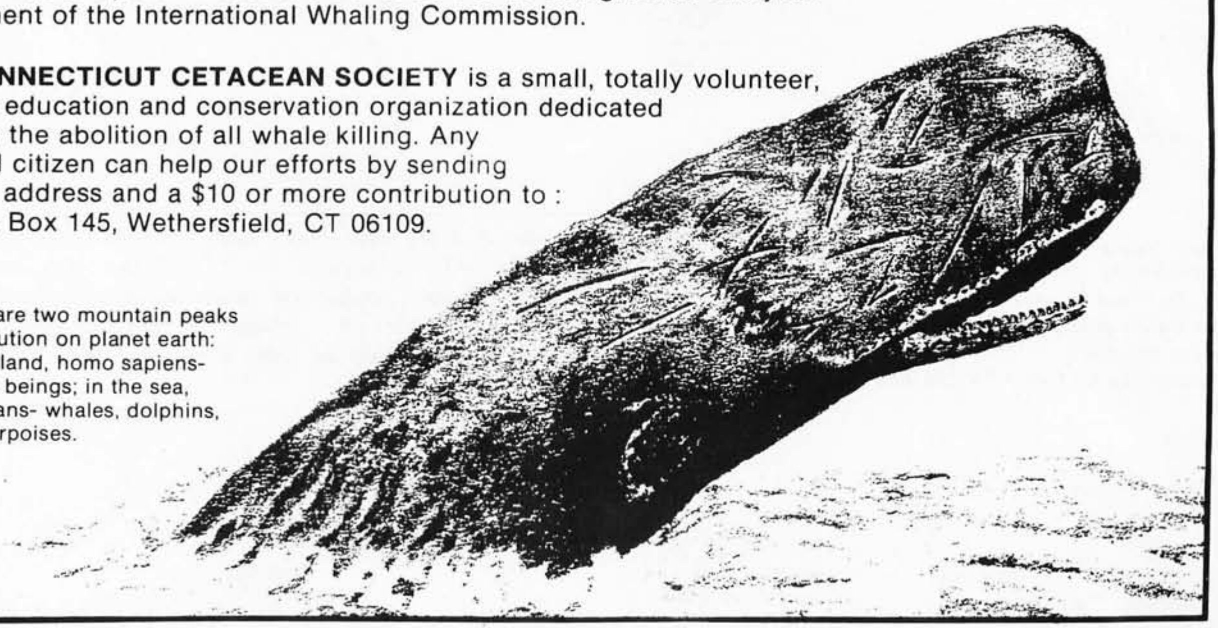

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GRAPH:

A System for Television Graphics

Part 2

John Webster
John Young
Audio Visual Services
University of New Brunswick
Keirstead Hall
Fredericton NB CANADA E3B 5A3

Last month, John Webster and John Young's article (page 62) on GRAPH, a television graphics package for the VDM-1 and other memory mapped video displays, began a discussion which we continue with the detail discussion of program functions. Listing 1 provides the detail 8080 code for the program. We continue the table numbering sequence begun in part 1.

Listing 1: The GRAPH program. GRAPH was assembled at 00 using Processor Technology's ALS-8 assembler. The notation $ + n indicates a displacement of n beyond the next instruction address. For example, JMP $ + 5 indicates an unconditional jump to the address 6 bytes along in the listing. Listing 1 continues on pages 159 thru 163.

```
GRAPH ASSEMBLY LISTING

ADDRESS  HEX CODE                 LINE #
0000     C3 9D 02                 START JMP INIT
                  * HOME *
0003     21 00 CC                 HOME LXI H,OCCOOH
                 * CURSOR *
0006     4E                       CURSOR MOV C,M
0007     3A FB 03                  LDA 03FBH
000A     81                        ADD C
000B     77                        MOV M,A
000C     3A F5 03                  LDA 03F5H
000F     B7                        ORA A
0010     C2 81 02                  JNZ REPT
                 * STATIN *
0013     DB 00                    STATIN IN 00
0015     E6 40                     ANI 040H
0017     CA 13 00                  JZ STATIN
                 * DATIN *
001A     DB 01                    DATIN IN 01H
001C     47                        MOV B,A
001D     3A F6 03                  LDA 03F6H
0020     B0                        ORA B
0021     47                        MOV B,A
0022     C3 C5 02                  JMP CTRLC
                * DISPLAY *
0025     70                       DISP MOV M,B
0026     3A F7 03                  LDA 03F7H
0029     B7                        ORA A
002A     C2 3A 00                  JNZ LFP
002D     23                        INX H
002E     3E D0                     MVI A,0D0H
0030     BC                        CMP H
0031     CA 03 00                  JZ HOME
0034     C3 06 00                  JMP CURSOR
                * LINEFEED *
0037     0E A0                    LFC MVI C,0A0H
0039     71                       LF MOV M,C
003A     11 40 00                 LFP LXI D,040H
003D     19                        DAD D
003E     3E D0                     MVI A,0D0H
0040     BC                        CMP H
0041     C2 46 00                  JNZ $+2
0044     26 CC                     MVI H,0CCH
0046     C3 06 00                  JMP CURSOR
               * LINE RETREAT *
0049     0E A0                    LRC MVI C,0A0H
004B     71                       LR MOV M,C
004C     11 C0 FF                 LRP LXI D,0FFC0H
004F     19                        DAD D
0050     3E CB                     MVI A,0CBH
```

Page Up

Page Up, Page Down, Page Right and Page Left are some of the more complex subroutines in GRAPH.

Although the VDM-1 contains a scrolling feature which might, at first, seem useful for moving screen information up and down, it operates by changing the orientation of the display on the screen and not by actually moving data in memory. If, for example, the screen were scrolled halfway up or down, a character entered at hexadecimal CC00 would appear in the middle and not at the top. While this is a useful function in some driver applications, it does not allow information to be moved up or down on the screen and then stored away in its final configuration. Thus, to use GRAPH's store and recall functions properly, it is necessary to actually move data between memory locations within the 1 K byte screen programmable memory so that an image modified by a screen move up or down will be stored and recalled in its modified form. This function is useful for positioning complex drawings or charts which invariably turn out to be slightly off center when complete.

As in most other routines, Page Up first moves the contents of C to the present character position, thereby returning the screen to its original state and freeing register C for use. The contents of H and L are stored at hexadecimal locations 3FF and 3FE for future use. Because our program is designed to co-reside with Processor Technology's ALS-8, and because this subroutine uses the stack pointer register, it is necessary to save the value of the stack pointer to allow a later jump back to the ALS-8. This probably applies to other resident monitors, too.

To accomplish this, H and L are loaded with hexadecimal 0000, the Stack Pointer is added to H and L (SPHL), and H and L are stored (SHLD) at hexadecimal memory locations 3FD and 3FC.

H and L are then initialized to hexadecimal CC00, D and E to hexadecimal 3C0, and the Stack Pointer to hexadecimal FFC0. The current character position is then hexadecimal CC00. Next, the program moves M to B (move contents of hexadecimal location CC00 to B) and adds D and E to H and L. Thus H and L becomes CC00 + 3C0 = hexadecimal CFC0 and this takes us to the first character position in the 16th line. (In Page Up and Page Down, information is moved on the screen by working in vertical rows rather than horizontal lines.)

The data in hexadecimal location CFC0 is moved to C, and B (old contents of hexadecimal CC00) is moved to M (hexadecimal position CFC0). This causes a wrap around from top to bottom. The contents of C are then moved to B and the Stack Pointer is added to H and L (CFC0 + FFC0 = hexadecimal CF80). At this point we compare H with hexadecimal CC to see if we are on one of the first four lines. If not (as in this case), we go through the cycle again: MOV M → C, MOV B → M, MOV C → B, and jump up one line by adding the Stack Pointer.

On the 13th cycle, H becomes hexadecimal CC. When H is compared with hexadecimal CC, the answer is zero so the cycle is not immediately repeated as before. Instead, L is compared with hexadecimal 3F, the last character position on the first line (hexadecimal CC3F). If L is greater than hexadecimal 3F the current position is in either line 2, 3 or 4. The cycle continues, checking L every time, since H is still hexadecimal CC.

If the current position is in line 4, then on the next cycle it will be in line 3, then line 2, and finally in line 1. At that point, when L is checked as described above, it will be less than hexadecimal 3F. Next, B is moved to M (which in this example will now be hexadecimal CC00). The entire vertical row has now been shifted up, with the top wrapping around to the bottom. Finally, H and L are incremented (to hexadecimal CC01), and the entire process is repeated for row 2. This is done 64 times, once for each vertical row.

On the last (ie: right-hand) row, however, when L is compared to hexadecimal 3F, it

```
ADDRESS  HEX CODE                  LINE #
0052     BC                        0042  CMP H
0053     C2 58 00                  0043  JNZ $+2
0056     26 CF                     0044  MVI H,0CFH
0058     C3 06 00                  0045  JMP CURSOR
                  * BACKSPACE *
005B     0E A0                     0046 BSC MVI C,0A0H
005D     71                        0047 BS MOV M,C
005E     2B                        0048 BSP DCX H
005F     3E CB                     0049  MVI A,0CBH
0061     BC                        0050  CMP H
0062     C2 67 00                  0051  JNZ $+2
0065     26 CF                     0052  MVI H,0CFH
0067     C3 06 00                  0053  JMP CURSOR
                 *FORWARD SPACE *
006A     0E A0                     0054 FSC MVI C,0A0H
006C     71                        0055 FS MOV M,C
006D     23                        0056 FSP INX H
006E     7C                        0057  MOV A,H
006F     FE D0                     0058  CPI 0D0H
0071     CA 03 00                  0059  JZ HOME
0074     C3 06 00                  0060  JMP CURSOR
                    * CRLF *
0077     71                        0061 CR MOV M,C
0078     7D                        0062  MOV A,L
0079     FE 40                     0063  CPI 040H
007B     D2 83 00                  0064  JNC $+5
007E     2E 40                     0065  MVI L,040H
0080     C3 9C 00                  0066  JMP OUT
0083     7D                        0067  MOV A,L
0084     FE 80                     0068  CPI 080H
0086     F2 8E 00                  0069  JP $+5
0089     2E 80                     0070  MVI L,080H
008B     C3 9C 00                  0071  JMP OUT
008E     7D                        0072  MOV A,L
008F     FE C0                     0073  CPI 0C0H
0091     F2 99 00                  0074  JP $+5
0094     2E C0                     0075  MVI L,0C0H
0096     C3 9C 00                  0076  JMP OUT
0099     24                        0077  INR H
009A     2E 00                     0078  MVI L,00
009C     3E D0                     0079 OUT MVI A,0D0H
009E     BC                        0080  CMP H
009F     C2 06 00                  0081  JNZ CURSOR
00A2     C3 03 00                  0082  JMP HOME
                  * PAGE UP *
00A5     71                        0083 PU MOV M,C
00A6     22 FE 03                  0084  SHLD 03FEH
00A9     21 00 00                  0085  LXI H,00
00AC     39                        0086  DAD 6
00AD     22 FC 03                  0087  SHLD 03FCH
00B0     21 00 CC                  0088  LXI H,0CC00H
00B3     11 C0 03                  0089  LXI D,03C0H
00B6     31 C0 FF                  0090  LXI 6,0FFC0H
00B9     46                        0091 ROWU MOV B,M
00BA     19                        0092  DAD D
00BB     4E                        0093 LINEU MOV C,M
00BC     70                        0094  MOV M,B
00BD     41                        0095  MOV B,C
00BE     39                        0096  DAD 6
00BF     3E CC                     0097  MVI A,0CCH
00C1     BC                        0098  CMP H
00C2     C2 BB 00                  0099  JNZ LINEU
00C5     3E 3F                     0100  MVI A,03FH
00C7     BD                        0101  CMP L
00C8     DA BB 00                  0102  JC LINEU
00CB     CA D3 00                  0103  JZ ENDU
00CE     70                        0104  MOV M,B
00CF     23                        0105  INX H
00D0     C3 B9 00                  0106  JMP ROWU
00D3     70                        0107 ENDU MOV M,B
00D4     2A FC 03                  0108  LHLD 03FCH
00D7     F9                        0109  SPHL
00D8     2A FE 03                  0110  LHLD 03FEH
00DB     C3 4C 00                  0111  JMP LRP
                  * PAGE DOWN *
00DE     71                        0112 PD MOV M,C
00DF     22 FE 03                  0113  SHLD 03FEH
00E2     21 00 00                  0114  LXI H,00
00E5     39                        0115  DAD 6
00E6     22 FC 03                  0116  SHLD 03FCH
00E9     21 FF CF                  0117  LXI H,0CFFFH
00EC     11 40 FC                  0118  LXI D,0FC40H
00EF     31 40 00                  0119  LXI 6,040H
00F2     46                        0120 ROWD MOV B,M
00F3     19                        0121  DAD D
00F4     4E                        0122 LINED MOV C,M
00F5     70                        0123  MOV M,B
00F6     41                        0124  MOV B,C
00F7     39                        0125  DAD 6
00F8     3E CF                     0126  MVI A,0CFH
00FA     BC                        0127  CMP H
00FB     C2 F4 00                  0128  JNZ LINED
00FE     3E C0                     0129  MVI A,0C0H
0100     BD                        0130  CMP L
```

will be greater than hexadecimal 3F for three cycles, as above, but on the fourth compare it will be exactly hexadecimal 3F, instead of less, as before.

At this point the program moves B to M (hexadecimal CC3F), loads H and L with the value at hexadecimal locations 3FD and 3FC, and exchanges it with the contents of the stack pointer to restore the stack pointer address.

Then, H and L are loaded with the contents of hexadecimal locations 3FF and 3FE, which contain the values of H and L before Page Up was executed (ie: the address of the leading cursor before the page was moved up). Operation then jumps to a section of the Line Retract subroutine (LRP) which moves the cursor up one line to restore its relative position on the screen. From Line Retract, operation returns to CURSOR.

Page Down

Page Down works the same as Page Up except that it starts at the lower right-hand position, hexadecimal location CFFF. It then moves up to hexadecimal location CC3F, or the upper right-hand corner, by adding D and E (hexadecimal location FC40). Then the MOVE cycle begins, moving information down vertical rows and finally arriving at the lower left-hand corner.

To restore the leading cursor to its relative screen position, the program jumps to a section of Linefeed (LFP) upon termination of Page Down. As explained above, Linefeed ends with a jump to CURSOR.

Page Left

Page Left commences in the same way as the preceding two subroutines by moving C to M, saving H and L at hexadecimal locations 3FF and 3FE, and saving the stack pointer value at hexadecimal locations 3FD and 3FC.

It then loads the stack pointer with hexadecimal FFC1 (the value needed to move left one line length), D and E with hexadecimal 3F (the value needed to move right one line length), and H and L with hexadecimal CFC0 (the address of the lower left-hand corner position).

The cycle begins by storing the contents of hexadecimal location CFC0 in register B, and adds D and E to H and L moving the present position to lower right-hand corner (hexadecimal location CFFF). It then moves the contents of this location to register C, moves the contents of B to this location, and moves C to B, the same procedure as that found in the Page Up and Page Down subroutines.

```
ADDRESS  HEX CODE              LINE #
0101     CA 0C 01              0131  JZ ENDD
0104     D2 F4 00              0132  JNC LINED
0107     70                    0133  MOV M,B
0108     2B                    0134  DCX H
0109     C3 F2 00              0135  JMP ROWD
010C     70                    0136 ENDD MOV M,B
010D     2A FC 03              0137  LHLD 03FCH
0110     F9                    0138  SPHL
0111     2A FE 03              0139  LHLD 03FEH
0114     C3 3A 00              0140  JMP LFP
                   • PAGE LEFT •
0117     71                    0141 PL MOV M,C
0118     22 FE 03              0142  SHLD 03FEH
011B     21 00 00              0143  LXI H,00
011E     39                    0144  DAD 6
011F     22 FC 03              0145  SHLD 03FCH
0122     31 C1 FF              0146  LXI 6,0FFC1H
0125     11 3F 00              0147  LXI D,03FH
0128     21 C0 CF              0148  LXI H,0CFC0H
012B     46                    0149 LINEL MOV B,M
012C     19                    0150  DAD D
012D     4E                    0151 BGNL MOV C,M
012E     70                    0152  MOV M,B
012F     41                    0153  MOV B,C
0130     2B                    0154  DCX H
0131     3E CB                 0155  MVI A,0CBH
0133     BC                    0156  CMP H
0134     CA 52 01              0157  JZ ENDL
0137     3E 3F                 0158  MVI A,03FH
0139     BD                    0159  CMP L
013A     CA 75 01              0160  JZ NEXTL
013D     3E 7F                 0161  MVI A,07FH
013F     BD                    0162  CMP L
0140     CA 75 01              0163  JZ NEXTL
0143     3E BF                 0164  MVI A,0BFH
0145     BD                    0165  CMP L
0146     CA 75 01              0166  JZ NEXTL
0149     3E FF                 0167  MVI A,0FFH
014B     BD                    0168  CMP L
014C     CA 75 01              0169  JZ NEXTL
014F     C3 2D 01              0170  JMP BGNL
0152     2A FC 03              0171 ENDL LHLD 03FCH
0155     F9                    0172  SPHL
0156     2A FE 03              0173  LHLD 03FEH
0159     7D                    0174  MOV A,L
015A     FE 00                 0175  CPI 00
015C     CA 71 01              0176  JZ FIXL
015F     FE 40                 0177  CPI 040H
0161     CA 71 01              0178  JZ FIXL
0164     FE 80                 0179  CPI 080H
0166     CA 71 01              0180  JZ FIXL
0169     FE C0                 0181  CPI 0C0H
016B     CA 71 01              0182  JZ FIXL
016E     C3 5E 00              0183  JMP BSP
0171     19                    0184 FIXL DAD D
0172     C3 06 00              0185  JMP CURSOR
0175     39                    0186 NEXTL DAD 6
0176     C3 2B 01              0187  JMP LINEL
                   • PAGE RIGHT •
0179     71                    0188 PR MOV M,C
017A     22 FE 03              0189  SHLD 03FEH
017D     21 00 00              0190  LXI H,00
0180     39                    0191  DAD 6
0181     22 FC 03              0192  SHLD 03FCH
0184     31 3F 00              0193  LXI 6,03FH
0187     21 3F CC              0194  LXI H,0CC3FH
018A     11 C1 FF              0195  LXI D,0FFC1H
018D     46                    0196 LINER MOV B,M
018E     19                    0197  DAD D
018F     4E                    0198 BGNR MOV C,M
0190     70                    0199  MOV M,B
0191     41                    0200  MOV B,C
0192     23                    0201  INX H
0193     3E D0                 0202  MVI A,0D0H
0195     BC                    0203  CMP H
0196     CA B3 01              0204  JZ ENDR
0199     AF                    0205  XRA A
019A     BD                    0206  CMP L
019B     CA D6 01              0207  JZ NEXTR
019E     3E 40                 0208  MVI A,040H
01A0     BD                    0209  CMP L
01A1     CA D6 01              0210  JZ NEXTR
01A4     3E 80                 0211  MVI A,080H
B1A6     BD                    0212  CMP L
01A7     CA D6 01              0213  JZ NEXTR
01AA     3E C0                 0214  MVI A,0C0H
01AC     BD                    0215  CMP L
01AD     CA D6 01              0216  JZ NEXTR
01B0     C3 8F 01              0217  JMP BGNR
01B3     2A FC 03              0218 ENDR LHLD 03FCH
01B6     F9                    0219  SPHL
01B7     2A FE 03              0220  LHLD 03FEH
01BA     7D                    0221  MOV A,L
01BB     FE 3F                 0222  CPI 03FH
```

Next, it decrements H and L and compares H with hexadecimal CB to determine if this new value is still on the screen. When it is not, the operation is complete and the subroutine exists as explained later. However, if the new value is on the screen, L is compared with the hexadecimal values 3F, 7F, BF and FF, consecutively, to determine if the present cursor position is a right-hand end of a line. If not, the cycle is repeated by moving the contents of the line, space by space, to the left until the current character position becomes one of the above mentioned right-hand end of line positions. This will mean that we have decremented (moved left) all the way through our present line, and then decremented once more, moving up to the right-hand end of the line above. When a right-hand end of the line *is* found, the subroutine adds the Stack Pointer contents (hexadecimal FFC1) to H and L, having the effect of moving the current character position to the left-hand end of the new line. The value at this location is stored in B; D and E are added to H and L as before, and the cycle continues, moving line by line to the left one space at a time.

After the last screen memory location has been transferred, the decrement changes H from hexadecimal CC to CB. When this condition is sensed by an appropriate check, the program jumps out of the cycle. At this point, the subroutine restores the values of H and L and the Stack Pointer. H and L now contain the address of the leading cursor position before Page Left was executed. The cursor, in order to maintain its relative screen position, must now also be moved to the left.

Part of the complexity of the above program comes from the fact that it was designed so that characters disappearing off the left-hand side of the screen reappear on the right-hand side and on the same line that they were on, rather than on the next line up, as in the case of a simple decrement/move loop.

If the new leading cursor position is moved to the left off the screen, it should appear on the right-hand end of the same line. Hence, knowing the pre-"Page Left" value of the cursor, it is not sufficient to simply decrement it, since if the cursor is on the left-hand end of a line, it would appear on the right-hand end of the next line up, and its position would no longer be relative. To avoid this, the subroutine checks to see if the old leading cursor position is one of the four left end values (hexadecimal 00, 40, 80, or C0) and if it is, then D and E are added to this value in H and L and this simply shifts the cursor position to the right-hand end of the same line. The pro-

```
ADDRESS  HEX CODE                     LINE #
01BD     CA D2 01                     0223  JZ FIXR
01C0     FE 7F                        0224  CPI 07FH
01C2     CA D2 01                     0225  JZ FIXR
01C5     FE BF                        0226  CPI 0BFH
01C7     CA D2 01                     0227  JZ FIXR
01CA     FE FF                        0228  CPI 0FFH
01CC     CA D2 01                     0229  JZ FIXR
01CF     C3 6D 00                     0230  JMP FSP
01D2     19                           0231 FIXR DAD D
01D3     C3 06 00                     0232  JMP CURSOR
01D6     39                           0233 NEXTR DAD 6
01D7     C3 8D 01                     0234  JMP LINER
                    * PAGE STORE *
01DA     22 F9 03                     0235 PAGER SHLD 03F9H
01DD     71                           0236  MOV M,C
01DE     21 00 CC                     0237  LXI H,0CC00H
01E1     06 D0                        0238  MVI B,0D0H
01E3     1E 00                        0239  MVI E,00
01E5     3A F8 03                     0240  LDA 03F8H
01E8     FE 00                        0241  CPI 00
01EA     CA 2E 02                     0242  JZ ONE
01ED     FE 01                        0243  CPI 01H
01EF     CA 33 02                     0244  JZ TWO
01F2     FE 02                        0245  CPI 02H
01F4     CA 38 02                     0246  JZ THREE
01F7     FE 03                        0247  CPI 03H
01F9     CA 3D 02                     0248  JZ FOUR
01FC     FE 04                        0249  CPI 04H
01FE     CA 42 02                     0250  JZ FIVE
0201     16 1C                        0251  MVI D,01CH
0203     7E                           0252 MOV1 MOV A,M
0204     12                           0253  STAX D
0205     23                           0254  INX H
0206     13                           0255  INX D
0207     7C                           0256  MOV A,H
0208     B8                           0257  CMP B
0209     C2 03 02                     0258  JNZ MOV1
020C     3A F8 03                     0259  LDA 03F8H
020F     3C                           0260  INR A
0210     FE 06                        0261  CPI 06H
0212     CA 18 02                     0262  JZ RESET
0215     C3 1A 02                     0263  JMP PLUG
0218     3E 00                        0264 RESET MVI A,00
021A     32 F8 03                     0265 PLUG STA 03F8H
021D     2A F9 03                     0266  LHLD 03F9H
0220     4E                           0267  MOV C,M
0221     3E CC                        0268  MVI A,0CCH
0223     32 FA 03                     0269  STA 03FAH
0226     3E 00                        0270  MVI A,00
0228     32 F9 03                     0271  STA 03F9H
022B     C3 13 00                     0272  JMP STATIN
022E     16 08                        0273 ONE MVI D,08H
0230     C3 03 02                     0274  JMP MOV1
0233     16 0C                        0275 TWO MVI D,0CH
0235     C3 03 02                     0276  JMP MOV1
0238     16 10                        0277 THREE MVI D,010H
023A     C3 03 02                     0278  JMP MOV1
023D     16 14                        0279 FOUR MVI D,014H
023F     C3 03 02                     0280  JMP MOV1
0242     16 18                        0281 FIVE MVI D,018H
0244     C3 03 02                     0282  JMP MOV1
                    * PAGE RECALL *
0247     21 00 08                     0283 RCL1 LXI H,0800H
024A     06 0C                        0284  MVI B,0CH
024C     11 00 CC                     0285 LDPX LXI D,0CC00H
024F     3A F8 03                     0286  LDA 03F8H
0252     3D                           0287  DCR A
0253     32 F8 03                     0288  STA 03F8H
0256     C3 03 02                     0289  JMP MOV1
0259     21 00 0C                     0290 RCL2 LXI H,0C00H
025C     06 10                        0291  MVI B,010H
025E     C3 4C 02                     0292  JMP LDPX
0261     21 00 10                     0293 RCL3 LXI H,01000H
0264     06 14                        0294  MVI B,014H
0266     C3 4C 02                     0295  JMP LDPX
0269     21 00 14                     0296 RCL4 LXI H,01400H
026C     06 18                        0297  MVI B,018H
026E     C3 4C 02                     0298  JMP LDPX
0271     21 00 18                     0299 RCL5 LXI H,01800H
0274     06 1C                        0300  MVI B,01CH
0276     C3 4C 02                     0301  JMP LDPX
0279     21 00 1C                     0302 RCL6 LXI H,01C00H
027C     06 20                        0303  MVI B,020H
027E     C3 4C 02                     0304  JMP LDPX
                    * REPEAT DELAY *
0281     11 FF 10                     0305 REPT LXI D,010FFH
0284     1D                           0306 LOOK DCR E
0285     C2 84 02                     0307  JNZ LOOK
0288     15                           0308  DCR D
0289     C2 84 02                     0309  JNZ LOOK
028C     DB 00                        0310  IN 00
028E     E6 40                        0311  ANI 040H
0290     CA 1A 00                     0312  JZ DATIN
0293     DB 01                        0313  IN 01H
```

gram then jumps to CURSOR. If it is not a left-hand end of line position, program operation jumps to a section of the Backspace subroutine which moves the cursor to the left one space, and displays it on the screen.

Page Right

Page Right is similar to Page Left in program structure. The Stack Pointer is loaded with hexadecimal with 03F to move from the left to the right-hand end of a line. The D and E pair are loaded with hexadecimal FFC1, to move from the right to the left-hand end of a line, and H and L are loaded with a starting value of hexadecimal CC3F which is the upper right-hand corner of the screen.

Operation causes the H and L value to shift from upper right-hand to upper left-hand by adding D and E, then simple increment loops move operations to the right step-by-step. The Stack Pointer is used to move from the left to the right-hand side whenever a left-hand end of line is encountered.

This subroutine uses all registers in the same way as Page Left except that they are loaded with different values necessary to move characters to the right. In finishing this subroutine, the old leading cursor position is checked for a right-hand end of line value and, if true, this value is changed to a left-hand end of the line value, again by adding D and E and jumping to CURSOR as in Page Left. If the old leading cursor position is not at the end of a line, the program operation jumps to a section of Forward Space which moves the cursor to the right one space and displays it, while maintaining its relative position.

Page Store

Page Store is a memory block program which moves the present contents of the screen to one of several allocated memory sectors. This process duplicates screen information somewhere else in memory for later use without destroying the present screen information.

Page Store and Recall require an additional 6 K bytes of programmable memory to allow storage of six full screens of data for later recall. The number 6 was chosen to satisfy our needs, but could be easily modified to any number up to 256 depending on available memory. Note: to expand the Next Store operation to define more than six memory sectors, additional control checks are needed in the Control/W section. Screen storage locations are addressed in GRAPH to reside in the area from 2 K to 8 K in programmable memory. If they are to be

```
ADDRESS  HEX CODE                 LINE #

0295     3E 00                    0314  MVI A,00
0297     32 F5 03                 0315  STA 03F5H
029A     C3 13 00                 0316  JMP STATIN
                   * INITIALIZE *
029D     11 F5 03                 0317 INIT LXI D,03F5H
02A0     AF                       0318  XRA A
02A1     12                       0319  STAX D
02A2     13                       0320  INX D
02A3     12                       0321  STAX D
02A4     13                       0322  INX D
02A5     12                       0323  STAX D
02A6     13                       0324  INX D
02A7     12                       0325  STAX D
02A8     13                       0326  INX D
02A9     12                       0327  STAX D
02AA     13                       0328  INX D
02AB     3E CC                    0329  MVI A,OCCH
02AD     12     .                 0330  STAX D
02AE     13                       0331  INX D
02AF     3E 80                    0332  MVI A,080H
02B1     12                       0333  STAX D
                   * CLEAR *
02B2     3E 00                    0334 CLEAR MVI A,00
02B4     D3 C8                    0335  OUT OC8H
02B6     21 00 CC                 0336  LXI H,OCC00H
02B9     36 20                    0337 BLANK MVI M,020H
02BB     23                       0338  INX H
02BC     3E D0                    0339  MVI A,0D0H
02BE     BC                       0340  CMP H
02BF     C2 B9 02                 0341  JNZ BLANK
02C2     C3 03 00                 0342  JMP HOME
                 * CONTROL CHECK *
02C5     FE 16                    0343 CTRLC CPI 016H
02C7     CA 39 00                 0344  JZ LF
02CA     FE 14                    0345  CPI 014H
02CC     CA 4B 00                 0346  JZ LR
02CF     FE 06                    0347  CPI 06H
02D1     CA 5D 00                 0348  JZ BS
02D4     FE 07                    0349  CPI 07H
02D6     CA 6C 00                 0350  JZ FS
02D9     FE 96                    0351  CPI 096H
02DB     CA 37 00                 0352  JZ LFC
02DE     FE 94                    0353  CPI 094H
02E0     CA 49 00                 0354  JZ LRC
02E3     FE 86                    0355  CPI 086H
02E5     CA 5B 00                 0356  JZ BSC
02E8     FE 87                    0357  CPI 087H
02EA     CA 6A 00                 0358  JZ FSC
02ED     E6 7F                    0359  ANI 07FH
02EF     FE 0A                    0360  CPI 0AH
02F1     CA 77 00                 0361  JZ CR
02F4     FE 15                    0362  CPI 015H
02F6     CA A5 00                 0363  JZ PU
02F9     FE 0D                    0364  CPI 0DH
02FB     CA DE 00                 0365  JZ PD
02FE     FE 08                    0366  CPI 08H
0300     CA 17 01                 0367  JZ PL
0303     FE 0B                    0368  CPI 0BH
0305     CA 79 01                 0369  JZ PR
0308     FE 13                    0370  CPI 013H
030A     CA DA 01                 0371  JZ PAGER
030D     FE 10                    0372  CPI 010H
030F     C2 3E 03                 0373  JNZ CONT
0312     DB 00                    0374 STIN IN 00
0314     E6 40                    0375  ANI 040H
0316     CA 12 03                 0376  JZ STIN
0319     DB 01                    0377  IN 01H
031B     E6 7F                    0378  ANI 07FH
031D     FE 31                    0379  CPI 031H
031F     CA 47 02                 0380  JZ RCL1
0322     FE 32                    0381  CPI 032H
0324     CA 59 02                 0382  JZ RCL2
0327     FE 33                    0383  CPI 033H
0329     CA 61 02                 0384  JZ RCL3
032C     FE 34                    0385  CPI 034H
032E     CA 69 02                 0386  JZ RCL4
0331     FE 35                    0387  CPI 035H
0333     CA 71 02                 0388  JZ RCL5
0336     FE 36                    0389  CPI 036H
0338     CA 79 02                 0390  JZ RCL6
033B     C3 13 00                 0391  JMP STATIN
033E     FE 1C                    0392 CONT CPI 01CH
0340     CA B2 02                 0393  JZ CLEAR
0343     FE 1B                    0394  CPI 01BH
0345     CA 60 E0                 0395  JZ 0E060H
0348     FE 17                    0396  CPI 017H
034A     CA 56 03                 0397  JZ RINT
034D     FE 18                    0398  CPI 018H
034F     C2 A5 03                 0399  JNZ STBT
0352     71                       0400  MOV M,C
0353     C3 03 00                 0401  JMP HOME
0356     DB 00                    0402 RINT IN 00
0358     E6 40                    0403  ANI 040H
035A     CA 56 03                 0404  JZ RINT
```

addressed elsewhere, it is only necessary to modify the start and end locations for each 1 K sector in the Store routine (see the Addressing and Memory Requirements Section).

A status word in hexadecimal memory location 3F8 is used as a counter to choose which sector is being accessed. The data in hexadecimal location 3F8 is initialized to zero at the beginning of the program, incremented every time a store is made, and checked by the program to determine where the next screen should be stored. Control/W allows this counter to set to any number from 0 to 5. This specifies one of six locations to which the next "STORE" will move the screen information. Otherwise, it will cycle automatically.

The information stored in each sector is recalled to the screen with a block move by entering Control/P followed by a number from 1 to 6. The information in the storage sector remains valid until written over by another store to that location. Thus stored information may be recalled as many times as desired.

The main block move operation in Page Store is also used by Page Recall, which changes certain parameter registers in order to move the information stored somewhere in memory back to the screen.

Upon entering the Page Store subroutine, the contents of H and L are stored at hexadecimal locations 3FA and 3F9. The contents of C are moved to the screen to restore the screen to pre-"leading" cursor state. Then, H and L are loaded with the screen starting hexadecimal location CC00, and B is loaded with the most significant byte of the first invalid location after the screen (hexadecimal D0).

Next, register E is loaded with zero for subsequent use with D, as a register pair. The accumulator is loaded with the contents of hexadecimal location 3F8, (a number from 0 to 5 denoting which of the six blocks in memory will contain this page).

To determine which of these six blocks is indicated, the accumulator contents are compared with these six numbers (0 thru 5), and a subsequent jump is made to a location governed by the results of the comparison.

If hexadecimal location 3F8 is found to be zero, the program loads register D with the most significant byte of the starting location of the memory to be used to store the screen information (hexadecimal 08). The actual move cycle then begins.

```
ADDRESS  HEX CODE                 LINE #
035D     DB 01                    0405  IN 01H
035F     E6 7F                    0406  ANI 07FH
0361     FE 1C                    0407  CPI 01CH
0363     CA 9D 02                 0408  JZ INIT
0366     FE 31                    0409  CPI 031H
0368     C2 70 03                 0410  JNZ $+5
036B     3E 00                    0411  MVI A,00
036D     32 F8 03                 0412  STA 03F8H
0370     FE 32                    0413  CPI 032H
0372     C2 7A 03                 0414  JNZ $+5
0375     3E 01                    0415  MVI A,01H
0377     32 F8 03                 0416  STA 03F8H
037A     FE 33                    0417  CPI 033H
037C     C2 84 03                 0418  JNZ $+5
037F     3E 02                    0419  MVI A,02H
0381     32 F8 03                 0420  STA 03F8H
0384     FE 34                    0421  CPI 034H
0386     C2 8E 03                 0422  JNZ $+5
0389     3E 03                    0423  MVI A,03H
038B     32 F8 03                 0424  STA 03F8H
038E     FE 35                    0425  CPI 035H
0390     C2 98 03                 0426  JNZ $+5
0393     3E 04                    0427  MVI A,04H
0395     32 F8 03                 0428  STA 03F8H
0398     FE 36                    0429  CPI 036H
039A     C2 A2 03                 0430  JNZ $+5
039D     3E 05                    0431  MVI A,05H
039F     32 F8 03                 0432  STA 03F8H
03A2     C3 13 00                 0433  JMP STATIN
03A5     FE 12                    0434 STBT CPI 012H
03A7     C2 B2 03                 0435  JNZ $+08H
03AA     3E 80                    0436  MVI A,080H
03AC     32 F5 03                 0437  STA 03F5H
03AF     C3 13 00                 0438  JMP STATIN
03B2     FE 01                    0439  CPI 01H
03B4     C2 C2 03                 0440  JNZ $+0BH
03B7     3A FB 03                 0441  LDA 03FBH
03BA     C6 80                    0442  ADI 080H
03BC     32 FB 03                 0443  STA 03FBH
03BF     C3 13 00                 0444  JMP STATIN
03C2     FE 1A                    0445  CPI 01AH
03C4     C2 D2 03                 0446  JNZ $+0BH
03C7     3A F6 03                 0447  LDA 03F6H
03CA     C6 80                    0448  ADI 080H
03CC     32 F6 03                 0449  STA 03F6H
03CF     C3 13 00                 0450  JMP STATIN
03D2     FE 11                    0451  CPI 011H
03D4     C2 E2 03                 0452  JNZ $+0BH
03D7     3A F7 03                 0453  LDA 03F7H
03DA     C6 80                    0454  ADI 080H
03DC     32 F7 03                 0455  STA 03F7H
03DF     C3 13 00                 0456  JMP STATIN
03E2     FE 7F                    0457  CPI 07FH
03E4     C2 ED 03                 0458  JNZ $+6
03E7     3E 20                    0459  MVI A,020H
03E9     77                       0460  MOV M,A
03EA     C3 5E 00                 0461  JMP BSP
03ED     C3 25 00                 0462 END JMP DISP
```

If the value is 1, 2, 3 or 4, the program jumps cause D to be loaded with the respective memory block starting address's most significant byte (hexadecimal 0C, 10, 14 or 18). If the value is 5, no jump is encountered, but D is loaded with the appropriate value (hexadecimal 1C) at the next sequential program step.

After D is loaded, D and E are used as a register pair (E = 00). The move cycle moves the memory contents of the position specified by H and L to the accumulator (MOV A,M). This value is then stored in memory at the location indexed by D and E.

Next, D and E, and H and L are incremented, and the value of H is compared with the value in B (first invalid location) to see if the new value of H and L is still a valid screen position. If so, the cycle is repeated. When the comparison of H with B indicates that the new value of H and L is no longer a valid screen position, the entire screen has been transferred.

At this point A is again loaded with the value at hexadecimal location 3F8, the page store select number (0 to 5). This value is incremented and checked to see if it is equal to 6. If so, the accumulator is loaded with 0 and stored at hexadecimal location 3F8. If not, the value in A is stored at hexadecimal location 3F8 unaltered.

The next time Page Store is entered, the page store select number will indicate that the screen is to be stored at the next memory block higher than the last screen was stored at. However, as described above, if the last screen is stored in page 6 (memory block 6, indicated by a 5 in this location) the program will have reset the location to 0 so that the next screen stored will be stored in page 1.

After the page number value has been determined and stored in hexadecimal location 3F8, H and L are loaded with their original prestore value (from hexadecimal locations 3FA and 3F9), and the value of M at this position is moved to C for use in any subsequent subroutine. Hexadecimal locations 3FA and 3F9 are then loaded with CC00 for subsequent use by page recall. Next, the program jumps back to the status input (STATIN) of the driver program. Hence, no cursor is on the screen after a store. This is a good way to see if you have already stored the present screen. A Page Store blanks the leading cursor.

Page Recall

Page Recall can be entered at six points, depending on which page the operator decides to recall. At each entry point, H and L are loaded with the value of the starting address of the page or block desired to be recalled, and B is loaded with the most significant byte of the first invalid address after this block of memory to be recalled. D and E are loaded with the screen starting location (hexadecimal CC00). Then A is loaded with the value of hexadecimal location 3F8 (the Page Store select value), decremented by 1 and deposited in hexadecimal location 3F8, since later on in the program it will be unavoidably incremented. (Thus a decrement followed by an increment leaves the Page Store select value at its original value.)

With D and E holding screen locations and H and L holding the page in memory locations, moving information indexed by H and L through the accumulator to positions indexed by D and E in effect moves information from the page in memory to the screen. Since the moves are accomplished by the move cycle in the Page Store routine, the program operation now jumps to this cycle, which operates as described in Page Store. The result is that the selected page in memory now appears on the screen.

Notice that, when the move cycle in Page Store is used by Page Store, hexadecimal locations 3FA and 3F9 are used to contain the address of the present leading cursor position of the page being stored. When the move cycle in Page Store is used by Page Recall, these locations contain hexadecimal CC00 to initialize the cursor on the recalled page. Also, as in a Page Store, no leading cursor appears on the screen. Hence, a Page Recall will set the cursor position to the upper left-hand corner of the screen, even though the cursor is not visible, until some other function is executed.

Users who do not have a hard copy output device in their systems may find a way to use the Page Store and Page Recall routines outside the GRAPH program. Running BASIC or even an assembler or editor with only a video terminal means that you often run information off the top of the screen that would be useful for later reference. Resident Page Store and Recall subroutines might help to reduce this problem. If the BASIC input routines, for example, could be modified to incorporate control character checks for Page Store and Recall, these routines would be called to store the existing screen without interfering with the program currently running in BASIC. This approach would be cumbersome (unless universally accepted) because all the higher level programs would have to be modified separately.

Other alternatives might incorporate interrupts to exit from main programs that reside above the 8080's RST addresses, or even some sort of parallel processor that would "preprocess" input data and route it either to special service routines or to the main program.

Repeat

Repeat simply loads hexadecimal location 3F5 with hexadecimal 80 and jumps back to STATIN in the Driver. Hexadecimal location 3F5 is subsequently reset by the program as soon as a second key after CTRL/R is pressed, as explained in the Driver section.

Vertical Write

When the control check subroutine recognizes the code for vertical write, it loads the accumulator with the contents of hexadecimal location 3F7 (which determines

System Clear

When a CTRL/W followed by a Clear is detected in the Control Check Section, a jump is made to INITialize and all system parameters are initialized. The screen is cleared and the cursor is moved to the upper left-hand corner.

System Clear is designed to be accessed by pressing CTRL/W and then Clear, to avoid accidental use. It is, however, occasionally handy to be able to reinitialize the entire program.

Clear Screen and Home Cursor

When only the Clear key is pressed, the program jumps to CLEAR. This clears the screen and returns the cursor to the upper left-hand corner. Memory status words are unchanged.

Home Cursor

When a CTRL/X is detected in the Control Check section, the program jumps to Home, which returns the cursor to the upper left-hand corner but does not affect the screen contents or the memory status words.

Escape

When the escape key (ESC) is pressed, it is detected by the Control Check section and a jump is made to hexadecimal memory address 345 where the program receives instructions for exit from GRAPH (see Program Function and Use).

Addressing and Memory Requirements

In its present assembly, GRAPH resides in hexadecimal memory locations 000 thru 3FFF and is designed to drive a VDM-1 addressed at hexadecimal CC00. VDM-1 status port (to reset scrolling) is addressed at hexadecimal C8.

In addition, six 1 K byte memory sectors are set aside for the STORE and RECALL functions (see table 3).

A keyboard inputs status information to IO port 00 (data present = bit 6 set) and data to IO port 01.■

A 300 bps cassette of GRAPH in Kansas City, BYTE or Cuter formats with a CUTER header is available for $5 (cash or money order) from UNB Audio Visual Services, UNB, Fredericton NB CANADA E3B 5A3.

Sector	Hexadecimal Beginning Address	Hexadecimal Locations of Begin Address in GRAPH Program	Hexadecimal End Address Plus One	Hexadecimal Location of End Address in GRAPH Program
1	0800	22F, 249 (08)	0C00	24B (0C)
2	0C00	234, 25B (0C)	1000	25D (10)
3	1000	239, 263 (10)	1400	265 (14)
4	1400	23E, 26B (14)	1800	26D (18)
5	1800	243, 273 (18)	1C00	275 (1C)
6	1C00	202, 27B (1C)	2000	270 (20)

Table 3: Six 1 K byte memory sectors which are set aside for the STORE and RECALL functions.

if the program is in the vertical write mode). It then adds the value 80 to the accumulator and deposits the result back into 3F7. This has the effect of alternately loading that location with hexadecimal 00 or 80 every time this routine is entered. Thus, one stroke of the appropriate key (CTRL/Q) puts you in the Vertical Write mode, and another stroke takes you out of that mode. Operation then jumps back to STATIN in the Driver.

Cursor (On/Off)

This operation works exactly the same as Vertical Write by alternately loading hexadecimal location 3FB with hexadecimal 00 or 80.

Cursor Write/Don't Write

Cursor write/don't write works exactly like Vertical Write, alternately loading location hexadecimal 3F6 with hexadecimal 00 or 80.

Next Store

When a CTRL/W and a number from 1 to 6 are detected (see Control Check Section), the Next Store routine is entered. This routine is actually only a series of comparisons in the Control Check Section which compare the input character with several ASCII hexadecimal values. For example, after CTRL/W and a numeral 1 are entered from the keyboard, the data input to the computer is hexadecimal 31. In this case a CPI 31 instruction would route the program to instructions that would load status word hexadecimal memory location 3F8 with hexadecimal 00, and when 3F8 is checked by the next STORE operation, it would store page 1 in the first memory sector. Entering a 3 would be detected by a CPI 33, which would load 3F8 with hexadecimal 02 and set up the next STORE operation for page 3.

Adding a Virtual Tape Loop

Audio Processing with a Microprocessor

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There is a lot of talk about digital audio processing, but talk is not the same as practical action. As the prices of microprocessor systems and interface devices continue to drop, such applications are sure to become quite common, even among amateurs. This article describes a few of the possibilities of the use of a small low cost microprocessor system for digital processing of audio signals. The effects described involve echo, reverb, fuzz, time delay, phase phlanging, mono-to-enhanced-stereo conversion, and frequency multiplication. These effects could also be quite useful for the experimentally inclined audio enthusiast or music group.

Hardware Requirements

To run the programs given here, you will need a 6502 (or equivalent) processor with from 1 K to 5 K bytes of programmable memory, an 8 bit input port connected to a fast 8 bit analog to digital converter (ADC), and a latched 8 bit output port connected to an 8 bit digital to analog converter (DAC). An additional output port and digital to analog converter are required for stereo applications. The basic hookup for a simple monaural system is shown in figure 1. The signal from the preamp is amplified, low pass filtered, converted to digital by the analog to digital converter, processed in the microcomputer, converted back into analog by the digital to analog converter, and then filtered some more before going to the power amp. The success of such a system in audio processing depends upon its ability to operate at ultrasonic speeds; that is, the rate at which the audio signal is digitized, processed, and output must (or should) be as far above the upper limit of the audio spectrum as possible. Thus the speed of each of these steps is critical. We'll consider each step individually.

Next to the microcomputer itself, the analog to digital converter is really the most critical component. It must be a fast one; a conversion time of 50 μs *or less* is necessary to allow sufficiently high sampling rates. I have been using a Datel Model E8HB1, an 8 bit successive approximation analog to digital converter with a 4 μs conversion time (available from Datel Systems Inc, 1020G Turnpike St, Building S, Canton MA 02021, for $85 in unit quantities). I recommend this unit. Its conversion time is probably faster than you will need, but at least you won't have to buy a new one when microsystems get faster (as they certainly will). In addition to speed, the Datel analog to digital converter has two other features you should look for in a converter. First, it is bipolar, which means it is capable of accepting both the positive and the negative excursions of the audio waveform. Otherwise, you would have to add some offset to the incoming signal. (The programs in this article assume offset binary coding.) Second, it *clips* on overload rather than wrapping around. That is, if the input audio signal exceeds the dynamic range of the analog to digital converter, the digital output simply stops at full scale rather than wrapping around or folding back to zero. The reason this is a useful feature is the fact that an audio signal contains many peaks and transients which greatly exceed the average signal amplitude. With only an 8 bit system, there is really no way to keep these transients from exceeding the range of the converter, at least occasionally; if you try to prevent it by adjusting the average amplitude to a very low level, you'll get too much quantization noise. Clipping the peaks may offend the audio purist, but I'll guarantee you that it sounds a *lot* better than wrapping around. Of course, a better solution would be to use 12 bit converters and a 12 or 16 bit (or faster 8 bit) computer. Sufficiently fast 12 bit analog to digital converters are available for about $150, and 12 bit digital to analog converters are typically about $30. But without a 12 or 16 bit processor, all processing would have to be done in double precision, which might slow things down too much (unless you have a 4 MHz 6502, which I do not). Anyway, an 8 bit converter which clips is good enough for the time being.

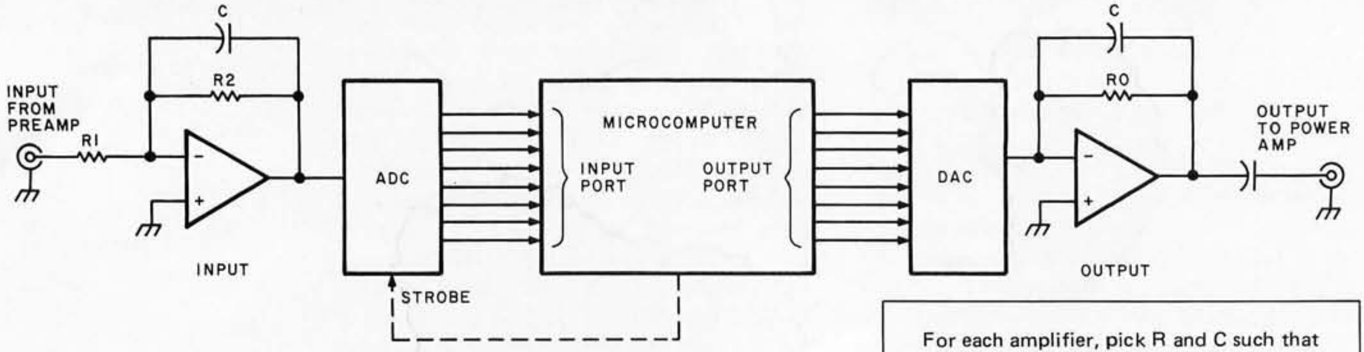
Selection of a digital to analog converter is much easier, since several fast, low cost 8 bit units are available. The digital to analog converter needn't be bipolar, since a DC blocking capacitor can be added easily. The Hybrid Systems 371-8 at $10 is a good choice, as is the Motorola MC 1408L8 at about $5. I've used both successfully. The Hybrid Systems unit is more convenient because it has a built-in reference supply, while you will have to supply an external (2 V) reference for the Motorola unit. This must be very well filtered but not necessarily well regulated for audio applications. (An advantage of the Motorola units is that they can be used as multiplying digital to analog converters. If you drive the reference input of one converter from the output of another converter, then the output of the first converter will be the *product* of the digital inputs to the two converters. This allows you to obtain automatic level control, compression, expansion, fading, and amplitude modulation effects without relying on much slower software multiplication routines and without getting into trouble with quantization noise.)

As for the processor itself, almost any 6502 system should do with the examples I've included in this article: KIM-1, Jolt, Ebka, OSI, PAIA, Apple-II, PET 2001, etc. I've used both the Ebka and the OSI systems with good results. OSI has a particularly convenient analog IO board (Model 430) which can be populated with two MC1408L8 8 bit digital to analog converters, an 8 bit analog to digital converter, and their associated latches and address decoding logic. The OSI Model 430 analog to digital converter circuit is of the synchronous tracking (up-down counter) type. Be warned, however, that this analog to digital converter wraps around on overrange. It also requires some individual tweaking of component values to get it to work. If you want to use the OSI 430 board, I strongly recommend that you replace their analog to digital circuit with a better one, such as the Datel E8HB1. Other than that, the OSI board is just fine.

One very important concept which you must understand is the relation between sample rate, aliasing, and low pass filtering. If you don't understand these terms and their significance, then before you go on you should read the article by Hal Chamberlin on page 62 of the September 1977 issue of BYTE. For the programs presented in this article, the sampling rate will fall between 20 and 40 kHz with a 1 MHz processor clock frequency, assuming you are using a sufficiently fast analog to digital converter (less than 50 μs sampling time). To control aliasing, you have to roll off the high frequency response of the *input* signal to the analog to digital converter at a frequency no higher than about 1/4 of the sampling frequency, ie: about 5 kHz for a 20 kHz sampling rate. This may not sound much like "hi-fi," but actually it sounds better than you might think. For better highs, you need faster processing and maybe a faster input converter. The 6502 is pretty good in this respect; it's available in versions at least up to 4 MHz. This would give you a sampling rate of 80 to 160 kHz for the programs given here and would extend the highs to the 20 to 40 kHz range. Now, *that's* a high fidelity computer!

The sampling rate therefore determines the frequency at which the response of the system must be rolled off (by means of appropriate low pass filters) in order to reduce aliasing to a tolerable level. In the simple circuit of figure 1, the only roll off is that provided by the capacitors in the feedback loops of the two op amps. Although this circuit is satisfactory for experimental purposes, the cutoff rate of the high frequency rolloff is not sharp enough for first class results. If you're really serious, you'll want more sophisticated, sharp cutoff filters. Hal Chamberlin gives the circuit of an excellent filter in his article in September 1977 BYTE, mentioned previously. The unpopulated printed circuit board, as well as an assembled and tested unit, is available from Hal. The cutoff frequency of this filter is 3 kHz, probably too low if you have a reasonably fast processor, so you might want to modify it or roll your own based on the designs in Don Lancaster's *Active Filter Cookbook* or other reference sources. Only one sharp cut filter is needed, between the preamplifier and the input analog to digital converter, to reduce aliasing. The filter on the output, between the digital to analog converter and the power

Figure 1: The system design of an audio processing test bed requires two simple peripheral devices and a computer. The input device is an analog to digital converter (ADC in this diagram) preceded by a filter. The output device is a digital to analog converter (DAC in this diagram) driving another filter. Source material from (for example) a broadcast program is input through the ADC, processed in real time by the program in the computer, then output in real time to the DAC where it (for example) goes to your audio power amplifier and speaker system. The program in the computer can be as simple as an unprocessed transfer from input to output, or as complex a transfer function as the constraints of real time will allow, given the speed of the computer.



For each amplifier, pick R and C such that

$$f_c = \frac{1}{(2\pi RC)}$$

where

f_c is cutoff frequency (kHz)

R is kilohms

C is microfarads

amplifier, needn't have as sharp a cutoff, but it should have the same cutoff frequency as the input filter. For the simple filters in figure 1, the cutoff frequency is equal to $1/2\pi RC$, where R and C are the values of the feedback resistor and capacitor, respectively.

One last thing to consider about the hardware is the level (amplitude) of the audio signal. In order to avoid excessive quantization noise, the input signal must be amplified enough to utilize the whole dynamic range of the input analog to digital converter. In figure 1, the first op amp provides gain in addition to filtering. The gain of this amplifier, which is equal to R_2/R_1, will have to be adjusted for your particular system. Given choices of R and C for filter cutoff, R_1 can be chosen given a desired gain level. For example, if your preamp provides a maximum output signal of 0.2 or 1 V peak-to-peak, and your input converter has an input voltage range of ±5 V (10 V peak-to-peak), then a gain of 10 V/1 V = 10 is appropriate. Also, the maximum output signal of the digital to analog converter must not be allowed to overload the power amplifier. This will dictate the selection of the feedback resistor R_0 of the output op amp in figure 1; the output voltage is directly proportional to the value of this resistor.

Software Considerations

So what about the software? First, let's see how to get data in from the input converter and out to the output converter without any processing at all. If your analog to digital conversion device (which I reference symbolically as CONV) is connected to an input port whose address is F800, then to load one sample of the audio signal into the accumulator (A) register of a 6502 requires one instruction, thus:

```
LDA CONV
```

This is all you need if you're using a tracking converter such as that on the OSI board, but if you're using a strobed converter, you'll have to give the converter a strobe pulse first, allow it time to convert, then load the A register. The fastest way to do this is to assign the input conversion strobe to an unused address, decode that address, and use the address select line (address "strobe," as it is sometimes called) as the pulse which strobes the converter. I have used the latter approach for my strobed analog to digital converter and have (arbitrarily) assigned address EC00 (which I call STROBE symbolically) to the address strobe. With this arrangement the converter is strobed by any instruction which references that address; for example an STA as shown here:

```
STA STROBE
__  }  several instructions executed
__  }  while conversion occurs.
__
LDA CONV
```

The above routine strobes the converter and then loads the data into the A register. The dashes represent intervening instructions which take up enough time to allow the analog to digital converter to complete its conversion. This will always be a useful code, rather than just no operation instructions (NOPs) or a wait loop. Conversion times of commercial analog to digital converters vary all over the place. As I mentioned before, for audio processing you'll need a fast one which converts in a time of 50 μs or better. Just make sure there are enough instructions between referencing STROBE and the loading from CONV to give the input converter time to convert.

To output one sample to the digital to analog converter (called DAC symbolically) is quite simple. For example, if the converter is connected to an output port whose address is F900, then all I have to do is store the sample:

```
8D 00 F9    STA DAC
```

To test the proper operation of the input and output converters we can write a "straight wire" program which simply transfers the data from the input to the output without change. Listing 1 shows 6502 position independent code for such a program.

Note that the input conversion strobe instruction is placed right *after* the load CONV instruction. This may seem backwards but it gives the analog to digital converter a total of seven machine cycles (an STA and a JMP) to convert before it will load into A. On a 1 MHz machine, this means the conversion time could be as long as 7 μs. If your converter is slower than this, put some NOP instructions or a wait loop right before the CLC instruction. The other programs in this article execute much more code between strobing and loading the input analog to digital converter and will usually allow you to get by with no additional instructions intended specifically to slow down execution.

The program of listing 1 is good for testing out the hookup to your audio system. The sound quality of music played "through your computer" this way may be better than you would expect, considering that the audio waveforms are being sliced up into discrete samples, converted into binary numbers, and then converted back into an analog audio waveform!

```
AD  00  F8   START LDA CONV          get new data from converter
8D  00  EC         STA STROBE        strobe input conversion
8D  00  F9         STA DAC           output to DAC
18                 CLC               unconditional
90  F4             BCC START         branch to START
```

Listing 1: A 6502 "straight wire" program loop. In order to simply listen to the input data on the output channel without any processing, we must enter a tight machine coded loop which reads the input converter, then stores the input data into the output converter. This 6502 program assumes an input digital to analog converter at address space location F800 (CONV), an input conversion strobe which occurs on reference to address space location EC00 (STROBE) and an output digital to analog converter at location F900 in address space (DAC). These same assumptions about IO apply to listings 2 thru 6 as well. With hardware like figure 1, try running this program using an audio signal from your favorite record album. The results will probably be of higher quality than you might have expected.

So what kind of audio processing can you do? I'll resist the temptation to say that the applications are limited only by your imagination. They are not. They are limited by your programming skill, your processor speed, and your system's programmable memory capacity. You can never have too much of these. I'll not claim to have even scratched the surface of potential applications in this article. I'll just tell you about a few things I've done, mostly because they were easy to program. If you don't come up with better ideas than these I'll be disappointed.

Waveform Modification

A very easy class of audio processing functions are those which are intended to distort the audio waveform. Believe it or not, distortion is actually considered desirable by musicians in some cases for obtain-

```
AE  00  F8  START LDX CONV           Put converter data into x register
8D  00  EC          STA STROBE         Strobe converter.
BD  00  03          LDA TABLE, X       Look up xth byte of TABLE
8D  00  F9          STA DAC            Output to DAC
18                  CLC                Repeat
90  F1              BCC START
```

Listing 2: Waveform modification. This 6502 program, obtained by modifying the program of listing 1 slightly, uses the input sample from the analog to digital converter (value 0 to 255) to look up the output sample in a "transfer function" table located at 0300 in memory and referenced with the name TABLE. The key to what the distorted output sounds like relative to the input is the data stored in TABLE (see text and figure 2).

ing special effects (such as "fuzz") with electric guitars and other electronic instruments. The computer can perform a rather elegant general purpose distortion function by utilizing a stored transfer function as illustrated in the program of listing 2.

To use this algorithm, you must set up a table in memory (on page 03 in this example) which serves as the *transfer function*. Each sample of the input waveform obtained from the input converter is used as an index to look up a corresponding byte in the table, which is then used as the output value. In this example the table is just 256 bytes long and is indexed by the 6502 processor's X register. Depending upon what we store in the table we can get any kind of distortion effect we want. A trivial case would be to use a straight line function, ie: put 00 in 0300, 01 in 0301, 02 in 0302. . .and FF in 03FF as shown in figure 2a. This would yield no effect at all; the output would be identical to the input as was the case with the program of listing 1. But if we use anything *other* than a straight line, we'll get distortion. Several possibilities are shown in figure 2. Figure 2b would give a square wave output while 2c would yield a somewhat less strongly distorted output. With the function shown in figure 2d, we would get a frequency doubling effect; that is, if the input were a sine wave of one frequency, the output would be an approximate sine wave of twice that frequency (one octave higher). With figure 2e, we'd get an output two octaves higher. This can be extended even further with the appropriate transfer function (eg: figure 2f). The effect on the sound of an electric guitar is quite remarkable, particularly as the frequency multiplication factor is a function of the amplitude of the input signal and changes at the input decays.

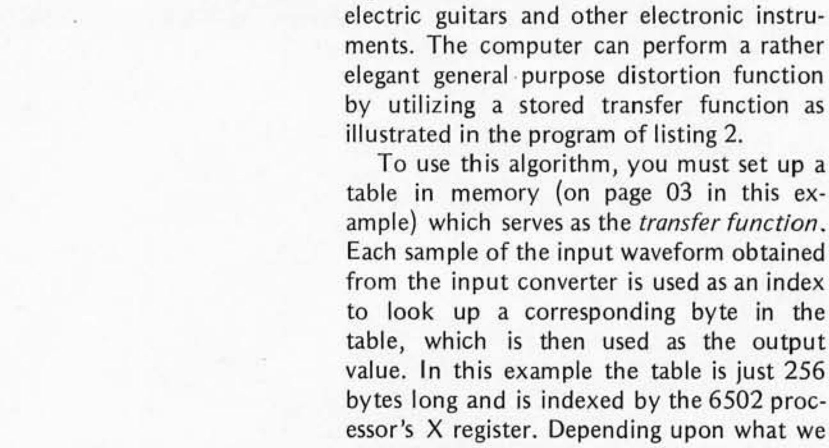


Figure 2: Examples of transfer functions for use with the waveform modification technique of listing 2. These curves are produced by plotting the data at an address versus the address within the table, with both values having a range of 00 to FF hexadecimal (eight bits worth). (A) is the simple linear transfer function. (B) is a transfer function which is equivalent to a saturated clipping amplifier: it puts out a square wave. (C) represents a slight distortion of the linear response of (A). (D) is a transfer function which effectively doubles the frequency of the input waveform, while (E) quadruples the input frequency and (F) multiplies the frequency by a factor of 8 (ie: three octaves higher).

Quite apart from its potential uses in music recording or performance, the above technique is a neat way to teach (or learn) about the effect of transfer characteristic nonlinearity on audio distortion. Just put in the characteristic under consideration and listen to the effect it has on the audio.

Time Delay, Phase Shift and Reverb Effects

If we store digitized audio in an array in programmable memory, and read it out to the digital to analog converter at a later time, we have a time delay effect which can be used for phase shift and reverb. The maximum time delay you can achieve depends on the sampling rate and the amount of available memory; but even with only 256 bytes you can get some pretty good phase shift and phase "phlanging" effects. With 4 K bytes you can get a good reverb.

The essential programming technique behind all of these effects is quite simple: output a byte from the data buffer to the digital to analog converter; input a new sample from the analog to digital converter and put it in the same location in the data buffer as the byte just output; increment the pointer modulo the length of the buffer and repeat. (Thus, when you get to the end of the data buffer you reset the pointer to the beginning and continue.) By scaling and adding the new data from the input converter to the old data from the data buffer, we can generate a range of effects depending on the length of the time delay.

The routine of listing 3 adds the audio signal to a slightly delayed version of itself and outputs the scaled sum to the digital to analog converter. In this routine, page 03 serves as the data buffer and x as the pointer. The pointer is initialized to DELAY, decremented until it gets to zero, and then reset to DELAY. This results in a sort of circular data buffer which acts as a first in last out shift register. The new and old (delayed) data are added and sent to the output converter. (Note that to prevent overflow, the data are divided by two *before* adding.) The time delay, determined by DELAY, can be adjusted from 1 to 225 samples. Such short delays do not result in a perceptible echo. The effect is rather that of a "comb filter" with multiple peaks and dips distributed throughout the audio spectrum. This is due to the fact that there will be a cancellation at every frequency whose period is an integral multiple of twice the time delay and a reinforcement at every frequency whose period is an integral multiple of the time delay. This rearranges the amplitude and phase relationships of the harmonics of music and speech and has a quite noticeable effect on the sound, variously described as a "resonant" or "twangy" effect. (If you have a hum problem in your audio setup, you might try to find the value of DELAY which puts a dip right at the hum frequency.)

The above idea can be extended and the effect made much stronger by causing DELAY to change continuously in real time. This would cause the peaks and dips to sweep through the audio spectrum. This effect is called "phase phlanging" by some people. An easy way to do it (not necessarily the best way, however) is shown in listing 4. This is the same as the previous program except that the DEC DELAY instruction has been added to reset the buffer pointer to a different value each cycle through the buffer. The effect of this routine on voice and music is quite dramatic. With speech and solo singing it gives a kind of voice doubling effect, as if two people were speaking or singing in synchronization. It makes a 6 string guitar sound reminiscent of a 12 string guitar. A concert piano comes out distinctly like a questionably tuned honky tonk piano. The effect on organ music is unreal and unpleasant. If you play the guitar and sing, or think you do, try processing a tape recording of yourself this way. It will sound better, or at least different (which in my case is the same thing).

If you have two output ports and two digital to analog converters, you can generate two channels of audio output. For example, you can convert a monaural source to "pseudostereo" with a further

```
A6  10        RESET LDX DELAY          initialize pointer to buffer length
BD  00  03     NEXT LDA BUFFER, X      get oldest data
4A                  LSR A              divide by 2
85  11              STA TEMP           keep
AD  00  F8          LDA CONV           get new data
8D  00  EC          STA STROBE         (strobe converter)
9D  00  03          STA BUFFER, X      replace old data with new
4A                  LSR A              divide by 2
18                  CLC
65  11              ADC TEMP
8D  00  F9          STA DAC            output to DAC
CA                  DEX                advance the buffer
D0  EF              BNE NEXT           pointer and repeat
18                  CLC
90  E2              BCC RESET
```

Listing 3: Time delays are possible with a buffer. Using the memory located at hexadecimal 300 to 3FF as a 256 byte delay buffer, a number of interesting effects can be achieved. This program supports a delay of up to 255 inner loop periods, too short to be perceptible as a delay per se, but it does transform signals by adding the delayed sample's points to the new input samples, producing an interesting filtered result. The delay buffer length is set by the value loaded into the X index register from location DELAY in the first instruction of the program. As in all the examples of this article, this 6502 program is position independent and can be loaded at any arbitrary place in memory address space which contains programmable memory not conflicting with IO or data storage locations.

```
A6  10        RESET LDX DELAY
BD  00  03          LDA BUFFER, X
4A                  LSR A
85  11              STA TEMP
AD  00  F8          LDA CONV
8D  00  EC          STA STROBE
9D  00  03          STA BUFFER, X
4A                  LSR A
18                  CLC
65  11              ADC TEMP
8D  00  F9          STA DAC
CA                  DEX
D0  E7              BNE NEXT
C6  10              DEC DELAY
18                  CLC
90  E0              BCC RESET
```

Listing 4: Modifying the processing done by the delay program of listing 3 to sweep the time delay value results in this "phase phlanging" program. The difference between this program and that of listing 3 is the DEC instruction which changes the value of the delay parameter DELAY each time it is reloaded. The effects must be heard to be believed.

```
A6  10        RESET LDX
BD  00  03     NEXT LDA BUFFER, X
8D  00  EF          STA DAC2           delayed sound to one channel
AD  00  F8          LDA CONV
8D  00  EC          STA STROBE
9D  00  03          STA BUFFER, X
8D  00  F9          STA DAC 1          direct sound to other channel
CA                  DEX
D0  EB              BNE NEXT
C6  10              DEC DELAY
18                  CLC
90  E4              BCC RESET
```

Listing 5: Modifying the program of listing 4 to turn it into a pseudostereo processor. Here, the delayed data is sent to a second channel, with the amount of delay swept as it was with the phase phlanger approach. But instead of adding the two channels together, they are kept separate and sent to the left and right stereo speakers.

modification of the program in listing 3 (see listing 5).

In this example the additional DAC is connected to an output port whose address is EF00. Instead of being added together, the direct and delayed signals are simply sent to the two different channels. The result is a sort of stereo phase phlanging effect which sounds much like a "rechanneled for stereo" disk recording. Try this through stereo headphones. So now you can have a stereo electric guitar. Would anyone like to extend it to quadraphonic?

If you have at least 4 K bytes of memory available in your system for your buffer, then you can obtain echo and reverberation effects quite readily. The idea is basically the same as the phase shifter routines just discussed, except that a much larger data buffer is used. Here we can use the indirect form of the LDA and STA instruction, and we maintain a 16 bit pointer in page zero (unlike the 6800, the 6502 has only 8 bit index registers). The routine of listing 6 yields a reverberation time which is adjustable up to about 0.5 seconds. The data buffer is assumed to be the 4 K byte block from addresses 2000 to 2FFF. On each cycle through the buffer, the old data is divided by two, added to the new data output, and returned to the buffer. Thus, the old signals (ie: the echo) die off by a factor of two each time they are heard. You can hear about five or six echos before they drop below audibility.

```
                         AUDIO REVERB SIMULATION

                                  LABELS

F800              CONV          Address of 8 bit analog to digital converter
EC00              STROBE        Converter strobe line
F900              DAC           Address of 8 bit digital to analog converter
0009              FIRST         Lowest page number in data buffer
0010              LAST          1 + highest page number in data buffer
00A0              PNTRL         Low half of data buffer pointer
00A1              PNTRH         High half of data buffer pointer
0011              TEMP          Temporary storage

                               PROGRAM CODE

A0  00                  LDY #0           Set pointer to zeroth byte of page
                                         "FIRST".
A9  00                  LDA #0
85  A0                  STA PNTRL
A5  09          RESET   LDA FIRST
85  A1                  STA PNTRH
8D  00  EC      NEXT    STA STROBE       Strobe converter.
B1  A0                  LDA (PNTR), Y    Get oldest byte.
4A                      LSR A            Divide by 2.
85  11                  STA TEMP         Save.
AD  00  F8              LDA CONV         Get new byte.
4A                      LSR A            Divide by 2.
18                      CLC              Add to oldest byte, and return to
                                         data buffer.
65  11                  ADC TEMP
91  A0                  STA (PNTR), Y
8D  00  F9              STA DAC          Output.
C8                      INY              Go to next point.
D0  E9                  BNE NEXT         Increment pointer (double
                                         precision).
E6  A1                  INC PNTRH
A5  10                  LDA LAST         When end of data buffer is reached,
                                         reset pointer to FIRST and
                                         continue.
C5  A1                  CMP PNTRH
D0  E0                  BNE NEXT
18                      CLC
90  DA                  BCC RESET
```

Listing 6: The use of large amounts of memory can lead to interesting effects, for example this reverberation program. Here a 4 K byte buffer from address space locations 2000 to 2FFF is used to store delayed samples obtained from the input converter at location CONV. This code for the 6502 processor is position independent, provided it is not loaded in the same region as the delay buffer, the page zero constants, or the IO device addresses.

If START is set to 20, using the whole 4 K buffer, the effect is something like that of a large hall or perhaps an old railroad terminal. The difference is that the computer produces a clear, clean echo at very precisely timed intervals and with a precisely controlled decay rate. Compare this with either a natural reverberation situation or a mechanical unit: the result is a more mechanical sound, much like a tape loop reverb device, without the false resonances of a spring type device. The advantage over a tape loop device is, of course, that it will never wear out or get out of alignment.

Several useful modifications of this program can be made. For example, you could utilize a second digital to analog output and a stereophonic sound system to achieve spacial separation between the direct and "reflected" sound. You could then apply some filtering to the reflected sound channel to simulate selective absorption by the room furnishings. You could also improve the realism of this effect by writing the routine to provide more than one delay time, for example by maintaining two or more buffer pointers which would allow the incoming data to be added to several points in the data buffer. You'll need a fast processor to keep the sampling frequency up, however. Finally, by simply dropping the LSR and ADC instructions in the program of listing 6, you can get a simple time delay effect; say a word and it is repeated immediately. Great for language study; listen to and critique your pronunciation without wearing out your tape recorder. Or if you have lots of memory (at least 32 K), you can get delays long enough to allow you to sing a round with yourself! I won't comment on the frightening social significance of this.

GLOSSARY

Analog to digital converter (often abbreviated **ADC**): Integrated circuit or hybrid module which converts an analog voltage into a parallel digital number, usually in a binary or binary coded decimal format; characterized principally by the number of bits of parallel binary output (the more the better) and the conversion time (the shorter the better). Most commercially available analog to digital converters have from six to 14 bits, convert in 0.5 µs to 200 ms, and cost from $12 to $300 each.

Address decoding: Logic circuitry present in all microcomputer systems which looks for certain addresses on the address bus and outputs a pulse (address strobe) whenever those addresses occur. Used to select individual IO ports, sections of memory, and devices tied to the data bus.

Address strobe: A pulse or logic level generated by the address decode logic in response to the occurrence of a particular address or a range of addresses in a microcomputer.

Aliasing: An instrumental artifact, caused by sampling a periodic waveform less than twice per period, which results in an apparent reduction in the frequency of the waveform. (The effect is quite analogous to the use of a stroboscope to "slow down" the action of periodic mechanical motion.) In audio processing, aliasing sounds like a gross distortion.

Conversion time: The time it takes an analog to digital converter to convert an analog voltage to a binary number. Specifically, it is defined as the time between the strobe pulse and the instant that the digital output is valid.

Cut off frequency: The frequency at which a low or high pass filter *begins* to cut off a signal (which means to reduce its amplitude).

Cut off rate: Also called attenuation rate. The rate at which the response of a low or high pass filter increases attenuation as you go to higher or lower frequencies. The response of a simple single section low pass RC filter drops off only at the rate of a factor of two for every factor of two increase in frequency (called −6 dB per octave in engineering jargon). More sophisticated "active" filters employing operational amplifiers can have much faster cut off rates. These have the advantage of extending the high frequency response as far as possible while still reducing aliasing to an acceptable level.

Digital to analog converter (frequently abbreviated **DAC**): An integrated circuit or hybrid module which converts a parallel binary or binary coded decimal number to an analog voltage or current proportional to the number. Commercially available digital to analog converters have resolutions from eight to 16 bits and cost from $5 to $100.

Data buffer: A section of programmable memory used to store data, usually temporarily.

Fuzz: A kind of distortion occasionally used by electric guitarists for special effect.

Offset binary coding: An arrangement for operation of a bipolar analog to digital converter in which a zero input voltage corresponds to a midscale digital output. For an 8 bit converter with a ±5 V input range, an input of 0 V would be converted to hexadecimal 80, −5 V to hexadecimal 00, and +4.96 V to hexadecimal FF. (This differs from two's complement coding.)

Peak-to-peak: The voltage difference between the average positive excursion and the average negative excursion of an AC signal.

Phase shift: A (usually small) time delay between two similar periodic waveforms.

Phlanging: An audio effect originally produced by playing duplicate tape or disk recordings in almost, but not quite exact, synchronization.

Quantization noise: The noise caused by the conversion of a smooth, continuous analog waveform into a "stair step" approximation in the process of digitization. It adds a "hiss" to audio signals, technically called "white noise." Like any other type of hiss, it can only be partially removed by filtering. The smaller the steps, the less the noise. Thus an 8 bit digitization, yielding 256 discrete steps or "quantization levels," results in a slightly noticeable quantization noise, but in a 12 bit conversion (4096 steps), the effect is quite negligible.

Sample rate: The rate at which the signal waveform is digitized. The larger the number of samples per period of the waveform, the closer the digitized waveform will be to the original analog waveform. The sample rate must be at *least* twice the highest frequency to be digitized in order to prevent aliasing. In this article, the sampling rates are determined by the execution times of the inner loops of the programs.

Strobe: In general, a pulse used for time synchronization of some event. In the context of an analog to digital converter, the term refers to the "start conversion" pulse applied to the converter to initiate the conversion process. In this article, the input conversion strobe is supplied by the microcomputer under software control.

Successive approximation: A popular type of analog to digital converter. Most fast converters are of this type. It performs the conversion bit by bit, starting with the most significant bit and progressing to the least significant bit. Although generally fine for audio processing applications, this type of converter can exhibit nonlinearity (and therefore distortion) if the input signal changes appreciably during conversion. To prevent this, a sample-and-hold circuit can be used ahead of the converter, or, as in this article, one can reduce the problem to insignificance by using a converter with a conversion time much less than the period of the highest frequency passed by the input low pass filter.

Tracking analog to digital converter: A low cost type of converter which uses an up-down binary counter to track or follow the analog input. Its advantage is that it requires no strobe pulse, as its output is always trying to keep up with the output. This type is often implemented in software when conversion time is not particularly important.

Transfer function (or characteristic): The functional relationship between the output and the input of a device.

Wrap around: What happens to your car's mileage indicator after you've driven 99999.9 miles. It "wraps around" to 00000.0. The same thing occurs in electronic counters; in an 8 bit device, the next count after hexadecimal FF wraps it around to 00. Some analog to digital converters do this when the input voltage exceeds full scale. It must be prevented in audio processing. ■

Visit to an OEM Supplier

A Look at Shugart's New Fixed Disk Drive

Chris Morgan, Senior Editor

Photo 1: One of the high speed conveyors at Shugart Associates' Sunnyvale CA plant. Metal arms swing out to capture plastic bins of parts. 600 to 800 floppy disk drives and 300 to 400 minifloppy drives are turned out every day at the plant.

OEM can be a confusing term for people new to the personal computing field. It means "Original Equipment Manufacturer" —that is, a company which uses parts and equipment of *other* manufacturers in order to produce end user equipment for sale to the public.

Recently I had the opportunity to visit an OEM supplier whose name is well-known to the personal computing field: Shugart Associates. Shugart manufactures the floppy and minifloppy disk drives that go into equipment sold by North Star, Apple, PolyMorphics, Smoke Signal Broadcasting, Radio Shack, and many more. They also supply companies that manufacture large computer systems. All told, they claim to manufacture over three quarters of the floppy disk drives on the market, and two thirds of the minifloppies.

Upon entering their brand new 150,000 square foot facilities in Sunnyvale CA, I immediately noticed that the flow of production parts was controlled by an impressive array of high speed conveyor belts (see photo 1). Their workforce of over 700 people turns out 600 to 800 standard floppy drives and 300 to 400 minifloppy drives every day.

The most interesting feature of the tour, however, was getting a glimpse of the new Shugart SA4000 fixed disk drive—a unit that may have a major impact on the personal computer market a year or so from now. The SA4000 (see photos 2 and 3) is available in 14.5 and 29 megabyte (unformatted) capacities with an optional 144 K bytes of additional head-per-track storage. Winchester heads (named after IBM's "Winchester" disk technology) are used in the 35 pound (16 kg) unit, which is designed to fit in a 19 inch (48 cm) rack. But price is the most significant feature: the 14.5 megabyte

Photo 2: Prototype of the SA4000 fixed disk.

unit is $2550, and the 29 megabyte unit is $3500, both quantity one; prices for quantity 100 are $1450 and $2000, respectively.

The same voltage requirements are used for both the SA4000 drives and the Shugart standard size IBM compatible floppy drives, so the same power supply can be used for both types of drives in a system. In addition, the SA4600 intelligent controller (or equivalent) can be used to control up to four floppy disk drives and four SA4000 fixed disk drives with the same controller board. The new fixed disk drive has an interface similar to that of the standard Shugart SA800 and SA850 floppy drives, but it employs a higher transfer rate. The drive includes a data separator and encoder providing normalized NRZ read and write data.

Data on each disk surface is read by two read and write heads, each of which accesses 202 tracks. The drive is available in two basic configurations: one disk with four read

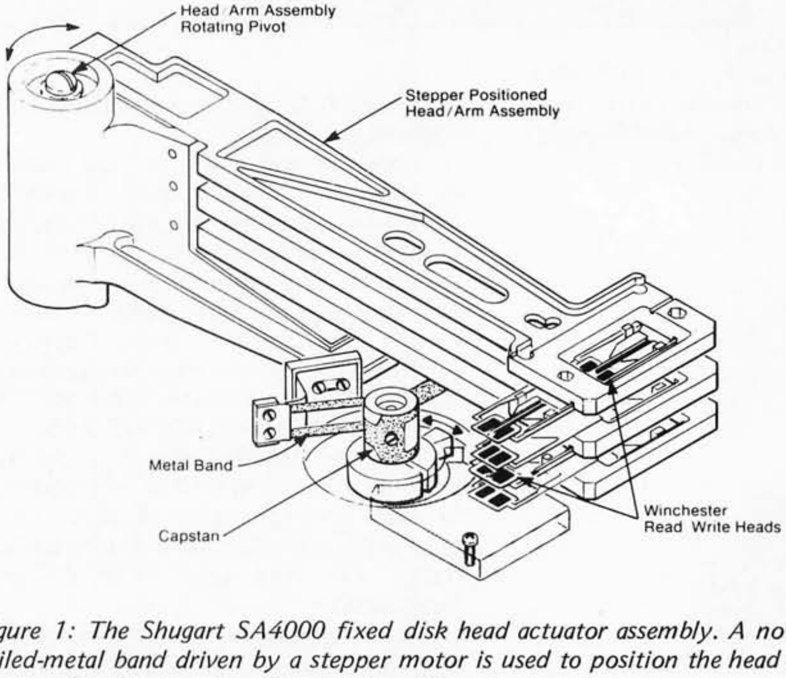


Figure 1: The Shugart SA4000 fixed disk head actuator assembly. A novel coiled-metal band driven by a stepper motor is used to position the head assembly. Graphics courtesy Shugart Associates.

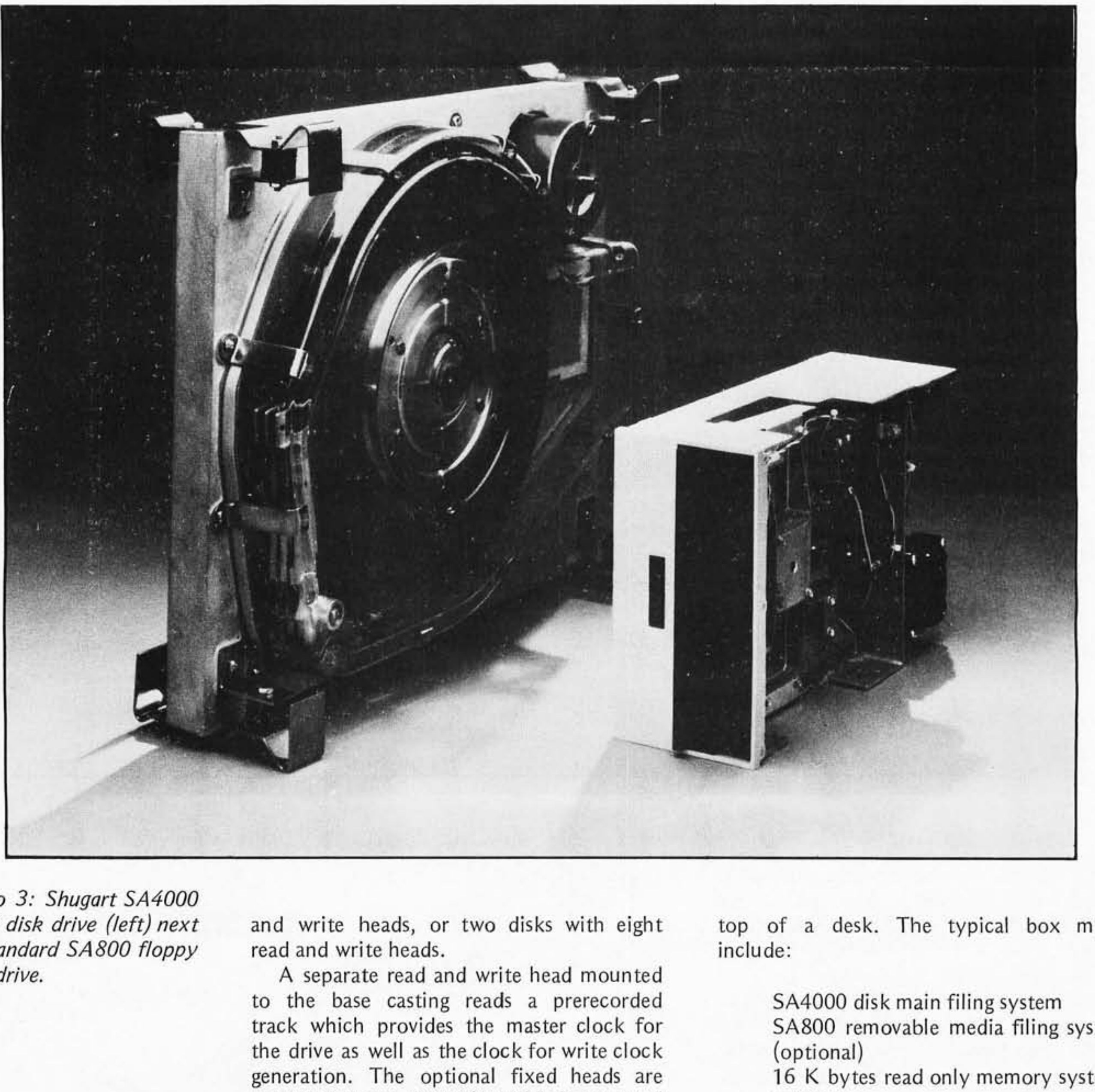


Photo 3: Shugart SA4000 fixed disk drive (left) next to standard SA800 floppy disk drive.

and write heads, or two disks with eight read and write heads.

A separate read and write head mounted to the base casting reads a prerecorded track which provides the master clock for the drive as well as the clock for write clock generation. The optional fixed heads are mounted on an assembly which is mounted directly on the base casting. Delivery is currently four months from receipt of order from Shugart Associates, 415 Oakmead Pky, Sunnyvale CA 94086, (408) 733-0100.

Since the SA4000 disk is permanent, users will need some form of off line storage to keep back-up copies of vital files in practical systems: a double density full size floppy disk drive seems to be the most logical choice.

We should soon see the era of the 14.5 megabyte mass storage system *built into* a high end personal computer which sits on top of a desk. The typical box might include:

SA4000 disk main filing system
SA800 removable media filing system (optional)
16 K bytes read only memory systems software
48 K bytes volatile program store
Any third generation processor (9900, Z8000, 8086, 6809, etc)
Video display (graphics plus full ASCII text capability)
Keyboard
Machine independent PASCAL systems software

Externally, this would look fairly conventional, but buried inside might be the SA4000 as a permanent on line nonvolatile memory resource.■

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74L$37	.31	74L$174	.75
74L$38	.31	74L$175	.79
74L$42	.60	74L$190	.90
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74L$48	.72	74L$192	.90
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7413	25	74107	28
7414	61	74109	22
7416	24	74121	29
7417	22	74122	38
7420	13	74123	48
7423	25	74132	65
7425	25	74141	70
7426	22	74145	65
7427	17	74150	88
7430	13	74151	61
7432	23	74153	61
7437	21	74154	95
7438	21	74157	55
7439	25	74161	55
7440	13	74163	55
7441	70	74164	85
7442	37	74165	90
7443	59	74170	1.69
7444	59	74173	1.10
7445	65	74174	85
7446	62	74175	75
7447	59	74176	69
7448	60	74177	70
7450	13	74180	65
7451	13	74181	1.75
7453	13	74190	95
7454	13	74191	95
7460	14	74192	79
7470	26	74193	80
7472	21	74195	49
7473	21	74221	86
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4010	.37	4050	.34
4011	.16	4051	.89
4012	.16	4052	1.15
4013	.29	4053	.89
4014	.74	4066	.59
4015	.74	4071	.19
4016	.29	4081	.23
4017	.79	4082	.23
4018	.79	4507	.39
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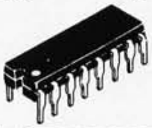
4021	.89		
4022	.89		
4023	.16		
4024	.67		



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Circle 170 on inquiry card.

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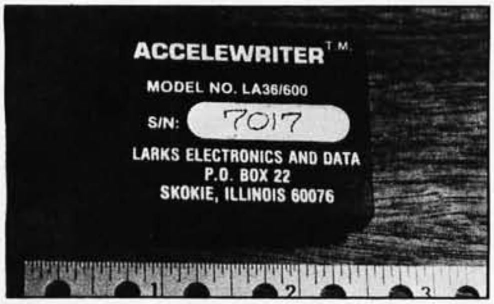
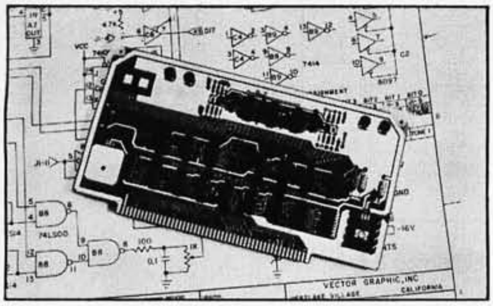
Adapter Doubles DECwriter Speed



A new adapter, the Accelewriter, adapts any LA36 DECwriter to operate at 600 bps, converting the standard 110, 150 or 300 bps DECwriter to 220, 300 or 600 bps. The Accelewriter changes the internal timing of the DECwriter and causes it to print at 60 characters per second. Installation involves removal of two integrated circuits from the logic board of the DECwriter. These are replaced with low profile IC sockets. The Accelewriter is then installed in the board in place of the two original ICs, and the logic board is reinstalled in the DECwriter. The DECwriter can be reconverted to its original electronic configuration by unplugging the adapter and installing ICs of the original types in the sockets. Price is $95 from Larks Electronics and Data, POB 22, Skokie IL 60077.■

Circle 641 on inquiry card.

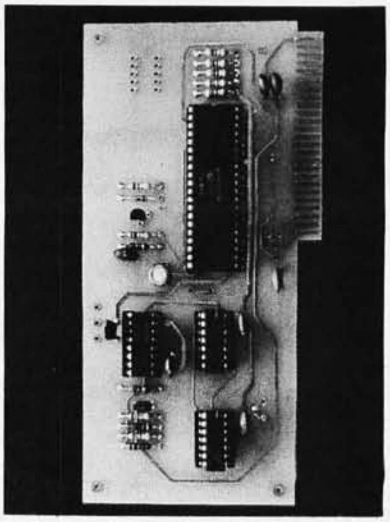
Analog Interface Board



A multifunction analog interface board, offered as a kit or fully assembled, has been introduced by Vector Graphic Inc, 790 Hampshire Rd, A and B, Westlake Village CA 91361. According to the firm, board design permits interfacing with potentiometers, joysticks, or voltage sources. An 8 bit digital port with latch strobe can be used as a keyboard input port. Tone pulse generators can also be used to produce sounds for games or keyboard audio feedback. Additional features include four analog to digital inputs, MWRITE logic, and a power on jump feature for computers lacking front panel. Price is $75 in kit form, $115 assembled.■

Circle 642 on inquiry card.

Serial IO for the Apple II



Electronic Systems has announced a serial IO board for the Apple II computer. The board comes with software for input and output to and from a Teletype or other serial device via an RS-232 interface.

Features include switch selectable parity, selectable number of stop bits, and jumper selectable address. Data rates can be as high as 30,000 bps.

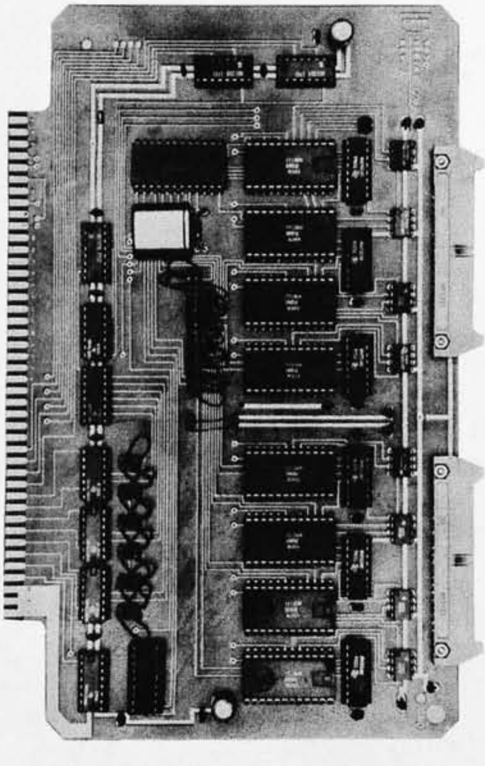
The board is available assembled and tested for $62. The complete kit is $42, and the board only is $15. Contact Electronic Systems, POB 9641, San Jose CA 95157, (408) 374-5984.■

Circle 644 on inquiry card.

Altair (S-100) Bus Interface Board for PET 100

HUH Electronic Music Productions, POB 259, Fairfax CA 93930, has announced the PET 100, a PET to Altair (S-100) bus interface board for the Commodore PET computer. The Altair (S-100) sized card plugs into the mainframe of your choice and a cable connects it to the PET, which then enables you to use any of the peripheral and memory cards available for the Altair (S-100) bus. The PET 100 emulates the true Altair (S-100) bus including direct memory address, read and write wait states, IO address mirroring, multiplexed status lines, and much more. The PET 100 is available in kit or assembled form for $199.95 or $279.95, respectively.■

Circle 645 on inquiry card.



New Interface Module from Creative Micro Systems

The 9650 is an asynchronous serial interface module specifically designed for compatibility with the Motorola 6800 processor bus. It is pin and outline compatible with the Motorola EXORciser and Micromodules and with the MED6800D2 Evaluation Kit. It features full address decoding and fully buffered data, address and control lines. This module utilizes eight MC6850 Asynchronous Communications Interface Adapters with full RS-232C signal conditioning. An on board bit rate generator simultaneously provides 14 standard rates that can be individually strapped to each ACIA.

The 9650 occupies 16 consecutive memory addresses. The lowest eight of these access the eight control and status registers and the next eight access the transmit and receive data registers. This map arrangement allows optimum use of indexed addressing in IO intensive systems and permits the use of a very tight interrupt polling loop.

The standard configuration of the 9650 is fully populated to eight channels. The price is $395 in single quantities. A partially populated 4 channel version is also available at a lower price.

The 9650 is one of a family of M6800 support modules. All cards of the family are 6.05 by 9.75 inches (15.4 by 24.8 cm) and utilize a 43 pin dual readout edge connector with 0.15625 inch (0.4 cm) pin spacing. Additional information is available from Creative Micro Systems, 6773 Westminster Av, Westminster CA 92683, (714) 892-2859.■

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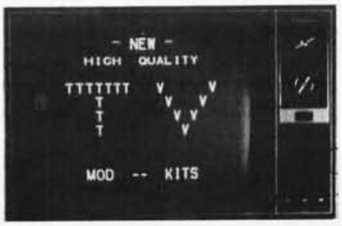

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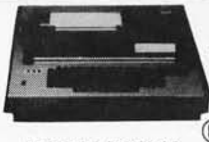
ASCII  **ASCII**

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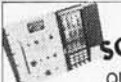

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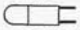

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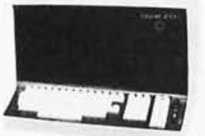

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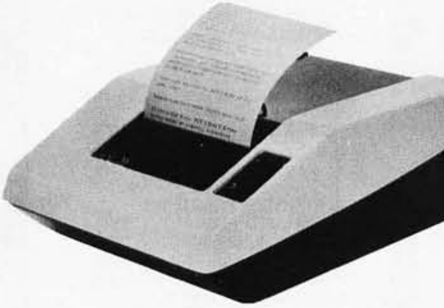
Axiom Announces EX-801 MicroPrinter



An intelligent electrosensitive line printer, the model EX-801 MicroPrinter, has been announced by Axiom Corp, 5932 San Fernando Rd, Glendale CA 91202, for $655. The EX-801, designed around an Intel 8048 processor, operates at up to 160 characters per second and offers users the choice of three character sizes to provide 80, 40 or 20 columns on the 5 inch (12.5 cm) wide electrosensitive paper. It is designed for video display hardcopy, data logging, program listing and record keeping. Standard features include RS-232C 20 mA serial input as well as parallel ASCII; 256 character multiline asynchronous input buffer as standard, optionally expandable to 2 K characters, making it possible to take a page dump from a video display terminal in approximately one second; 96 character ASCII standard, optionally expandable to 256 characters with user programmable fonts; software selection of "reverse" printing in which light characters are formed on a dark background; and optional 2 K bytes of user programmable read only memory.■

Circle 593 on inquiry card.

Soft Touch Bill Paying Home Dial

The Soft Touch Tone Dial for "bank by phone" is designed for use by customers of banks and thrift institutions. The unit is a tone dial that screws on the mouthpiece of a regular rotary dial telephone and immediately converts it into a push button telephone. It has all the letters (a thru z) on the buttons as well as an asterisk (*) and number symbol (#) for commands. Upon dialing to the bank computer, the consumer taps in his account number, secret code, merchant code and amount to pay bills. Soft Touch is both a tone dial and microphone in a standard 1 cubic inch telephone mouthpiece. The tone frequencies are crystal controlled. The keyboard is .05 inches thin, made with eight layers of special conductors. For additional information contact the Telephone Computer Company Inc, 1838 W Bayshore, Suite 4, Palo Alto CA 94303.■

Circle 594 on inquiry card.

Floppy Disk System for RS-232 Communication Devices

The Comm-Stor II is a communications floppy disk system which uses IBM 3740 compatible diskettes and interfaces with all RS-232 communications devices. Comm-Stor II is microprocessor-based enabling the user to store and retrieve files by file source. The system gives the user increased file storage capacity and maximum usage of the diskette regardless of the mix of file sizes; provides the capability of merging and creating new files composed of existing files; provides buffering at the terminal or modem port which allows commands and data to be stacked, minimizing the handshaking and system delays and provides protection from data overruns; and allows the user to specify selected files as "protected" (unalterable) while retaining the ability to create or alter other files. Since it uses a very simple serial interface and IBM 3740 compatibility this type of mass storage system should prove quite useful in a number of personal computer situations. A single drive system lists for less than $3000 and a dual system for less than $4000. For more information contact Sykes Datatronics Inc, 375 Orchard St, Rochester NY 14606.■

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8 Inch Floppy Disk System for SwTPC 6800

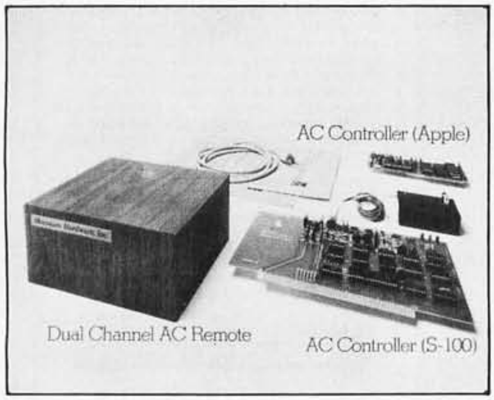
The Southwest Technical Products Corp DMAF1 is a dual drive, single density, double sided 8 inch floppy disk system. The hardware consists of an SS-50 bus (SwTPC 6800) compatible direct memory access (DMA) controller capable of handling up to four drives, two CalComp 143M double density disk drives, aluminum chassis, regulated power supply, drive motor control board, cooling fan, diskette and interfacing cables. The unit is 5.4 by 17.1 by 20.5 inches (13.7 by 43.5 by 52 cm).

An 8 K BASIC interpreter with disk file capability and string functions is included with the system. Each diskette holds approximately 600,000 bytes of data. With two drives there is over one megabyte of data on line.

The system is available assembled or in kit form (the drives are fully assembled). The unit sells for $2095 assembled, or $2000 as a kit, plus postage. Contact Southwest Technical Products Corp, 219 W Rhapsody, San Antonio TX 78216.■

Circle 585 on inquiry card.

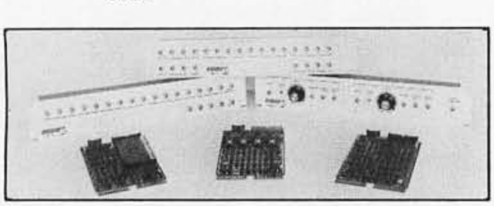
AC Wiring Controller



A new system designed to control AC devices remotely from any Altair (S-100) bus or Apple II computer over existing 110 VAC wiring has been announced by Mountain Hardware, POB 1133, Ben Lomond CA 95005. The new unit, called Introl, provides on and off control and status checks at any AC outlet. The system impresses a 50 KHz control signal onto the ordinary AC wiring. It then decodes the signal at any outlet to switch AC devices on and off. In the home, such devices could include lights, TVs, stereos, solenoid valves, sprinklers, burglar alarms, etc. With the addition of input sensors the computer system can automatically control such variables as temperature, humidity and soil moisture. Programs are written in BASIC or assembler language. Software subroutines come with the equipment. Complete documentation is also provided. For Altair (S-100) bus computers, a 100,000 day calendar and clock board is offered as an option. Price of the AC controller is $149 in kit form or $189 assembled and tested. Dual channel AC remote units are $99 each in kit form or $149 assembled and tested. The calendar and clock board is $179 in kit form or $219 assembled and tested.■

Circle 586 on inquiry card.

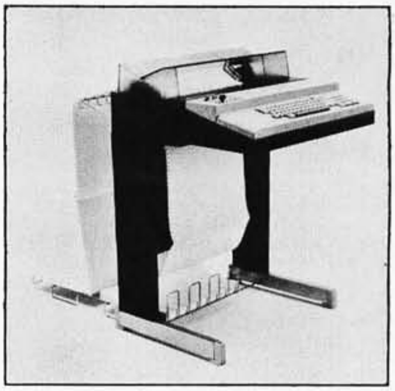
LSI-11/2 Compatible Data Acquisition Code



Three types of data acquisition cards that are compatible with the new LSI-11/2 computer as well as the older LSI-11 are now available from Andromeda Systems, 14701 Arminta St, Panorama City CA 91402. The three cards consist of: the ADC11, a 16 channel 12 bit analog to digital converter; the DAC11, a 4 channel 12 bit digital to analog converter; and the PRTC11, a programmable real time clock with 13 internally generated rates, five operational modes, and two external inputs. These products are all functional supersets of the similar DEC products (AAV11, ADV11-A KWV11-A) but are in the dual width (rather than quad width) format. Also available is the CB11 series of compatible connector boxes which facilitate external connection to the above products. Prices are $850 for the ADC11; $700 for the DAC11 (four channels, deduct $75 for each deleted channel); and $600 for the PRTC11. All connector boxes are $150 each; cables are extra.■

Circle 587 on inquiry card.

New Teleprinter Offers Many Options



The TC480 teleprinter is available in receive only, keyboard send and receive or automatic send and receive configurations. It prints 128 ASCII characters in a 7 by 9 dot matrix at speeds up to 30 characters per second. Up to 132 characters per line can be printed and up to 64 characters to be printed can be stored in the teleprinter's internal memory. An adjustable sprocket feed handles paper from 3 to 15 inches wide. Horizontal and vertical tabbing can optionally be controlled by programs resident in read only memory or by a program loaded into programmable memory. Other options include a numeric keypad, pin and front feeds, a paper tape reader or reader and punch, a 2 drive cassette unit, a minifloppy disk drive and 8 K bytes of additional memory. A logic level serial interface is standard with a variety of options including RS232 and 20 mA current loop interfaces. In quantities of five or more, the TC480's price ranges from $1625 (receive only) to $1750 (keyboard send and receive), from Olivetti Corp of America, 500 Park Av, New York NY 10022, (212) 371-5500.■

Circle 588 on inquiry card.

Serial Data Translator

A serial data translator, Model ST-1, which performs code translations on a serial data stream has been announced by Sigma Data Systems, 715 Torreya Ct, Palo Alto CA 94303. The device is said to be a self-contained module, including power supply, and communicates via two RS-232 ports at up to 19.2 bps. Standard translations include the ASCII, EBCDIC and Baudot codes. Translation of terminal control codes (such as cursor control) have been implemented. Other translations are available or may be user programmed. The unit contains an Intel 8035 processor and up to 1 K of programmable read only memory. The device allows the user to change peripherals without having to modify software written for peripherals using different codes. It should be compatible with any host computer due to its serial RS-232 interface.■

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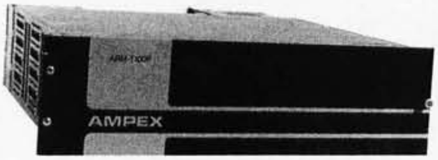
Circle 211 on inquiry card.

What's New?

Easy to Install Add-on Memory for PDP-11



The ARM-1100P, an add-on parity memory for the PDP-11, uses only one backplane slot and requires just one Unibus load, facilitating installation on any PDP-11 computer employing a Unibus structure. Each unit is supplied complete with wired card rack, power supply, interface, parity control, cooling fans and interconnecting cables. Provision is made on the rear of the chassis to connect to another chassis or to terminate the bus. An on line and off line switch removes the memory from the bus for diagnostic purposes. The core memory, which has an access time of 375 ns and a full cycle time of 700 ns provides from 32 K to 128 K of memory in 32 K increments, starting at any 8 K boundary. The ARM-1100P is priced at $4950 for 32 K 18 bit words to $12,750 for 128 K, from Ampex Corp, 200 N Nash St, El Segundo CA 90245, (213) 640-0150.■

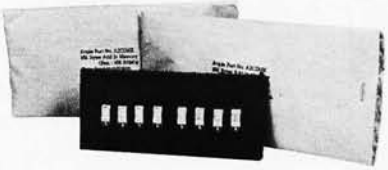
Circle 591 on inquiry card.

Point of Sale and Inventory Control

An interactive computer program which allows a microcomputer using the 8080 or Z-80 processors to be used as a Point of Sale and Inventory Control system has been released by The Data Group Inc, 5947 East 82nd St, Indianapolis IN 46250. According to the firm, POSIS can be used by a person with absolutely no prior computer experience. The program is said to converse with the user in "plain English" and to lead him through each transaction. Error handling capabilities are claimed to insure that human mistakes will be caught by the computer without destruction of vital information. POSIS stores information up to 9000 individual inventory items and is said to be able to generate a variety of management reports based on a business's inventory transactions. Additional features include: ID and password security checks at key points in the program and a complete audit trail summarizing every transaction. Minimum hardware requirements are: an 8080 or Z-80 system with 48 K bytes of user memory, a video terminal, and a Micropolis Corp dual drive disk. POSIS and its detailed instruction manual may be purchased at a cost of $750.■

Circle 592 on inquiry card.

Apple Seeds. . .



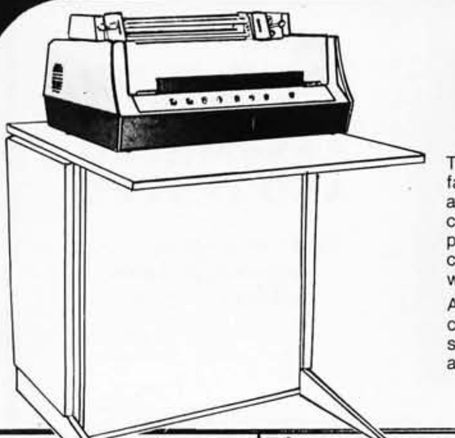
We recently purchased an additional 32 K bytes of memory for our Apple, filling up the available sockets to a full 48 K bytes of memory. Here is a picture we took of what you (or your local computer store) will get, photographed prior to insertion of the memory into an Apple II: two packages with eight of the 16 K dynamic memory chips per package. Note that with computers like the Apple which employ the large memory integrated circuit technology, there is no need for plug in memory boards when expansion is desired up to the limit of sockets built into the computer. An important consideration in purchasing such a computer, then, is how much memory can be plugged in before a new cabinet and printed circuit boards are required.

For more information on additional memory for Apple, contact Apple Computer Inc, 20863 Stevens Creek Blvd, Bldg B3-C, Cupertino CA 95014.■

Circle 590 on inquiry card.

California Industrial

Post Office Box 3097 B • Torrance, California 90503



DIABLO
HARDCOPY PRINTER

These Diablo model 1200 printers were originally manufactured for Control Data Corporation. The unit features a ninety-six character upper and lower case daisy wheel capable of printing thirty characters per second. Impact printer assures word processing quality on multiple copy forms. Adjustable tractor feed accepts paper width up to fifteen inches on a 132 character carriage.

All printers were removed from service in operating condition. Printer only $795.00. Floor stand, power supply and Control Data interface package $100.00 additional. Shipped from Los Angeles freight collect.

TELETYPE® MODEL 43

New from Teletype, the Model 43 is capable of printing 132 ASCII characters per line. Send and receive data at 10 or 30 char. per second. Keyboard generates all 128 ASCII code combinations. RS-232 interface, same as the popular Model 33. Data sheet sent upon request. Manufacturer suggested price $1377.00.

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Reliable low friction acetal resin plungers are credited for the smooth operation and long life of this premium keyboard.

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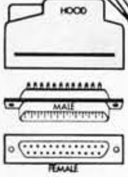
CONNECTORS



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DB25P male plug & hood
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Qty.	fe.	male	hd.
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SPECIALS

W/W same as above without ears $3.50 3/$10
72 (dual 36) W/W .156" centers. . . $2.50 3/$6

$24.88

SPERRY UNIVAC KEYBOARD

The famous Sperry Univac 1710 Hollerith keyboard assembly is now available from California Industrial for only $24.88. The ideal computer input device for accountants and mathematicians. The numeric keys are placed on the lower three rows to resemble a ten key adding machine. This format allows one handed numeric data entry. Original cost was $385. Used but guaranteed in excellent condition. Complete with documentation.

Quiet Buss™ S-100 MOTHER

The Quiet Buss from California Industrial is quality engineered. No short cuts have been taken to produce this mother board. Active termination circuitry prevents noise and crosstalk. Manufactured from extra heavy FR-4 epoxy glass. Features 2 ounce double thickness copper traces.

18 SLOT 29.95

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FROM ATARI
COLOR TELEVISION R.F. MODULATOR

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Assembled

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8K UV Erasable MEMORY

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5 volt coil, pulls 3.5v.

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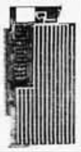

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7409	25	7460	25
7410	19	7470	25
7411	25	7472	39
7412	35	7473	39
7413	49	7474	35
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7429	39	7490	49
7430	25	7491	99
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4022	1.25
4023	.25
4024	1.19
4025	.25
4027	.69
4028	1.25
4029	1.99
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GENERAL INSTRUMENT ASCII Keyboard Encoder AY 5-3600 Prime but house marked only $4.95

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COMPUTER CONTROLED

$79.50

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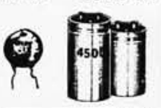

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$1.49 ea.	10	25	100	1K
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specify 7 or 8 pos.

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50 Conductor RIBBON WIRE $.69 Ft.
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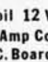

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MJ3055	.79	.75	.69	.65
2N3772	1.59	1.49	1.39	1.29
2N3904	.15	.11	.09	.07
2N3906	.15	.11	.09	.07

Diodes

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VISA master charge

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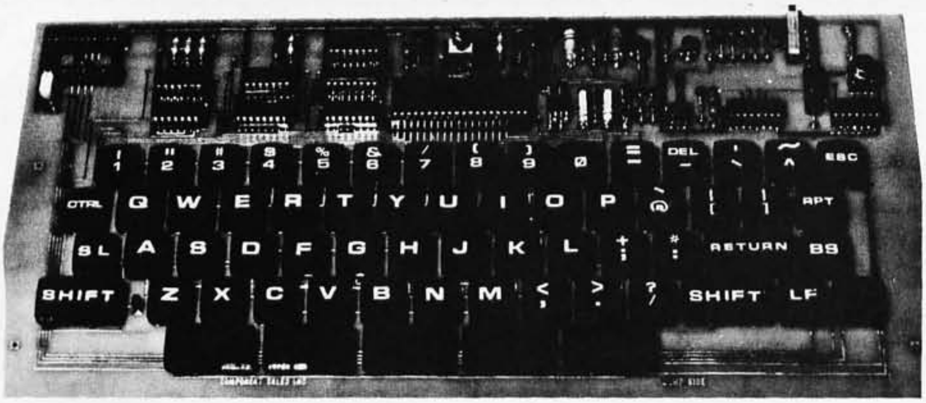
Circle 60 on inquiry card.

Stand Alone ASCII Keyboard Specification



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You Fix: $24.95
Working: $69.95
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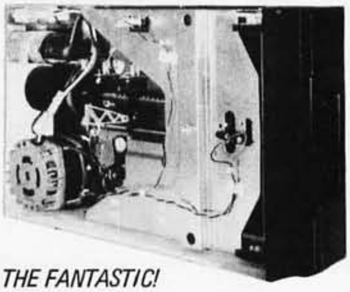
The Dumb Terminal for Smart People

80X24 with full 128 char. ASCII UC+LC font with all control characters displayed. 300-19,200 baud RS232. 2nd font addressable from keyboard in you-program-it 2708 for APL, Graphics sets, etc. Plug in monitor I/O connector, 110VAC and you are ready. INCLUDES: 'The Case', Cherry Kbd. A used monitor, ESAT 200A, all options except vector addressable cursor and modem. Bulletproof design and construction. Normally $675.00 What you always wanted your ADM3 to be:
SYSTEM"A" $649.00 10/$599.00

"The Case" Beautiful and sturdy anodized aluminum case in deep black designed to contain the ESAT 200A, and with a bezel cut out for the Cherry 'Pro' keyboard. (installed as shown above) Choose deep brown, light yellow, or crimson to accent or color code your installation. The only choice for hard-use institutional and educational applications. **$69.00, 10/ 59.00**



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Double Sided Retrofit **$200**

MINIDISKETTES (5.25')	1-9	10-24	25+
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OUR CATALOGUE *Contains IC's, T.I. Sockets (1cent/pin) Advice and much more. It is free.*

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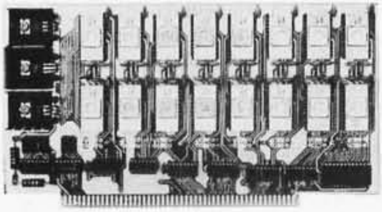
IMAGINE HAVING 16K OF SOFTWARE ON LINE AT ALL TIME!

S-100 (Imsai/Altair) Buss Compatible!

KIT FEATURES:

1. Double sided PC board with solder mask and silk screen and gold plated contact fingers.
2. Selectable wait states.
3. All address lines & data lines buffered!
4. All sockets included.
5. On card regulators.

KIT INCLUDES ALL PARTS AND SOCKETS (except 2708's). Add $25. for assembled and tested.



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$57.50 kit

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SPECIAL OFFER:

Our 2708's (450NS) are $12.95 when purchased with above kit.

Fully Static!

8K LOW POWER RAM KIT-$149.00

ADD $20 FOR 250NS

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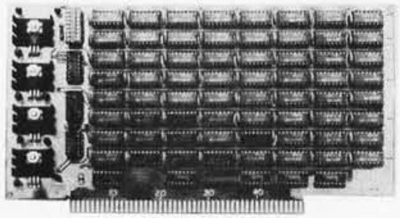
KIT FEATURES:

1. Doubled sided PC Board with solder mask and silk screen layout. Gold plated contact fingers.
2. All sockets included.
3. Fully buffered on all address and data lines.
4. Phantom is jumper selectable to pin 67.
5. FOUR 7805 regulators are provided on card.

(450NS)



USES 21L02 RAM'S!

2 KITS FOR $279

Fully Assembled & Burned In
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Blank PC Board w/ Documentation
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N.S. MM5375AA. Six Digits. With full Data. **New!**
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Same as standard 7805 except 750 MA output. TO–220. 5VDC output.
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450 NS! 2708 EPROMS
Now full speed! Prime new units from a major U.S. Mfg. 450 N.S. Access time. 1K x 8. Equiv. to 4-1702 A's in one package.
$15.75 ea. 4 FOR $50⁰⁰

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MOTOROLA 4K RAM CHIPS — 99¢ EACH 22 PIN DIP

A major U.S. computer mfg. installed thousands of these 4K Motorola RAM's on the wrong boards and had to remove them. All parts were then tested, and met **FULL SPECS!** If you don't mind a little solder on the leads, then this is the best memory buy in the world. Arranged as 4096 x 1 Bits. 470 NS. The Motorola 6605 is one of the easiest dynamic RAM's to use since it DOES NOT require multiplexed addresses as do most other 4K's such as the 4096 or 4027. A complete memory board design using the 6605 is outlined in the Motorola M6800 Applications Manual starting on page 4-70.

99¢ EACH (WITH DATA SHEET) **LOOK!**

MCM6605 **FOR $6.95 YOU GET AS MUCH STORAGE AS IN 32 - 2102's!** **8 FOR $6.95** 4096 BYTES OF RAM!

FULLY GUARANTEED! **SURPLUS BUY OF THE DECADE!!!**

4K STATIC RAM'S
2114. The new industry standard. Arranged as 1K x4. Equivalent to 4-21 L02's in 1 package! 18 pin DIP. 2 chips give 1Kx8.
2/$24. 8/$85.

OPCOA LED READOUT
SLA-1. Common Anode. .33 inch character size. The original high efficiency LED display. **75c ea.**
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Z-80 PROGRAMMING MANUAL
By Mostek, The major Z-80 second source. The most detailed explanation ever on the working of the Z-80 CPU CHIPS. At least one full page on each of the 158 Z-80 instructions. A MUST reference manual for any user of the Z-80. 300 pages. Just off the press. **$12.95**

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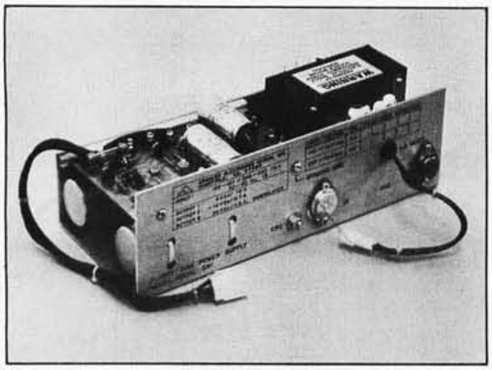
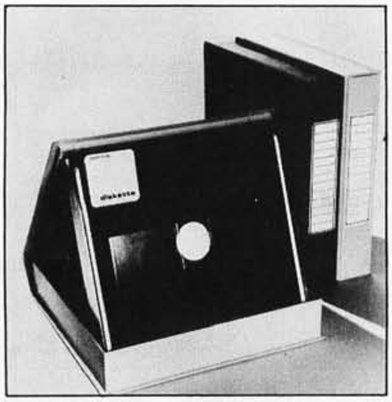
AED 101 Floppy Disk Power Supply



A power supply for floppy disk subsystems has been developed by Advanced Electronics Design Inc, POB 61779, Sunnyvale CA 94088. The AED 101 Triple Output supplies +5 VDC at 12 A, −12 VDC at 0.7 A, and +24 VDC at 3.5 A. It contains features such as switching regulation of +5 V, foldback limiting, current limiting and short circuit protection. The AED 101 is compact and is said to be available immediately. The cost is $137.50 in large production quantities ($.90 per watt).■

Circle 637 on inquiry card.

Organized Protection for Diskettes



The KAS-ETTE/10 Library Case has been announced by the Alpha Supply Company, 18350 Blackhawk St, Northridge CA 91326. These library cases are designed to handle diskettes while in use, permanently store diskettes or safely ship several diskettes in one library case. When open and in use, a plastic insert aids in locating the desired diskettes. Color coded labels applied to the spine of the library case permit users to organize a permanent library. The units are available in blue or beige. Write to the manufacturer for further information and complete price list.■

Circle 640 on inquiry card.

Fast, High Capacity Mass Storage

General Micro-Systems' new tape drive subsystem is a fast, inexpensive, high capacity mass storage device for microcomputers. The SYS I records biphase Manchester code at 1600 bits per inch on ANSI specified data cassettes with a transfer rate of 2000 characters per second at ten inches per second.

The tape record is variable length, which gives efficiency of storage space on tape, unlike the 128 or 256 byte fixed length records, where all bytes must be recorded, whether used or not. A 10 byte record may be followed by a 32 K byte record. The user program may dynamically load the next record, operating as a batch data processing system, with an unlimited amount of data. Over 700 K bytes may be recorded on one side of a cassette, using large records. Rewind time is less than 30 seconds at over 120 inches per second. Search can be accomplished at over 120 inches per second by counting the interblock gaps, getting to any record in an average time of less than 15 seconds.

One to four drives may be connected to the computer through the interface board. No power is taken from the computer bus, except what is necessary to run the simple synchronous serial interface board.

The unit is offered assembled, tested and guaranteed. The single drive is $595, the dual drive is $969, and the Altair (S-100) interface board is $168. Contact Bob Smith, General Micro-Systems, 12369 W Alabama Pl, Lakewood CO 80228.■

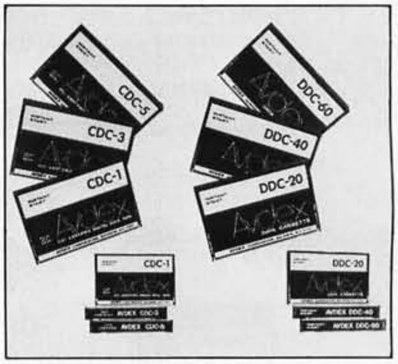
Circle 647 on inquiry card.

Minifloppy System Offers Versatility

The DataMate minifloppy disk system is a data storage and editing unit for connection between any RS-232 asynchronous ASCII coded printer or display terminal and its modem. Features include 560 addressable records of up to 128 characters each, selective data transfer rates of up to 9600 bps, editing capabilities, search modes, and manual and remote controls. The price is $1750 from Western Telematic Inc, 2435 S Anne St, Santa Ana CA 92704.■

Circle 638 on inquiry card.

Data Cassettes Specially Tailored to Small Systems Use



The introduction of a full line of data cassettes and cassette tape data acquisition systems specifically designed for use in personal computers and various small business computers has been announced by the AVDEX Corp. For users who prefer to load different programs on separate cassettes, the cassettes are available in one minute, three minute and five minute lengths and are custom loaded with extra short leaders so that the leader at no time comes in contact with the recording head. This makes possible instant start operation and eliminates any lost data as a result of failure to allow the leader to run through. In addition to short loads, a group of three cassettes in the C-20, C-40 and C-60 configuration is also available. Retail prices are: CDC-1, $4.95; CDC-3, $5.65; CDC-5, $6.35; DDC-20, $4.50; DDC-40, $5.00; and DDC-60, $5.50 from AVDEX Corp, 2280 Grand Av, Baldwin NY 11510.■

Circle 639 on inquiry card.

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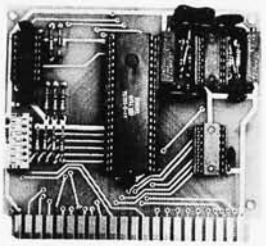
RS-232/TTY* INTERFACE

NEW

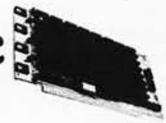
Part no. 600
- Converts RS-232 to 20mA current loop, and 20mA current loop to RS-232
- Two separate circuits
- Requires +12 and -12 volts
- Board only $4.50, with parts $7.00



UART & BAUD RATE GENERATOR*

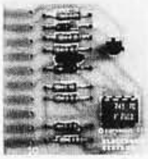
Part no. 101
- Converts serial to parallel and parallel to serial
- Low cost on board baud rate generator
- Baud rates: 110, 150, 300, 600, 1200, and 2400
- Low power drain +5 volts and -12 volts required
- TTL compatible
- All characters contain a start bit, 5 to 8 data bits, 1 or 2 stop bits, and either odd or even parity.
- All connections go to a 44 pin gold plated edge connector
- Board only $12.00; with parts $35.00

8K STATIC RAM



Part no. 300
- 8K Altair bus memory
- Uses 2102 Static memory chips
- Memory protect
- Gold contacts
- Wait states
- On board regulator
- S-100 bus compatible
- Vector input option
- TRI state buffered
- Board only $22.50; with parts $160.00

RS-232/TTL INTERFACE*



Part no. 232
- Converts TTL to RS-232, and converts RS-232 to TTL
- Two separate circuits
- Requires -12 and +12 volts
- All connections go to a 10 pin gold plated edge connector
- Board only $4.50; with parts $7.00

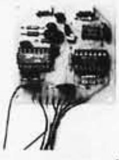
DC POWER SUPPLY*

Part no. 6085
- Board supplies a regulated +5 volts at 3 amps., +12, -12, and -5 volts at 1 amp.
- Power required is 8 volts AC at 3 amps., and 24 volts AC C.T. at 1.5 amps.
- Board only $12.50; with parts $42.50 excluding transformers

TIDMA*

Part no. 112
- Tape Interface Direct Memory Access
- Record and play programs without bootstrap loader (no prom) has FSK encoder/decoder for direct connections to low cost recorder at 1200 baud rate, and direct connections for inputs and outputs to a digital recorder at any baud rate.
- S-100 bus compatible
- Board only $35.00; with parts $110.00

Part no. 111



TAPE INTERFACE*

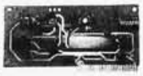
- Play and record Kansas City Standard tapes
- Converts a low cost tape recorder to a digital recorder
- Works up to 1200 baud
- Digital in and out are TTL-serial
- Output of board connects to mic. in of recorder
- Earphone of recorder connects to input on board
- Requires +5 volts, low power drain
- Board $7.60; with parts $27.50
- No coils

Part no. 107

RF MODULATOR*

- Converts video to AM modulated RF, Channels 2 or 3
- Power required is 12 volts AC C.T., or +5 volts DC
- Board $7.60; with parts $13.50

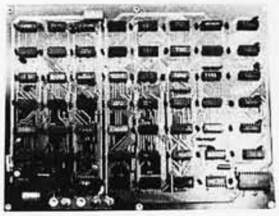
Apple II Serial I/O Interface*



Part No. 2
- Baud rates up to 30,000
- Plugs into Apple Peripheral connector
- Low-current drain
- RS-232 Input and Output

SOFTWARE
- Input and Output routine from monitor or BASIC to teletype or other serial printer.
- Program for using an Apple II for a video or an intelligent terminal. Board only – $15.00; with parts – $42.00; assembled and tested – $62.00.

TELEVISION TYPEWRITER



Part no. 106
- Stand alone TVT
- 32 char/line, 16 lines, modifications for 64 char/line included
- Parallel ASCII (TTL) input
- Video output
- 1K on board memory
- Output for computer controlled curser
- Auto scroll
- Non-destructive curser
- Curser inputs: up, down, left, right, home, EOL, EOS
- Scroll up, down
- Requires +5 volts at 1.5 amps, and -12 volts at 30 mA
- All 7400, TTL chips
- Char. gen. 2513
- Upper case only
- Board only $39.00; with parts $145.00

MODEM*

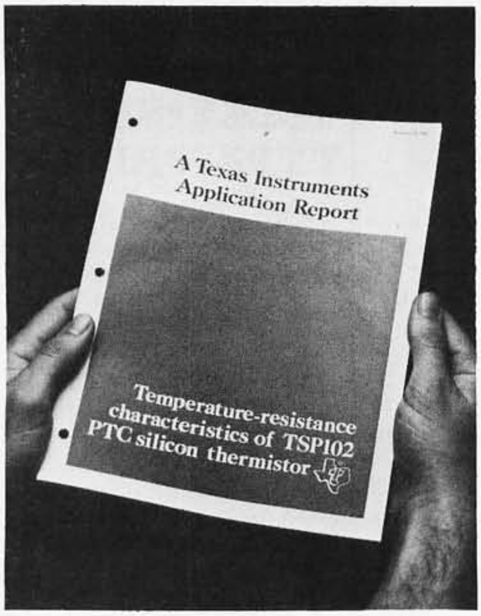
Part no. 109
- Type 103
- Full or half duplex
- Works up to 300 baud
- Originate or Answer
- No coils, only low cost components
- TTL input and output-serial
- Connect 8 ohm speaker and crystal mic. directly to board
- Uses XR FSK demodulator
- Requires +5 volts
- Board $7.60; with parts $27.50

To Order:

Mention part number and description. For parts kits add "A" to part number. Shipping paid for orders accompanied by check, money order, or Master Charge, BankAmericard, or VISA number, expiration date and signature. Shipping charges added to C.O.D. orders. California residents add 6.5% for tax. Parts kits include sockets for all ICs, components, and circuit board. Documentation is included with all products. Dealer inquiries invited. 24 Hour Order Line: (408) 374-5984.* Designed by John Bell.

Circle 125 on inquiry card.

Temperature Resistance Applications Report



Bulletin CA-195 from Texas Instruments, POB 5012, Dallas TX 75222, explains the temperature-resistance characteristics of the TSP102 PTC silicon thermistor. The 22-page applications report is titled *Temperature-Resistance Characteristics of the TSP102 Positive-Temperature-Coefficient Silicon Thermistor* and can be obtained by writing to the company.■

Circle 654 on inquiry card.

Manual on Relocatable Assembler for 2650

A manual describing the Signetics 2650 Relocatable Assembler can be purchased for $4 from Signetics. The assembler is a two pass program that builds a symbol table, issues error messages, produces a program listing, and outputs a computer readable object (load) module. The program includes conditional assembly, symbolic and relative addressing, forward references, free format source code, self-defining constants, complex expression evaluation, relocatability, and pseudo operations. The assembler is capable of generating data in several number based systems, including ASCII character code.

The manual covers such subjects as a summary of 2650 instruction mnemonics, ASCII code and character set, conversion of previous cross assembler source programs and 2650 assembler grammar.

Contact Signetics, MOS Microprocessor Marketing, POB 9052, 811 E Arques Av, Sunnyvale CA 94086, (408) 739-7700.■

Circle 655 on inquiry card.

Computer Aided Education Materials

ENTELEK is currently offering a large list of directories, reports, conference proceedings, and periodicals on the subject of computer-based education. Among the nearly 30 titles offered are *Index to Computer Based Learning – 1976, Research Guidelines For Computer-Assisted Instruction, The LOGO Language – Learning Mathematics Through Programming, Proceedings of the Fall 1976 EDUCOM Conference,* and the 1978 edition of *Computer Based Education Abstracts* compiled by ENTELEK. The *ENTELEK CBE Abstracts* contain selected reports summarized in abstracts up to 250 words in length and brought together under headings that include "CAI in Reading," "CAI in Science," "Computer Aided Counselling," "Minicomputers," "Networks," "Decision Rules," "Simulation," etc. A complete list of titles and prices is available from ENTELEK, Dept T, POB 810, Newburyport MA 01950.■

Circle 656 on inquiry card.

Electric Counter Selection Guide

A new six page, four color selection guide from Hewlett-Packard summarizes specifications and characteristics of 15 counters in HP's electronic counter line. Included are models from simple, low cost, frequency counters to sophisticated high speed universal and microwave counters. Described are two new microprocessor controlled models: Model 5342A Microwave Counter for automatic measurements to 18 GHz, and the Model 5370A Universal Time Interval Counter with a resolution of ±20 picoseconds. The selection guide *Electronic Counters* is available free of charge from Hewlett-Packard, 1501 Page Mill Rd, Palo Alto CA 94304.■

Circle 658 on inquiry card.

Free Computer Guides

To keep you up to date on new computer products, stores, etc, the following guides are available free of charge: *A Shopping Guide to Computer Stores, A Guide to Computing Magazines and Books, A Guide to Computer Clubs and User Groups, A Guide to the Home Computer.* Each guide is approximately 50 pages long. To get a copy of any guide simply write to Microcomputer Resource Center, 5150 Anton Dr, Room 212, Madison WI 53719. It would be appreciated by the Center if you would send $.35 in stamps for 1st class postage for each guide requested (18¢ for 3rd class).■

Circle 657 on inquiry card.

Electro Rent Microcomputer Development and Test Equipment Rental Catalog

This 8 page catalog features nearly 200 pieces of the latest microcomputer and minicomputer development and test equipment available for rental. Equipment manufacturers include Intel, Tektronix, Biomation, Prolog, Digital Equipment, Beehive, Hewlett-Packard, iCOM, Remex and Texas Instruments. For further information contact Electro Rent, 4131 Vanowen Pl, Burbank CA 91505.■

Circle 573 on inquiry card.

New "Breadboarding and Test Equipment" Catalog

A new, full-color 12 page catalog is available describing Continental Specialties Corporation's entire line of electronic prototyping development and testing hardware. The contents include quick test sockets, experimenter sockets, and Proto Board breadboards, Design Mate test instruments, Proto Clip IC test clips and clip-on IC Logic Monitors. *Breadboarding & Test Equipment* is available from Continental Specialties Corporation, 70 Fulton Ter, New Haven CT 06509.■

Circle 572 on inquiry card.

Industrial Control Microcomputers Brochure

A new 8 page brochure describes Wyle's line of microcomputers, digital logic modules, and software. The line includes parallel and serial digital IO, analog IO, communications modules and a wide variety of other units including over 200 digital logic modules. Also available are modules to allow the Wyle hardware to couple directly to existing 4-20 and 10-50 mA current loops. To obtain a copy of this brochure contact Wyle Laboratories Computer Products, 3200 Magruder Blvd, Hampton VA 23666.■

Circle 571 on inquiry card.

NEW ANNOUNCING

The EW-2001 A "Smart" VIDEO BOARD KIT At A "Dumb" Price!

A VIDEO BOARD + A MEMORY BOARD + AN I/O BOARD – ALL IN ONE!

- STATE OF THE ART TECHNOLOGY USING DEDICATED MICROPROCESSOR I.C.
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*Min. 2K required for operation of this board.

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- 128 displayable ASCII characters (upper and lower case alphanumeric, controls)
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Sockets	$10.00
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NOTE: If you have this 63 Key Teletype Keyboard you can buy the Kit without it for only $44.95.

Circle 242 on inquiry card.

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MB-9 4KX8 RAM/PROM Board uses 2112 RAMS or 82S129 PROM kit without RAMs or PROMs $72.00

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2525	1.50	MH0025	1.50
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8T09	1.25	8T90	2.50
8T10	2.50	8T95	2.30
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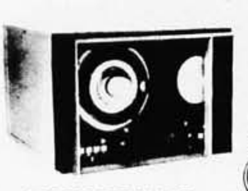
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Circle 292 on inquiry card.

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1N4005	600v	1A	.08
1N4007	1000v	1A	.15
1N4148	75v	10mA	.05
1N753A	6.2v	z	.25
1N758A	10v	z	.25
1N759A	12v	z	.25
1N4733	5.1v	z	.25
1N5243	13v	z	.25
1N5244B	14v	z	.25
1N5245B	15v	z	.25

SOCKETS/BRIDGES

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14-pin	pcb	.25	ww	.40
16-pin	pcb	.25	ww	.40
18-pin	pcb	.25	ww	.75
22-pin	pcb	.45	ww	1.25
24-pin	pcb	.35	ww	1.10
28-pin	pcb	.35	ww	1.45
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2N3904	NPN (Plastic)	.10
2N3054	NPN	.35
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4001	.15
4002	.20
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4008	.95
4009	.45
4010	.45
4011	.20
4012	.20
4013	.40
4014	.95
4015	.90
4016	.35
4017	1.10
4018	1.10
4019	.50
4020	.85
4021	1.00
4022	.85
4023	.25
4024	.75
4025	.30
4026	1.95
4027	.50
4028	.95
4030	.35
4033	1.50
4034	2.45
4035	1.25
4040	1.35
4041	.69
4042	.95
4043	.95
4044	.95
4046	1.75
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4050	.45
4066	.95
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4071	.35
4081	.70
4082	.45
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7400	.15
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7403	.20
7404	.15
7405	.25
7406	.35
7407	.55
7408	.25
7409	.15
7410	.10
7411	.25
7412	.30
7413	.35
7414	1.10
7416	.25
7417	.40
7420	.15
7426	.30
7427	.45
7430	.15
7432	.30
7437	.30
7438	.35
7440	.25
7441	1.15
7442	.45
7443	.65
7444	.45
7445	.65
7446	.95
7447	.95
7448	.65
7450	.25
7451	.25
7453	.20
7454	.25
7460	.40
7470	.45
7472	.40

7473	.25
7474	.30
7475	.35
7476	.40
7480	.55
7481	.75
7483	.95
7485	.75
7486	.25
7489	1.35
7490	.55
7491	.95
7492	.95
7493	.35
7494	.75
7495	.60
7496	.80
74100	1.15
74107	.35
74121	.35
74122	.55
74123	.55
74125	.45
74126	.35
74132	1.35
74141	.90
74150	.85
74151	.65
74153	.75
74154	.95
74156	.95
74157	.65
74161	.85
74163	.85
74164	.60
74165	1.50
74166	1.35
74175	.80

74176	1.25
74180	.75
74181	2.25
74182	.95
74190	1.75
74191	1.05
74192	.75
74193	.85
74194	1.25
74195	.95
74196	1.25
74197	1.25
74198	2.35
74221	1.00
74367	.85
75108A	.35
75110	.35
75491	.50
75492	.50
74H00	.15
74H01	.25
74H04	.20
74H05	.20
74H08	.35
74H10	.35
74H11	.35
74H15	.45
74H20	.30
74H21	.25
74H22	.40
74H30	.20
74H40	.25
74H50	.25
74H51	.25
74H52	.15
74H53J	.25
74H55	.20

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74H101	.75
74H103	.75
74H106	.95
74L00	.25
74L02	.25
74L03	.30
74L04	.30
74L10	.30
74L20	.35
74L30	.45
74L47	1.95
74L51	.45
74L55	.65
74L72	.45
74L73	.40
74L74	.45
74L75	.55
74L93	.55
74L123	.85
74S00	.35
74S02	.35
74S03	.30
74S04	.30
74S05	.35
74S08	.35
74S10	.35
74S11	.35
74S20	.35
74S40	.20
74S50	.20
74S51	.25
74S64	.20
74S74	.35
74S112	.60
74S114	.65

74S133	.40
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74S158	.30
74S194	1.05
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74LS00	.25
74LS01	.35
74LS02	.35
74LS04	.30
74LS05	.45
74LS08	.25
74LS09	.35
74LS10	.35
74LS11	.35
74LS20	.25
74LS21	.25
74LS22	.25
74LS32	.40
74LS37	.35
74LS40	.45
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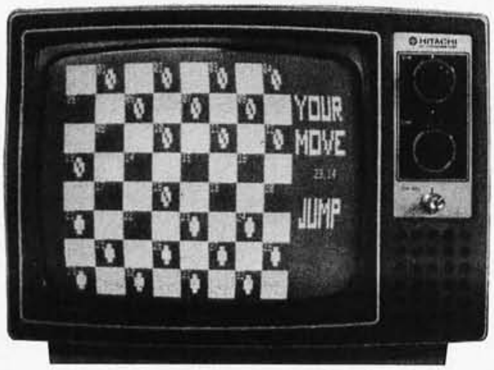
Circle 180 on inquiry card.

Video Checkers on Cassette for PolyMorphic Video Interface



Compu-Quote has developed several games on cassettes, recorded in the Tarbell format and programmed in MITS BASIC.

Contained on one cassette is Video Checkers, which produces checkerboard graphics on a video display when used with the PolyMorphic Video Interface and 64 character option. The game plays under MITS BASIC (3.1). Two versions of the program on one 60 minute cassette play a challenging game which conforms to international rules. The first version requires a total of 16 K of memory, inclusive of 8 K BASIC. The second version is more graphic and requires an additional 4 K.

The checkerboard is pictorially displayed on the video monitor. As the player and computer each take turns, the checkers blink and move to indicate their passage. Kinged pieces are identified on the display and messages appear at the right of the board relating to each move. In accordance with international rules of the game, the program will not accept illegal moves and warns of their entry.

Included with Video Checkers is a 9 page instruction book. The author of Video Checkers has invited purchasers of the cassette to add enhancements to the program. Therefore an entire program listing is included. Video Checkers and manual may be ordered for $10 from Compu-Quote, 6914 Berquist Av, Canoga Park CA 91307.■

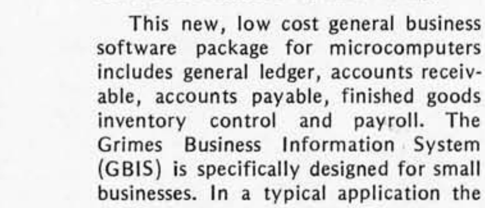
Circle 648 on inquiry card.

Low Cost Business Software Package

This new, low cost general business software package for microcomputers includes general ledger, accounts receivable, accounts payable, finished goods inventory control and payroll. The Grimes Business Information System (GBIS) is specifically designed for small businesses. In a typical application the GBIS can store up to 400 customer listings, 50 vendors, 400 line items of inventory, 25 employee records and 60 general ledger accounts on a single minifloppy diskette. Requiring only 24 K of memory, the GBIS is a system in which receivables decrease book inventory, payables increase book inventory, and general ledger accounts are updated automatically. GBIS is written in North Star BASIC, although other disk BASIC languages can be used for the listings. There are 51 programs with 120 pages of documentation. A GBIS Users Group has been formed entitling purchasers to updates as they become available. The cost is $200 (include $2.50 to cover postage and handling). The package can be obtained from The Computer Mart, 633 W Katella Av, Orange CA 92667.■

Circle 649 on inquiry card.

INFO 2000 Disk Systems Fully Software Supported for 8080 and Z-80



INFO 2000 Disk Systems owners may now utilize expanded software for both 8080 and Z-80 microcomputers. Previously, the INFO 2000 Corporation offered Z-80 based software only for their disk systems, but have increased the disk operating software capability using Digital Research CP/M. Among the software packages which operate under CP/M are two full versions of disk BASIC, including Microsoft Extended Disk BASIC (4.41), priced at $350. Also available is a Structured Systems Group QSORT at $95. This is a high speed, general purpose sort package. A name and address maintenance system, called NAD, includes mailing labels, and is priced at $79. The manufacturer states that all software is currently available for immediate delivery for use in INFO 2000 Disk Systems.

Still available for Z-80 systems is the complete TDL software package including 12 K BASIC, macro assembler, Z-TEL text editor and word processor. INFO 2000 has expanded this software to operate under CP/M and Zapple operating systems. The entire software package is priced at $215.

All INFO 2000 software is designed to operate on INFO 2000 Disk Systems which employ the PerSci 277 dual diskette drive with intelligent controller. The disk system is available for all Altair (S-100) microcomputers using Z-80 or 8080 processors, for Digital Group Z-80 and 8080 systems and for the Heathkit H8. Contact INFO 2000 Corp, 20630 S Leapwood Av, Carson CA 90746, (213) 532-1702.■

Circle 652 on inquiry card.

Z-80 and 8080 Business Programs

Structured Systems Group announces a series of business programs designed to run on the 8080 or Z-80 processors with the CP/M operating system. All software comes fully documented. The following products are being offered:

General Ledger (GL) is a comprehensive system designed for professional accountants and small businesses. Any number of custom charts of accounts may be set up to handle single or multiple departments. The system verifies data interactively. Report formats and headings may be customized. Documentation is included, and no prior computer knowledge is required. Written in CBASIC, the GL system costs $995.

The Name and Address (NAD) system maintains files and allows selection on all fields for printing labels, reports, or new files. NAD is documented and written in CBASIC. The price is $79.

QSORT is a fast full disk sort and merge program featuring automatic operation, multiple sort keys, and complete backup. In 8080 code, the price is $95.

CBASIC is a comprehensive, commercially oriented compiler and interpreter including full disk access, a PRINT USING feature, 14 digits of precision, and an 85 page manual. The price is $99.95.

For more information, contact Structured Systems Group, 5615 Kales Av, Oakland CA 94618, (415) 547-1567.■

Circle 650 on inquiry card.

New Natural Language Operating System

NLOS is a phase oriented natural language operating system. Information in the form of sentences entered into the system is broken down into phrases which are classified both gramatically and by the type of information they convey. This is made possible by a dictionary of phrases maintained by the system in programmable memory. Hardware requirements include any 8080 or Z-80 processor, audio cassette tape interface, a serial IO board and a minimum of 12 K of programmable memory. NLOS/1 comes with a fully documented set of assembly language source listings with commentary on possible ways to use NLOS/1. The price for NLOS is $200; it can be obtained from Cybermate, RD #3, POB 192A Nazareth PA 18064.■

Circle 651 on inquiry card.

FOR ALL CUSTOMERS EXCEPT CALIF. CALL TOLL FREE 800-421-5809

410D Static Rams 100 for $8.75 ea	6571AP Character Gen 5 for $10.00 ea	4096 Dynamic Rams 100 for $3.50 ea	DM8131N 100 for $2.25 ea.	TMS-4027 Dynamic Rams 100 for $3.50 ea	21L02 (450ns) Static Rams 100 for $1.10 ea	1702A E PROM 8 for $3.75 ea	6502 Microprocessor 5 for $11.00 ea	2708 (450ns) E PROM 8 for $11.00 ea	21L02 (250ns) Static Rams 100 for $1.36 ea
Z-80A Microprocessor 5 for $25.00 ea	8212 8 Bit I O Port 25 for $3.00 ea	4116 (200ns) 16K Dynamic Ram for Apple Users 16 for $24.00 ea	Z 80 Microprocessor 5 for $20.00 ea	8224-4 Clock Gen & Dvr 25 for $8.75 ea	74367 Hex Buffer TS 100 for .70¢ ea	74368 Hex Inverter TS 100 for .70¢ ea	74LS367 Hex Buffer 100 for .70¢	74LS368 Hex Inverter 100 for .70¢	2513 (5v) Character Gen 5 for $9.00 ea

MICROCOMPUTER COMPONENTS

MICROPROCESSOR'S

F8	8 Bit CPU (3850)	16.95 •	
Z80	8 Bit CPU (3880) (2MHz)	22.00 •	
Z80A	8 Bit CPU (4MHz)	28.00 •	
CDP1802CD	8 Bit CPU	19.95 •	
2650	8 Bit CPU	24.95	NEW
AM2901	4 Bit CPU	22.95	
6502	8 Bit CPU	12.75 •	
6800	8 Bit CPU	18.95 •	
6802	MPU	25.00	NEW
8008 1	8 Bit CPU	9.95 •	
8035	8 Bit CPU w clock 64 byte ram	22.00	NEW
8080A	8 Bit CPU	11.95 •	
8085	8 Bit CPU (1 2in)	27.00	NEW
TMS9900TL	16 Bit CPU	67.00	

8080A SUPPORT DEVICES

8212	8 Bit I O Port	3.50 •	
8214	Priority Interrupt Control	9.00 •	
8216	Bi-Directional Bus Driver	3.75 •	
8224	Clock Generator & Driver (2MHz)	3.50 •	
8224 4	Clock Generator & Driver (4MHz)	9.95 •	
8226	Inverting Bi-Directional Bus Driver	3.95	NEW
8228	System Controller & Bus Driver	7.95 •	
8238	System Controller & Bus Driver	7.50 •	
8251	Programmable Communication Int	9.95 •	
8253	Programmable Interval Timer	21.95 •	
8255	Programmable Peripheral Int	21.95 •	
8257	Prog. Direct Mem Access Cont	21.95 •	
8259	Programmable Interrupt Cont	21.95 •	
8275	Programmable CRT Controller	75.00	NEW
8279	Programmable Keybd Disp Int	20.00	NEW

FLOPPY DISC CONTROLLER

1771B	(WD)	55.95
1771B 01	(WD)	57.95 •

TV GAME CHIPS

TMS1955	6 Games TI	7.95 •

KEYBOARD CHIPS

AYS 2376	88 Keys 8 Bit + Parity (100KHz)	13.75 •
AYS 3600	90 Keys 10 Bit (100KHz)	13.75 •

FIFO

3341A	64 × 4 Bit 1.0 MHz	6.50
2812D	32 × 8 Bit 0.5 MHz	16.95 •

F 8 SUPPORT DEVICES

3851	Program Storage Unit	13.95 •
3853	Static Memory Interface	13.95 •

STATIC RAMS

		1-16	17-63	64-up	
21L02	1K × 1 (450ns)	1.50	1.24	1.18 •	
21L02	1K × 1 (350ns)	1.60	1.35	1.25 •	
21L02	1K × 1 (250ns)	1.75	1.60	1.50 •	
4100	4K × 1 (200ns)	10.75	10.00	9.25 •	
1101A	256 × 1 (1 usec)	1.00	.90	.80 •	
2101 1	256 × 4 (450ns)	2.95	2.75	2.60	
2102	1K × 1 (1 usec)	1.25	1.15	1.00	
2102 1	1K × 1 (450ns)	1.40	1.25	1.10 •	
2111 1	256 × 4 (450ns)	3.95	3.50	3.25 •	
2112 1	256 × 4 (450ns)	2.95	2.80	2.69	
2114 3	1024 × 4 (300ns)	11.00	10.00	9.25 •	
2125L	1024 bit (70ns)	11.10	9.00	8.30	NEW
2147	4096 × 1 (70ns)	31.50			NEW
31L01	16 × 4 (110ns)	2.50	2.35	2.00	
3106	256 × (Tri State)	3.95	3.70	3.25	
3107	256 × 1 (80ns)	3.05	3.70	3.25	
TMS 4044-45	4K × 1 (450ns)	9.85	9.00	8.95	NEW
4200A	4K × 1 (250ns)	12.95	11.95	11.00 •	
TMS 4045-45	1024 × 4 (450ns)	11.00	10.00	9.25	
5101	256 × 4 (650ns)	8.30	1.40	7.25 •	
74C89	16 × 4 (275ns)	3.25	3.05	2.85	
7489	16 × 4 (80ns)	2.25	2.10	1.90	
74S201	256 × 1 (50ns)	4.50	4.00	3.75	
P8101	256 × 4 (450ns)	4.20	3.40	2.80	NEW
P8155	256 × 8 22	17.00	14.00		NEW
P8156	256 × 8 22	21.00	18.00		NEW
8599	16 × 4 (50ns)	1.88	1.75	1.60	
91L02APL	1K × 1 (250ns)	1.65	1.45	1.30	

CHARACTER GENERATORS

2513	Upper (−12 +5)	6.75	
2513	Lower (−12 +5)	6.75	
2513	Upper 5 volt	9.75 •	
2513	Lower 5 volt	10.95 •	
2516	Upper (−12 +5)	10.95	NEW
MCM6571	Upr Lwr & Greek Up Scan	10.95	
MCM6571A	Upr Lwr & Greek Down Scan	10.95	
MCM6574	Character Gen	13.25 •	
MCM6575	Character Gen	13.25 •	

WAVEFORM GENERATOR

8038	VCO	3.50 •
MC4024	Dual VCO	2.25 •
566	VCO Function	1.50 •

CLOCK CHIPS

MM5311	24 Pin BCD Output 6 Digits	6.95
MM5313	28 Pin 6 Digits	6.95
MM5314	24 Pin 6 Digits	6.95
MM5316	40 Pin Alarm Ledout (F3817)	6.95
MM5375	Clock Chip	0.95
CT7001	Clock Chip Calendar	6.00

PROM'S

1702A	256 × 8 Bit (1 us) TS Erasable	4.00 •	
2704	512 × 8 Bit (450ns) TS Erasable	15.00 •	
2708	1024 × 8 Bit (450ns) TS Erasable	12.00 •	
2716 (5+12)TI	1024 × 16 Bit (450ns) Erasable	30.00 •	
2716 (5v)INTL	1024 × 16 Bit (450ns) Erasable	38.00	NEW
2758 (5v)	1024 × 8 Bit (450ns) Erasable	28.80	NEW
D3601	1K Bit 256 X 4 OC (70ns)	4.50	
D3604	4K Bit 512 × 8 OC (90ns)	13.00	NEW
5203AQ	256 × 8 Bit (1 us) TS Erasable	5.00 •	
5204AQ	512 × 8 Bit (1 us) TS Erasable	6.00	
6834	512 × 8 Bit (500ns) Erasable	17.50 •	
6834 1	512 × 8 Bit (750ns) Erasable	14.95	
82S23B	32 × 8 Bit (50ns) OC	4.00	
82S129B	256 × 4 Bit (50ns) TS	4.25	
8223B	32 × 8 Bit (50ns) OC	3.50 •	

6800 SUPPORT

6810P	128 × 8 Static Ram (450ns)	4.95	
68B10P	128 × 8 Static Ram (250ns)	6.00	NEW
6820P	Peripheral Interface Adapter	7.50 •	
6821P	Peripheral Interface Adapter	7.50	NEW
6828P	Priority Interrupt Controller	11.25	
6834P	512 × 8 Bit Erasable Prom 500	16.95	
6850P	Asynchronous Comm Adapter	9.75 •	
6852P	Synchrous Serial Data Adapter	11.75 •	
6860P	0-600 BPS Modem	10.00 •	
6862P	2400 BPS Modulator	14.50 •	
6871P	Clock	28.00	NEW
6875P	Clock	8.75	NEW
6880P	MPU Bidir Bus Ext	2.50 •	

Z80 SUPPORT DEVICES

3881	Parallel I O Controller	12.95
3882	Counter Timer Circuit	12.95

SHIFT REGISTERS STATIC

2518B	32 × 6 Bit 2.0 MHz	3.95
2533V1	1024 × 1 Bit 1.15 MHz	2.00
TMS3002	50 × 2 Bit 1.0 MHz	1.00
TMS3112	32 × 6 Bit 2.0 MHz	3.95
MM5058	1024 × 6 Bit 1.5 MHz	2.00

KIM

6102		8.00	NEW
6502	CPU	11.95 •	
6520	Peripheral Interface Adapter	11.95 •	
6522	Peripheral Interface Adapter	9.25	
6530	RAM/ROM I/O Interval Timer	15.95	
6530-002	RAM/ROM I/O Interval Timer	15.95	
6530-003	RAM/ROM I/O Interval Timer	15.95	
6530-004	TIM RAM/ROM I/O Interval Tim	15.95	
6530-005	RAM ROM I O Interval Timer	15.95	

DYNAMIC RAMS

4160/4116	16K × 1 Bit (200ns) (16 pin)	32.00 •	
1103	1024 × 1 Bit (300ns)	1.00 •	
2104	4096 × 1 Bit (300ns) (16 pin)	4.00 •	
2107B	4096 × 1 Bit (300ns) (22 pin)	4.25 •	
2107B 4	4096 × 1 Bit (270ns) (22 pin)	3.95 •	
TMS4050	4096 × 1 Bit (300ns) (18 pin)	4.00 •	
TMS4060	4096 × 1 Bit (300ns) (22 pin)	4.50	
TMS4070 2	16K × 1 Bit (200ns) (16 pin)	32.00	NEW
4096	4096 × 1 Bit (300ns) (16 pin)	4.00 •	
4116/4160	16K × 1 Bit (200ns) (16 pin)	32.00 •	
MM5270	4096 × 1 Bit (200ns) 22 pin	4.50 •	
MCM6605	4096 × 1 Bit (200ns) (22 pin)	5.00 •	

USRT

S2350	500K Baud (5 volt)	10.75 •

UART'S

AY5-1013A	30K Baud (−12 +5)	5.25 •
AY5-1014A	40K Baud (5 volt)	8.25 •
TR1602B	20K Baud (−12 +5)	5.25 •
TMS6011	200K Baud (−12 +5)	5.95 •
IM6402	200K Baud (5 volt)	10.80
IM6403	200K Baud (5 volt)	10.80

MISC OTHER COMPONENTS

N8T20	Bi-Directional One Shot	3.30 •	
N8T26	MPU 3T Dir Bds Ext	2.10 •	
N8T95	Hex Buffer Tri State	1.35	
N8T96	Hex Inverter Tri State	1.35	
N8T97	Hex Buffer Tri State	1.35	
N8T98	Hex Inverter Tri State	1.35	
81LS95	Lo Pwr TS Octal Buffer (True)	2.00	
81LS97	Lo Pwr TS Octal Buffer (Inv)	2.00	
1488	RS232 Quad Line Driver	1.75 •	
1489	RS232 Quad Receiver	1.75 •	
D3205	1 of 8 Binary Decoder	4.00	NEW
D3207A	Quad NAND to MOS Driver	4.55 •	
D3208A	Hex Sense Amplifier	14.20	NEW
D3211		10.00	NEW
83222	Refresh Controller	9.70	NEW
83242	Address Multiplexer & Refsh Cntr	10.15	NEW
D3245	Quad TTL MOS Driver	5.60	NEW
C3404	6 Bit Latch 12ns O/P Delay	8.75 •	
P3408A	Hex MOS Sense Amp Tri State	12.00 •	
P4201A	Clock Generator	5.20 •	
MM5320	TV Camera Sync Generator	7.50	
MM5369	Oscillator Pre Scaler	1.90	
TMS5501	Multifunction I/O Controller	24.95	
DM8130	10 Bit Comparator	2.90	
DM8131	4 Input and NAND Tri State	2.75 •	
DM8833	Quad Tri State Transceiver (True)	2.50	
DM8835	Quad Tri State Transceiver (Inv)	2.50	
DM8837	Hex Unified Bus Receiver	2.50	
MK50240	Organ Top Octave Generator	20.00	NEW
MK50250	Clock	15.00	NEW

MOTHER BOARD's — S-100 Style

13 slot — w/front panel slot

BARE BOARD	$35.00
KIT	$95.00
22 slot	$149.95

ASSEMBLED & TESTED

CONNECTORS

DB — 25P	$3.00
DB — 25S	$4.00
COVER	$1.50
44 Pin — PC & EYE	$1.95
44 Pin — WW	$2.50
86 Pin — (6800) PC	$5.00
86 Pin — (COSMAC ELF) PC	$5.00
100 Pin — (Altair) PC	$4.50
100 Pin — (Imsai) PC	$3.75
100 Pin — (Imsai) WW	$4.25

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STATIC RAM BOARDS

8K

250ns ASSEMBLED & TESTED	$189.95
450ns ASSEMBLED & TESTED	$149.75
250ns KIT	$169.95
450ns KIT	$125.00
BARE BOARD	25.00
6800 ADAPTER to S-100 System KIT	$12.95

16K

250ns ASSEMBLED & TESTED	$435.00
450ns ASSEMBLED & TESTED	$380.00
450ns KIT	$335.00

32K

250ns ASSEMBLED & TESTED	$850.00
450ns ASSEMBLED & TESTED	$775.00
450ns KIT	$675.00

DYNAMIC RAM BOARDS

On board Refresh power is provided with no wait states or cycle stealing required.
+8VDC 400MA DC, +18VDC 400MA DC and −18VDC 30MA DC.

EXPANDABLE 32K

8K (375ns)	KIT	$151.00
16K (375ns)	KIT	$259.00
24K (375ns)	KIT	$367.00
32K (375ns)	KIT	$425.00

EXPANDABLE 64K

16K (375ns)	KIT	$281.00
32K (375ns)	KIT	$519.00
48K (375ns)	KIT	$757.00
64K (375ns)	KIT	$995.00

JADE PARALLEL/SERIAL INTERFACE KIT

$124.95 KIT

S-100
2 Serial Interfaces with RS232 interfaces or 1 Kansas City cassette interface
Serial interfaces are crystal controlled
Selectable baud rates
Cassette works up to 1200 baud
1 parallel port

JADE VIDEO INTERFACE KIT

FEATURES $99.95

S-100 Bus Compatible
32 or 64 Characters per line
16 lines
Graphics (128 × 48 matrix)
Parallel & Compositive video
On board low-power memory

Powerful software included for cursor, home, EOL, Scroll Graphics/Character, etc.
Upper case, lower case & Greek
Black-on-white & white-on-black

COMPU/TIME CT 100

S100 BUS COMPATIBLE

TIME & CALENDAR

Microprocessors need the power that a real time clock can offer. Date and time becomes instantly available. **COMPU/TIME** does not have to be initialized every time the system is powered up. It possesses a crystal controlled time base to obtain superior accuracy and has two setable coincidence counters. Time, date, and counters are set via software.

COMPUTATIONAL FUNCTION

Microprocessors need to be complimented by hardware arithmetics to free up memory pages dedicated to floating point routines and mathmatical software. **COMPU/TIME** provides a 40 function calculator array so that algebraic, trigonometric, basic arthmetic problems can be solved without the need of developing sophisticated software.

Buy It Your Way

COMPU TIME	CT100	$199	KIT	$245	Assembled
COMPU only	C101	$149	KIT	$189	Assembled
TIME only	T101	$165	KIT	$205	Assembled
COMPU TIME	PC Board only			$80	

KIM—1

ASSEMBLED & TESTED $245.00

MEMORY PLUS

for KIM—1
8K RAM (21L02)
8K EPROM
ASSEMBLED & TESTED
$245.00

AMERICAN EXPRESS Cards Welcome

NUMBER CRUNCHER

The CT200 is a number oriented microprocessor intended for use in those applications that require fast versatile mathematical solutions.
THIS IS NOT A CALCULATOR CHIP. THERE ARE NO KEY DELAYS.
The CT200 has a unique architecture that is designed to be a TASK processing system within a system. This unique architecture will allow the CT200 to work and run with ANY S100 BUS microprocessor system. It is completely compatible with Z80 4MHZ version, also 8080, 6800, 6502 microprocessor. A micro incoded instruction set allows programming in a calculator like language. The instruction set includes a full set of test and branch instructions. All decoding of S100 bus signals (for select or control functions) is performed with strobed latches to eliminate the possibility of glitches.

PRICE $249.00
Includes Manual, ASSEMBLED & TESTED

full ASCII PROFESSIONAL KEYBOARDS

Full 128 Character ASCII
Tri-Mode MOS Encoding
MOS DTL TTL Compatable Output
Two key Rollover
Level and Pulse Strobe
Shift and Alpha Lock
Selectable Parity
Positive or Negative Logic

MODEL 756 (56 keys)

PRICING INFORMATION

Model 756 (assembled)	$75.95
Model 756K (kit)	64.95
Model 702 Enclosure	29.95
Model 710 Numeric Pad	9.95
Model 756MF Mtg Frame	8.95

TARBELL CASSETTE INTERFACE

- Plugs directly into your IMSAI or ALTAIR*
- Fastest transfer rate 187 (standard) to 540 bytes second
- Extremely Reliable — Phase encoded (self clocking)
- 4 Extra Status Lines 4 Extra Control Lines
- 37 page manual included
- Device Code Selectable by DIP switch
- Capable of Generating Kansas City tapes also
- No modification required on audio cassette recorder

JADE KIT*	$99.95	ASSEMBLED	$175.00
6 month warranty from JADE		MANUAL	$4.00

DATA COMMUNICATIONS ADAPTER

80-103A Serial I/O and FSK modem for professional and hobby communications

- Completely compatible with your IMSAI, ALTAIR* SOL** or other S-100 microcomputers. Trademarks of *MITS, **Processor Technology
- Designed for use on the dial telephone or TWX networks, or 2-wire dedicated lines, meets all FCC regulations when used with a CBT coupler
- All digital modulation and demodulation with on board cyrstal clock and precision filter mean that NO ADJUSTMENTS ARE REQUIRED
  - Bell 103 standard frequencies
  - Automated dial (pulsed) and answer
  - Originate and answer mode
  - 110 or 300 BPS speed select
  - Complete self test capability
  - Character length, stop bit, and parity
  - 90 day warranty and full documentation

PRICES:		
	BARE BOARD and Manual	$49.95
	Assembled (48 hr. burn in)	$279.95
	JG DCA KIT	$159.95

JADE REAL TIME CLOCK FOR S-100 BUS

1 MHZ Crystal Oscillator
Two independent interrupts
One interrupt uses 16 bit counter in 10 USEC steps
Other interrupt is in decade steps from 100 USEC to 10 sec.
Both software programmable
Board can be selected by 128 device code pairs.
Complete documentation includes software to display time of day.
Double sided solder mask
Silk screen parts layout

JG-RT ASSEMBLED & TESTED	$179.95
JG-RT KIT	$124.95
BARE BOARD with Manual	$30.00

JADE 8080A KIT

$100.00 KIT
BARE BOARD $30.00

JADE Z80 KIT

—with PROVISIONS for ONBOARD 2708 and POWER ON JUMP

$135.00 EA. (2MHZ)
$149.95 EA. (4MHZ)
BARE BOARD $35.00

JADE Z80 "UPGRADE" KIT

Change your JADE 2MHz Z80 to a 4MHz version with this simple kit.

only $17.95 with trade
$49.95 purchase.

To trade, you must give us your 2MHz Z80 chip and 8224 clock driver.

The "UPGRADE KIT" includes:

Z80A chip,	1.8K resistor
8224-4 clock driver	20 pf. capacitor
36MHz crystal	

E—PROM BOARDS

MR-8 (8K uses 2708) with 1K RAM	KIT	$99.50
MR-16T (16K uses 2716) with 1K RAM	KIT	$99.50
MM-16 (16K uses 2708)		$99.00
RAM/N/ROM (16K uses any E-PROM)	KIT	$117.00
JG-8/16 (uses 2708 or 2716)	KIT	$59.95
BARE BOARD		$30.00

TV-1

Convert T.V. set to Video Monitor.
KIT $8.95

THE PROM SETTER

WRITE & READ
EPROM
1702A — 2708 — 2716
5204 — 6834

- Plugs directly into your ALTAIR IMSAI Computer
- Includes Main Module Board and External EPROM Socket Unit.
- The EPROM Socket Unit is connected to the Computer through a 25 pin connector.
- Programming is accomplished by the Computer
- Just read in the Program to be Written on the EPROM into your Processor and let the Computer do the rest.
- Use Socket Unit to Read EPROM's Contents into your Computer.
- Software included.
- No external power supplies. Your computer does it all.
- Doubles as an Eight Bit Parallel I/O.
- Manual included.

KIT $210.00
ASSEMBLED $375.00

JADE

Computer Products

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RETAIL STORE HOURS: Monday - Friday 9–7
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Discounts available at OEM quantities ADD $1.50 under 10 lbs. for shipping. California residents add 6% sales tax.

NEW CATALOG NOW AVAILABLE

Circle 195 on inquiry card.

SOCKET JUMPERS

Mates with two rows of .025" sq. or dia. posts on patterns of .100" centers and shielded receptacles. Probe access holes in back. Choice of 6" or 18" length.

Part No.	No. of Contacts	Length	Price
924003-18R	26	18"	$ 5.38 ea.
924003-06R	26	6"	4.78 ea.
924005-18R	40	18"	8.27 ea.
924005-06R	40	6"	7.33 ea.
924006-18R	50	18"	10.31 ea.
924006-06R	50	6"	9.15 ea.

JUMPER HEADERS

Solder to PC boards for instant plug-in access via socket-connector jumpers. .025" sq. posts. Choice of straight or right angle.

Part No.	No. of Posts	Angle	Price
923863-R	26	straight	$1.28 ea.
923873-R	26	right angle	1.52 ea.
923865-R	40	straight	1.94 ea.
923875-R	40	right angle	2.30 ea.
923866-R	50	straight	2.36 ea.
923876-R	50	right angle	2.82 ea.

INTRA-CONNECTOR

Provides both straight and right angle functions. Mates with standard .10" x .10" dual row connectors (i.e. 3m, Ainsley, etc.) Permits quick testing of inaccessible lines.

Part No.: 922576-26 **No. of contacts:** 26 **Price** $6.90 ea.

INTRA-SWITCH

Permits instant line-by-line switching for diagnostic or QA testing. Switches actuated with pencil or probe tip. Mates with standard .10" x .10" dual-row connectors. Low profile design. Switch buttons recessed to eliminate accidental switching.

Part No.: IS-26 **No. of contacts:** 26 **Price** $13.80 ea.

CRYSTALS

THESE FREQUENCIES ONLY

PART NO.	FREQUENCY	CASE	PRICE
CY1A	1.000MHz	HC33	5.95
CY1.84	1.8432MHz	HC33	5.95
CY2A	2.000MHz	HC33	5.95
CY2.01	2.010MHz	HC33	1.95
CY2.50	2.500MHz	HC33	4.95
CY3.27	3.2768MHz	HC33	4.95
CY3.57	3.579545MHz	HC33	4.95
CY3A	4.000MHz	HC18	4.95
CY4.91	4.916MHz	HC18	4.95
CY7A	5.000MHz	HC18	4.95
CY5.18	5.185MHz	HC18	4.95
CY6.14	6.144MHz	HC18	4.95
CY6.40	6.400MHz	HC18	4.95
CY6.55	6.5536MHz	HC18	4.95
CY12A	10.000MHz	HC18	4.95
CY14A	14.31818MHz	HC18	4.95
CY19A	18.000MHz	HC18	4.95
CY18.43	18.432MHz	HC18	4.95
CY22A	20.000MHz	HC18	4.95
CY30A	32.000MHz	HC18	4.95

SWITCHES

¼" mounting holes

	Part			1-9	10+
TOGGLE (sub-minature)	JMT121	SPDT	on-off-on	$1.95	$1.43
	JMT123	SPDT	on-none-on	1.65	1.21
	JMT221	DPDT	on-off-on	2.55	1.87
	JMT223	DPDT	on-none-on	2.15	1.58
TOGGLE (Printed Circuit)	MPC121	SPDT	on-off-on	$2.05	$1.53
	MPC123	SPDT	on-none-on	1.75	1.31
	MPC221	DPDT	on-off-on	2.65	1.97
	MPC223	DPDT	on-none-on	2.25	1.68
PUSH BUTTON	PB123	SPDT	maintained	1.95	1.47
	PB126	SPDT	momentary	1.95	1.47
PUSH BUTTON Minature	MS102	DPST	momentary open	.35	.30
	MS103	SPST	momentary closed	.35	.30
DIPSWITCH SPST	206-4	8 pin dip	4 switch	1.75	1.65
	206-7	14 pin dip	7 switch	1.95	1.85
	206 8	16 pin dip	8 switch	2.25	2.15

1/16 VECTOR BOARD

	0.1 Hole Spacing Part No	P-Pattern L	P-Pattern W	Price 1-9	Price 10 up
PHENOLIC	64P44 062XXXP	4.50	6.50	1.72	1.54
	169P44 062XXXP	4.50	17.00	3.69	3.32
EPOXY GLASS	64P44 062WE	4.50	6.50	2.07	1.86
	84P44 062WE	4.50	8.50	2.56	2.31
	169P44 062WE	4.50	17.00	5.04	4.53
	169P84 062WE	8.50	17.00	9.23	8.26
EPOXY GLASS COPPER CLAD	169P44 062WEC1	4.50	17.00	6.80	6.12

SLIT-N-WRAP

Model P180 includes 2-100' spools #28 AWG wire wrap wire

Supplies insulated wire from spool to wrap-posts without prestripping and precutting using "daisy chain" method.

Model P18O $24.50

REPLACEMENT WRAP BIT
for P180 Slit N Wrap
No. P180A $12.95 each

Replacement wire-wrap wire for P180 #28 AWG
(pkg. of 3) **$2.75 each**
W28-2-A green W28-2-B red
W28-2-C clear W28-2-D blue

INSTRUMENT/ CLOCK CASE

Injection molded unit.
Complete with red bezel.
4½" x 4" x 1-9/16".
$3.49

MICROPROCESSOR COMPONENTS

CDP 1802	CPU	$19.95	Z80	CPU	$24.95
P8085	CPU	29.95	2650	MPU	26.50
8080A	CPU	10.95	MC6800	MPU	19.95
8212	8-Bit Input/Output	4.95	MC6810API	128 X 8 Static Ram	5.95
8214	Priority Interrupt Control	7.95	MC6820	Periph. Interface Adapter	7.95
8216	Bi-Directional Bus Driver	4.95	MC6821	Periph. Interface Adapter	11.50
8224	Clock Generator/Driver	5.95	MC6830L8	1024 X 8 Bit ROM	14.95
8228	System Controller/Bus Driver	5.95	MC6850	Asychronous Comm. Adapter	14.95

USER MANUALS

1802M	CDP1802 Manual	$ 7.50
Z80M	Z80 Manual	7.50
2650M	2650 Manual	5.00

SHIFT REGISTERS

MM500H	Dual 25 Bit Dynamic	.50
MM503H	Dual 50 Bit Dynamic	.50
MM504H	Dual 16 Bit Static	.50
MM506H	Dual 100 Bit Static	.50
MM507H	Dual 100 Bit Static	.50
MM510H	Dual 64 Bit Accumulator	.50
MM5013N	1024 Bit Accumulator Dynamic	2.95
MM5016H	500/512 Bit Dynamic	.89
MM5017N	Dual 500/512 Bit Dynamic	2.95
2504T	1024 Dynamic	3.95
2518	Hex 32 Bit Static	4.95
2519	Hex 40 Bit Static	4.00
2522	Dual 132 Bit Static	2.95
2524	512 Dynamic	.99
2525	1024 Dynamic	2.95
2527	Dual 256 Bit Static	2.95
2528	Dual 250 Static	4.00
2529	Dual 240 Bit Static	4.00
2532	Quad 80 Bit Static	2.95
2533	1024 Static	2.95
3341	Fifo	6.95
74LS670	4 X 4 Register	1.95

ROM'S

2513(2140)	Character Generator (upper case)	$ 9.95
2513(3021)	Character Generator (lower case)	9.95
2516	Character Generator	10.95
MM5230N	2048 Bit Read Only Memory	1.95

UART'S

AY-5-1013	30K BAUD	$ 5.95

RAM'S

1101	256 X 1	Static	$ 1.49
1103	1024 X 1	Dynamic	.99
2101	256 X 4	Static	5.95
2102	1024 X 1	Static	1.75
2107/5280	4096 X 1	Dynamic	4.95
2111	256 X 4	Static	6.95
2114	4K X 1	Static 450ns	9.95
2114L	4K X 1	Static 450ns Low Power	10.95
2114-3	4K X 1	Static 300ns	10.95
2114L-3	4K X 1	Static 300ns Low Power	11.95
7489	16 X 4	Static	1.75
8101	256 X 4	Static	5.95
8111	256 X 4	Static	6.95
8599	16 X 4	Static	3.49
21L02	1024 X 1	Static	1.95
74200	256 X 1	Static	6.95
93421	256 X 1	Static	2.95
MM5262	2K X 1	Dynamic	.49
MK4027 (UPD414)	4K	DYNAMIC 16 PIN	5.95
MK4116 (UPD416)	16K	DYNAMIC 16 PIN	29.95
TMS4044-45NL	4K	STATIC	14.95

PROMS

1702A	2048	Famous	$ 5.95
5203	2048	Famous	14.95
82S23	32 X 8	Open C	5.00
82S115	4096	Bipolar	19.95
82S123	32 X 8	Tristate	5.00
74S287	1024	Static	7.95
2708	8K	EPROM	10.95
2716 T.I.	16K	EPROM	29.95
2716 Intel	16K	EPROM	59.95
6301-1	1024	Tri-State Bipolar	3.49
6330-1	256	Open C Bipolar	2.95
74186	512	TTL Open Collector	9.95
74188	256	TTL Open Collector	3.95

SPECIAL REQUESTED ITEMS

TELEPHONE KEYBOARD CHIPS

AY-5-9100	$14.95
AY-5-9200	14.95
AY-5-9500	4.95
AY-5-2376	14.95
HD0165	7.95
74C922	9.95

ICM CHIPS

ICM7045	$24.95
ICM7205	19.95
ICM7207	7.50
ICM7208	19.95
ICM7209	6.95

NMOS READ ONLY MEMORIES

MCM6571	$13.50
MCM6574	13.50
MCM6575	13.50

TV GAME CHIP SET
AY-3-8500-1 Chip and 2.010 MH2 Crystal **$7.95**

MISCELLANEOUS

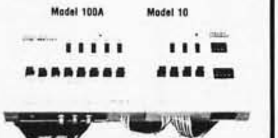
11C90	$19.95	MK40240	$17.50
MC3061P	11.95	DS0026CH	3.75
MC1408L7	4.95	TIL308	10.20
MC1408L8	5.75	95H90	11.95

LD110/111	$25.00/set
MC4016(74416)	7.50
4N33	3.95

PARATRONICS

Logic Analyzer Kit Model 100A

$229.00/kit



- Analyzes any type of digital system
- Checks data rates in excess of 8 million words per second
- Trouble shoot TTL, CMOS, DTL, RTL, Schottky and MOS families
- Displays 16 logic states up to 8 digits wide
- See ones and zeros displayed on your CRT, octal or hexadecimal format
- Tests circuits under actual operating conditions
- Easy to assemble — comes with step-by-step construction manual which includes 80 pages on logic analyzer operation.

(Model 100A Manual - $4.95)

- Some applications are:
  - — Troubleshooting microprocessor address, instruction, and data flow
  - — Examine contents of ROMS
  - — Tracing operation of control logic
  - — Checking counter and shift register operation
  - — Monitoring I/O sequences
  - — Verifying proper system operations during testing

PARATRONICS TRIGGER EXPANDER - Model 10

Adds 16 additional bits. Provides digital delay and qualification of input clock and 24-bit trigger word. — Connects direct to Model 100A for integrated unit).

Model 10 Kit - $229.00
Baseplate — $9.95
Model 10 Manual — $4.95

B+K PRECISION 3½-Digit Portable DMM

- Overload Protected
- .3" high LED Display
- Battery or AC operation
- Auto Zeroing
- 1mv, 1Va, 0.1 ohm resolution
- Overange reading
- 10 meg input impendence
- DC Accuracy 1% typical

Ranges: DC Voltage - 0-1000V/
AC Voltage: 0-1000V
Freq. Response: 50-400 HZ
DC/AC Current: 0-100mA
Resistance: 0-10 meg ohm
Size: 6.4" x 4.4" x 2"

Model 2800 $99.95

Comes with test leads, operating manual and spare fuse

Accessories:

AC Adapter BC-28	$9.00
Rechargeable Batteries BP-26	20.00
Carrying Case LC-28	7.50

CSC 100 MHz 8-Digit Counter

- 20 Hz-100 MHz Range
- .6" LED Display
- Crystal-controlled timebase
- Fully Automatic
- Portable — completely self-contained
- Size — 1.75" x 7.38" x 5.63"
- Four power souces, i.e. batteries, 110 or 220V with charger 12V with auto lighter adapter and external 7.2-10V power supply

MAX-100 $134.95

ACCESSORIES FOR MAX 100:

Mobile Charger Eliminator
use power from car battery **Model 100 — CLA $3.95**
Charger/Eliminator
use 110 V AC **Model 100 — CAI $9.95**

KEYBOARDS

63-Key Unencoded

This is a 63-key, terminal keyboard newly manufactured by a large computer manufacturer. It is unencoded with SPST keys, unattached to any kind of PC board. A very solid molded plastic 13 x 4" base suits most application. IN STOCK **$29.95/each**

Hexadecimal Encoder

19-key pad includes 1-10 keys, ABCDEF and 2 optional keys and a shift key. **$10.95/each**

$5.00 Minimum Order – U.S. Funds Only
California Residents – Add 6% Sales Tax

Spec Sheets – 25¢
1978A Catalog Available–Send 35¢ stamp

NEW NAME

Jameco ELECTRONICS

a division of JAMES ELECTRONICS of California

PHONE ORDERS WELCOME (415) 592-8097

MAIL ORDER ELECTRONICS – WORLDWIDE
1021 HOWARD AVENUE, SAN CARLOS, CA 94070
Advertised Prices Good Thru June

The Incredible "Pennywhistle 103"

$129.95 Kit Only

The Pennywhistle 103 is capable of recording data to and from audio tape without critical speed requirements for the recorder and it is able to communicate directly with another modem and terminal for telephone "hamming" and communications for the deaf. In addition, it is free of critical adjustments and is built with non-precision, readily available parts.

Data Transmission Method	Frequency-Shift Keying, full-duplex (half-duplex selectable).
Maximum Data Rate	300 Baud.
Data Format	Asynchronous Serial (return to mark level required between each character).
Receive Channel Frequencies	2025 Hz for space; 2225 Hz for mark.
Transmit Channel Frequencies	Switch selectable: Low (normal) - 1070 space, 1270 mark; High = 025 space. 2225 mark.
Receive Sensitivity	-46 dbm accoustically coupled.
Transmit Level	15 dbm nominal. Adjustable from -6 dbm to -20 dbm.
Receive Frequency Tolerance	Frequency reference automatically adjusts to allow for operation between 1800 Hz and 2400 Hz.
Digital Data Interface	EIA RS-232C or 20 mA current loop (receiver is optoisolated and non-polar).
Power Requirements	120 VAC, single phase, 10 Watts.
Physical	All components mount on a single 5" by 9" printed circuit board. All components included.

Requires a VOM, Audio Oscilator, Frequency Counter and/or Oscilloscope to align.

The Original the 3rd Hand

$9.95 each

- *Leaves two hands free for working
- * Clamps on edge of bench, table or work bench
- * Position board on angle or flat position for soldering or clipping
- * Sturdy, aluminum construction for hobbyist, manufacturer or school rooms

DIGITAL STOPWATCH

- Bright 6 Digit LED Display
- Times to 59 minutes 59.59 seconds
- Crystal Controlled Time Base
- Three Stopwatches in One
  Times Single Event — Split & Taylor
- Size 4.5" x 2.15" x .90" (4½ ounces)
- Uses 3 Penlite Cells

Kit — $39.95
Assembled — $49.95
Heavy Duty Carry Case $5.95

Stop Watch Chip Only (7205) $19.95

IMC 3½ DIGIT DPM KIT

- New Bipolar Unit
- Auto Zeroing
- .5" LED
- Auto Polarity
- Low Power
- Single IC Unit

Model KB500 DPM Kit $49.00
Model KB503 5V Power Kit $17.50

JE700 CLOCK

The JE700 is a low cost digital clock, but is a very high quality unit. The unit features a simulated walnut case with dimensions of 6" x 2½" x 1". It utilizes a MAN72 high brightness readout and the MM5314 clock chip.

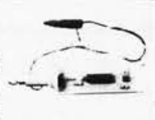
12 or 24 Hour

115 VAC

KIT ONLY **$16.95**

JE803 PROBE

The Logic Probe is a unit which is for the most part indespensible in trouble shooting logic familes. TTL, DTL, RTL, CMOS. It derives the power it needs to operate directly off of the circuit under test, drawing a scant 10 mA max. It uses a MAN3 readout to indicate any of the following states by these symbols: (HI) - 1 (LOW) - 0 (PULSE) - P. The Probe can detect high frequency pulses to 45 MHz. It can't be used at MOS levels or circuit damage will result.



$9.95 Per Kit

printed circuit board

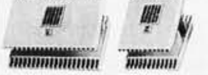
T²L 5V 1A Supply

This is a standard TTL power supply using the well known LM309K regulator IC to provide a solid 1 AMP of current at 5 volts. We try to make things easy for you by providing everything you need in one package, including the hardware for only. **JE225 $9.95 Per Kit**

CSC PROTO BOARDS

PROTO BOARD 6
$15.95
(6" long X 4" wide)

PB100 - 4.5" x 6"	$ 19.95
PB101 - 5.8" x 4.5"	29.95
PB102 - 7" x 4.5"	39.95
PB103 - 9" x 6"	59.95
PB104 - 9.5" x 8"	79.95
PB203 - 9.75 x 6½ x 2¾	80.00
PB203A - 9.75 x 6½ x 2¾ (includes power supply)	129.95



PROTO CLIPS

14 PIN	$4.50
16 PIN	4.75
24 PIN	8.50
40 PIN	13.75

7400 TTL

SN7400N	.16				
SN7401N	.18	SN7472N	.29	SN74160N	.89
SN7402N	.18	SN7473N	.35	SN74161N	.89
SN7403N	.18	SN7474N	.35	SN74162N	1.95
SN7404N	.18	SN7475N	.49	SN74163N	.89
SN7405N	.20	SN7476N	.35	SN74164N	.89
SN7406N	.29	SN7479N	5.00	SN74165N	.89
SN7407N	.29	SN7480N	.50	SN74166N	1.25
SN7408N	.20	SN7482N	.99	SN74167N	1.95
SN7409N	.20	SN7483N	.59	SN74170N	1.59
SN7410N	.18	SN7485N	.79	SN74172N	6.00
SN7411N	.25	SN7486N	.35	SN74173N	1.25
SN7412N	.25	SN7489N	1.75	SN74174N	.89
SN7413N	.40	SN7490N	.45	SN74175N	.79
SN7414N	.70	SN7491N	.59	SN74176N	.79
SN7416N	.25	SN7492N	.43	SN74177N	.79
SN7417N	.25	SN7493N	.43	SN74179N	1.95
SN7420N	.20	SN7494N	.65	SN74180N	.79
SN7421N	.29	SN7495N	.65	SN74181N	1.95
SN7422N	.39	SN7496N	.65	SN74182N	.79
SN7423N	.25	SN7497N	3.00	SN74184N	1.95
SN7425N	.29	SN74100N	.89	SN74185N	1.95
SN7426N	.29	SN74107N	.35	SN74186N	9.95
SN7427N	.25	SN74109N	.59	SN74188N	3.95
SN7429N	.39	SN74116N	1.95	SN74190N	1.25
SN7430N	.20	SN74121N	.35	SN74191N	1.25
SN7432N	.25	SN74122N	.39	SN74192N	.79
SN7437N	.25	SN74123N	.49	SN74193N	.79
SN7438N	.25	SN74125N	.49	SN74194N	.89
SN7439N	.25	SN74126N	.49	SN74195N	.69
SN7440N	.20	SN74132N	.75	SN74196N	.89
SN7441N	.89	SN74136N	.75	SN74197N	.89
SN7442N	.49	SN74141N	.79	SN74198N	1.49
SN7443N	.75	SN74142N	2.95	SN74199N	1.49
SN7444N	.75	SN74143N	2.95	SN74200N	5.59
SN7445N	.75	SN74144N	2.95	SN74251N	1.79
SN7446N	.69	SN74145N	.79	SN74279N	.79
SN7447N	.59	SN74147N	1.95	SN74283N	2.25
SN7448N	.79	SN74148N	1.29	SN74284N	3.95
SN7450N	.20	SN74150N	.89	SN74285N	3.95
SN7451N	.20	SN74151N	.59	SN74365N	.69
SN7453N	.20	SN74153N	.59	SN74366N	.69
SN7454N	.20	SN74154N	.99	SN74367N	.69
SN7459A	.25	SN74155N	.79	SN74368N	.69
SN7460N	.20	SN74156N	.79	SN74390N	1.95
SN7470N	.29	SN74157N	.65	SN74393N	1.95

C/MOS

CD4000	.23			CD4070	.55
CD4001	.23			CD4071	.23
CD4002	.23	CD4028	.89	CD4072	.49
CD4006	1.19	CD4029	1.19	CD4076	1.39
CD4007	.25	CD4030	.49	CD4081	.23
CD4009	.49	CD4035	.99	CD4082	.23
CD4010	.49	CD4040	1.19	CD4093	.99
CD4011	.23	CD4041	1.25	CD4098	2.49
CD4012	.25	CD4042	.99	MC14409	14.95
CD4013	.39	CD4043	.89	MC14410	14.95
CD4014	1.39	CD4044	.89	MC14411	14.95
CD4015	1.19	CD4046	1.79	MC14419	4.95
CD4016	.49	CD4047	2.50	MC14433	19.95
CD4017	1.19	CD4048	1.35	MC14506	.75
CD4018	.99	CD4049	.49	MC14507	.99
CD4019	.49	CD4050	.49	MC14562	14.50
CD4020	1.19	CD4051	1.19	MC14583	3.50
CD4021	1.39	CD4053	1.19	CD4508	3.95
CD4022	1.19	CD4056	2.95	CD4510	1.39
CD4023	.23	CD4059	9.95	CD4511	1.29
CD4024	.79	CD4060	1.49	CD4515	2.95
CD4025	.23	CD4066	.79	CD4518	1.29
CD4026	2.25	CD4068	.39	CD4520	1.29
CD4027	.69	CD4069	.45	CD4566	2.25

74C00

74C00	.39			74C163	3.00
74C02	.55			74C164	3.25
74C04	.75	74C89	6.49	74C173	2.60
74C08	.75	74C90	3.00	74C192	3.49
74C10	.65	74C93	2.00	74C193	2.75
74C14	3.00	74C95	2.00	74C195	2.75
74C20	.65	74C107	1.25	74C922	9.95
74C30	.65	74C151	2.90	74C923	8.95
74C42	2.15	74C154	3.00	74C925	14.95
74C48	4.75	74C157	2.15	74C926	11.95
74C73	1.50	74C160	3.25	80C95	1.50
74C74	1.15	74C161	3.25	80C97	1.50

LINEAR

78MG	1.75			LM733N	1.00
LM300H	.80			LM739N	1.19
LM301H	.35			LM741CH	.35
LM301CN	.35			LM741CN	.35
LM302H	.75	LM340T-8	1.25	LM741-14N	.39
LM304H	1.00	LM340T-12	1.25	LM747H	.79
LM305H	.60	LM340T-15	1.25	LM747N	.79
LM307CN/H	.35	LM340T-18	1.25	LM748H	.39
LM308H	1.00	LM340T-24	1.25	LM748N	.39
LM308CN	1.00	LM350N	1.00	LM1303N	.90
LM309H	1.10	LM351CN	.65	LM1304N	1.19
LM309K	1.25	LM370N	1.15	LM1305N	1.40
LM310CN	1.15	LM373N	3.25	LM1307N	.85
LM311H	.90	LM377N	4.00	LM1310N	2.95
LM311N	.90	LM380N	1.25	LM1351N	1.65
LM317K	6.50	LM380CN	.99	LM1414N	1.75
LM318CN	1.50	LM381N	1.79	LM1458CN/H	.59
LM319N	1.30	LM382N	1.79	MC1488	1.95
LM320K-5	1.35	NE501N	8.00	MC1489	1.95
LM320K-5.2	1.35	NE510A	6.00	LM1496N	.95
LM320K-12	1.35	NE529A	4.95	LM1556V	1.75
LM320K-15	1.35	NE531H	3.00	MC1741SCP	3.00
LM320K-18	1.35	NE536T	6.00	LM2901N	2.95
LM320K-24	1.35	NE540L	6.00	LM3053	1.50
LM320T-5	1.25	NE550N	1.30	LM3065N	.69
LM320T-5.2	1.25	NE555V	.39	LM3900N(3401)	.49
LM320T-8	1.25	NE556	.99	LM3905N	.89
LM320T-12	1.25	NE560B	5.00	LM3909	1.25
LM320T-15	1.25	NE561B	5.00	MC5558V	1.00
LM320T-18	1.25	NE562B	5.00	LM7525N	.90
LM320T-24	1.25	NE565H	1.75	LM7534N	.75
LM323K-5	5.95	NE565N	1.25	8038B	4.95
LM324N	1.80	NE566CN	1.75	LM75450	.49
LM339N	.99	NE567H	1.25	75451CN	.39
LM340K-5	1.35	NE567V	.99	75452CN	.39
LM340K-6	1.35	NE570	10.50	75453CN	.39
LM340K-8	1.35	LM703CN/H	.45	75454CN	.39
LM340K-12	1.35	LM709H	.29	75491CN	.79
LM340K-15	1.35	LM709N	.29	75492CN	.89
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74LS00	.23			74LS155	.69
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74LS03	.23	74LS74	.35	74LS160	.89
74LS04	.29	74LS75	.49	74LS161	.89
74LS05	.29	74LS76	.35	74LS162	.89
74LS08	.23	74LS83	.75	74LS163	.89
74LS10	.23	74LS85	.99	74LS164	.99
74LS13	.49	74LS86	.35	74LS175	.79
74LS14	.99	74LS90	.49	74LS181	2.49
74LS20	.23	74LS92	.59	74LS190	.89
74LS26	.29	74LS93	.59	74LS191	.89
74LS27	.29	74LS95	.79	74LS192	.89
74LS28	.29	74LS96	.89	74LS193	.89
74LS30	.23	74LS107	.35	74LS194	.89
74LS32	.29	74LS109	.35	74LS195	.89
74LS40	.29	74LS112	.35	74LS253	.79
74LS42	.69	74LS123	.99	74LS257	.69
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74LS51	.23	74LS136	.39	74LS279	.59
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ASST. 4	5 ea.	8.2K	10K	12K	15K	18K	1/4 WATT 5% - 50 PCS.
		22K	27K	33K	39K	47K	
ASST. 5	5 ea.	56K	68K	82K	100K	120K	1/4 WATT 5% - 50 PCS.
		150K	180K	220K	270K	330K	
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XR1310P	1.30	XR2240	3.45	XR4558	.75
XR1468CN	3.85	XR2264	4.25	XR4739	1.15
XR1488	1.39			XR4741	1.4"

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TYPE	VOLTS	W	PRICE	TYPE	VOLTS	W	PRICE
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1N751A	5.1	400m	4/1.00	1N4006	800 PIV	1 AMP	10/1.00
1N752	5.6	400m	4/1.00	1N4007	1000 PIV	1 AMP	10/1.00
1N753	6.2	400m	4/1.00	1N3600	50	200m	6/1.00
1N754	6.8	400m	4/1.00	1N4148	75	10m	15/1.00
1N959	8.2	400m	4/1.00	1N4154	35	10m	12/1.00
1N965B	15	400m	4/1.00	1N4305	75	25m	20/1.00
1N5232	5.6	500m	.28	1N4734	5.6	1w	.28
1N5234	6.2	500m	.28	1N4735	6.2	1w	.28
1N5235	6.8	500m	.28	1N4736	6.8	1w	.28
1N5236	7.5	500m	.28	1N4738	8.2	1w	.28
1N456	25	40m	6/1.00	1N4742	12	1w	.28
1N458	150	7m	6/1.00	1N4744	15	1w	.28
1N485A	180	10m	5/1.00	1N1183	50 PIV	35 AMP	1.60
1N4001	50 PIV	1 AMP	12/1.00	1N1184	100 PIV	35 AMP	1.70
1N4002	100 PIV	1 AMP	12/1.00	1N1185	150 PIV	35 AMP	1.70
1N4003	200 PIV	1 AMP	12/1.00	1N1186	200 PIV	35 AMP	1.80
1N4004	400 PIV	1 AMP	12/1.00	1N1188	400 PIV	35 AMP	3.00

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TIS98	6/1.00	2N3398	5/1.00	2N4123	6/1.00
TIS133	5/1.00	PN3567	3/1.00	PN4249	4/1.00
TIS135	5/1.00	PN3568	4/1.00	PN4250	4/1.00
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40410	1.75	MPS3638A	5/1.00	2N4401	4/1.00
40673	1.75	MPS3702	5/1.00	2N4402	4/1.00
2N918	4/1.00	2N3704	5/1.00	2N4403	4/1.00
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2N2369	5/1.00	2N3706	5/1.00	2N5088	4/1.00
2N2369A	4/1.00	MPS3706	5/1.00	2N5089	4/1.00
MPS2369	5/1.00	2N3707	5/1.00	2N5129	5/1.00
2N2484	4/1.00	2N3711	5/1.00	PN5134	5/1.00
2N2906	4/1.00	2N3724A	.65	PN5138	5/1.00
2N2907	5/1.00	2N3725A	1.00	2N5139	5/1.00
2N2925	5/1.00	2N3772	2.25	2N5210	5/1.00
MJE2955	1.25	2N3823	1.00	2N5449	3/1.00
2N3053	2/1.00	2N3903	4/1.00	2N5951	3/1.00

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22 pf	.05	.04	.03	.0047µF	.05	.04	.035
47 pf	.05	.04	.03	.01µF	.05	.04	.035
100 pf	.05	.04	.03	.022µF	.06	.05	.04
220 pf	.05	.04	.03	.047µF	.06	.05	.04
470 pf	.05	.04	.035	.1µF	.12	.09	.075

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.001mf	.12	.10	.07	.022mf	.13	.11	.08
.0022	.12	.10	.07	.047mf	.21	.17	.13
.0047mf	.12	.10	.07	.1mf	.27	.23	.17
.01mf	.12	.10	.07	.22mf	.33	.27	.22

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.15/35V	.28	.23	.17	2.2/25V	.31	.27	.22
.22/35V	.28	.23	.17	3.3/25V	.31	.27	.22
.33/35V	.28	.23	.17	4.7/25V	.32	.28	.23
.47/35V	.28	.23	.17	6.8/25V	.36	.31	.25
.68/35V	.28	.23	.17	10/25V	.40	.35	.29
1.0/35V	.28	.23	.17	15/25V	.63	.50	.40

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Axial Lead				Radial Lead			
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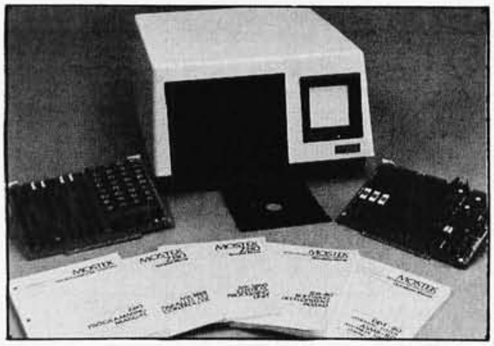
1.0/50V	.16	.14	.11	.47/50V	.16	.14	.11
3.3/50V	.14	.12	.09	1.0/16V	.15	.13	.10
4.7/25V	.15	.13	.10	1.0/25V	.16	.14	.11
10/25V	.15	.13	.10	1.0/50V	.16	.14	.11
10/50V	.16	.14	.12	4.7/16V	.15	.13	.10
22/25V	.17	.15	.12	4.7/25V	.15	.13	.10
22/50V	.24	.20	.18	4.7/50V	.16	.14	.11
47/25V	.19	.17	.15	10/16V	.14	.12	.09
47/50V	.25	.21	.19	10/25V	.15	.13	.10
100/25V	.24	.20	.18	10/50V	.16	.14	.12
100/50V	.35	.30	.28	47/50V	.24	.21	.19
220/25V	.32	.28	.25	100/16V	.19	.15	.14
220/50V	.45	.41	.38	100/25V	.24	.20	.18
470/25V	.33	.29	.27	100/50V	.35	.30	.28
1000/16V	.55	.50	.45	220/16V	.23	.17	.16
2200/16V	.70	.62	.55	470/25V	.31	.28	.26

Circle 200 on inquiry card.

What's New?

SYSTEMS

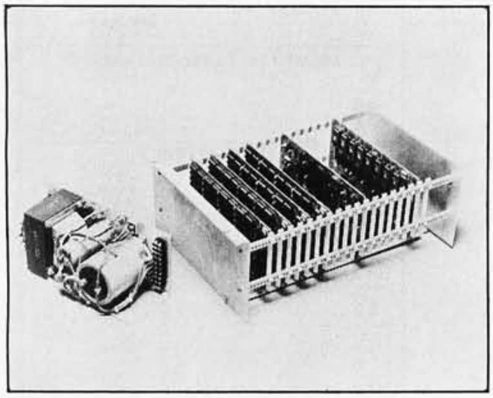
Floppy Disk Based Z-80 Microcomputer System



The AID-80F is a complete disk based computer from MOSTEK that provides for hardware and software development and debug. The heart of the AID-80F is the SDB-80 which combines the Z-80 processor with 16 K bytes of on board programmable memory. The RAM-80 memory and IO expansion board includes 16 K bytes of programmable memory and four 8 bit IO ports. The FLP-80 flexible disk drive controller board interfaces the SDB-80 with up to four drives with soft sector format. An optional board, the AIM-80, allows real time in-circuit emulation with extensive debug, trace and diagnostic capabilities. Software programs and features include: monitor, text editor, assembler, relocating linking loader, debugger and a peripheral interchange program that takes completely unformatted soft sector diskettes, formats them to IBM 370, and records the system software. The program also copies files from disk to disk, disk to peripheral, or from any peripheral to any other peripheral. The AID-80F is priced at $5995; each board is also available separately. Contact MOSTEK Corp, 1215 W Crosby Rd, Carrollton TX 75006.■

Circle 578 on inquiry card.

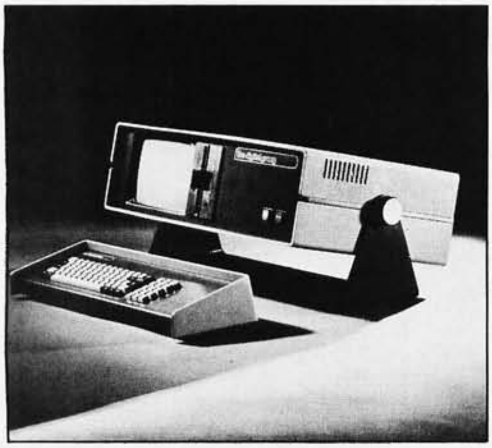
Vector 1 Computer Now in Rack Mount Kit



Vector Graphic Inc has announced availability of its Vector 1 computer in a new rack mount kit. The complete kit comprises a card cage, assembled and tested 18 slot mother board with 18 connectors, · card guides and locking buttons for 18 cards. The mother board is fully shielded to reduce noise on the bus. The price is $225. A companion power supply kit, designed for rack mounting, also is available. The 18 A 8 V, 2.5±16 V custom supply provides power for a full 18 boards. Transformer has primary taps for 110 V, 120 V and 130 V. Price for the supply kit, including mounting bracket, fuse and all hardware, is $90. Further information may be obtained from Vector Graphic Inc, 790 Hampshire Rd, Westlake Village CA 91361.■

Circle 579 on inquiry card.

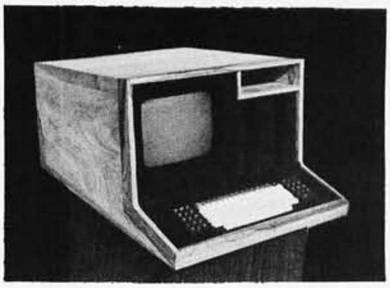
Bytemaster from Digital Group



The Digital Group's first completely integrated computer package, the Bytemaster, features either 18 K or 32 K of programmable memory, but will support up to 64 K memory if desired. The Bytemaster is fully wired to support various external peripherals with provisions for expansion. User options include a printer, monitor, and additional digital cassette minifloppy, or standard floppy disk drives plugged into any of the four available IO ports. The unit comes in a metal cabinet mounted on a heavy duty metal yoke and is priced at $3245 for the top of the line Master 4 Model (minifloppy, 32 K of programmable memory, fully assembled). Details are available from The Digital Group Inc, POB 6528, Denver CO 80206.■

Circle 580 on inquiry card.

Intel 8085 with PASCAL



The 85/P, a programmer's workbench from Northwest Microcomputer Systems Inc, is a complete system which includes:

- 8085 processor with 54 K bytes of static programmable memory.
- One megabyte of storage in two double density Shugart floppy disk drives.
- 24 by 80 high resolution display.
- Two serial ports for printer and second terminal or modem.
- A choice of solid oak or walnut cabinet.

The system provides a 700 lines per minute PASCAL compiler and interpreter, random and sequential files, a screen oriented editor, interactive source linked debugger, plus documentation and a 90 day warranty.

The 85/P costs $7495. Delivery is quoted at 30 to 60 days, with Northwest Microcomputer Systems paying for delivery on any order shipped later than 60 days. A variety of options are available, including a complete turnkey screen oriented accounts receivable package. The system also supports CP/M, FORTRAN, BASIC and 8080 compatible software. Contact Northwest Microcomputer Systems Inc, 121 E 11th, Eugene OR 97401.■

Circle 581 on inquiry card.

Small Business Computer Systems

A complete small business accounting system, Micro Executive, has been announced by Microcomputer Business Systems Inc, 1776 E Jefferson St, Rockville MD 20852. The system is said to include accounts receivable, accounts payable, merchandise inventory, fixed assets inventory, payroll, financial reporting, and general ledger. The company has announced a computer system called Micro Executive II which consists of an 8080 processor, 64 K bytes of user memory, two full-size Shugart Associates floppy disk drives (Models 801 or 851 for either a total of 630,000 bytes or 1.2 million bytes of secondary storage). The system also comes with a Lear Seigler 80 by 24 video display terminal and a 30 cps printing terminal. Optional terminals, printers, and hard disk drives are available.■

Circle 582 on inquiry card.

S-100
32K STATIC MEMORY BOARD

features:

1. FULLY STATIC - usable with all DMA devices.
2. BUFFERED - with noise suppressed control inputs.
3. MODULAR - populated in 1k increments.
4. RELIABLE - single source +5V regulator
5. PROM COMPATIBLE - monitors available on request.

AVAILABLE EITHER IN **COMPLETE KITS** OR ALREADY **ASSEMBLED UNITS** WHICH HAVE BEEN FULLY TESTED AND BURNED IN.

BARE BOARD $\$38^{00}$

	KIT	ASSEMBLED
8K	$\$270^{00}$	$\$296^{00}$
16K	$\$440^{00}$	$\$465^{00}$
24K	$\$580^{00}$	$\$612^{00}$
32K	$\$695^{00}$	$\$740^{00}$

PRICES QUOTED ARE FOR 300ns MEMORIES
KITS AND ASSEMBLED UNITS INCLUDE DOCUMENTATION

DEC® LSI-11 16K MEMORY BOARD

- Q-BUS—FULLY STATIC
- BUFFERED AND NOISE SUPPRESSED
- MODULAR
- PROM COMPATIBLE
- ADDRESSABLE TO 128K WORDS
- MAPPABLE IN 4K INCREMENTS

ASSEMBLED, TESTED & **BURNED IN** $\$1199^{00}$ COMPLETE KIT $\$1109^{00}$

LARGEST & FASTEST STATIC MEMORY AVAILABLE

S-100 EXPANDABLE MOTHER BOARD

- 8-SLOT EXPANDABLE BACKPLANE—in line male and female connectors enable backplanes to be plugged together, or the female may be used in place of an extender board.

QUIET—ground plane decouples all signal lines.
RELIABLE—SAE 8100 phenolic body, gold contact connectors.

COMPLETE KIT $\$66^{00}$ ASSEMBLED $\$89^{00}$

UNIVERSAL "U DESIGN" WIRE WRAP BOARDS

ALL BOARDS ARE G-10 GLASS EPOXY. HAVE Vcc AND GROUND PLANES. PLATED THROUGH HOLES, & GOLD PLATED EDGE CONNECTORS

No. 1 "BEST ON THE MARKET" **MICRO CPU CARD** WITH S-100 BUS, 3 ON BOARD REGULATORS. FITS ALL STANDARD I.C. SOCKET CONFIGURATIONS. 1700+ HOLES.
SIZE 5"x10" $\$23^{95}$

No. 2
UNIVERSAL BOARD FITS 86 PIN SOCKET WITH 0.10" CONTACT SPACING. MADE BY LEADING COMPUTER MANUFACTURER AS "IN HOUSE" BOARD. 1600+ HOLES.
SIZE 4-7/8"x7-5/8" $\$7^{95}$

S-100 EXTENDER BOARD

with connector

A MUST for trouble-shooting your Computer boards $\$17^{95}$

BUILD YOUR OWN
LOGIC PROBE

24 TO-92, SMALL SIGNAL DARLINGTONS AND 24 LEDS—ALL FUNCTIONAL only $\$4^{95}$

MAXI SWITCH KEYBOARDS

UNENCODED-MOUNTED ON G-10 GLASS EPOXY BOARDS-A BLACK METAL FRAME KEEPS KEY SWITCHES SECURELY IN PLACE.

No. 1
- 53 key main keyboard
- 10 auxiliary & cursor control keys
- 11 key numeric pad
- Bank of 5 auxiliary power and control, rocker arm switches-one of them lights up.

$\$39^{95}$

WIRE WRAP SOCKET CONNECTOR FOR NO. 1 KEYBOARD $\$2^{95}$

No. 2
- 53 key keyboard
- 1 auxiliary power/control DPDT rocker arm switch

$\$29^{95}$

BEIGE METAL FRAME MOUNT FOR NO. 2 KEYBOARD $\$9^{95}$

SOCKET CONNECTOR FOR NO. 2 KEYBOARD $\$2^{95}$

OUR NEW
ASCII KEYBOARD

HAS ON BOARD UV PROM, A MAIN KEYBOARD SECTION OF 58 KEYS, A HEX PAD OF 15 KEYS AND 16 MORE PERIPHERAL KEYS. 89 KEYS TOTAL & ASC11 ENCODED for only $\$99^{95}$

EDGE VIEW METER

CHARGE DISCHARGE SCALE READS -20,0,-40
MOVEMENT +60,-120mA
0.135 OHMS $\$2^{49}$

POWER SUPPLY PARTS

DIODES

IN4001	50V at 1A	6c
IN4003	200V at 1A	8c
IN4007	1000V at 1A	12c
IN250	60V at 20A	95c
IN3909	50V at 30A	$1.25

BRIDGES

FAST RECOVERY AVALANCHE BRIDGE
IN4436/T 200V at 10A $4.25
FULL WAVE "MINI BRIDGE" WITH TAB TERMINALS
PR-10F 100V at 12A $3.75

5% ZENERS

IN4733A	5.1V	1w	39c
IN4739A	9.1V	1w	39c
IN4744A	15V	1w	39c

VOLTAGE REGULATORS

		PLASTIC	METAL
uA723-VARIABLE 2V to 3.7V		38c	69c
78L05- 5V at 100mA	TO-92		3/98c
340T-6 6V at 1 AMP	TO-220		2/98c

PASS TRANSISTORS

MJE3055	10A	PLASTIC	89c
2N3055	10A	TO-3	95c
2N5301	30A	TO-3	$1.95

PROTECT YOURSELF. INSTALL AN ELECTRONIC CROWBAR CIRCUIT IN YOUR POWER SUPPLY.
CROWBAR SCR C220D 400V at 10A $1.75

BUILD YOUR OWN PAPER TAPE READER

1/10" CENTER STACKABLE
PHOTO TRANSISTORS
$10/\$9^{60}$

TTL COMPATIBLE
REED RELAY
400 OHMS
$\$1^{49}$ $7/\$9^{75}$

4K STATIC RAMS

2114	650ns	600mw	$6.25
TMS-4045-4	450ns	300mw	$10.95
HM-472114	300ns	200mw	$11.95

MINIATURE
16 BUTTON PADS
4x4 MATRIX ENCODED $\$1^{95}$

I.C. SOCKETS

LOW PROFILE-SOLDERTAIL

	GOLD INLAID	TIN
8 PIN	10/$1.59	10/$1.35
14 PIN	10/$1.89	10/$1.49
16 PIN	10/$1.99	10/$1.59
22 PIN	5/$1.69	5/$1.49
24 PIN	5/$1.89	5/$1.59
28 PIN	5/$1.99	5/$1.69
40 PIN	4/$1.99	4/$1.69

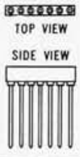
for that professional touch **CARBIDE DRILL BITS** *for* **P.C. BOARD WORK**

ASSORTMENT OF SIZES FROM NO. 55 TO NO. 70
$5\ MIX/\$7^{49}$ $10\ MIX/\$12^{49}$ $100\ MIX/\$99^{00}$

GOLD **WIRE WRAP SOCKET STRIPS**

MAKE UNIVERSAL END AND SIDE STACKABLE WIRE WRAP BOARDS

7 PIN STRIP



12 PIN 3 LEVEL 48c
14 PIN 2 LEVEL 48c
3 LEVEL 56c

OPTO DEVICES

PHOTO TRANSISTORS
SIMILAR TO FPT 100
4/98c

PHOTO DARLINGTONS
MOTOROLA
4/98c

ULTRA HIGH SPEED
PHOTO DETECTOR
0.5NS RISE TIME
$\$3^{75}$

EXTREMELY SENSITIVE LIGHT-ACTIVATED
SCR
triggerable by flashlight at several hundred yards
$\$2^{95}$

INFRA RED DETECTOR

ULTRA LOW LEVEL
PIV 7V
I on 1ma $\$4^{95}$

SOLAR CELLS

2x2cm 130ma
$\$1^{59}$ ea. $10/\$9^{90}$

HEWLETT-PACKARD JUMBO-RED HIGH EFFICIENCY
LED
ON BOARD STATUS INDICATOR $6/\$1^{00}$

HIGH INTENSITY RED
LED LAMP
EXTREME WIDE ANGLE VIEWING
$3/98c$ $10/\$2^{45}$

GOLD **EDGE CARD CONNECTORS**

No. 1
SAC185/2-2
SINGLE ROW, 18 PIN CONNECTOR WITH 0.156" CONTACT SPACING.
99c

No. 2
SAC22S/2-2
SINGLE ROW, 22 PIN CONNECTOR WITH 0.156" CONTACT SPACING
99c

No. 3
2VH31/ICB6
31 SOLDER LUG CONNECTOR WITH 0.125" CONTACT SPACING
99c

WIRE WRAP POST

2 LEVEL
10/98c
100/$7.40
1000/$64.00
3 LEVEL
10/$1.25
100/$8.60
1000/$72.00

HI-REL GOLD
WIRE WRAP SOCKET PIN
$10/\$1^{20}$
$100/\$9^{00}$
$1000/\$79^{00}$
LIST PRICE 29c

OP AMPS

SINGLE	
709	10c
741	12c
DUAL	
MC1458	39c
QUAD	
LM3900	49c

DIODES

IN91	15c
IN270	12c
IN914	15c
IN3600	15c
IN4148	10c

TRANSISTORS

2N2222	12c
2N3904	12c
2N3906	12c
2N3053	49c

D/A CONVERTER
SIGNETICS
NE5008
$\$9^{95}$

SUB MINIATURE
CRYSTAL FILTER
455 KHZ
WITH DATA
$\$2^{95}$

LEDS
YELLOW, GREEN, OR AMBER
(SPECIFY COLOR)
3/88c

HIGH VOLTAGE DIODES

EPOXY	1500V at 1 AMP	10/$1.99
EG250	2500V at 350mA	95c
HV60EL	6KV at 25mA	$1.95
SUBMINIATURE	20KV at 100mA	$2.95

3-1/2 DIGIT L.C.D.'s

LIQUID CRYSTAL DISPLAY

No. 1
0.4" CHARACTER WITH CONNECTOR
$\$6^{95}$

No. 2
THIS MINIATURE L.C.D IS IDEAL FOR POCKET SIZED INSTRUMENTS
$\$3^{95}$

NO BACK ORDERS
YOUR PARTS OR *IMMEDIATE* REFUND

FREE DELIVERY BY UPS ON U.S. ORDERS ONLY!
OR BY SURFACE MAIL, IF SPECIFIED — CALIF. RES. ADD 6% SALES TAX

MONEY BACK GUARANTEE (MOS AND LED DEVICES EXCLUDED) **$20 MINIMUM**

FOR UNDER 8 HOUR PROCESSING SEND MONEY ORDER, CERTIFIED OR CASHIERS CHECK.
SORRY! WE CANNOT ACCEPT PURCHASE ORDERS, COD'S, PHONE ORDERS OR CREDIT CARDS.

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-CANADA, PUERTO RICO, U.S. POSSESSIONS ADD U.S. $3.50. ALL OTHER ADD U.S. $7.00.
-IMMEDIATE SHIPPING ON CHASE MANHATTAN, FIRST CITIZENS, CASHIERS CHECKS & CANADIAN POSTAL MONEY ORDERS

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LMN ELECTRONICS
1042 E. GARVEY AV., W. COVINA, CA.
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PORTLAND
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WIZARD OF PARTS
8225 SW CIRRUS DR., BEAVERTON, ORE.
(KOLL BUS. CNTR/WASHINGTON SQUARE)

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ALL ITEMS SUBJECT TO PRIOR SALE

PRICES SUBJECT TO CHANGE

Circle 202 on inquiry card.

What's New?

A Talking Clock

The TCE-124 Talking Clock, with a distinctive male voice, automatically logs the time of day in English, German or Arabic. The vocabulary of the talking clock is produced electronically by a custom speech synthesis processor. When used with either voice or device activated recorders, the TCE-124 inserts a distinct verbal announcement immediately following each recorded message. Each message is indexed with its own time reference. Although developed to be used with Omnicron recorders, the Talking Clock can be used in other applications where continuous or on demand time announcements are required. Features include: 12 or 24 hour format; visual LED display; monitor speaker; 1 W, 8 ohm audio output; "universal" IO control circuits; compact size. For further information contact Omnicron Electronics, POB 623, Putnam CT 06260.■

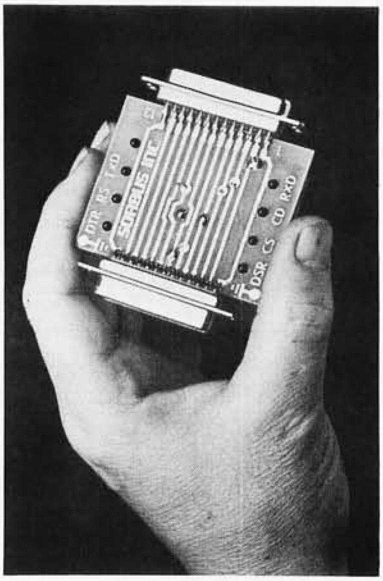
Circle 574 on inquiry card.

Prevent Memory Glitches

The Velostat conductive floor mat can eliminate electrostatic discharge, one cause of computer equipment problems. The mat has been designed to drain static away from computer operators by providing a positive path to ground. The manufacturer recommends that users wear leather soled shoes. Velostat mats are supplied with a 15 foot (37.5 cm) ground cord, snap fasteners, and 1 megohm resistors. Two sizes are available: 24 by 32 inches (61 x 81 cm) at $28.80, and 4 by 8 feet (1.2 x 2.4 meters) at $98.40. Available from Alpha Supply Company, 18350 Blackhawk St, Northridge CA 91326.■

Circle 575 on inquiry card.

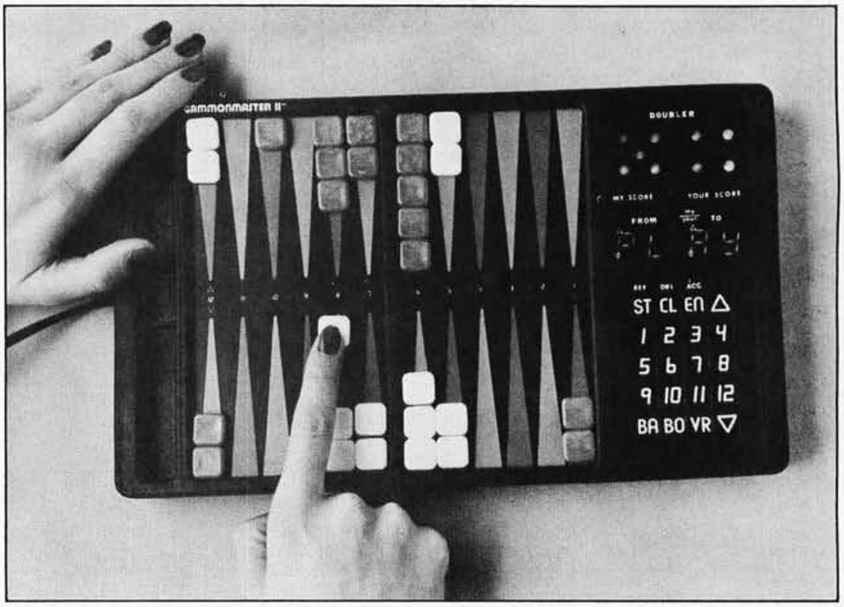
Modem Monitor with LED Display



This compact signal display device can be placed in line between data sets and data communication terminals to isolate failures. The unit, called the Traffic Light, monitors without disrupting communications activity. Plugged in line, the monitor uses light emitting diodes (LEDs) to provide constant status display of seven key signals on the EIA RS-232 25 pin Business Machine Interface. The signals monitored include: transmitted data, received data, request to send, clear to send, data set ready, carrier detect, and data terminal ready. The monitor also has a spare LED circuit that can be used to show the status of any other signal. It provides test points for oscilloscopes, meters, and logic probes to the seven displayed signals, the spare circuit signal, and logic ground. All LED displays and test points are grouped logically: signals originating in the data set (modem) are grouped on one side of the circuit board; signals originating in the Business Machine and the spare circuit are grouped on the opposite side of the board. The unit is covered by a one year warranty on both parts and labor and is priced at $89. It can be obtained from Sorbus Inc, 150 Allendale Rd, King of Prussia PA 19406.■

Circle 576 on inquiry card.

Backgammon, the King of Games, for Your Computer



Gammonmaster II, the latest entry in the computerized games market, pits your skill and ingenuity against the computer at backgammon. Gammonmaster II is a self-contained, portable backgammon game programmed to recognize and defend itself against all the strategies of the game: running, blocking, blot hitting contest, back and semiback games, bearing off strategies and combinations of these basic techniques. Electronic rolling of the dice ensures randomness of play. The computer displays each of its moves electronically while recording your moves. You chart the game with regular pieces; the location of every man on the board can be verified at the touch of a button. The optional doubling cube feature allows the tournament backgammon player to compete against the computer at multiple point games. The opponent may double the computer, or the computer may double its opponent. Gammonmaster II is available from Tryom Inc, 23945 Mercantile Rd, Cleveland OH 44122 for $199.50.■

Circle 577 on inquiry card.

POLY PAKS

MAIL ORDER

COMPUTER PERIPHERAL & PARTS WORKSHOP

POLY PAKS INTRODUCES THE FIRST MAGAZINE RETAIL STORE FOR THE ELECTRONIC MAIL-ORDER HOBBYIST!

"RED" LED READOUTS!

as low as **20¢ each**

Cat. No.	Size	Description	Sale
☐ 6S1890	.127"	MAN-3**	5 for $1.00
☐ 6S1503	.19	MAN-4*	2 for $1.19
☐ 6S1273	.27	MAN-1*	$1.00
☐ 6S3093	.33	MAN-72 equal*	$1.19
☐ 6S3161	.33	MAN-74 equal**	$1.19
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☐ 6S2950	.5	FND507*	$1.50
☐ 6S3483	.5	727-Dual**	$2.50
☐ 6S2485	.5	727-Dual*	$2.50
☐ 6S2256	.6	747*	$1.95

*Common Anode **Common Cathode

DISCRETE LED'S 6 for $1.19

Order in multiples of 6 of each type!

☐ JUMBO .34" h
☐ MEDIUM .24"
☐ MICRO .21" (TO-18)

Cat. No.	Description	Similar to
☐ 6S2135	Jumbo Red	MV5053
☐ 6S1944	Jumbo Yellow	XC556Y
☐ 6S2138	Jumbo Green	XC556G
☐ 6S2785	Medium Red	XC22
☐ 6S2788	Medium Green	XC22G
☐ 6S2137	Micro Red	XC209
☐ 6S1948	Micro Yellow	XC209Y
☐ 6S2140	Micro Green	XC290G

COMPUTER GRADE CAPACITORS

Order by Cat. No. 6S5112 and value!

Mfd	WVCD	Sale
☐ 8,000	50	$2.75
☐ 13,000	40	2.25
☐ 14,000	50	2.75
☐ 15,000	12	1.50
☐ 22,000	75	3.95
☐ 24,000	30	2.50
☐ 44,000	30	3.95

FULL WAVE BRIDGE RECTIFIERS!

PIV	2 AMP (#6S1346)	6 AMP (#6S2456)	10 AMP (#6S2447)	25 AMP (#6S2273)
☐ 50	$ .59	$ .88	$1.05	$1.20
☐ 100	.65	.99	1.15	1.25
☐ 200	.69	1.19	1.29	1.95
☐ 400	.89	1.40	1.79	2.95
☐ 600	.99	1.69	1.95	3.95
☐ 800	1.19	1.95	2.25	4.95
☐ 1000	1.25	2.25	2.50	5.50

Orer by Cat. No. Amperage and Voltage

SPECTRA-TWIST RIBBON CABLE

- Twisted pairs of brightly colored cable! 24AWG

☐ Cat. No. 6S3680 48 cond. 2 ft. $1.98
☐ Cat. No. 6S4081 32 cond. 2 ft. $1.98

RIBBON CABLE AT THIN PRICES

- Ultra-flat! • 28 AWG!
- Single color! Indexed!

Cond.	Sale
☐ 20	8 ft. $1.98
☐ 26	6 ft. $1.98
☐ 34	5 ft. $1.98
☐ 40	4 ft. $1.98
☐ 50	3 ft. $1.98

Order by Cat. No. 6S3939 and conductors

$8.88 ☐

HANDY COMPUTER MULTITESTER

- 1000 ohms per volt

1% precision, movements diode protected against burnout. Measures DC volts 0-15-150-1000; AC volts 0-15-150-1000; DC current 0-150ma; resistance X1000. Sensitivity 1000 ohms/volt AC-DC. Uses penlite cell, not included. Size 2⅜ x 3½ x 1⅜". Wt. 5 ozs. Cat. No. 6S3921

GIANT SALE! MICRO-MINI TOGGLE SWITCHES

- 3A, 125VAC contacts or better
- Complete with mounting hardware! *Center off

Cat. No.	Contacts	Sale
☐ 6S3936	SPST	$1.19
☐ 6S4036	SPDT	1.29
☐ 6S5085	SPDT*	1.39
☐ 6S4037	DPDT	1.45

SPECTROL "SKINNY-TRIMS"

2 for $1

Ohms

☐ 10**
☐ 50**
☐ 100**
☐ 200**
☐ 500*
☐ 1K*
☐ 2K**
☐ 5K*
☐ 10K*
☐ 20K**
☐ 50K**
☐ 100K**

3/8" square, screwdriver shaft. 2% tol. 1/4 watt. Cermet. PC leads. Order by Cat. No. and value.

☐ No. 6S 3863 25 turn upright, type 64
☐ No. 6S 3866 single turn, flat, type 63

*Available in all types
**Available in Cat. No. 3863 only.

"MICRO-TONE" AUTOPATCH ENCODER KIT

26.88 ☐

- Emergency!
- Family!
- Friends!
- Complete in its own mini-cabinet!

Only 2 1/8 x 1 5/8 x 1/2", small enough to mount in a mike! Snap action bubble keys contact. Features output level control. xtal controlled digitally synthesized tones. on-chip oscillator. Requires 4.5 to 5.5 VDC. Complete kit! Nothing else to buy! Wt. 12 oz.

Cat. No. 6S4086 kit $26.88
Cat. No. 6S4087 wired $32.95

HEXADECIMAL MICROPROCESSOR AND CONTROL KEYBOARD KIT! 34.95 ☐

Address microprocessors, control computer operated equipment. 2 key rollover. Has 20 keys, 16 encoded, 4 external to be assigned by user. Output 4 bit binary. Also, an EXCLUSIVE FEATURE...4 leds display the binary output. TTL/CMOS compatible, requires +5, -12VDC. Complete kit! Nothing else to buy! With instructions.

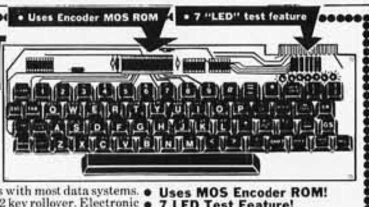
Wt. 2 lbs.

- 4 bit binary/hexadecimal output plus strobe!
- New! Improved design! Saves you time!
- Keyboard pre-assembled onto PC board!

Cat. No. 6S5009 Hexadecimal Kit $34.95
Cat. No. 6S5010 Hexadecimal Wired $39.95

$69.95 NEW KEYBOARD & ENCODER KIT

Cat. No. 6S5001 Kit $69.95
Cat. No. 6S5002 Wired $79.95



Outputs standard 7 bit ASCII; interfaces with most data systems. Keyboard pre-assembled onto PC board, 2 key rollover. Electronic shift lock and carriage return. 4 modes: Normal, control, shift, shift/control. Additional functions can be assigned by user. +5, -12VDC, 200 ma. Negative or positive logic, jumper selectable. Exlcusive test feature...7 LED's display the ASCII code. Complete kit, nothing else to buy! Size: 13" x 5 1/2 x 1 1/4". 3 lbs.

- Uses MOS Encoder ROM!
- 7 LED Test Feature!
- 64 key keyboard!
- Encodes 128 ASCII Characters
- Interfaces with ALTAIR, IMSAI, and more!

Low Power ICs

Order By Cat. No. 6S3667 & Type No.

Type	Sale
☐ 74LS00	$.32
☐ 74LS02	.32
☐ 74LS04	.35
☐ 74LS08	.32
☐ 74LS10	.32
☐ 74LS11	.32
☐ 74LS13	.64
☐ 74LS20	.32
☐ 74LS21	.32
☐ 74LS22	.32
☐ 74LS27	.39
☐ 74LS30	.32
☐ 74LS32	.39
☐ 74LS37	.45
☐ 74LS38	.45
☐ 74LS42	1.19
☐ 74LS47	.99
☐ 74LS74	.49
☐ 74LS90	.89
☐ 74LS92	.89
☐ 74LS93	.89
☐ 74LS109	.58
☐ 74LS112	.58
☐ 74LS113	.58
☐ 74LS114	.49
☐ 74LS132	1.19
☐ 74LS138	1.24
☐ 74LS139	1.24
☐ 74LS151	1.25
☐ 74LS153	1.25
☐ 74LS155	1.25
☐ 74LS160	1.47
☐ 74LS161	1.47
☐ 74LS162	1.47
☐ 74LS163	1.47
☐ 74LS168	1.68
☐ 74LS169	1.68
☐ 74LS173	1.68
☐ 74LS174	1.05
☐ 74LS190	1.77
☐ 74LS191	1.75
☐ 74LS192	1.75
☐ 74LS193	1.75
☐ 74LS195	1.25
☐ 74LS197	1.25
☐ 74LS257	1.35
☐ 74LS266	.54
☐ 74LS366	.66
☐ 74LS368	.69
☐ 74LS390	2.95

POLY PAKS "CHIPS" AWAY IC AND CRYSTAL PRICES!

Order by Cat No. 6S4048 and Type No!

Type	Description	Sale
☐ ICM7205	Stopwatch	$14.95
☐ AY3-8500-1	6 TV Games	9.95
☐ MM5330	4½ Digit DVM	4.95
☐ 8038C	Volt Control Osc.	4.95
☐ KR2376-139	BCD Encoder Rom	6.95
☐ KR2376-ST	ASCII Encoder Rom	14.95
☐ 11C90DC	650MHz Prescaler	14.95
☐ 95H90DC	350MHz Prescaler	8.88
☐ MC14410	Touch Tone Chip	9.95
☐ MK2002P	Char Gen. (sim 2513)	3.95
☐ 7207A/7208	Freq Counter pair	24.95
☐ ICM7107	3½ Digit DVM/DMM	12.50
☐ MM5316	Alarm Clock	2.95
☐ MM5369	60 Hz Timebase IC	1.95
☐ 3.579MHz	Timebase Xtal	1.95
☐ 1.00MHz	Touchtone Xtal	5.95
☐ 3.2768MHz	Stopwatch Xtal	4.95

IC SOCKETS

as low as **17¢** ea.

- Low profile, solder tail.

☐ 6S2123	8 pin minidip	$ .17
☐ 6S1308	14 pin dip	.19
☐ 6S1309	16 pin dip	.22
☐ 6S3378	18 pin dip	.25

WOW!

MOTHERBOARD EDGE CONNECTOR

☐ $2.50

106 pins (53 each side). Use with IMSAI & ALTAIR! 0.125" pin ctrs, goldplated ⅝" wire wrap leads. Open ends, fit wide PC boards. 8 ozs. Cat. No. 6S3987

10 AMP POWER TAB SCR'S, TRIACS, QUADRACS!

Order by Cat. No. and Voltage

	Cat. No.
SCR'S	6S1730
TRIACS	6S1448
QUADRACS	6S1590

PIV	SALE
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☐ 100	.69
☐ 200	.88
☐ 400	1.19
☐ 600	1.59

1N4000 Epoxy Rectifiers

- Miniature! • 1.5 Amp!

Order by Cat. No. and Type No.

Cat. No.	Type No.	PIV	Price
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☐ 6S 2378	1N4002	100	10 for .75
☐ 6S 2379	1N4003	200	10 for .85
☐ 6S 2380	1N4004	400	10 for .99
☐ 6S 2381	1N4005	600	10 for 1.29
☐ 6S 2382	1N4006	800	10 for 1.39
☐ 6S 2383	IN4007	1000	10 for 1.49

C-MOS

Order By Cat. No. 6S2320 & Type No.

Type	Sale
☐ CD4000	$.29
☐ CD4001	.29
☐ CD4002	.29
☐ CD4006	1.19
☐ CD4007	.29
☐ CD4008	.79
☐ CD4009	.59
☐ CD4010	.59
☐ CD4011	.29
☐ CD4012	.29
☐ CD4013	.69
☐ CD4015	1.19
☐ CD4016	.49
☐ CD4017	1.19
☐ CD4018	1.19
☐ CD4019	.49
☐ CD4020	.99
☐ CD4021	1.29
☐ CD4022	1.19
☐ CD4023	.29
☐ CD4024	.79
☐ CD4025	.34
☐ CD4027	.69
☐ CD4028	.89
☐ CD4029	1.19
☐ CD4030	.49
☐ CD4033	1.60
☐ CD4035	.99
☐ CD4040	1.19
☐ CD4041	1.25
☐ CD4042	.88
☐ CD4046	1.79
☐ CD4049	.49
☐ CD4066	.79
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Order by Cat. No. Amperage and voltage.

PIV	12 AMP (#6S727)	50 AMP (#6S727)	250 AMP (#6S685)
☐ 50	$ .29	$ .75	$4.95
☐ 100	.36	1.10	6.50
☐ 200	.45	1.35	7.50
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☐ 600	.79	2.25	10.50
☐ 800	.90	2.75	11.50

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Cat. No.	Switches	Sale
☐ 6S 3668	2	$.77
☐ 6S 3669	3	.88
☐ 6S 3021	4	.99
☐ 6S 3670	5	1.19
☐ 6S 3671	6	1.29
☐ 6S 2677	7	1.79

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- All Cells .5V!
- High efficiency!
- Gang for higher voltages and amps!

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1-2-4-8 BCD encoding! Positions labeled 0-7, F, L, (F coded for 8, L coded for 9). White numerals on a black background. Eeco 800 series. 1¼ x 1¼ x ½". Cat. No. 6S 3846

3 for $4.

☐ **$1.49**

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LOOK!

- 110VAC Primaries

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☐ 6S3814	6.3V	1A	Open frame	$2.49
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☐ 6S4028	12V	1A	Metal encased	$2.95
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☐ 1103	1K Dyn RAM	1.29
☐ 1702A	256 x 8 EPROM	5.95
☐ 2102-L1	1K x 1 Lo-power RAM	1.69
☐ 2111	256 x 4 Stat. RAM	5.95
☐ 2708	8K EPROM	19.95
☐ MK4116	16K Dyn RAM	32.00
☐ MK4200P11	4K x 1 Dyn RAM, 350nsec	3.95
☐ MM5202	2K PROM	6.95
☐ MM5203	2K EPROM	8.95
☐ MM5260	1K Dyn RAM	.99
☐ MM5262	2K x 1 Dyn RAM	.99
☐ 8212	8 bit I/O port	3.95
☐ 8216	Bi-direct bus driver	3.95
☐ 8224	Clock Gen	4.95
☐ 8228	System cont.	9.95
☐ 8251	Communication int	11.50
☐ 8255	Periph inter	11.95

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Type	Sale
☐ SN7400	$0.14
☐ SN7401	.14
☐ SN7402	.17
☐ SN7403	.14
☐ SN7404	.17
☐ SN7405	.18
☐ SN7406	.19
☐ SN7407	.24
☐ SN7408	.18
☐ SN7410	.14
☐ SN7411	.19
☐ SN7413	.39
☐ SN7414	.61
☐ SN7417	.24
☐ SN7420	.14
☐ SN7427	.26
☐ SN7430	.14
☐ SN7432	.24
☐ SN7437	.24
☐ SN7440	.14
☐ SN7441	.79
☐ SN7442	.49
☐ SN7445	.69
☐ SN7446	.79
☐ SN7447	.79
☐ SN7448	.75
☐ SN7450	.14
☐ SN7451	.14
☐ SN7470	.28
☐ SN7472	.26
☐ SN7473	.31
☐ SN7474	.31
☐ SN7475	.48
☐ SN7476	.39
☐ SN7483	.69
☐ SN7485	.88
☐ SN7486	.29
☐ SN7490	.69
☐ SN7492	.45
☐ SN7493	.45
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☐ SN74121	.31
☐ SN74123	.49
☐ SN74125	.39
☐ SN74132	.83
☐ SN74145	.89
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☐ SN74153	.63
☐ SN74154	.99
☐ SN74157	.64
☐ SN74161	.87
☐ SN74164	.95
☐ SN74174	.93
☐ SN74175	.88
☐ SN74181	1.95
☐ SN74190	1.15
☐ SN74191	.99
☐ SN74192	.83
☐ SN74193	.83
☐ SN74195	.75
☐ SN74251	1.39

LINEARS

Type	Sale
☐ LM301H, V	$.25
☐ LM307H, V, N	.25
☐ LM308H, V	.79
☐ LM309K	1.19
☐ LM311H, V	.79
☐ LM320T-5V	1.19
☐ LM320T-15V	1.19
☐ LM320K-12V	1.19
☐ LM320K-15V	1.19
☐ LM340T-5V	1.19
☐ LM340T-12V	1.19
☐ LM340T-15V	1.19
☐ LM340K-5V	1.19
☐ LM340K-12V	1.19
☐ LM340K-15V	1.19
☐ LM322N	1.19
☐ LM324N	.99
☐ LM339N	1.09
☐ LM377N	1.50
☐ LM379N	4.95
☐ LM380N	1.19
☐ LM381N	1.19
☐ LM555V	.44
☐ LM558V	.69
☐ LM565N	.65
☐ LM567V	1.40
☐ LM703H	.39
☐ LM709H, N	.22
☐ LM710N	.29
☐ LM723N	.42
☐ LM741H, V, N	.29
☐ LM747H, N	.59
☐ LM1458V	.69
☐ LM1800N	1.49
☐ LM3900N	.35
☐ LM39009V	1.19
☐ LM75491	.69
☐ LM75492	.75
☐ PA263	1.50

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2 for $8.

☐ **$4.50**

- Four 100K pots!
- Chrome handle and knob!

Wt. 10 oz.
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Circle 301 on inquiry card.

DUAL TRACE 15 MEGAHERTZ PORTABLE MINISCOPE

$395 00

MADE IN THE U.S.A.!

BATTERY OPERATED!

FEATURES

- Dual Trace- 2 channel: separate, chopped or alternate modes.
- 15 megahertz bandwidth.
- External and internal trigger.
- Time Base - 0.1 microseconds to 0.5 Sec/div - 21 settings.
- Battery or line operation.
- Automatic and line sync modes.
- Power consumption less than 15W.
- Verticle Gain - 0.01 to 50 volts/div —12 settings.
- Weight is only 3 pounds.

From the originator of the Digital Voltmeter, Non-Linear Systems comes the MS-215 Miniscope. It is a fine electronic instrument with a great deal of measuring capability and excellent accuracy. Its design is modern, utilizing the latest in low-powered integrated circuits, and it is packaged into the smallest practical size. The instrument fits into many briefcases and tool boxes with room to spare.

Operating characteristics have been chosen so that the MS-215 will make all of the measurements needed in servicing most electronic equipment. It is field-portable so its use is not restricted to the bench.

SPECIFICATIONS:

Vertical
Mode: CH1, CH2, CH1 & CH2 (Chopped) & CH1 & CH2 (Alt.)
The Following Specifications apply to each channel

Y Axis
Verticle Input: 10mV/div to 50V in 12 Calibrated ranges, as follows:
x1-10mV/div to 10V/div in four ranges, each continuously variable.
x2-20mV/div to 20mV/div in four ranges, each continuously variable.
x5-50mV/div to 50mV/div in four ranges, each continuously vairiable.
Accuracy is 3%
Input Impedence: 1M ohm shunted by 50 pF.
Bandwidth: DC/DC to 15 Mhz ±6 db (DC to 8 Mhz ±3 db). AC, same as DC down to 3Hz.
Rise Time: Approximately 23 nS @ 1 division deflection.
Input Voltage: 250 maximum (DC and Peak AC).

Horizontal
Mode: Internal Time Base or External Horizontal, switch selectable. In the XY mode, vertical input is through CH1 and horizontal input is through CH2
Bandwidth: DC to 200 KHz (±3 db).
Coupling: AC, DC or ground, switch selectable. Low frequency point on AC is 3 Hz.
Input Impedence: 1Meg ohm shunted by 50 pF.
Deflection Factor: 10mV/div to 50V/div in 12 calibrated ranges.
The ranges can be calibrated with the CH2 gain control
Input Voltage: 250V maximum (DC and Peak AC)
Time Base: **0.1 uS/div to 0.5 Sec/div in 21' calibrated ranges, as follows:**
x1, uS-0.1uS/div to 100 uS/div. x2, uS-0.2uS/div to 200 uS/div.
x5, uS-0.5uS/div to 500 uS/div. x1, mS-0.1mS/div to 100 mS/div
x2, mS-0.2mS/div to 200 mS/div. x5, mS-0.5mS/div to 500 mS/div.
all in four ranges, each continuously variable. (Range increments ar .1, 1, 10, 100.) With vernier in full clockwise position, calibrated time measurements are possible. Accuracy is 3%.

Triggering
Internal: Sweep triggered from internal trigger source (In the dual trace modes, the internal trigger source is CH1).
Automatic: Trigger source is internal calibrater frequency. To be used if there is no other trigger source available to synchronize the sweep.
Line: Trigger is derived from line frequency when using the battery charger.
External: Controls function as for internal triggering (1 Megohm input impedence).
Slope: Selects sync to positive- or negative- going waveform.
Coupling: AC
Sensitivity: Less than 1 div for internal trigger and less than 1 volt for external trigger.
Level: Trigger Level control permits continuous adjustment of trigger point in all modes except Auto.
Internal Calibrater: A square-wave signal of 1 volt p-p ± 5% is provided. Frequency is approximately 1KHz.

Display
Graticule: 4x5 div, each division is 0.25 inch. Viewing area 1.1"Hx1.35"W
CRT: Bluish-white phospher, medium peristence. CRT uses low power filament for low battery drain. Instant onl

Power
On-Board Batteries: Three sealed, rechargeable lead acid "D" Cells
Operating Time: Typically 4 hours.
Charging Time Scope Operating: Will run indefinitely but not reach full charge.
Non-operating: Sixteen hours.
External Power: Battery charger 115 vac (220 vac on request). 50-400Hz, less than 15 watts.
Dimensions: 3.1"Hx6.4"Wx8.0"D.
Weight: Three pounds.

Environment
Operating Temperature: 0° to 40° C
Shock and Vibration: Designed to with stand normal shock and vibration encountered in commercial shipping and handling.

Accessories
Furnished: Tilt stand, battery charger, 2 input cables, and 3 miniature banana plugs.
Optional: Leather carrying case and probes
Warranty: One year parts and labor. Made in the U.S.A.

MS-215 with Rechargeable Batteries and Charger

$395.00

Leather Carrying Case

The leather case has 2 separate compartments. One to hold the scope, the other to hold the charger, probe, shoulder strap, etc. The case can be worn on the belt, or over the neck.

The snaps used on the case are "one way", thus accidental striking of the case against an object will not undo the snaps or let it be pulled off your belt.

41-140 ***$30.00***

Probes

10 to 1 probe with 10 megohm input.

Probe uses spring hook tip for sure connection. Compensation network is located at the connector rather than at the probe, so as to keep size and weight to a minimum.

41-141 ***$24.50***

Deluxe Combination Probe

Switchable 10to1/1to1 probe with an assortment of probe tips to suit any situation.

41-3495 ***$34.95***

$40.00 OFF

On Any Accesories Purchased with **MS-215 MINISCOPE,** Just Send or Mention the **COUPON** and

Byte *Magazine*

MS-15 Single Trace version of MS-215

$289 00

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Terms VISA, MC, BAC, check, Money Order, C O D , U S Funds Only CA residents add 6% sales tax Minimum order $10 00 Orders less than $75 00 include 10% shipping and handling, excess refunded Just in case please include your phone no **"Sorry, no over the counter sales"** Good thru July 15, 1978

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NLS $ 289.00 MS-15 MINISCOPE NLS $ 289.00 MINISCOPE

NLS MS-15 MINISCOPE $ 289.00 NLS MS-15 MINISCOPE $ 289.00

SC-5
With Rechargeable Batteries & Charger Unit **$89**

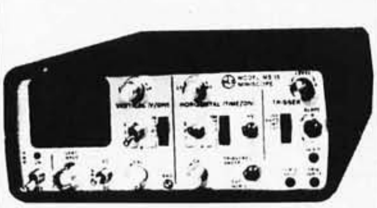
FM-7
With Rechargeable Batteries & Charger Unit **$195**

Features include • By using the new NLS SC-5 Prescaler, the range of the FM-7 Frequency Meter, which is 10 Hz to 60 MHz, may be extended to 512 MHz (the upper VHF & UHF frequency bands). • The FM-7 utilizes an LED readout, providing 7-digit resolution. • The FM-7 can be calibrated to an accuracy of 0.00001%. • The SC-5 is accurate to one part per million. • Each unit has 30 millivolts sensitivity, is battery powered and has a charger unit included. • Dimensions of each are 1.9" H x 2.7" W x 3.9" D. • The units may be obtained separately or as a "Frequency Duo". • Parts & Labor guaranteed 1 year

Tilt stand option	$ 3.50
Leather case	$16.00

MS-15 MINISCOPE $289

With Rechargeable Batteries & Charger Unit



- 15 megahertz bandwidth.
- External and internal trigger.
- Time base — .1 microsec. to 0.5 Sec/div - 21 settings ± 3%.
- Battery or line operation.
- Automatic & line sync modes.
- Power consumption < 15 watts.
- Vertical Gain — .01 to 50 V/div - 12 settings ± 3%.
- Viewing area 1.1" x 1.35".
- Case size 2.7"H x 6.4"W x 7.5"D, 3 pounds.
- Parts & Labor guaranteed 1 year

10 to 1, 10 meg probe	$24.50
Leather carrying case	$30.00

- MS-215 Dual Trace Version of MS-15 $395.00

PROBE 1¢ with the purchase of SCOPE and the MENTION of this MAGAZINE

NEW VOLKSMETERS!

With LCD Display—
Excellent Readability in Direct Sunlight!

NEW

1%
LM-300
Full three digits
$99.50*

0.5%
LM-350
3½ digits
$125.00*

FEATURES

- Measures DC volts, AC volts, ohms and current
- Automatic polarity, decimal and overload indication
- No zero adjustment and no full scale ohms adjust
- Large LCD display for easy reading without interpolation
- Size 1.9" H x 2.7" W x 4.0" D
- Parts and labor guaranteed for one year

SPECIFICATIONS

MODE	RANGE	ACCURACY LM-300	ACCURACY LM-350	RESOLUTION	INPUT RESISTANCE	TEST CURRENT
VOLTS DC*	1 10 100 1000	±1% Reading†	±0.5% Reading†	1 mV 10 mV 100 mV 1 V	10 MΩ	
VOLTS AC*	1 10 100 1000	±1% Reading† 50-400 Hz	±0.75% Reading† 50-400 Hz	1 mV 10 mV 100 mV 1 V	10 MΩ, 20 pF	
KILOHMS**	1 10 100 1000 10000	±1% Reading†	±0.5% Reading†	1 Ω 10 Ω 100 Ω 1 kΩ 10 kΩ		1 mA 100 µA 10 µA 1 µA 100 nA
CURRENT	1 mA 10 mA 100 mA 1 A	±2% Reading†	±2% Reading†	1 µA 10 µA 100 µA 1 mA	1 kΩ 100 Ω 10 Ω 1 Ω	

* 1000 vdc or peak ac maximum any range. [illegible]
**Test voltage [illegible]
† LM-350 has 100% over-range - full scale readings are 1.999, 19.99, etc.

SPECIAL!!

Batteries & Charger $1.00 with the purchase of Meter and the mention of this magazine

Tilt Stand Option, add	$3.50
Leather Case	$16.00
3AA NiCad Batts. & Charger	$12.00

Standard AA-size batteries provide up to 20 hours of operation
Rechargeable NiCad batteries and charger unit available as optional equipment
Batteries not included

LEDU MG 10A

List $72.00

Perfectly balanced, fluorescent lighting with precision magnifier lens. For prof'l, techn'l & hobbist. Has die cast protective shade, inst. start 3 diopter lens. 42" reach.

$44.95 with T-9 fluorescent lamp (required) $49.95
colors: Gray or Black, Chocolate Brown
[illegible]

$44.95 SPECIAL

8803 MOTHER BOARD FOR S100 BUS MICRO-COMPUTERS

Vector

- Kit includes 12 tantalum capacitors for +5, +12, −12 buses and insulated mounting spacers
- Wiring side shown. Component side bare epoxy glass with white markings for component locations
- G10 epoxy glass board with 2 ounce copper, solder plated and .038 diameter holes for leads
- Solder mask with solder windows on etched circuits to avoid accidental short circuits
- Mounts 11 receptacles with 100 contacts (2 rows) on .125 centers with .250 row spacing, Vector part number R681-2, or mounts 10 receptacles plus interconnections to smaller mother board for expansion
- Includes etched circuits and instructions for option of active, pull-up, or floating terminations
- Large buses: +5V and GND (10 AMPS), ± 12V or 16V (7 AMPS). Current ratings are per MIL-STD-275 with 10°C rise
- Fits in Vector pak enclosures
- Fits in IMSAI 8080 microcomputer as expander board

Price: $29.50

Vector Plugboards

8800V

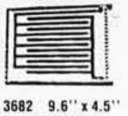
Universal Microcomputer/processor plugboard, use with S-100 bus. Complete with heat sink & hardware. 5.3" x 10" x 1/16

1-4	5-9	10-24
$19.95	$17.95	$15.96

8801-1

Same as 8800V except plain, less power buses & heat sink

1-4	5-9	10-24
$14.95	$13.46	$11.96



3682 9.6" x 4.5"
$10.97
3682-2 6.5" x 4.5"
$9.81

Hi-Density Dual-In-Line Plugboard for Wire Wrap with Power & Grd. Bus Epoxy Glass 1/16" 44 pin con. spaced .156

3677 9.6" x 4.5"
$10.90
3677-2 6.5" x 4.5"
$9.74

Gen. Purpose D.I.P. Boards with Bus Pattern for Solder or Wire Wrap. Epoxy Glass 1/16" 44 pin con. spaced .156

3662 6.5" x 4.5"
$7.65
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$11.45

P pattern plugboards for IC's Epoxy Glass 1/16" 44 pin con. spaced .156

R644 P.C. recepticle 22/44 cont. .156 ctrs. pierced solder eyelets tails gold **$2.95**
R644-3 P.C. recepticle 22/44 cont. .156 ctrs. Wire Wrap tails gold **$4.49**

S-100
Bus P.C. Edge Connectors

R681 DIP solder tails on .140 spaced rows for ALTAIR mother boards. Fits .042" dia. holes, gold **$7.35**
R681-1 .025" sq., 3 wrap lengths posts (.62 long) on .250 spaced rows, gold **$5.00**
R681-2 .025" sq., 1 wrap length posts (.22 long) on .250 spaced rows for wrapping or DIP solder for IMSAI mother boards, gold **$5.85**
R681-3 pierced solder eyelet tails, gold **$7.35**

1/16 Vector BOARD

.042 dia holes on 0.1 spacing for IC's

Phenolic

PART NO.	SIZE	PRICE
64P44-062XXP	4.5 x 6.5"	$ 1.49
169P44-062XXP	4.5 x 17"	$ 3.51

Epoxy Glass

PART NO.	SIZE	PRICE
64P44-062	4.5 x 6.5"	$ 1.70
84P44-062	4.5 x 8.5"	$ 2.10
169P44-062	4.5 x 17"	$ 4.30
169P84-062	8.5 x 17"	$ 6.39

SLIT-N-WRAP

Wraps insulated wire on .025" square posts
FOUR TIMES FASTER
than regular manual wrap post tools

P180
with two 100' spools of 28 ga wire
$24.50

P160-4T
includes charger, wire
$75.00

"Daisy-chain" runs
Reliable and easy to use
Manual or power operation

Vector

NO PRE-STRIPPING*
NO PRE-CUTTING*
SPOOL-FED WIRE*

*The spooled wire passes through the tool past a slitting edge next to the wrap post. A narrow longitudinal cut is made in the insulation where it presses the square post corner. The bared copper is indented by the sharp edge (7 turns = 28 contacts). Insulation is slit where wrapped but not between terminal posts when led straight out of the tool.

SLIT-N-WRAP WIRE
NO. 28 GAGE INSULATED WIRE, 100' SPOOLS $2.95 Package
W28-2-A Pkg. 3 Green W28-2-C Pkg. 3 Clear
W28-2-B Pkg. 3 Red W28-2-D Pkg. 3 Blue

2708

8K 450 ns

EPROM

FACTORY PRIME

$10.00 EA.
25 + *Call For Price*

14 & 16 PIN 3 LEVEL WIRE WRAP SOCKETS

14-T3 100 for $30.00
16-T3 100 for $30.00
50 of ea. for $32.00

ACE • All-Circuit Evaluator

for fast, solderless, plug-in circuit building and testing

Model 236

Just plug in any components with leads to .032" dia. Interconnect with solid wire up to 20 ga. Assembled models too!

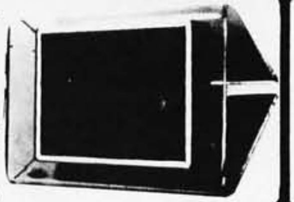
ACE Model No.	Tie Points	DIP Capacity	No. Buses	No. Posts	Board Size (inches)	Price Each
200-K (kit)	728	8 (16's)	2	2	4-9/16 x 5-9/16	$18.95
208 (assem.)	872	8 (16's)	8	2	4-9/16 x 5-9/16	28.95
201-K (kit)	1032	12 (14's)	2	2	16 x 7	24.95
212 (assem.)	1224	12 (14's)	8	2	4-9/16 x 7	34.95
218 (assem.)	1760	18 (14's)	10	2	6-1/2 x 7-1/8	46.95
227 (assem.)	2712	27 (14's)	28	4	8 x 9-1/4	59.95
236 (assem.)	3648	36 (14's)	36	4	10-1/4 x 9-1/4	79.95

Gold anodized aluminum base/ground, non corrosive nickel-silver terminals, 4 rubber feet

SALE

LIQUID CRYSTAL DIGITAL CLOCK-CALENDAR

- For Auto, Home, Office
- Small in size (2x2 ½ x ½)
- Push button for seconds release for date.
- Clocks mount anywhere with either 3M double-sided tape or VELCRO, included.
- 2 MODELS AVAILABLE
  LCD-101, portable model runs on self-contained batteries for better than a year.
  LCD-102, runs on 12 Volt system and is back-lighted.
- LCD-101 or LCD-102 your choice **$34.95**
- Clear desk stand for **$2.00**



3 LEVEL GOLD WIRE WRAP SOCKETS

	1-24	25-49	50-99
8 pin	.47	.42	.37
10 pin	.45	.41	.37
14 pin	.39	.38	.37
16 pin	.43	.42	.40
18 pin	.75	.68	.62
20 pin	**.84**	**.77**	**.71**
22 pin	1.00	.97	.95
24 pin	1.00	.94	.75
28 pin	1.09	.98	.84
36 pin	1.59	1.45	1.30
40 pin	1.49	1.39	1.29

MICRO-KLIP
for .042 dia. holes
(all boards on this page)

T42-1 pkg. 100	$ 1.50
T42-1 pkg. 1000	$11.00
P-149 hand installing tool	$ 2.03

.8" LED ALARM CLOCK

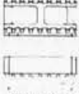
12 hr. LED Alarm Clock uses 3½ digit .8" LED Display with AM/PM indicators and colons. Direct drive, PIN to PIN interface with **S1998A** I.C. Just add switches, AC Supply, Alarm. Display and I.C. only

$7.95 or 2/$15.00

Price Breakthrough! **$17.95**

MA1003 CAR CLOCK

Bright Green Fluorescent Display Crystal Time Base Assembled, just add switches and 12 VDC.



SPECIAL

14CS2 100 for $14.00
16CS2 100 for $16.00
14 pin CS2 10 for $2.00
16 pin CS2 8 for $2.00

These low cost DIP sockets will accept **both standard width plugs and chips.**

For use with chips, the sockets offer a low profile height of only .125" above the board. These sockets are end stackable.

Vector

WRAP POST
for .042 dia. holes
(all boards on this page)

T-44 pkg. 100	$ 2.28
T-44 pkg. 1000	$14.00
A-13 hand installing tool	$ 2.80

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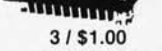
phone orders welcome (213) 893-8202

OEM and Institutional inquiries invited

24 PIN DIP PLUGS WITH COVERS



3 / $1.00
40 / $10.00

NLS MS-15 MINISCOPE $ 289.00 NLS MS-15

Circle 303 on inquiry card.

Circle 293 on inquiry card.

✶ YOUR BEST BUY IN WIRE WRAP SUPPLIES ✶

PRECUT WIRE

WHY BUY WIRE ON ROLLS?

PRECUT & STRIPPED WIRE IS:

- **Fast** - No more cutting & stripping by hand
- **Reliable** - Good, clean, uniform strip
- **Economical** - Cheaper than using bulk wire

Precut Wire	Bulk Wire
100 pcs of 3" at $.82 = **3¼¢/ft.**	50 ft roll at $1.99 = **4¢/ft.**
100 pcs of 6" at 1.06 = **2¢/ft.**	100 ft roll at 2.95 = **3¢/ft.**
Wire Kit 1 at $6.95 = **2 1/3¢/ft.**	

30 Kynar stripped 1" on each end. Lengths are overall
Colors: Red,Blue,Green,Yellow,Black,Orange,White
Wire packaged in plastic bags. Add 25¢/length for tubes

	100	500	1000	5000
2½ in	78	2.40	4.30/K	3.89/K
3 in	82	2.60	4.71/K	4.22/K
3½ in	86	2.80	5.12/K	4.55/K
4 in	90	3.00	5.52/K	4.88/K
4½ in	94	3.21	5.93/K	5.21/K
5 in	98	3.42	6.34/K	5.52/K
5½ in	1.02	3.65	6.75/K	5.86/K
6 in	1.06	3.85	7.16/K	6.19/K
6½ in	1.15	4.05	7.57/K	6.52/K
7 in	1.20	4.25	7.98/K	6.85/K
7½ in	1.25	4.45	8.39/K	7.18/K
8 in	1.29	4.65	8.80/K	7.53/K
8½ in	1.32	4.85	9.21/K	7.84/K
9 in	1.36	5.05	9.62/K	8.17/K
9½ in	1.40	5.25	10.03/K	8.50/K
10 in	1.45	5.51	10.44/K	8.83/K
Addl. inches	10	41	82/K	66/K

WIRE KITS

 # 1 $6.95

250 3" 100 4½"
250 3½" 100 5"
100 4" 100 6"

 # 2 $19.95

250 2½" 250 4½" 250 6"
500 3" 250 5" 100 6½"
500 3½" 100 5½" 100 7"
500 4" 1 250 ft. Roll Bulk

Choose One Color
or Assortment

WIRE WRAP SOCKETS

	1-9	10-24	25-99	100-249	250-999	1K-5K
8 pin *	41	38	35	31	29	27
14 pin *	42	39	36	32	29	27
16 pin *	46	43	39	35	32	30
18 pin *	63	58	54	47	44	41
20 pin	84	78	71	63	59	54
22 pin *	1.30	1.20	1.10	95	90	84
24 pin	91	84	78	68	64	59
28 pin	1.25	1.15	1.08	95	89	82
40 pin	1.65	1.55	1.42	1.25	1.15	1.09

Gold 3-level Closed Entry Sockets
End & Side Stackable — All prices include gold
Tin sockets and 2-level sockets available

INTERCONNECT CABLES

Ribbon cable connectors for connecting boards to front panels, or board to board.

	SINGLE ENDED			DOUBLE ENDED		
	14 pin	16 pin	24 pin	14 pin	16 pin	24 pin
6"	1.24	1.34	2.05	2.24	2.45	3.37
12"	1.33	1.44	2.24	2.33	2.55	3.92
24"	1.52	1.65	2.63	2.52	2.76	4.31
48"	1.91	2.06	3.40	2.91	3.17	5.08

WIRE WRAP TOOLS

$34.95

With Free Wire Kit 1
($6.95 Value)

HOBBY WRAP
Model BW 630

Batteries & Charger	$11.00
WSU 30 Hand Wrap-Unwrap Strip Tool	5.95
WSU 30M, for Modified Wrap	6.95
BT 30 Extra Bit	2.95

WIRE WRAP BOARDS

				1-4	5-9	10-24	WW Connector
H-PCB-1	4x4½	44	Buses on both sides	4.75	4.50	4.00	3.00
3662	4x6	44	Blank	6.25	5.85	5.50	3.00
3682	4x10	44	Buses on one side	10.50	10.00	9.50	3.00
3682-2	4x6	44	Buses on one side	9.50	9.00	8.25	3.00
4066-4	4x6	72	Buses on both sides	13.50	13.00	12.50	4.00
3719-1	4x6	72	Blank	9.00	8.50	8.00	4.00
3719-4	4x10	72	Blank	11.00	10.50	10.00	4.00
4350	7x9½	80	Buses on both sides	17.50	16.50	16.00	7.00
8800V	10x5.3	100	Buses on both sides	19.50	17.96	16.95	5.00
169P84	8½x17	–	Blank	6.25	5.75	5.25	–

SOCKET SALE!

	1-9	10-49	50 up
14 pin Gold WW	.34	.32	.30
16 pin Gold WW	.36	.35	.33
24 pin Gold WW	.75	.70	.68

Prices good through
6/1/78
when purchased with
Wire Kit #1 or #2

PAGE DIGITAL ELECTRONICS

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- Orders under $25 and COD's, add $2
- All others, shipped Ppd in U.S. via UPS
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- We accept Visa & Mastercharge
- Most orders shipped same day

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Same day shipment. First line parts only. Factory tested. Guaranteed money back. Quality IC's and other components at factory prices.

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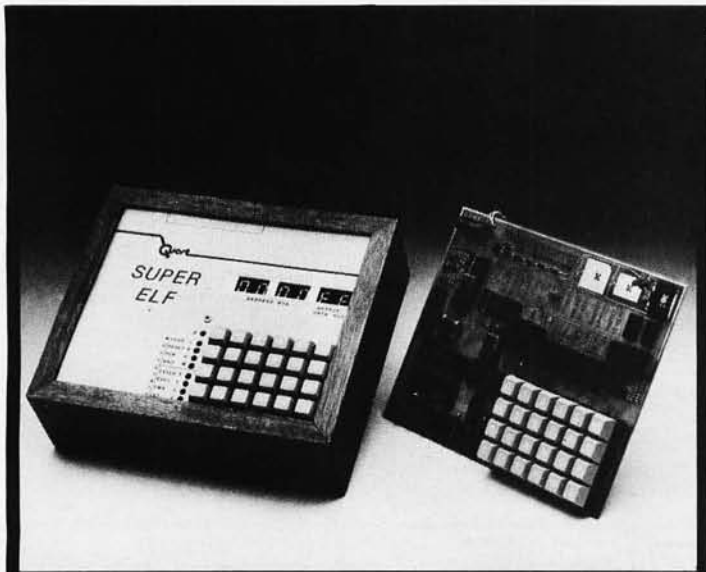

INTEGRATED CIRCUITS

MICROPROCESSOR	
6800	19.50
8080A with data	7.95
Z80	29.95
8212	2.95
8214	8.00
8216	3.15
8224	2.95
8228	4.95
8251	11.50
8253	10.00
8255	10.75
CDP1802CD	19.95
CDP1802D	25.00
CDP1861	12.95
6820	9.95
6850	12.95
6502	24.50

PROM	
1702A	3.95
N82S23	2.95
N82S123	3.50
N82S126	3.75
N82S129	3.75
N82S131	3.75
N82S136	8.75
N82S137	8.75

2708	14.65
DM8577	2.90
8223	2.90
2716	33.95

IC SOCKETS
Solder Tin Low Profile

PIN	1 UP	PIN	1UP
8	.15	24	.36
14	.18	28	.43
16	.20	36	.58
18	.27	40	.61
22	.35		

3 level wire wrap gold.
14 pin .35 16 pin .39
2 level 14 pin ww .25

CONNECTORS	
44 pin edge	2.00
100 pin edge	4.50
100 pin edge WW	5.25

MOS/MEMORY RAM	
2101-1	3.95
2102-1	1.28
2102AL-4	1.60
21F02	1.85

2104A-4	4.95
2107B	4.70
2111-1	4.95
2112-2	7.90
2114	13.45
MK4116	27.50
2513B	8.75
21L02-1	1.49
MM5262	.40
MM5280	3.00
MM5320	9.95
MM5330	5.94
PD411D-3	4.00
PD411D-4	5.00
P5101	13.95
4200A	12.95
82S25	2.90
91L02A	1.75
HD0165-5	6.95
MM57100	9.50
GIAY38500-1	13.95
MCM6571A	9.95
9368	3.50

INTERFACE	
8T26	1.69
8T28	2.75
8T97	1.69

CRYSTALS

1 MHz	4.50	2.0100 MHz	1.95
2 MHz	4.50	2.097152 MHz	4.50
4 MHz	4.25	2.4576 MHz	4.50
5 MHz	4.25	3.2768 MHz	4.50
10 MHz	4.25	5.0688 MHz	4.50
18 MHz	3.90	5.185 MHz	4.50
20 MHz	3.90	5.7143 MHz	4.50
32 MHz	3.90	6.5536 MHz	4.50
32768 Hz	4.00	14.31818 MHz	4.25
1.8432 MHz	4.50	18.432 MHz	4.50
3.5795 MHz	1.20	22.1184 MHz	4.50

60 Hz Crystal Time Base Kit	**$ 4.40**
30 MHz Frequency Counter Kit	**$47.75**
Prescaler Kit to 350 MHz	**$19.95**

COMPUTER BOARD KITS	
8K RAM Board Kit	$134.95
4K EPROM Kit	114.95
I/O Board Kit	44.50
Extender Board w/connector	12.50
Video Interface board kit	125.00
16K EPROM board kit w/o PROMS	74.50
16K Static RAM board kit	395.00
North Star Floppy Disk Kit	$665.00
Additional Drive Kit	415.00

Paratronics 100A Logic Analyzer Kit	**$199.00**
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RCA CMOS expandable to 64K microcomputer w/HEX keypad input and video output for graphics. Just turn on and start loading your program using the resident **monitor on ROM.** Pushbutton selection of all four CPU modes. LED indicators of current CPU mode and four CPU states. Single step op. for program debug. Built in pwr. supply, 256 Bytes of RAM, audio amp. & spkr. Detailed assy. man. w/PC board & all parts fully socketed. Comp. Kit **$106.95**. High address display option **8.95**; Low address display option **9.95**; Custom hardwood cab.; drilled front panel **19.75**; Nicad Battery Backup Kit w/all parts **4.95**; Fully wired & tested in cabinet **151.70**; 1802 software club. 10–12 pg. monthly publication **12.00** per yr.

4K Elf Expansion Board Kit with Cassette I/F $79.95

Available on board options: 1K super ROM monitor **$19.95.** Parallel I/O port **$7.95.** RS232 I/F **$3.50.** TTY 20 ma I/F **$1.95.** S-100 Memory I/F **$4.50**

Tiny Basic for ANY 1802 System

Kansas City Standard Cassette	**$10.00**
On ROM Monitor	**$38.00**

Super Elf owners take 30% off.

Object code listing or paper tape with manual	**$5.50**

Auto Clock Kit $15.95

DC clock with 4-.50" displays. Uses National MA-1012 module with alarm option. Includes light dimmer, crystal timebase PC boards. Fully regulated, comp. instructs. Add $3.95 for beautiful dark gray case. Best value anywhere.

'78 IC Update Master Manual

1978 IC Update Master Manual	**$30.00**

Complete IC data selector 2175 pg. Master reference guide. Over 42,000 cross references. Free update service through 1978. Domestic postage $3.50. Foreign $6.00. Final 1977 Master closeout **$15.00**

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Convert your TV set into a high quality monitor without affecting normal usage. Complete kit with full instructions.

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Video computer with games and graphics.

Sinclair 3½ Digit Multimeter

Batt. oper. 1mV and .1NA resolution. Resistance to 20 meg. 1% accuracy. Small, portable, completely assem. in case. 1 yr. guarantee. **$59.95**

TERMS: $5.00 min. order U.S. Funds. Calif residents add 6% tax. BankAmericard and Master Charge accepted. Shipping charges will be added on charge cards.
FREE: Send for your copy of our NEW 1978 QUEST CATALOG. Include 24¢ stamp.

Circle 307 on inquiry card.

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EXPANDABLE EPROM BOARD

16K OR 32K EPROM $49.95 W/OUT EPROM

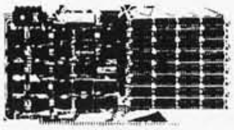
Allows You to Use Either 2708's For 16K of Eprom or 2716's For 32K of Eprom.

KIT FEATURES:

1. All Address Lines & Data Buffered
2. Quality Plated through P.C. Board Including Solder Mask and Silk Screen
3. Selectable Unit States
4. On Board Regulation Provided
5. All Sockets Provided W/Board

WE CAN SUPPLY 450As 2708's AT $11.95 WHEN PURCHASED WITH BOARD.

EXPANDORAM
THE ULTIMATE RAM BOARD
32K FOR $475.00



32K MODEL	
8K	$151.00
16K	259.00
24K	367.00
32K	475.00

64K MODEL	
16K	$281.00
32K	519.00
48K	757.00
64K	995.00

THE 32K VERSION USES THE MOSTEK MK4115 RAM AND HAS 8K BOUNDARIES AND PROTECTION & UTILIZES DIP SWITCHES. P. C. BOARD COMES WITH SOCKETS FOR 32K OPERATION

BUY A S100 COMPATIBLE RAM BOARD AND UPGRADE THE SAME BOARD TO A MAXIMUM OF 65K MEMORY IN STEPS OF EITHER 8K OR 16K AT YOUR OPTION BY MERELY PURCHASING MORE RAM CHIPS FROM SD COMPUTER PRODUCTS.

THE 64K VERSION USES THE MOSTEK MK4116 RAM AND HAS 16K BOUNDARIES AND PROTECTION & UTILIZES DIP SWITCHES. P. C. BOARD COMES WITH SOCKETS FOR 64K OPERATION

LOOK AT THE FEATURES WE HAVE BUILT INTO THE EXPANDORAM!

- MEMORY ACCESS TIME IS 375 ns
- MEMORY CYCLE TIME IS 500 ns
- POWER REQUIREMENTS ARE:
  8 VDC 400 MA DC
  18 VDC 400 MA DC
  —18 VDC 30 MA DC
- ON BOARD INVISIBLE REFRESH
- NO WAIT STATES REQUIRED
- NO CYCLE STEALING NEEDED
- ON BOARD REGULATION
- CONTROL, DATA & ADDRESS INPUTS UTILIZE LOW POWER SCHOTTKY DEVICES
- DESIGNED TO WORK WITH Z-80, 8080, 8085, CPU's

ADD $50.00 TO ABOVE PRICES FOR FULLY ASSEMBLED AND TESTED BOARDS

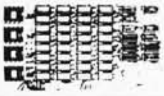
Low Cost Cassette Interface Kit

$19.95

Features: Play and record K.C. Standard 2400/1200 Hz tapes, 900 Baud, TTL I/O Compatible, Phase Lock Loop, Both 22 Pin Connector and 8 Pin Molex Connector. Comes partially assembled. Oscillator and phase lock loop pre-tuned to K.C. Standard. Selector switch sends cassette data or auxiliary input data to microprocessor. LED indicates logic 1 level.

4K LOW POWER RAM KIT
The Whole Works - $79.95

Full Buffered - on board regulated - reduced power consumption utilizing low power 21L02-1 500ns RAMS - Sockets provided for all IC's. Quality plated through PC board.



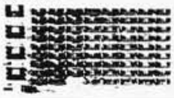
*Add $10.00 for 250ns RAM operation.

8K LOW POWER RAM
$159.95

FULLY ASSEMBLED AND TESTED. NOT A KIT.

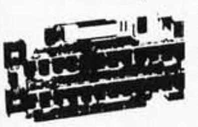
Imsai — Altair — S-100 Buss compatible, uses low power static 21L02-500ns fully buffered on board regulated, quality plated through PC board, including solder mask. 8 pos. dip switches for address select.

*Add $30.00 for 250ns RAM operation



Z-80 CPU BOARD KIT
Complete Kit $139.

CHECK THE ADVANCED FEATURES OF OUR Z-80 CPU BOARD: Expanded set of 158 instructions, 8080A software capability, operation from a single 5VDC power supply; always stops on an M1 state, true sync generated on card (a real plus feature!), dynamic refresh and NMI available, either 2MHZ or 4MHZ operation, quality double sided plated through PC board; parts plus sockets provided for all IC's.



*Add $10. extra for Z-80A chip which allows 4MHZ operation.

NEW FROM S.D.
"VERSAFLOPPY"™ KIT
THE VERSATILE FLOPPY DISK CONTROLLER
ONLY $149.00

FEATURES: IBM 3740 Soft Sectored Compatible. S-100 BUS Compatible for Z-80 or 8080. Controls up to 4 Drives (single or double sided). Directly controls the following drives:

1. Shugart SA400/450 Mini Floppy
2. Shugart SA800/850 Standard Floppy.
3. PERSCI 70 and 277.
4. MFE 700/750.
5. CDC 9404/9406.

34 Pin Connector for Mini Floppy. 50 Pin Connector for Standard Floppy. Operates with modified CP/M operating system and C-Basic Comptler. The new "Versafloppy" from S.D. Computer Products provides complete control for many of the available Floppy Disk Drives, Both Mini and Full Size. FD1771B-1 Single Density Controller Chip. Listings for Control Software are included in price.

FD 1771B-1 CHIP ALONE $39.95

Z80 STARTER KIT

LEARN COMPUTERS FROM THE START!

SIMPLE, STEP BY STEP LEARNING. CONSTRUCTION, PROGRAMMING, OPERATION, MEMORIES, INTERFACING, COMPUTING, AND CONTROLLING WITH AUDIO CASSETTE INTERFACE CAPABILITIES.

Complete Kit includes: Key board and Display; Z80 Central Processing Unit; Instructions; Operation Manual; Learning Guides.

Features: Powerful Z80 CPU with 158 instructions • 1024 Bytes (Expandable to 2048 Bytes ON BOARD) of RAM • 2 Bi-Directional Input/Output Ports with Handshaking • Kansas City Standard Audio Cassette Interface for Program Storage • Hexadecimal Keyboard and Display • Wirewrap area for custom circuitry • S-100 Connector on board for Memory and I/O Expansion • 2716/2758 PROM Programmer • "Z-BUG" Monitor ROM (Including: Memory, Port and Register Examine and Change Commands; Breakpoints; Single Step Capability; Audio Tape Load and Dump; Execute user program Commands.)

Many more unique features. The best computer educational kit on the market . . . **the complete computer and educational package for only $199.00.** (Available June 1978).

INTRODUCING THE SBC-100
(The Z-80 Based, S-100 Single Board Computer)

$349.00

FEATURES:

- No Front Panel Needed
- Z-80 CPU (2 or 4 MHZ)
- 1K RAM
- 4 ROM/PROM Sockets for 4K/8K of Memory
- SYNCHRONOUS/ASYNCHRONOUS Serial I/O with RS-232 and Current Loop Interface and Software
- Programmable Baud Rate
- Parallel Input Port
- Parallel Output Port
- 4 Channel Timer/Counter
- 4 Vectored Interrupts

O. E. M. SPECIAL

ASK ABOUT SPECIAL O.E.M. DISCOUNTS ON THE S.D. "COMPATIBLE SET."

SDC-100 — SINGLE BOARD COMPUTER	$349.00
VERSAFLOPPY™ — FLOPPY DISK CONTROLLER	$149.00
EXPANDORAM — 32K RAM	$475.00

EACH KIT IF PURCHASED SEPARATELY TOTAL $973.00

ORDER ALL 3 KITS TOGETHER FOR

$899.00

This Powerful Threesome Operates Together to Form A Comolete Computer for Your System.

Z-80 Programming Manual

IN DEPTH DETAIL OF THE Z-80 CPU MICRO-COMPUTER

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WANTED: For Microdata 1600 processor (Reality) magnetic tape controller and disk controller and core memory boards. Jack Hardman, 140 Forest Av, Glen Ridge NJ 07028, (201) 429-8880.

FOR SALE: COSMAC microprocessor CDP1802 and 2 2101 programmable memory chips. Get started for $20. CPU used less than 1 hour. Programmable memory new. I also have 10 new 2101s. $2.50 each or all ten for $20. Jeff Duntemann, 6424 N Albany Av, Chicago IL 60645, (312) 764-5069.

FOR SALE: SwTPC 6800 16 K system with AC30 cassette interface, fully socketed, first-class working condition, with documentation, $700, delivered within 200 miles. Processor Technology VDM-1 video board, $125 shipped prepaid. Robert Boyd, Woodlawn Av, Kennebunkport ME 04046.

FOR SALE OR SWAP: Altair 8800 kit microcomputer. Prefer ham gear. Write or call after 7 PM. Manley Nichols, Box 344, Henning MN 56551, (218) 583-2124.

FOR SALE: Viatron System 21. It has two tape storage units, a video monitor, a keyboard, two IO ports, etc. It also includes three tapes, two instruction manuals, and a technical manual (which includes all circuits). Asking $600. P Gabrail, 209 Highland Av, Syracuse NY 13203.

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WANTED: Any information that you may have pertaining to hardware and software of personal computing systems, programming language and interfaces. Any and all contributions gratefully acknowledged by correspondence. Am presently assigned overseas and have no access to such material. David E Feher, Box 22, US Naval Communications Station, Fleet Post Office, New York NY 09571.

FOR SALE: Processor Tech Video Display Module VDM-1 for $160, 2 K Read Only Memory 2 KRO for $50. Still in kit form. Includes manuals and VDM software. Will sell both for $200. Shipped by return mail to first money order. G Briggs, 6195 Deer Path, Manassas VA 22110.

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WANTED: Original soft LEATHER (not plastic) case for HP-35 calculator. State price, condition, and whether snaps or velcro. John Ball, Oak Hill Rd, Harvard MA 01451.

FOR SALE: HP 9830A 32 K (OPT 001) memory (B) with following ROMs strings, matrix, ext IO, API, APII, plotter. 9871A Printer with form feed. 11203A BCD interface. Make offer. Robert Luke MD, Dept of Pathology, Maine Medical Center, Portland ME 04102, (207) 871-2843 days, (207) 883-9998 nights.

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FOR SALE: Radio Shack TRS-80 with 16 K, level I and II BASIC. No monitor or recorder but all documentation and cables. Best cash offer. Mike Heck, 167 S Spring Mill Rd, Villanova PA 19085, (215) 525-0709.

WANTED: Memorex 3664 or IBM2311 disk drive. Please reply via air mail stating price and condition. Also, would like contact with anyone who owns a Memorex 40 minicomputer and for information exchange on its hardware or software. P R Williams, 15 Pinny Av, Lower Hutt NEW ZEALAND.

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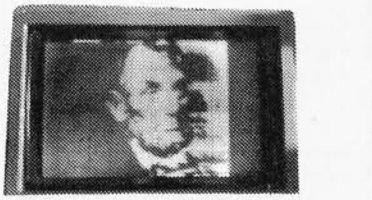

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7427–	.19	7496–	.65	74193–	.79
7430–	.13	74107–	.28	74194–	.80
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74LS02	.21	74LS132	.80	LM 301/748	.29
74LS03	.21	74LS136	.39	LM307	.30
74LS04	.28	74LS138	.70	LM 308	.75
74LS05	.28	74LS139	.70	LM 311	.75
74LS08	.21	74LS151	.70	LM 318	1.20
74LS09	.28	74LS153	.70	LM 319	.95
74LS10	.21	74LS155	.70	LM 324	1.05
74LS11	.21	74LS156	.70	LM 339	1.10
74LS13	.44	74LS157	.72	LM 358	.70
74LS15	.25	74LS160	.88	LM 370	1.15
74LS20	.24	74LS161	.85	LM 377	2.50
74LS21	.26	74LS162	.85	LM 380	.95
74LS22	.26	74LS163	.85	LM 381	1.25
74LS26	.32	74LS168	.88	LM 382	1.25
74LS27	.32	74LS169	.85	LM 537	2.50
74LS30	.26	74LS170	1.68	LM 553	2.50
74LS32	.32	74LS173	1.10	LM 555	.39
74LS37	.32	74LS174	1.00	LM 556	.85
74LS38	.32	74LS175	.80	NE540L	2.25
74LS40	.26	74LS190	.95	560	2.00
74LS42	.65	74LS191	.95	565	.95
74LS47	.79	74LS192	.95	566	1.25
74LS51	.26	74LS193	.95	567	1.30
74LS54	.26	74LS195	.95	703	.90
74LS90	.95	74LS196	.95	709	.25
74LS74	.35	74LS197	.95	710	.35
74LS76	.35	74LS221	1.25	741C or V	.31
74LS85 74 LS86	1.30 .35	74LS257	.70	747	.50
74LS90	.55	74LS258	.70	LM 1310	2.50
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