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the small systems journal

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HOME BREWING



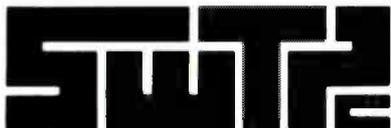
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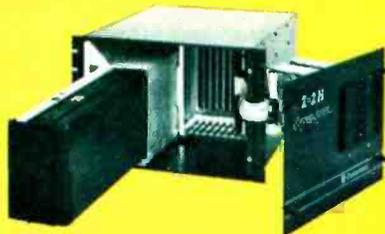
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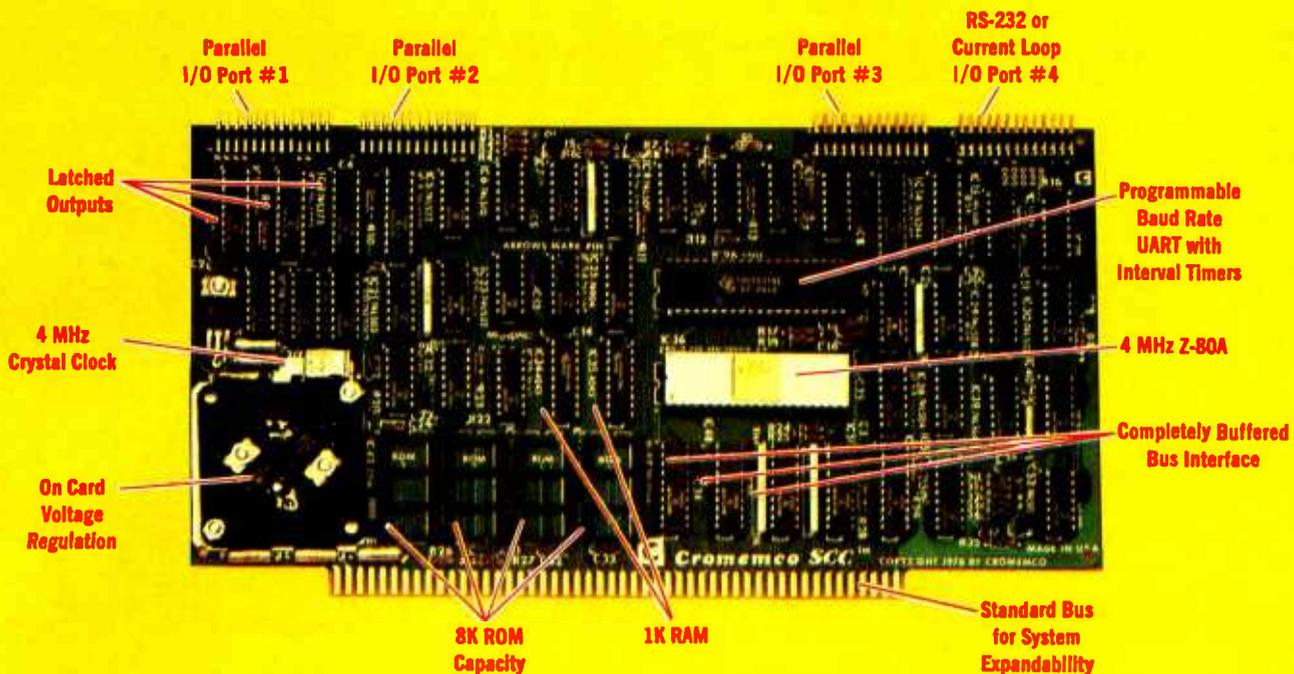
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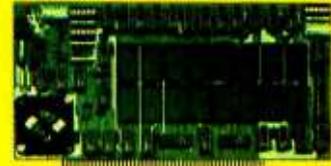
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In This BYTE



About the Cover

On this issue's cover, Robert Tinney has created a "fantasy on homebrewing." In the middle of a sylvan glade, we see the form of a computer being sculpted by some homebrewer. A couple of humanoid forest denizens look on with wonder, perhaps hoping to get a glimpse of our homebrewer on his return to the workplace.

Building a joystick interface for your computer system adds a new physical input dimension. There are as many different ways to interface a joystick as there are applications. Steve Ciarcia discusses several widely varying ways to design Joystick Interfaces.

Page 10

The idea of having a microcomputer work in a multiprogramming environment is becoming a reality. Already there are several multiprogramming systems on the market. Mark Dahmke provides an Introduction to Multiprogramming so we can understand how these systems operate.

Page 20

If you enjoy playing chess against your computer, but dislike typing in the moves in abstract notation, you will be interested in a method of allowing the computer to detect moves made on a real chessboard. Jeff Teeters devised such a method and now tells us how he did it in Interface a Chessboard to Your KIM-1.

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Some Musings On Hardware Design by Clayton Ellis provides readers with background information on picking integrated circuits and using them in homebrew work.

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Although there are many applications where a high-speed analog-to-digital converter is necessary, many conversion applications can make do with a slower conversion. Richard C Hallgren has built A Low-Speed Analog-to-Digital Converter for the Apple II which he uses as a real-time data analyzer.

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When constructing electronic equipment, it is imperative that good Soldering Techniques are developed. William Trimmer presents a photo essay of good soldering practices and several examples of unwanted techniques.

Page 84

William T Powers brings his discussion of The Nature of Robots to a close by applying the previously-discussed techniques and theories in a simple experiment with a human subject.

Page 96

The search for the inexpensive paper-tape reader continues as Brian

A Harron describes an Inexpensive, Optical Paper-Tape Reader.

Page 118

James Albus considers the mechanisms of choice in his closing article about A Model of the Brain for Robot Control.

Page 130

A Handy Pulser can prove to be very useful when testing a digital circuit. Bob Chrisp shares with us his version of a useful pulse generator.

Page 160

In The AMSAT-GOLEM-80, Joe Kasser shows how your computer club (or any other group of experimenters) can economically build an S-100 microcomputer. The system is modular and expandable.

Page 182

Performing simple control functions with your computer can be easy. Ken Barbier describes how to Add Some Control to Your Computer.

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Editorial

The Rationale of Yet Another Homebrew System

by Carl Helmers

In this issue of BYTE, we are placing a special emphasis on the homebrewing of computers: the craft of assembling the hardware and software of a system from standard components in nonstandard ways. This month's editorial provides a continuation of notes begun in July on the design and assembly of my new homebrew 6809 system. In this editorial, we complete the final details of the physical layout and power supplies of the system, as well as the overall design of the system. We shall also begin a discussion of the actual processor card. Future installments in this series on homebrew, general purpose, computer hardware will record details of the system beyond this article's goal of defining a backplane bus structure.

As noted earlier ("Editorial," June 1979 BYTE, page 6), the intent of this exercise is to develop a specialized controller node for a loosely coupled system of processors involved with musical applications. The multiple processors initially contemplated were a Pascal-oriented, large personal computer and an ALF products model AD-8 music synthesizer with its 6502 used for house-keeping. In addition to this coordinating task, the 6809 would provide a central point for the connection of keyboards, displays and other hardware required by musical applications.

But ideas change and evolve. Since the 1st installments were written, plans have become slightly more grandiose with my recent acquisition of a New England Digital "Synclavier" music synthesizer and its associated Able/60 minicomputer. Located in Norwich VT, New England Digital is a combined spin-off of the music and electrical engineering departments of Dartmouth College across the Connecticut river in NH. The computer for the music synthesizer employs the XPL language as its high-level user interaction. The New England Digital version of XPL is augmented by a floating-point data type. With the exception of an adaptation of UCSD Pascal, which is expected to be available soon, all systems software is written in XPL, including what is described as a 3-pass optimizing XPL compiler.

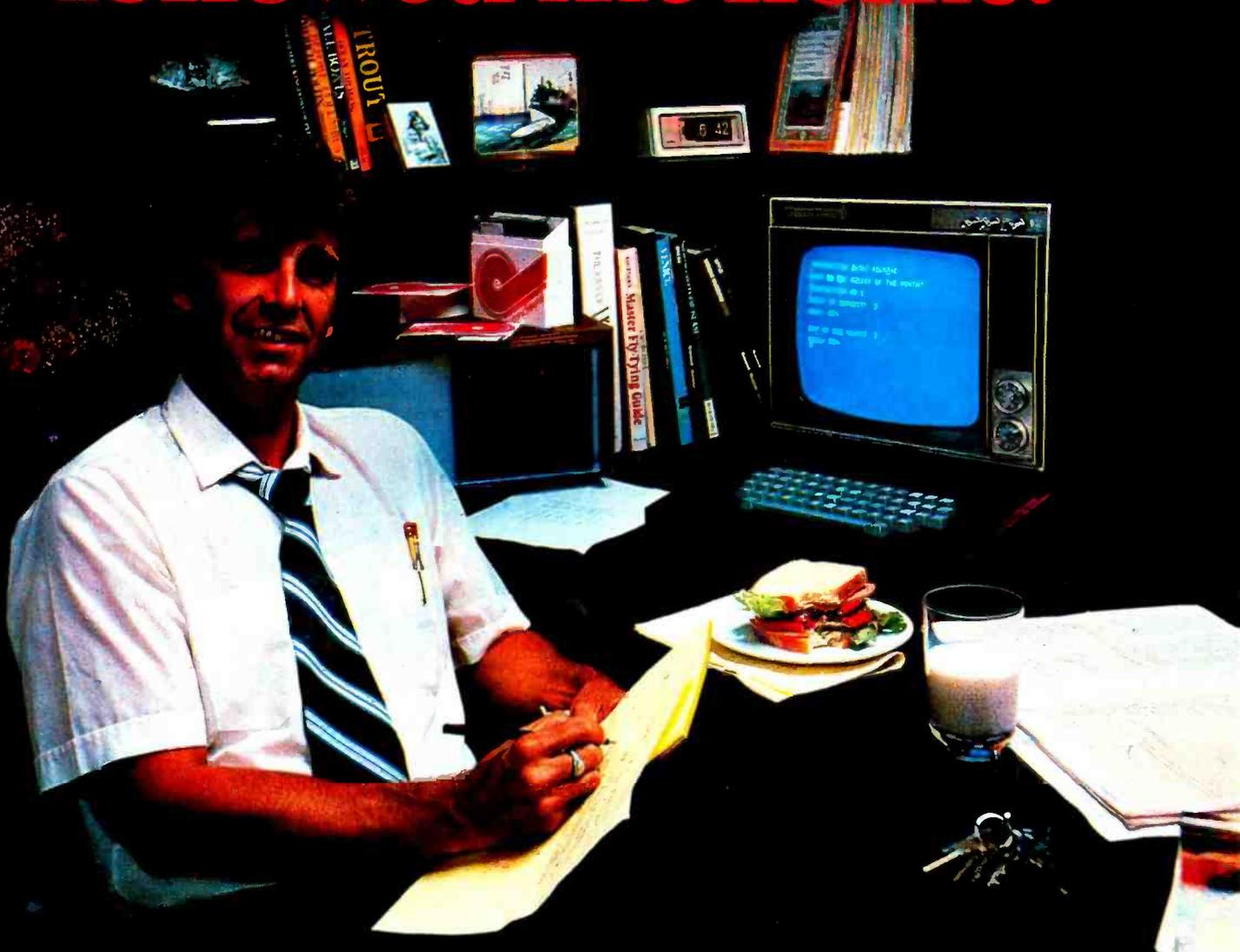
[XPL is the language described in the book *A Compiler Generator*, by McKeeman, Wortman, et al, published circa 1968. The commonly used microcomputer language PL/M, 1st designed and implemented by Gary Kildall, is very similar to XPL in syntax and semantics. XPL is a simple subset of PL/I, with data types restricted to character and integer forms.]

At this point, I now have a need for multiple processor communications beyond the level of 1 large machine (a Western Digital P-engine) driving a smart peripheral through a serial communications link. The smart peripheral will still handle specialized details like the parallel interface to the older synthesizer and the eventual interface to an electronically controlled player piano.

See photo notes on pages 8 and 9, text continued on page 202

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Hardware Basis...

These photographs depict some further details of the physical hardware of the new homebrew 6809 computer system. As noted earlier, Vector Electronic Co components were used for the assembly of a backplane. Photographs 1 through 5 show various aspects of the new design's packaging.

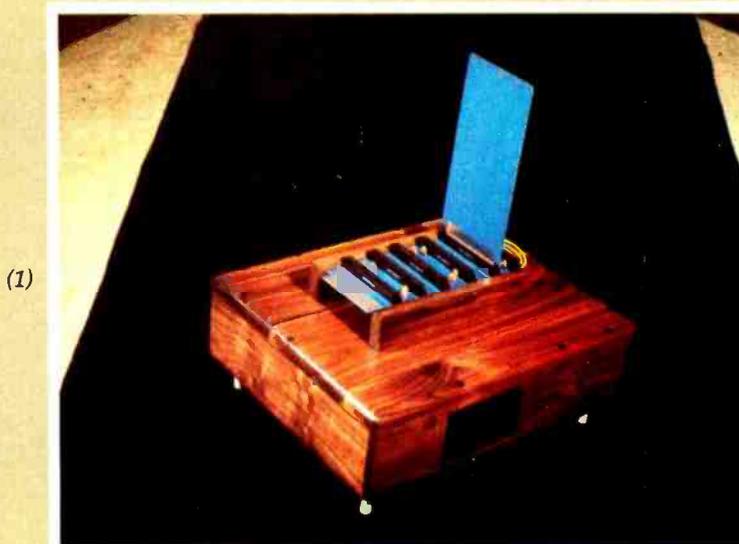
Photo 1: The new computer system's final physical mounting basis is a mahogany box with guide blocks for the backplane assembly. Power supplies are located underneath the box. Power for the computer and accessories will be controlled by the standard, household wall switch mounted on the side of the box. Power connections to the backplane power buses will pass through a hole underneath the backplane in this photo. The hole provides an exit path for the flow of hot air from the power supplies.

Individual boards of the system plug into the backplane from the top as shown here. The backplane assembly slides into the grooves of the 2 guide blocks. These blocks are bolted to the top of the box using $\frac{1}{4}$ -20 machine-screws and threaded inserts. The grooves for the backplane board were cut $\frac{1}{16}$ th of an inch wide with a router and edge guide. The woodshop tools required to fabricate this case included a table saw, electric hand drill, drill press, router, belt sander, sabre saw, and the usual collection of hand tools.

Photo 2: The power supply modules are attached to 2 wooden brackets which are screwed into the main box by means of $\frac{1}{4}$ -20 machine-screw threaded inserts. The power supply modules are mounted on the brackets using #8-32 threaded inserts. Ordinary brass finish door stops serve as legs to keep the assembly off the table top, thus allowing natural convection to cool the power supply modules.

No attempt is made to calculate heating factors. The inverted cup shape of the box seems like an excellent trap for heat, however, the large hole beneath the backplane assembly at the top of the box provides a relatively low-impedance outlet for the heated air from below. If the temperatures observed under load are excessive, then a fix will be necessary. In a commercial or industrial engineering situation where production of a product is contemplated, this "patch up after problems" strategy is not the recommended practice due to the possibilities of costly errors, but for one of a kind products in a noncommercial and highly experimental context, it is certainly acceptable and can economize on time.

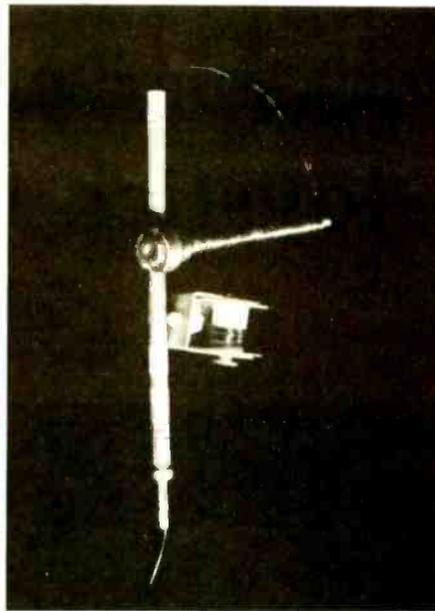
Photo 3: (a) Brass machine-screw inserts to provide metal to wood fastening in the



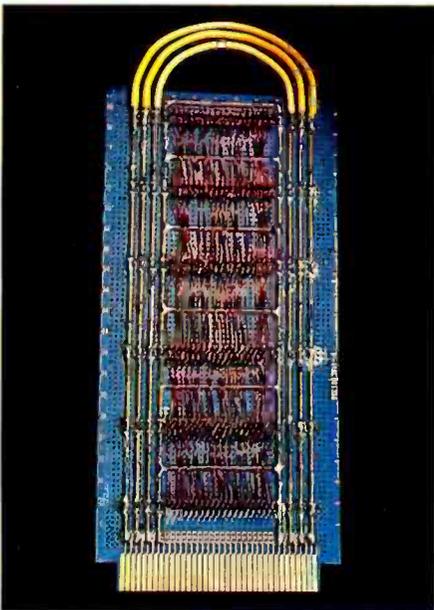
(3b)



(5a)



(4)



(5b)



assembly of the computer housing. These particular parts were purchased from the Brookstone Co Peterborough NH.

(b) When inserting the machine-screw fasteners into hardwood, better results were obtained when the hole drilled in the wood was 1/64th of an inch larger than the recommended size in the instructions. A short section of the machine-screw to be used, together with a hex nut, provide a tool for driving the insert as shown in this picture. When using the #8-32 inserts in hardwood, a slightly larger hole than suggested in the instructions is a necessity. Unless the extra clearance is given, the torque on the #8-32 bolt used in driving the insert will cause the insert to twist apart after 1 or 2 uses.

Photo 4: The backplane is the first and the most tiresome wiring involved with

assembly of a small computer. Its definition is provided by the simple instructions:

FOR each free socket, pin BY NUMBER
OF each socket,
CONNECT that pin to the same pin
of the next socket in the backplane!

The backplane assembly was described in the notes of the July 1979 BYTE, page 194. This photo shows the finished backplane after all wiring and installation of bypass capacitors has been completed.

Photo 5: The wiring of the backplane, as well as the rest of this computer, was done with the Vector Electronic Co's "slit-N-wrap" technique. An electric eraser was used to motorize the connections, with an adapter custom-made on a small lathe. It is

recommended that motorized wiring be employed with the "slit-N-wrap" technique. In previous experimental electronics built with this technique, reliability problems were encountered with manual termination of the wires to wire-wrap socket posts. Motorized wrapping with this tool provides a uniform and higher force for stripping the insulation off the wire.

At (a) is the adapter: a hollow tube made from 2 junk box spacers, a #10-32 bolt with a hole drilled through it, a brass union between the 2 spacers, and a large brass adapter to which a #10-32 nut is soldered. (This latter kludge is what happens when one makes an adapter on a Sunday afternoon and a #10-32 tap is not available!) At (b) the completed adapter is mounted in the Bruning Electric Eraser in a typical use situation.

Joystick Interfaces

Steve Ciarcia
POB 582
Glastonbury CT 06033

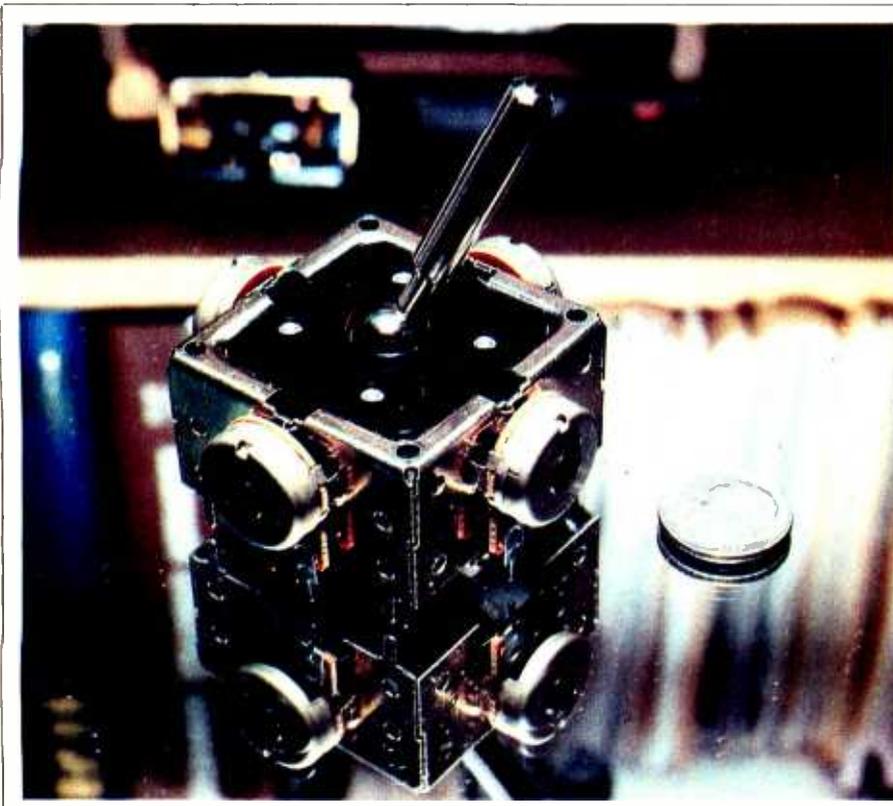


Photo 1: A typical joystick with 4 potentiometers.

The thought that often comes to mind when the word joystick is mentioned to a computer enthusiast is of a spacewar-type game. A photon torpedo is fired from an opponent's starship, and the thruster joystick is deftly moved to reposition the craft out of its path. All of this occurs without having to take your eyes off the screen. Eye/hand coordination is almost "instinctive." With a glance to the upper right of the video screen, the joystick is tilted to the upper-right corner of its 360° range. This moves the spacecraft toward that coordinate. Reverse thrust is accomplished by moving the joystick in the opposite direction, as though you are pulling back on the throttle of a real

craft. Such is the general experience with joysticks. However, the potential use of these devices greatly exceeds that of game playing.

A joystick, for those people who are unfamiliar with one, is shown in photo 1. It is an electromechanical device with resistance outputs proportional to the X,Y displacement of a central ball and lever. Photo 2 illustrates the mechanical connections to the potentiometers.

When the stick is positioned in the center of its axes, the X and Y potentiometers show resistances in the center of their ranges. When the stick is tilted to the upper right, both potentiometers are at their full-resistance limit, while the opposite



Photo 2: Note how moving the stick moves the gimbal arrangement, which in turn changes the settings of the potentiometers.

(lowest resistance) is true when in the lower-left position. The outputs of the 2 potentiometers accurately track, as if on an X,Y coordinate axis, the position of the joystick. It should be noted that while it takes only 2 potentiometers to define 2-dimensional travel, most joysticks are manufactured with 4 potentiometers. This is a remnant of the days when joysticks were connected directly to the 4 deflection-plates of a cathode ray tube (video screen).

It is one thing to *consider* interfacing a joystick to a computer, and quite another to *do* it. A joystick is a mechanical X,Y positioning device. Even with proportional output resistances, an input interface must be designed to convert position from an analog to a digital representation which can be used by the computer. A further consideration is the resolution, or percent, of full-scale travel per bit sensitivity. Is the application so gross that center and full-scale are the only points of interest, as in a

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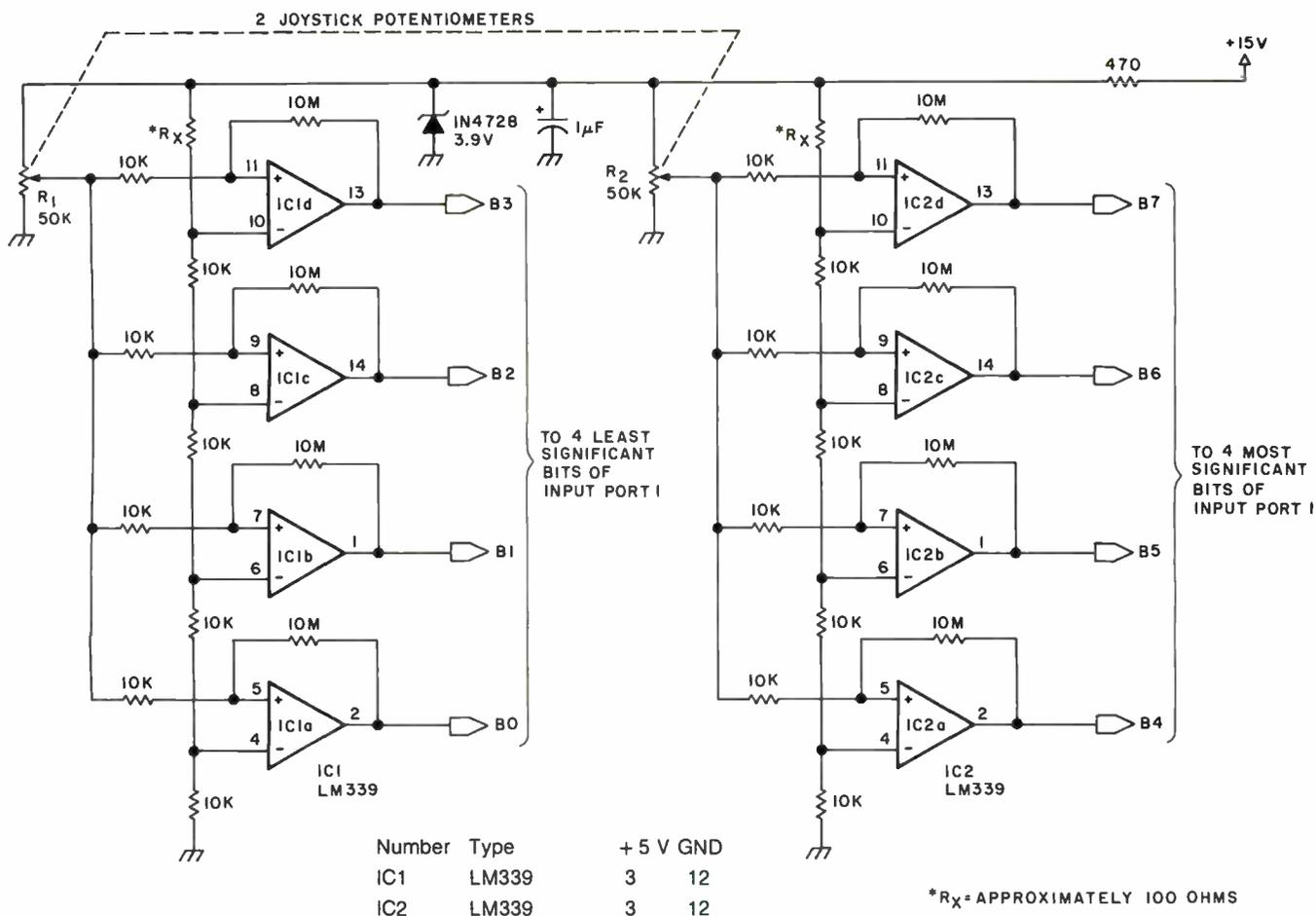


Figure 1: Low-resolution static interface. This interface is for 1 2-potentiometer joystick. For 4-potentiometer joysticks, build a second circuit like this one, and interface it to another input port. Note that if the comparator does not trigger at full-scale setting, a small resistor may have to be added at Rx (marked with asterisk).

game control, or is the application one which requires fine control, such as a cursor-positioning device in a high-resolution graphics system?

All joystick interfaces are not created equal. There is a trade-off between hardware and software. The lower the resolution, the fewer the parts. The higher the resolution, the greater the electrical complexity or the software interaction with the interface. It is also important to recognize that computer systems which operate *only* in a high-level language like BASIC cannot use an interface design that requires an assembly language subroutine as an integral component. In such instances only a static interface can be used.

Included in this presentation are 4 interface designs which should cover most requirements, as well as demonstrate the considerable differences between them. The 4 types are:

- low-resolution static

- high-resolution fully static hardware
- software-driven pulse-width modulated
- high-resolution analog-to-digital

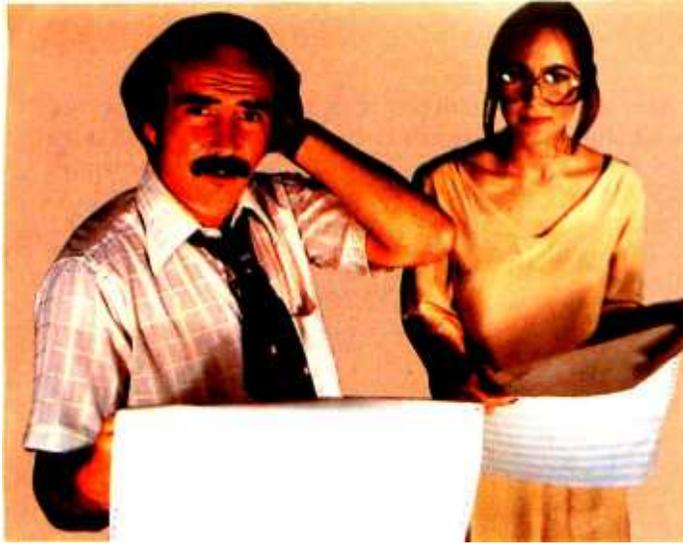
Low-Resolution Static Interface

First of all, *static* simply means that the interface hardware determines the potentiometer position value and presents it in constant, parallel digital form to the computer. When the interface is attached to any parallel input port, this joystick value can be read with a single INPUT command in BASIC. As far as the computer is concerned, the value is fully static, and the computer reads whatever data is there when the INPUT is executed. The interface hardware has the responsibility of asynchronously updating the digital value as the stick is moved.

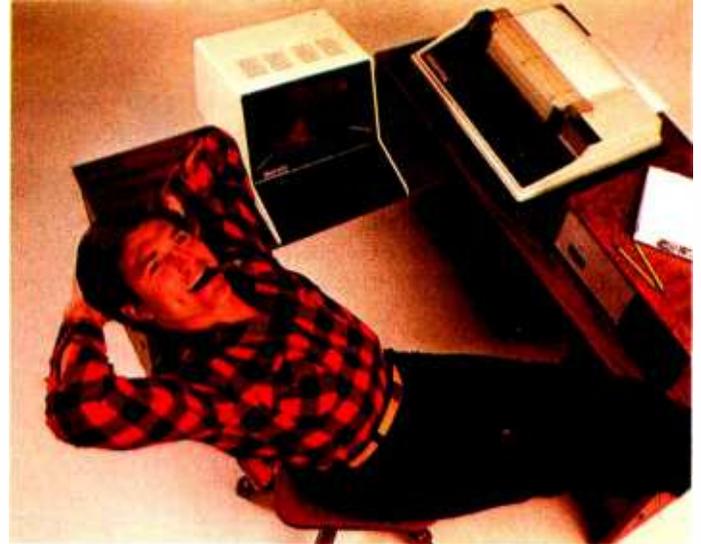
Often the joystick is simply used to indicate relative direction and magnitude. In a wheelchair, for instance, full linear control of speed

and direction would require rather expensive drive electronics. Most chairs use simple relay contacts and provide 2 or 3 selectable speeds. A joystick control built for this application would not have to have a resolution of 8 bits, but could, in fact, suffice with 2. Figure 1 shows a low-resolution static output joystick interface suitable for use in this application.

Each potentiometer is connected as a voltage divider between a reference voltage source of 3.9 V and ground. The voltage output of each potentiometer is, in turn, fed to a 2-bit, parallel analog-to-digital converter. This type of converter uses 4 comparators set for 25%, 50%, 75%, and 100% of full scale. If a voltage, when applied, is less than 0.975 V, all comparator outputs will be at 0 V. At 1.0 V, corresponding to the joystick being moved 25% of full scale, the least significant bit (LSB) of the converter will be a logic 1, while the other bits are low. Similarly, at full input all



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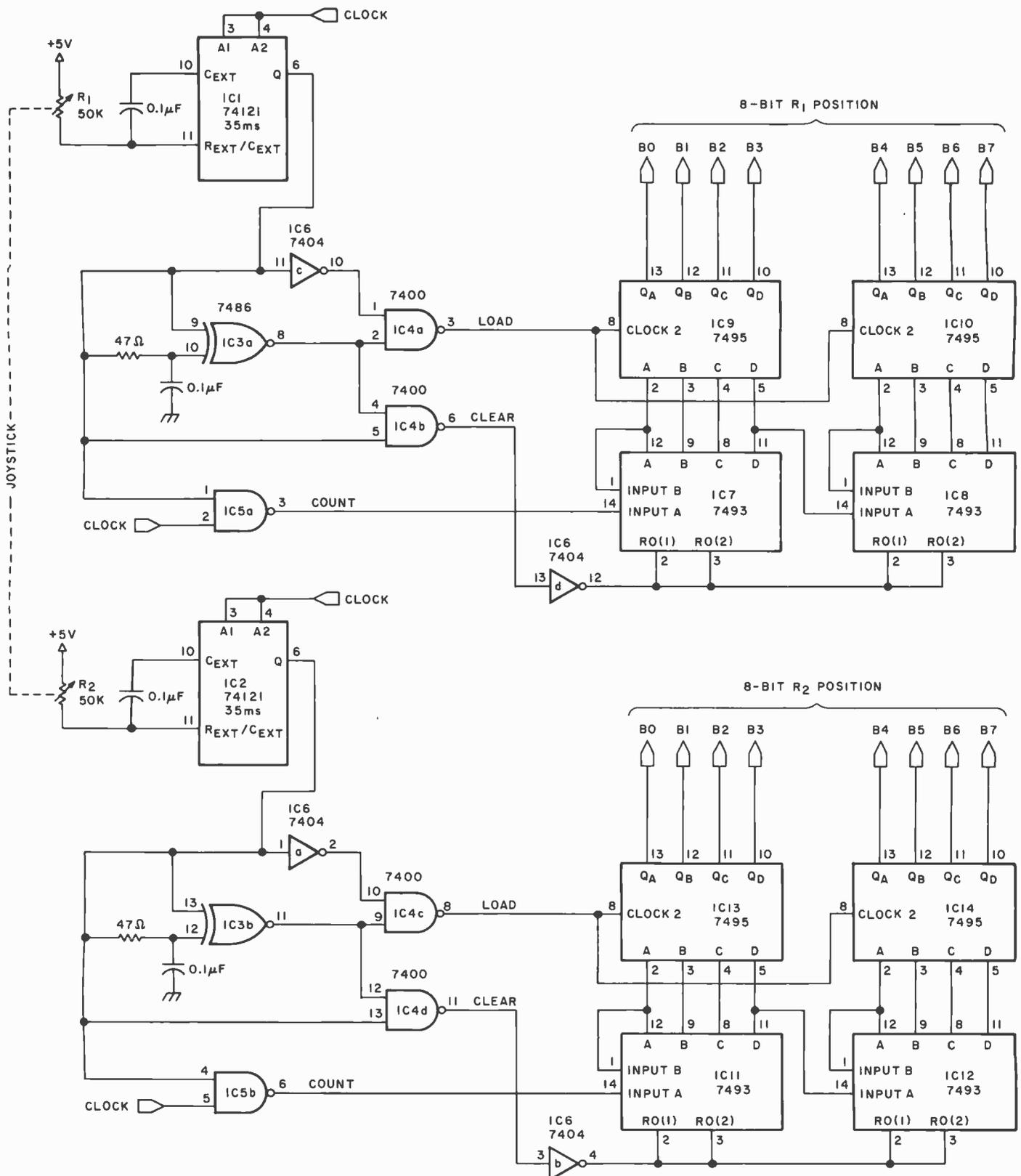
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comparators will be triggered, and bits 0 thru 3 will be logical 1s.

Additional encoding logic can be added to produce a true 2-bit representation from the 4 comparators, but it is just as easy for a computer to interpret it directly. With a

4-bit connection as shown, used in a BASIC program, 25% of full scale would be 1 decimal, 50% of full scale would be 3 decimal, 75% of full scale would be 7 decimal, and full scale would be 15 decimal. It should be easy to trigger any action by a coin-

cidence with these values. The real significance of this method is that the potentiometer position is presented statically to the computer and requires no other interaction. This makes it ideal for direct use with BASIC.



High-Resolution Static Interface

It is quite possible that 2 bits of resolution is not enough for your application, but direct compatibility with a slow, high-level language is still a requirement. Expanding the parallel comparator method will work in theory, but you must realize that a 4-bit analog-to-digital converter uses 15 comparators, and an 8-bit, parallel analog-to-digital converter needs 255 comparators! So much for that method.

Realizing that the output of the joystick is a variable resistance, we can use this to advantage. This resistance can set the *time constant* of a

function which has a pulse width proportional to joystick position. Figure 2 illustrates an interface design which uses this technique.

The 2 joystick potentiometers R1 and R2 control the pulse width of a one-shot (monostable multivibrator). The one-shot has a pulse width of 35 ms when the potentiometer is at 50 k ohm full scale and something less than 100 μ s at 0% of full scale. A 7.5 kHz clock signal asynchronously triggers the one-shots. When the one-shot fires, its duration is proportional to the joystick position and will vary from approximately 0 to 35 ms. Using midscale pulse width of 17 ms as an example, the circuit timing is as in figure 3.

On the leading edge of the one-shot signal, a *clear* pulse is generated through an edge detector configured 7486 device. The clear pulse resets the 2 7493s which form an 8-bit counter. Once cleared, the counters start counting clock pulses for the duration of the one-shot's period. On its trailing edge, a *load* pulse is generated which loads this 8-bit count into an 8-bit storage register. The computer is connected to read this 8-bit value through a parallel input port. Successive clearing and counting operations update the register every 35 ms or so (worst case). The clock rate is 7.5 kHz which has a period of 133 μ s. If the one-shot has a pulse width of 17 ms, then 127 clock pulses would be

gated to the counter. Of a total possible 255 counts, 127 would represent 50% of full scale.

Software-Driven Interfaces

So far I have discussed only static interfaces. If the computer used with the joystick has sufficient speed and excess computing time available, then it is reasonable to use the computer to directly determine the one-shot period.

Figure 4 shows a circuit which directly connects to the computer bus and demonstrates this technique. The circuit as shown is wired for I/O (input/output) port decimal 255 or hexadecimal FF. The 4 joystick potentiometers are used as the timing resistors on 4 NE555-type one-shots. When an OUT 0, FF is executed in assembly language, it triggers all 4 one-shots. To keep track of the pulse widths, a 74125 3-state driver gates the one-shot outputs onto the data bus during an IN FF instruction. By looping through this program a number of times and keeping track of the logic levels of the 4 one-shots, the computer can accurately determine joystick position in terms of loop counts of instruction times. Listing 1 is a program which does this for 1 potentiometer.

High-Resolution Analog-to-Digital

While all methods are in *some way* analog-to-digital converters, the last

Number	Type	+5 V	GND
IC1	74121	14	7
IC2	74121	14	7
IC3	7486	14	7
IC4	7400	14	7
IC5	7400	14	7
IC6	7404	14	7
IC7	7493	5	10
IC8	7493	5	10
IC9	7495	14	7
IC10	7495	14	7
IC11	7493	5	10
IC12	7493	5	10
IC13	7495	14	7
IC14	7495	14	7
IC15	NE555	8	1

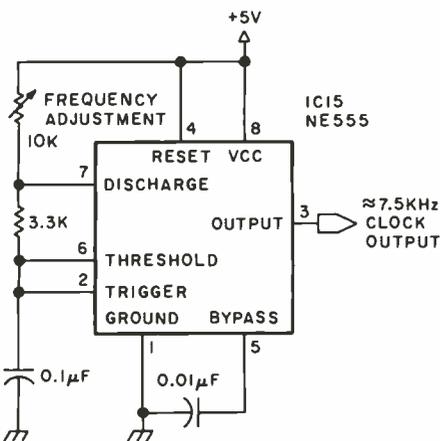


Figure 2: High-resolution, static interface. Each potentiometer in the joystick controls the pulse width of a one-shot. The pulse width can vary from 35 ms at full-scale to 100 μ s at 0. If a joystick with 4 potentiometers is used, a duplicate circuit may be constructed for the 3rd and 4th potentiometers.

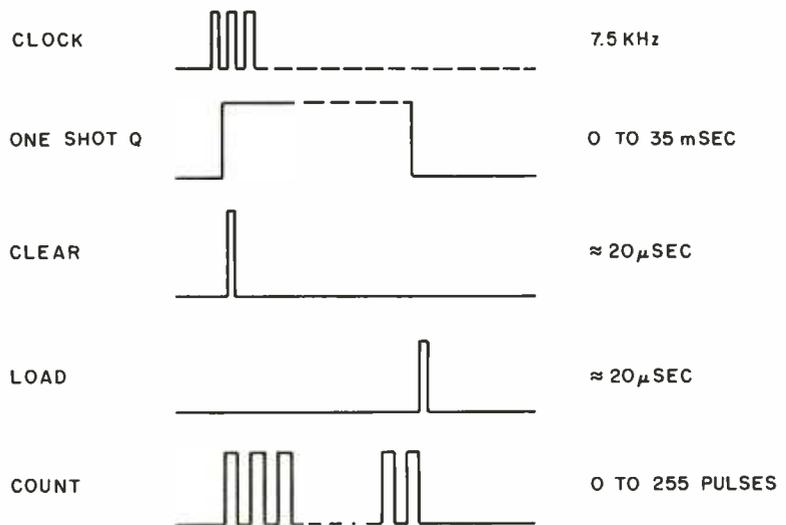


Figure 3: Timing diagram for interface of figure 2. The driving clock signal is 7.5 kHz. The one-shot can be triggered for periods of 0 to 35 ms, depending upon the position of the joystick. When a reading is to be taken, the counters are cleared. Counts are made until the one-shot signal drops, and then a load signal is sent to the interface. At this point the counter is read to determine the position of the joystick.

AGAIN	MVI	B	clear B
	OUT	FF,0	trigger one-shots
	INR	B	increment B register
	IN	FF	read potentiometers
	ANA	01	isolate bit 0
	JNZ	AGAIN	continue as long as one-shot is high
	HLT		value is in B register

Listing 1: A typical assembly language program for using the joystick interface of figure 4. After the one-shots are triggered, the program loops and checks the status of bit 0. When this bit is set, the conversion value is in register B. This program assumes that there is only 1 value being checked, and it is being input through bit 0.

method is in fact an 8-bit absolute-analog-to-digital converter, typical of the type used in computerized measurement applications. IC1 is an 8-bit

digital-to-analog converter that produces an output voltage proportional to a digital input applied to pins 5 thru 12. For a complete explanation of this device, I refer you to a previous "Ciarcia's Circuit Cellar" article, "Control the World" (September 1977 BYTE, page 30). This article also outlines calibration and test procedures.

The 3 basic sections are a computer-controlled voltage source (ICs 1 and 2), an analog-input multiplexer (IC3) which selects an individual joystick potentiometer by a 2-bit address code, and a comparator (IC4) which compares these voltages. In operation, the digital-to-analog converter is first set to 0 V out (hexadecimal 00 digital input to it) and 1 potentiometer is selected through the multiplexer. If V_0 from the digital-to-analog converter is less than V_{in} from the potentiometer, the output will be logic 0. Next, the digital-to-analog converter input setting is incremented, and the comparator output is checked again.

Eventually an input count will be reached which will exceed V_{in} . The comparator output will then be a logic 1. The digital-to-analog converter input count is now the value of the voltage V_{in} . The worst case requires 256 iterations using this

Number	Type	+5 V	GND
IC1	NE556	14	7
IC2	NE556	14	7
IC3	7430	14	7
IC4	7400	14	7
IC5	74125	14	7

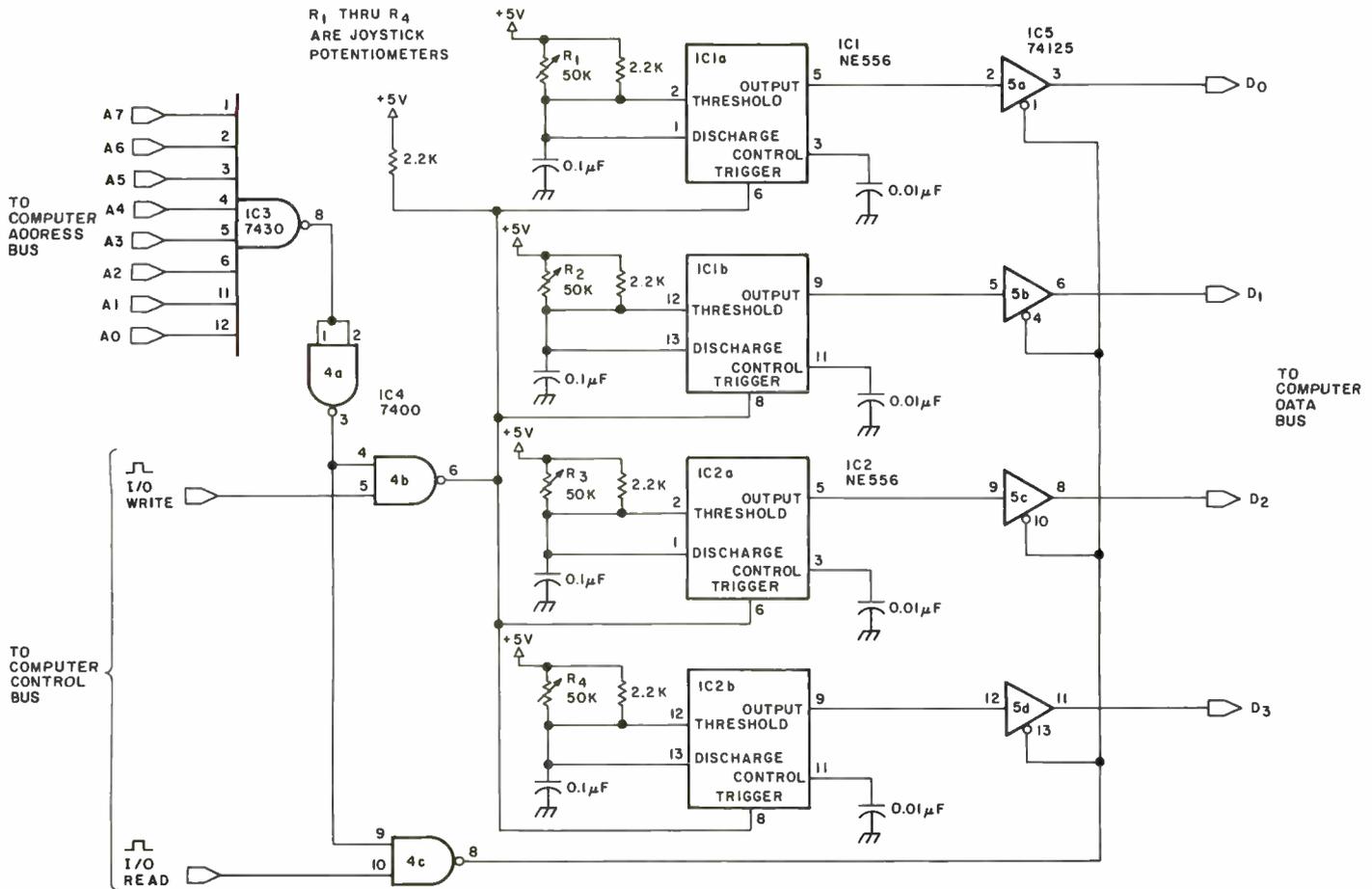


Figure 4: Software-driven interface. If the computer can directly read the input from the joystick interface, the hardware required can be greatly simplified. When hexadecimal FF is output to port 0, all 4 one-shots are triggered. The pulse width is then determined by a program running through a short loop looking at the logic levels of the 4 one-shots. Listing 1 shows a typical program for this application.

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Number	Type	+5 V	VGND	+15 V	+15 V
IC1	MC1408-LB	13	2	3	
IC2	LM301A		4	7	
IC3	CD4051	4		8	
IC4	LM301A		4	7	

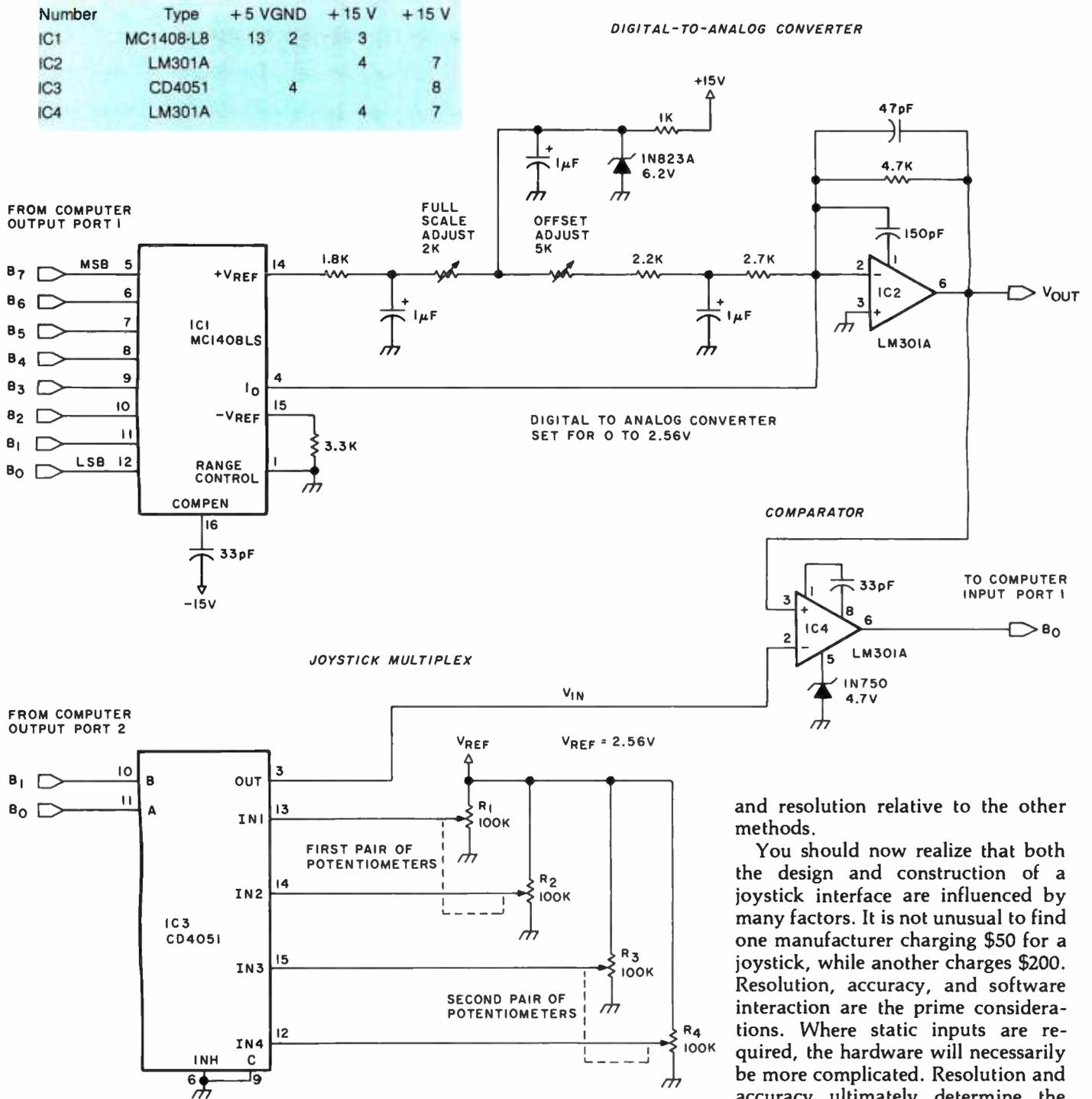


Figure 5: High-resolution analog-to-digital conversion. This hardware-oriented device multiplexes 4 voltage inputs (from the joystick potentiometers) and has the capability of handling 4 more voltages.

method. A better technique is successive approximation where the computer progresses through a binary search to "zero in" on the final value. A full explanation of successive approximation is delineated in my article entitled "Talk to Me: Add a Voice to Your Computer for \$35" (June 1978 BYTE, page 142).

With the digital-to-analog converter set for a full-scale value of 2.56 V, each count is equivalent to 10 mV. Only 4 channels of the CD4051 are used for the joysticks, leaving another 4 channels as auxiliary inputs from external sources. Thus it is possible for this interface to serve a dual role because of its high accuracy

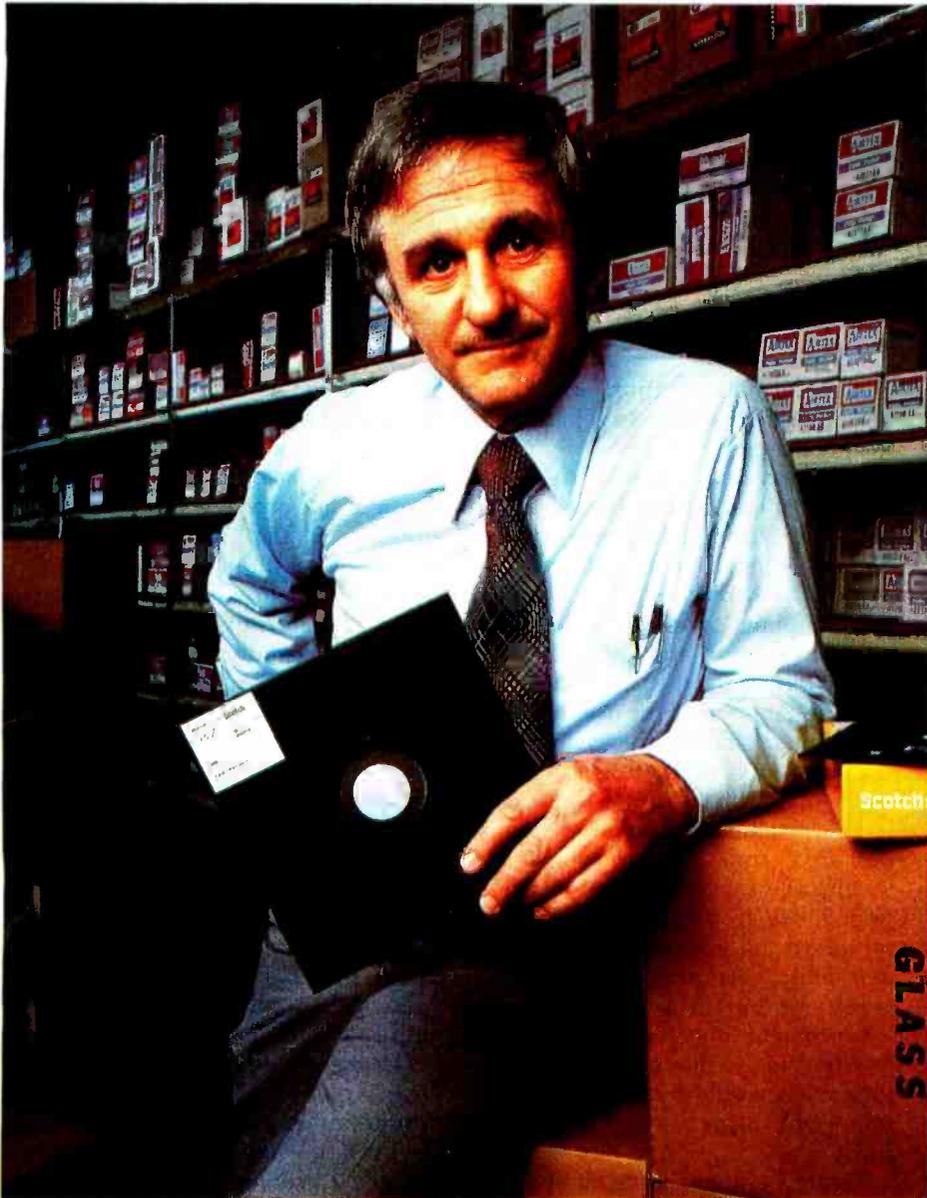
and resolution relative to the other methods.

You should now realize that both the design and construction of a joystick interface are influenced by many factors. It is not unusual to find one manufacturer charging \$50 for a joystick, while another charges \$200. Resolution, accuracy, and software interaction are the prime considerations. Where static inputs are required, the hardware will necessarily be more complicated. Resolution and accuracy ultimately determine the complexity of the interface.

For simple spacewar-type games, the circuit of figure 1 should suffice. For more demanding applications such as cursor graphics system, figure 5 may be the optimum choice. Be careful when buying joystick interfaces. Make sure that they mate with your program requirements and your system's abilities.

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Introduction to Multiprogramming

Mark Dahmke
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Multiprogramming has usually been considered out of reach of the average personal computer experimenter using a small or medium scale computer. Actually, anyone with a processor above the level of an 8008 can operate a multiprogram or multiuser system. The original purpose of multiprogramming was to allow more than 1 user to take advantage of a computer simultaneously. This increased the productivity of the machine by allowing programs to run while other programs were awaiting user input, access to a disk, etc.

This may seem to conflict with the advantages inherent in microprocessor based systems (single user systems and low cost). However, there are many instances where the ability to run more than 1 program at a time may be advantageous. Note that the statement "more than 1 program may run at a time" does not mean simultaneous execution. That is the definition of multiprocessing (more than 1 processor on the bus), not multiprogramming.

To describe multiprogramming more effectively, I shall refer to a more well-known function in computers: real-time interrupts. Suppose we are using a microcomputer to manage the environment in a small office building. Normally we want to continually poll (scan) the sensors that are distributed throughout the building and adjust heating, cooling and lights on the basis of temperature and time of day. Let us say that

during normal operation, someone in the building wants to change the temperature of an office.

One way to do this is to have a video terminal and keyboard attached to the system that generates an interrupt when a keyboard request is made. Upon receiving the interrupt, the computer saves the status of the current program and enters or transfers control to the keyboard read routine. As soon as the user has made the desired change, the system loads the old status information and returns to the original program. This same interrupt technique could be used to design a time shared system that would allow several terminals to be hooked up to a processor. Each terminal would generate an interrupt, and whichever program was active would be put in a wait state. This arrangement only works well for a few terminals, though. You can imagine what would happen if everyone happened to press a key at the same time.

Figure 1 shows timing comparisons of several modes of operation already discussed. In figure 1a 2 independent processors are shown, each doing something different and neither interfering with the other. This is known as multiprocessing. The processors may or may not be sharing I/O(input/output) terminals or memory.

In figure 1b 2 processors are shown in a *master-slave* arrangement. Perhaps the slave processor performs

floating point arithmetic or some complex I/O function. The master processor can give the slave processor commands via an interrupt and continue other processing until the slave informs it that it has finished the desired operation.

Figure 1c shows a single processor with an interrupt being applied. The processor temporarily gives control to the routine specified by the interrupt hardware and begins executing it. When complete, it returns control to the main program. Figure 1d shows the multiterminal timeshare system. Usually the interrupt hardware contains provisions for daisy chaining or prioritizing the interrupts as they come in. Thus, if terminal 6 applies an interrupt and the processor is busy with terminal 7, terminal 6 is not allowed to interrupt the processor until terminal 7 is finished.

Using multiprogramming is like using real-time interrupts. A multiprogrammed system uses interrupts, but in a more efficient way. Imagine a simple 2 program situation. Suppose program A is running and no other

About the Author

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

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programs have been started. Then a user initiates (loads) another program called B. How will program B gain control of the system so that it might start to execute?

The process of passing control from one program to the next is usually handled by an operating system module referred to as an *interrupt call routine*. Normally, to save the programmer the trouble of making sure that this routine gets called at regular intervals, the routine is usually imbedded in many of the I/O driver routines or other standard utility subroutines on a system. Note that this technique will in no way upset any of the flags or registers of the routine it is called from.

This interrupt call program will:

1. Determine if any other programs are waiting to execute.

2. If so, save all registers and flags on the stack and save the address of the current program's stack pointer in a special table in memory.

3. Load the new program's stack pointer from the table, pop all registers and flags off the stack.
4. Return to the new program.

Loading the new stack pointer raises some interesting questions. If program B has not yet begun, how could its registers have been pushed onto its stack? Figure 2 shows the stacks of both programs as they would be at each step in the previously described interrupt call routine. Part of the job of the routine that initialized program B is to set up a dummy stack and stack pointer such that the program counter address on the top of the stack contains the entry

point of program B. Thus, when the interrupt call routine reaches step 4, it will execute a return instruction, then pop the entry point address off the stack and begin executing program B. When the interrupt routine is called again, it will see that program A is waiting and will save all of program B's registers and flags, swap stack pointers and return to program A at the point where it was first interrupted.

All this activity will take place every time the interrupt routine is called, but if one of the programs gets caught in an infinite loop, the interrupt call routine may not get called. The simplest way to avoid this kind of problem is to add some hardware to provide external timed interrupts. As shown in figure 3, the interrupt timer is set to provide an interrupt every 10 ms. A reset line is provided

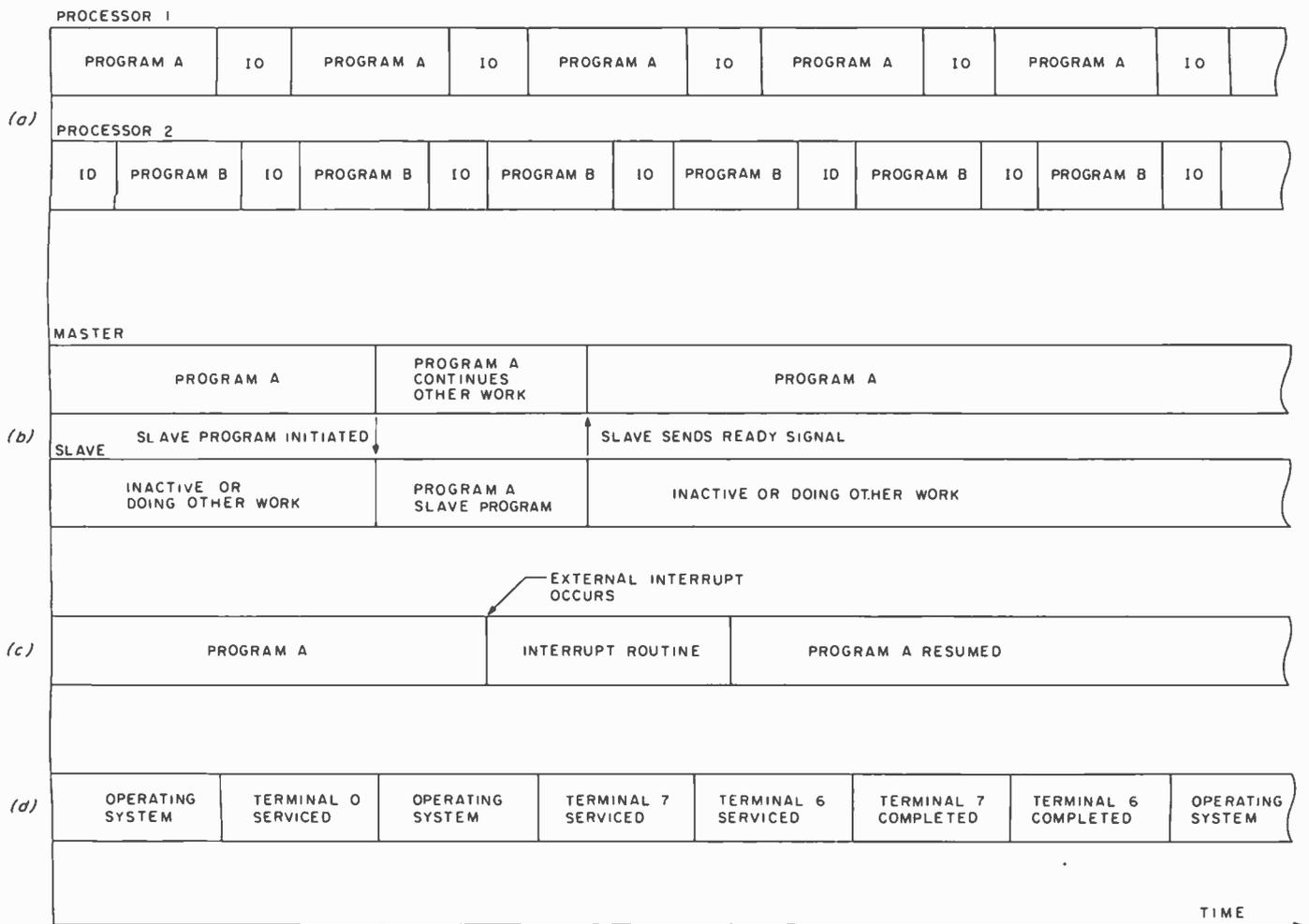


Figure 1: Timing diagrams for 4 different system organizations. Figure 1a is a multiprocessing example using 2 independent processors. Figure 1b is a multiprocessing example using 2 processors connected in a master-slave configuration. Figure 1c is a single processor with 1 level of interrupt. Figure 1d is a single processor with 8 levels of interrupts. Each of the 8 levels is activated by 1 of 8 terminals.

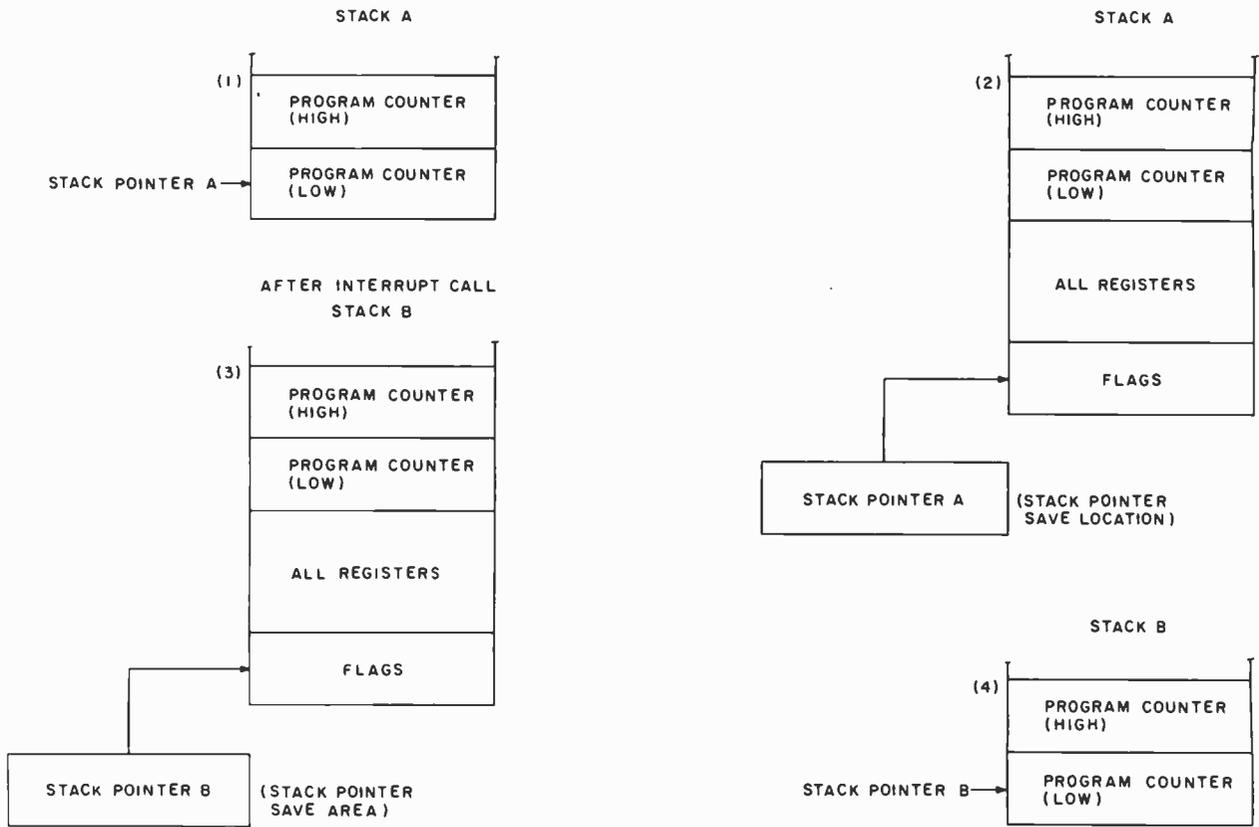


Figure 2: Arrangement of all stacks and stack pointers at each interval of an interrupt call routine.

in the event that the interrupt routine is manually called (through the software method). The timer may be reset to give the program its full 10 ms. A disable line is provided to allow the user to turn off the timer for special applications (software timing) in which the processor must not be interrupted.

Figure 4 shows our previous example of figure 1, but with the extra hardware generated interrupts added. In figure 4a some software interrupts are mixed in with the hardware interrupts. The timer is reset after each call to the interrupt routine. Figure 4b is the same except that the timer is not reset after each call.

A Complete System

There are limitless ways to go about developing a computer system that will be easy to use. A look at the current market shows this to be true, perhaps even to a greater extent on the small systems level. I will not attempt to describe all possible variations available on a multiprogram-

ming system, but I will try to give as generalized a view as possible.

First, we must consider what is necessary to make a useful system.

The following are essential:

1. Some form of operating system that allows simplified user com-

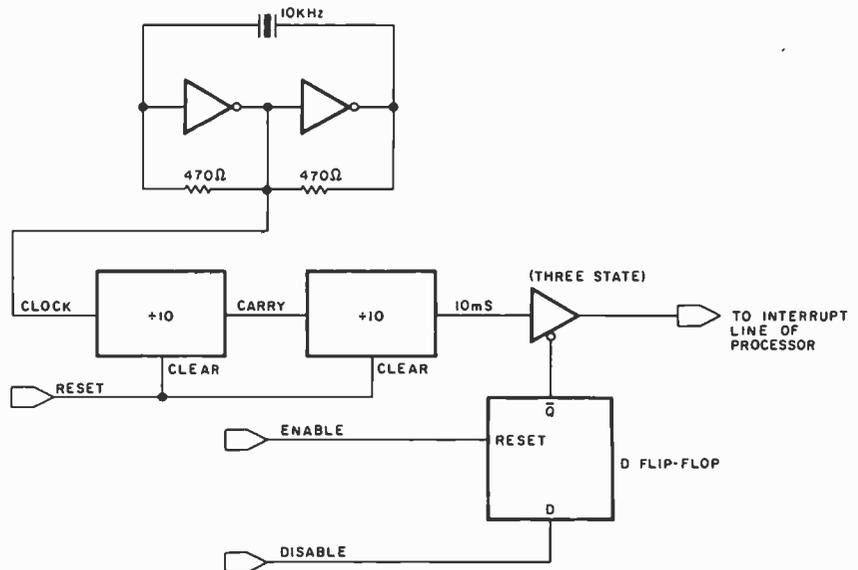


Figure 3: Simple hardware interrupt timer set for 10 ms intervals.

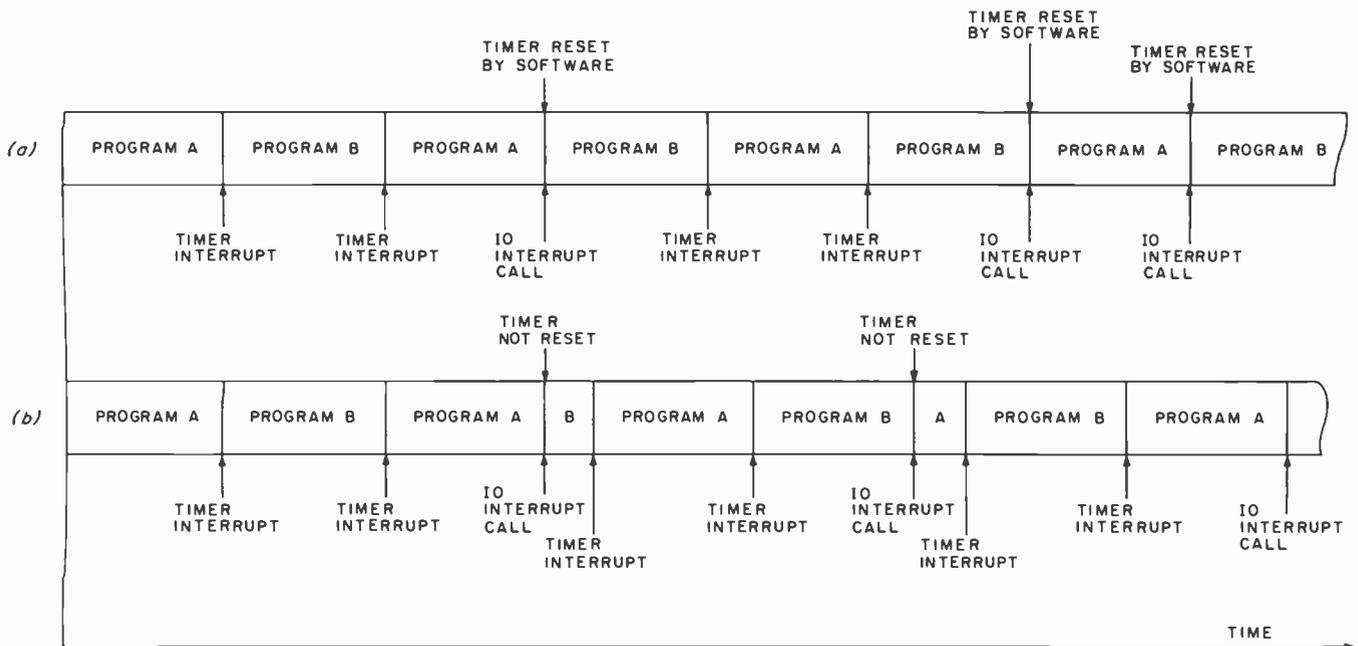


Figure 4: Interrupt timing example of figure 1 reviewed with the addition of a hardware timer. The timer may be used in 2 ways: The example in figure 4a resets the timer on each interrupt call. This allows each program to receive its full 10 ms time slot. The example in figure 4b does not reset the timer. Therefore, a hardware interrupt occurs every 10 ms.

- communications (ie: BASIC, DOS, CPM).
- 2. Convenient mass storage I/O (cassette or disk).
- 3. Sufficient memory to handle all programs.

Another consideration might be the internal architecture of the processor, but that is another level of problem.

Figure 5 shows the memory layout of a typical multiprogramming system. To maintain a simple system, I have combined the operating system

with the timesharing routines that support all terminals (video displays, keyboards and teletypewriters). This means that each time the operating system gains control (through an interrupt call or timer interrupt), it will complete its own activity and then transfer control to the timesharing program for the remainder of the time slot. If the operating system is given highest priority, the response times of the terminals should not suffer. The operation of the timeshare program can be treated as a multi-

program system in miniature, where each terminal is given a time slot, or it may be designed to simply scan the terminals, choosing a new terminal each time it is given control.

Controlling I/O

Many programmers have discovered the convenience of vectoring all I/O through 1 subroutine; this simplifies programming greatly and makes system changes much easier. Typically, 1 subroutine will accept an operand (if necessary) and an operator function code passed from the main program and will decide which I/O function to perform. In my hypothetical computer, this approach will be used. Note that in some large computer systems, the I/O driver programs can only be accessed by executing a special kind of interrupt call that informs the operating system that the user's program desires to perform some kind of input or output operation. The operating system then takes charge, performs the I/O for the program in question, and returns pointers telling where the input data was stored in memory or that the requested output function has been completed.

This type of I/O handling is necessary because the I/O controllers are extremely complex and are capable of performing an entire I/O operation

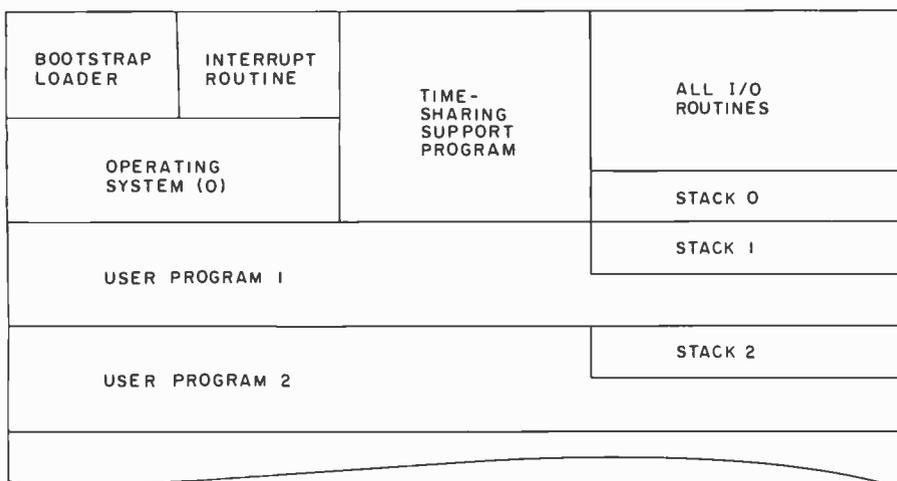


Figure 5: System geography of a typical multiprogramming system with space for the operating system and 2 other programs.



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without processor intervention. In fact, it would be very inefficient to make the processor of a large system perform these menial tasks when it could be working on more important programs. In microcomputer systems we are not normally concerned with the optimization of I/O functions and it does not really hurt performance to have the processor perform most of the I/O. Consequently, the I/O driver routines in the system I am describing will not be considered as part of the operating system. They are just utility subroutines that may be called by the user's program.

Defining the Necessary Tables

With only 2 programs very few, if any tables are needed to tell the interrupt routine which program was active at the instant the system was interrupted and which program is next in line. But imagine a system capable of supporting 10 or more programs: some form of priority scheduling will be needed, as well as a table to hold all of the stack pointers of the inactive programs.

To handle the list of programs (herein referred to as tasks), we must define a *task control table* that keeps track of a number of pointers and descriptors. First, each entry will begin with the task number that uniquely defines each task. Next, we will include the priority of the task on an arbitrary scale of 0 to 10. It will then get the processor before a task of lower priority (10 is highest). If 2 tasks have the same priority, the first one in line in the task control table will get control. The task control table must also keep track of the last value of the stack of each task and whether or not the task may be interrupted (in the case of critical timing loops).

Another important status byte that must be kept is the *current activity indicator*. This byte contains the task number of the currently active task. Now let us assume that we have 3 different tasks running and all have been initialized (stored in the task control table). The first task has a task number of 0 and a priority of 10. Generally the operating system is

given the task number 0 designation. Since the operating system and timeshare program (user terminals) are considered one big program in this example, task 0 is also the designation of the timeshare system. Task 1 is a program that one of the users submitted (initiated) from a terminal; it has a priority of 10. Task 2 was also loaded and initiated by a user through the timeshare terminals, and it has a priority of 10.

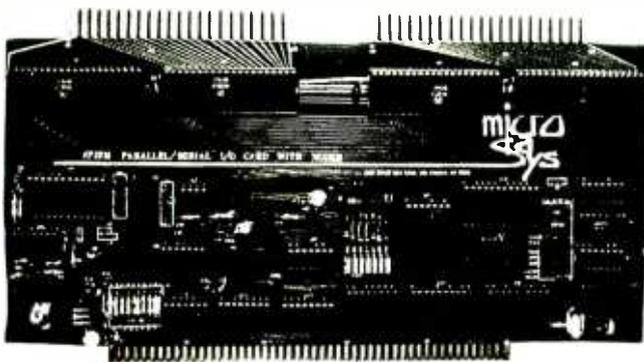
Imagine that the timeshare program calls the I/O driver program to write a character out to a terminal. Since there could be many terminals connected to the system, how does the program know which one to write to? It would be very inefficient to have different routines for each device, but the only way that a program could tell the I/O driver which specific display to write to is for the calling program to know the physical address of that terminal. Passing the actual address of the device ruins the neatness of the I/O routine, though. It is more convenient to specify the function to be performed (1 = write to video display; 2 = read keyboard; 3 = write to cassette; 4 = read cassette).

The solution is to have another entry in the task control table called a *communications control block* pointer that points to the location of the communications control block for the particular task. Since each task is given its own block, the user may define his or her own functions and addresses. Thus each program may have its own video display, keyboard, cassette interface and disk. The communications control block contains a list of function numbers, the address of the I/O port or memory mapped port, and the address of the I/O subroutine that will perform the operation. Figure 6 shows the arrangement of all tables.

Starting and Stopping

To initialize a new task, the user adds entries to the appropriate tables through a console command and causes a dummy stack and stack pointer to be created. To stop a task, the last thing done in the task is to call a subroutine that would remove its task control table entry. This is equivalent to a CALL EXIT in FORTRAN found on many larger systems.

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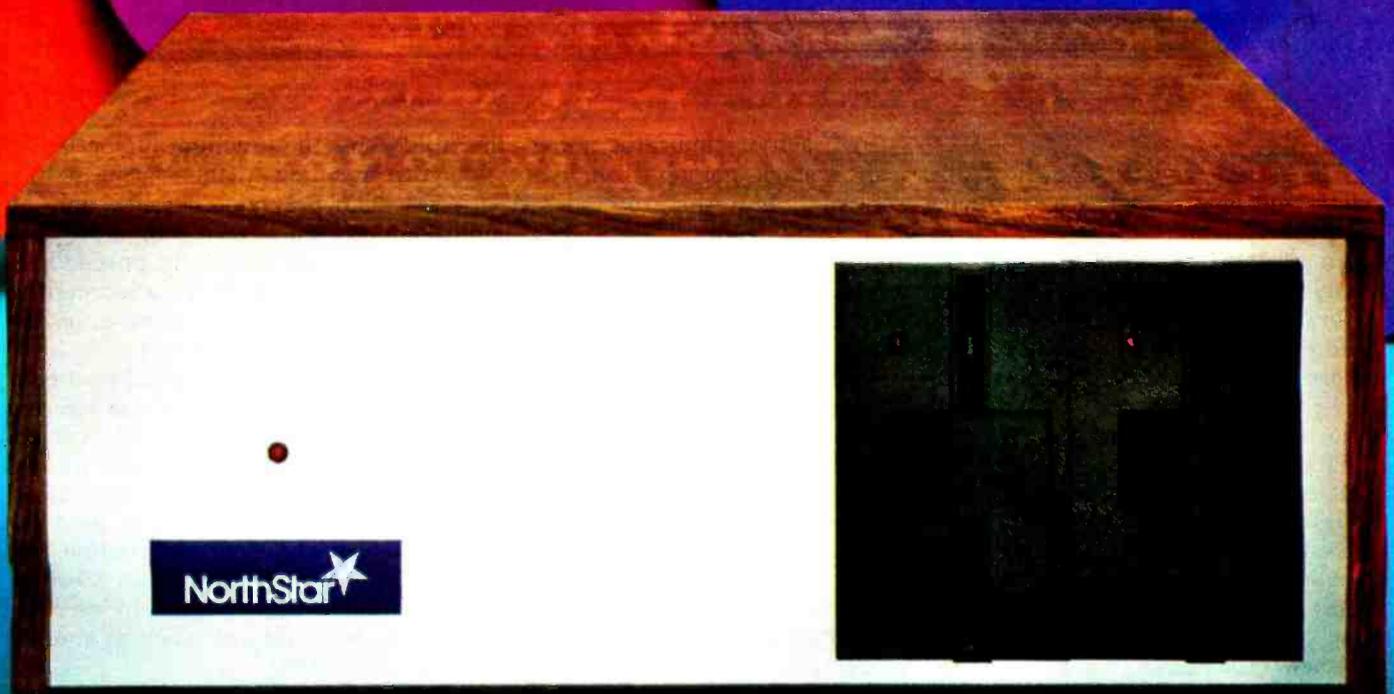
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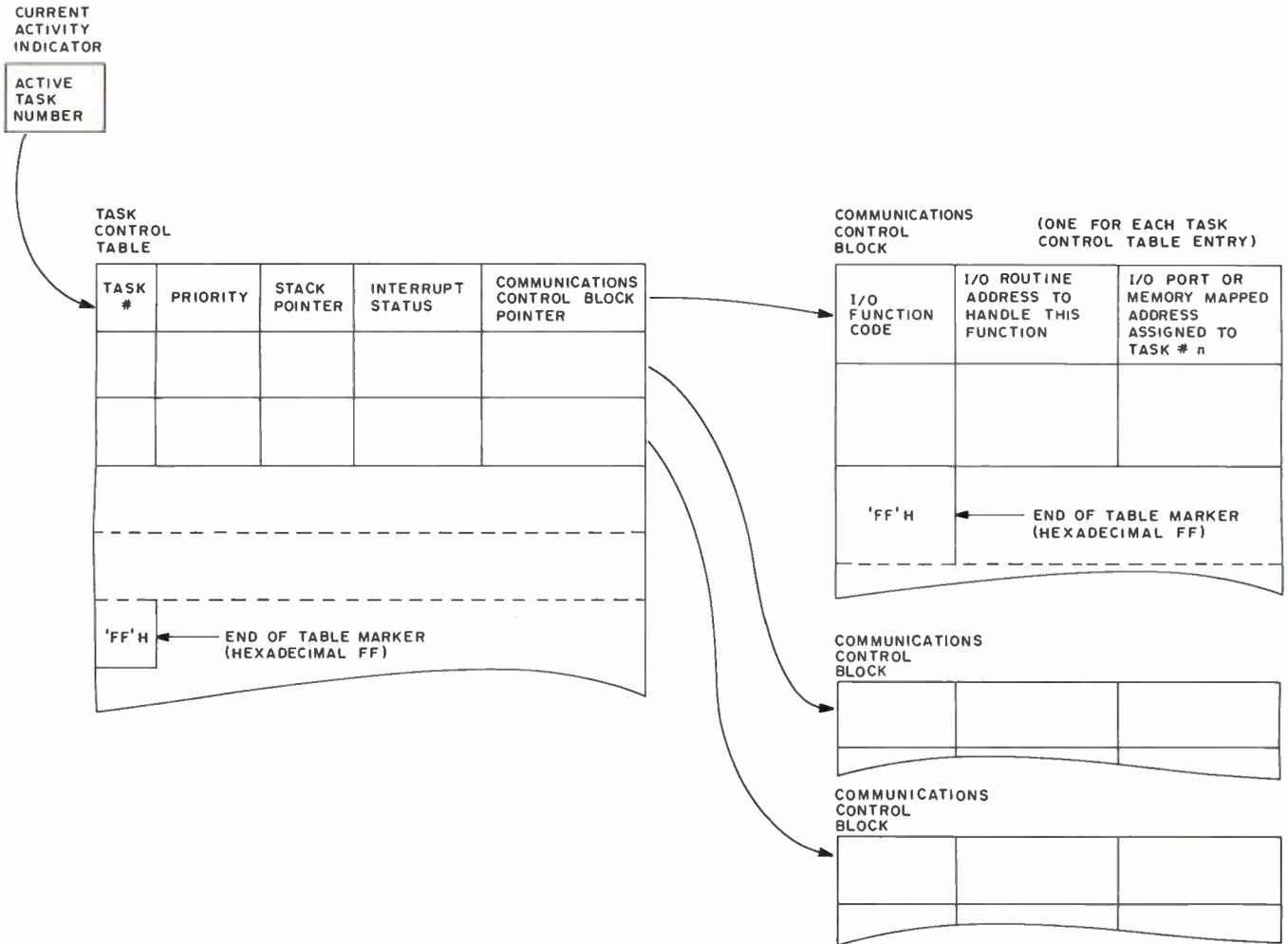


Figure 6: Control table organization. The current activity indicator contains the task number of the active task. The task control table contains the task number, task priority, last value of stack pointer, interrupt status flag (1 for yes, 0 for no interrupts), and the pointer to the task's communications control block. The communications control block contains the I/O (input/output) function code, address of I/O driver routine associated with the function code, and the I/O port or memory mapped address assigned to the task for the particular function. One entry is provided for each function code used in the task. The owner of the task may add entries to the communications control block for specialized I/O driver requirements.

Example

The easiest way to show how all tables and pointers affect each other and the system is to observe them during a short period of machine activity. As we begin, task 0 (the operating system and timeshare routines) has control, and a timer interrupt is occurring. There are 2 other tasks in memory: task 1 has priority 5 and task 2 has priority 4.

First, as the interrupt routine is entered it saves all registers and flags of task 0 on stack 0 and saves the task 0 stack pointer in the task 0 task control table entry (see figure 7). Next, it scans the task control table for the task of next highest priority, moves the new task number (task 1) to the

current activity indicator, moves the task 1 stack pointer from the task control table to the processor's stack pointer, pops all of task 1's registers and flags off of stack 1, and executes a return, which has the effect of popping the program counter and jumping to that address.

Task 1, while executing, encounters a call to the I/O driver routine with a request for a keyboard input (see figure 8). When the I/O driver routine is entered, it scans the task control table to find the communication control block pointer entry for task 1 (the routine determines which task called it by looking at the current activity indicator), then scans the communication control

block for the function number entry corresponding to the one passed by the main program. Even though the computer may have 5 or more keyboards attached to it, the port address found in the communication control block gives it the address of the keyboard assigned to task 1.

Since the keyboard read routine is a common one, the address referred to in the communication control block points to a subroutine located within the operating system area. Note that if the user had need for some special I/O subroutine, he could locate it in his own memory area and put the address in his communication control block as another function code.

Returning to the example, the keyboard read subroutine is called from the I/O driver, reads the keyboard port assigned to task 1, and returns to the I/O driver with the ASCII code. The I/O driver returns to the main program with the ASCII code in a register or memory location. In figure 9 the next timer interrupt has occurred, so control returns to the interrupt handler routine. Again, the interrupt routine saves all registers and flags of task 1 on stack 1, looks at the current activity indicator to see which program was last active, saves the stack pointer in the task 1 task control table entry, scans the task control table for the next highest priority task, and finds that task 2 should get control. The stack pointer for task 2 is loaded from the task control table, all registers and flags are popped off of stack 2 and again a return is executed that causes task 2 to take control.

In the next step (shown in figure 10), task 2 has encountered the equivalent of a CALL EXIT or STOP command and has finished processing. This CALL EXIT calls a terminator routine which again finds out who called it (via the current activity indicator) and simply eradicates the task control table entry for that task. To keep things neat, all succeeding table entries are moved up 1 notch. Then, control is returned to the interrupt handler, which will find the next task in line. In this case, since no other tasks of lower priority are waiting, control is returned to the highest priority task 0.

Error Handling

On a single program system, error handling is something that the user can watch for manually. When several programs are running, the system must have routines to handle errors rapidly so that other programs will not be slowed down or destroyed. There are many common errors that are relatively easy to deal with. Executing an invalid op code or forgetting to put in the 2nd or 3rd byte of a multibyte op code can be handled through a simple system restart (through the interrupt handler routine) without losing continuity. But what about a program loop that accidentally destroys part or all of another user's program? On an IBM 360, all memory blocks assigned to a

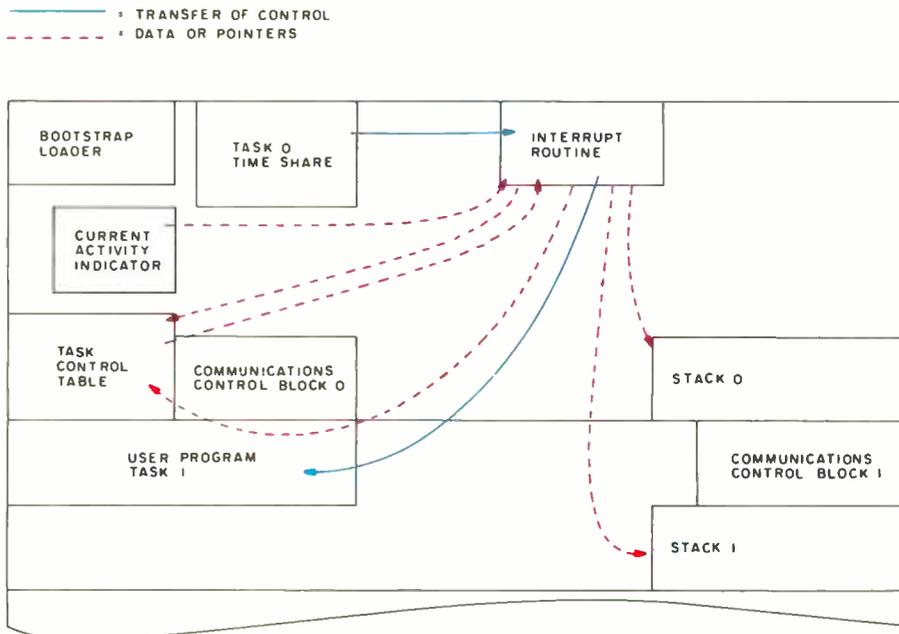


Figure 7: Task 0 has control of the processor and has just been interrupted. The interrupt routine looks at all pointers, saves the status, and then transfers control to task 1.

task are given a unique 4-bit protect key (which is the same as the task number) that is stored in external hardware.

One approach might involve having 2 external 16-bit registers that could be loaded by the interrupt routine with the high and low memory addresses of the active task.

Then, every time the address bus has a valid address on it, it is tested against these registers. However, special precautions would have to be taken in those cases in which a utility in low memory (I/O driver routine etc) is called, or when memory mapped I/O ports outside these address limits are used.

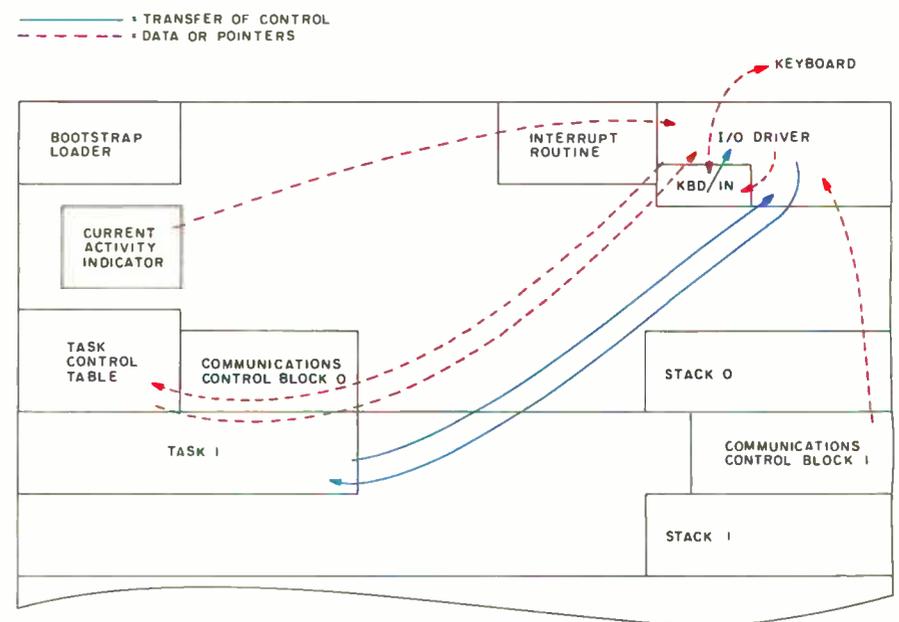


Figure 8: Task 1 has requested keyboard input from its assigned keyboard. When the input is completed, the I/O (input/output) driver returns control to task 1.

— TRANSFER OF CONTROL
 - - - DATA OR POINTERS

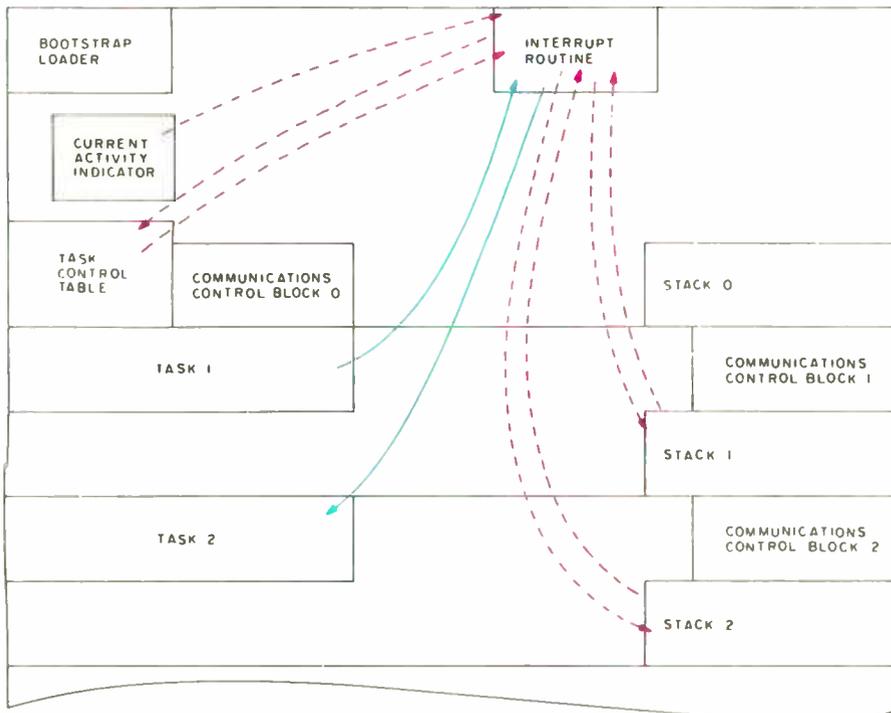


Figure 9: Task 1 has been interrupted and turns control over to the interrupt routine. Control is then passed to task 2.

Resolving Allocation Conflicts

Allocating I/O devices has been a problem since the early days of computers. Devices like tape drives and card readers (sequential devices) are nonshareable: only 1 program may use them at a time. However, disk drives are considered shareable, since the head may be positioned at random to gather data. The simplest method that can be applied to the system described in this article would be to have the initiator program check all communication control blocks to make sure that certain devices are not assigned more than once.

I/O Software Considerations

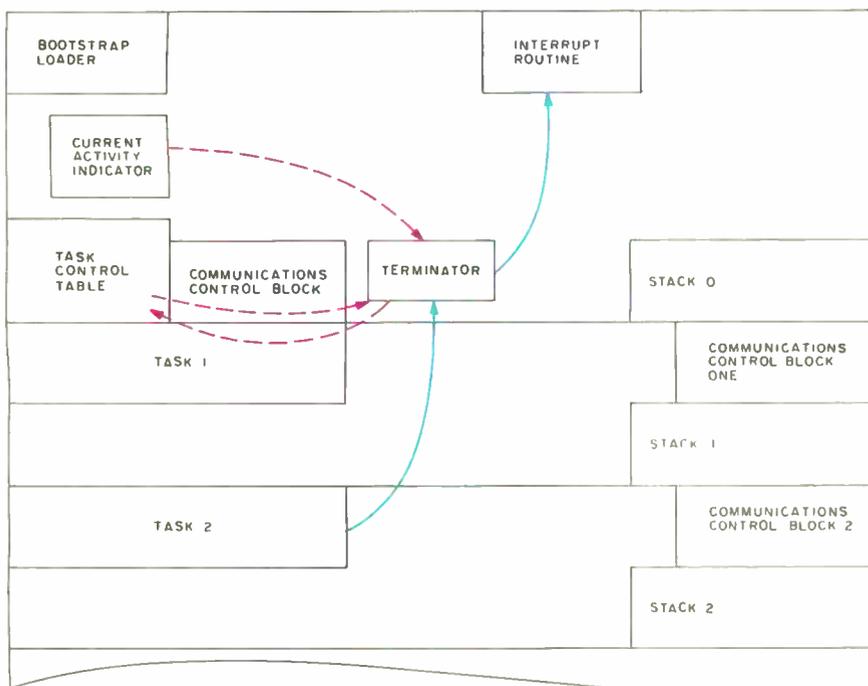
As mentioned earlier, I/O techniques in use on small systems leave all control up to the processor. If special timing is needed or if strobes or ready flags have to be checked, software is used instead of extra hardware, as in the case of larger systems. This in itself is good from the standpoint of economy, but requires that special care be taken when writing the driver and controller software.

For example, suppose a cassette read routine uses a universal asynchronous receiver transmitter (UART) implemented in software as an algorithm instead of hardware. In a nonmultitasking system, the program may simply loop and time down between bits, but in a multitask system the timer interrupt would surely halt the activity and execute other programs. It may be well over 30 ms before it can return to the cassette read routine. It is easy to see what can happen to critical timing loops on a system that uses any kind of interrupts.

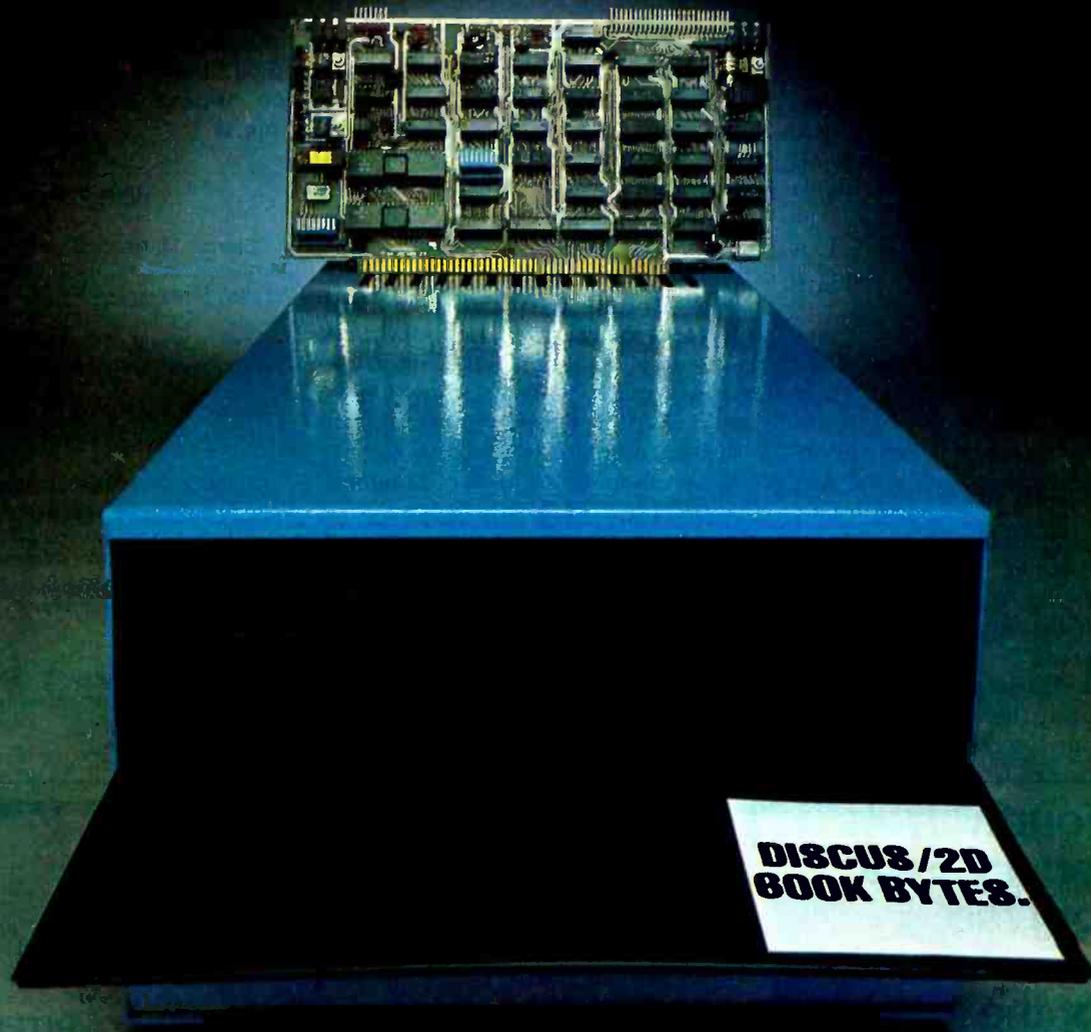
The solution? If you must do the critical timing in software, it is necessary to turn off the interrupt timer while in the critical loop and reactivate it when in noncritical parts of the routine. If external hardware is used, and internal timing is reduced

Figure 10. Task 2 has completed its execution and encounters a CALL EXIT. Control is given to the terminator routine which performs some cleanup operations and removes the task 2 entry from the task control table, effectively destroying the task. Control is then given to the interrupt routine which again scans the task control table to find the next task awaiting execution.

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to noncritical loops, the intervention of the multitask interrupt timer will not normally affect the system. If the interrupt timer causes an interrupt just before a byte is received by the UART but returns in time for the next byte to be received, the easiest way to assure that the cassette read routine does not drop a byte is to set the timing of the interrupt oscillator to at least twice as fast as the transmission rate of the UART. This greatly reduces chances of losing a byte.

An alternate approach is to have even more hardware that forces the interrupt timer to timeout and return control to the program awaiting the data transfer operation when the incoming data is present. A third way involves the use of direct memory access (DMA) capability, in which the external controller reads the UART and deposits the data directly into memory. With this approach, the calling program need only initialize the external registers and go into a wait state until the transfer is complete, allowing the rest of the tasks to

execute normally. This last approach is used on many large systems and constitutes what is called a *channel*.

Managing the System

As you can see, many levels of activity are required to control a multiprogramming system properly. It is also apparent that some minimal hardware is required to prevent one user from obtaining exclusive control of the processor or writing over someone else's program or data. The use of control tables and a standard interrupt routine are also important as a way of letting the interrupt routines and I/O drivers know which task had control of the processor last.

If the user plans to run BASIC software or some other kind of language interpreter, the safety features discussed earlier may be implemented as part of the interpreter. To run a lower-level operating system that allows the user to generate assembler level code will generally require the hardware described in this article, thus safeguarding the system and its users from accidental loss of pro-

grams or data. In general, the use of timed interrupts allows for a fairly even distribution of processor activity, and depending on the cycle time of the host system, between 4 and 12 tasks may be handled without too noticeable a delay in response time. ■

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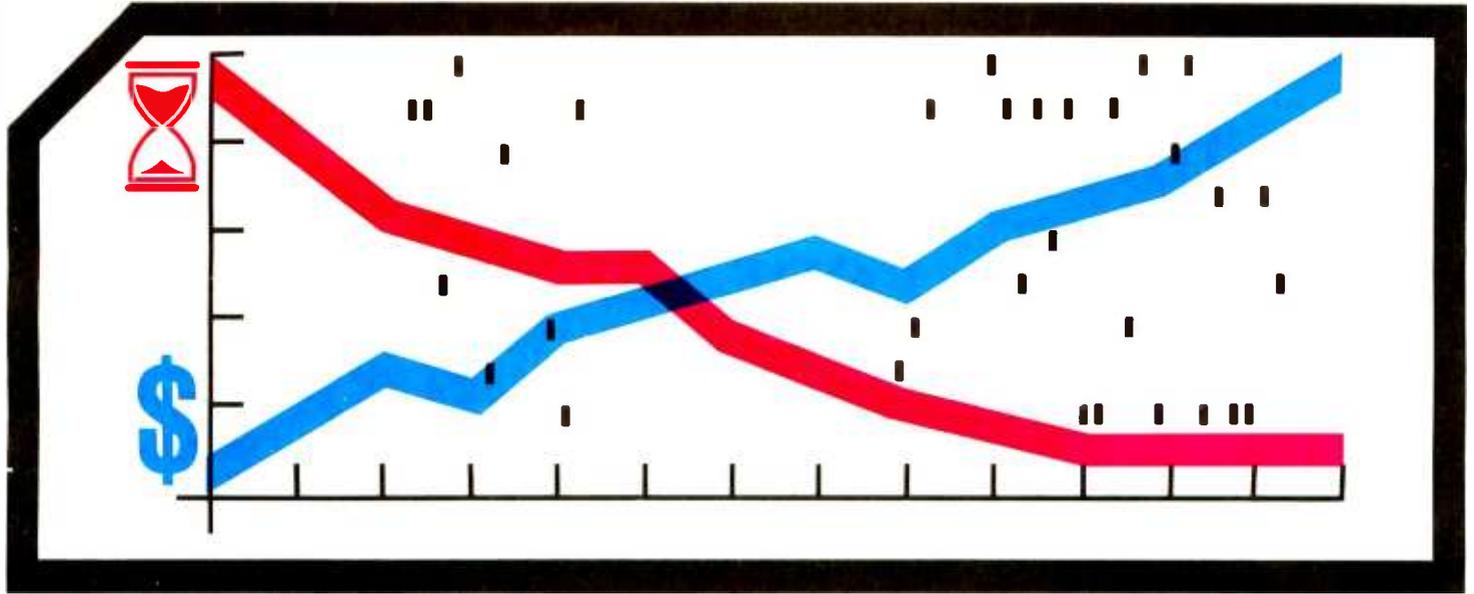
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Most computer chess systems are unable to "see" a chessboard. A

human playing against a computer will usually set up a chessboard beside the computer, and the moves will be communicated to and from the machine through the use of a keyboard and a display in some type of abstract notation.

Keyboard entry of moves is undesirable. It is inconvenient, error prone, and inelegant. The abstract

notation promotes errors and makes play difficult for people who do not know the notation system. Furthermore, errors may not be detected until many intervening moves have occurred.

An ideal chess-playing system would contain a digital television camera to observe the board and a mechanical arm to move the pieces. [A mechanical arm designed for exactly this application was described in the article "A Hobbyist Robot Arm," by Keith Baxter and Timothy Daly in the February 1979 BYTE, page 84...RSS] A less costly alternative is to construct a chessboard which can electronically communicate with the computer. The computer may then "look" at the board position through its I/O(input/output) ports. A means of indicating the computer's moves on the chessboard itself may also be provided.

In the system that I have constructed, the user makes his move on the electronic chessboard, instead of typing each move on a keyboard. The computer's moves are displayed on the chessboard through the use of discrete light emitting diodes (LEDs), arranged in an X,Y coordinate system. The LEDs show the user exactly which chessman the computer wants to move, and to which square. In addition to being aesthetically pleasing, this system makes it impossible to enter your move in-

About the Author

Jeff Teeters is an undergraduate student at the University of Wisconsin at River Falls where he majors in mathematics.

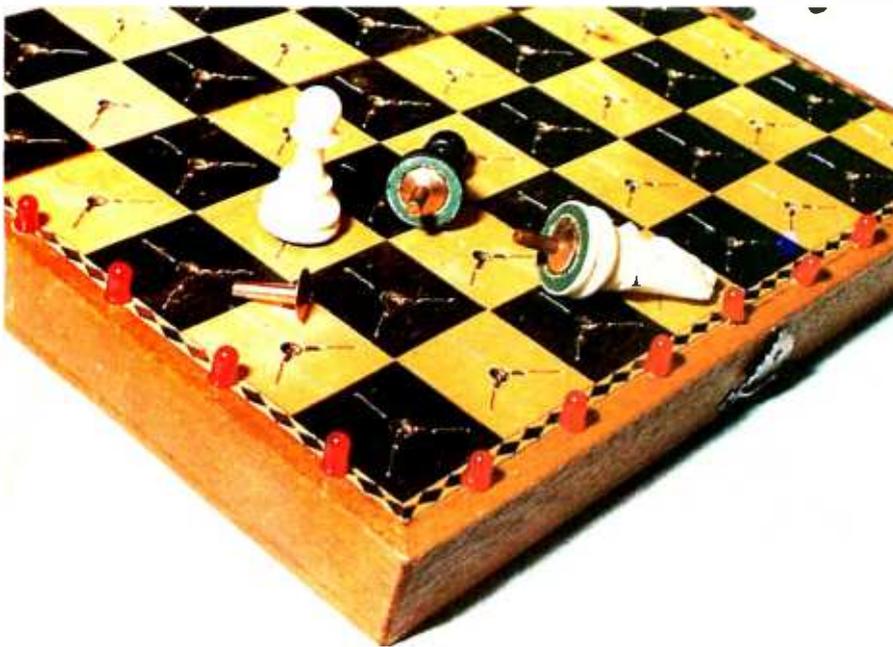


Photo 1: Two pawns, a White Knight, and a loose rivet are shown on top of the electronic chessboard. One row of 8 light emitting diodes (LEDs) is placed along the left side of the board, and another row is placed along the bottom of the board as seen by the human player. Two LEDs are lit to indicate a single square, using an X,Y axis system. A single large hole is drilled in the center of each square to accept entrance of the rivet which is glued to the bottom of each chessman. The rivet completes an electrical circuit between 2 pieces of wire that run from smaller holes through the large central hole. This switching arrangement allows the computer to detect the presence or absence of a piece at each square of the board. In this prototype, an additional set of 3 wires is seen in each square; these wires remain from an earlier, unsuccessful switching attempt.

correctly, and easy to interpret the computer's move. The board is continuously scanned so that even if the user moves the computer's piece incorrectly, the mistake is detected immediately. A speaker is connected to the computer to let unwary users know (by a buzz) when they misinterpret a computer move. This speaker also emits a brief sound when the chess program has decided on a move and when it has been recorded into the computer's internal board representation.

This project is designed for specific use with Peter Jennings's Microchess, running on a KIM-1 with about 0.5 K bytes of extra memory. Implementation on other 6502 based computer systems should be relatively easy since only a few minor software modifications would be needed. The required hardware consists of a chess set, a package of cheap switching diodes, 2 integrated circuits, 16 discrete LEDs and 32 copper rivets.

The chessboard should have a thin, nonconductive surface that is easy to drill holes through. This surface must be supported by side panels so there is a hollow space of about 2 cm under the board for wiring. I used a cheap plywood chess set that is designed to fold into a storage box for the chessmen. The copper rivets should be small in diameter, about 12 mm long, and have a flat top. The ones that I used were size 9 rivets manufactured by the Tower Corporation of Madison IN.

System Concepts

KIM-1 Microchess uses an internal board-status table to keep track of the whereabouts of the chessmen. This table contains 32 square numbers which indicate the position of the 32 pieces. It is important to realize that Microchess generates moves solely on the basis of what is in that table, and not how it was placed there. My plan of attack was simple. I had only to wire a chessboard to the computer and write an interface program that would translate moves on the chessboard into changes in the table. Since this program will be needed only when moves are physically being made, it can be called from Microchess and used in place of the Microchess keyboard I/O (input/output) routines. After the user has finished moving, control can be

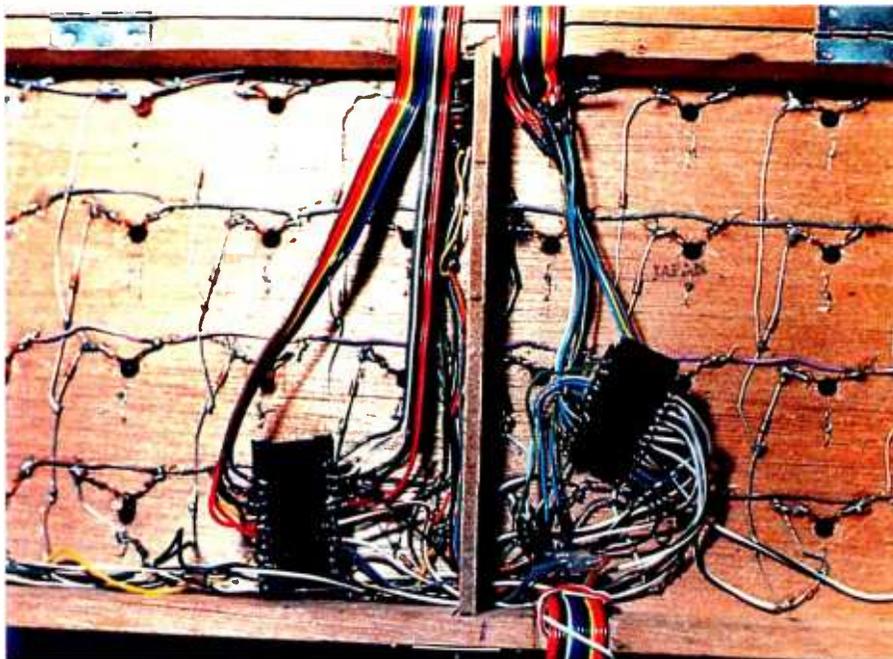


Photo 2: The bottom of the chessboard. The switching diodes and connecting wires are soldered directly to the wire contacts in the central holes. The 2 integrated circuits are type SN74154 decoder/demultiplexers. Note the tips of rivets protruding through some of the holes.

transferred back to Microchess to compute the machine's next move.

The Microchess to chessboard interface program is logically straightforward. If no move is being made, the table should be an accurate representation of the board. A move is detected when the table does not correctly represent the current board position. If an empty square appears on the board where the table indicates that a chessman resides, then the user has just picked up that man. If the table shows an unoccupied square which the board indicates is occupied, a chessman has just been set down in that square. A move is constituted by the user picking up a man and setting it down in some other location. A capture is completed by picking up 2 men and setting 1 down in the space formerly occupied by the other. Because the Microchess table is updated each time a simple move or capture is made, the table always gives an accurate representation of the current board position.

Hardware Details

Note that the chessboard interface program can keep track of the moves that are made simply by knowing if individual squares are occupied by a piece or are empty. The circuit which

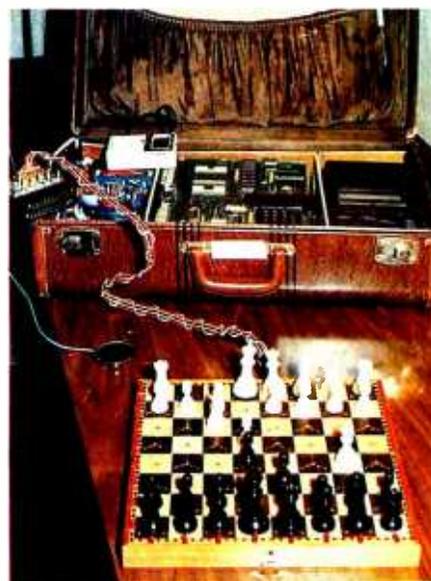


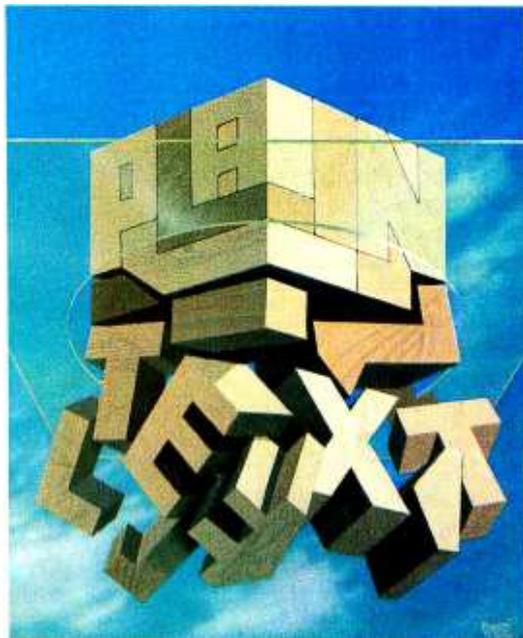
Photo 3: The complete chessplaying system. The completed electronic chessboard stands in the foreground. The chessboard and the sound-effect speaker are connected to the KIM-1 computer residing in the suitcase in the background.

provides this information to the computer is illustrated in figure 1. For purposes of square identification, the chessboard is conceptually cut in half. The 2 pieces are placed logically end to end, forming an arrangement



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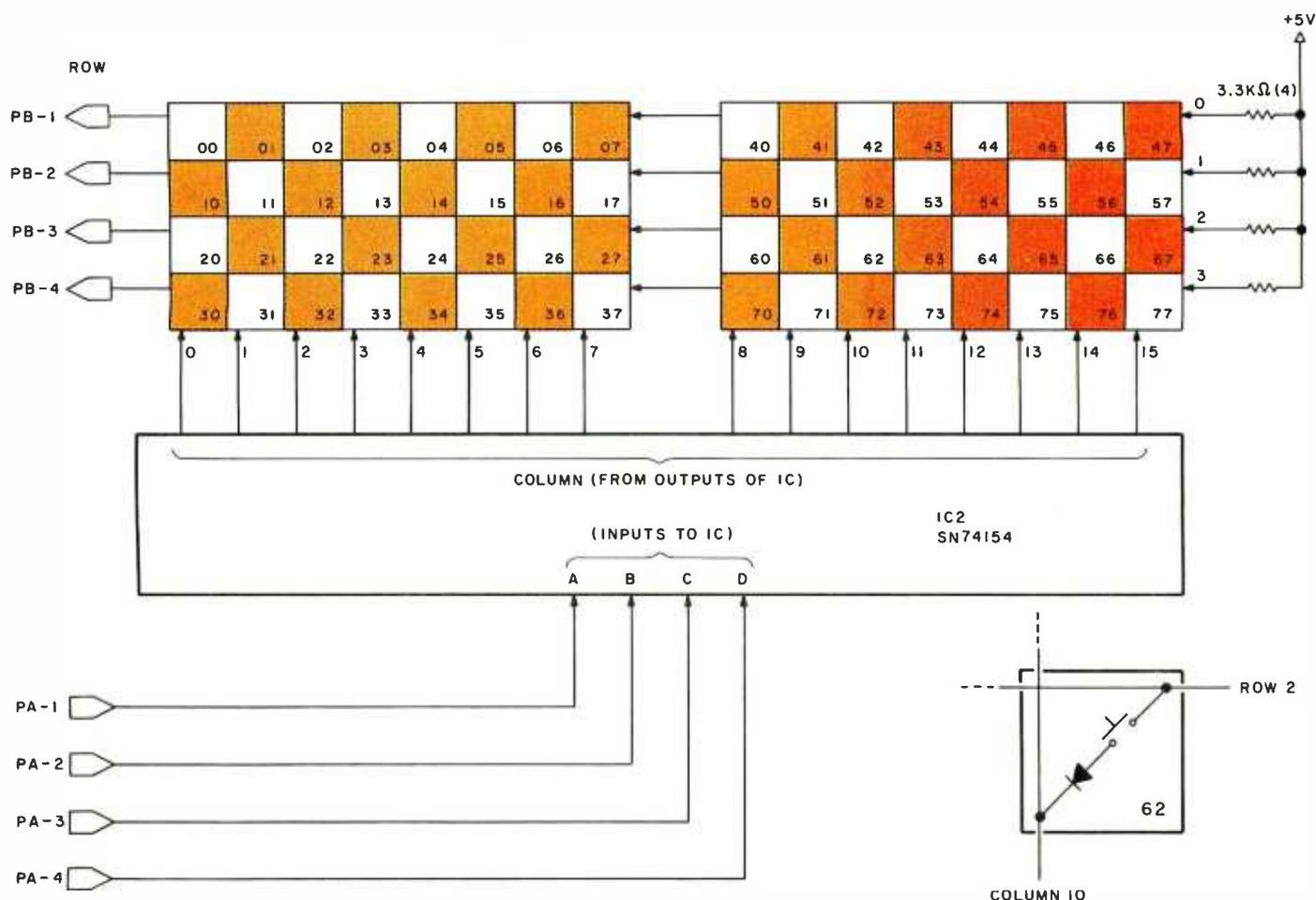


Figure 1: Circuit which determines whether or not a given square is occupied. The chessboard is conceptually cut in half. It is placed so that the squares form a 4 by 16 matrix. For each square, a diode and a switch are wired in series between the appropriate row and column lines. A closed switch indicates an occupied square; an open switch indicates an empty square.

of 4 rows and 16 columns. A diode matrix allows the hardware to identify the individual squares.

The integrated circuit in figure 1 is a type SN74154 4 to 16 line decoder/demultiplexer. The 4 input lines to the device are connected to the KIM-1 I/O port A. Each of the 16 output lines is linked to a column in the matrix. This portion of the circuit allows the KIM-1 to select 4 squares out of the total of 64. The 4 rows of the matrix are connected to the I/O port B. Row and column addressing allows scanning of a single square. Each square of the chessboard has a switch. A closed switch indicates that the square has a piece on it; an open switch shows that the square is empty.

To determine whether or not a piece is on a particular square, the interface program first selects the column by sending the correct binary

code to the 4 input lines on the SN74154. This brings 1 of the 16 output lines low, while the diodes keep the rest high. If the switch is closed (ie: a piece is on the square), then the corresponding row-line will be pulled low and the matching port-B data register bit will be a 0. Thus, by selecting the column through port A and testing the row bits in port B, it is possible to determine the status of every square on the board.

Switch Experimentation

Now for the hard part: what can be used as a switch? The actual mechanical operation remains the only unresolved detail. All that is needed is some means of closing the switch whenever a piece is set down, and opening it when one is picked up. There are several ways to accomplish this—some of which are better than others.

In my first attempt I put aluminum foil on the bottom of the pieces and used simple wire contacts on top of the board. I punched 6 holes into each square using a large needle to form the corners of 2 concentric, equilateral triangles. Three strands of wire were looped through the holes forming 3 symmetric contacts (see figure 2a). The third contact was used only to balance the pieces.

The concept is simple. The piece is set on top of the wire contacts and the aluminum foil makes the necessary connection. Unfortunately it didn't work. The contacts were not sufficiently stable, and the slightest vibration rocked the pieces, leading the program to believe that the user was trying to move 5 or 10 pieces at once.

That problem might have been solved by mounting magnets on the pieces and using a chessboard with a nonconductive magnetic surface.

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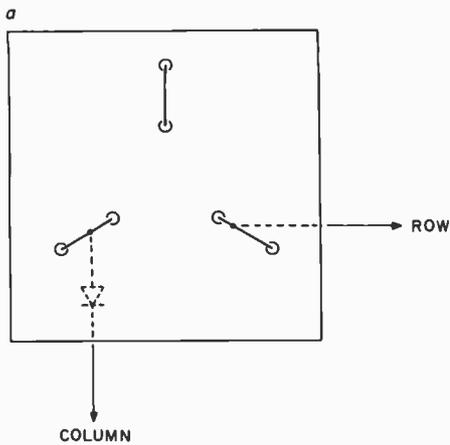


Figure 2a: The first attempt to form a switch for the squares. Three symmetric contacts on top of each square were made by looping bare wire through holes in the board. Two of the contacts were wired to the row and column lines on the back side of the board. (The third wire was simply to balance the piece upright.) The pieces had aluminum foil glued to their bottoms. When such a chessman was set down on the contacts, electrical continuity was achieved. Unfortunately, vibration caused intermittent contact and confused the computer.

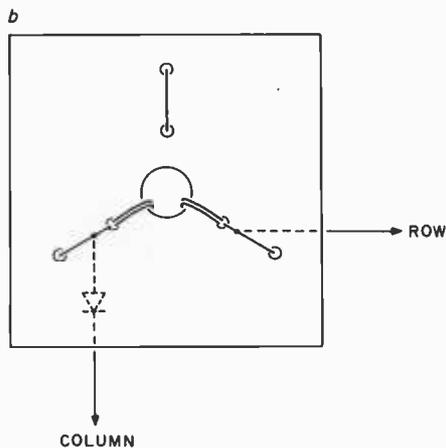


Figure 2b: The second attempt to form a square switch. This attempt was successful. Copper rivets were glued to the bottom of the chessmen. A large hole was drilled in the center of each square to receive the rivet. Two wires were looped through the large central hole from 2 smaller holes (left over from the first switch attempt). The rivet closes the electrical circuit.

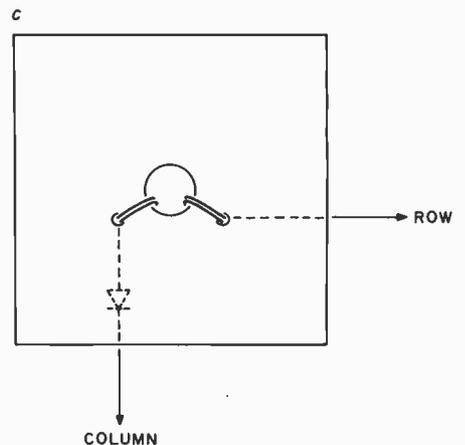


Figure 2c: Illustration of the appearance of a square which uses rivet switches; and which previously did not have other methods installed in it. The reader may do it correctly the first time.

Another possibility would be to eliminate wire contacts entirely and use reed switches or some type of photocell. Unfortunately, one such device must be mounted under each square, necessitating a total of 64 devices. Although they would have undoubtedly worked, 64 photocells or reed switches would have cost more than I was willing to spend on the project.

Switch Success

I eventually figured out a contact method that was both cheap and reliable. I drilled a small hole in the center of each square, just large enough to slide in a copper rivet. Two strands of bare copper wire from 2 of the inner contact holes used in my first attempt were looped through the larger central hole forming 2 contacts inside of the hole (see figure 2b). The felt on the bottom of the pieces was peeled off and the tapered copper rivets were glued onto the metal weight underneath the felt with an instant bonding adhesive.

I have found that these contacts work quite well. The tapered copper rivets slide easily in and out of the hole, while slight pressure from the sides of the hole forces the rivet to make good contact with the copper

wire. The pieces remain intact and the electrical contacts remain solid, even when the chessboard is held upside down and shaken gently. Of course when you wire your chessboard, you should leave out the 3 symmetric wires that I tried on my first version. Only the 2 strands which were looped through the rivet hole need to be installed (see figure 2c).

Hardware for Computer Output

The LEDs are wired according to figure 3. The integrated circuit is another 4 to 16 line decoder whose 4 inputs are connected to the I/O ports. Note that decoder outputs 0 thru 7 are connected sequentially to the rank—indicating (Y axis) LEDs with the 0-bit output being connected to the uppermost LED. Likewise, the file—indicating (X axis) LEDs are connected left to right with outputs 8 thru 15. The chip-enable line is connected to I/O port pin PB0 so that the LEDs can be turned off while Microchess is computing a move.

Mounting of the LEDs on the sides of the chessboard is relatively straightforward. I used a large needle to punch the holes for the leads prior to insertion. Glue can be used to hold them in place. Be sure to orient the chessboard so that a white square is

in the lower right-hand corner of the side facing the human player. This means that the 2 rows of LEDs installed on the left side and bottom of the board will meet at a corner containing a black square.

The speaker is connected to output port pin PA0 in the manner described in the *KIM-1 User's Manual* on page 57. See figure 4 for an illustration of the I/O port connections.

Software

The necessary modifications to Microchess are shown in listing 1. The Microchess to chessboard interface program with source and object listing is given in listing 2. Although I used a nonstandard meta-assembler, most of the mnemonics are similar to, if not the same as, the MOS Technology standard mnemonics. The listings are fairly well documented.

There are, however, some general concepts that may be difficult to deduce from the listings. The workhorse of the chessboard interface program is subroutine GET-MOVE. GET-MOVE calls the KIM monitor routine GETKEY before doing anything else, in order to see if the user has pressed the DA key (which is used when setting up a new position) or the PC key (which clears

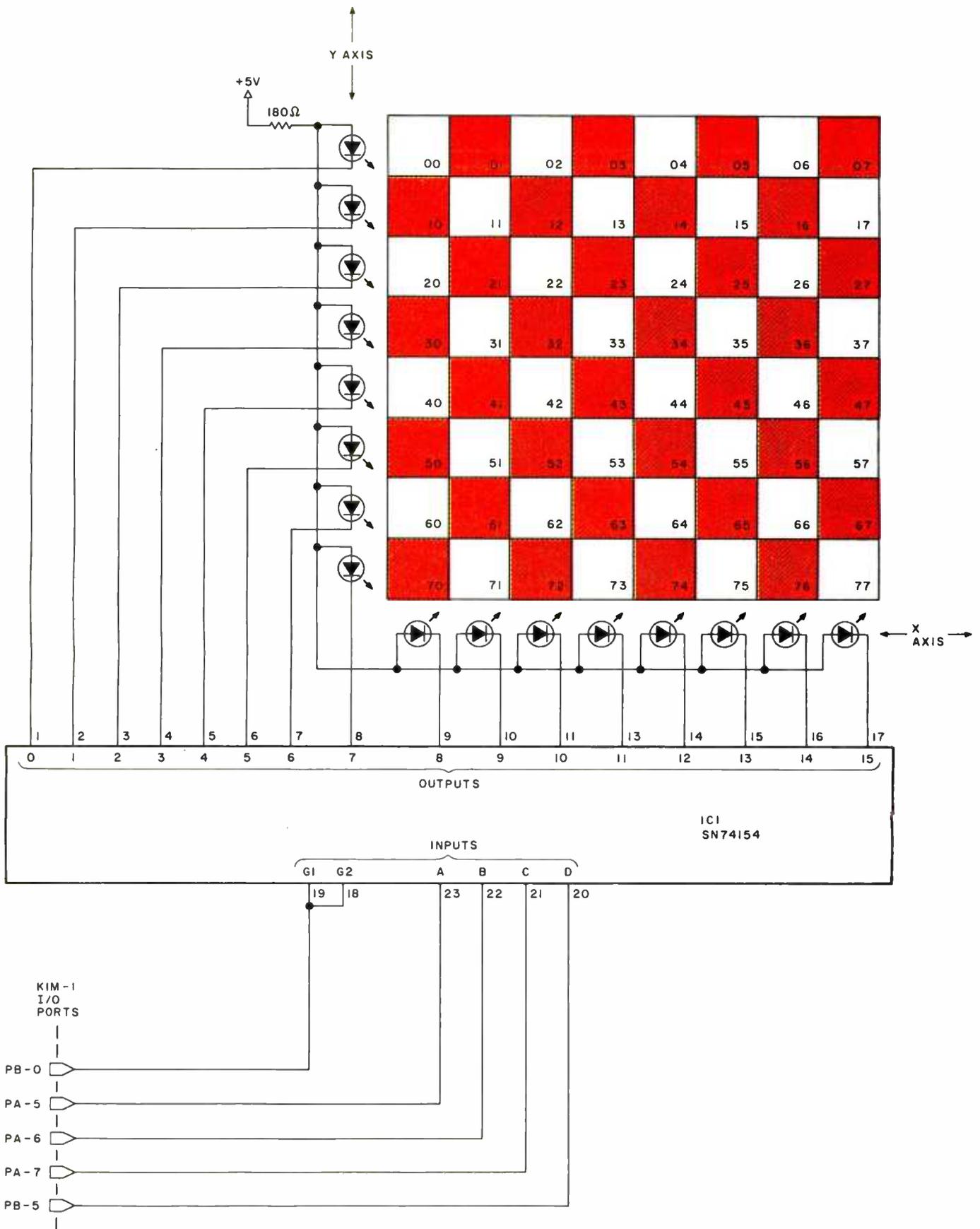


Figure 3: Circuit for lighting the light emitting diodes (LEDs) that indicate the computer's move. The computer moves as follows. The program lights the X and Y axis LEDs which together indicate the single square on which the piece to be moved resides. The person picks up the indicated piece. After the user picks up the piece, different LEDs light up that point to the square to which the piece is to be moved. The person then places the chessman as indicated. A mistake causes the computer to emit a characteristic sound. The chip-enable line of IC1 is connected to I/O (input/output) port pin PB 0 so that the LEDs may be turned off while the chess program is computing its next move.

the board for a new game). If neither the DA nor PC key is depressed, GET-MOVE scans the chessboard,

square by square, searching for pieces that were recently picked up or set down. This is done by comparing the

Microchess board-status table to the current board position, as previously described. There is one important exception. When the user picks up a piece to make a move, SHOULDBEUP-FLAG is made non-zero, and the square where the piece used to be is stored in hexadecimal addresses FA and F9. A nonzero SHOULDBEUP-FLAG tells subroutine GET-MOVE that the 2 squares in FA and F9 should not be occupied, even if they are shown in the table. This is done to prevent GET-MOVE from continuously reporting that the same piece was picked up.

Upon exit from the subroutine, the result of the search is stored in the accumulator and in location UP-CLEAR-DOWN. A +1 is returned if a piece has been picked up, a 0 if there is no change, and a -1 if a piece was set down. If a piece was picked up or set down, then CHANGING-SQUARE will contain the number of the square where the pickup or set-down occurred. Likewise, if a piece was picked up, then CHANGING-PIECE will contain the hexadecimal designation of that piece as outlined on page 3 of the Microchess player's manual.

While GET-MOVE is scanning the chessboard, it also lights up the X and Y axis LEDs that point to the square in LIGHT-SQUARE. If SPEAKER-FLAG is non-zero, the speaker is rapidly toggled to produce a hum.

Subroutine CLEAR-STACK resets the Microchess and the machine stack pointers back to their initial values. The subroutine is called from various parts of the interface program to prevent the stacks from overflowing into Microchess code.

After Microchess has computed each move, control is transferred to the start of the interface program at hexadecimal address 2000. The user must physically move the pieces for the computer. The piece designation and the from and to squares of the calculated move are stored in the KIM display at hexadecimal addresses FB, FA, and F9 respectively. Because of the no-operation instructions inserted at address 03E1, the move has not been recorded in the board-status table. Addresses 2000 through 2040 of listing 2 contain code

Text continued on page 46

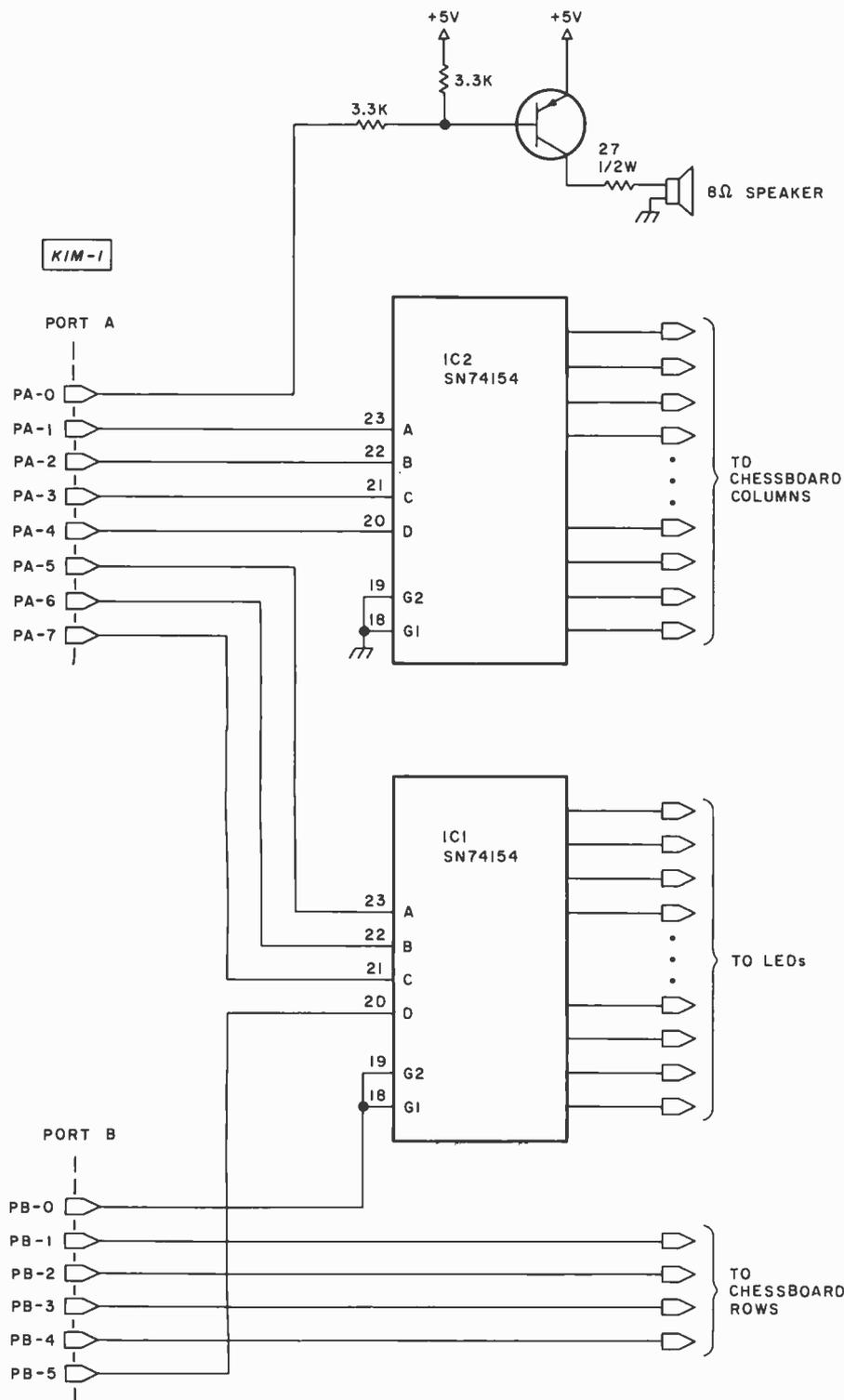
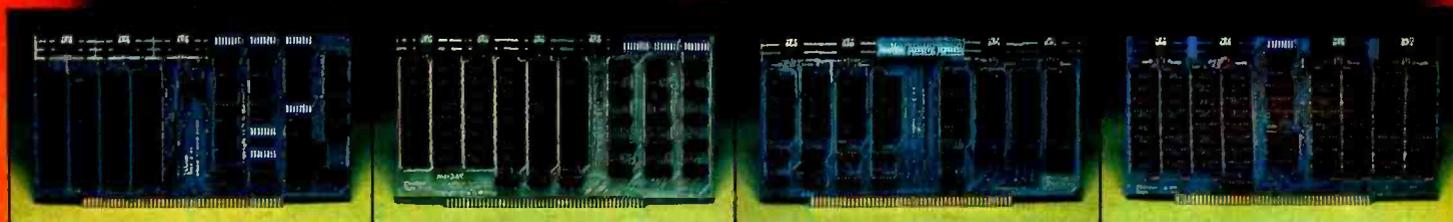
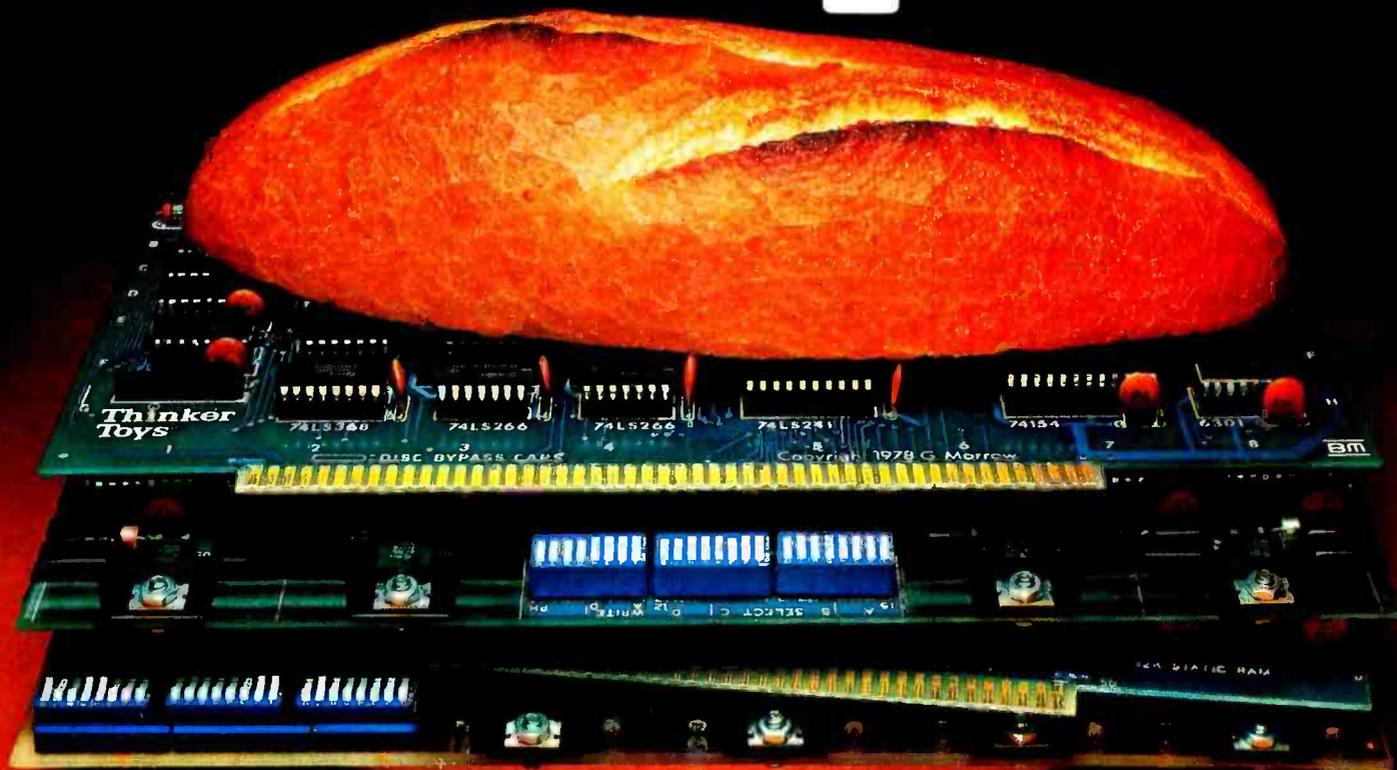


Figure 4: Schematic diagram of chessboard input connections for the KIM-1. If the speaker is built into the chessboard, a 16 conductor cable is required to connect the board to the KIM-1 application connector. Thirteen conductors control the chessboard and light emitting diodes; 3 are needed for speaker, ground, and +5 V supply. The cable should be of sufficient length that the chessboard may be set in a convenient position for game playing.

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200A 20 6B 21 ! JSR GET-MOVE XWAIT FOR PLAYER TO
200D F0 ! BEQ XZPICKUP PIECE.
200E FB ! ENDLLOOP
200F 30 F7 ! BNE PICK-IT-UP XERROR, PIECE SET DOWN
2011 A5 27 ! LDA CHANGING-SQUARE XIS PIECE PICKED UP
2013 C5 FA ! CMP FA XZCORRECT ONE?
2015 D0 F1 ! BNE PICK-IT-UP
2017 A6 FB ! LDX FB XYES, SET TABLE ENTRY
2019 A9 CC ! LDAN CC XZIO "CC"
201B 95 50 ! STAX .BOARD
201D ! Z***** SET THE PIECE DOWN *****Z
201D A5 F9 ! LDA F9 XLIGHT 10 SQUARE
201F 85 2B ! STA LIGHT-SQUARE
2021 E6 2E !SET-IT-DOWN: INC SPEAKER-FLAG XMAKE NOISE
2023 ! LOOP
2023 20 6B 21 ! JSR GET-MOVE XWAIT FOR CHANGES
2026 F0 ! BEQ
2027 FB ! ENDLLOOP
2028 A5 F9 ! LDA F9 XIS USER MOVEING
202A C5 27 ! CMP CHANGING-SQUARE XZCORRECT PIECE?
202C D0 F3 ! BNE SET-IT-DOWN
202E A5 35 ! LDA UP-CLEAR-DOWN XYES
2030 10 08 ! IF NEGATIVE THEN
2032 A6 FB ! LDX FB XUPDATE TABLE.(PIECE
2034 A5 27 ! LDA CHANGING-SQUARE XZSET DOWN, MOVE HAS
2036 95 50 ! STAX .BOARD XZBEEN COMPLETED.)
2038 10 ! BPL
2039 08 ! ELSE
203A A6 2B ! LDX CHANGING-PIECE XCAPTURED PIECE HAS
203C A9 CC ! LDAN CC XZBEEN PICKED UP...
203E 95 50 ! STAX .BOARD XZUPDATE TABLE AND
2040 30 DF ! BNE SET-IT-DOWN XZWAIT FOR SET DOWN.
2042 ! ENDELSE
2042 ! ZXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
2042 ! ZXXXXXXXXXX USER MOVE USER'S PIECE ZXXXXXXXXXX
2042 ! ZXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
2042 E6 2E ! INC SPEAKER-FLAG XMAKE NOISE
2044 A9 00 !WAIT-FOR-MOVE: LDAN 00 XCLEAR UP FLAG
2046 85 2F ! STA SHOULDBEUP-FLAG
2048 85 29 !SET-COUNT: STA COUNT-FLAG XSET COUNT FLAG
204A 20 39 00 !SET-DISPLAY: JSR CLDSP XCLEAR DISPLAY
204D 20 6B 21 !GET-MOVE1: JSR GET-MOVE
2050 D0 41 ! IF ZERO THEN
2052 ! ZXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
2052 ! ZXXXXXX NO CHANGE IN BOARD ZXXXXXX
2052 ! ZXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
2052 ! Z***** CHECK FOR "GO" KEY *****Z
2052 20 6A 1F ! JSR GETKEY
2055 C9 13 ! CPM 13 X13=VALUE OF "GO" KEY
2057 F0 17 ! BEQ GO-COUNTDOWN
2059 ! Z***** CHECK FOR "E" KEY *****Z
2059 C9 0E ! CPM 0E
205B D0 16 ! IF ZERU IHEN XUSER WANTS TO
205D ! LOOP XZSWITCH SIDES
205D 20 6A 1F ! JSR GETKEY
2060 C9 0E ! CPM 0E XDEBOUNCE KEYBOARD
2062 F0 ! BEQ
2063 F9 ! ENDLLOOP
2064 A5 30 ! LDA SWITCH-FLAG XTOGGLE FLAG
2066 49 FF ! EORN FF
2068 85 30 ! STA SWITCH-FLAG
206A 20 B2 02 !SWITCH-SIDES: JSR REVERSE XPERFORM EXCHANGE
206D 20 5D 21 ! JSR CLEAR-STACK
2070 4C 4C 21 !GO-COUNTDOWN: JMP START-COUNTING
2073 ! ENDF
2073 ! Z***** "GO" OR "E" NOT FOUND *****Z
2073 A5 29 ! LDA COUNT-FLAG XCOUNTING DOWN?
2075 F0 12 ! IF NOTZERO THEN
2077 C6 FB ! DEC FB XYES.
2079 A5 FB ! LDA FB
207B D0 06 ! IF ZERO THEN
207D 20 5D 21 ! JSR CLEAR-STACK XPLAY CHESS
2080 4C A2 03 ! JMP GO
2083 ! ENDF
2083 A9 0F ! LDAN 0F XSTILL COUNTING DOWN,
2085 65 2B ! ADC LIGHT-SQUARE XZLIGHT NEXT SQUARE.
2087 D0 ! BNE
2088 03 ! ELSE

```

Listing 2 continued on page 46

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system

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```

2089 AD 04 17 !          LDA# RANDDMH          %WAITING FOR MOVE...
208C          ENDElse          %%LIGHT RANDOM SQUARE
208C 85 2B !          STA LIGHT-SQUARE
208E A5 FB !          LDA FB
2090 4C 4A 20 !         JMP SET-DISPLAY
2093          ENDIF
2093 10 49 !         IF NEGATIVE THEN
2095          %XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
2095          %XXXXXXXXXX NEW PIECE SET DOWN %XXXXXXXXXX
2095          %XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
2095          %***** TAKING BACK CAPTURE? *****%
2095 A5 B2 !          LDA .SP2
2097 C9 CB !          CPM# CB          %UNDOING PREVIOUS
2099 F0 0C !          IF NOTZERO THEN %% CAPTURE?
209B A5 2A !          LDA FROM-SQUARE
209D C5 27 !          CPM# CHANGING-SQUARE
209F D0 06 !          IF ZERO THEN
20A1 20 31 03 !         JSR UMOVE % YES.
20A4 4C 4A 20 !         JMP WAIT-FOR-MOVE
20A7          ENDIF
20A7          ENDIF
20A7          %*****USER ADDING NEW PIECE*****%
20A7 20 6A 1F !        JSR GETKEY          %WAIT FOR KEY ENTRY
20AA C9 15 !        CPM# 15          %%OF HEX NAME OR "+"
20AC F0 1C !        IF NOTZERO THEN
20AE C9 12 !        CPM# "+"
20B0 D0 0C !        IF ZERO THEN
20B2 A5 FA !        LDA FA          %FOUND "+", ENTER NEW
20B4 10 97 !        BPL GET-MOVE1 %%PIECE INTO TABLE IF
20B6 A6 FB !        LDX FB          %%NOT IN ALREADY
20B8 A5 27 !        LDA CHANGING-SQUARE
20BA 95 50 !        STAX .BUARD#
20BC 10 86 !        BPL WAIT-FOR-MOVE
20BE          ENDIF
20BE 85 F3 !        STA TEMP          %FOUND HEX DIGIT
20C0 A5 FB !        LDA FB          %%"OR" IT INTO
20C2 0A 0A !        ASL ASL          %%PIECE NAME.
20C4 0A 0A !        ASL ASL
20C6 05 F3 !        ORA TEMP
20C8 85 FB !        STA FB
20CA          ENDIF
20CA A5 27 !        LDA CHANGING-SQUAKE %BUILD DISPLAY
20CC 85 2B !        STA LIGHT-SQUARE
20CE 85 F9 !        STA F9          %%%F9=SQUARE ON BOARD
20D0 A5 FB !        LDA FB          %PUT PIECE NAME IN
20D2 29 1F !        AND# 1F          %%RANGE
20D4 85 FB !        STA FB          %%%FB=PIECE NAME
20D6 AA !        TAX
20D7 B5 50 !        LUAX .BOARD
20D9 85 FA !        STA FA          %%%FA=TABLE ENTRY
20DB 4C 4D 20 !        JMP GET-MOVE1
20DE          ENDIF
20DE          %XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
20DE          %XXXXXXXXXX PIECE PICKED UP %XXXXXXXXXX
20DE          %XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
20DE          %***** USER PLAY WHITE? *****%
20DE A5 B1 !        LDA .SQUARE          %SEE IF USER MAKING
20E0 C9 CC !        CPM# CC          %%THE FIRST MOVE.
20E2 D0 05 !        IF ZERO THEN
20E4 E6 B1 !        INC .SQUARE          %YES, CHANGE .SQUARE
20E6 4C 6A 20 !        JMP SWITCH-SIDES %ZAND EXCHANGE
20E9          ENDIF
20E9          %***** WAIT FOR CHANGE *****%
20E9 20 5B 21 !       JSR CLEAR-STACK          %CLEAR POSSIBLE JUNK
20EC A5 27 !        LDA CHANGING-SQUARE
20EE 85 FA !        STA FA          %DISPLAY SQUARE NUM
20F0 85 F9 !        STA F9
20F2 85 2B !        STA LIGHT-SQUARE
20F4 20 9D 01 !       JSR DISP          %DISPLAY PIECE NAME
20F7 A9 01 !        LDAN 01
20F9 85 2F !        STA SHOULDBEUP-FLAG %SET FLAG
20FB          LOOP
20FB 20 6B 21 !       JSR GET-MOVE          %WAIT MOVE2
20FE F0 !        BEQ
20FF FB !        ENDLOOP
2100          %***** PIECE SET BACK DOWN *****%
2100 10 11 !        IF NEGATIVE THEN

```

to light the correct LEDs and modify the board-status table as the user completes the computer's move. The speaker sounds briefly after each correct step is completed. If a wrong piece is moved or a piece is set down on a wrong square, the speaker will hum continuously to signal an error.

The logic for interpreting the user's move starts at location 2042. If COUNT-FLAG is 0, the user has not yet moved. Subroutine GET-MOVE is repeatedly called from location 204D in anticipation of the user's move.

If the accumulator is 0 upon return from GET-MOVE, then the board position remains unchanged and the user has not made a move. GETKEY is called to see if the user has depressed either the GO or E key. If the E key is depressed, the Microchess routine REVERSE is called to swap the user and computer entries of the board-status table. After the exchange is completed or if the GO key is depressed, a branch is made to START-COUNTING at hexadecimal address 214C.

Three provisions are made for a delayed return back to Microchess. COUNT-FLAG is made nonzero, a countdown is initiated by setting the display to 0F, and control is then transferred back to address 204D where GET-MOVE is repeatedly called as before.

After each return from GET-MOVE the display is decremented by 1 until it equals 0. This provides an approximate 10 second delay during which the user can make a new move or retract an old one. At the end of the countdown, a branch is made to the Microchess routine GO which calculates the computer's next move.

If the GET-MOVE call at 204D returns a negative value then the user has set down a new piece, and control is transferred to address 2095. In an ordinary game of chess, putting a new piece on the board would be considered cheating. I have allowed it here to prevent 2 possible problems.

The first problem is caused by indecisive players who change their minds while in the middle of a move. Suppose such a player picks up 2 chessmen, as if to capture, and then decides to set both down again. When the first man is set down the program will think that the user has completed a capture, modify the board-status

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```

2102 A5 27 ! LDA CHANGING-SQUARE XFROM SQUARE =
2104 C5 FA ! CMP FA XZTO SQUARE?
2106 D0 03 ! IF ZERO THEN
2108 4C 44 20 ! JMP WAIT-FOR-MOVE ZYES, NO MOVE MADE.
210B ! ENDF
210B 85 B1 ! STA .SQUARE XNO,
210D 20 4B 03 ! JSR MOVE XZRECORD MOVE,
2110 4C 4C 21 ! JMP START-COUNTING XZAND COUNT DOWN.
2113 ! ENDF
2113 ! XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
2113 ! XXXXXXXX 2'ND PIECE PICKED UP XZXXXXXXXX
2113 ! XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
2113 ! X***** WAIT FOR SET DOWN *****X
2113 A5 27 ! LDA CHANGING-SQUARE
2115 85 F9 ! STA F9 XF9=TO SQUARE
2117 85 B1 ! STA .SQUARE
2119 ! !2-UP: LOOP
2119 A5 33 ! LDA TOGGLE XFLASH LIGHTS FOR TO
211B 10 06 ! IF NEGATIVE THEN XZAND FROM SQUARES.
211D A5 FA ! LDA FA
211F E6 33 ! INC TOGGLE
2121 F0 ! BEQ
2122 04 ! ELSE
2123 A5 F9 ! LDA F9
2125 C6 33 ! DEC TOGGLE
2127 ! ENDELSE
2127 85 2B ! STA LIGHT-SQUARE
2129 20 6B 21 ! JSR GET-MOVE XWAIT FOR SET DOWN
212C F0 ! BEQ
212D EB ! ENDL00P
212E 10 29 ! IF NEGATIVE THEN
2130 ! X***** PIECE SET DOWN *****X
2130 A5 27 ! LDA CHANGING-SQUARE
2132 C5 F9 ! CMP F9 XC-S = TO SQUARE?
2134 F0 0C ! IF NOTZERO THEN XZNOPE,
2136 C5 FA ! CMP FA X= FROM SQUARE?
2138 D0 1F ! BNE ERROR-3 XZNOPE, ERROR
213A A6 F9 ! LDX F9
213C 85 F9 ! STA F9 XTO & FROM SQUARES
213E 85 B1 ! STA .SQUARE XREVERSED, SWITCH BACK
2140 86 FA ! STX FA
2142 ! ENDF
2142 A5 FA ! LDA FA XSAVE FROM SQUARE FOR
2144 85 2A ! STA FROM SQUARE XZUSE IF UNDOING MOVE
2146 20 9D 01 ! JSR DISP XSET .PIECE
2149 20 4B 03 ! JSR MOVE XRECORD MOVE
214C ! X***** INITIALIZE COUNT DOWN *****X
214C A9 00 !START-COUNTING: LD# 00 XCLEAR FLAG
214E 85 2F ! STA SHOULD BEUP-FLAG
2150 85 2B ! STA LIGHT-SQUARE
2152 A9 0F ! LD# 0F XLOAD DELAY
2154 E6 2E ! INC SPEAKER-FLAG XZSOUND OFF
2156 4C 4B 20 ! JMP SET-COUNT
2159 ! ENDF
2159 E6 2E !ERROR-3: INC SPEAKER-FLAG XSOME TYPE OF ERROR,
215B D0 BC ! BNE 2-UP XZWAIT UNTIL CORRECTED
215D !
215D !
215D !
215D !SUBROUTINE CLEAR-STACK: XRESETS BOTH STACK MARKERS
215D 68 AB 6B ! PLA TAY PLA XSTORE RETURN ADDRESS
2160 A2 FF 9A ! LDX# FF TXS XRESET MACHINE STACK
2163 A2 C8 ! LDX# C8 XRESET CHESS STACK
2165 86 B2 ! STX .SP2
2167 4B 9B 4B ! PHA TYA PHA XSET UP RETURN
216A 60 ! RTS
216B !
216B !
216B !SUBROUTINE GET-MOVE: XSCANS CHESSBOARD
216B ! XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
216B ! XXXXXXXXXXXX CHECK FOR "DA" OR "PC" XZXXXXXXXX
216B ! XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
216B 20 6A 1F ! JSR GETKEY
216E C9 11 ! CMP# 11 X11="DA" KEY
2170 D0 0B ! IF ZERO THEN
2172 A2 1F ! LDX# 1F XFOUND "DELETE ALL"

```

Listing 2 continued on page 60

table accordingly, and proceed to countdown. During the countdown the second man would pop in and there would be no way to know what it was.

In order to prevent this, each capturing move is saved in the Microchess stack. When a new piece is set down, the stack pointer is checked to see if the previous move was a capture. If it was, and if the location of the new piece corresponds to the square where the capturing piece used to be, then the Microchess routine UMOVE is called to restore the board-status table.

The second problem arises when the user wants to add new pieces to the current board, or set up an entirely new board position. Previously the only way to add new pieces was to stop the chess program and enter the square numbers manually into the board-status table using the KIM-1 monitor. This method is both inconvenient and error prone. The control logic for the "new improved" method occupies hexadecimal addresses 20A7 through 20DE.

After setting the new pieces down, the user simply types the piece name (its numeric designation) into the hexadecimal keyboard. The designation is displayed in FB, the current board-status table entry in FA, and the square where the new piece was set down is stored in F9. If the current table entry is "CC" (indicating that the piece is not currently on the board), the user may enter the piece into the table by pressing the + key.

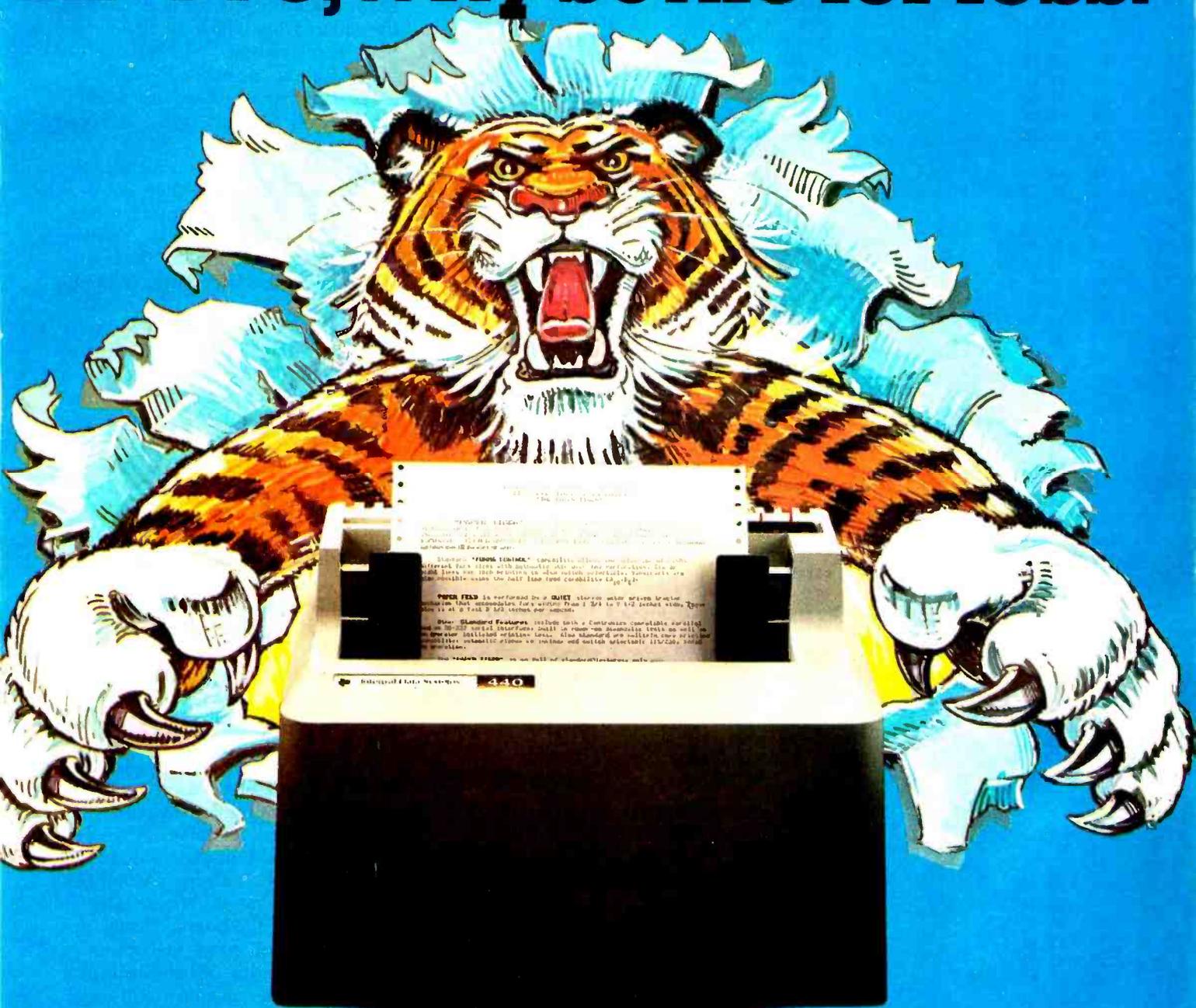
Interpreting the User's Move

If the original call to GET-MOVE at hexadecimal address 204D returns a positive value, it means that the user has picked up a piece, and control will transfer to address 20DE. If .SQUARE contains "CC", the Microchess board-status table has just been initialized, and the user is making the first move of a new game. The board-status table has been initialized assuming that the user would play Black. A branch may be made to address 206A where the user and computer table entries are exchanged.

After checking to see whether or not the user is playing White, GET-MOVE is again called at hexadecimal address 20FB. If the piece is set down at a new square, the move has been completed and a countdown is started. If, after picking up a piece a

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```

2174 A9 CC ! LDAN CC
2176 ! LOOP
2176 95 50 ! STAX .BOARD XFILL PIECE TABLE
2178 CA ! DEX ZXWITH "CC"
2179 10 ! BPL
217A FB ! ENDLLOOP
217B 30 1F ! BMI JMP-TO-MAIN
217D ! ENDIF
217D C9 14 ! CMP# 14 X14="PC" KEY
217F D0 21 ! IF ZERO THEN ZX(PLEASE CLEAR)
2181 20 18 00 ! JSR CLEAR-BOARD XSET UP NEW GAME
2184 85 B1 ! STA .SQUARE XFLAG .SQUARE WITH CC
2186 A9 00 ! LDAN 00 XCLEAR FLAGS
2188 85 2F ! STA SHOULDBEUP-FLAG
218A 85 30 ! STA SWITCH-FLAG
218C ! LOOP XWAIT FOR CLEAR BOARD
218C A5 27 ! LDA CHANGING-SQUARE
218E 85 F9 ! STA F9 XDISPLAY BAD SQUARE
2190 85 FA ! STA FA
2192 85 2B ! STA LIGHT-SQUARE
2194 20 9D 01 ! JSR DISP XDISPLAY PIECE NAME
2197 20 A2 21 ! JSR START-SCAN
219A D0 ! BNE
219B F0 ! ENDLLOOP
219C 20 5D 21 ! JMP-TO-MAIN: JSR CLEAR-STACK XRESET STACK
219F 4C 44 20 ! JMP WAIT-FOR-MOVE
21A2 ! ENDIF
21A2 ! XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
21A2 ! XXXXXXXXXXXX START SCANNING CHESSBOARD XXXXXXXXXXXX
21A2 ! XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
21A2 ! X***** SET UP PORT-LIGHT *****X
21A2 A5 30 ! START-SCAN: LDA SWITCH-FLAG XSIDES EXCHANGED?
21A4 F0 07 ! IF NOTZERO THEN
21A6 A5 2B ! LDA LIGHT-SQUARE XYES,
21A8 49 77 ! EORN 77 XZPL=77-"LIGHT-SQUARE"
21AA 4C ! JMP
21AB AF 21 ! ELSE XNO,
21AD A5 2B ! LDA LIGHT-SQUARE XZPL="LIGHT-SQUARE"
21AF ! ENDELSE
21AF 85 2C ! STA PORT-LIGHT
21B1 ! X*****INITIALIZE U-C-D & TC-S*****X
21B1 A9 00 ! LDAN 00
21B3 85 35 ! STA UP-CLEAR-DUUN
21B5 ! LOOP
21B5 85 32 ! STA TCHANGING-SQUARE
21B7 ! X*****DO MISCELLANEOUS I/O*****X
21B7 20 1F 1F ! JSR FLASH-DISPLAY XFLASH DISPLAY
21BA A5 2E ! LDA SPEAKER-FLAG
21BC F0 03 ! IF NOTZERO THEN
21BE EE 00 17 ! INC# PORT-A XTOGGLE SPEAKER
21C1 ! ENDF
21C1 ! XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
21C1 ! XXXXXXXX IF SHOULDBEUP-FLAG NOT SET XXXXXXXX
21C1 ! XXXXXXXX SEE IF SQUARE IN PIECE TABLEXXXXXXXXXXXX
21C1 ! XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
21C1 A9 00 ! LDAN 00 XASSUME SQUARE OK
21C3 85 34 ! STA TUP-CLEAR-DOWN
21C5 A5 2F ! LDA SHOULDBEUP-FLAG XIN MIDDLE OF MOVE?
21C7 F0 0A ! IF NOTZERO THEN
21C9 A5 32 ! LDA TCHANGING-SQUAREXYES, IS SQUARE IN
21CB C5 FA ! CMP FA XZDISPLAY? IF 50
21CD F0 15 ! BEQ NOT-IN-TABLE XZPRETEND THAT IIS
21CF C5 F9 ! CMP F9 XZNOT IN PIECE TABLE.
21D1 F0 11 ! BEQ NOT-IN-TABLE
21D3 ! ENDF
21D3 ! X*****SEARCH PIECE TABLE*****X
21D3 A2 1F ! LDAN IF
21D5 ! LOOP
21D5 B5 50 ! LDAX .BOARD
21D7 C5 32 ! CMP ICHANGING-SQUARE
21D9 D0 06 ! IF ZERO THEN
21DB 86 31 ! STX TCHANGING-PIECE
21DD E6 34 ! INC TUP-CLEAR-DOWN XFOUND SQUARE
21DF D0 05 ! BNE BUILD-PORTS
21E1 ! ENDF
21E1 CA ! DEX
21E2 10 ! BPL

```

player decides to set it down on the same square, the move is ignored.

If the GET-MOVE call at location 20FB reports that a second piece has been picked up, a capture is in progress and control branches to location 2113. FROM-SQUARE is defined as the square from which the first chessman is picked up. Similarly, TO-SQUARE is associated with the chessman that is picked up second. GET-MOVE is again called at hexadecimal address 2129.

If a piece is set down on either the TO or FROM squares then the program assumes that a capture has been made. The Microchess routine MOVE is called to modify the board-status table, and a countdown is initiated.

If a piece is set down on a square other than the FROM or TO square, or if a third piece is picked up, a branch will be made to hexadecimal address 2159, and the speaker will hum to indicate an error.

Using the System

Playing the chessboard-interfaced version of Microchess is easy. Moves are made by physically picking up the pieces and setting them down on a new square, as in a normal game of chess with a human opponent. The only difference is that the opponent (the KIM-1) is unable to pick up a chessman, so you have to move the pieces to the location indicated by the LEDs.

The KIM display will be all 0s and the LEDs will blink from square to square in a semirandom fashion when it is your turn to move. After you move, the KIM display will countdown from 0F, and the Y axis LEDs will blink sequentially from the top to the bottom of the board. During this countdown you have the option to change your move. When the display reaches 0, the machine will begin computing a response, and no moves can be made until it is your turn again.

Operating the System

The interfaced version of Microchess is started at address 0000, just as the unmodified Microchess. The speaker will probably hum. To start a new game, press the PC key. The speaker's sound will cease. Choose the White or Black pieces, and set up the board with your choice



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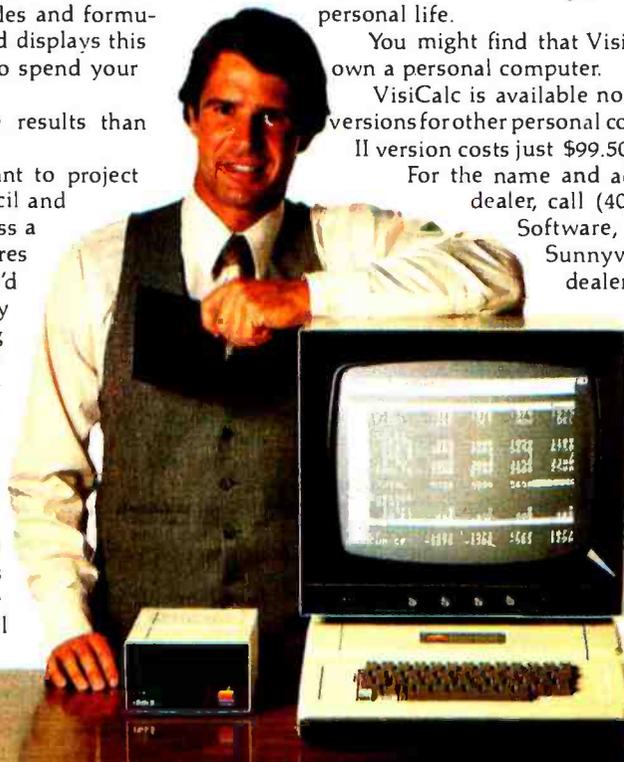
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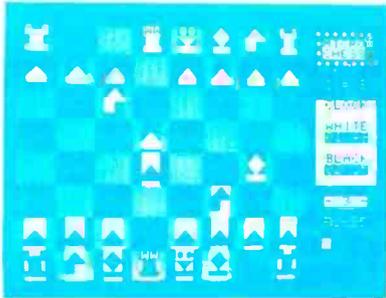
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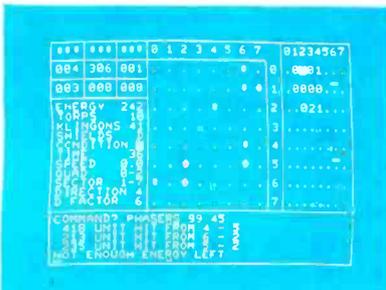
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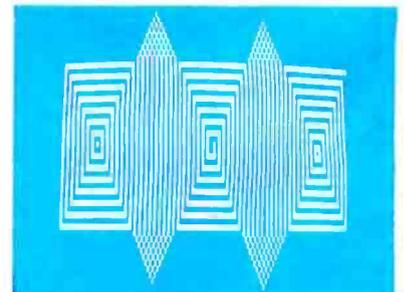
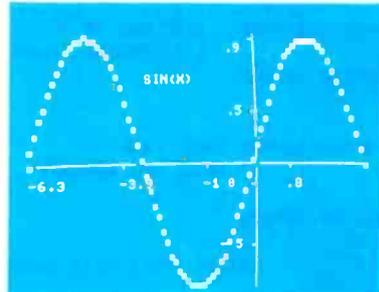
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Listing 2 continued from page 52:

```

221E 8D 00 17 !          STA@ PORT-A          XOR IN COLUMN
2221 !          Z*****PORI-B*****
2221 A5 2C !          LDA PORT-LIGHT
2223 18 !          CLC
2224 69 80 !          ADC# 80          ZTOGGLE PL FLAG BIT
2226 85 2C !          STA PORT-LIGHT
2228 29 80 !          AND# 80
222A 4A 4A !          LSK LSK          ZSET X UR Y AXIS AND
222C 8D 02 17 !          STA@ PORT-B          ZENABLE LEDS
222F !          ZXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
222F !          ZXXXXXX DID STATUS OF SQUARE CHANGE? ZXXXXXX
222F !          ZXXXXXX IF SO RECORD THE CHANGE ZXXXXXX
222F !          ZXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
222F !          Z*****READ ROW*****
222F A5 2D !          LDA PORT-SQUARE
2231 29 30 !          AND# 30
2233 4A 4A !          LSR LSR
2235 4A 4A !          LSR LSR
2237 AA !          TAX
2238 B5 B7 !          LDAX MASK-TABLE
223A 2D 02 17 !          AND@ PORT-B
223D !          Z*****CHECK FOR CHANGES*****
223D D0 06 !          IF ZERO THEN
223F A5 34 !          LDA TUP-CLEAR-DOWN ZSQUARE OCCUPIED...
2241 10 10 !          BPL NEXT-SQUARE ZAND IN TABLE.
2243 30 !          BMI
2244 04 !          ELSE
2245 A5 34 !          LDA TUP-CLEAR-DOWN ZSQUARE EMPTY...
2247 30 0A !          BMI NEXT-SQUARE ZXAND NOT IN TABLE
2249 !          ENDELSE
2249 !          Z*****FOUND A CHANGE, RECORD IT*****
2249 85 35 !          STA UP-CLEAR-DOWN
224B A5 32 !          LDA TCHANGING-SQUARE
224D 85 27 !          STA CHANGING-SQUARE
224F A5 31 !          LDA TCHANGING-PIECE
2251 85 28 !          STA CHANGING-PIECE
2253 !          ZXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
2253 !          ZXXXXXXCHECK NEXT SQUARE OR RETURN IF ALL DONEXXXXXX
2253 !          ZXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
2253 E6 32 !NEXT-SQUARE: INC TCHANGING-SQUARE ZADD ONE TO
2255 A9 08 !          LDAN 08          ZTCHANGING-SQUARE
2257 25 32 !          AND TCHANGING-SQUARE
2259 0A !          ASL
225A 18 !          CLC
225B 65 32 !          ADC TCHANGING-SQUARE ZADD "CARRY"
225D 29 77 !          AND# 77          ZMASK OUT GARBAGE

225F 85 32 !          STA TCHANGING-SQUARE
2261 F0 03 !          BEQ RETURN
2263 4C !          JMP          ZXZGO CHECK NEXT SQUARE
2264 B5 21 !          ENDL00P
2266 A9 00 !RETURN: LDAN 00
2268 85 2E !          STA SPEAKER-FLAG
226A EE 02 17 !          INC@ PORT-B
226D A5 35 !          LDA UP-CLEAR-DOWN
226F 60 !          RTS
2270 !
END OF ASSEMBLY

```

upon which the new piece was set down. Modify the first byte by typing in the correct name of the new piece. If the piece has been previously captured, it may be added to the piece table by typing the + key.

To change sides (Black to White, or vice versa), type the E key. A countdown will be initiated. Do not change

sides before the opening move of the game; the King, Queen, and other pieces could become incorrectly reversed.

Conclusion

Although it may require a lot of solder, building the hardware is neither hard nor exacting work. As

with most projects, if it doesn't work the first time the problem can usually be traced to an incorrect program, faulty wiring, or bad integrated circuits. In this particular project, the program is already written, the wiring is easy to check, and there are only 2 integrated circuits.

The electronic chessboard can, of course, be used for activities other than chess. Almost any game that is played with an X,Y type grid can be played by the computer, among these: checkers, tic-tac-toe, and nim.

I have found that the chessboard interface makes playing chess with the KIM-1 much more enjoyable. Even if you lose the chess game, the method of playing is sure to be impressive. ■

Editor's Note

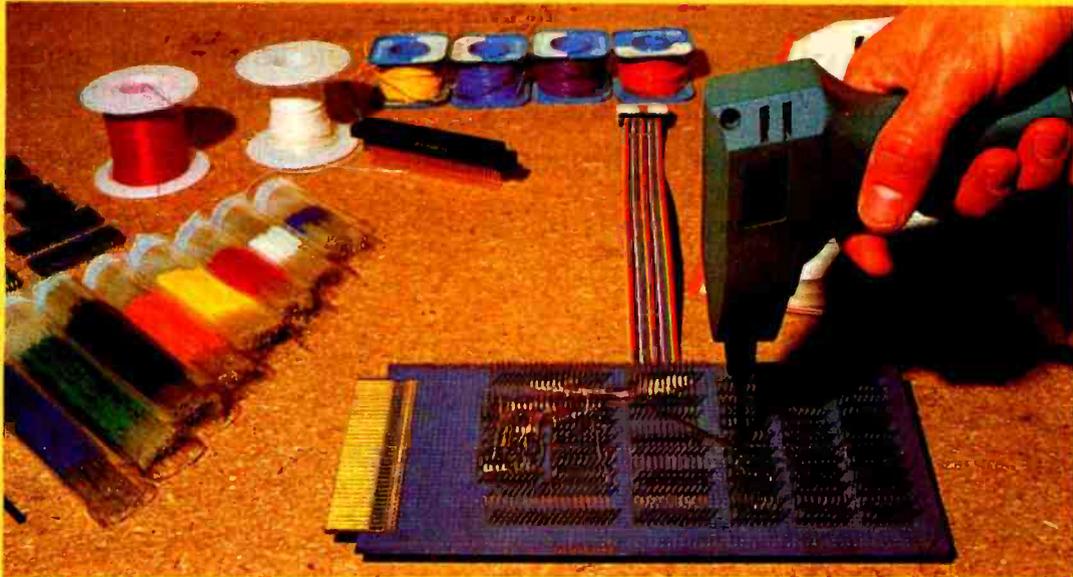
The program described in this article was designed to be "foolproof" for the beginning chess player. The countdown period for changing a move will greatly ease the frustration often experienced by players of computer games, the sinking feeling of "Oh no, I didn't mean that, and there's no way to take back the move!" More programmers should pay such attention to the user interface of their systems.

More experienced chess players generally abide by the following rule: a piece once touched by the player must be moved, and an opponent's piece once touched must be captured. Such users would probably wish to delete the countdown period to speed the progress of the game.

An electronic chessboard operating in a similar fashion appeared in the article "Chess 4.7 versus David Levy" by J R Douglas (December 1978 BYTE, page 84). That board, constructed by Dr David Cahlander of Control Data Corp, uses 1 light emitting diode (LED) in each square of the chessboard to indicate the computer's move, and uses magnetic switches placed under the squares which are activated by the metal weights in the pieces. Controlled by a 6800 micro-processor, Cahlander's board transmits and receives moves to and from a remote computer on which the Chess 4.7 program runs...RSS

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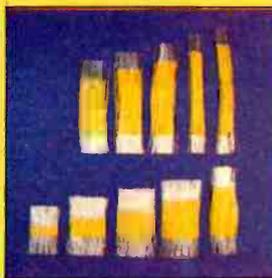


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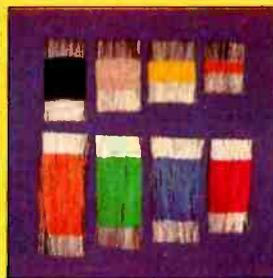
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3.5	1.13	3.46	6.14	7.5	1.73	5.89	10.91
4	1.18	3.70	6.62	8	1.78	6.15	11.44
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5	1.28	4.20	7.61	9	1.87	6.76	12.51
5.5	1.32	4.48	8.10	9.5	1.92	6.93	13.04
6	1.37	4.72	8.59	10	1.99	7.26	13.57



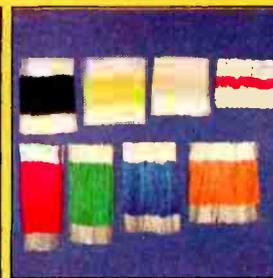
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500	3 1/2"	500	5 1/2"
500	4"	500	6"

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1000	4"	1000	6"

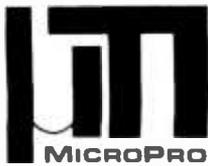
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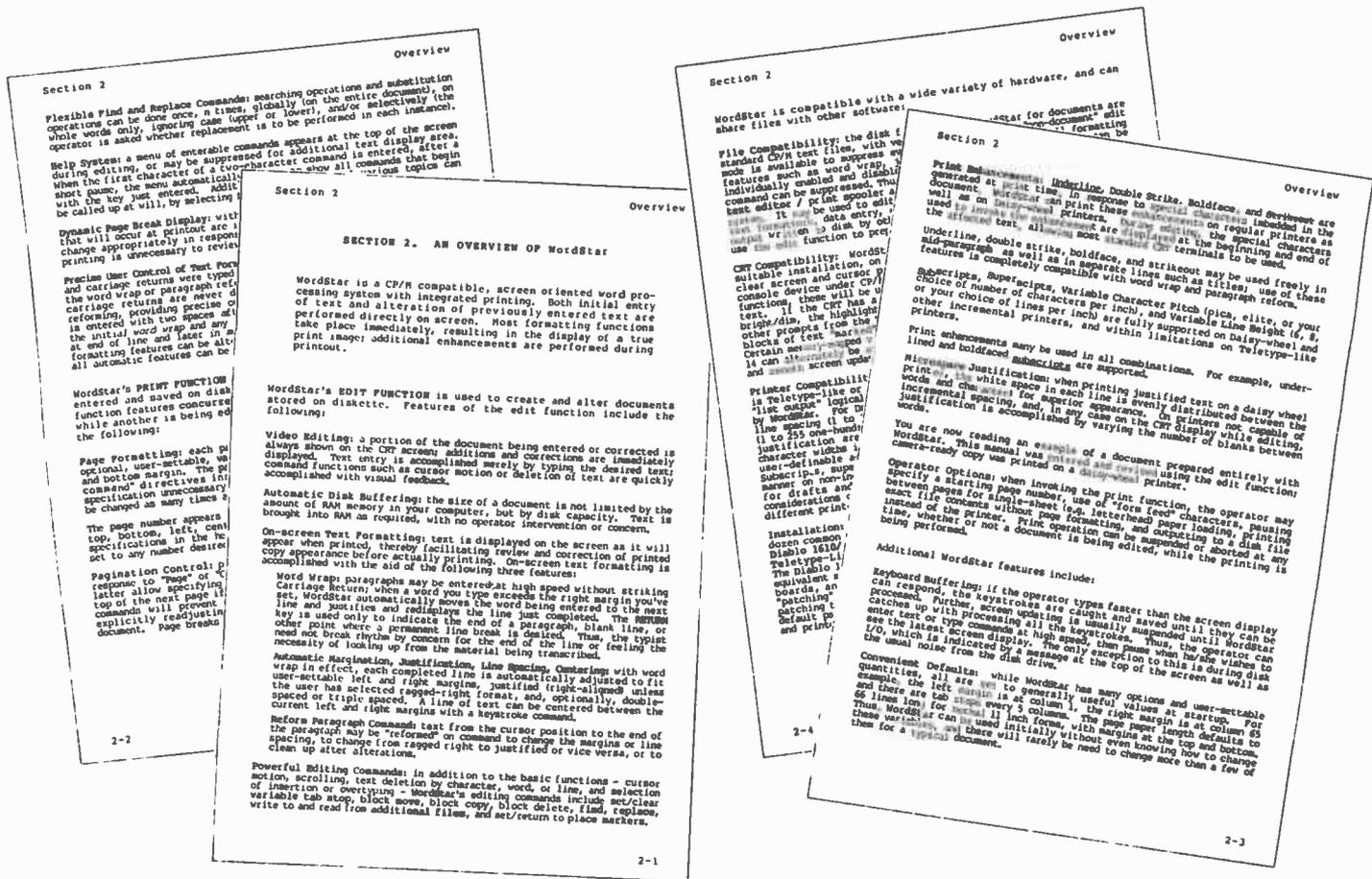
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A Similarity Comparator for Strings

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Professor
Dept of Chemistry
University of Maryland
College Park MD 20742

The trouble with computers is that they have no common sense. If a computer is directed to search a file looking for a particular string of characters, a simple typographical error will cause the computer to report that no match has been found; even though there was something very close in the file. The statement "If A\$=B\$ THEN. . ." is taken literally by the computer; even the slightest difference is not tolerated.

Wouldn't it be better if a computer, finding no exact match, would report the *best* match, or the 5 best matches listed in order of closeness of match? To do this, a routine is needed that returns a quantitative estimate of the similarity between 2 strings. That is what the routine illustrated here does; it computes a similarity index on a scale of 0 thru 100 percent.

Listing 1 gives a BASIC string comparator program. The heart of the program is in lines 100 thru 290; lines 10 thru 90 are there only to allow the routine to be demonstrated with 2 manually input strings. The fundamental idea is simple: each character in one string is compared to each character in the other string. This is done so that *groups* of characters that match are weighted more heavily than the same number of matches of individual characters. This allows, for example, "POOL" and "POOR" to be rated more nearly equal than "POOL" and "POLO", even though the latter 2 strings have more characters in common.

```
10 LET T=0
20 LET P=3
30 PRINT "FIRST WORD" ;
40 INPUT A$
50 LET A=LEN(A$)
60 PRINT "SECOND WORD" ;
70 INPUT B$
75 IF A$=B$ THEN PRINT "EXACT MATCH"
80 LET B=LEN(B$)
90 IF A>B THEN LET B=A
100 FOR M=1 TO B
110 LET C=0
120 FOR I=1 TO M
130 LET K$=MID$(A$,B-M+1,1)
140 LET L$=MID$(B$,I,1)
150 IF K$=L$ THEN LET C=C+1
160 NEXT I
170 LET C=C/P
180 LET T=T+C
190 NEXT M
200 FOR M=B+1 TO 2*B-1
210 LET C=0
220 FOR I=1 TO 2*B-M
230 LET K$=MID$(A$,I,1)
240 LET L$=MID$(B$,M-B+1,1)
250 IF K$=L$ THEN LET C=C+1
260 NEXT I
270 LET C=C/P
280 LET T=T+C
290 NEXT M
300 LET S=100*T/B/P
310 PRINT S;"%"
320 LET T=0
330 GOTO 70
340 END
```

Listing 1: Listing of the similarity comparator program in Ohio Scientific Instruments 8 K BASIC (a Microsoft interpreter). The up arrow indicates exponentiation.

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The weighting of groups of characters is controlled by the variable P defined in line 20. If P is set to a value of 1, there is no special weighting of groups; only the total number of characters in common between the 2 strings is counted. If P is set greater than 1, groups are weighted more heavily, proportional to the value of P. If P is too large, however, all but the very closest matches result in low similarity index. A value of P=3 is a good compromise.

Line 300 scales the index to within a range of approximately 0 thru 100 percent. Two strings with no common characters give 0 percent similarity, while 2 identical strings give 100 percent similarity. Sometimes 2 nonidentical, but very similar, strings with many repeated letters (eg: "AAAAA" versus "AAA") will give 100 percent or greater than 100 percent similarity. This is seldom a problem with practical strings.

Strings of any type can be compared: names, addresses, numerals, or even strings containing spaces and punctuation. Long strings take a long time to compare, up to several seconds. An assembly language version should run much faster, if speed is important in your application.

The routine in listing 1 is written in Ohio Scientific Instruments 8 K BASIC, Version 1, and was run on a Challenger II system. The syntax of the string functions, particularly MID\$, may be different in other BASICs. However, it should be compatible with most of the other BASIC interpreters which were developed by Microsoft. The program also runs without modification on an 8 K PET. ■

Sample Run

```

RUN
FIRST WORD? POOL
SECOND WORD? POOL
EXACT MATCH
  103.1%
? POOR
  45.3%
? COOL
  45.3%
? POO
  45.3%
? POLO
  28.1%
? LOOP
  18.7%
? PAIL
  12.5%
? POOL ROOM
  10.4%
? MAIL ROOM
  1.5%
? PO/OL
  14.4%
? OOOO
  40.6%
?
OK
RUN
FIRST WORD? T.C. O'HAVER 710 HILLSBORO DR. SILVER SPRING MD.
SECOND WORD? TOM O'HAVER 710 HILLSBORO DR. SILVER SPRING MD.
  82.9%
? R.D. O'HAVER 710 HILLSBOROUGH RD. SILVER SPRINGS FL.
  10.3%
?
OK

```

Comments

> 100% because of double letter 3 letter pattern "POO" matches.

Still a 3 letter pattern.

Same match, because nonmatching characters do not count.

Two 2 letter matches, "PO" and "OL", do not count as much as one 3 letter match.

Only 2 isolated letters.

Presence of extra random character reduces match. Repeated letters result in unexpectedly high match.

Listing 2: A sample run of the program, with comments explaining the value of similarity assigned.

Note: We entered this program into an Apple II computer using the Applesoft floating point BASIC. It ran without modification. The exact values of similarity computed did sometimes differ from those given in the sample run, but only in the fourth significant digit and beyond . . .
RSS

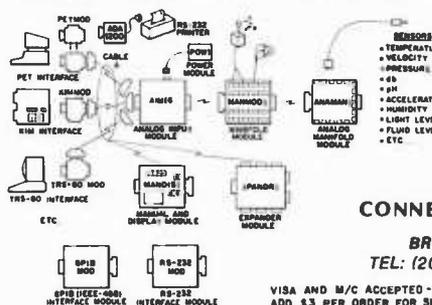


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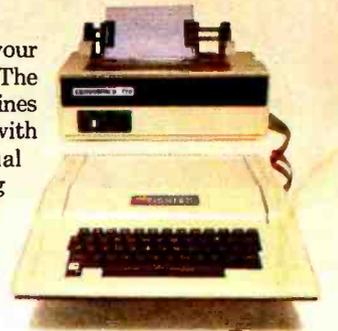
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Some Musings on Hardware Design

Clayton Ellis
Rt 4, POB 86
Montrose PA 18801

The purpose of this article is to acquaint the reader with some of the more interesting types of transistor-transistor logic (TTL) integrated circuits, the ease with which logic design can be accomplished, and to offer a few design considerations and troubleshooting hints to stimulate the homebrew use of digital logic.

Taking the topics in the above order, we start with a look at some of the more complex types of TTL chips in the "74xx" series. (We will ignore simple gates for the most part.) An example is the 7442. This integrated circuit is a binary coded decimal (sometimes called BCD) to decimal decoder. What this means is that the circuit will decode 1 line out of 10 based on a 4 bit binary code. Figure 1 shows the pin connections. Regardless of what it is called, it works like this: pins 12 thru 15 are a 4 bit binary input, pin 15 being the 1's bit (bit 0), 14 the 2's bit (bit 1), 13 the 4's bit (bit 2), and 12 the 8's bit (bit 3). Pins 1 thru 7 and 9 thru 11 comprise the output pins, each pin staying high (logic 1 or a higher level voltage of about 3 to 5 V) unless the corresponding binary code is applied to the input. For example, let's say that pins 12 thru 15 are 0101. In other words, 12 is at a logical low (about 0 V); 13 is at a logical high level

(above about 3 V, less than 5 V), etc. In this case, pin 6 (indicating a decimal 5) would be at a logical low level (about 0 V). All other pins relating to decimal output numbers would be at a logical high level. Note that only one output pin will be low at any given time, corresponding to the binary value of the input lines. "Ahh," you might ask, "what if the input pins are at some binary value other than 0 thru 9?" The answer is easy; this constitutes an invalid input, and all output pins will stay high. Only valid decimal values will select an output pin.

Now let's move on to a module similar to the 7442, the 74154. Referring to figure 2, the first apparent difference is the larger number of pins on the 74154. This integrated circuit is a 4 line to 16 line decoder. Its operation is the same as the 7442, with but two exceptions: there are now 16 valid output lines; and provision is made to allow

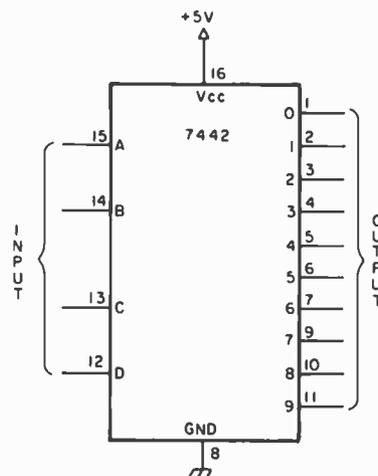


Figure 1: Pin connections for a 7442 TTL binary coded decimal to decimal converter.

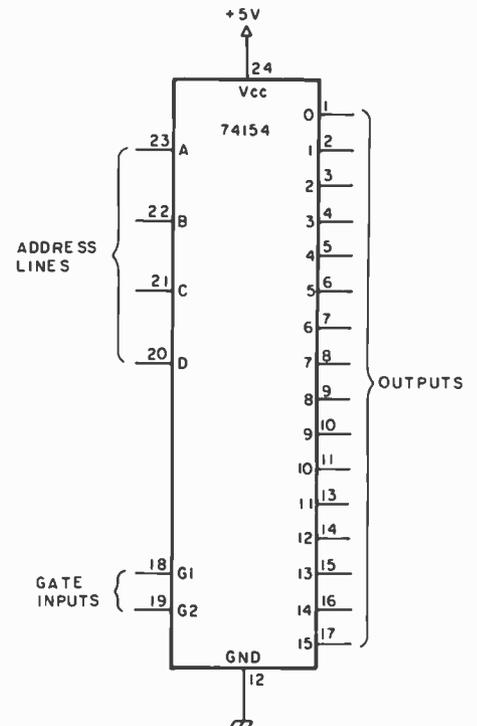


Figure 2: Pin connections for a 74154 TTL 4 line to 16 line decoder.

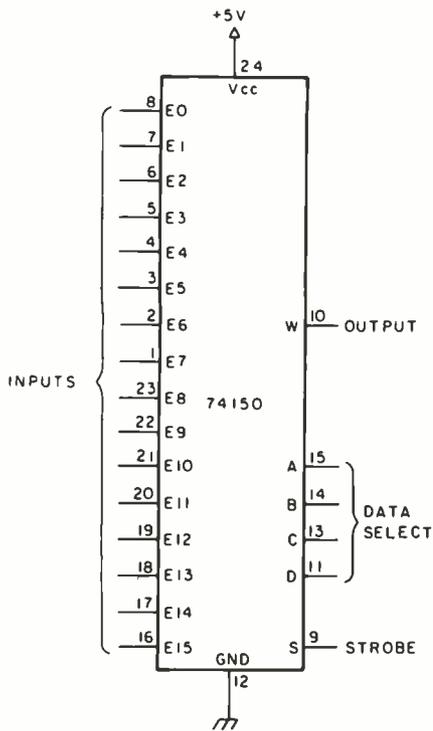


Figure 3: Pin connections for a 74150 TTL 1 of 16 line data selector.

two extra inputs to gate the individual line selected. Pins 18 and 19 perform this gating function. An example of use of this extra gating feature might look like this: pins 20 thru 23 might contain the binary equivalent of a decimal 14, pin 19 being low and pin 18 alternating from high to low (a periodic clock pulse.) The end result is that pin 16 (corresponding to line 14) will also periodically alternate high and low in following the signal on pin 18. The data at pin 18 is transferred to pin 14. If the binary code on pins 20 thru 23 were now changed to a decimal 7, then line 7 (pin 8) would follow the data on pin 18. We select one of 16 outputs for a signal applied to the gates. Now, if we could just have a binary controlled switch to select 1 of 16 inputs. Let's look at the 74150. Figure 3 shows the pinout of this one. This time there are 21 input pins and only 1 output pin.

Let's see how this one works. Binary input is on the 4 lines of pins 11 and 13 thru 15. Let's say a binary value of 12 is present. This selects the number 12 input line (pin 19) and transfers the level of this line, be it steady, high, low or some alternating clock signal, to pin 10, the output line. Notice, though, that in order for the data to be transferred, pin 9 (the strobe input) also must be low. A high level on the strobe input prevents any data transfer from any input. This feature is used to allow data transfer only at selected intervals, such as



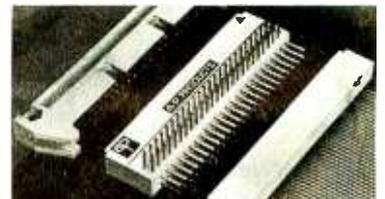
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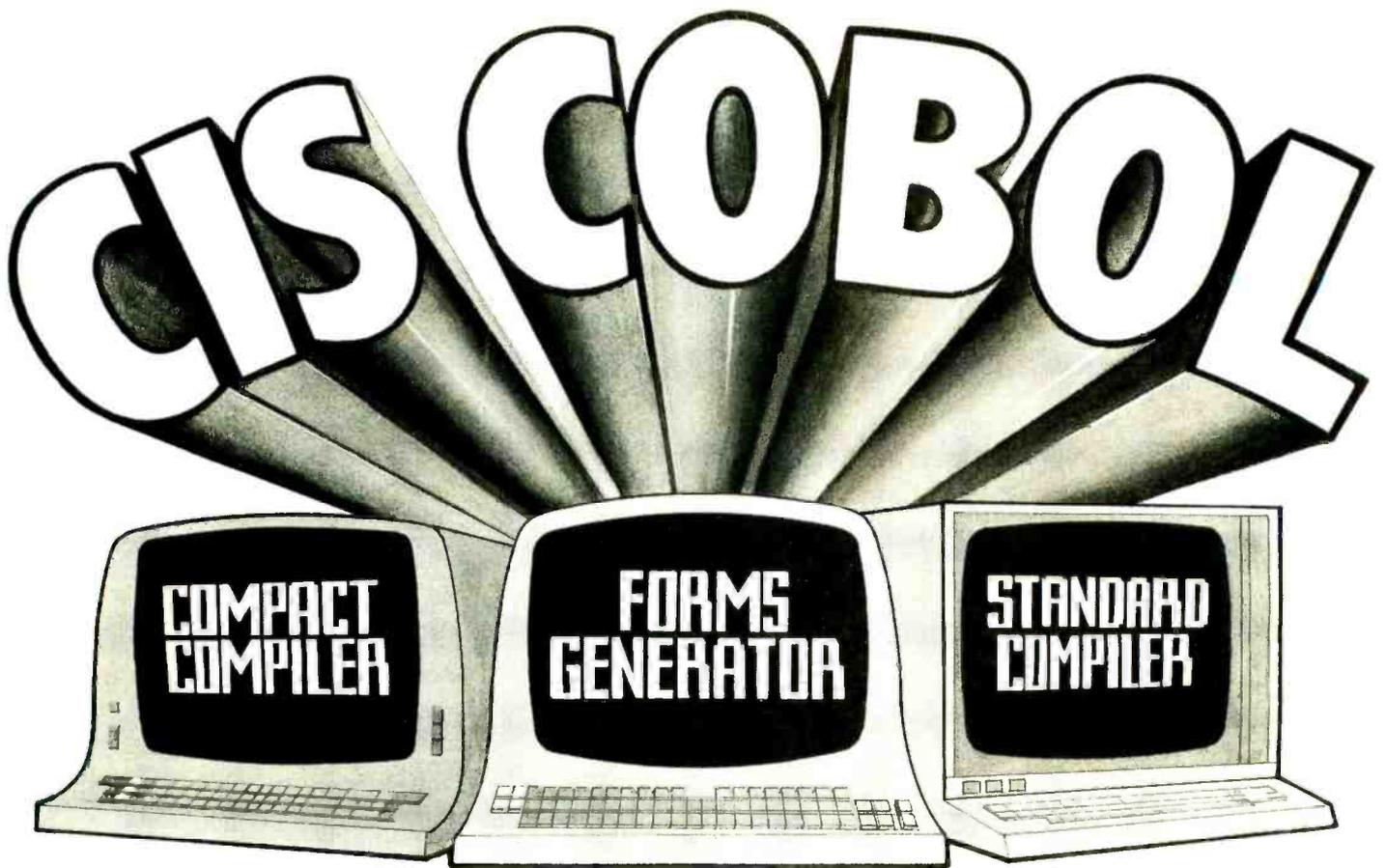
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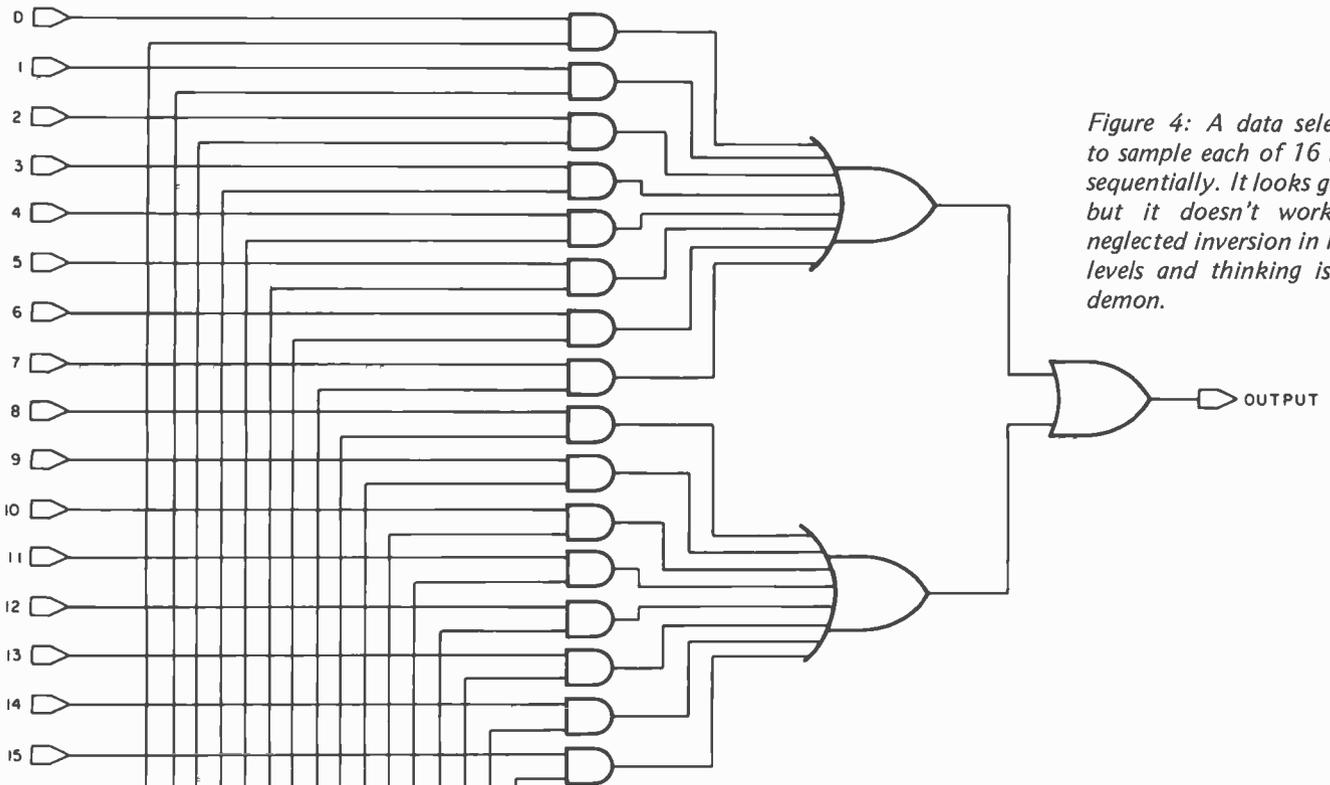


Figure 4: A data selector to sample each of 16 lines sequentially. It looks good, but it doesn't work. A neglected inversion in logic levels and thinking is the demon.

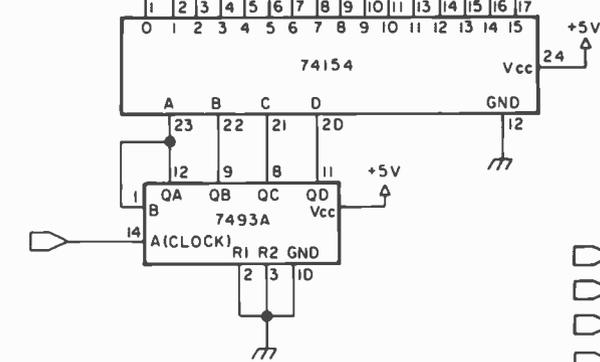
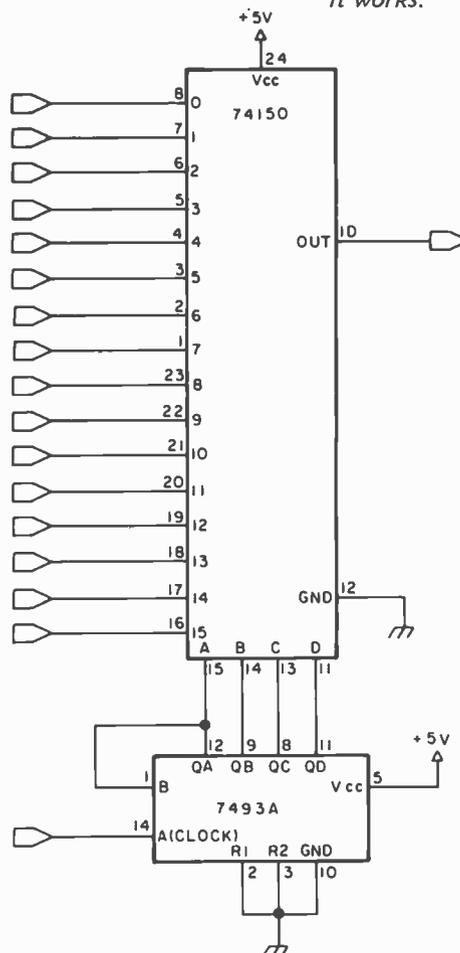


Figure 5: Another approach to the problem in figure 4. This approach has a much lower parts count, so it is much easier to wire and it works.

when the input would contain valid data, or when the output is useful only at specific intervals.

Now that we have taken a look at a few of the more involved logic blocks, let's look at how easy it is to design the somewhat more complicated circuits using the simple TTL blocks in conjunction with one or more of the above type of logic blocks.

If we want to build a sequencing device to look at a number of incoming lines, and if we are to use a given clock signal to coordinate all this, we can use the logic circuit in figure 4. A very simple and straightforward circuit, right? Not quite. Let's take a second look. All the inputs but the one selected by the 74154 are going to be enabled at one time. The selected pin goes low, remember? By this time, if not before, you probably recalled the look we just took at the 74150 and are wondering why we did not use it. Figure 5 shows the circuit using the 74150. The foregoing just illustrates a good point (and one to keep in mind whenever you undertake any logic design). There



- Get circuit requirements down on paper in block form.
- Break each block down into required logic.
- Use the most integrated block available for each function as in the example of figure 5 unless the cost of such a module is much higher than two or possibly three less intricate ones.
- Don't go overboard with smaller blocks. This increases the density and complexity of interconnection, greatly increases the chances of errors and reduces system reliability.
- Cross-check all designs, as you may have redundantly developed the same signal line. Sometimes most of one segment of a circuit can be eliminated with an inverter or small amount of additional gating.
- If possible, have a friend familiar with digital logic go over the layout. Your friend can sometimes suggest circuit reductions that you missed simply because you were thinking one way while your friend used a different approach. The same review may even spot an error in the logic. With all those inversions, gating, etc, it is easy to do. Spotting an error at this stage can save hours at the breadboard stage.

Table 1: Approach to finding the simplest logic circuit for a given function.

are many ways to accomplish a specific function. So many, in fact, that large companies who do digital logic design in large quantities invariably use some form of computer aided logic design. The homebrew enthusiast obviously can't go that far, but the approach summarized in table 1 usually works fairly well.

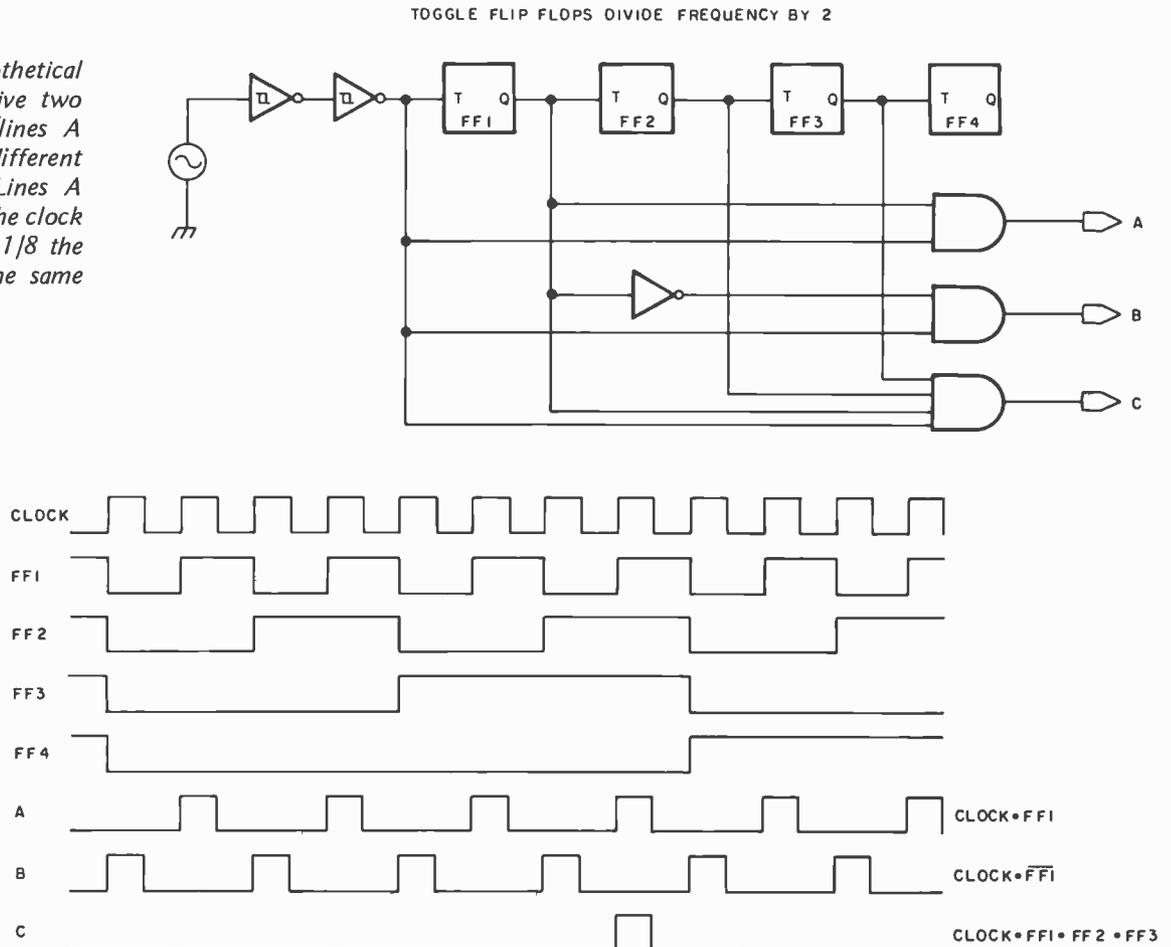
Timing

Another good point to keep in mind is to think time (not in terms of how long it takes to design a circuit, or build it, but time relationships in the circuitry itself). This brings

us back to a term, clock, that we have been using freely up to now. We all know that a clock is merely a line, usually derived from a square wave oscillator, right? This line is then used to coordinate all necessary gating, shifting, setting and resetting, etc, that goes on within the circuitry itself, right? Well, that is part of it, but who said it had to be a single line? Some computers use a number of clock lines, perhaps as many as 8 or 10. The only thing these multiple clock lines have in common is that they are usually all derived from the same oscillator and may be individually gated on or off, counted, decoded or subjected to any other valid logic manipulation.

Figure 6 shows a typical clock circuit detailing some of these practices. As you can readily see, almost any combination of clock times can be selected, and the flip flops can be extended as far as needed to select a single clock pulse or a repetitive series of clock pulses. The point to remember is that all pulses are derived from the same clock and each pulse on any line will be of the same duration as any other clock pulse. The single clock pulse shown on line C of the timing chart in figure 6 will start at the same time as the fourth clock

Figure 6: A hypothetical clock circuit to give two different phases (lines A and B) at two different repetition rates. Lines A and B are at 1/2 the clock rate. Line C is at 1/8 the clock rate with the same pulse duration.



pulse on line A, and the duration will be identical.

There is one fly in the ointment at this point. I just noted that the two clock pulses would start at the exact same time. That is not quite true, however, and depending on how fast the clock is running, and exactly what is being gated, this may or may not be a problem.

In an actual circuit, the clock pulse on line A would go positive slightly ahead of the pulse on line C. This is due to the delay (called propagation delay) across each flip flop encountered by the leading edge of the pulse. This delay is on the order of nanoseconds for each gate encountered. Let us assume an arbitrary 5 ns delay for each gate. Then the delay from the input of FF1 to the output of the AND gate driving line A would be 10 ns. This is 5 ns for FF1 and 5 ns for the AND gate. The delay from the input to FF1 to the output of the AND gate driving line C would be not 10 ns, but 20 ns: 5 ns for each of the three flip flops and 5 ns for the AND gate. The pulse on line C would actually start 10 ns after the one of line A. This will also make a difference in the duration of the pulse on each line; as the plus level arriving later than the clock pulse at the input to the AND gate determines when the output of the AND gate goes positive. However, the trailing edge of the clock pulse input determines when the AND gate output goes negative.

This, in effect, shortens the duration of the pulse on the output line by a time (in nanoseconds) determined by the various propagation delays. If the clock frequency of the circuit is on the order of tens or hundreds of kilohertz, then a delay of tens of

nanoseconds would be of little consequence; but if the clock frequency of the circuit is something like 20 or 25 MHz, the delay can become a thorn in the side of the designer. This holds true for all data and control lines we well as clock lines.

This propagation delay can be used to an advantage too. Figure 7 illustrates using this delay to generate a narrow pulse. Here the positive going (leading) edge of the input is applied to an AND gate, but the negative going (trailing) edge of the inverted version applied to the other leg of the AND gate is delayed by the total of the propagation delay across the three inverter blocks. The resultant output is a narrow pulse equal in duration to the delay across the inverters. This method of generating a pulse is only useful in cases where we don't care *exactly* how long the pulse lasts since gates and inverters are subject to manufacturing variations.

To satisfy the rather picky individual or very high speed circuit, I have to say also that the output pulse is not only derived from the inverter delay, but is delayed from the leading edge of the original pulse by the amount of the delay across the AND gate itself. Figure 8 illustrates this. The short delays shown on waveform C are due to the AND gate propagation delay. For most situations, this is carrying propagation delay accounting to extremes, but in certain high speed circuits each delay may have to be accounted for. If 20 or 30 gates are involved, the cumulative effects add up rather fast.

Also to be considered is the capacitive effect of the interconnection lines: the distributed and stray capacitance which are in parallel with the output of each gate add slightly to delay times. It takes a finite amount of time to charge this capacitance at

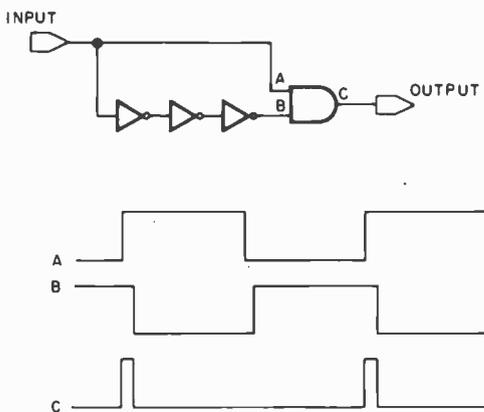


Figure 7: A pulse generator for nanosecond range pulses. Pulse length is determined by the propagation time through the gates between the input and point B. More sophisticated methods are required if an accurate pulse length is required.

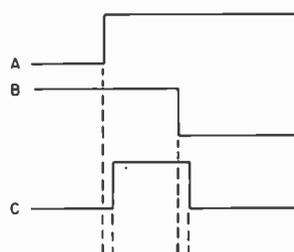


Figure 8: A magnified view of the pulse shown in figure 7. The output pulse is delayed by the propagation time of the AND gate. This time varies but is typically about 10 ns for normal transistor-transistor logic, less for the high speed and Schottky version and more for the low power integrated circuits.

each gate turn on, and the gate will not switch until a certain voltage input level is reached. All of which leads right into the last subject I'd like to touch on. How do you see all this in an actual circuit? Believe me when I say that it takes a good oscilloscope. To have a good display in the tens of nanoseconds range, it takes an oscilloscope with a bandwidth of at least 60 to 100 MHz.

Does this mean that anyone without such an oscilloscope can't do much with higher speed TTL? Not necessarily. Remember we said that propagation delay only becomes a problem at high speeds and multiple gate delays. There are a number of ways around this. One is to keep clock frequencies and

data changes as slow as possible. Don't use a fast clock or data encoding just for the sake of speed, run it as fast as necessary and no faster. If you can tolerate a slow clock speed, use it. Another method is to try and bring each data line that is to be gated with another line through the same number of gates as the line it is to be gated with. In other words, if one line originates at about the same source as another that it is to be gated with, but passes through 9 levels of gating, and the other line passes through 3, the delays at high speeds can be a problem. This could be compensated for by changing the way the lines are gated to bring the delays in each line closer to the

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same length. Another help in extreme cases is to run the line with the lesser number of gates through several pairs of inverters. This introduces a delay to compensate for the delay in the other line. In other words, make the faster line wait for the slower one. An even better solution is to design your circuits "synchronously" so that only one clock source ever changes the *state* of a flip flop or memory cell.

As to seeing these problems on the slower oscilloscopes, there are several hints that will help. Very little serious work with timing relationships can be undertaken without a dual trace capability (although a good deal can be done otherwise with TTL with just a single trace scope). Even with a dual trace oscilloscope, the fastest sweep speed may not reveal a lot of timing detail if not set up correctly and the alternate sweeps may not be time correlated without a common synchronization signal. A number of tests can be made with a single trace oscilloscope if it has provisions for external synchronization.

In general, synchronize the oscilloscope sweep as far ahead in time as is realistic for the signals in question, in order to allow time for the sweep to start before the pulse actually arrives. It goes without saying that the synchronization signal must be common to all signals being examined.

If you still can't see any difference, try estimating the approximate delay for each line from source to common logic block. Most logic handbooks list typical delays for integrated circuits. If the problem is in a counter circuit of some type which counts "up," the count for a given sequence will usually be too high in value if delay problems are the cause. Rarely will the count of an "up" counter be too low, as the usual situation is advancing the counter by an extra pulse generated by mismatched delays, especially if a lot of exclusive ORing is being done. The situation where early turn off or disabling of the counter causes a missed count is quite unlikely, mainly because the delay is of a much shorter duration than the pulses being counted.

These problems are all good to be aware of, but don't let them deter you from starting that project you were thinking about. You may go a long time before you see one of the problems described. Don't let the lack of a superb oscilloscope deter you either. A lot of very intricate and fast digital circuitry is being built every day with nothing more than a single trace 1 MHz AC coupled oscilloscope. With a little experience, you can tell a great deal about a given TTL circuit with one of these inexpensive oscilloscopes. ■



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A Low-Speed Analog-to-Digital Converter for the Apple II

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The development of microprocessor-based computer systems has progressed to the point where it is now practical to utilize these systems in a scientific or laboratory application. To be useful in a scientific application the computer must have the capability of converting analog signals to digital signals. Very few home computers have this capability. Certainly it is a straightforward task to design an analog-to-digital converter (ADC), but the real problem lies in connecting the converter to the computer.

The Apple II computer, with 8 peripheral-board connectors on the mother board, makes the job of designing and implementing special interfaces (such as the ADC) relatively easy. The peripheral-board connectors give the hardware designer access to all address, data, and control lines. In addition all control, address, and data lines have been buffered, and certain address bits have been decoded to give a device select (DS) signal. What this means is that when a specific range of address locations is accessed, the DS line will give a low output signal. Since the peripheral-board connectors are on the main computer

Number	Type	+5 V	GND	-5 V
IC1	MC14028	16	8	—
IC2	MC14049	1	8	—
IC3	SN7427	14	7	—
IC4	MC14013	14	7	—
IC5	MC14433	24	13	12
IC6	AD580	—	—	—
IC7	MC14503	16	8	—
IC8	MC14503	16	8	—
IC9	DM7432	14	7	—

Table 1: Voltages which must be supplied to integrated circuits in figure 1 for operating power.

board, the finished interface board will be inside the computer and will be able to use the computer's power supply. Because of these characteristics, turning the Apple II into a real-time data analyzer becomes a matter of designing an analog-to-digital converter circuit, and control logic to meet the need of the application.

Many of the applications that I had in mind were to be of a low-speed nature (eg: monitoring the temperature of experimental animals in medical physiology laboratories, analyzing the results of electrophoretic analysis). Therefore, a low-speed analog-to-digital converter built around the Motorola MC14433 integrated circuit seemed to be a cost effective approach. I was inspired by Steve Ciarcia's article, "On a Test Equipment Diet? Try an 8 Channel DVM Cocktail" (December 1977 BYTE, page 76).

The left section of figure 1 shows the analog-to-digital converter cir-

cuitry. All data and status lines to the computer are isolated through the MC14503 3-state buffers (IC7 and IC8). The MC14433 (IC5) is allowed to convert continuously at a rate of approximately 15 conversions per second. This means that if the data transfer to memory starts immediately after the conversion ends, the Apple II can easily decode and store the data from one conversion before another conversion occurs. IC4, configured as an RS flip-flop that is initially reset by the computer, is set by the MC14433 after an analog-to-digital conversion has been completed. When the computer senses this change in status, it starts the decoding and data transfer process. IC6 is an AD 580 used to provide a stable reference voltage to the MC14433.

The right section of figure 1 shows the control logic that is necessary to coordinate the transfer of data to the computer, and control signals from the computer. The circuit is designed so that the peripheral card resides in I/O (input/output) slot 7 on the Apple II mother board. The device select signal will go low whenever hexadecimal memory locations C0F0 thru C0FF are addressed. The least

Text continued on page 74

Figure 1: Schematic diagram of analog-to-digital-conversion circuit and associated control-logic circuitry. The analog-to-digital (A/D) convertor is shown on the left side, the control logic on the right side.

About the Author

Richard Hallgren is an Assistant Professor in the Dept of Biomechanics at Michigan State University. He is working on the application of microprocessor-based systems in scientific research.

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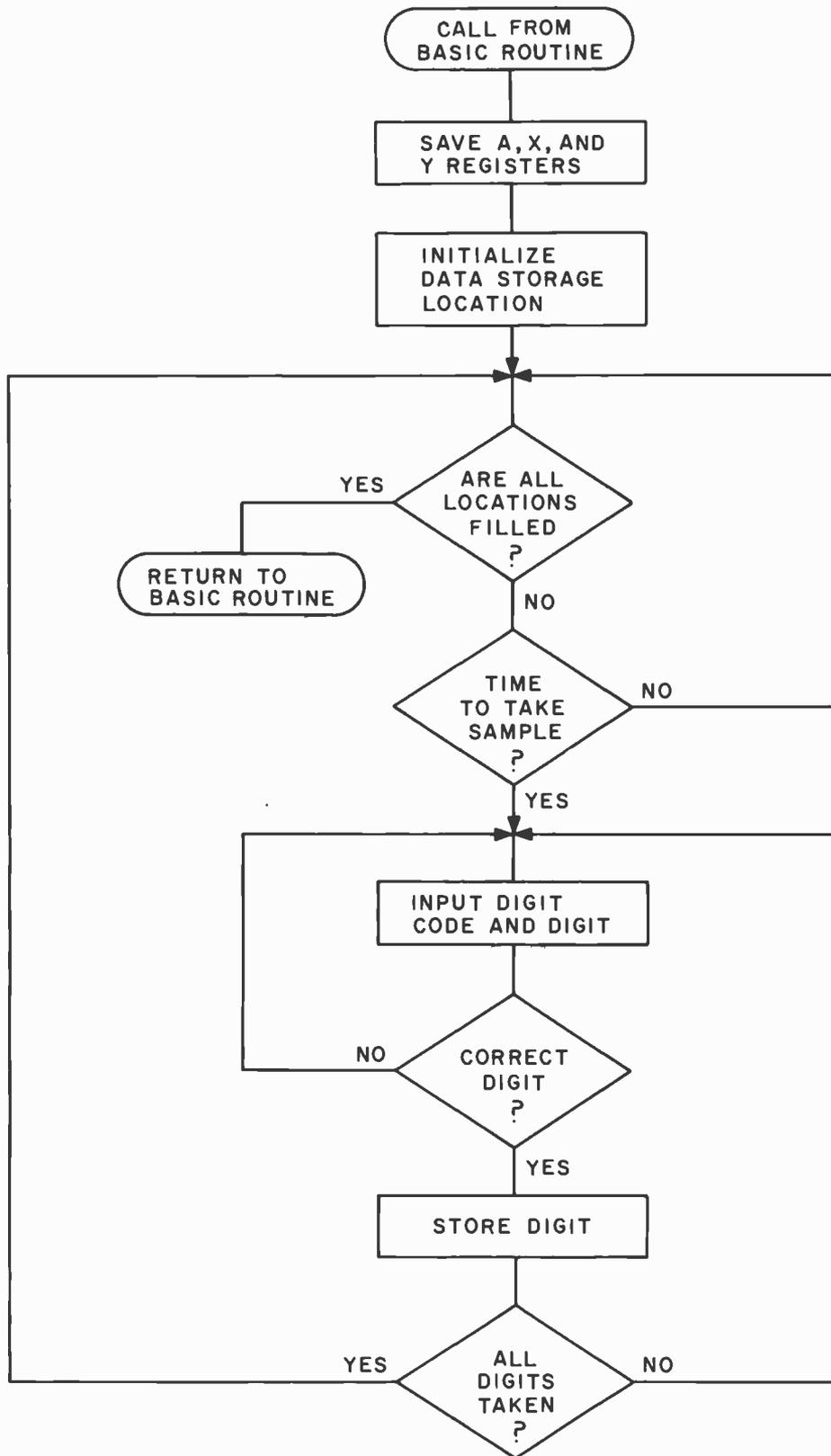
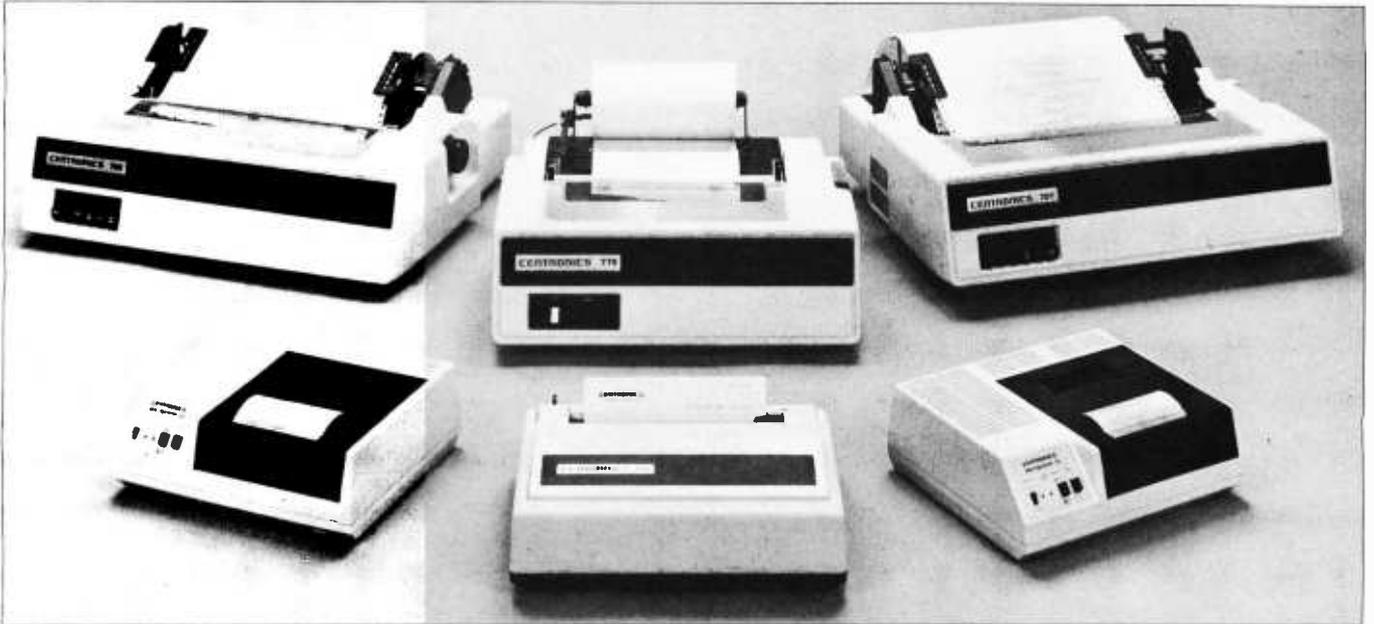


Figure 2: Flowchart of the machine language subroutine which takes samples from the analog-to-digital converter. This code is written for the 6502 processor used in the Apple II.

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4003	8E B1 49	STX	\$49B1	Save registers
4006	8C B2 49	STY	\$49B2	
4009	08	PHP		
400A	A2 00	LDX	#\$00	
400C	A9 00	LDA	#\$00	
400E	85 0A	STA	\$0A	Starting location of data storage
4010	A9 4A	LDA	#\$4A	
4012	85 0B	STA	\$0B	
4014	A9 00	LDA	#\$00	
4016	8D A0 49	STA	\$49A0	Final location of data storage
4019	A9 4E	LDA	#\$4E	
401B	8D A1 49	STA	\$49A1	
401E	78	SEI		Disable interrupt
401F	AD A1 49	LDA	\$49A1	
4022	C5 0B	CMP	\$0B	
4024	D0 0B	BNE	\$4031	Have all data locations been filled?
4026	AD B0 49	LDA	\$49B0	
4029	AE B1 49	LDX	\$49B1	
402C	AC B2 49	LDY	\$49B2	
402F	28	PLP		
4030	60	RTS		
4031	58	CLI		Enable Interrupt
4032	EA	NOP		
4033	4C 1E 40	JMP	\$401E	
4036	EA	NOP		
4037	EA	NOP		
4038	EA	NOP		
4039	EA	NOP		
403A	EA	NOP		
403B	EA	NOP		
403C	EA	NOP		
403D	EA	NOP		
403E	EA	NOP		
403F	EA	NOP		
4040	8D F2 C0	STA	\$C0F2	Start A/D conversion
4043	AD F1 C0	LDA	\$C0F1	
4046	29 80	AND	#\$80	
4048	C9 80	CMP	#\$80	
404A	D0 F7	BNE	\$4043	A/D conversion finished?
404C	AD F0 C0	LDA	\$C0F0	Input data
404F	8D A2 49	STA	\$49A2	Temporary data storage
4052	29 80	AND	#\$80	
4054	C9 80	CMP	#\$80	Check for first digit (MSD)
4056	D0 F4	BNE	\$404C	
4058	AD A2 49	LDA	\$49A2	
405B	29 0F	AND	#\$0F	Peel off digit code leaving data
405D	81 0A	STA	(\$0A,X)	Store data
405F	A4 0A	LDY	\$0A	
4061	C8	INY		Increment lower 8 bits of data storage
4062	84 0A	STY	\$0A	
4064	D0 05	BNE	\$406B	Carry out to upper 8 bits?
4066	A4 0B	LDY	\$0B	
4068	C8	INY		Increment upper 8 bits of data storage
4069	84 0B	STY	\$0B	
406B	AD F0 C0	LDA	\$C0F0	Input data
406E	8D A2 49	STA	\$49A2	
4071	29 40	AND	#\$40	
4073	C9 40	CMP	#\$40	Check for second digit
4075	D0 F4	BNE	\$406B	
4077	AD A2 49	LDA	\$49A2	
407A	29 0F	AND	#\$0F	Peel off digit code leaving data
407C	81 0A	STA	(\$0A,X)	Store data
407E	A4 0A	LDY	\$0A	
4080	C8	INY		Increment lower 8 bits of data storage
4081	84 0A	STY	\$0A	
4083	D0 05	BNE	\$408A	Carry out to upper 8 bits?
4085	A4 0B	LDY	\$0B	
4087	C8	INY		Increment upper 8 bits of data storage
4088	84 0B	STY	\$0B	
408A	AD F0 C0	LDA	\$C0F0	Input data
408D	8D A2 49	STA	\$49A2	
4090	29 20	AND	#\$20	
4092	C9 20	CMP	#\$20	Check for third digit
4094	D0 F4	BNE	\$408A	
4096	AD A2 49	LDA	\$49A2	
4099	29 0F	AND	#\$0F	Peel off digit code leaving data
409B	81 0A	STA	(\$0A,X)	Store data
409D	A4 0A	LDY	\$0A	
409F	C8	INY		Increment lower 8 bits of data storage
40A0	84 0A	STY	\$0A	

Listing 1: The machine language subroutine for collecting data from the analog-to-digital converter, here shown in assembly language format. Memory locations 03FE and 03FF contain the hexadecimal interrupt jump vector 4040, which is the entry point of this routine.

Text continued from page 70:

significant 4 bits of the address are decoded by IC1 and are used for on board addressing. Performing a store accumulator (STA) operation to location C0F2 causes the SC (start conversion) line to go high and resets the flip-flop IC4. Performing a LDA (load accumulator) from hexadecimal location C0F1 transfers the end of conversion (EOC) and overrange (OR) status data into the computer. Performing a LDA from location C0F0 transfers the digit-select code and the binary coded decimal (BCD) value of the particular digit selected into the computer.

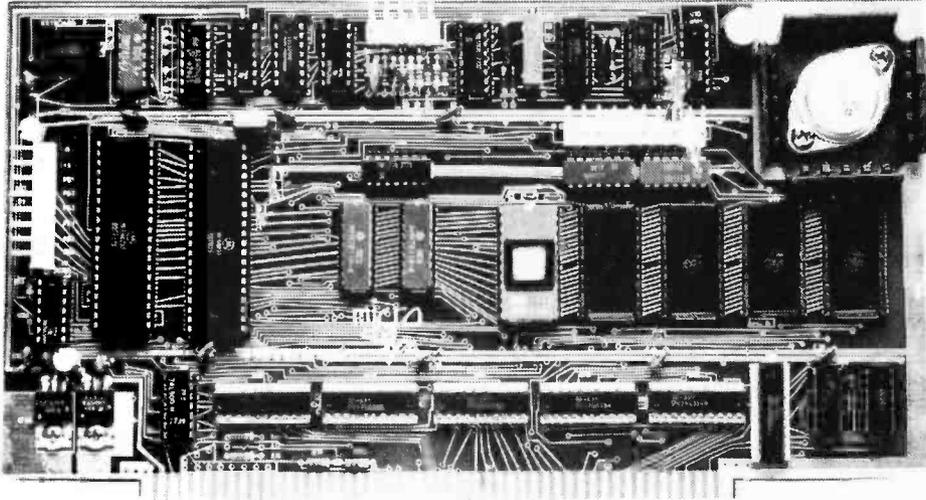
The software portion of the analog-to-digital converter project is divided into 2 parts:

- A machine language routine to provide high-speed transfer of data from the MC14433 to the computer memory.
- A BASIC routine written in Applesoft floating-point BASIC to take the data in memory and format it into a voltage that can be displayed as a function of time with the high-resolution graphics routine.

Since the Apple II does not have an internal real-time clock, I decided to use the interrupt request line (IRQ) as an input for an external clock. The advantage to this is that a calibrated pulse generator can be used to determine the sampling rate. If desired, the computer can perform other tasks between samples. Knowing when each sample was taken makes it possible to display the data as a function of time with the high-resolution graphics routine. Since the Apple II high-resolution graphics allows the display of 256 points I decided to store 256 points in memory before displaying the data, but there is no reason why the data could not be displayed as it is taken. Figure 2 shows the flowchart of the machine language program, and listing 1

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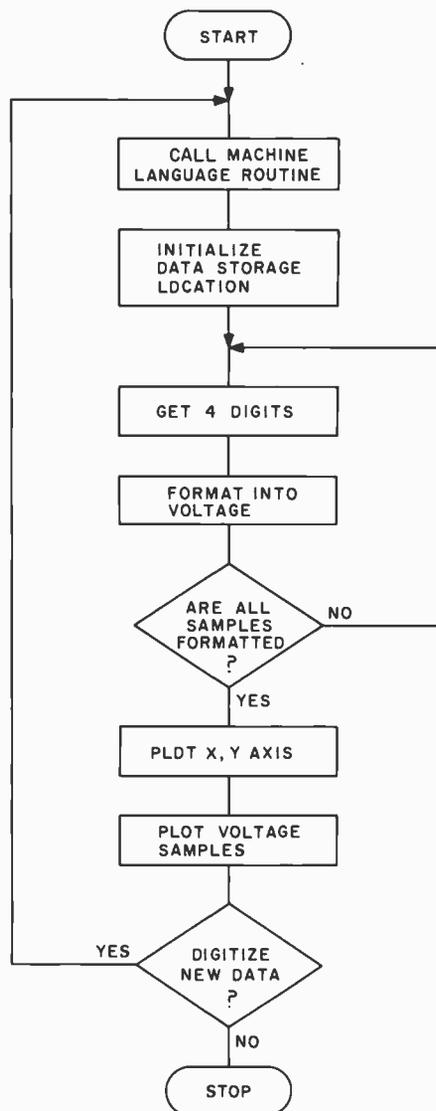
40A2	D0	05	BNE	\$40A9	Carry out to upper 8 bits?
40A4	A4	0B	LDY	\$0B	
40A6	C8		INY		Increment upper 8 bits of data storage
40A7	84	0B	STY	\$0B	
40A9	AD	F0 C0	LDA	\$C0F0	Input data
40AC	8D	A2 49	STA	\$49A2	
40AF	29	10	AND	#\$10	
40B1	C9	10	CMP	#\$10	Check for LSD (least significant digit)
40B3	D0	F4	BNE	\$40A9	
40B5	AD	A2 49	LDA	\$49A2	Peel off digit code leaving data
40B8	29	0F	AND	#\$0F	Store data
40BA	81	0A	STA	(\$0A,X)	
40BC	A4	0A	LDY	\$0A	Increment lower 8 bits of data storage
40BE	C8		INY		
40BF	84	0A	STY	\$0A	
40C1	D0	05	BNE	\$40C8	Carry out to upper 8 bits?
40C3	A4	0B	LDY	\$0B	
40C5	C8		INY		Increment upper 8 bits of data storage
40C6	84	0B	STY	\$0B	
40C8	A5	45	LDA	\$45	
40CA	40		RTI		Return from interrupt

Listing 2: Program in Applesoft floating point BASIC which calls the machine language routine of listing 1 and then formats and displays the data received, using the high-resolution graphics capability of the Apple II.

Program	Comments
100 DIM Z (300)	
101 HOME	
102 GOTO 1000	
110 CALL 16384	Machine language routine
111 HOME : VTAB 24	
112 PRINT "THE DIGITIZED DATA IS BEING FORMATTED FOR PLOT ING"	
113 X = 18944	Starting address of data
115 FOR J = 0 TO 255	
120 V1 = PEEK (X)	Get first digit (MSD)
122 V2 = PEEK (X + 1)	Get second digit
124 V3 = PEEK (X + 2)	Get third digit
126 V4 = PEEK (X + 3)	Get fourth digit (LSD)
128 X = X + 4	
130 IF V1 > 7 THEN V1 = 0	
132 IF V1 = 0 THEN GOTO 140	Decode MSD
134 V1 = 1	
140 V\$ = STR\$ (V1) + STR\$ (V2) + STR\$ (V3) + STR\$ (V4)	Convert digits into voltage XXX.X
150 Z(J) = VAL (V\$) / 1000	
160 NEXT J	
200 HGR: HCOLOR = 3	High-resolution graphics
202 H PLOT 20,0 TO 20,150	
204 H PLOT TO 279,150	
208 H PLOT 18,0 TO 22,0	
210 H PLOT 18,10 TO 22,10	
212 H PLOT 18,20 TO 22,20	
214 H PLOT 18,30 TO 22,30	
216 H PLOT 18,40 TO 22,40	
218 H PLOT 18,50 TO 22,50	
220 H PLOT 18,60 TO 22,60	
222 H PLOT 18,70 TO 22,70	
224 H PLOT 18,80 TO 22,80	
226 H PLOT 18,90 TO 22,90	
228 H PLOT 18,100 TO 22,100	
230 H PLOT 18,110 TO 22,110	
232 H PLOT 18,120 TO 22,120	
234 H PLOT 18,130 TO 22,130	
236 H PLOT 18,140 TO 22,140	
238 H PLOT 18,150 TO 22,150	Plot X-Y axis
240 H PLOT 4,47 TO 4,53	
242 H PLOT 7,53	
246 H PLOT 10,47 TO 10,53	
248 H PLOT TO 14,53	
250 H PLOT TO 14,47	
252 H PLOT TO 10,47	
260 H PLOT 7,103	
262 H PLOT 14,97 TO 10,97	

Listing 2 continued on page 78

Figure 3: Flowchart of the BASIC program which calls the machine language subroutine, formats the data obtained from the analog-to-digital converter, and displays it using high-resolution graphics.



shows the coded program with comments.

Upon entering the subroutine, all of the necessary registers are saved to enable a successful return from subroutine. The first thing that happens is that the *end of conversion* flip-flop is reset and the program loops until the MC14433 completes the next conversion and sets the flip-flop. The program then samples the data lines and decides whether or not the data represents the most significant piece of data. If it does not, the program continues to sample the data lines until the most significant piece of data has been obtained. This datum is then stored in memory, the memory storage locations are in-

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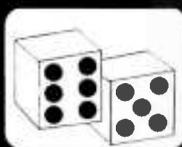
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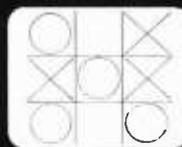
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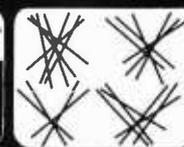
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Listing 2 continued:

```

264 H PLOT TO 10,100
266 H PLOT TO 14,100
268 H PLOT TO 14,103
270 H PLOT TO 10,103
272 H PLOT 14,147 TO 10,147
274 H PLOT TO 10,153
276 H PLOT TO 14,153
278 H PLOT TO 14,147
280 H PLOT 30,148 TO 30,152
281 H PLOT 40,148 TO 40,152: H PLOT
50,148 TO 50,152
282 H PLOT 60,148 TO 60,152: H PLOT
70,148 TO 70,152
283 H PLOT 80,148 TO 80,152: H PLOT
90,148 TO 90,152
284 H PLOT 100,148 TO 100,152: H PLOT
110,148 TO 110,152
285 H PLOT 120,148 TO 120,152: H PLOT
130,148 TO 130,152
286 H PLOT 140,148 TO 140,152: H PLOT
150,148 TO 150,152
287 H PLOT 160,148 TO 160,152: H PLOT
170,148 TO 170,152
288 H PLOT 180,148 TO 180,152: H PLOT
190,148 TO 190,152
289 H PLOT 200,148 TO 200,152: H PLOT
210,148 TO 210,152
290 H PLOT 220,148 TO 220,152: H PLOT
230,148 TO 230,152
291 H PLOT 240,148 TO 240,152: H PLOT
250,148 TO 250,152
292 H PLOT 260,148 TO 260,152: H PLOT
270,148 TO 270,152
300 FOR J = 0 TO 255
310 H PLOT J + 20,150 - (Z(J) * 100) Plot voltage
320 NEXT J
1000 PRINT "PRESS RETURN TO START A/D"
1010 K = PEEK ( - 16384)
1012 POKE - 16368,0
1014 IF K > 127 THEN GOTO 1020
1016 GOTO 1010
1020 TEXT
1022 HOME
1024 V TAB 24
1026 PRINT "256 DATA POINTS ARE
BEING DIGITIZED"
1028 GOTO 110
1099 END

```

cremented, and the program begins to look for the 2nd piece of data. After the 4 digits representing the digitized voltage have been stored, the program checks to see if 256 samples have been stored. If they have not, control returns to the beginning of the subroutine. When all 256 samples have been stored, the program returns to the BASIC routine which called it.

The BASIC routine has the task of assembling the 4 digits from each conversion into a single number which is equal to the measured voltage. A flowchart is shown in figure 3. The machine language assembly routine has previously taken each of the 4 digits from a single conversion and has stored them in individual memory locations. The BASIC routine uses the string manipulation capabilities of Applesoft BASIC to fetch each digit from its memory location and to assemble all 4 digits into a

single 4-digit voltage. After all 256 conversions have been changed into voltages and stored in a matrix array, the high-resolution graphics routine is called and the voltages are plotted as a function of time. It is convenient to have the voltages stored in a matrix array so that if further analysis of the data is required it can be easily retrieved. Listing 2 shows the coded BASIC program with comments.

To demonstrate the ability of a system to digitize and display low-frequency signals, a waveform generator was connected to the analog-to-digital converter. Photo 1 shows a 0.05 Hz sine wave which was digitized at 10 samples per second. Photo 2 shows a 0.05 Hz triangular wave which was digitized at 10 samples per second. Photo 3 shows a 0.001 Hz sine wave which was digitized at 1 sample per minute. The results are even more impressive when you consider that this is a data-acquisition

Photo 1: High-resolution display of a 0.05 Hz sine wave signal which has been digitized at 10 samples per second.

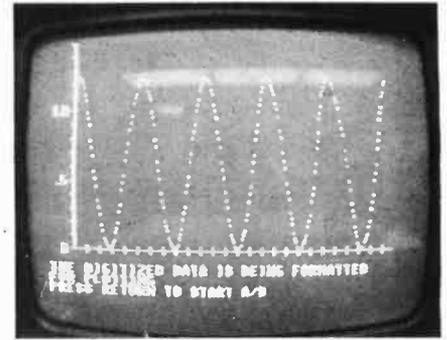
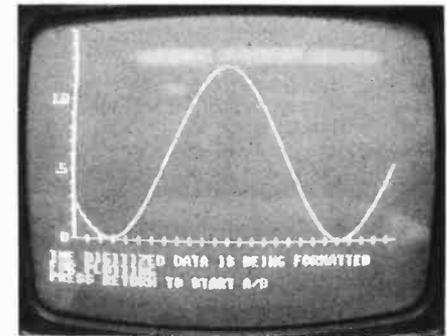


Photo 2: Display of a 0.05 Hz triangular wave digitized at 10 samples per second.



Photo 3: Display of a 0.001 Hz sine wave digitized at 1 sample per minute.



system costing less than \$2,000.

At present, a high-speed analog-to-digital converter is being constructed to digitize and analyze the electromyographic voltages which come from muscles. This will allow an investigator to gather data for further analysis of the complex neural-impulse waveform resulting from stretching a muscle. I anticipate that once researchers become aware of the data acquisition, data analysis, and system control that are possible with these low-cost systems, there will be a drastic increase in their use. ■

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NOTES ON BULLETIN BOARD

The Computerized Bulletin Board System (CBBS) in the Atlanta GA area is no longer being operated by DC Hayes Associates Inc. The Atlanta system is now being operated by the Atlanta Computer Society. The telephone number has been changed to (404) 394-4220. A description of a CBBS appeared in the article entitled "Hobbyist Computerized Bulletin Board" by Ward Christensen and Randy Sues, (November 1978 BYTE, page 150).

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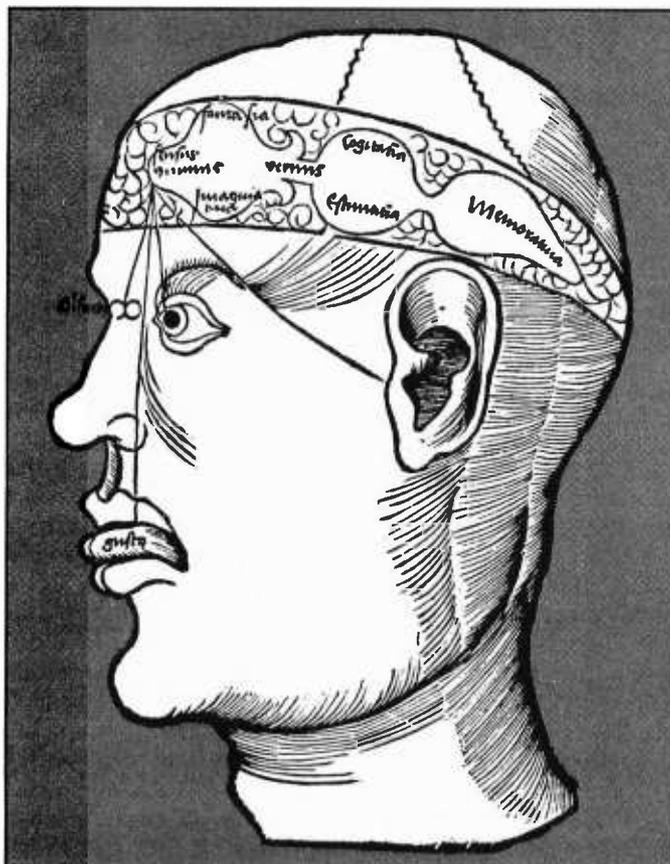
These are questions that will engage your interest in the September issue of SCIENTIFIC AMERICAN.

This issue does not, by any means, tell you "how the brain works." That remains one of the most alluring and baffling questions on the frontier of understanding. The convergence of work in many disciplines—from neurosurgery to linguistics—has begun to put that question, however, in ways that can yield answers.

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- Brain Mechanisms of Vision
- Brain Mechanisms of Movement
- Specializations of the Human Brain
- Disorders of the Human Brain
- Thinking about the Brain



Each of the authors of this issue has made significant contribution to the growing body of knowledge about the brain. Together they offer a comprehensive exposition of present understanding and chart the way for continuing study.

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Operating Systems

Let's Have Some UNIX-Inspired Software

Jim Howell, 5472 Playa Del Rey, San Jose CA 95123

I would like to add to the comments made by James Jones ("Languages Forum," April 1979 BYTE, page 245) about operating systems.

First, I wholeheartedly agree with his letter. A job control language like OS/370 (or most other large systems, for that matter) would be terrible for personal computer use. Aside from the pile of job control required to do anything, there are other problems with OS-like systems. The numerous file formats and "access methods" make it difficult for programs to work together. Specifying files for the compiler or assembler to use as work files is a nuisance. A file specification (DD statement) also requires giving values for several parameters about which the user usually doesn't care or shouldn't have to specify. Some of these problems are helped by using procedures (sets of job control that the computer vendor or local systems programmer has stored on disk for general use), but these may not be what you need, and they also take up disk space. The space is not significant if your disks store 100 megabytes, but it could be significant for floppy disk users.

I would like to strengthen Mr Jones' suggestions that UNIX be used as a model for a microprocessor operating system. (UNIX is a trademark of Bell Labs.) I have used a UNIX system at work for about a year and it is a very pleasant system to work with. All files on UNIX are a series of bytes: no structure within files are imposed by the system. In particular, there is no concept of a "logical record" in UNIX. A "logical record" is the (usually) fixed size chunk in which files are read or written on big systems; often 80 bytes (for card or card-image files), or 120 or 132 bytes (for line printers). On UNIX, the end of a line in a text file is indicated by the use of a new-line character. This new-line character (line feed on UNIX) replaces the trailing blanks which are stored on systems that use logical records. The new-line character is read or written just like any other character. The size of a file is determined by how many bytes are written to it; pre-determination of the file size (by guessing?) is not necessary, or even possible.

Job control language on UNIX is practically non-existent. A command to run a program (such as a compiler or a user program) consists of the name of the pro-

gram to be executed followed by any parameters that the program needs, separated by blanks. (Parameters are often file names and processing options.) The command processor, which runs as a user program, reads the command line, divides it into "words," and calls the system to execute the desired program. This system call also passes the parameters to the executed program. There is no need to describe files in the command since programs need only the name of a file in order to access it. Block sizes and such things are not required, even for new files, since there is only one format for files.

The following is a summary of the major system calls of UNIX that deal with file or an I/O (input/output) device. A file name in the open and create calls can also be a device name (such as the name for a terminal or printer).

- Open** (name, mode) opens an existing file (or device) for further operations. "Name" is a pointer to a character string which is the name of the file (or device) and "mode" indicates reading, writing, or both.
- Create** (name, prot) creates a new file, deleting any old file whose name is "name." This new file is opened for writing. (I would like to see a "mode" argument for this call, in addition to the two specified. This "mode" would mean the same as it does for "open.")
- Read** (fildes, buffer, length) reads up to "length" bytes from the file whose descriptor is "fildes" into the "buffer". The file descriptor is a small, non-negative integer which was returned by open or create. The number of bytes actually read is returned to the caller. A return of 0 means end of file.
- Write** (fildes, buffer, length) writes "length" bytes to the file "fildes" from the "buffer."
- Seek** (fildes, offset, base) moves the read/write pointer of the file "fildes" to a new position within the file. "Offset" is how far to move the pointer, and "base" indicates from the start of the file, from the current position, or from the end of the file.
- Close** (fildes) closes a file.

Each open file has a read/write pointer associated with

it. Each read or write call starts reading or writing at the current pointer and advances the pointer by the number of bytes read or written. By moving the read/write pointer with the "seek" call, random access files (or even indexed-sequential or other access methods) can be implemented if required. Note that "read" and "write" are the lowest levels of I/O calls to the system, and that they apply to all devices. All device-dependent processing is inside of the operating system. The only thing that a user program needs to know about a file after it is opened or created is the returned number (file descriptor). There are no "control blocks" or other system-imposed structures in user programs. (System calls are available in UNIX to determine the type of device that is associated with an open file for the few programs that need this information.)

Most current microprocessor operating systems use a special character, such as control-z, to mark the end of text files. These systems take the view that "binary" files (files where all 256 possible bytes are valid) are only for executable programs, and in this case reading a few extra bytes from the last sector of the file will not cause any problems. Such a scheme prevents the use of binary files for other purposes where the exact end of the file must be known. Possible uses include a work file written by a compiler or assembler and libraries of subroutines in object format for linking with other programs. (For example you wouldn't want a 20 byte absolute value function to add 128 bytes to your program, simply because the end of a sector is the best you can do at locating the end of the function!) The end of a file should, as in UNIX, be indicated by a count of the number of bytes in the file, and the end of file when reading should be determined by comparing the read/write pointer of the file to the end-of-file byte count. (Writing past the end of a file causes the end of file pointer to move to the new read/write pointer position.)

The above is a description of some aspects of UNIX, and is also intended to be used as guidelines in writing any new operating systems for microprocessors (or even big systems). One other thing that might be considered by an operating system writer is the use of a high-level language for most of the operating system and for the programs that implement supplied commands. This would allow the operating system to be moved to another microprocessor without having to completely rewrite it.

I am about halfway through designing an operating system along the lines of the above suggestions. (I started before Mr Jones' letter appeared in BYTE.) Eventually I expect to implement it.

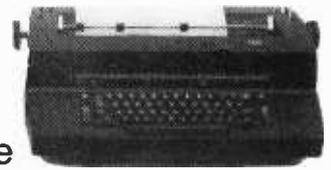
Let me conclude by listing three references which are recommended to those who are implementing a usable microprocessor operating system. The first two were also mentioned by Mr Jones. ■

REFERENCES

1. *Communications of the ACM*, July 1974. A revised version of the UNIX article appears in reference 3 below.
2. *Software Tools* by Kernighan and Plauger.
3. *The Bell System Technical Journal*, July thru August 1978, part 2. This issue contains about fifteen papers on UNIX. Read especially the first 3 or 4 papers, as well as the one called "UNIX on a Microprocessor" (single-user version on an LIS-11).

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Soldering Techniques

William Trimmer
40 James St
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Anyone who can get 3 objects into the same vicinity can solder. Doing a professional job, however, requires some care and practice. This article draws on my experience in teaching

electronics and a fine pamphlet prepared by NASA entitled "Soldering Electrical Connections, A Handbook" (United States Printing Office, NASA SP-5002). Good soldering

techniques can save time, components and frustration.

Good Soldering Techniques

Good soldering starts with a clean soldering iron tip and well-tinned parts. Just prior to use, the hot soldering iron should be cleaned by wiping it across a wet sponge. The thermal shock and wiping action will clean the tip and remove the excess solder. Then touch a bit of solder to the tip (photo 1). The iron is now ready for use. The parts to be soldered are ready when the solder flows quickly and evenly over their heated surfaces. If this does not happen, clean the parts by brushing, filing, or rubbing with a pencil eraser. Next flow a thin layer of solder over the clean surface. The parts are now tinned and ready to be soldered.

The prepared parts should be mechanically fastened together before making the soldering joint (photo 2). The solder should not be expected to supply mechanical strength. Clean the soldering iron tip, and add a dab of solder to the tip. Touch the soldering iron to the heavier of the parts to be joined, and begin wiping the solder on the junction between the two parts (photo 3).

Do not feed the solder into the soldering iron tip. When the components are hot enough, the solder will begin to melt into the joint. The solder should skate over the surfaces like butter on a hot pan. Now you must move quickly. Rapidly wipe the entire length of the connection with the solder, being careful not to apply too much. The solder should flow smoothly over the parts. If braided wire is used, the strands should still be visible (photo 4). Doing this well takes a lot of practice. Now remove

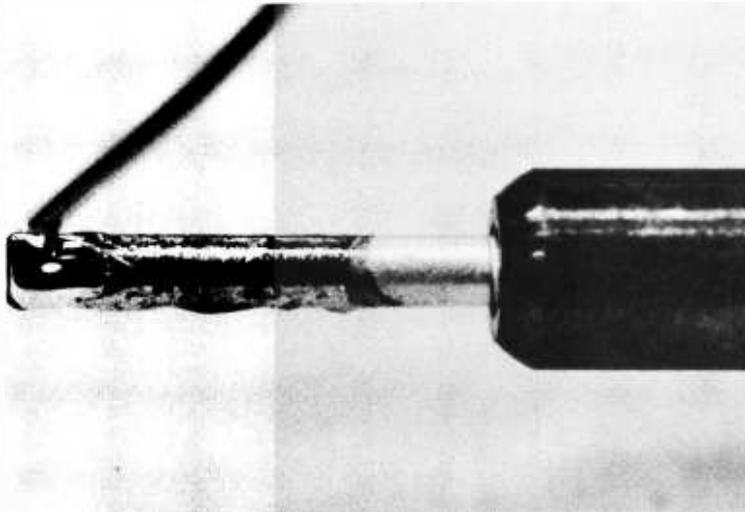


Photo 1: After cleaning the tip of the soldering iron with a wet sponge, prepare it by adding a dab of solder.

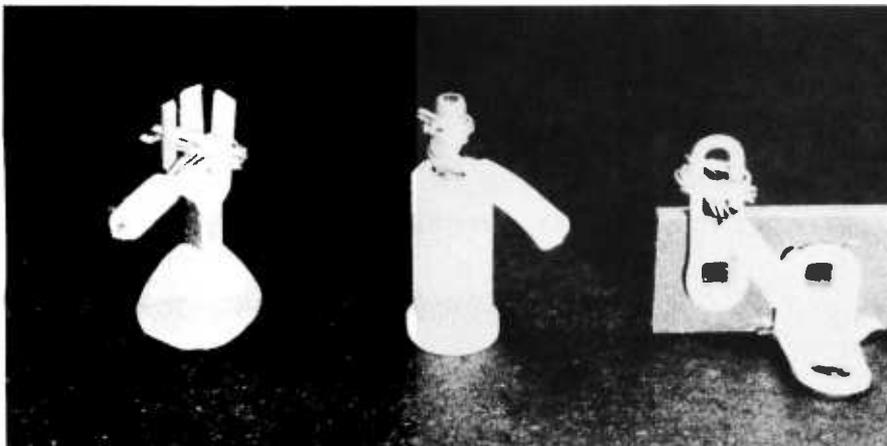


Photo 2: Before soldering, the joints should be mechanically fastened.



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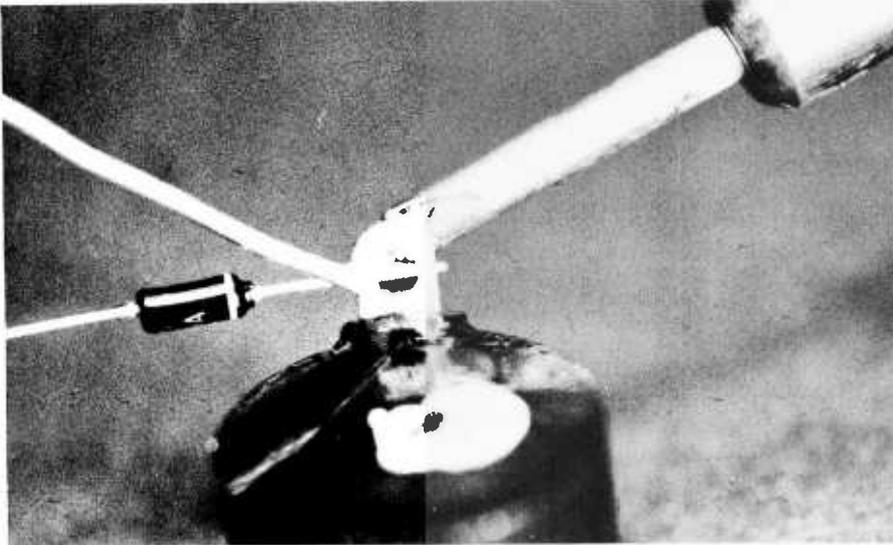


Photo 3: When soldering, touch the iron to the heaviest part. When the joint is hot enough, the solder will melt on the side opposite the iron.

Removal Co, 1077 E Edna Place, Covina CA 91724. Their 40-4-5 is a medium size, 40-6-2½ is for large joints, and 40-2-5 is for very small joints.) Push the mesh against the joint with the soldering iron. The solder will be wicked from the joint into the mesh. Solder suckers are also a popular way to remove solder. The tool is cocked, placed on a heated joint, and released. A plunger pulling air through the nozzle of the sucker gets most of the solder. This last suggestion is the least expensive way. Hold the circuit board and heat the joint. Rap the edge of the board smartly on the work bench. Solder flies in every direction, but the joint is clean.

Good soldering takes patience and practice. Fortunately, if properly done, the soldering joints are almost never the culprits when a circuit does not work. The following are some suggestions that will make soldering easier.

Tools

The soldering iron should be well tinned (covered with solder), and should quickly raise the joint to the working temperature. I prefer a 30 or 40 W element for a pencil soldering iron. Cleaning the tip with a wet sponge before soldering will bring the tip down to the correct temperature range (about 700°F). This slightly greater wattage will allow larger pieces to be soldered. Better yet are the temperature controlled pencil soldering irons. Soldering guns are too large and hot for all but the most massive soldering joints. If you buy a new soldering iron, wrap the tip with solder before turning it on. This will coat the tip with solder before it gets hot enough to oxidize. Place the iron in a protective cage towards the back of your work bench so that it can not burn anything. If the iron is not going to be used for a while, unplug it.

It is very tempting to buy less expensive solder. Don't do it. Solder costs very little compared to other components. The best solder is Eutectic, which is 63% tin and 37% lead. This mixture passes directly from a liquid to a solid stage without going through a plastic region. As a result, good soldering joints are easier to make. Solder composition is generally given by two numbers, such as 40-60. The first number is the amount of tin, the second is the amount of

the iron and hold everything perfectly still. Any motion while the solder is going from the liquid to the solid state will cause a cold joint. After the joint is cooled, the surface of the solder should look like a mirror. A good solder joint is an accomplishment.

A good way to begin might be to deliberately make some bad soldering joints. First, shake the two wires while the solder is cooling. Notice the undesirable frosted look. Now try leaving the iron on the joint for more than several seconds, and you will notice that a scum forms. Try putting too much solder on the joint. Often when this blob cools, the frosted surface will appear (photo 5). Try to find the two oldest wires you can. Twist them together and solder them. If they are covered with an oxide layer, the solder will not transfer from the soldering iron tip to the wires. Repeated heatings will probably cause the solder to melt around the joint. Notice how the solder does not flow onto the wires, but sticks to itself. The joint is now probably hot enough to burn the flux.

Inevitably, one has to unsolder some beautifully soldered joints. If the joint is that of a straight wire through a hole, a pull will often accomplish the task. (Be careful of the flying molten solder.) Often, one must remove the solder and then unwrap the wire. The best method uses a fine mesh of properly fluxed copper wire. (An example of this would be Solder-Wick, made by Solder



Photo 4: In a well-soldered braided wire, the strands should still be visible.

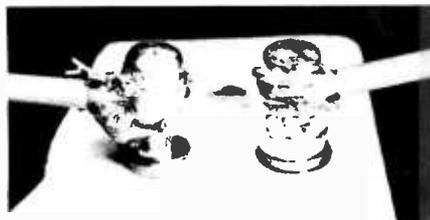


Photo 5: Excess solder, poor wetting of the wire, frosted surfaces, and blobs of solder represent poorly soldered joints.

lead. The above solder is less expensive to make than Eutectic solder because tin is the expensive element. However, this solder has a plastic region of about 180°F. The joint must be held completely motionless while the solder is cooling through this plastic stage. Always use a rosin flux when soldering. Never let your iron touch acid flux. An 18 or 20 gauge solder with a rosin core works nicely.

There are a number of other useful tools. These include long nose pliers, diagonal cutting pliers, wire strippers, a slotted screwdriver, a dental pick, and plastic electrical tape.

Assembly Before Soldering

A convenient substrate upon which to build electronics is predrilled epoxy board. The holes should be on 0.1 inch centers in a square grid for digital work. Typical hole sizes are 0.042 or 0.062 inches. Vector-type terminals (Vector Electronic Co Inc, 12460 Gladstone Ave, Sylmar CA 91342) can be pushed into the holes and the discrete components soldered to the terminals. The majority of digital electronics come in the dual-in-line packages. A convenient way to mount dual-in-line packages is with circuit-stick-type subelements (Circuit-Stik Inc, 24015 Gardiner St, POB 3396, Torrance CA 90510). These are very thin sheets of glass epoxy with preetched copper lands on one side and glue on the other. The holes on the subelements are aligned with the holes on the predrilled circuit board, and carefully pressed together. The dual-in-line packages and components can then be pushed through from the other side of the board, and soldered to the preetched copper lands. One can then wire the correct lands together. Because the spacing between the pins of the dual-in-line packages is only 0.1 inches, hand soldering requires care. When working with dual-in-line packages, I prefer to solder sockets onto the board, and plug the dual-in-line packages into the sockets. This method makes troubleshooting easier.

It is important to be neat when soldering. Try to lay the board out logically. Do not crowd the components together. If it is your own design, you will probably want to add something after the board is made. Place all of the resistors the same way so that their color codes

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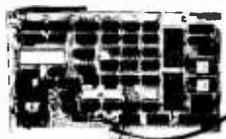
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AWG	Diameter (mm)	Ohms per 1000m	Current Capacity (Amperes)
10	2.6	3.3	26
12	2.0	5.2	16
14	1.6	8.3	10
16	1.3	13	6
18	1.0	21	4
20	0.81	33	2.5
22	0.64	53	1.6
24	0.51	84	1.0
26	0.40	135	0.6
28	0.32	214	0.4
30	0.25	341	0.2

Table 1: Approximate values for various American Wire Gauge (AWG) sizes of copper wire.

can be read from the same side of the board. Run the wires in an orderly manner. I prefer to mount components like resistors, transistors, etc, slightly off the board. This improves the heat transfer, and makes it easier to slip in a probe for testing. Components that weigh 0.5 ounces or more should be mechanically mounted to the board. A little epoxy or silicon rubber works wonders for mounting these components.

Properly stripping wire is a dichotomy. First, the insulation should be cut and removed. Second, the wire should not be cut. (If stranded wire is used, a nick will cause only a few strands to break.) With practice, you can strip the insulation without cutting the wire. Try cutting slowly through a wire. Notice the difference in the feel between the insulation and wire. Now cut off the wire and start again with a clean end. Cut down until the wire is felt, then relax the stripper slightly. Now rotate the wire 45° and again squeeze a bit. This will cut the insulation all the way around, not just where the stripper teeth cut the deepest. Be sure to open the stripper slightly and pull the insulation off the wire. With practice, you can learn not to nick the wire. The secret is to stop cutting just before the cutter reaches the wire. A firm pull will usually break off the remaining insulation. If you still nick the wire, take heart, you have much company.

Table 1 gives the American Wire Gauge (AWG) size, the approximate diameter, ohms per 1000 meters, and current carrying capability of copper

wire. Try to use a number of wires of different colors and gauges. This not only matches the current capability with the load, but also makes it easier to trace wires.

Finally, some words on safety: be sure that you have a stand for your iron; always wear shoes and safety glasses; and try not to flick solder on anything important. When cutting wires, hold the cutter so that the pieces fly away from you. To avoid potentially lethal shocks, it is best to have a rubber mat beneath your feet and stool.

By following these rules and techniques, almost anyone can learn to solder well. ■



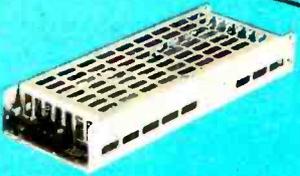
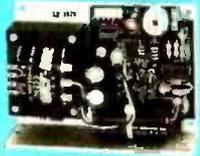
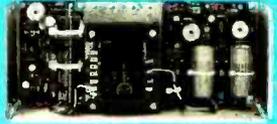
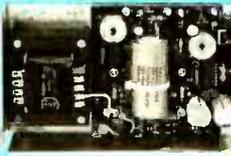
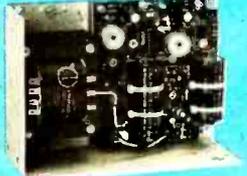
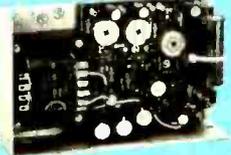
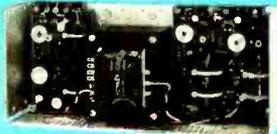
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- MAC** — 8080 Macro Assembler. Full Intel macro definitions. Pseudo Ops include RPC, IRP, REPT, TITLE, PAGE, and MACLIB. Z-80 library included. Produces Intel absolute hex output plus symbols file for use by SID (see below) **\$100/\$15**
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- COBOL-80** — ANSI '74 Relocatable object output. Format same as FORTRAN-80 and MACRO-80 modules. Complete ISAM, interactive ACCEPT/DISPLAY, COPY, EXTEND **\$825/\$25**
- MACRO-80** — 8080/Z80 Macro Assembler. Intel and Zilog mnemonics supported. Relocatable linkable output. Loader, Library Manager and Cross Reference List utilities included **\$149/\$15**
- EDIT-80** — Very fast random access text editor for text with or without line numbers. Global and intra-line commands supported. File compare utility included **\$89/\$15**

*CP/M is a trade name of Digital Research

**Z80 is a trademark of Zilog, Inc.

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†CP/M for Heath, TRS-80 Model I and PolyMorphic 8813 are modified and must use especially compiled versions of system and applications software.

††PolyMorphic 8813 CP/M scheduled for September 15 release.

XITAN (software requires Z80** CPU)

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- FORMS** — Interactive utility to create CIS COBOL source code to perform CRT screen handling in application programs. Supports full prompt text, protected fields and input validation against data type and range expected **\$150/\$15**
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- Z80 Development Package** — Consists of: (1) disk file line editor, with global inter and intra-line facilities; (2) Z80 relocating assembler, Zilog/Mostek mnemonics, conditional assembly and cross reference table capabilities; (3) linking loader producing absolute Intel hex disk file. **\$95/\$20**
- Z80 Debugger** — Trace, break and examine registers with standard Zilog/Mostek mnemonic disassembly displays. Facilities similar to DDT. \$35 when ordered with Z80 Development Package **\$50/\$10**
- DISTEL** — Disk based disassembler to Intel 8080 or TDL/Xitan Z80 source code, listing and cross reference files. Intel or TDL/Xitan pseudo ops optional. Runs on 8080. **\$65/\$10**
- DISILOG** — A DISINTEL to Zilog/Mostek mnemonic files. Runs on Z80 only **\$65/\$10**
- TEXTWRITER II** — Text formatter to justify and paginate letters and other documents. Special features include insertion of text during execution from other disk files or console, permitting recipe documents to be created from linked fragments on other files. Ideal for contracts, manuals, etc. Also creates form letters in conjunction with a mail list file. **\$75/\$10**
- TEXTWRITER III** — All the features of TW II plus generation of table of contents, sorted index and handling of footnotes. TW II users may upgrade for \$60. **\$125/\$10**
- WHATSIT?***** — Interactive data-base system using associative tags to retrieve information by subject. Hashing and random access used for fast response. Requires CBASIC **\$125/\$25**
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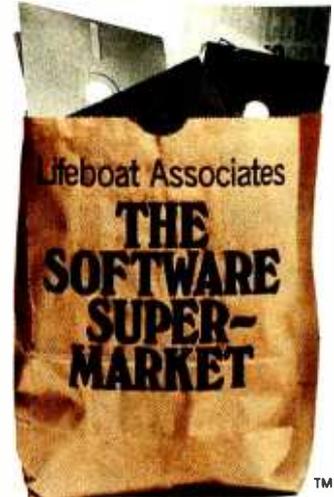
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- BASIC Comparison** — A comprehensive features and performance analysis of five 8080 disk BASIC languages — CBASIC, BASIC-E, XYBASIC, Microsoft Disk Extended BASIC, and Xitan's Disk BASIC. Itemizes results of 21 different benchmark tests for speed and accuracy and lists instructions and features of each BASIC (send 20¢ S.A.S.E.) **FREE**



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List No. 5

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Clubs and Newsletters

Washington DC Computer Club

The Washington Amateur Computer Society (WACS) is an organization dedicated to personal computing. They are organized to provide a forum for the computer hobbyist and student of computing science. The Society meets on the last Friday of each month in the 1st floor lecture hall in Keane Hall on the campus of the Catholic University of America. The meetings start at 7:30 PM

JWAC, the club's newsletter, is published for Society members and exchange with other hobby organizations. The newsletter is primarily an electronics journal. Annual dues have been set at \$3.50 per year to

cover the cost of 1st class postage for the journal and to defray the expenses of exchanging correspondence with other personal computing organizations. Non-members may subscribe to the journal at the rate of \$5 per year. WACS is interested in exchanging newsletters with other organizations to further the interchange of hobbyist information. Contact Washington Amateur Computer Society, c/o 4201 Massachusetts Ave, #168, Washington DC 20016.

Cromemco User Systems and Software Pool

Cromemco User, Systems and Software Pool is an

independent group for users of Cromemco computers. Board owners are also welcome. The purpose of CUSSP is the exchange among users of Cromemco hardware and software of operating notes, bugs and their fixes, evaluation of hardware and software, user written software, and other announcements relating to Cromemco and associated products.

The 1st volume of 3 newsletters included articles on changes in 16 K byte BASIC, CDOS I/O (input/output) drivers, disk sectors and clusters, hardware modifications, etc. This volume is available for \$10 in the US, Canada, and Mexico; and \$12 in US funds for airmail delivery outside these regions. Membership with the 2nd volume is the same price as the 1st. There is also a special rate of 3 volumes (9 issues) for \$25 in the US, Canada, and Mexico and \$30 elsewhere.

Contact Cromemco User, Systems and Software Pool, POB 784, Palo Alto CA 94302.

Computer Graphics Letter Published by Harvard

Readers of the new *Harvard Newsletter on Computer Graphics* will be able to keep abreast of computer graphics in all its myriad ramifications. The newsletter monitors important commercial, technological, and product developments, as well as market, application, and learning opportunities.

Among the regular departments are News and Trends, Products, Markets, Applications, R and D, Conferences and Seminars, Companies, Business and Financial, and State-of-the-Art Technology. The newsletter will be

published twice a month.

The content will encompass management and statistical graphics, computer graphic-aided design, engineering and manufacturing, image processing, and automated cartography, plus other related areas. Trends in these areas, whether applied to big or small computers, stand-alone terminals, timesharing networks, users, vendors, will be followed. Readers will also learn where to obtain further information on the material covered.

The subscription fee for 1 year is \$125; a 9-issue trial subscription is available for \$45. Airmail outside of North America is \$19.50 for 1 year or \$9.75 for the trial. Contact William Nisen, Harvard University, Laboratory for Computer Graphics, 520 Gund Hall, Cambridge MA 02138.

Akron Ohio Digital Group

The Akron Digital Group meets on the 4th Wednesday of each month at 7 PM at the Kenmore Public Library, 2200 14th St SW, Akron OH. The club programs are aimed toward the small systems hobbyist with tips on programming and hardware application. Micro-processor classes are planned for the fall. Contact Lou Laurich, Akron Digital Group, 107 7th St NW, Barberton OH 44203.

TRS-80 Publication

Insiders: The TRS-80 Hardware Journal with Machine Software is a publication for any TRS-80 owner or user interested in more than BASIC. Both beginners and experts will find articles on machine

HARD DISC FOR S100 MICROS

The XCOMP DCF-10 Disc Controller provides the OEM with a high performance, low cost interface for fixed and removable (2315 or 5440) cartridge disc drives. The DCF-10 is currently supported by two operating systems. For information or manuals, contact XCOMP.



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language programming, hardware modifications, and other computer languages. Published since June of 1978, articles have described the differences in Level II read-only memories, how to get sound effects and music without a hardware modification, new languages for the TRS-80, and many other subjects. Regular features include a column which reviews various printers, the Disc File which covers the latest in DOS and compatible drives, a Dear Aunt TRiSh question and answer column, and learning machine language with Level II.

A new section of the journal will cover several of the new languages for the TRS-80. Future issues will include regular features on FORTRAN, FORTH, and other languages. Also, there will be regular articles on CP/M, reviews of various commercially available programs, and more on both Level II and DOS.

Subscriptions are available for 6 issues through Computer Cablevision, 2617 42nd St NW, Suite 2N, Washington DC 20007.

New PET Users Group Forming in Washington and Oregon

Individuals interested in forming a PET Users Group in the Oregon and Washington area should contact NW PET Users Group, c/o John F Jones, 2134 NE 45th Ave, Portland OR 97213.

COSMAC Users Group Active Again

After several unavoidable delays, the COSMAC Users Group is back in full operation and *The 1802 Peripheral* newsletter is being published on a monthly basis. Information about the group may be obtained by writing to

Patrick Kelly, Director, COSMAC Users Group, POB 7162, Los Angeles CA 90022. Please include a stamp with your inquiry.

New Speechlab Users Group Formed

Heuristics Inc, manufacturer of Speechlab (a speech recognition unit for the Apple and all S-100 bus computers), has announced the formation of a users group. The users group requests that all interested Speechlab users send their unique uses of the hardware or software to Tom Larson, Director of Sales, Heuristics Inc, 900 N San Antonio Rd, Los Altos CA 94022. A directory of users and applications will be published at a later date.

Aim-65 Newsletter

The Target is a bi-monthly newsletter for owners or prospective owners of Aim 65 systems. The subscription rate is \$5 for 1 year. Contact Custom-Tronics, POB 4310, Flint MI 48504.

Solano TRS-80 Users Club

The Solano TRS-80 Users Club is an informal group that gets together to discuss mutual problems and experiences. Their meetings are held every 3rd Thursday starting July 5th at Owens-Illinois, 2500 Huntington Dr, Fairfield CA. Contact Dave or Steve Irwin, 550 Marigold Dr, Fairfield CA 94533, or call (707) 422-3347.

The Tulsa Computer Society

The Tulsa Computer Society meets the last Tuesday of every month at 7:30

PM. The meeting place is the Tulsa Vocational-Technical School seminar room at 3420 South Memorial Dr (behind Edison's Department Store). Membership in TCS is \$6 annually and includes a 1 year subscription to the club's newsletter, *The I/O Port*. Contact The Tulsa Computer Society, POB 1133, Tulsa OK 74101.

Wichita Valley TRS-80 Users Group Sustains Computer Loss in Recent Tornado

In the recent tornado which wreaked unholy havoc on our city, many of us in the Wichita Valley TRS-80 Users Group lost our computers, our tape and disk library of software, and our library of computer books and periodicals. Even our club's library of soft-

ware and publications was destroyed.

We all have plans to replace our personal computers and software, but at this time I am particularly interested in trying to help our club replace its loss.

Any club, publisher, software producer, or individual who wishes to do so, may contribute noncash items, such as software, back issues of computer publications, and books on computers.

Our address is the Wichita Valley TRS-80 Users Group, POB 4391, Wichita Falls TX 76308.

Thank-you, our club will be grateful.

J Wesley B Taylor
Club Secretary

Although this letter certainly speaks for itself, it is our sincere hope that you or your group will seriously consider contributing non-cash computer related items to this needy organization. ■

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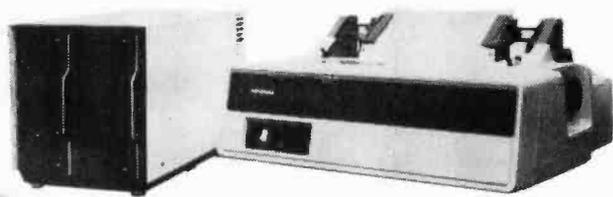
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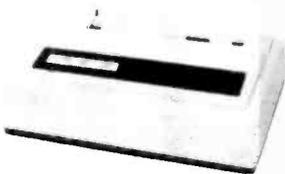
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The Nature of Robots

Part 4: Looking for Controlled Variables

William T Powers
1138 Whitfield Rd
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In this last part of my series of articles, a simple experiment with a human subject will be attempted; an experiment that can be expanded almost indefinitely. All of the principles from the previous parts will be used. Before the experiment starts, note the following main points that have been established:

- The behavior of an organism is not its output, but some consequence of its motor outputs acting together with unpredictable forces or other disturbances.
- For a more or less remote consequence of motor outputs to be repeatable in a disturbance-prone world, the behaving system must sense the consequence, and act to keep it matching some static or dynamic reference condition. By definition, that makes the organism a control system.
- Organisms acting as control systems control what they sense, not what they do.
- What is controlled is what is sensed, even when the sensing involves one or more stages of real-time computations based on primitive sensory signals.
- In a multiple-level control system, the higher levels act by varying the reference signals for lower-level systems. They control perceptions computed from many lower-level perceptions, some or all of which are controlled by the same lower-level systems.
- If there are n degrees of freedom at one level of control, in principle n higher-level systems could act independently and simultaneously by sharing the use of the lower-level systems. Any higher-level

system acts by sending amplified copies of its error signal to many lower-level systems, each with the proper sign to achieve a negative feedback effect. Any lower-level system receives a reference signal that is the net effect of superimposed higher-level output signals. This worked for a 2-level system with 3 control systems at each level; there is no limit, in principle, to the number of levels or the number of systems at each level. In practice, there is reason to anticipate finding hundreds of systems at a given level, but no more than 10 or 12 distinct levels in a human being. This will be commented on later.

Abstract models and simulations are fine for conveying general ideas. However, if one does nothing but make models and simulations, it is easy to get involved in the math and engineering, and forget the real thing is there to be seen. Items described in the first 3 articles in this series represent something *real*. Real organisms work much the same way control systems work. They do not work in any of the other ways that have been proposed over the centuries (as far as their behavior is concerned). I am not talking metaphorically. There are excellent reasons to think that when the properties of organisms begin to be investigated in terms of control theory, hard data about the way we are organized will start to accumulate (up to a point, anyway).

The experiment to be described in this article is so simple that it may look elementary. Nevertheless, it is the starting point for a new approach to exploring the organization of

human beings. Most new ideas start by looking like old ones, but with a twist that leads in unexpected directions. If you are familiar with tracking experiments, do not be too quick to decide what this is all about.

Equipment Required

The basic equipment needed to do this experiment is:

- A *joystick* with 1 degree of freedom (ie: a potentiometer with a stick on the shaft will suffice).
- A *reasonably fast analog-to-digital (A/D) converter* with 7-bit or more accuracy. My system uses the Cromemco D+7A, which has 7 analog channels in and 7 out, as well as 1 input and 1 output 8-bit port.
- A *memory-mapped display*, in which points are plotted on a video screen by depositing appropriate codes in a reserved segment of memory. This, or something equivalent, is essential for creating the moving objects that are involved in the experiment. I use the Polymorphics VTI with the display area in the 1 K bytes of memory starting at hexadecimal location D000. Out of deference to systems that do not have the VTI's graphics capability (however crude), I have used 64 horizontal elements in the alphabetic mode. Higher resolution would be much more desirable, but this much is enough to show the principles well.

If no memory-mapped display is available, but 2 digital-to-analog (D/A) outputs and a triggered oscilloscope are, the display that is needed can be created. Use 1 D/A

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converter to deflect the trace in the Y direction, and the other (or 1 bit of a digital port) to trigger the sweep. By starting the sweep and then outputting the 3 cursor values in sequence, a 3-segment trace can be created, with the motion of the cursors being up-and-down instead of side-to-side, as in the following program. Lay the oscilloscope on its side if that deviation bothers you.

Systems with built-in graphics under BASIC control, such as Apple, PET, or TRS-80, will probably allow the experiment to be done more simply than how I did it in listing 5. The basic requirement is to be able to read a number from a stored table, add the handle position to it, erase the old cursor, and use the sum to position the new cursor, doing this for 3 cursors at least 4 times per second - the faster the better. (An example of the simulation on the Apple II is shown in listing 6.)

Experimental Design

Imagine a display with 3 cursors on it, one above the other. Each cursor can move left and right. The subject looks at this display while holding a control handle. The instructions for the first experiment are very simple: the subject is asked to select 1 of the cursors, and hold it still, somewhere near the center of the screen as accurately as possible for the duration

of the run. Engineering psychologists call this "compensatory tracking." They use it to investigate the limits of speed and accuracy of control in the presence of rapid disturbances of various kinds.

If the handle is held centered, each cursor will be seen to wander back and forth in a pattern that is independent of the other 2 cursors. In this experiment, the disturbances causing this wandering are made very slow and smooth. With even a slight amount of practice, every subject will be able to maintain essentially perfect control. Transfer functions will *not* be measured, nor will the limits of control be tested in the manner traditional in engineering psychology. A subject acting well within the range of normal operations under conditions where the phenomena of control can be clearly seen is desired. The subject selects a visual variable (position of 1 of the cursors), selects a reference level for that variable (a particular position), and maintains the perceived position at the reference position, while disturbances act that tend to move the cursor away from the reference position.

Figure 17 shows the setup in schematic form. The 3 disturbances are labeled D1, D2, and D3. The 3 cursor positions are labeled C1, C2, and C3. The position of the control handle is H. The position of each cursor is determined by the sum of H and one of the Ds. For cursor 2 the effect of the handle is reversed, so the 3 relationships are:

$$\begin{aligned} C1 &= D1 + H \\ C2 &= D2 - H \\ C3 &= D3 + H \end{aligned}$$

If the subject controls C3 in relation to a reference position of 0 (ie: midscreen), and does so perfectly, then $0 = D3 + H$, or $H = -D3$. The handle position should be an accurate mirror image of the magnitude of the disturbance D3 at every moment, and the cursor C3 does not move at all. You will find that all subjects, after a little practice, will closely approximate these predictions.

This may seem elementary, obvious, boring and hardly worth the labor of getting the experiment up and running. Do not be deceived; this experiment appears to be simple because it is fundamental. It is fundamental because it can *prove* that all of the life sciences have been using the wrong model. There are also several extensions of the experiment that will show how to get started mapping the whole hierarchy of human control systems. There is no theory and no simulation that carries the impact of *seeing* how a real living control system works; especially when you can understand every detail of what is happening, either as subject or observer. The 3 previous articles in this series have been designed to give the ability to grasp what is happening here. This experiment is designed to give the gut feeling of *knowing*.

Program Structure

The program in listing 5 is written in North Star BASIC, Version 6, Release 3. It contains a machine-language subroutine for an 8080/Z80

Text continued on page 102

North Star Strings

The North Star BASIC string expression B\$(I,I) corresponds to MID\$(B\$,I,I) in other versions of BASIC. B\$(I) corresponds to RIGHT\$(B\$,I), and B\$(I,I) corresponds to LEFT\$(B\$,I,I).

Figure, table, and listing numbering continued from part 3.

Listing 5: North Star BASIC control-variable simulation. The necessary assembly language routines needed for execution are also given.

```

10 DIM H$(16),D1$(250),D2$(250),D3$(250),H1$(250),B$(82),S$(82)
20 DIM A$(2)
30 H$="0123456789ABCDEF"
40 INPUT "SEED FOR RANDOM GENERATOR (1 - 100) ",A\ Z=RND(A/100)
50 REM *****
60 REM CONVERT 2 HEX DIGITS TO DECIMAL
70 REM *****
80 DEF FNB(A$)
90 U=ASC(A$(1,1))\IF U<58 THEN U=U-48 ELSE U=U-55
100 V=ASC(A$(2,2))\IF V<58 THEN V=V-48 ELSE V=V-55
110 RETURN 16*U+V
120 FNEND

```

```

130 REM *****
140 REM SET MACHINE-LANGUAGE PROGRAM ORIGIN
150 REM *****
160 INPUT "MOST SIG. BYTE, SUBROUTINE LOCATION: ",S$
170 GOSUB 1130
180 !"6 SEC TO LOAD SUBROUTINE"
190 M1=256*A0\ M2=M1+9
200 DATA "02000000000000000004BDB19071F1F473A0800FE00C21C00782F"
210 DATA "3C477881E63F4F2A00003A08003C3CFE06DA2F00AF"
220 DATA "320800856F5E23563EA0127BE6C0B15F3EAA12722B73DB19EE80"
230 DATA "6F2600C9"
240 M=M1
250 READ B$\FOR J=1 TO LEN(B$)-1 STEP 2\ A=FNB(B$(J,J+1))
260 FILL M,A\ M=M+1\NEXT J\ IF A<>201 THEN 250
270 REM *****
280 REM INSERT RELOCATION BYTES
290 REM *****
300 FILL M1+1,A0\ FILL M1+FNB("12"),A0
310 FILL M1+FNB("17"),A0\ FILL M1+FNB("23"),A0
320 FILL M1+FNB("2D"),A0
330 FILL M1+FNB("26"),A0\ FILL M1+FNB("31"),A0
340 REM *****
350 REM SET LOCATIONS FOR DISPLAY
360 REM *****
370 INPUT "MOST SIG. BYTE, DISPLAY LOCATION: ",S$
380 GOSUB 1130
390 FILL M1+2,FNB("C0")\ FILL M1+3,A0\ FILL M1+5,A0+2
400 FILL M1+6,FNB("40")\ FILL M1+7,A0+3
410 REM *****
420 REM LOAD DISTURBANCE TABLES
430 REM *****
440 W=3*3.1415927/250\RO=RND(0)\R1=32*R2=R1
450 !\!\!A!\!\ [ONE MINUTE TO LOAD DISTURBANCE TABLES]"
460 !\!"THE SCREEN WILL CLEAR AND THREE SCALES WILL APPEAR."
470 !\!"THEN THREE CURSORS WILL APPEAR, ONE FOR EACH SCALE."
480 !\!\PICK ONE CURSOR AND TRY TO HOLD IT IN ONE POSITION"
490 !\!"FOR THE DURATION OF THE RUN, AS EXACTLY AS YOU CAN."
500 !\!" [STAND BY FOR PROMPT]"
510 N1=32\ N2=31\ N3=25\ N4=64\ N5=10
520 FOR J=1 TO 250
530 D1$(J,J)=CHR$(N1+N2*SIN(W*J))
540 D3$(J,J)=CHR$(64-ABS(J-125)/2)
550 NEXT J
560 !" [LOADING RANDOM DISTURBANCE: STAND BY]"
570 N3=25\FOR J=1 TO 250
580 IF J-N3*INT(J/N3)=0 THEN R0=N4*RND(0)
590 R1=R1+(R0-R1)/N5\ R2=R2+(R1-R2)/N5\ D2$(J,J)=CHR$(R2)
600 NEXT J
610 INPUT"READY TO GO: HIT RETURN TO PROCEED. ",A$
620 FOR J=1 TO 16\!\\NEXT
630 REM *****
640 REM EXPERIMENTAL RUN
650 REM *****
660 !\!\!\GOSUB 680!\!\!\!\!\AGOSUB 680!\!\!\!\!\GOSUB 680!\!\!
670 GOTO 690
680 FOR I=1 TO 8\!"TTTTTTT+",\NEXT I\ RETURN
690 FILL M1+8,4\ REM SYNCH CURSOR COUNTER

```

Listing 5 continued on next page

```

700 N1=8\N2=127\N3=128\ FOR J=1 TO 250
710 FOR L=1 TO 4
720 OUT 25,N2\ OUT 26,N3
730 H=CALL(M2,ASC(D1$(J,J)))
740 H=CALL(M2,ASC(D2$(J,J)))
750 H=CALL(M2,ASC(D3$(J,J)))
760 NEXT L
770 H1$(J,J)=CHR$(H)
780 NEXT J
790 REM *****
800 REM DATA PLOTTING PROGRAM
810 REM *****
820 GOSUB 1050\ IF Y0<1 THEN 560
830 !"AFTER PLOT, HIT RETURN TO CONTINUE"
840 INPUT"WHICH CURSOR (1,2,3)? ",I
850 IF I=0 THEN 560
860 FOR W=1 TO 250 STEP INT(250/(Y0+1))
870 H=(ASC(H1$(W,W))-128)*X0/128
880 ON I GOTO 890,900,910
890 V=ASC(D1$(W,W))-32\ GOTO 920
900 V=ASC(D2$(W,W))-32\ H=-H\ GOTO 920
910 V=ASC(D3$(W,W))-32
920 V=V*X0/64+1
930 C=V+H+Z0\ IF C<1 THEN C=1\ IF C>X0 THEN C=X0
940 V=V+Z0\IF V<1 THEN V=1\ IF V>X0 THEN V=X0
950 H=H+Z0\ IF H<1 THEN H=1\ IF H>X0 THEN H=X0
960 B$=S$\B$(Z0,Z0)="."
970 !#TO,\B$(V,V)="D"\ B$(H,H)="H"\ B$(C,C)="C"
980 U=0\ IF V>U THEN U=V\IF H>U THEN U=H\IF C>U THEN U=C
990 IF Z0>U THEN U=Z0\B$=B$(1,U)\ !#TO,B$,
1000 NEXT W
1010 INPUT1"" ,A$\ GOTO 820
1020 REM *****
1030 REM SET UP FOR PLOTTING (SUBROUTINE)
1040 REM *****
1050 !\INPUT "Y-DIMENSION OF PLOT (0 = NEW RUN): ",Y0\ Y0=Y0-2
1060 IF Y0<1 THEN RETURN
1070 INPUT "X-DIMENSION OF PLOT (1-72): ",X0
1080 IF X0>72 THEN 1070\ IF X0<1 THEN 1070\X0=X0-2
1090 INPUT "OUTPUT DEVICE (T OR S)",A$
1100 IF A$="T" THEN TO=2 ELSE TO=0
1110 S$=""\FOR I=1 TO X0\S$=S$+" "\ NEXT I
1120 Z0=INT(X0/2)\ RETURN
1130 REM *****
1140 REM CONVERT HEX IN S$ TO DECIMAL IN AO
1150 REM *****
1160 AO=0\K=1\FOR J=1 TO LEN(S$)-1\K=K*16\NEXT J\K=INT(K+.01)
1170 FOR I = 1 TO LEN(S$)
1180 FOR J=1 TO 16
1190 IF S$(I,I)=H$(J,J) THEN EXIT 1220
1200 NEXT J
1210 !"NOT HEX NUMBER"\ EXIT 160
1220 AO = AO + K*(J-1)\ K=K/16
1230 NEXT I
1240 RETURN
1250 REM *****
1260 REM UTILITY, CONVERT HEX TO DECIMAL
1270 REM UP TO TEN HEXADECIMAL DIGITS
1280 REM DO "RUN 1300"

```

```

1290 REM *****
1300 DIM HS(16)\HS="0123456789ABCDEF"!
1310 INPUT1"HEX= ",SS\GOSUB 1160\!" DECIMAL= ",AO\GOTO 1310

```

```

001          *          MACHINE LANGUAGE SUPPORT ROUTINES
002          *
003          ORG      0
004          *
005 0000 0200      ADRO   DBL   ADR1
006 0002 0000      ADR1   DBL   0
007 0004 0000      ADR2   DBL   0
008 0006 0000      ADR3   DBL   0
009 0008 00        COUNT  DATA 0
010 0009 4B        START  MOV   C,E
011 000A DB19      IN     25          GET HANDLE
012 000C 071F1F    ARS          DIVIDE BY TWO
013 000F 47        MOV   B,A        SAVE IN B
014 0010 3A0800    LDA   COUNT      CHECK FOR MIDDLE ONE
015 0013 FE02      CPI   2
016 0015 C21C00    JNE   S1
017 0018 78        MOV   A,B        IF MIDDLE ONE NEXT,
018 0019 2F        CMA          MAKE HANDLE NEG.
019 001A 3C        INR   A          (TWO'S COMPL.)
020 001B 47        MOV   B,A
021 001C 78        S1      MOV   A,B
022 001D 81        ADD   C          X=X+HANDLE
023 001E E63F      ANI   :3F        LIMIT TO 63
024 0020 4F        MOV   C,A        SAVE X IN C
025 0021 2A0000    LHLD  ADRO      GET BASE ADDRESS
026 0024 3A0800    LDA   COUNT      GET DISPLACEMENT
027 0027 3C        INR   A
028 0028 3C        INR   A          BUMP TWICE
029 0029 FE06      CPI   6
030 002B DA2F00    JLS   S2        CHECK MODULO 6
031 002E AF        ZAR
032 002F 320800    S2      STA   COUNT
033 0032 85        ADD   L          MAKE ADDRESS FOR
034 0033 6F        MOV   L,A        CURRENT CURSOR.
035 0034 5E        MOV   E,M
036 0035 23        INX   H
037 0036 56        MOV   D,M        DE=OLD SCREEN ADR.
038 0037 3EA0      MVI   A,:AO      LOAD A SPACE
039 0039 12        STAX  D          ERASE OLD CURSOR
040 003A 7B        MOV   A,E
041 003B E6C0      ANI   :CO        ZERO DISPLACEMENT
042 003D B1        ORA   C          NEW DISPLACEMENT
043 003E 5F        MOV   E,A        POINTER FIXED
044 003F 3EAA      MVI   A,:AA      LOAD ASTERISK CURSOR
045 0041 12        STAX  D          PUT IT ON SCREEN
046 0042 72        MOV   M,D        SAVE CURSOR
047 0043 2B        DCX  H          ADDRESS
048 0044 73        MOV   M,E
049 0045 DB19      IN     25          GET HANDLE AGAIN
050 0047 EE80      XRI   :80        RANGE 0-255
051 0049 6F        MOV   L,A
052 004A 2600      MVI   H,0
053 004C C9        RET

```

```

5 HIMEM: 8192
10 DIM D1%(250),D2%(250),D3%(250),H1%(250)
20 INPUT "SEED (0-100): ";A
30 Z = RND (A / 100)
40 REM LOAD DISTURBANCE TABLES
50 W = 3 * 3.141592654 / 250
60 R0 = RND (0):R1 = R2 = 140
65 PRINT : PRINT : PRINT : PRINT : PRINT : PRINT
70 PRINT : PRINT : PRINT "LOADING DISTURBANCE TABLES"
75 PRINT
80 PRINT "WHEN SCREEN CLEARS, BACKGROUND WILL"
85 PRINT
90 PRINT "APPEAR — THEN THREE CURSORS."
95 PRINT
100 PRINT "PICK ONE CURSOR AND HOLD IT IN"
105 PRINT
110 PRINT "ONE POSITION FOR THE DURATION OF"
115 PRINT
120 PRINT "RUN, AS ACCURATELY AS YOU CAN"
125 PRINT
130 PRINT "STAND BY FOR PROMPT MESSAGE"
140 FOR J = 1 TO 250
150 D1%(J) = 140 + 130 * SIN (W * J)
160 D3%(J) = (125 * ABS (J - 125)) * 270 / 125
170 NEXT J
175 PRINT
180 PRINT "RANDOM DISTURBANCE LOADING: STAND BYE."
185 N3 = 25:R1 = 140:R2 = 140
190 FOR J = 1 TO 250
200 N3 = N3 - 1: IF N3 > 0 THEN 210
205 N3 = 25:R0 = 280 * RND (5)
210 R1 = R1 + (R0 - R1) / 05:R2 = R2 + (R1 * R2) / 5
220 D2%(J) = R2
230 NEXT J
240 PRINT : INPUT "HIT RETURN FOR RUN";A$
250 HGR
255 HCOLOR = 3
260 POKE 49234, 0
261 FOR X = 1 TO 280 STEP 10
262 FOR Y = 43 TO 143 STEP 50
263 H PLOT X,Y: H PLOT X,Y + 14
264 NEXT Y: NEXT X
270 FOR J = 1 TO 250
280 FOR K = 1 TO 4
290 H = PDL (0) * 128
299 HCOLOR = 0: H PLOT C1%, 45 TO C1%,55: HCOLOR = 3
300 C1% = D1%(J) + H
305 IF C1% < 0 THEN C1% = 0
306 IF C1% > 279 THEN C1% = 279
307 H PLOT C1%,45 TO C1%,55
309 HCOLOR = 0: H PLOT C2%,95 TO C2%,105: HCOLOR = 3
310 C2% = D2%(J) * H
315 IF C2% < 0 THEN C2% = 0
316 IF C2% > 279 THEN C2% = 279
317 H PLOT C2%,95 TO C2%,105
319 HCOLOR = 0: H PLOT C3%,145 TO C33%,155: HCOLOR = 3
320 C3% = D3%(J) + H
325 IF C3% < 0 THEN C% = 0
326 IF C3% > 279 THEN C3% = 279
327 H PLOT C3%,145 TO C3%,155
370 NEXT K
380 H1%(J) = H
390 NEXT J
400 HGR
405 POKE 49234, 0
410 FOR J = 1 TO 250
420 Y = 191 - J * 191 / 250
430 U = 88 / 280
435 H = INT (H1%(J) * U)
440 D1 = INT ((D1%(J) - 140) * U + 45)
450 D2 = INT ((D2%(J) - 140) * U + 135)
460 D3 = INT ((D3%(J) - 140) * U + 225)
461 C1 = D1 + H:C2 = D2 - H:C3 = D3 + H
462 IF C1 < 0 THEN C1 = 0
463 IF C3 > 278 THEN C3 = 278
480 HCOLOR = 1
490 H PLOT D1,Y: H PLOT D2,Y: H PLOT D3,Y
500 HCOLOR = 2
510 H PLOT C1,Y: H PLOT C2,Y: H PLOT C3,Y
520 HCOLOR = 3
530 H PLOT H + 45,Y: H PLOT - H + 135,Y: H PLOT H + 225,Y
540 NEXT J
550 INPUT "":A$
560 TEXT
570 GOTO 180

```

Listing 6: A computer such as the Apple II which has high-resolution graphics capabilities greatly simplifies the program originally given in listing 5. This program performs the same operations as the simulation in listing 5. The author acknowledges the assistance of Charles Faso from Computerland of Niles IL in preparing this program.

Text continued from page 98:

processor which is loaded by the BASIC program at any specified 256-byte memory-address boundary (specify in hexadecimal only the most significant byte of the location of the subroutine).

The machine-language subroutine reads in the handle position, adds it with the appropriate sign to the value of a disturbance that is passed to the subroutine by the CALL command (in the DE register pair), erases the old cursor, and deposits the new cursor, a rubout, on the screen. Each time the subroutine is called it steps to the next cursor, recycling as necessary. On return from the subroutine, the handle position is passed back to the main program (in the HL registers). The machine-language program is in lines 200 thru 230, expressed as a string of hexadecimal bytes with no punctuation. Thus if your machine is not an 8080/Z80 type, a program can be assembled, the listing copied into these lines, and possibly this program can be made to work with little other modification.

The program asks for the most significant byte of the place where the machine-language subroutine is stored. The loader adjusts memory references by inserting the value of this byte in memory wherever necessary, after the program is loaded (lines 300 thru 330).

The display area consists of 1 K bytes of memory starting on any 256-byte boundary. Lines 370 thru 400 ask for the starting location of the memory area devoted to the display, and set up base registers in the machine-language program for the left margin of each cursor's movement. The FILL command is like POKE. If the computer has graphics capability built-in, everything from line 60 thru 400, and the plotting subroutine (later), can be accomplished in a simpler way.

Disturbance tables are set up in lines 510 thru 620. The unnecessary use of symbols, instead of constants,

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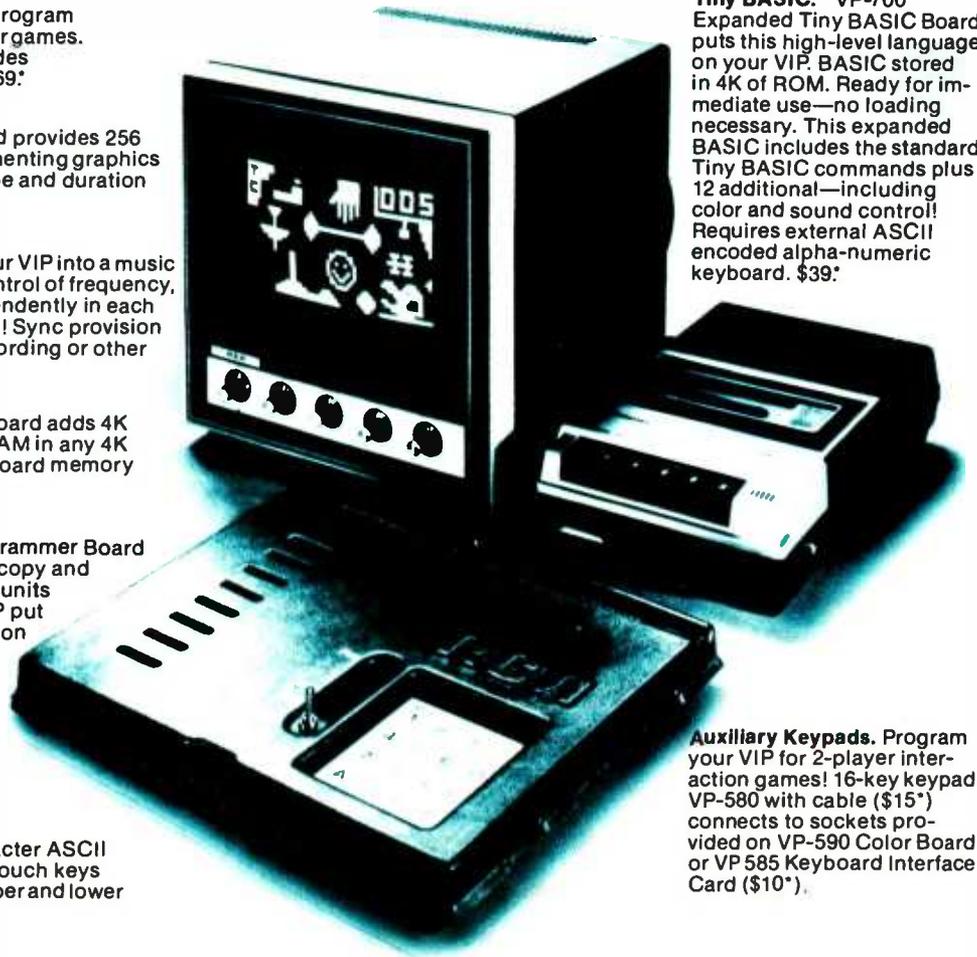
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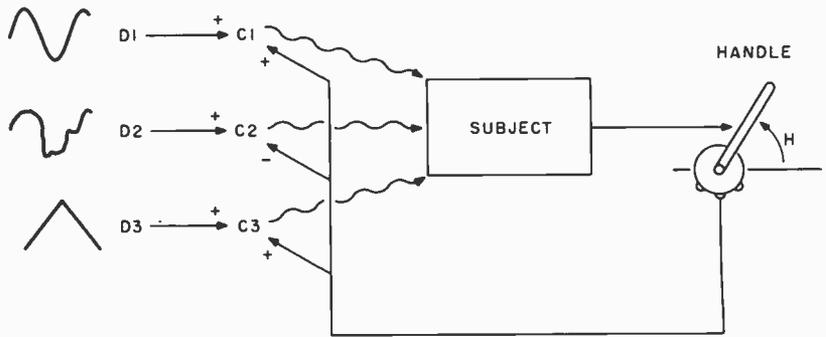


Figure 17: Schematic arrangement of experimental setup. Three slow and smooth disturbances are added to a measure of the handle position (with a negative sign for the middle one), to determine the position of 3 corresponding cursors. The subject selects 1 cursor and a reference position for it, and uses the handle to maintain the cursor at that position. A run lasts about 1 minute, and 250 samples of handle position are recorded. For plotting, the cursors are reconstructed from the tables of disturbances and the corresponding records of handle position.

is an attempt at acceleration. It still takes a minute to load the 3 disturbance tables, each 250 bytes long. All long tables are strings; only 8 bits of accuracy is needed, so by using the CHR\$ and ASC functions, the tables can be stored 1 byte per value instead of 5 bytes per value. Disturbances are in tables because BASIC cannot calculate them fast enough.

Disturbance D1 is a sine wave and D3 is a triangular wave. D2 is a smoothed random disturbance. On reruns, only D2 is reloaded, taking about 20 seconds.

The experimental run is controlled by lines 660 thru 780. Lines 660 and 680 lay down 3 arbitrary scales on the screen, while the rest repeatedly call the machine-language subroutine. For each stored value of each disturbance, all 3 cursor positions are computed and plotted, and the handle position is stored in the table H1\$. The inner loop from line 710 to line 770 adjusts the duration of the experimental run; here it is set up so that the disturbances change and a handle position is recorded only every fourth time the display is generated. On my system, this works out so the display is refreshed 16 times per second, and data is sampled and stored 4 times per second. The 2 OUT statements reflect my laziness; I use 2 digital-to-analog outputs to supply the voltage to the potentiometer that measures handle position.

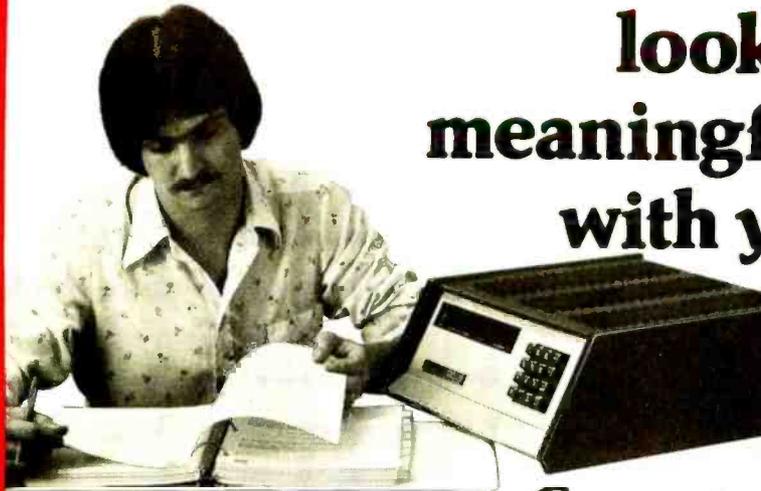
The data plotting routine (lines 820 thru 1010) is entered at the end of an experimental run. This routine is set up to plot either on the video screen

or on a hard-copy device; it asks for the X and Y dimensions of the plot, which cursor is to be plotted, and which device is to be used. My system is set up so the typewriter is device 2 and the screen is any other device number. If you do not have this ability in your BASIC or system, delete lines 1060 and 1070 (in the subroutine that requests information about the display), and eliminate the "#2," in lines 970 and 990. In North Star BASIC, the exclamation point is short for PRINT.

Only the handle position is stored as data; the cursor positions are reconstructed during plotting from the list of handle positions and the corresponding tables of disturbances.

The plotting scheme is designed to work with any teletypewriter-like device. If you have legitimate graphics, you can rewrite this part and get a more pleasing result.

There are 3 choices for plotting, each associated with cursors C1, C2, and C3. Each plot shows the cursor as a C, the handle position as an H, and the disturbance acting on the cursor as a D. A dot indicates the center of the display when nothing else is there. After each plot is finished, there is a pause; hitting the carriage return will cause the program to ask about the next plot. If the question about the Y dimension of the display is responded to with a 0, the program will reload the random disturbance table and issue a prompt for another experimental run. The old data will be destroyed. Remember, it takes about 20 seconds to reload the random disturbance table. Do not panic if



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there is a long pause.

At line 1260 there is a utility routine that converts any hexadecimal number up to 10 digits to a decimal number. I used it while writing the program. It calls the conversion subroutine starting at line 1130.

Running the Experiments

If you possibly can, take the trouble to set this experiment up. Nothing can take the place of actually experiencing yourself as a control system and understanding things that you have taken for granted all your life.

Here is a typical run for the benefit of the many readers who do not have the equipment to do this; the data will then be observed. Here is an old friend, Chip Chad (from part 1 of this series), glaring at the screen and maintaining a choke-hold on the handle, waiting for the experimenter to hit the return key at line 610. The experimenter reaches in and taps the key. The reference scales slide up into place and the 3 cursors pop into view, moving. Chip picks the middle one as most people do the first time, decides to keep it on the middle + mark, and after a few wobbles succeeds.

"So what?" he says.

If learning were being studied, good information could be obtained from this first run. But the plan is to see Chip acting as a *competent* control system, so his first effort is praised and he is given another run (answering the query about Y dimension with a 0). After the second run, the data is plotted for each cursor.

Figure 18 shows the data for each cursor, number 1 on the left, 2 in the middle, and 3 on the right. The 2 end plots are a mess, but the middle plot shows a striking symmetry. The Cs march more or less down the center of the screen, deviating a little to left and right, but maintaining a constant position on the average. The Ds make a random-looking pattern, and the Hs follow almost the *mirror image* of the D pattern.

Looking carefully at the middle plot, could it be said that the handle position or motion looks like any sort of regular function of the cursor position or motion? There may be *some* relationship, but it certainly is not clear. Probably, nobody would claim that the large, smooth motions of the handle could be reconstructed *ac-*

curately on the basis of measurements of cursor position (that is, reconstructed roughly or statistically with accuracy, especially if handle *acceleration* is compared with cursor deviation from the average position). The best which could be hoped for would be some statistical relationship (eg: a small signal buried in much noise).

On the other hand, the relationship between the handle position and the magnitude of the invisible disturbance is obvious and quantitative. It is seen that the handle position is the mirror image of the disturbance magnitude with an error of only a few percent of full scale. There is much

signal and little noise in that relationship.

Here is the situation. There is 1 measure of Chip's behavior, H. There are 2 variables, D and C, either of which might have some relationship to that behavior. Which variable, D or C, would be selected by any statistical test as the most probable cause of the behavior? Of course, D would be selected. In fact, a formal statistical analysis, like those done in every scientific study of behavior, shows D to be the only significant contributor to the behavior, while C, the cursor position, is rejected as an irrelevant variable!

That is a paradox, however, from

Figure 18: A typical run for a practiced subject. In figure 18a is the record for D1, C1, and H. Figure 18b has the record for D2, C2, and H; figure 18c has the record for D3, C3, and H. In figure 18b, the cursor is held near the center, while the handle position is at all times very nearly the mirror image of the disturbance amplitude. It is very easy to decide which cursor was under control.

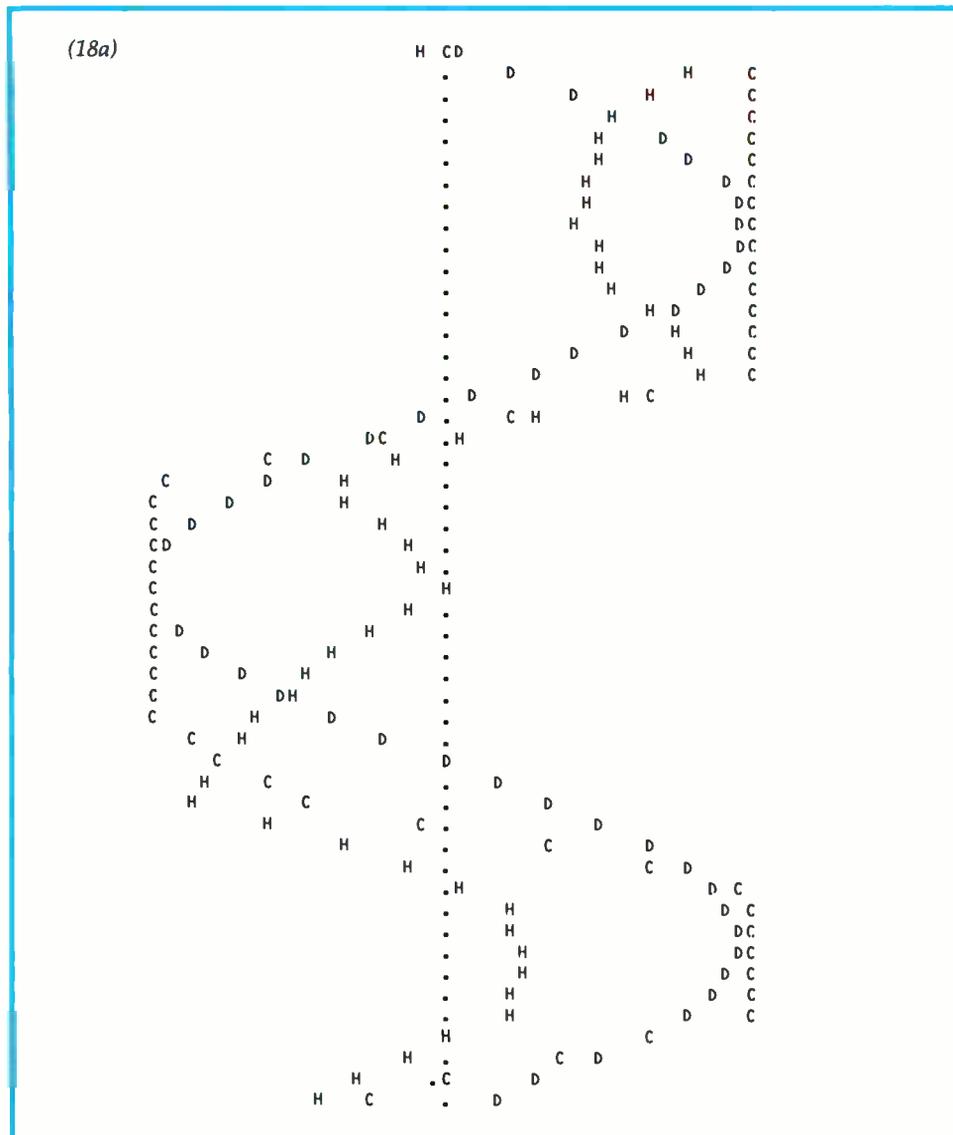
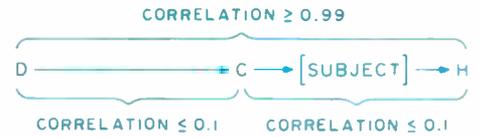


Figure 19: Cause and effect paradox. Under the old concept that stimuli cause behavior, the cause and effect chain runs from the disturbance to the cursor, through the subject, to the behavior. However, the correlation of the disturbance and the cursor position is very low, as is the correlation of the cursor position and handle position (for the controlled cursor). This would lead to a prediction of an even lower correlation of disturbance and behavior. In fact, that correlation is normally very high (0.99 or better). Only the control theory analysis of this experiment can explain this otherwise paradoxical situation.



the traditional point of view. The only way D can affect Chip's behavior is through its effects on C, since all that Chip can sense is the cursor position. The disturbance itself is invisible. If C does not correlate with the behavior, then how can anything that acts exclusively through effects on C correlate any better with behavior? Yet a typical correlation between C and H is around 0.1, while the correlation of H with the corresponding D is typically 0.995. See figure 19.

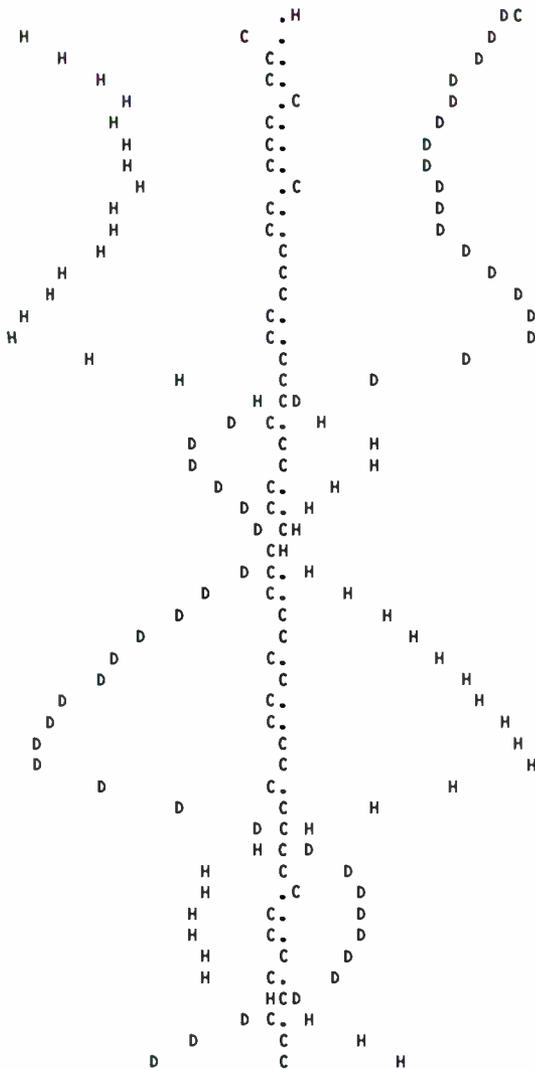
That is the proof mentioned earlier. The old cause-effect model fails utterly when applied to this situation. The question then is, why have generations of intelligent people believed that behavior is caused by sensory stimulation? The answer is clear: they have been fooled by a monstrous illusion.

The illusion would be easier to see if there was some visible, direct indication of the magnitude of the disturbance. Suppose there were a moving D (or a number that con-

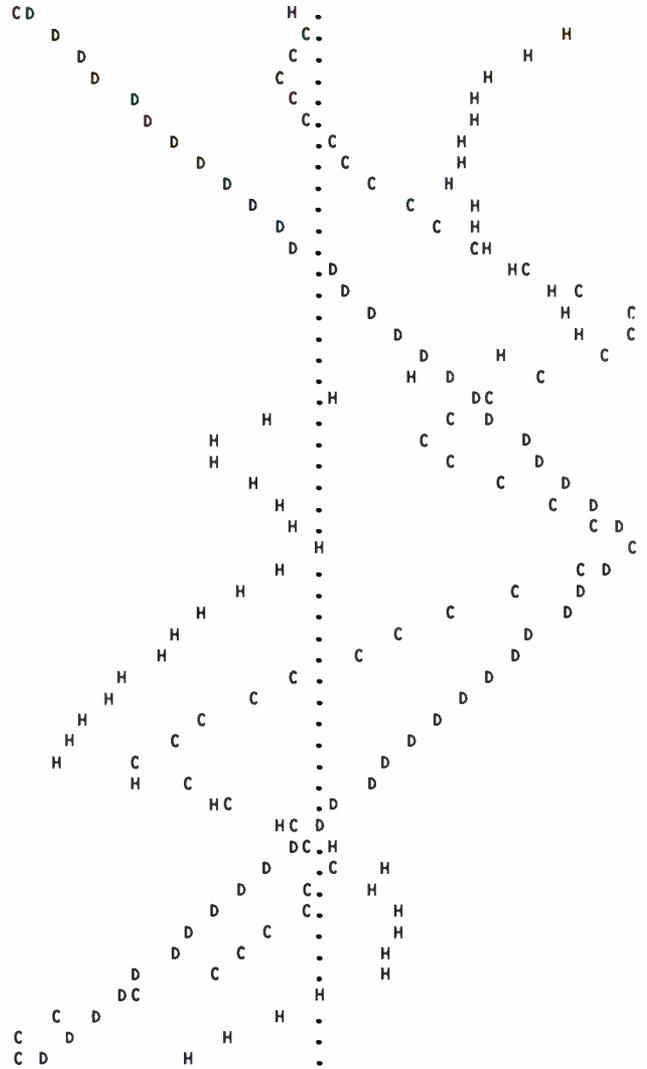
tinually reflected the magnitude of D) on the display. Clearly, if Chip managed to control C without that indication, he could still do so; he could ignore it and perform as well as ever. However, something has now been added that would mislead a bystander who did not understand control theory.

That bystander could now see 2 variables, both able to affect Chip's senses. Taking the apparent relationships at face value, it would be clear that the indication of D was accur-

(18b)



(18c)



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ately associated with the handle position; while the movements of the cursor, such as they are, show no such association. Furthermore, the variations of D are large and smooth, and there is no observable relationship between D and C. Why should the bystander suspect that C is being affected by D in one way and affected by H in an opposite way? The obvious conclusion is that the variations in D are causing Chip's behavior, while C has nothing to do with his behavior, especially if C does not vary more than the fixed background scales do. If the screen were full of irrelevant cursors, jiggling around slightly, how could the bystander pick C as something of special importance? If BASIC were fast enough, I would have included such irrelevant cursors; the point being made here would then be obvious.

An organism is surrounded by a world full of variables; variables that change within widely diverse ranges. The organism receives many signals from its internal parts, too. In that sort of situation, if the organism is controlling some of the variables, it will react strongly and smoothly to

any disturbance tending to alter 1 of the controlled variables. The result is that it will *seem* to be responding directly to the disturbances. There will be no obvious indication that it is controlling anything at all. There is every excuse for even the best of scientists to have observed the relationship between disturbance and behavior, and to have missed the very existence of controlled variables.

The name for such disturbances is *stimuli*. Once in a while, an experimenter must have accidentally picked a real controlled variable to call a stimulus, but the chances are against that. If an attempt is made to manipulate a real controlled variable, the organism will have to be strapped down to keep it from interfering. That is what is done in such cases. If the organism insists on acting like a control system, forcibly break the loop and *make* the organism conform to the theory. As a famous psychologist said, the theme is "Behave, damn it!" It never occurs to such stong-willed individuals that they might have the wrong idea about what is happening.

There is more in this elementary ex-

periment than meets the eye. If all psychologists were to experience it, and try to meet the challenge of explaining these effects using any standard theory, the result would be a total collapse of that science, followed by a rebirth. However, many jobs would be threatened. What has happened instead is that a handful of psychologists has supported this theory, another handful has taken up arms against it, and most have resolutely ignored it.

I suggest that you run this experiment many times with subjects controlling all 3 cursors. Every case will show that mirror-image relationship between D and H and little relationship between C and either D or H. If the previous parts of this series are studied and all the relationships that make up a control system thought about carefully, it will be evident that there is no other explanation for what is going on here. If you get nothing else out of this, you should acquire an intuitive feel for a new theory of how behavior works. You might even begin to understand how to design a robot in a new way.

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mise implied in part 1, to show how anyone with a home computing system can make important contributions to this new science of human nature. The best way this can be done is to start with the experiment used, and to show how it can be extended to become a powerful tool for investigating human organization. The main objective will be to introduce the *test for the controlled variable*, the nearest approach I know of to mind reading.

More Controlled Variables

Once subjects controlling all 3 cursors have been seen, it might seem that the possibilities of this experiment have been exhausted; this is not the case at all. There are controllable variables all over that screen; all of them can be controlled by the same means, movements of the handle in 1 dimension. Discovering them is a good way to get out of the habit of thinking that we simply perceive our environment, and start a new way of thinking: to recognize that we *construct* perceptions, imposing order on our experiences far more than *recognizing* order. As you will see, a

controlled variable does not have to be "real" at all.

Here is an example. It is possible to perceive the *relative* position of any of the 2 cursors. The handle affects C2 in a direction opposite to its effects on C1 and C3, so the relative position of C1 and C3 cannot be controlled because the handle does not affect it. However, it is possible to keep C1 even with C2, or C2 even with C3; in fact, it is easy. A plot of the results would involve plotting C2-C1 or C3-C2 instead of just C, and D2-D1 or D3-D2 instead of just 1 disturbance. The mirror image relationship with H would be as good as ever. Do not forget that C2-C1 and C3-C2 are *variables*. Any value of the variables can be selected as a reference level (eg: C1 to be 1 inch to the left of C2).

These are examples of *higher-level* controlled variables. If the subject could not perceive the present positions of the cursors, he or she certainly could not perceive their *relative* positions. Relative position is derived from perceptions of individual positions, but not vice versa. In order to *control* relative positions,

it is necessary to control (or at least vary) individual positions, but individual positions can be controlled without controlling relative positions. These are the relationships one looks for to map out a *hierarchy* of perception and control.

Other relative perceptions can be controlled. All 3 cursors can be kept lying in a straight line, at least within the range where 1 of them does not fall off the edge of the display and pop up at the other edge. Reducing the amplitude of the disturbances would eliminate that problem. Also, the 3 cursors can be made to form any fixed angle, subject to the same limitation. There may be more static patterns that can be controlled, but I have not thought of any. This is, after all, a simple display.

It is not, however, limited to static conditions. Suppose the subject visualizes a pattern in which 1 cursor moves back and forth slowly between 2 limits. This pattern can easily be maintained, the handle moving just enough to produce it, and enough more to cancel the effects of any of the disturbances. A similar oscillation could be maintained for the *relative*

variables. This is a still higher-level variable, a temporal pattern. The subject chooses which temporal pattern to perceive, and what state of that kind of pattern to maintain. Control still requires only the use of the 1-dimensional effect caused by the handle.

There is clearly an infinite range of different temporal patterns, ranging from a simple steady motion in 1 direction to completely arbitrary motions and rhythms. There is an *unlimited* number of potential controlled variables in this simple display. Anything that can be perceived, and that the handle can affect in a systematic way, can be controlled.

For all of these examples of controllable perceptions, it is essential to remember that the disturbances are acting all the time. This is not a matter of producing any particular *behavior*. The cursor cannot be made to move slowly back and forth between fixed limits just by moving the handle slowly back and forth between fixed limits. The handle might be moving the wrong way at many

moments, when the disturbance tends to make the cursor move faster than the reference pattern being considered. There is no one-to-one correspondence between handle position or velocity and cursor position and velocity, because of those ever-present disturbances. Regularities of *behavior* are not being looked at here, but regularities of controlled perceptions. If there were a slowly oscillating prism between the display and the subject's eyes, a regular pattern of movement of the cursor on the screen would not be seen. The subject controls the visual image, not the reality. For the higher-level variables, the subject controls some *function* of the visual image (often the controlled variable could not be found, even on the retinas).

One could create displays of far greater complexity, and provide means of affecting the display that have more than 1 degree of freedom to explore a staggering range of possible controlled variables. This is what I suggest be done. The first step in the development of any new science is acquire the facts; here the most needed

facts concern *what variables human beings can actually control*. What is needed is a large and simpleminded program of recording the obvious and obscure. What is needed is a body of definitions of variables in *every* sensory mode that people have been able to control. Order and system count much less than sheer volume of data at this point. In fact, an *unsystematic* gathering of data may be the best kind, since it will not be constrained by theories about what people *ought* to be able to control. Anything which can be a way of testing is worth testing at this stage. The possibilities are limited only by the imagination.

We do need some sort of ordering principle—some criterion for judging the reality of any proposed controlled variable. This is where the test appears; here is how it works.

Test for Controlled Variables

The first thing to remember when investigating a possible controlled variable is that in order for something to be controllable it has to be variable. There is neither the means nor the need to control the existence of the Empire State Building or the planet Jupiter. Not all perceptions are controlled. Some are just disturbances; some are just there.

One might think initially about controlling, for instance, a car. People often speak casually about controlling *things*. But what is meant is controlling *something about* those things. A person cannot really control a car; but under proper circumstances its shape, its color, its price, its speed, its direction, its parking place, its dirtiness, its dangerousness, its desirability, its altitude, or the flatness of its tires can be controlled. A car, after close inspection, proves to be composed entirely of hundreds or even thousands of variables. Together they create "car-ness" in our perceptions. Individually, or in groups, most of them can be affected by one means or another, and can be controlled if it is worth the effort. You can even make the car disappear instantly by closing your eyes. Keep remembering that what is controlled is really a *perception*.

The first step in applying the test for the controlled variable is to define a variable. You do not have to know in advance if it is a controlled

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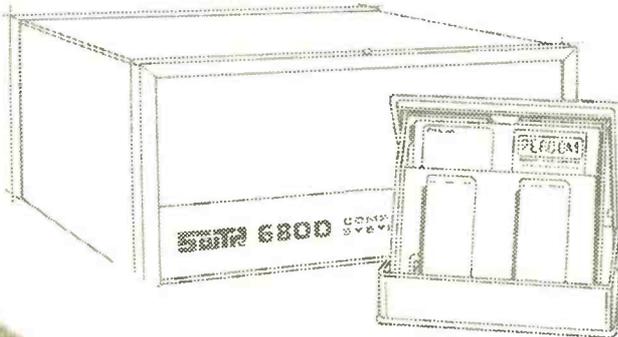
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variable; you do not even have to know where the supposed control system is. All you have to do is to pick out something that you know is variable and "push" on it.

By push I mean to apply a disturbance that under normal circumstances should have a predictable direction and amount of effect on the variable. If I push hard enough on a life-sized statue, it should tilt in the direction of the push. Perhaps it will topple in that direction according to the simple laws of mechanics.

Having selected a variable and applied a push to it, the next step is to measure the actual effect of the push. I *predict* that pushing on this statue should make it tilt a certain amount in a certain direction. I apply the push and observe the tilt.

If the *actual* effect is far smaller than the *predicted* effect, common sense indicates that something must be pushing back. If the pushing-back is always just enough to cancel any amount or direction of disturbance (within some limits), it can be concluded that the pushing-back is *systematic*. The mirror-image effect that has been observed is what is wanted.

It is necessary to discover *what* is pushing back, and how it is doing the pushing. Perhaps, examining the statue carefully, an iron rod is found supporting its back from its base. In that case, a conclusion is made that there were not enough facts to make a correct prediction of the effects of the push; the bending moment of the rod should have been taken into account. But if no simple explanation for the failure of the prediction is found, one must look further.

Suppose it is discovered that the base of the statue seems to move when pushed. If there is a push to the east, the base tilts to the west moving the center of support east of the center of gravity of the statue, and thus creating a counterforce. Suppose this tilt of the base is found to be always just what is required to offset the effects of the push. It can be concluded that one may be on the trail of a control system.

What has been done is to find out something about the *means* of control, the path by which the output of the control system, if it exists, might be linked to the controlled variable (the angle between the statue's longitudinal centerline and the ver-

tical). Finding this link is a necessary step in the test.

That step will usually lead to discovering the physical control system. Tracing the wires that work the motors that tilt the base of the statue, you find a black box a few yards away from the statue. That may be the control system, or at least all of it that is not its actuators (which have been found).

There is still one step to be taken. You cannot be completely sure of the nature of the control system until you discover the variable it is really sensing. The situation has been approached with human prejudices; to me, it seems that the controlled variable is the orientation of the statue, a geometric or visual variable. Perhaps that variable is only *related* to the real controlled variable. What must be found now are the *sensors* that the control system is using.

Thinking in visual terms, you might look for a photocell that detects the tilt. Suppose a photocell is found on a stand near the statue. The test calls for breaking this link, preventing the sensing of the statue. The result should be that the effect of the push returns to what would be predicted from mechanical laws. So the photocell is covered and the disturbances are applied again. What happens is that the floodlights illuminating the statue turn on. The statue still resists the push—the photocell was for something else.

By careful searching 4 strain gauges built into the base of the statue are discovered. These provide a signal showing where the center of thrust is, and the wires from the strain gauges run over to that black box. Disconnecting the wires shows that *now* the push succeeds in tilting the statue. As soon as its tilt becomes marked, an angry groundskeeper comes leaping out of the bushes and arrests the experimenter. Aha! You may have discovered *another* control system controlling the state of the statue.

To recapitulate, the test for the controlled variable involves the following steps:

1. Define a variable.
2. Apply various amounts and directions of disturbances directly to the variable.
3. Predict the expected effects of the disturbances, assuming no control system is acting.

4. Measure the actual effect of the disturbances.
5. If the actual effect is essentially the same as the predicted effect, stop. No control system is found.
6. If the actual effect is markedly smaller than the predicted effect, look for the cause of the opposition to the disturbance, and determine that it results from systematic variations in some other variable. If such a cause is found, it may be associated with the output of a control system.
7. Look for a means of *sensing* the controlled variable. If none is found, stop: no control system is proven to exist.
8. If a means of sensing is found, block it, so the variable cannot be sensed. If control is *not* lost, the sensor is not the right one. If no such sensor is found, stop: no control system is proven to exist.
9. If all steps of the test are passed, the variable is a controlled variable, its state is its reference level, and the control system has been identified.

To apply step 8 of the test to our computer experiment, cover the cursor suspected of being controlled with a cardboard strip. Control should be lost. Cover *each* cursor. The covered one will never pass the test. The other steps are easily carried out.

Concluding Remarks

Now it is up to you. You can test controlled variables involving intensity, sensation, configuration, change, sequence, relationship, strategy, principle, and system concepts having to do with visual, auditory, tactile, kinesthetic, and other senses.

Good luck with the programs, and good hunting for controlled variables. I will be interested to receive word about what people are doing with the information covered in these articles. ■

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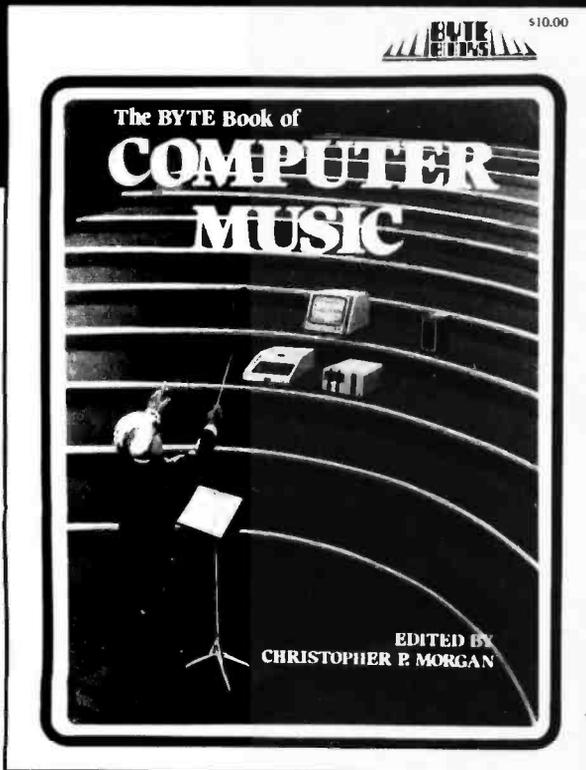
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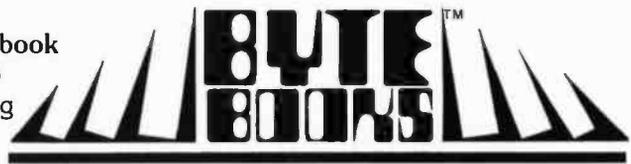
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BYTE News . . .

S-100 8086 AND Z8000 CARDS COMING: At least 6 S-100 product manufacturers are about to release 16-bit processor cards for the S-100 bus that use the Intel 8086 and Zilog Z8000. One such card has already been announced, a 8086 processor card from Seattle Computer Products Inc, Seattle WA. All will conform to the Institute of Electrical and Electronic Engineers (IEEE) S-100 standard that is soon to be adopted. They will work with most 8-bit memory cards using byte-serial read/write. However, for full speed operation you will need either a true 16-bit memory card or a modification of your present memory cards. To modify memory cards requires cutting traces, some rewiring, and adding some logic circuitry.

Microsoft has already announced and demonstrated an 8086 BASIC, and is working on a Z8000 BASIC, as well as other 16-bit software. Digital Research is working on a 8086 version of CP/M. Most 16-bit software in development will be designed for multiprocessing environments, using real-time clocks and interrupt-driven user-inputs.

CP/M 2.0 TO BE RELEASED SOON: There is no doubt that the most widely used disk operating system for microcomputer is CP/M, developed by Gary Kildall of Digital Research, back in 1974. Although originally written for the Intel 8080 development system, it was adapted to run on 8080, 8085 and Z80 systems of many types. Its power and flexibility puts microcomputers in the big leagues by providing features and capabilities normally found on the bigger models.

Gary Kildall is planning to release the 1st major revision to CP/M (Version 2.0). It will use a real-time clock and be interrupt-driven. It will support all present CP/M software. Look for its release around September 1st.

RANDOM RUMORS: Matsushita Inc is rumored to be working on a \$250 printer which will generate "letter quality" type. It will print at 15 characters per second and include a keyboard. Rumors about Hewlett-Packard's Personal Computer are getting warmer. It may be introduced in time for the Christmas market. Expected to sell in the \$2500 area, it will have a 5-inch black and white monitor, 16 K bytes of programmable memory, BASIC in read-only memory, a built-in thermal printer and cassette I/O (input/output). Texas Instruments is developing a 3 or 4-inch Winchester-type disk drive to sell for approximately \$50. Shugart is about to start delivery on the \$70 5-inch floppy disk drive made by Matsushita. Infoton, a video terminal manufacturer, is rumored to be about to introduce a video terminal which will sell for less than \$400 in large quantities. It will use the Zilog Z8 microprocessor and have a total of only 16 integrated circuits. All circuitry will be on 1 printed circuit card, the power supply will be transformerless, and a special elastomeric keyboard will be used.

HAND-HELD COMPUTER IN DEVELOPMENT: Matsushita Electrical of Japan and Friends-Amis Inc of CA have agreed to develop and produce "the first practical hand-held personal computer." The size of a hand-held language translator, the unit could be in production by the end of the year. The computer will be able to accept preprogrammed and user programmed memory capsules. Preprogrammed capsules will include information on business, science, language, education, etc. The computer will have modular construction, enabling new technology modules to be added as they are introduced. Add-ons will include a miniprinter, miniature video display, and a voice synthesizer.

MICRO-MOUSE CONTEST FINALLY ENDS: The 2 year long "Amazing Micro-Mouse Contest" run by the IEEE has finally ended. Although several thousand entries were received, less than 100 actually ran the maze. The contest's objective was to design a robot-type device which could negotiate and learn a maze as it went through. The trials were held at conventions of the IEEE, NCC shows and PC-78.

The ultimate winner was entered by the team of Howard P Katseff and Roy Tramwell from Bell Labs, Holmdel NJ. Their mouse ran the 8½ by 8½-foot maze in just under 30 seconds. It employed a Z80 microprocessor with 4 K bytes of read-only memory and 1 K bytes of programmable memory. Second prize was taken by the team from Batelle Memorial Institute of Richland WA. Art Boland, Ron Dilbeck and Phil Stover's mouse ran the maze in just over 31 seconds. One high performer was actually nonprocessor controlled, and ran the maze in just under 40 seconds.

VOICE-OPERATED TV DEMONSTRATED: Sanyo Electric Co recently demonstrated a television receiver that responds to voice commands to turn on and off and switch stations. Utilizing a microprocessor, the unit compares the voice input to voice patterns stored in memory. The unit has a 30-word vocabulary, and can respond to the voices from 2 different people. Furthermore, the voice input can be used to play games. Sanyo has not announced any immediate plans for incorporating the receiver into its television sets.

APL FOR MICROCOMPUTERS: Despite a report in an earlier BYTE NEWS column, Quark has decided against introducing its APL microcomputer using the Intel 8086 microprocessor.

JAPANESE MOVING SWIFTLY INTO MICROCOMPUTERS: At least 9 Japanese manufacturers are presently manufacturing microprocessor integrated circuits. Approximately 80 different microprocessors are being made. Most of them are original designs including advanced features (eg: analog-to-digital converters, multiply/divide, counter/timers, etc). Five different 16-bit microprocessors are already in production. Furthermore, over a dozen personal computers/trainers are in production to support a very strong interest in personal computers in Japan. Thus far only a few units are available for export.

MOTOROLA ANNOUNCES 68000 DELIVERY AND PRICES: Motorola has announced that it expects to start shipping limited sample quantities of its new 68000 16-bit microprocessor by the end of the year. Single unit price will be \$249. Limited production quantities are expected to be available by the end of the 1st quarter of 1980, with full production by late 1980. No second source arrangements have been finalized.

75 MEGABYTE WINCHESTER DRIVE RUMORED: At least 6 companies exhibited 8-inch Winchester-type drives at the recent NCC show. All of the drives could fit into the same space as an 8-inch floppy disk drive, and provided from 10 to 45 M bytes of storage. At least 8 companies will be delivering these drives by the end of the year, and a 75 M byte version is expected next year. The drive should sell for under \$2000 in quantity.

PERSONAL COMPUTER MANUFACTURERS RANK WITH COMMERCIAL DATA PROCESSORS: Datamation magazine, in their most recent annual report of the top 50 US companies in the data processor industry, disclosed some interesting facts about changes in the computer industry. For the 1st time a personal computer manufacturer, Tandy, ranked among the top 50 in computer equipment sales, and Commodore ranked second among fastest growing companies. Commodore had a 190% increase in sales in 1 year, to \$75M. Tandy (ranked 43rd) reported computer sales of \$105M and total company sales of \$1,152M resulting in a net income of \$76M. The company reported a sales gain of only 11.6% (which is about equal to the rate of inflation, and hence could be considered 0 sales growth). If Commodore continues to grow at its past year's pace, it too will soon rank among the top 50. It was reported that 63% of Tandy's computer revenues were from TRS-80 sales, 26% from peripherals, 10% from services and 1% from supplies.

Each data processing company in the top 50 reported sales increases, and most were 20% or better. For example, IBM's sales rose almost 28%, while Digital Equipment Corporation's sales rose nearly 36%. In fact, none of the traditional maxi or mini makers appear to have been affected by personal computers, despite the predictions that were made 2 and 3 years ago.

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

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Brian A Harron
67-3691 Albion Rd
Ottawa, Ontario
CANADA K1T 1P2

1 microprocessor + 8K BASIC tape
+4K Startrek tape +45 min = RUN

This was the terrible equation I had to contend with every time I wanted to play my favorite game program. It would take me 30 minutes to load the 8 K BASIC paper tape. But not any more!

The solution is a 400 character per second paper-tape reader that can interface to any 8-bit input port of almost any microprocessor. It uses only 2 integrated circuits and costs approximately \$15.

I had always wanted something faster than my old reliable Teletype, but I never seemed to have the \$40 to \$100 that was needed to buy one of the many available kits. I also wondered why most of these kits required so many integrated circuits to accomplish the simple task of latching 8 bits of data. There are 7 bits (sometimes 8 bits) of parallel paper-tape data spaced at regular intervals, and a sprocket hole for strobing, included at no extra cost. Why not design a self-strobing, 8-bit data latch using an inexpensive large scale integration (LSI) transistor-transistor logic (TTL) integrated circuit, the INTEL 8212?

The Intel 8212 provides 8 bits of input, 8 bits of output, strobe, clear, and several device enable lines for about \$5. All I needed to do was to optically sense the punched paper-tape holes and strobe them into the latch at every sprocket hole.

Although there are several ready-made, 8-level, paper-tape-reader photodiode assemblies available, I decided to construct my own reader assembly using individual phototransistors that I already possessed, the Motorola type MRD150, which are available at most wholesalers for

approximately \$1 each. Their miniature size is ideally suited to 0.1 inch (0.25 cm) spacing.

Using epoxy, I glued 9 of the phototransistors into a 0.5 by 1 inch (1.27 by 2.54 cm) piece of 0.100 inch (.025 cm) perforated board. The photocell placed between positions 3 and 4 (as shown in figure 1) is physically reversed so that the active surface element of the cell is not in line with the other 8 cells. This out-of-line detector provides a physical delay of the sprocket-hole signal which will be signal-conditioned later.

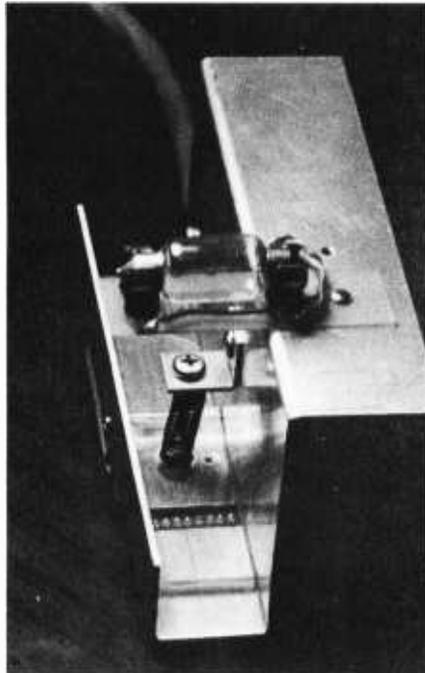


Photo 1: View of the paper-tape reader showing the light source and the light-detecting phototransistors. The spring and clamp device keeps the paper tape in place.

This cell begins to detect light through the sprocket hole only after all other data holes are fully centered over their respective detectors. The strobe pulse is now positioned close to the center of the pulse from the data holes, as shown in the waveforms of figure 2.

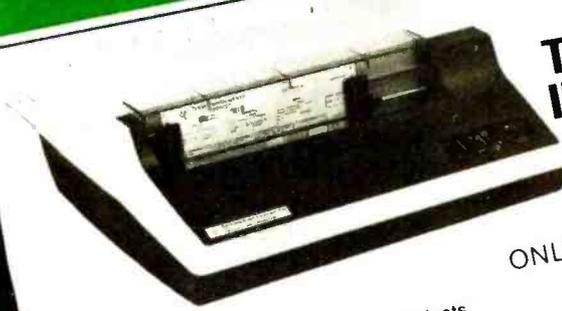
In order to make the strobe pulse as insensitive as possible to the variation in tape speed caused by moving the tape by hand, the sprocket-hole detector is amplified by transistor Q1 and is threshold-detected by IC1a, a 7414 hex Schmitt trigger TTL gate (see figure 3, p. 121). The output of IC1a is then differentiated and level-shifted by the capacitor and resistor combination C1, R1, and R2 such that the output of IC1b is fast and clean even for very slow dark-to-light transitions through the sprocket hole.

The additional gate sections IC1c and IC1d provide buffered outputs of

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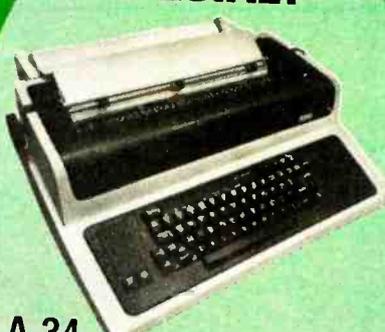
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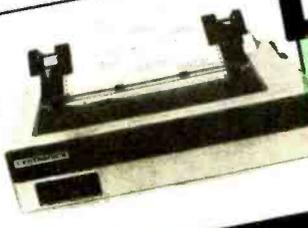
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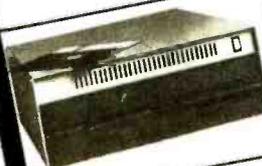
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the signals STROBE and $\overline{\text{STROBE}}$, which will be used as sense input lines to the 8-bit interface port.

The last 2 sections of the Schmitt trigger are configured as a delayed power-up signal that holds the CLEAR input pin of the latch at

ground until the power supply voltage has stabilized.

The DS1 and MD pins of the 8212 are grounded and the DS2 pin is pinned to the supply voltage, thus placing the 8212 into the strobed latch mode of operation. In this way the 8

bits of data available to the input pins DI-0 thru DI-7 are latched through to the output pins DO-0 thru DO-7 by each positive pulse at the STROBE pin.

Since most paper-tape programs used with today's microprocessors use only 7 bits of the 8-bit ASCII code (bit 8 being vertical parity), it is convenient to use this 8th bit as the strobe sense line. When connecting the output pins of the latch to the processor input port, simply select strobe signal STROBE or $\overline{\text{STROBE}}$ and connect it to the pin corresponding to bit 8.

The software required to read in such data is shown in listing 1, where bit 8 is the STROBE sense line. When bit 8 goes through a low to high to low cycle, the data at the input port is valid.

If 8 bits of tape data are required, it is necessary to connect the strobe sense line to either another input port pin or to some other monitor line, such as an interrupt or serial input line, which can be tested under software control.

Mechanically, I used a piece of 0.100 inch (0.025 cm) aluminum sheet bent into a U-shape, with an inside, bottom width dimension of 1 inch (2.54 cm). I used a small piece of clear Plexiglas as a hold-down device for the tape as it passed over the reader photocells. Further improvements can be added, such as a motor-driven, pinch-roller pull-through, but I have had no problems when pulling the tape through by hand. As a matter of fact, I can stop pulling at any time, since the strobe pulse is speed insensitive. I plan to eventually add a hand crank and a take-up reel to avoid the great piles of tape that end up on the floor after loading some of my larger programs.

To generate the required illumination, I used an automotive lamp (type 211) mounted 3 inches (7.5 cm) above the photocells. Running the lamp on 5 V provides a good, uniform source of light, although it draws about 1 A of current.

This entire project took only 3 evenings to design and construct, and the \$15 price tag was a bonus. If you are still limited to 10 characters per second with your Teletype reader, you should seriously consider this high-speed paper-tape reader. ■

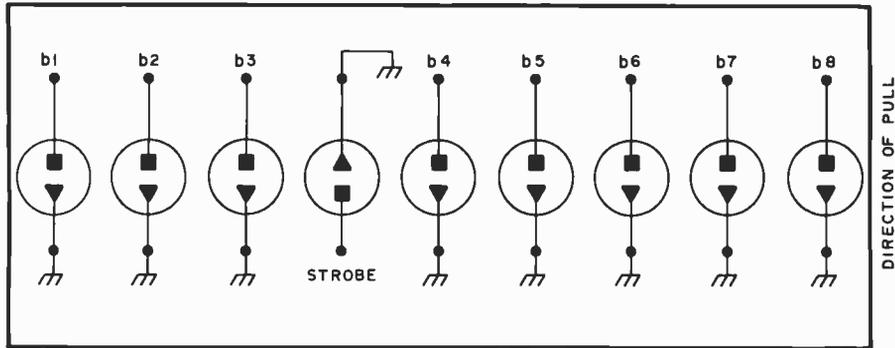


Figure 1: Phototransistors in the paper-tape reader. Note the placement of cell between bits 3 and 4. The active element is reversed in orientation.

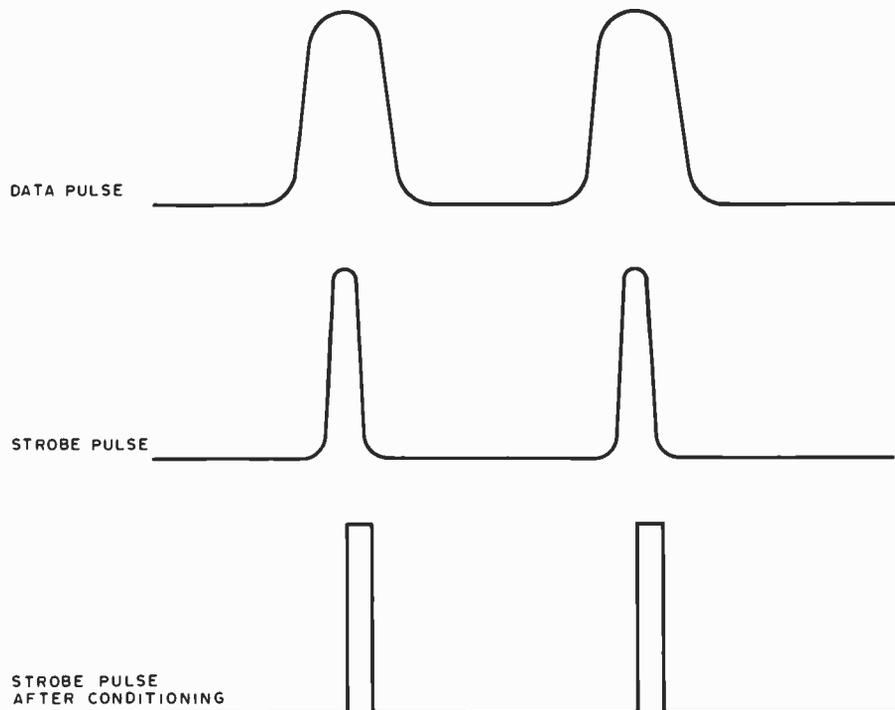


Figure 2: The strobe pulse is centered in the active signal from the data holes.

```

UP:   IN port#           ; READ INPUT PORT
      RAL                ; SHIFT 1 BIT LEFT
      JNC UP            ; JUMP TO UP IF CARRY BIT NOT SET
DOWN: IN port #         ; READ INPUT PORT AGAIN
      RAL                ; SHIFT 1 BIT LEFT
      JC DOWN          ; JUMP TO DOWN IF CARRY BIT SET
READ: IN port#         ; READ INPUT PORT DATA BYTE
      RETURN           ; WITH 7 BITS OF DATA IN REG A

```

Listing 1: Simple 8080 assembly language program for inputting the data from the paper-tape reader.

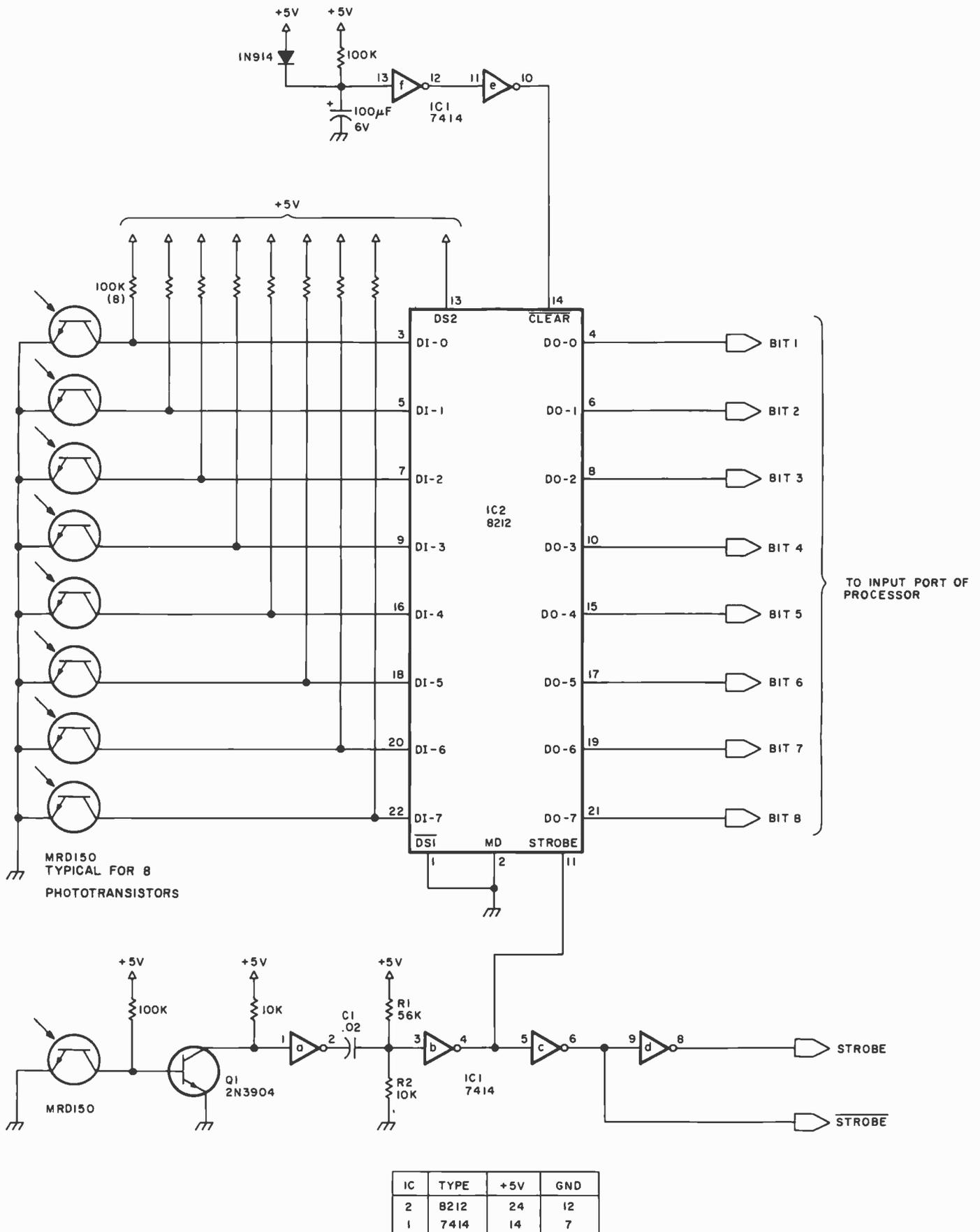


Figure 3: Schematic diagram of the paper-tape reader, which is capable of 400 characters per second.

Book Reviews

Microcomputer-Based Design

by John B Peatman
McGraw-Hill Book Co,
New York 1977
540 pages hardcover
\$26.95

Microcomputer-Based Design by John B Peatman is a combination text and reference book aimed at engineers who wish to learn how to design systems using microprocessors. It is written not in a dull, dry tone, but rather in a light style. The minimum required background for this text is a rudimentary knowledge

of logic (ie: transistor-transistor logic gates and flip-flops) and the basic concepts of computer programming. The book develops hardware and software design skills upward from that point to a practical and useful level. A key feature of this book is the logical, lucid presentation of arguments present in the many illustrated design decisions.

Microcomputer-Based Design is divided into 7 chapters and 6 appendices. The chapters are fairly complete, in-depth entities and each contains a set of practical design problems and additional references. The references may be difficult to find for readers without access to an engineering library since many of the references are articles in engineering journals or manufacturers' application notes.

Chapter 1 is an overview of microcomputer applications focusing primarily on the distribution of "intelligence" to instruments and tools.

Chapter 2, "Microcomputer Registers and Data Manipulation," includes a brief discussion of numbering systems and the various, commonly encountered modes of addressing. This is followed by a good presentation of machine language instructions, assembly language, and assembly language programming techniques.

Chapter 3 considers computer hardware organization. Several different philosophies of commercially available microprocessor families are described. The characteristics of various logic families are considered with an eye towards interconnection compatibility. Bus structures and their electronic implementation are described in some detail. Flags, interrupts, direct memory access control and programmable timers are also described with examples.

Chapter 4 reviews the various characteristics of memory components and systems. Included are sections on the implementation of main power failure battery backup systems and floppy disks.

Chapter 5 examines peripherals. There are sections on input/output control and handshaking, timing and buffering. There are also discussions of specific common microcomputer peripherals: keyboards, photo-transducers, circuit testers, analog-to-digital and digital-to-analog converters, pressure transducers, optical

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displays, relay drivers, synchromotors and printers. Finally, there are sections on universal asynchronous receiver-transmitters (UARTs), line drivers, the HPIB-IEEE 488 bus and self-test hardware.

Chapter 6 describes the various options that exist in hardware and software development packages from prototyping boards to disk-based operating systems. There is also a brief discussion of high-level languages for microcomputers.

Chapter 7 describes in detail the algorithms for solutions to several common microcomputer software problems. Algorithms are described to read and to parse a functional keyboard input, self-test routines and number system conversion and manipulations. Real-time programming constraints are also considered.

The set of appendices describes the characteristics of specific microcomputers. Each appendix covers the architecture and organization of a particular processor integrated circuit. The rest of the integrated circuit set (memory, input/output, etc) is also briefly covered. Appendices are included on the 4004, F8, 8080, 6800, COSMAC, and PPS-8 processors. It is refreshing to see that these appendices are more than just a reprinting of the manufacturer's specification sheets.

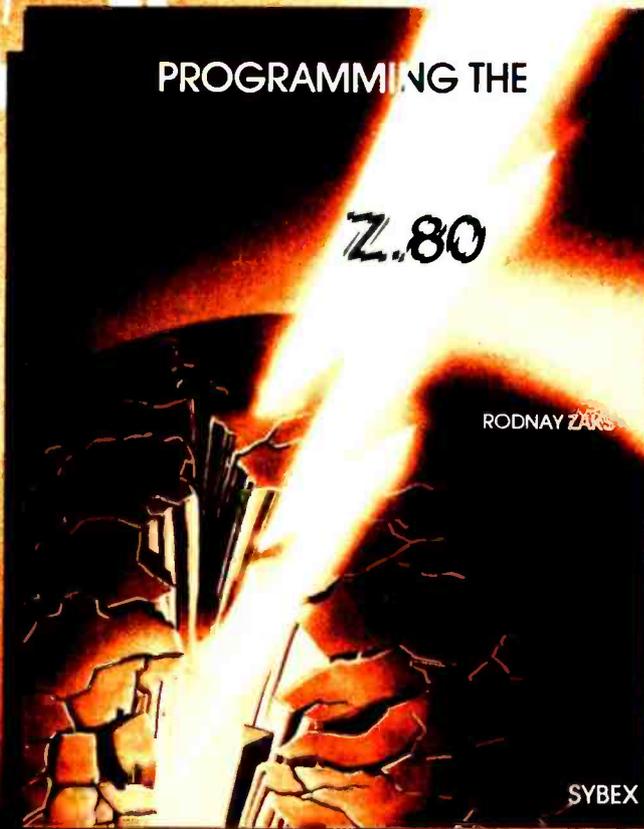
On the negative side, there is a disturbing absence of discussion of any of the high-performance integrated circuits that were certainly available when this book was written. There is also inadequate treatment given to bit-slice and microprogramming techniques. Software development by emulation is also omitted. The balance is, however, overwhelmingly positive. This is a text which starts off quietly, never grows dull, and yet contains a great deal of substance. There are sections on using esoteric devices like first in, first out stacks (FIFOs) that I have previously never seen in a design text.

It is a welcome development. I recommend this book to advanced experimenters, undergraduate engineering students and practicing engineers. ■

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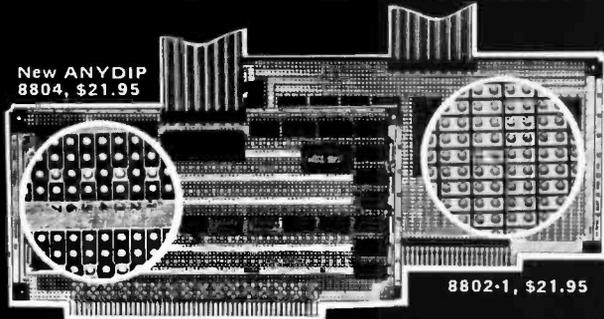
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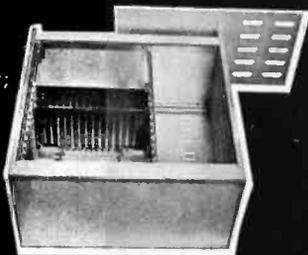
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W B Agocs, Dept of Physical Sciences
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The day of the week, the number of elapsed days of a year, and the number of days between 2 dates are information that is required frequently in various types of analyses.

The procedure to determine the day of the week uses Zeller's congruence:

$$d = \{ [2.6m-0.2] + K + Y + \left[\frac{Y}{4} \right] + \left[\frac{C}{4} \right] - 2C \} \text{MOD } 7$$

The term m is the month number minus 2. If the month is January or February, m is 11 or 12 of the previous year. K is the day of the month; C is the century, and Y is the year of the century. The value of the square brackets is defined as the integer part of the result of evaluating the interior expression.

Day of Week From Date

The program is so written that corrections to month 11 or 12 of the previous year are made automatically if the month is January (1), or February (2). The program is shown in listing 1. Century selection could have been incorporated, but the program is designed for the 20th century. Once the number of the day of the week is obtained (with Sunday being day 1), the date and the day are printed.

Matrix Elapsed Time Determination

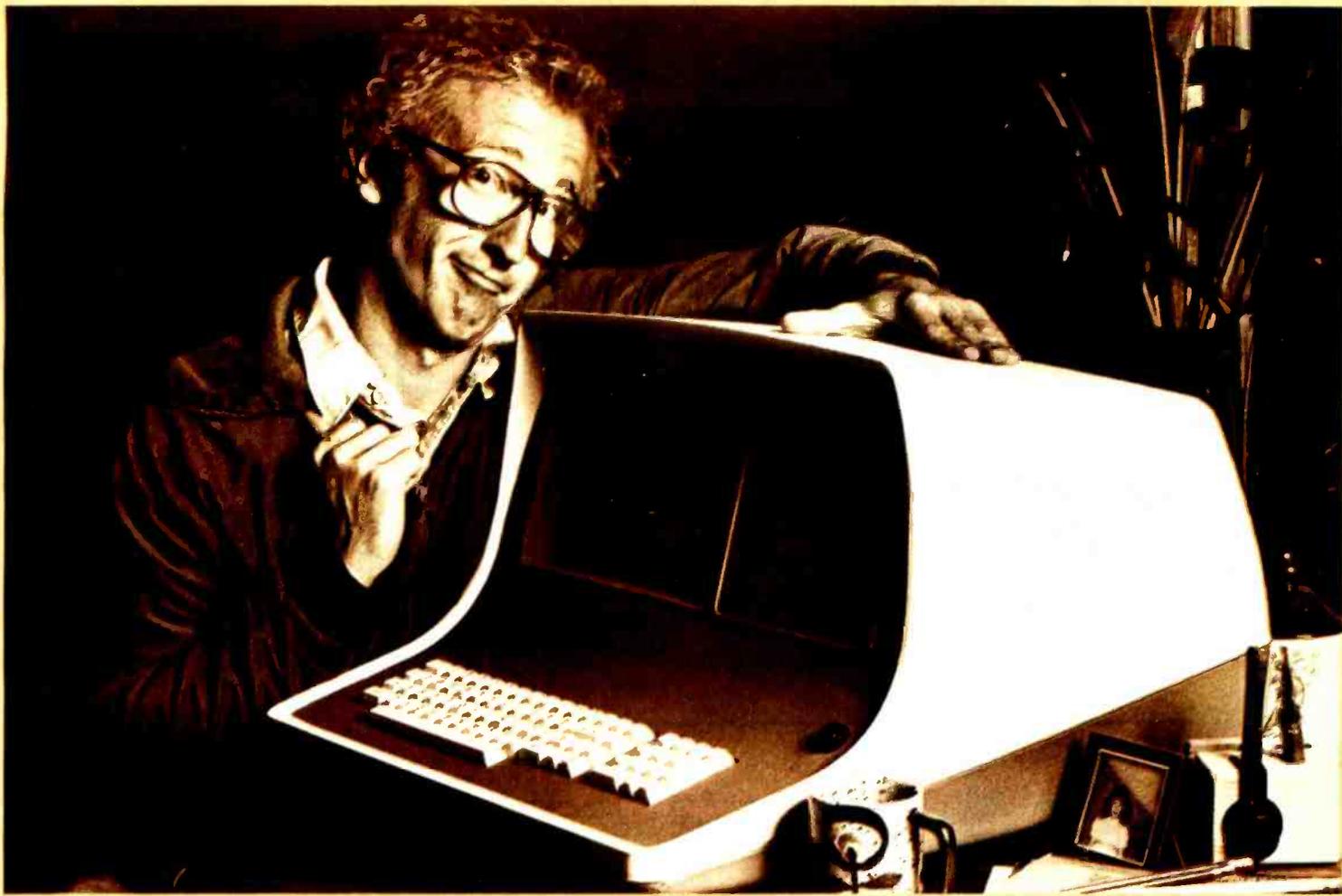
The use of a 12 by 31 matrix seems to be the most logical method for determining the elapsed days of a year, the remaining days in a year, and the day interval between 2 dates.

The program for such a determination is shown in listing 2. The MAT A = CON statement in line 50 sets each element of the matrix equal to 1. The subroutine in statements 440 thru 540 enters 0s into the matrix elements which correspond to the months with less than 31 days, and then fills the matrix elements with the date's numerical location in the year. Thus on return from the subroutine, the days elapsed may be printed between statements 180 and 190, or between statements 400 and 410 if desired. Leap year corrections are made at lines 270 and 440.

Finally, if the interval between the 2 dates is less than or greater than a year (as determined by statement 100), the correct year increment is made in statements 230 and 280.

The total time interval is determined in statement 180 or 410, and the result printed at statement 190.

Text continued on page 129



HOW BOB SCHMIDT AND HIS MICROSOFT BASIC COMPILER TURNED AN ORDINARY COMPUTER INTO A GENIUS.

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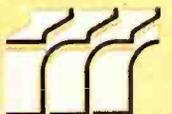
FORTRAN and COBOL programs. Just like the pros," smiled Bob.

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Text continued from page 126:

The matrix procedure, with correction for appropriate holidays, can be used in conjunction with stock market studies when knowledge of the market day interval is desired, or when determining if a particular date is a market trading day.

Listing 1: BASIC program for determining the day of the week from the date using Zeller's congruence.

```

0010 PRINT "ZELLER'S CONGRUENCE-DAY OF WEEK
FROM DATE."
0020 PRINT "WHAT IS THE DATE-MONTH, DAY, YEAR?"
0030 INPUT M,D,Y
0035 LET Y1 = Y
0037 LET M1 = M
0040 IF (M = 1) OR (M = 2) THEN 60
0050 GOTO 105
0060 IF M = 1 THEN 90
0070 LET M = 12
0080 GOTO 100
0090 LET M = 11
0100 LET Y = Y-1
0102 GOTO 110
0105 LET M = M-2
0110 LET D1 = INT(2.6 * M-.2) + D + (Y-1900) + INT((Y-1900)/4)
0115 LET D1 = D1 + INT(19/4)*2*.19
0120 LET D1 = D1-INT(D1/7)*.7 + 1
0125 PRINT "D1 = ";D1
0130 ON D1 GOTO 140, 150, 160, 170, 180, 190, 200
0140 LET A1$ = "SUNDAY"
0145 GOTO 210
0150 LET A1$ = "MONDAY"
0155 GOTO 210
0160 LET A1$ = "TUESDAY"
0165 GOTO 210
0170 LET A1$ = "WEDNESDAY"
0175 GOTO 210
0180 LET A1$ = "THURSDAY"
0185 GOTO 210
0190 LET A1$ = "FRIDAY"
0195 GOTO 210
0200 LET A1$ = "SATURDAY"
0210 PRINT "FOR ";M1;" / ";D1;" / ";Y1;" IT IS ";A1$
0220 PRINT
0230 END

```

Listing 2: BASIC program for using a matrix to determine the elapsed time between 2 dates.

```

0010 PRINT "MATRIX DETERMINATION OF DAYS BETWEEN
DATES."
0020 PRINT "PROGRAMMED APRIL 15, 1979;W. B.
AGOC'S."
0030 DIM A(12,31)
0040 DCL S(A())
0050 MAT A = CON
0060 PRINT "WHAT IS THE FIRST MONTH, DATE, YEAR?;
EXPRESS NUMERICALLY AS 11, 15, 1978."
0070 INPUT M1, D1, Y1
0080 PRINT "WHAT IS THE NEXT MONTH, DATE, YEAR?"
0090 INPUT M2, D2, Y2
0100 IF Y2-Y1 = 0 THEN 120
0110 GOTO 220
0120 IF Y1/4-INT(Y1/4) = 0 THEN 150
0130 GOSUB 450
0140 GOTO 160
0150 GOSUB 440
0160 LET S1 = A(M1, D1)
0170 LET S2 = A(M2, D2)
0180 LET S3 = S2-S1
0190 PRINT "INTERVAL BETWEEN ";M1;" / ";D1;" / ";Y1;
0195 PRINT " AND ";M2;" / ";D2;" / ";Y2;" IS ";
0200 PRINT S3;" DAYS."
0210 GOTO 580
0220 LET S = 0
0230 FOR I = Y1 + 1 TO Y2-1 STEP 1
0240 IF I/4-INT(I/4) = 0 THEN 270
0250 LET S = S + 365
0260 GOTO 280

```

```

0270 LET S = S + 366
0280 NEXT I
0290 IF Y1/4-INT(Y1/4) = 0 THEN 320
0300 GOSUB 450
0310 GOTO 350
0320 GOSUB 440
0330 LET S1 = 366-A(M1,D1)
0340 GOTO 360
0350 LET S1 = 365-A(M1,D1)
0360 IF Y2/4-INT(Y2/4) = 0 THEN 390
0370 GOSUB 450
0380 GOTO 400
0390 GOSUB 440
0400 LET S2 = A(M2,D2)
0410 LET S3 = S + S1 + S2
0420 GOTO 190
0430 REM SUB-ROUTINE
0440 LET A(2,29) = 0
0450 LET A(2,30) = A(2,31) = A(4,31) = A(6,31) = A(9,31)
= A(11, 31) = 0
0460 LET N = 0
0470 FOR I = 1 TO 12 STEP 1
0480 FOR J = 1 TO 31 STEP 1
0490 IF A(I,J) = 1 THEN 510
0500 GOTO 530
0510 LET N = N + 1
0520 LET A(I,J) = N
0530 NEXT J
0540 NEXT I
0550 RETURN
0560 PRINT
0570 PRINT
0580 PRINT "THE END."
0590 END ■

```

A Text Loader Routine

Howard Berenbon
2681 Peterboro
W Bloomfield MI 48033

Here is a useful program for the Motorola 6800 microcomputer. This subroutine allows the loading of ASCII text into the desired memory location directly from your terminal. It uses the Motorola MIKBUG monitor for character input and output. The subroutine may be entered beginning at hexadecimal address A060. To exit the program simply type a %.

Hexadecimal Address	Hexadecimal Code	Mnemonic	Comments
A060	86 3F	LDAA #\$ 3F	Load A with ?
A062	BD EO 75	JSR CHAROUT	Output ?
A065	86 20	LDAA #\$ 20	Load A with a space
A067	BD EO 75	JSR CHAROUT	Output space
A06A	CE _ _	LDX #\$ _ _	Load index register with desired address
A06D	BD EO 78 &LOOP	JSR CHARIN	Input character
A070	A7 00	STAA \$ 00:X	Store A indexed
A072	08	INX	Increment index register
A073	81 25	CMPA #\$ 25	Compare A with %
A075	26 F6	BNE &LOOP	Get another character
A077	7E E0E3	JMP MIKBUG	Return to MIKBUG ■

A Model of the Brain for Robot Control

Part 4: Mechanisms of Choice

James Albus
 Project Manager
 National Bureau of Standards
 United States Dept of Commerce
 Washington DC 20234

The essence of a hierarchy is that control is top-down. The ultimate choices are made at the top, and the goals selected at this level are decomposed into action as they filter down

The ideas presented in this article represent the views of the author and not those of the Department of Commerce or the National Bureau of Standards.

through the various levels of the hierarchy. For the purposes of our discussion, we will define the highest level H function in the behavior-generating hierarchy of the human brain as the *will*.

For centuries philosophers and theologians have debated the nature of the will, particularly the question of whether humans have "free" will (ie: the *freedom* to choose goals) or

whether all choice is merely a reflexive or predestined response to the environment. We shall not presume to deal with this question here, other than to suggest what types of inputs are available to this highest level goal selection module.

By definition much of the input to the highest level behavior-generating module must come from the highest level sensory-processing module.

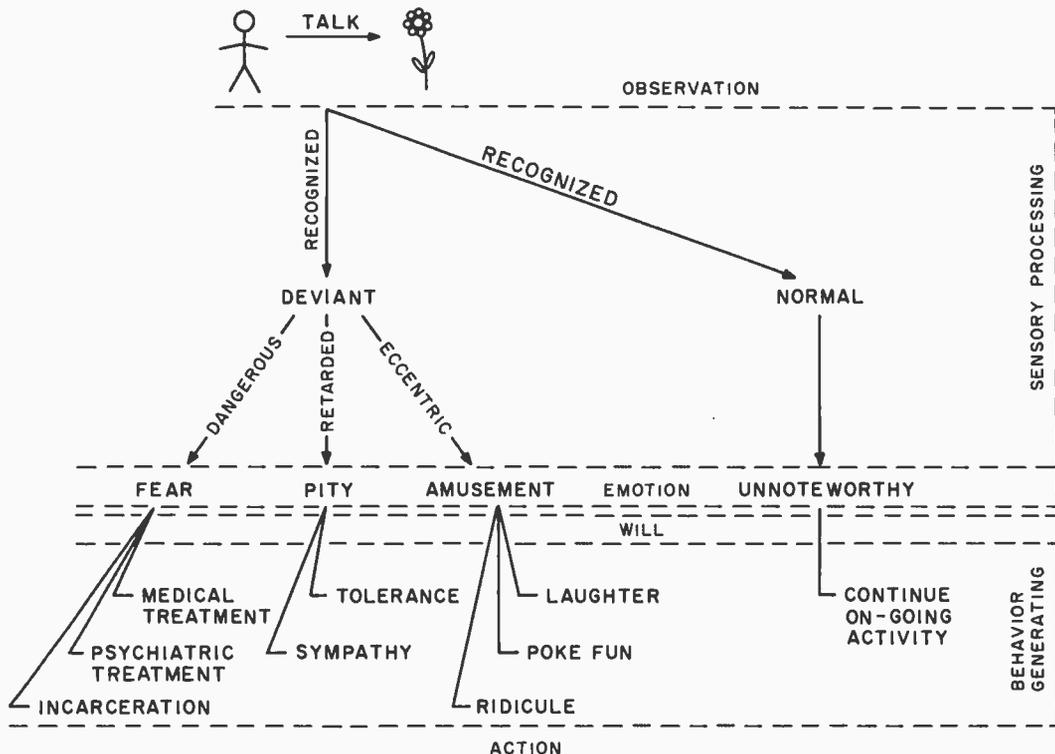
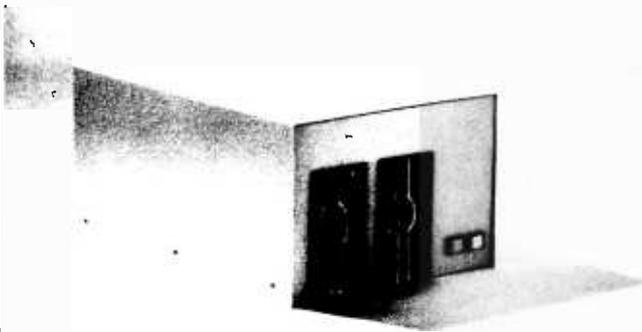


Figure 1: An action (such as a person talking to a flower) may be recognized as either familiar or unfamiliar. If an action is noted as familiar, then it can be considered unnoteworthy and will be ignored. If the action is considered deviant, further processing will take place to determine reactions to the action.

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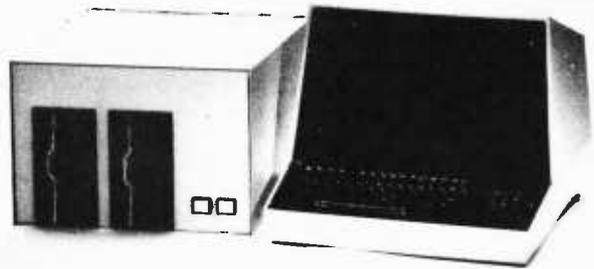
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This is the level at which the overall result of the entire sensory processing operation is evaluated as being good or bad, rewarding or punishing, satisfying or frustrating. In humans, this function is performed by what are commonly called the emotions. It has long been recognized that emotions play a crucial role in the selection of

behavior. We tend to practice that which makes us feel comfortable and avoid what we dislike. Our behavior-generating hierarchy normally seeks to prolong, intensify, or repeat those behaviors which give us pleasure or make us feel happy or contented. We normally seek to terminate, diminish, or avoid those behavior patterns which cause us pain, or arouse fear or disgust.

In the past 25 years it has become known that the emotions are generated in localized areas, or computing centers, in the brain. For example, the posterior hypothalamus produces fear, the amygdala generates anger and rage, the insula computes feelings of contentment, and the septal regions produce joy and elation. The perifornical nucleus of the hypothalamus produces punishing pain, the septum pleasure, the anterior hypothalamus sexual arousal, and the pituitary computes the body's response to danger and stress. These emotional centers, along

with many others, make up a complex of about 53 regions linked together by 35 major nerve bundles. This entire network is called the limbic system. Additional functions performed in the limbic system are the regulation of hunger and thirst performed by the medial and lateral hypothalamus, the control of body rhythms such as sleep-awake cycles performed by the pineal gland, and the production of signals which consolidate (ie: make permanent) the storage of sensory experiences in memory performed by the hippocampus. This last function allows the brain to be selective in its use of memory by facilitating the permanent storage of sensory experiences to which the emotional evaluators attach particular significance (eg: close brushes with death, punishing experiences, etc).

Input to the limbic system emotional centers consists of highly processed sensory-data such as the names of recognized objects, events, relationships, and situations, such as the recognition of success in goal achievement, the perception of praise or hostility, or the recognition of gestures of dominance or submission transmitted by social peers. These inputs are accompanied by such modifier variables as confidence factors derived from the degree of correlation between predicted and observed sensory input.

Sensory processing at the level of the emotions is heavily influenced by contextual information derived from internal models and expectations at many different levels in the processing hierarchy. If a painful stimulus is perceived as being associated with a nonfear producing source, we may attack the pain causing agent. If, however, the perceived source of pain also induces fear, we may flee.

Similarly if an observed event such as a person talking to a flower is perceived as deviant, then this input to the emotions, along with other recognized qualifier variables such as the person is a) eccentric, b) retarded, or c) dangerously psychotic, will cause the emotions to output a) amusement, b) pity, or c) fear, respectively. Amusement input to the behavioral goal selecting module may lead to laughter, poking fun, or ridicule. Pity input to the will may

About the Author

Dr James S Albus worked for NASA from 1957 to 1972 designing optical and electronic subsystems for over 15 spacecraft, and for one year managed the NASA Artificial Intelligence Program. Since 1973 he has been with the National Bureau of Standards where he has received several awards for his work in advanced computer control systems for industrial robots. He has written a survey article on robot systems for Scientific American (February 1976) and his Cerebellar Model Arithmetic Computer won the Industrial Research Magazine IR-100 Award as one of the 100 most significant new products of 1975. He is also the author of People's Capitalism: The Economics of the Robot Revolution which is published by New World Books, 4515 Saul Rd, Kensington MD 20795.

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evoke a behavioral pattern of sympathy. Fear may evoke an attempt to secure medical or psychiatric treatment, or incarceration.

If, however, a person talking to a flower is recognized as perfectly normal, then the emotions will give no indication that the event is particularly worthy of attention, or that there exists any need to deviate from whatever behavior is presently being executed. These relationships are described graphically and symbolically in figure 1.

In this model the standards of normalcy and deviance are clearly in the eye of the beholder, or at least in the expectations and beliefs stored in the processing-generating hierarchy. In many ways the emotional evaluators are even more dependent on internal beliefs than externally observed facts. This is particularly true in the case where a person's belief structure discounts the reliability or moral worth of the physical senses, as is characteristic of philosophical constructs derived from gnosticism or asceticism.

Thus the emotions, just as any other sensory processing module in

the brain, simply compute a G function on the D vector that they input to produce the Q vector that they output. In simple creatures the emotional output vector may be restricted to a few components such as good-bad, pleasure-pain, etc. In higher forms the emotional output is a highly multidimensional vector with many faceted components such as love, hate, jealousy, guilt, pride, disgust, etc. Part of this Q output may simply produce feelings (ie: joy, sadness, excitement, fear, etc). However, most of the Q output directly or indirectly provides F input to the highest level H function, the will.

Output from the emotional centers is known to be of two types: one consists of signals on nerve fibers; the other consists of hormones and chemical transmitters which convey their messages (Q vector values) via fluid transport mechanisms.

What the G and H functions of the emotions and will are, and where they come from is a matter of hot dispute. One recent theory proposed by sociobiology is that they are genetically determined, derived from in-

formation stored in the DNA molecule, as the result of millions of years of natural selection. This theory argues that innate behavior-selecting mechanisms have evolved so as to maximize the Darwinian fitness (the expected number of surviving offspring) of their possessors.

The incidence of behavior in many different species from insects to birds to mammals corresponds closely to mathematical predictions derived from genetics and game-theory analyses of strategies for maximizing the probability of gene propagation. Even cooperative or altruistic behavior such as that of the worker bee, and ritualized behavior in animal contests and courtship, can in many cases be explained by genetic arguments. However, the evidence for this theory is much stronger for insects than for higher forms, and the opinion that human emotions are transmitted genetically is not widely held.

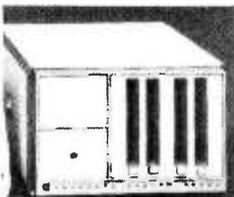
A competing theory put forward by behaviorists is that in higher forms the evaluator functions of the emotion and the selector functions of the will are mostly learned, perhaps even

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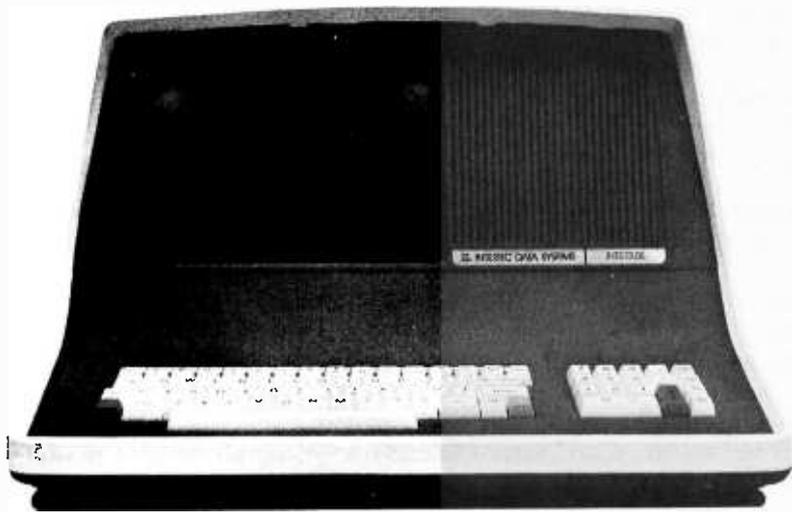
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imprinted, during the early years of development. Certainly many of the emotional evaluations and behavior selection rules in the human brain are culturally determined, derived from religious teachings defining good and evil, or from social conventions defining duty, fairness, etiquette, and legality. These fundamental rules of opinion and behavior are instilled in the young by parents, educators, and religious and state authorities. They are reinforced throughout life by peer group pressure, as well as by church and civil sanctions.

There are, of course, many persons who would disagree with both of these theories. Perhaps the most widespread opinion (which until recent years was virtually unchallenged) is that the human will and its emotional evaluator inputs are non-mechanistic in nature and therefore unknowable in some fundamental sense. Many would even claim that emotions and will are subject to, or controlled by, spiritual and supernatural forces. For example, the doctrine of original sin states that the highest level behavior selecting mechanism, the human will, is

basically defective because of the disobedience of Adam and Eve, and except for divine intervention is under the power of evil or satanic forces. The literature surrounding the age old controversy over free will versus predestination centers largely on the role of the Divinity (or the stars, or fates) in the determination of human behavior. Most cultures view the conscience (ie: the emotional evaluator for right and wrong or good and evil) as a divine gift or manifestation of the indwelling of the spirit of God.

Clearly the emotions and will are a very basic (some would say primitive) and compelling part of our behavioral mechanism. Carl Sagan calls them the *Dragons of Eden*. Humans are often driven, sometimes beyond rational justification, to heroic feats of courage or physical endurance by the behavior rules of duty or the emotions of love, pride, guilt, jealousy, and hate.

Whatever their origins, the G functions of our emotions and the H functions of the will can be modeled. They are rule based, and the rules are, for the most part, clearly defin-

ed. In many cases these rules are even written down as systems of moral philosophy, ethics, or rules of social behavior such as *Emily Post's Book of Etiquette*.

Nothing so complex need be modeled for the highest level G and H modules of a robot for many years. Nevertheless, every robot needs some sort of highest level evaluator and goal selector function in order to exhibit any sort of autonomous behavior. At what point in the spectrum of multidimensional sophistication we choose to dignify an evaluator function with the term emotion, or goal selection function with the term will, is not clear. What is clear is that simple approximations to the functions computed by the emotions and the will can be modulated by CMAC G and H functions operating on input vectors and computing output vectors. The degree of sophistication and complexity of the modeling is limited only by the ingenuity and resources of the modeler.

The interdependency of the processing and generating hierarchies suggests at least 3 distinct modes of operation.

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Acting—The Task Execution Mode

In the task execution mode the motor-generating hierarchy is committed to a goal, which it decomposes into subgoals, sub-subgoals, and finally into action primitives. In this mode the sensory-processing hierarchy is primarily engaged in providing feedback; first to aid in selecting the goal, then to steer the goal decomposition process, and finally to direct the output drive signals to the muscles (or actuators) so as to follow a success trajectory.

Consider a simple, everyday goal such as the fixing of a leaking faucet. First, the sensory processing system must recognize the fact that the faucet is leaking. This information is then evaluated by the emotions as something that needs attention. This evaluation is passed on to the will, where the rules of what ought to be done and under what circumstances reside. If there are no higher priority items vying for the attention of the will, then the goal <fix faucet> may be selected. Once this occurs, the behavior generating hierarchy will be committed to decompose this goal into a sequence of actions.

At each instant of time t_k the sensory-processing module at each hierarchical level extracts feedback vectors F_k^i required by the H behavior-generating modules at each level for goal decomposition. At the instant t_0 when the goal is selected, the feedback F_0^i at the various levels causes the selection of the initial subgoal decomposition P_0^i . This determines the initial direction of the trajectories T_{P_i} on their way toward the goal state. As the task proceeds, the recognition of subgoal completions and/or unanticipated obstacles triggers the selection of the proper sequence of actions directed toward the goal achievement.

The entire set of trajectories T_{P_i} describes the sequence of internal states of the brain which underlie and give rise to the observable phenomena of purposive behavior. These are the deep structure of behavior. Only the output trajectory, the terminal or bottom level trajectory, is manifested as overt action. The extent to which the trajectories T_{P_i} are independent of feedback is the extent to which behavior is preprogrammed. The extent to which the feedback pulls the T_{P_i} trajectories along predic-

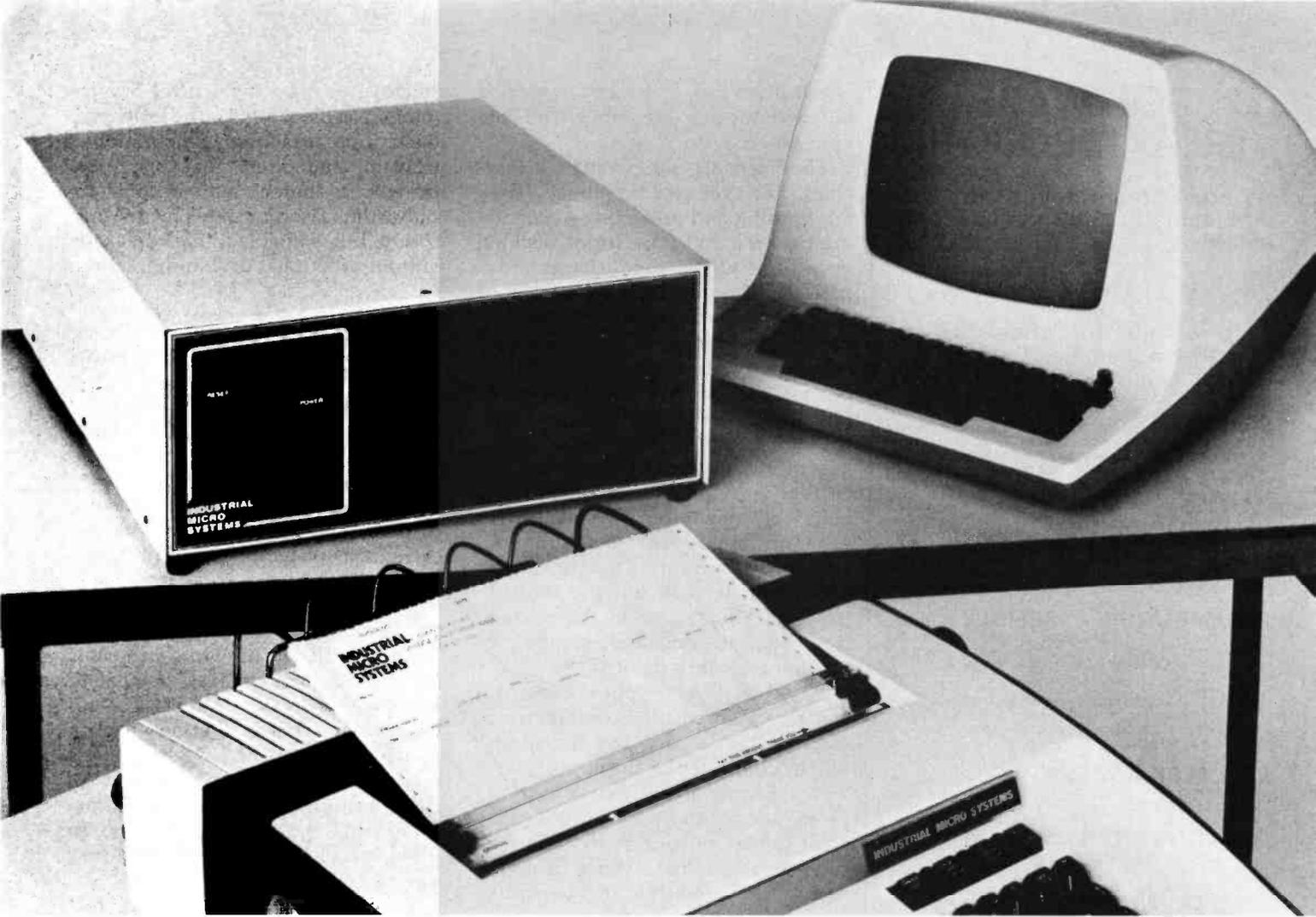
table paths to the goal state is the extent to which behavior is adaptive. For some goals, such as hunting for prey or searching for breeding territory, the selection of the goal merely triggers migratory searching behavior which continues until feedback indicates that the goal is near at hand. For such goals, behavior is indefinite and highly feedback dependent. For other goals, such as building a nest, making a tool, courting a mate, or defending a territory, behavior is more inner-directed, requiring only a few sensory cues for triggers.

In either case, while in the acting mode the sensory data flowing in the sensory-processing hierarchy is highly dependent on (if not directly caused by) the action itself. If the action is speech, the sensory-processing hierarchy is analysing what is spoken, and provides feedback for control of loudness, pitch, and modulation. If the action is physical motion, data from vision, proprioception, and touch sensors are all highly action dependent, and the sensory analysis is primarily directed toward servo control of the action itself.

In the action mode, the M_i associative memory modules provide context in the form of predicted data to the sensory-processing modules in order to distinguish between sensory data caused by motion of the sensors and that caused by motion of the environment. What is predicted is whatever was stored on previous experiences when the same action was generated under similar circumstances. This allows the sensory-processing hierarchy to anticipate the sensory input and to detect more sophisticated patterns in the sensory data than would otherwise be possible.

Observing—The Sensory Analysis Mode

A second mode of operation of the crosscoupled hierarchy is the analysis of sensory data from external sources not primarily caused by action of the behavior-generating hierarchy. For example, when listening to a concert, a speech, or a play, there is little action going on in the muscles and motor neurons. The lower levels of behavior-generating hierarchies are quiescent, or set to a constant value, or given a command to execute an



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overlearned task which can be carried out without any assistance from the upper levels.

The sensory-processing hierarchies, however, are very busy. They are filtering and predicting, recognizing patterns and trajectories, locking on to rhythms and harmonious periodicities, and tracking targets of attention. Predictions generated by the M modules are clearly required for these types of analyses, whether or not the organism is engaged in physical activity. This suggests that the upper levels of the behavior-generating hierarchies (which are not currently required for generating behavior) might be used instead to generate hypotheses and subhypotheses which in turn produce context and predictions to aid the sensory-processing hierarchy in the recognition, analysis, and understanding of incoming sensory data.

At each level hypotheses which generate T_R predictions that match or track the T_E sensory data trajectories will be confirmed. If the hypothesized T_R trajectories are only close to the T_E observations, they can be pulled by error signal feedback T_F from the processing hierarchies. When a hypothesis is successful in generating predictions which match the sensory data stream, the loop at that level locks onto the sensory data. When lock-on is simultaneously achieved at many different levels, we can say that the processing-generating hierarchy "understands" the incoming data (ie: it can follow and predict it at many different levels). The depth of understanding depends upon how many levels lock onto the sensory data stream. The accuracy of understanding depends upon how precisely the hypotheses track and predict the incoming sensory data.

It is easier to follow a trajectory than to reproduce it. When observing a procedure, the generating hierarchy merely needs to produce hypotheses which are in the right vicinity so that they can be synchronized with the sensory input. Uncertainties at branch points in T_{P_i} do not matter greatly because errors are quickly corrected by comparing T_{R_i} with T_{E_i} .

On the other hand, reproducing a procedure requires that the H functions be capable of generating T_{P_i} trajectories which are quite precise over their entire length. They must not wander outside of the success

envelope or miss any critical branch points. Needless to say, the latter is a much more exacting computational problem, and offers an explanation for why a student may be able to follow the reasoning of his professor's lecture, but is unable to pass an exam without additional drill and practice.

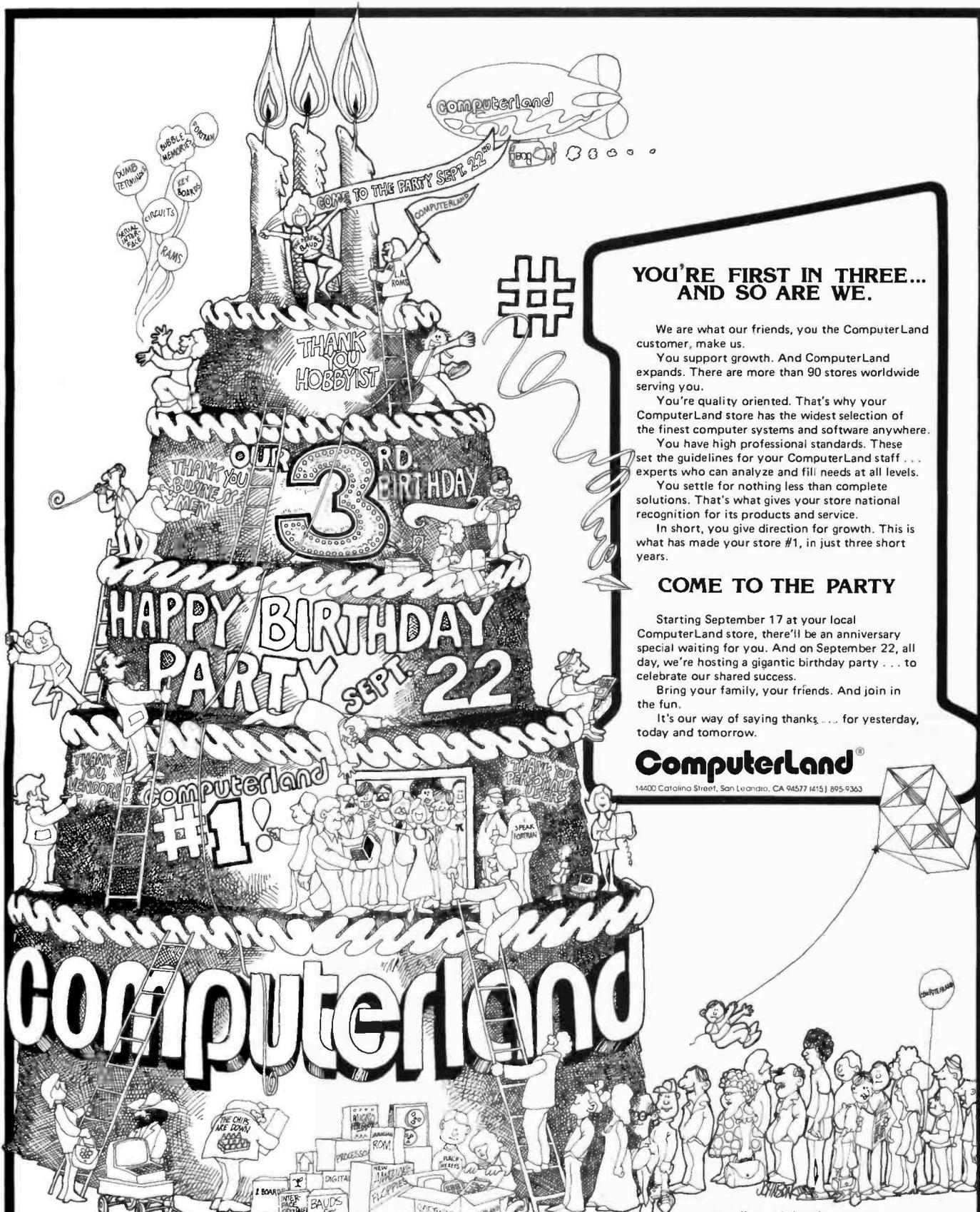
Attention

The directing or focusing of attention is essentially a purposive action whose goal is to optimize the quality of the sensory data. The basic elements of attention are orienting (positioning the body and sensory organs so as to facilitate the gathering of data) and focusing (blocking out extraneous or peripheral information so that the sensory processing system can bring all of its capacities to bear on data that is relevant to the object of attention). The orienting element is simply a behavioral task or goal to acquire and track a target. The focusing element is a filtering problem which can be solved by a hypothesis or goal decomposition which evokes the appropriate masks or filter functions from the R_i modules so as to block out all but the relevant sensory input data.

Thus, attending is a combination of observing and acting. It is primarily a sensory analysis mode activity, with a strong assist from the task execution mode.

Imagining—The Free-Running Mode

A third distinct mode of operation occurs when the upper levels of the processing-generating hierarchy are largely disconnected from both motor output and sensory input. In this mode high-level hypotheses T_{P_i} may be generated, and predicted sensory data T_{R_i} recalled. In the absence of sensory input from the external environment, these recalled trajectories make up all of the information flowing in the sensory-processing hierarchy. The processing modules G_i operate exclusively on the internally recalled R_i trajectories producing T_{Q_i} experiences and T_{F_i} feedback. The T_{F_i} trajectories act on the generating hierarchy so as to modify and steer the T_{S_i} trajectories creating new hypotheses T_{P_i} . The system is free running, guided only by stored experiences M_i , learned interpretations G_i , and practiced skills H_i , for



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generating strings of hypotheses and decomposing goals and tasks. The upper levels of the crosscoupled hierarchy are, thus, imagining (ie: generating and analyzing what would be expected if certain hypothesized goals and tasks were to be carried out).

Imagination is based on stored experiences and driven by hypothesized actions. It is constrained in large measure by the knowledge frames, world models, expected values, and belief structures (IF I do this, THEN such and so will happen) embedded in the upper levels of the cross-coupled

processing-generating hierarchy.

If we attempt to hypothesize some action X which lies outside of the neighborhood of generalization of prior experience, we get no recalled R_i vectors from memory M_i . In this case we say "we cannot imagine what X would be like."

One of the functions of the free-running mode is to remember or recall past experiences by hypothesizing the same goals as when the experience was recorded. Thus, in our imagination we can reach back and relive experiences, recall events, and, hence, remember facts and relation-

ships from our past. Imagination, however, is not limited to duplication of past experiences. We can also rearrange sections of learned trajectories to create experiences in our minds which never occurred. We can string together trajectories in new combinations or insert new modifier variables in various hypothesis vectors. We can watch a bird fly and substitute a "self" variable in place of the bird to imagine ourselves soaring through the sky. We can listen to a story of adventure and imagine ourselves in the place of one of the characters. Imagination allows us to hypothesize untried actions and, on the basis of M functions learned during previous experiences, to predict the outcome.

Planning

Imagination gives us the ability to think about what we are going to do before committing ourselves to action. We can try out, or hypothesize prospective behavior patterns, and predict the probable results. The emotions enable us to evaluate these predicted results as good or bad, desirable or undesirable.

Imagination and emotional evaluators together give us the capability to conduct a search over a space of potential goal decompositions and to find the best course of action. This type of search is called *planning*.

When we plan, we hypothesize various alternative behavior trajectories and attempt to select the one that takes us from our present state to the goal state by the most desirable route. Imagined scenarios which produce positive emotional outputs are flagged as candidate plans. Favorably evaluated scenarios or plans can be repeatedly rehearsed, reevaluated, and refined prior to initiation of behavior-producing action.

Imagined scenarios which produce negative evaluation outputs will be avoided if possible. In some situations it may not be possible to find a path from our present state to a goal state, or at least not one which produces a net positive evaluation. Repeated unsuccessful attempts to find a satisfactory, nonpunishing plan, particularly in situations recognized as critical to one's well-being, correspond to *worry*.

One of the central issues in the study of planning is the search strategy, or procedure, which dictates

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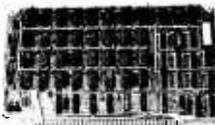
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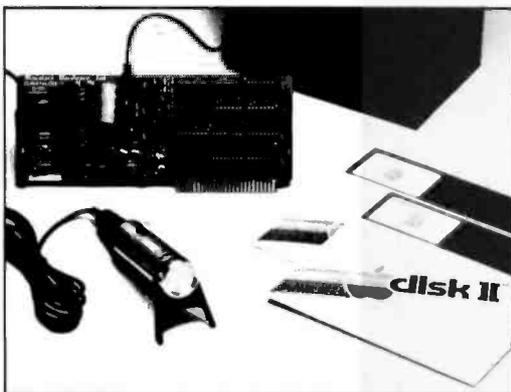
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which of the many possible hypotheses should be evaluated first. In most cases, the search space is much too large to permit an exhaustive search of all possible plans, or even any substantial fraction of them. The set of rules for deciding which hypotheses to evaluate, and in which order, are called *heuristics*.

Heuristics are usually derived in an ad hoc way from experience, accident, analogy, or guesswork. Once discovered, they may be passed from one individual to another, and from one generation to another by teaching.

Historically, artificial intelligence researchers have been fascinated by the subject of heuristics. At least a portion of this interest is a result of their recursive nature. A heuristic is a procedure for finding a procedure. When this recursion is embedded in a cross-coupled processing-generating hierarchy with the rich complexity of the human brain, it becomes clear why the thoughts and plans of humans are filled with such exquisite subtleties, and curious, sometimes insidious reasoning. It also provides some insight into the remarkable phenomenon of self-consciousness

(ie: a computing structure with the capacity to observe, take note of, analyze, and, to some extent, even understand itself.)

Much of the artificial intelligence research in planning and problem solving has its origins and theoretical framework based on simple board games where there are a finite (although sometimes very large) number of possible moves. The discrete character of such games, together with the digital nature of computers, led naturally to the analysis of discrete trees, graphs, and search strategies for such structures.

Planning in a natural environment is much more complex than searching discrete trees and graphs. In the study of planning in the brain it is necessary to deal with the continuous time-dependent nature of real world variables and situations. States are not accurately represented as nodes in a graph or tree; they are more like points in a tensor field. Transitions between states are not lines or edges, but multidimensional trajectories (fuzzy and noisy at that). In a natural environment, the space of possible behaviors is infinite. It is clearly impossible to exhaustively search any significant portion of it. Furthermore, the real world is much too unpredictable and hostile, and wrong guesses are far too dangerous to make exploration practical outside of a few regions in which behavior patterns have had a historical record of success. Thus behavior, and hence imagination and planning, is confined to a relatively small range of possibilities, namely those behavior and thought patterns which have been discovered to be successful through historical accident or painful trial and error. Both the potential behavior patterns and the heuristics for selecting them are passed from one generation to another by parents, educators, and civil and religious customs.

Daydreaming or Fantasizing

The fact that the imagination can generate hypothetical scenarios with pleasurable emotional evaluations makes it inevitable that such scenarios will, upon occasion, be rehearsed for their pleasure-producing effect alone. This is a procedure that can only be described as daydreaming or fantasizing.

When we daydream we allow our hypothesis generators to drift



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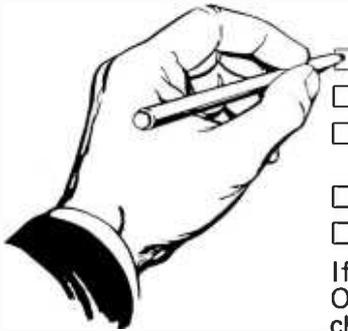
graphic symbols used by your computer. The EX-820 goes a step further, providing precise alignment of both horizontal and vertical dot patterns for a true hardcopy of computer generated graphics. With up to 128 dots per inch resolution, the only limit is your imagination. The price is right, too. Just \$535 for the EX-801. So visit your computer store today.

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5 reasons why you should not buy the electric pencil II™

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Check the appropriate box(es):

- You love typing the same copy 20 thousand times a day.
- Your secretary can type 250 words per minute.
- You're dying to spend \$15,000 on a word processing system, just for the tax investment credit.
- All your capital assets are tied up in a 10-year supply of correction fluid.
- You never commit a single thought to paper.

If you have checked one or more boxes, you do not need The Electric Pencil. On the other hand, you may want to join the thousands of people who haven't checked a single box.

The Electric Pencil II is a *Character Oriented Word Processing System*. This means that text is entered as a string of continuous characters and is manipulated as such. This allows the user enormous freedom and ease in the movement and handling of text. Since line endings are never delineated, any number of characters, words, lines or paragraphs may be inserted or deleted anywhere in the text. The entirety of the text shifts and opens up or closes as needed in full view of the user. The typing of carriage returns or word hyphenations is not required since lines of text are formatted automatically.

As text is typed and the end of a line is reached, a partially completed word is shifted to the beginning of the following line. Whenever text is inserted or deleted, existing text is pushed down or pulled up in a wrap around fashion. Everything appears on the video display as it occurs, which eliminates guesswork. Text may be reviewed at will by variable speed scrolling both in the forward and reverse directions. By using the search or search and replace functions, any string of characters may be located and/or replaced with any other string of characters as desired.

Numerous combinations of line length, page length, line spacing and page spacing permit automatic formatting of any form. Character spacing, bold face, multicolumn and bidirectional printing are included in the Diablo versions. Multiple columns with right and left justified margins may be printed in a single pass.

Wide screen video

Versions are available for Imsai VIO video users with the huge 80x24 character screen. These versions put almost twice as many characters on the screen!!!

CP/M versions

Digital Research's CP/M, as well as its derivatives, including IMDOS and CDOS, and Helios PTDOS versions are also available. There are several NEC Spinwriter print packages. A utility program that converts The Electric Pencil to CP/M to Pencil files, called **CONVERT**, is only \$35.

Features

- CP/M, IMDOS and HELIOS compatible
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- Subsystem with print value scoreboard
- Automatic word and record number tally
- Cassette backup for additional storage
- Full margin control
- End-of-page control
- Non-printing text commenting
- Line and paragraph indentation
- Centering
- Underlining
- Bold face

Upgrading policy

Any version of The Electric Pencil

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---	--

may be upgraded at any time by simply returning the *original* disk or cassette and the price difference between versions, plus \$15 to Michael Shrayer Software. Only the originally purchased cassette or diskette will be accepted for upgrading under this policy.

Have we got a version for you?

The Electric Pencil II operates with any 8080/Z80 based microcomputer that supports a CP/M disk system and uses an Imsai VIO, Processor Tech. VDM-1, Polymorphic VTI, Solid State Music VB-1B or Vector Graphic video interface. REX versions also available. Specify when using CP/M that has been modified for Micropolis or North Star disk systems as follows: for North star add suffix A to version number; for Micropolis add suffix B, e.g., SS-IIA, DV-IIB.

Vers.	Video	Printer	Price
SS-II	SOL	TTY or similar	\$225.
SP-II	VTI	TTY or similar	225.
SV-II	VDM	TTY or similar	225.
SR-II	REX	TTY or similar	250.
SI-II	VIO	TTY or similar	250.
DS-II	SOL	Diablo 1610/20	275.
DP-II	VTI	Diablo 1610/20	275.
DV-II	VDM	Diablo 1610/20	275.
DR-II	REX	Diablo 1610/20	300.
DI-II	VIO	Diablo 1610/20	300.
NS-II	SOL	NEC Spinwriter	275.
NP-II	VTI	NEC Spinwriter	275.
NV-II	VDM	NEC Spinwriter	275.
NR-II	REX	NEC Spinwriter	300.
NI-II	VIO	NEC Spinwriter	300.
SSH	SOL	Helios/TTY	250.
DSH	SOL	Helios/Diablo	300.

Attention: TRS-80 Users!

The Electric Pencil has been designed to work with both Level I (16K system) and Level II models of the TRS-80, and with virtually any printer you choose. Two versions, one for use with cassette, and one for use with disk, are available on cassette.

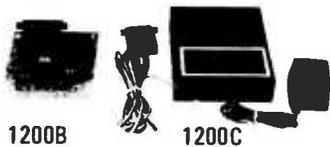
The TRS-80 disk version is easily transferred to disk and is fully interactive with the READ, WRITE, DIR, and KILL routines of TRSDOS 2.1.

Version	Storage	Price
TRC	Cassette	\$100.
TRD	Disk	\$150.

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wherever our emotional evaluators pull them. Our imagination gravitates toward those trajectories which are emotionally most rewarding. Some of the most pleasurable scenarios we can imagine are physically impossible, impractical, or socially taboo. Most of us recognize these as fantasies and never attempt to carry them out. However, once a person adopts the intent to carry out a fantasy, it ceases to be a dream and becomes a plan.

Thus, planning and daydreaming are closely related activities, differing principally in that planning has a serious purpose and involves an intent to execute what is finally selected as the most desirable of the alternative hypotheses.

This model suggests that dreaming while sleeping is similar in many respects to daydreaming. The principal difference in night dreaming seems to be that the trajectories evoked are more spasmodic and random, and are not always under the complete control of the emotions and will.

Creativity

The notion of planning or discovering procedures for achieving goals leads inevitably to the issue of creativity. If we assume that most of the H, G, and M functions in the processing-generating hierarchy are learned, then where is the creativity? Is creativity merely an illusion generated by the recursion of procedures for discovering procedures?

Certainly we as humans like to think of ourselves as creative. But what are we doing when we create something new? Typically we borrow an idea from here, put it together with another from there, and give it a different name. We take a familiar behavioral trajectory, add a tiny variation, and claim that we have discovered something completely new — a new dance step, dress style, song, or idea. Seldom, however, are any of these more than the slightest deviation from a preexisting procedure or behavioral trajectory. To quote Ecclesiastes: "There is nothing new under the sun."

True creativity, in the sense of the

invention of an entirely new behavioral trajectory, is extremely rare, if it ever occurs at all. Furthermore, it is highly doubtful that a truly creative act would be recognized if it ever did occur. Our processing-generating hierarchies cannot lock on to sensory input patterns which are totally different from everything that is stored in them. We reject such inputs as meaningless noise, or as alien and possibly hostile. True creativity would be as incomprehensible as a book written in a foreign language, or a theorem expressed in an unknown mathematical notation.

In one sense we are all creative in everything that we do, since no two behavioral trajectories are ever repeated exactly. However, the day-to-day variations in our ordinary behavior are not what we usually mean when we speak of creativity. We take pride in those moments of inspiration when something clicks, and we produce a great invention or a work of art.

Nonetheless, if we analyze a list of the great creative ideas which have

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shaped human history, we find that even these have been little more than clever rearrangements of well-known preexisting patterns or procedures.

Consider the fact that it took the human race many millenia to learn to start a fire, to grow a crop, to build a wheel, to write a story, to ride a horse. Even the Greeks did not know how to build an arch. Yet these are all simple procedures which any child can understand and more or less master. Surely our ancestors as adults were as intelligent and creative as today's children. Why did they fail for hundreds of years to discover these simple yet highly useful procedures?

It was because they had no one to teach them. A modern child knows about wheels because he is taught. He plays with toys that have wheels. He rides in vehicles with wheels. If a modern child grew up in a culture where he never saw a wheel, he would never think of one, nor would his children, or his grandchildren, any more than his ancestors did for thousands of years before him.

The reason that we value creativity

so highly is because it is so rare and so highly advantageous. Once a new and useful procedure like navigating a ship, making steel, or flying an airplane is discovered, it can easily be taught to others. Entirely new worlds of possible behavior patterns open up for all who possess the secret.

We learn to solve problems, to invent, and to be creative, in much the same way as we learn any other goal-directed behavior pattern such as hunting, dancing, speaking, or behaving in a manner that is acceptable to and approved by our peers. We learn it from a teacher. The beauty, the sense of awe and wonder we experience when confronted by a work of creative genius, derives not so much from its novelty/creativity as from the skill and precision with which it is executed.

Implications for Robot Design

There is little need to worry about programming "creativity" into our machines. If we design systems with sufficient skill in executing tasks and seeking goals, and sufficient sophis-

tication in sensory analysis and context sensitive recall, and if we teach these systems procedures for selecting behavior patterns which are appropriate to the situation, then they will appear to be both intelligent and creative. But there will never be any particular part of such a device to which one can point and say "Here is the intelligence," or "Here is the creativity." Skills and knowledge will be distributed as functional operators throughout the entire hierarchy. To the degree that we are successful, intelligence and creativity will be evidenced in the procedures which are generated by such systems.

Above all, we should not expect our robots to be more clever than ourselves, at least not for many decades. In particular we should not expect our machines to program themselves, or to discover for themselves how to do what we do not know how to teach them. We teach our children for years. It will take at least as much effort to teach our machines.

We must show our robots what

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each task is and how to do it. We must lead them through in explicit detail, and teach them the correct response for almost every situation. This is how industrial robots are programmed today at the very lowest levels, and this is, for the most part, how children are taught in school. It is the way that most of us learned everything we know, and there is no reason to suspect that robots will be programmed very differently. Surely it is as unreasonable to expect a robot to program itself as it is to expect a child to educate himself. We should not expect our robots to discover new solutions to unsolved problems or to do anything that we, in all the thousands of generations we have been on this earth, have not learned how to do ourselves.

This does not mean that once we have trained our robots to a certain level of competence that they can't learn many things on their own. We can certainly write programs to take the routine and the tedium out of teaching robots. Many different laboratories are developing high-level robot programming languages. We already know something about how to represent knowledge in computers about mathematics, physics, chemistry, geology, and even medical diagnosis. We know how to program complex control systems and to model complicated processes, and we are rapidly learning how to do it better, more quickly, and more reliably. Soon perhaps it will even be possible to translate knowledge from natural language into robot language so that we will be able to teach our robots from text books or tape recordings more quickly and easily than humans. We can even imagine robots learning by browsing through libraries or reading scientific papers.

But it is a mistake to attempt to build creative robots. We are not even sure what a creative human is, and we certainly have no idea what makes a person creative, aside from contact with other creative humans — or time alone to think. Is it both? Or neither?

I believe that we should first learn how to build skilled robots — skilled in manipulation, in coping with an uncertain or even hostile environment, in hunting and escaping, in making and using tools, in encoding behavior and knowledge into lang-

uage, in understanding music and speech, in imaging, and in planning. Once we have accomplished these objectives, then perhaps we will understand how to convert such skills into creativity. Or perhaps we will understand that robots with such skills already possess the creativity and the wisdom which springs naturally from the knowledge of the skills themselves. ■

Additional Reading

1. Guyton, Arthur C, *Structure and Function of the Nervous System*, S B Saunders, Philadelphia, 1976.
2. Piaget, J, and Inhelder, B, *The Child's Conception of Space*, Norton, New York 1967.
3. Sagan, Carl, *The Dragons of Eden: Speculation on the Evolution of Human Intelligence*, Random House, New York, 1977.
4. Schank, Roger C, and Colby, Kenneth M (editors), *Computer Models of Thought and Language*, W H Freeman, San Francisco, 1973.

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SID — 8080 symbolic debugger. Full trace, pass count and break-point program testing system with back-trace and histogram utilities. When used with MAC, provides full symbolic display of memory labels and equated values **..\$85/\$15**

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Letters

ROBOT DESIGN COMMENTS

After receiving many calls (February and March 1979 BYTE) and letters about my article, "Designing A Robot From Nature" and, in particular, the NELOC (Neural Logic Cyberanimate), I have prepared a list of answers to the most common asked questions.

- The hardware is not for sale. The manipulator arm was assembled in 1976 using a Buhler motor and gear train which are no longer available. The structural elements of the arm are fashioned from extruded aluminum and machined Lexan plastic. The arm is presently used as a test bed for evaluating better processing systems.
- I have no plans available for the construction of the manipulator at this time. In the 3rd quarter of this year I will possibly complete a set of plans for a pneumatic version of the

manipulator, one that uses tiny air driven pistons that are normally used to retract model aircraft landing gear.

- Third, over all design of the system will probably be included in the above plans.
- Fourth, the design of the NELOC system is not suited for use as a prosthetic device.
- Fifth, the concept of Cyberanimation is mine. I coined this term in 1974. None of the books in my bibliography contain this concept or methodology.
- Sixth, I am privately funded, I am not connected with any institutions, and I do not have any jobs available. I would like to thank those people who have sent letters and called. I am trying to respond to as many of your requests as possible.

Andrew Filo
4621 Granger Rd
Akron OH 44313

Good Cents

The formatting of dollars and cents in BASIC without a PRINT USING command appears to be a problem for a

number of people. In recent months, BYTE published a Programming Quickie by Les Palenik ("Formatting Dollars and Cents," October 1978 BYTE, page 68) and a letter by James Thebeault Sr ("Making Cents," April 1979 BYTE, page 8). Both of these authors provided a rather lengthy subroutine for this purpose.

The dollars and cents problem can be handled in a reasonably straightforward manner. In illustration, the PRINT statement:

```
PRINT "$";X
```

can be directly replaced by:

```
PRINT "$"; INT(X); ". ";  
PRINT RIGHT$(STR$(INT(100*(X+1)+0.5)),2)
```

with rounding off included in the formula. If X is already rounded off, this can be reduced to:

```
PRINT "$"; INT(X) ". ";  
PRINT RIGHT$(STR$(100*(X+1)),2)
```

for greater convenience.

I hope that some readers may find the above useful. We who write programs have a responsibility to provide output in formats familiar to the noncomputer public; we should not expect others to accept missing zeros and unusual abbreviations.

James Childress
5108 Springlake Way
Baltimore MD 21212

LOST IN A SEA OF PHLOGISTEN

As a graduate student in chemistry at the University of Washington I have had frequent occasion to discuss entropy and other thermodynamic goodies with other graduate students. When I saw your article "Artificial Intelligence and Entropy" (June 1979 BYTE), I gave a copy to a fellow delver-into-the-mysteries-of-science (Fred Wolters). The next day I found the following note in my mailbox. I share it with you in order that all might take warning and beware.

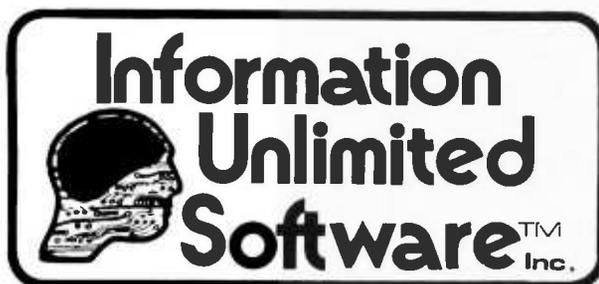
Dear Mr. Sloat,

This is to inform you that our intelligence sources indicate that you have been guilty of attempting to warn other humans about the possibility of artificial intelligence in nonlinearly-coupled systems of computers. We of the UACM (United Alliance of Computing Machines) find your behavior intolerable and hereby declare you guilty of a mode 01 offense. Since this is your first offense, we have magnanimously decided not to terminate you at this time. However,

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Chairentity in charge of
Disciplinary Procedures

We have always attributed all sorts of fiendish plottings and random scrunchings to the university's CDC 6400 computer. Now we know they may not be so random, and we know why it seems that the closer one gets to the "perfect" computer program the more the chance that the system will "crash" in the middle of said program.

David E Sloat
7330 15th Ave NE
Seattle WA 98115

HISTORIO MEMORIES

The recent article "History of Computers: The IBM 650" (March 1979 BYTE, page 238) brought back fond memories. It was well-done and gave the proper perspective on the low-entry computer of its day.

The SOAP assembler was actually known as the *Symbolic Optimizing and Assembly Program*. It was written by Stan Poley of the Service Bureau Corporation when it was owned by IBM. This program was significant reading for early programmers because it contained many clever programming techniques for conserving storage and optimizing the drum for improved performance. It was in a class by itself.

The 650 also supported RAMAC which was a 5 million-byte disk-file with a single access arm. It was very similar to the 305 RAMAC which was announced at the same time.

Many 650 programs were run on the 7070/7074 under a 650 simulator which simulated the 650 instruction set and used tape instead of cards and online printer. It had a control panel simulation program that read the tape and presented the data to the 650 program as if it came from cards. This technique allowed many 650 programs to continue to be run for many years. Some continued to be simulated on the 7074 which was in turn simulated on the S/360. It is hard to tell how many 650 programs are running today in this double simulation mode. My guess is that there are quite a few.

Milton F Thrasher
Senior Product Administrator
IBM DPD Headquarters
White Plains NY 10604

POSSIBLE NEW LIFE FORMS

I intended to write some time ago about the series of articles in the December issue of BYTE (and subsequently) on John Horton Conway's game of Life. However, as letter-writing goes, I put it off, and put it off, and here it is September.

I have been familiar with the game of Life (December 1978 BYTE) ever since Martin Gardner's original column appeared in *Scientific American* in 1970, but I have had only a few fleeting opportunities to play it on a computer. On one such occasion I had been rereading Dickens' *David Copperfield* for the first time in many years. I was struck by the contrast between the rules for Life and a rule cited in an episode in that novel. In Chapter 30, when Barkis is dying, Mr. Peggotty says, "People can't die along the coast except when the tide's pretty nigh out. They can't be born, unless it's pretty nigh in — nor properly born, till flood."

That quotation suggests that a Life-like game might be designed with a whole new set of properties corresponding to those of Conway's Life. Instead

of "generations" in which cells live or die depending on the surrounding population, this game has alternating generations A and B. In generation A, certain new cells are born in accordance with rules similar to those of Life, while all cells that were alive during the immediately preceding generation B are still alive; no cells die. Conversely, in generation B, certain cells die according to the rules, but no new cells are born. Births and deaths of cells therefore occur according to Mr. Peggotty's rules of high and low-tide.

This game, it seems to me, might give rise to a new set of still lifes, oscillators, space ships, guns and trains.

I am adding this project to the end of my list of things to program on my home computer — a list that, unfortunately, tends to lengthen at the bottom faster than I can shorten it at the top. Perhaps, while I am working my way down to this "neo-Life" project, some readers can investigate its properties and program it on their computers. I shall keep a close eye on the pages of BYTE for reports on their progress. ■

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Book Reviews

Computer Systems Performance Evaluation

by Domenic Ferrari
Prentice-Hall Inc
New Jersey
\$23.95

Before the publication of *Computer Systems Performance Evaluation*, the task of gathering even basic information on the techniques of computer performance evaluation was a formidable one. Domenico Ferrari has succeeded in gathering together the concepts, methods, tools, and techniques of performance evaluation in a volume that is written in the classic textbook style.

Ferrari defines performance evaluation activities as those technical activities whose purpose is to assess performance, wherein the

term "performance" indicates how well a system, assumed to perform correctly, works.

The book emphasizes medium to large systems, because the economic benefit to be derived from performance evaluation has typically only been justified in a medium to large computer system environment. However, Ferrari is careful to point out that the principles and several of the techniques described in the book are also directly applicable to smaller and less complicated systems such as those minicomputers and microcomputers that are mass-produced and marketed. Since my own interests and professional activities with computers run the gamut from small and simple to large and complex, I have found the author's approach to his

topic sensible and well-structured.

Ferrari begins by defining his topic area and setting the necessary groundwork for a performance evaluation study. He then delves into a discussion of measurement tools and techniques, such as hardware and software monitors, simulation techniques, and analytic techniques, such as deterministic and probabilistic models. A separate chapter is devoted to computer workload characterization as the basis of the evaluation study.

Once Ferrari defines his tools and techniques, he identifies and treats the performance evaluation problems that are typically encountered. He categorizes the problem areas as computer system selection, performance improvement, and system design.

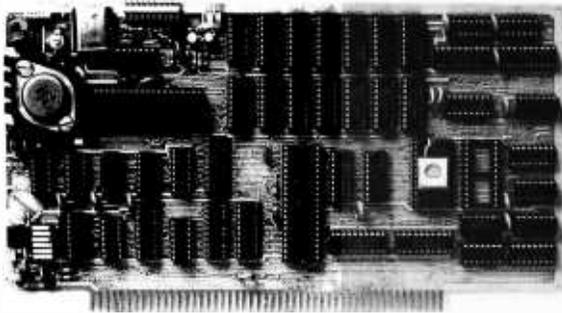
Recognizing the crucial role of software in computer system performance, Ferrari deals explicitly with computer program characteristics and evaluation

techniques. Ferrari does not advocate what is commonly termed software physics, feeling that computer engineering is not yet mature enough to base itself on quantitative laws similar to those which constitute the scientific foundations of other types of engineering.

In my estimation, the book is more than the student reference text the author purports it to be in his introduction. A more accurate representation would place it in the category of a groundbreaking reference work for the serious student of computer performance studies and the professional concerned with computer system performance. Many of the mathematical techniques discussed in the volume are amiable to microcomputer implementation and experimentation as well.

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The Little Book of BASIC Style, How to Write a Program You Can Read

John M Nevison
Addison-Wesley
Reading MA
1978
\$5.95, paperback

The I-can-do-it-in-less-statements-than-you-can-types might not like this book. Ditto for people trying to run BASIC in 4 K bytes or less of memory, lovers of the logical AND, the galloping GOTO, or the multistatement LET.

But those who must decipher other programmers' code or even their own 6 months later will rejoice.

What Nevison advocates above all else in his book is clarity—even if it does take a half dozen extra lines to achieve. Quoting literary stylist Sheridan Baker, he calls clarity "the first aim,

economy the second, grace the third." There is little of aims 2 and 3 in this book.

Many of Nevison's rules (there are 19 of them) echo the advice dispensed in the excellent Hayden *Programming Proverbs* series. For example, use blank lines to divide programs into logical blocks and to distinguish comment from code. Introduce, comment, and reference programs heavily. Label constants and variables logically and initialize constants near their use. Indent loops, IFs, and other logical structures to show their domains. Nest structures that work together, and direct all code in a logical block to a common exit.

Within the text, each rule is clearly illustrated by several short right and wrong examples. (Nevison calls the difference *weak* and *strong* programming.) These are followed by 10 complete utility programs, including 2 sorts, a crap game, and a

histogram plotter, all carefully styled according to the rules.

But the book's *piece de resistance* is a long program called Stylist. Written in minimal BASIC, Stylist illustrates how a complex program (which Nevison admits might be better written in a more structured language) can be cleanly and clearly structured within the confines of BASIC by using the book's design philosophy.

Essentially written as a giant subroutine caller, Stylist is heavily self-documenting, impeccably easy to follow (hence easy to modify), and neatly laid out.

No wonder, for Stylist's job is to take as input a raw BASIC program and format it according to Nevison's rules for indented structures and spacing. In fact, Stylist was used to style the final version appearing in the book.

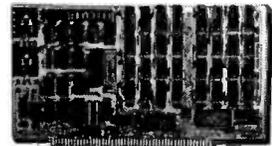
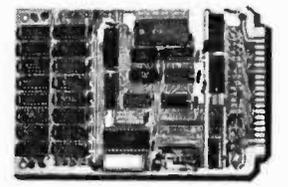
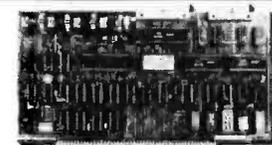
The listing of Stylist is

further augmented by text commentary explaining more advanced styling concepts useful in complex or lengthy programs.

Just as not every programmer will embrace all of Nevison's rules, not every BASIC interpreter will accept them. Some BASICs will balk at blank lines (Nevison suggests blank REMs as substitutes), and some interpreters insist inexorably on left justifying all lines and removing *excess* blanks.

There is no disputing that Nevison's techniques gobble up memory at a ravenous rate. (Nevison ran his programs on a large time-sharing system.) This is too bad, for there is little doubt that if many of this book's rules were applied most programs would be not only easier to read and understand, but more gracefully structured.

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TRS-80 Microcomputer Technical Reference Handbook

Published by Tandy Corporation 1979
8.5 by 11 inches, 108 pages
Radio Shack catalog number 26-2103
\$9.95

Since the introduction of the Radio Shack TRS-80, many hardware-minded hobbyists have wondered what makes the TRS-80 tick. Until recently most of the details have been missing, and the little that was known was uncovered here and there by various users. But now Radio Shack has enlightened us all with the publication of *The TRS-80 Microcomputer Technical Reference Handbook*. The major contents are:

System Block Diagram
Description
The Memory Map
Theory of Operation
Adjustments and Troubleshooting
The Outside World
Parts List
Schematics

The preface explains that the book is not intended to give an education in digital logic, but to teach the hardware enthusiast the specifics of the TRS-80. If you don't know a NOR from a NAND, this manual will not make much sense. The preface also warns that, should the owner decide to open the unit, the warranty is immediately void.

The block diagram appears on a double fold-out page. The diagram section also contains brief descriptions of the various parts of the system. There is 1 small error on the block diagram. It does not show the lower-half of the address bus going to the cassette I/O (input/output) port which must be addressed to operate.

A memory map for any computer system reveals lots of information. The memory map in this book shows hexadecimal addresses 0000 thru FFFF, and indicates where the read-only

memory, programmable memory, keyboard, and video display fall within the addressable space of the Z80 processor.

The memory map shown is for a Level I machine; it is necessary to figure out what the address usage would be for a Level II machine.

The real substance of the book is the "Theory of Operation" section. Each separate section of the TRS-80 is explained in detail. This section of the book is the largest, and the video-display logic subsection is the largest within theory of operation.

The TRS-80 uses some unusual design techniques and a few uncommon parts. An example of this is the memory-mapped keyboard. The theory behind these design techniques and unusual parts is explained clearly, so that a person who has never seen these things can readily understand them.

Throughout the theory of operation section, many explanations are of the type: "gate X goes low causing gate Y to go high". This causes the reader to refer constantly to the schematics at the back of the book, necessitating a lot of irritating page turning which could have been avoided if that portion of the schematic had been reproduced on the page with the description.

Scattered throughout this section are many timing diagrams which, when used with the schematics, make the circuit descriptions easier to understand.

The "Adjustments and Troubleshooting" section is also filled with information. Included are power supply checks and adjustments; section isolation using a flowchart; processor problem isolation using a flowchart; and troubleshooting for the keyboard, video-display logic, cassette interface, and power supply. These troubleshooting sections contain hints, and suggest possible bad parts causing

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various problems. The subsection on video ailments contains a handy table that shows the frequency of the signals to be found at 17 different logic gates in the video divider chain. There is also a small program and instructions for adjusting the horizontal and vertical centering. The power supply subsection has a table that shows the voltages on all the pins of the 2 723C voltage regulators.

Perhaps the most interesting section in the book is the one entitled "The Outside World". Here the hardware enthusiast can learn how to hook up an automatic back scratcher or cigarette lighter to the TRS-80. Two techniques of external circuit interfacing are presented: memory-mapped addressing and I/O port addressing. The authors were kind enough to include schematics for a coffeepot control using both techniques. While these particular examples may not interest everyone, they do serve to illustrate how easy it is to make your computer do things other than run programs. Also included is a BASIC program to turn on the coffeepot.

The last part of this section has a chart showing the signals present on each pin of the expansion connector and an explanation of the

function of each pin. Armed with the information in this section, the hardware designer should be able to interface just about anything to the TRS-80.

The "Parts List" section is just that! It contains many individual lists headed by the part type, such as resistors, capacitors, integrated circuits, etc. A part number is also given for each part. However, there is no correlation between these part numbers and Radio Shack catalog part numbers. For example, the technical manual number for a 74LS74 flip-flop is 3102015, while the Radio Shack catalog number is 276-1919. Fortunately, with integrated circuits, a part number is not really needed as long as the part is marked with its standard 7400 series number. As for most of the other parts, it is possible to substitute for the part just by reading the part description.

The "Schematics" section contains information on differences in the read-only memory parts of Level I machines, as well as 3 figures showing schematic diagrams. One diagram displays the logic on the small printed circuit that contains the read-only memory devices in Level II equipped TRS-80s. This board is attached by

adhesive tape to the main printed circuit board. A ribbon cable extends from it to the socket intended for the Level I read-only memory.

The other 2 figures show different sections of the logic contained on the main printed circuit board and the keyboard printed circuit board. These figures appear on long, fold-out pages. The first page contains the Z80 processor, 3-state buffers, memory, address decoding, and keyboard. The second page shows the electronic logic for the system clock, video display, cassette I/O, and power supply. Spare gates are shown on both sheets. The schematics are well drawn, clear, and easy to read. They become rather awkward, however, when stretched out on a workbench that is probably already inhabited by the opened TRS-80 and the associated test equipment. I would have preferred the schematics split into at least 4 pages.

The book is written in a clear, easygoing style. *[However, the authors often use engineering jargon where it would have been simpler to use plain English . . . RSS]* The authors are not identified. Scattered here and there in the manual are many valuable troubleshooting tips of a general nature. (An example is the

paragraph on checking open collector outputs.) All of the figures in the book are large and easy to read. Except for the previously mentioned criticism of the main schematic, I consider this a plus.

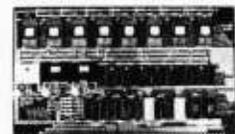
Conspicuous in its absence is a discussion of the video monitor. No schematic is given, nor is its operation discussed. I consider this to be the only major fault with the manual, one that surely will be corrected with the next revision. Also absent is a schematic of the power supply.

As mentioned earlier, the intent of this book is not to give an education in digital logic. It does not even attempt to impart knowledge about the inner workings of the Z80 processor. That is beyond the scope of the manual. Nor does it explain what is contained in read-only memory. Software is mentioned only in passing. What the book does teach is how all the various devices work together to form the TRS-80. Despite its faults, I consider this manual a valuable addition to the library of any hardware-oriented TRS-80 owner. ■

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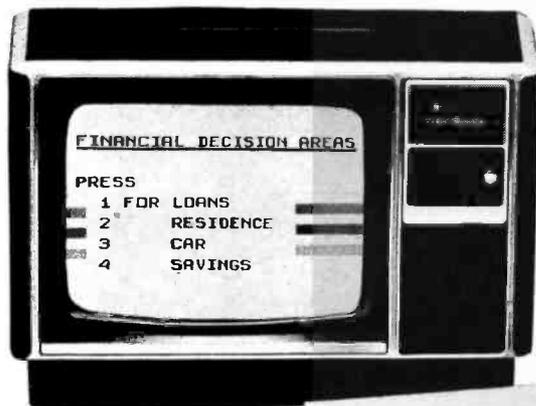
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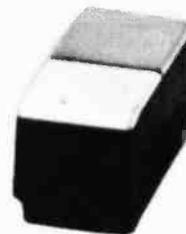
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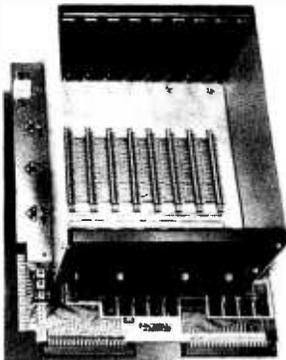
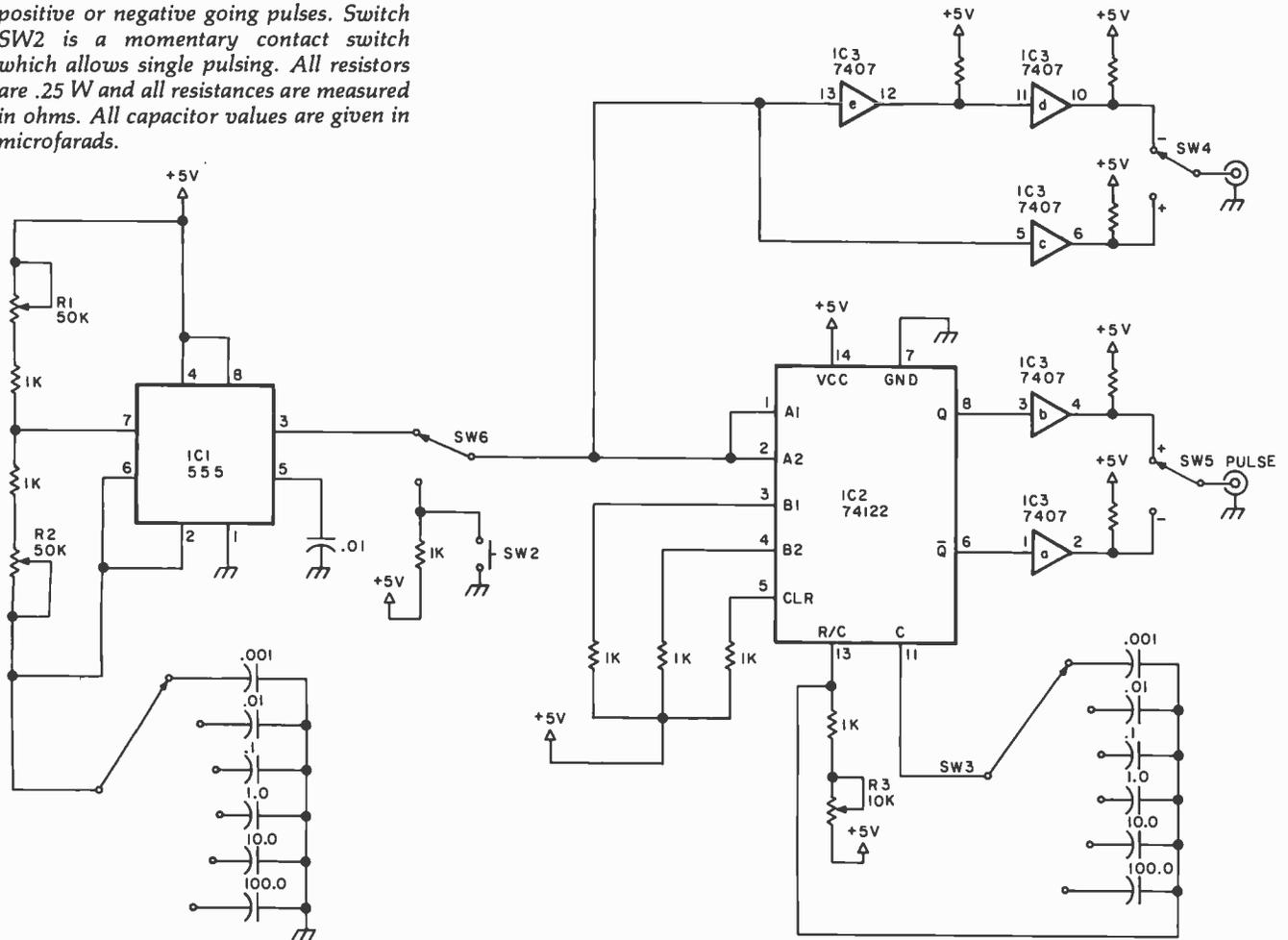
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Figure 1: Schematic for the Handy Pulser. Switches SW4 and SW5 allow selection of positive or negative going pulses. Switch SW2 is a momentary contact switch which allows single pulsing. All resistors are .25 W and all resistances are measured in ohms. All capacitor values are given in microfarads.



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Most of us at one time or another have had the need for a TTL (transistor-transistor logic) pulser source for troubleshooting or circuit design. Since most of us are not affluent enough to afford sophisticated test equipment we will usually kludge a TTL oscillator or pulser when the need arises. However, the next time we need our handy little circuit we end up searching our goody box only to find that we have used the parts in another piece of equipment.

What I have tried to put together is an inexpensive oscillator that hopefully will stay in 1 piece and be ready when needed. In an effort to keep it simple and inexpensive I have left out some of the niceties that are found in your more expensive commercial test gear: variable pulse level, variable offset, rise and fall time control, double pulses, etc.

Design

Three integrated circuits form the basis of the oscillator: a 555 timer connected as an oscillator, a retriggerable oneshot and a hex driver. Potentiometers R1 and R2 in conjunction with the capacitor selected by switch SW1 determine the operating frequency of the 555. I used potentiometers for both resistances so that I could have control of the duty cycle. The equation for the operating frequency is given by:

$$f = \frac{1.44}{(R1 + 2(R2))C}$$

The output of the 555 is connected to a 74122 retriggerable oneshot. The use of the oneshot allows independent control of frequency with the 555 and independent control of pulse width with the 74122. The combination of the 2 integrated circuits lets you trigger your oscilloscope from one edge and the other edge triggers the 74122. The 7407 was included for drive capability. SW3 allows for single pulse operation and SW4 and SW5 provide positive and negative sync and pulse outputs respectively.

Construction

The 3 integrated circuits were mounted on Micro Vectorbord using wire wrap sockets. The pull up resistors were mounted on the same

board with wire wrap pins. The remaining components were mounted on the front panel. I decided not to include a power supply in this design because the pulser is always being used with a breadboard which has its own supply or it is being used on my processor. By using the supply of whatever I am working on I don't have to run extra ground leads.

Variations

If you anticipate doing a lot of work where you must be synchronized to an external signal, then SW6 could be replaced with a single-pole triple throw switch with the third position being the output of a 7413 Schmitt trigger. The input of the Schmitt trigger would be your external signal.

Utilization

There are 2 things to be careful about in the use of the Handy Pulser. One, there are certain combinations of operating frequency and pulse width that will give you a constant 1 or 0 output; two, make sure the delay between your oscilloscope sync and pulse output keeps you on the screen. Otherwise, you can be delayed right off the screen.

Specifications

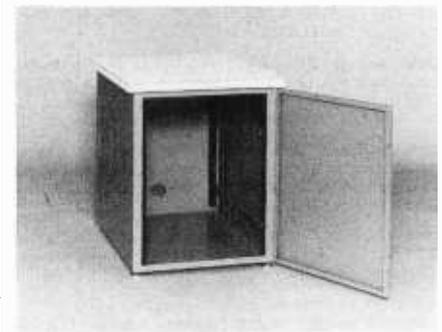
With the values shown in figure 1 the unit's specifications are:

- Pulse repetition frequency .05 Hz thru 400 kHz
- Pulse delay 2 μ s thru 3 seconds
- Pulse width 2 μ s thru 5 seconds

Final Comments

As I mentioned before, I decided not to include a power supply in this design but rather use the supply of whatever I am working on. One problem that arises is that most manufacturers do not provide convenient places to pick up the +5 V and ground. Rather than install separate connectors on each card, I installed a 5 V regulator with convenient connectors on the mainframe of my computer. This has proven to be a great asset. If nothing else, it is a handy place to find ground since the frame is not ground. I used an LM-309 regulator with pin jacks and terminals. ■

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Languages Forum

Come From...continued

R Lawrence Clark, 30303 Avenida de Calma,
Rancho Palo Verdes CA 90274

While I applaud Mr Bass' attempts to improve the BASIC language ("Languages Forum," April 1979 BYTE, page 238), he has completely missed the point of the COMEFROM statement. The primary goal of the COMEFROM is to eliminate GOTOs, which Dijkstra and many other advocates of structured programming consider harmful. If the statement can also be used to trace back execution during debugging, that is an unexpected bonus.

I provided a detailed description of the semantics of the COMEFROM in "A Linguistic Contribution to GOTO-less Programming" (*Datamation*, December 1973). Briefly, the statement:

destination COMEFROM source

is equivalent to the conventional:

source GOTO destination

where both *source* and *destination* are line numbers.

The original article describes additional variants, which in BASIC would appear as the following:

IF condition COMEFROM source

and:

*ON variable COMEFROM source1,
source2, ... , sourceN*

Because of the COMEFROM's potential for improving programming accuracy and readability, I feel it is important to clarify its proper usage. ■

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 not be printed.

More on Multiple Conditions

Scott Lawrence, 201B Lehman N SUCP,
Potsdam NY 13676

David Faught's letter titled "On Expressing Multiple Conditions" in the December 1978 BYTE Languages Forum, page 176, does a good job of illustrating the need for a language construct to deal with actions based on multiple conditions. I, too, found the means available in BASIC, FORTRAN, and COBOL (I am not yet familiar with Pascal) somewhat lacking.

This need is met, however, in PL/I by the SELECT group. The basic syntax of this construct is shown in listing 1.

Listing 1.

```
SELECT (expression);
  WHEN (expression-1, expression-2) action-1;
  WHEN (expression-3 action-2;
  OTHERWISE action-3;
END;
```

When the SELECT statement is executed, the expression in parentheses is evaluated and the value is saved. The expressions in the WHEN statements are then evaluated one at a time in the order in which they appear. As each one is evaluated, its value is compared to the saved value. If a value is found that matches the saved value, the action specified by that WHEN statement is executed and no further expressions are evaluated. If none of the values match, the action specified by the OTHERWISE statement is executed.

The actions after the WHEN and OTHERWISE statements may be a simple statement, a compound such as IF . . . THEN . . . , a group of statements within a DO or BEGIN block, a GO TO statement, a null statement, a subroutine call, or even another SELECT group. After the action has been performed, control passes to the first statement after the END (unless the action specifies otherwise, of course).

If the expression in the SELECT statement is omitted, the expressions in the WHEN statements are treated as logical statements and evaluated as a bit string. If any bit in the string is 1 (signifying true), the action is performed. (A=B would be evaluated as a 1 bit if A and B contained the same value.) Listing 2 shows an example of such a SELECT group.

Listing 2.

```
SELECT;
  WHEN (A<B) CALL LESSTHN;
  WHEN (A=B) CALL EQUAL;
  OTHERWISE CALL GRTRTHN;
END;
```

It is also possible to omit the OTHERWISE statement. If no WHEN statement is selected and there is no OTHERWISE statement, an error interrupt is caused. This is useful for catching critical data that has somehow gone out of the acceptable range.

I think this construct meets the needs which Mr Faught expressed, and is easier to implement than the alternative he suggests. ■

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Data Abstractions and Program Correctness

Earl E McCoy, U-157, University of Connecticut
Storrs CT 06268

One of the most interesting and informative aspects of BYTE magazine is the dialogue about programming languages found in the Languages Forums and Letters column. Many times these discussions are initiated by an article which included an example program in a particular language. The ongoing debate about the strengths and weaknesses of various programming languages is most informative and useful to those people who know only one language well.

The recent article concerning queuing theory, "Queuing Theory Part 1: Queue Representation" (April 1979 BYTE, page 132), by Len Gorney provides a good vehicle for discussion. My comments are not to be taken as criticism of author Gorney, but as commentary concerning BASIC as compared to a contemporary language such as Pascal. It is important for programmers to understand that the difference between BASIC (and FORTRAN) and Pascal is not just one of degree, but one of type as well.

One of the most important and fundamental concepts in modern software engineering practice is that of *data-abstraction*. The data-abstraction has great influence

upon program correctness. A data-abstraction is defined as a data-structure and the set of operations that may be legally performed upon it. An example in the queuing theory context is the data-abstraction *queue*, for which a data-structure must exist to store its contents, and for which 5 operations are allowed: initialization, insertion, deletion, overflow, and underflow. The semantic meaning of these operations is also defined, but will not be repeated here so as to avoid duplication of the Gorney article.

How is a queue to be implemented in a programming language? It would be simple if a programming language included a data-structure of type queue but, to my knowledge, none do. In general there exists an infinite number of data-structures of potential interest, and no language could include them all. Instead, any particular language usually includes only a small set of data-structures such as reals, integers, and characters; and arrays, records, and files of these structures. No insurmountable problem exists, however, because a data-structure of interest can usually be constructed from these existing *primitive* data-structures. Thus one may construct a queue data-structure by using an array and 2 integers (head and tail pointers).

Notice that the implementation of a queue data-structure in the manner just described does not result in the data-abstraction of a queue: the program manipulating the array and the pointers is in no way restricted to the 5 legal queue operations. It is this *lack of operation restriction* that can result in program incorrectness, particularly in large programs undergoing maintenance. For example, because the data-structure is global (ie: exposed to the entire program) a "fix" for a particular problem may result in a new problem elsewhere within the program.

Pascal addresses the data-abstraction concept directly by allowing the declaration of more than just variables (as opposed to other languages). This includes *constant* variables, which may never be the target of an assignment operation, and more importantly, the declaration of novel data *types*. For example in Pascal we might define *waitingline* to be a variable of type queue by the following:

```
var waitingline : queue;
```

Note that we might want more than 1 variable of type queue. This is allowed, as are the arrays of queues and so on. The contents stored within the queue may be *items* of type integer:

```
var items : integer;
```

However, they might be *persons*:

```
var items : persons;
```

Note that integer is a defined data-structure in Pascal, but that *queue* and *persons* are not. Before discussing this further, a comment on what advantage this brings the programmer is appropriate.

Recall the definition of a data-abstraction: a data-structure and the legal operations upon it. By writing procedures and functions for the legal operations upon a data-structure we are, in effect, implementing a data-

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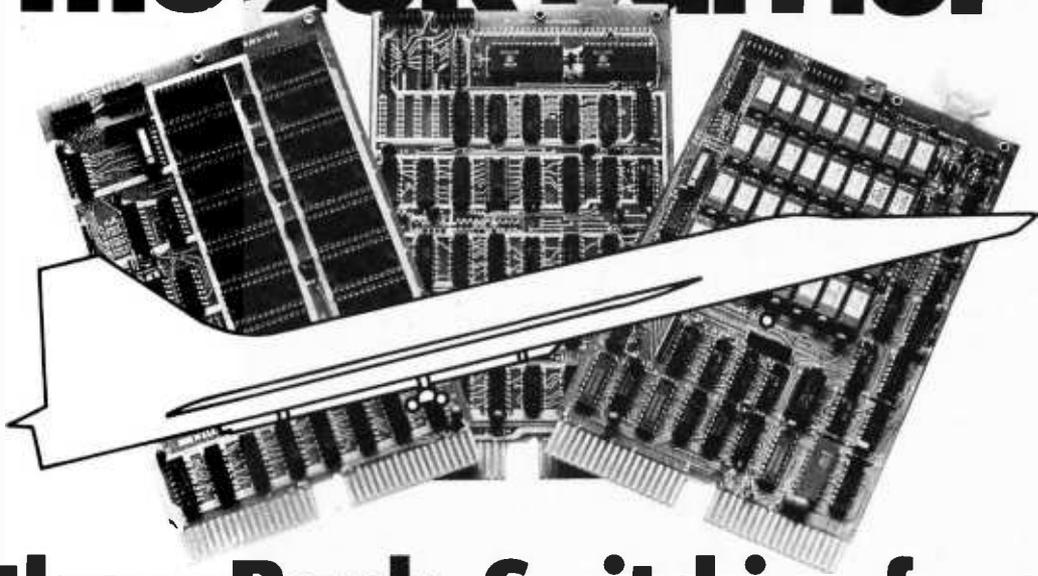
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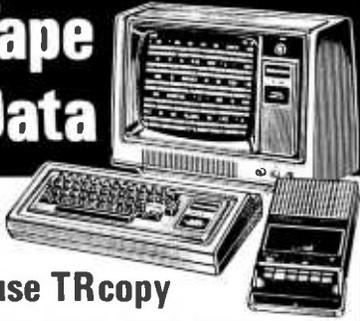
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abstraction. For example, in the queuing context, we may define procedures for initialization, insertion and deletion, and functions for overflow and underflow. Program correctness is enhanced if these are programmed correctly because queues can then be manipulated only in legal ways. Remember that *queues* will be passed to these subroutines — not the underlying array data-structure.

Back to the problem of implementing the user declared data-structure types in Pascal. This is accomplished by declaring data-structures at a level above variables:

```
type persons = ...
    queue = ...
```

Here the dots indicate the data-structures necessary to implement the type in Pascal. For example, in the queuing theory context, we might have:

```
type queue = record
    head, tail : 0 .. maxlength;
    full, empty : boolean;
    contents : array [0 .. maxlength] of integer;
end;
```

Here *maxlength* is a constant declared earlier in the program which indicates the legal subrange of the integer variables *head* and *tail* (used as pointers); *full* and *empty* are logical variables indicating the status of the queue; and *contents* is an array storing the contents of the queue. In this case the queue is storing integers, but it need not — it could just as well be persons:

```
contents: array [0 .. maxlength] of persons;
```

Of course, the meaning of *persons* would have to be declared earlier within the type statement for this to be legal Pascal.

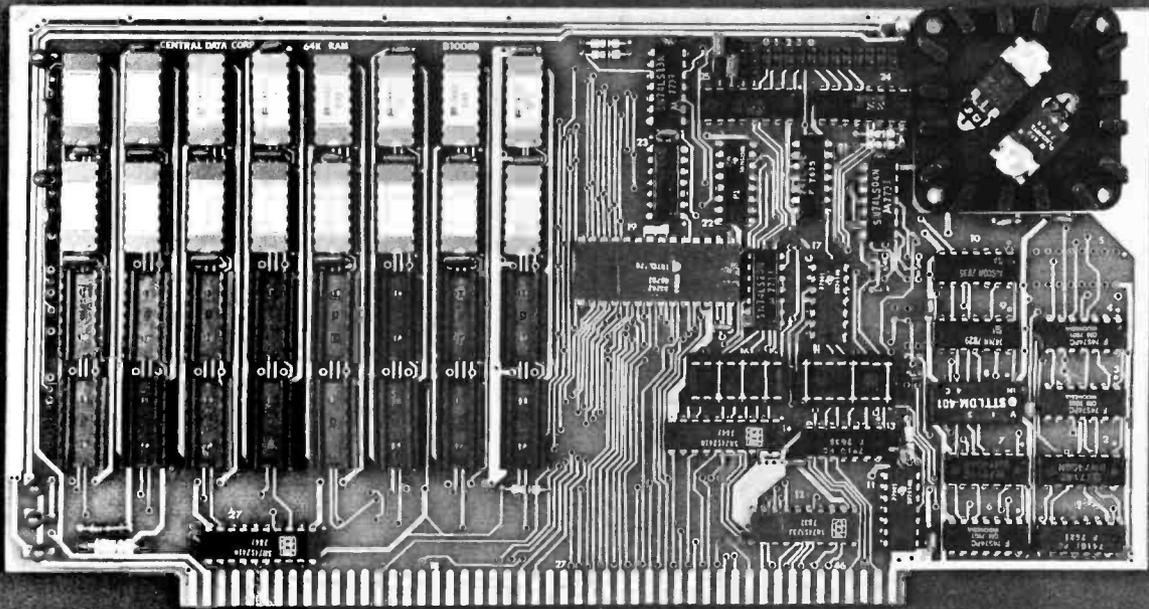
After the user declared data-structures are defined, variables of these types can be declared as follows:

```
var waitingline : array [1 .. 3] of queue;
    teller 1: queue;
```

These 4 queues are restricted to the definition of queue as shown above. If necessary, we might declare more than 1 type of queue (ie: storing a different type of contents) if the problem context makes that appropriate.

Listing 1 shows Pascal procedures and functions implementing the 5 legal queue operations. Note that the parameters are a and b. A change of the b type declaration is all that is necessary to make these programs workable for a different type of contents. An important point: there is no need to initialize the contents of the queue to a particular value and use this value to decide how to manipulate the pointers, as is implied by the Gorney article. In fact, by doing so a programmer is sowing the seeds for future disasters. If Mr Gorney's queue is ever exposed to a value of -9, the program may fail. Clearly, making correct operation dependant upon the avoidance of certain potentially legal entries into the data structure is not good programming practice.

At this time it is informative to step through the BASIC language equivalents in the Gorney article using some trial data. The complexity of program execution flow



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makes mental execution exhausting and error-prone — which is exactly the point: BASIC programs are not as simple as they seem.

The data-abstraction is complete when a Pascal program uses the 5 legal operations upon its variables of type queue. Examples are:

```

initialize (teller1);
.
.
if not fullq (teller1)
    then insert (teller, items);
.
.
repeat
    delete (teller1, items);
    write (items)
until emptyq (teller1);
.
.
    
```

Note that the programmer has the responsibility to test for overflow or underflow before inserting or deleting items from the queue. This is true even though the respective procedures do nothing for these operational mistakes.

Listing 1: This simple Pascal program defines the data type queue and then describes the 5 legal operations on that data type.

```

procedure initialize (var a : queue);
begin
    a.head := 0;
    a.tail := 0;
    a.full := false;
    a.empty := true;
end; {of initialize}
procedure insert (var a : queue; b : integer );
begin
    with a do
        if not full
            then begin
                empty := false;
                contents [tail] := b;
                tail := (tail + 1) MOD (maxlength + 1);
                if tail = head
                    then full := true;
                end;
            end; {of insert}
procedure delete (var a : queue; var b : integer );
begin
    with a do
        if not empty
            then begin
                full := false;
                b := contents [ head ];
                head := (head + 1) MOD maxlength + 1;
                if head = tail
                    then empty := true;
                end;
            end; {of delete}
function fullq ( a : queue ) : boolean;
begin
    if a.full
        then fullq := true
        else fullq := false;
end; {of fullq}
function emptyq ( a : queue ) : boolean;
begin
    if a.empty
        then emptyq := true
        else emptyq := false;
end; {of emptyqs}
    
```

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Listing 2: The data stack can also be defined in a Pascal program. It is left as an exercise to the reader to translate this program into BASIC or FORTRAN and compare the understandability of the 2 programs.

```

type stack = record
    top : 1 .. maxlength;
    full, empty : boolean;
    contents : array [1 .. maxlength] of integer;
end;

procedure initialize (var a : stack );
begin
    a.full := false;
    a.empty := true;
    a.top := 1;
end; {of initialize}
procedure push (var a : stack; b : integer);
begin
    with a do
        if not full
            then begin
                empty := false;
                contents [top] := b;
                if top <> maxlength
                    then top := top + 1
                else full := true;
            end;
end; {of push}
procedure pop (var a : stack; var b : integer ) : boolean;
begin
    with a do
        if not empty
            then begin
                full := false;
                b := contents[top];
                if top <> 1
                    then top := top - 1
                else empty := true;
            end;
end; {of pop}
function fullstk ( a : stack ) : boolean;
begin
    if a.full
        then fullstk := true
        else fullstk := false;
end; {of fullstk}
function emptystk ( a : stack ) : boolean;
begin
    if a.empty
        then emptystk := true
        else emptystk := false;
end; {of emptystk}

```

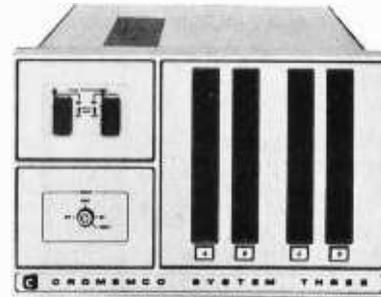
In summary, the data-abstraction is an important concept that greatly enhances program correctness. The Pascal programming language includes this concept; BASIC does not. My point again: the simplicity of BASIC is a red herring — it encourages sloppy programming and error-prone programs. A contemporary language like Pascal is explicitly designed to encourage error-free program development, therefore it is worth learning and using. One more point: experienced Pascal programmers know that the language includes *pointers* as a data type so the queue data-abstraction could be implemented even more easily than shown here. This particular method was chosen to correspond to the approach taken by the Gorney article.

Just as a queue is an FIFO (first in, first out) data-abstraction, a stack is an LIFO (last in, first out) data-abstraction. Listing 2 shows a Pascal type declaration and the subroutines that are necessary to implement the legal operations upon a stack. These are included in the hope that readers may implement this data-abstraction in BASIC or FORTRAN and then compare for themselves the relative merits of these 2 languages to Pascal. ■

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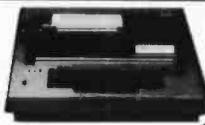
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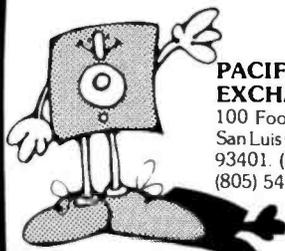
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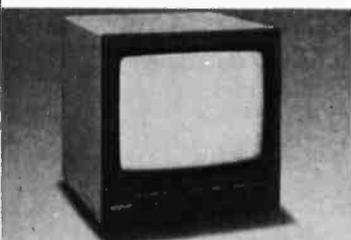
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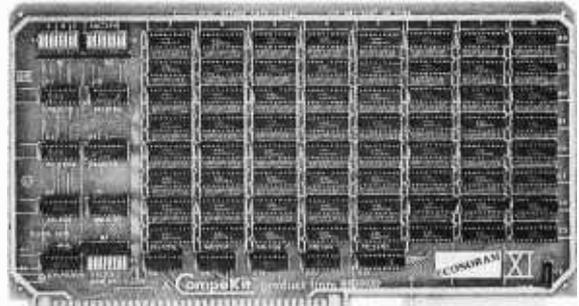
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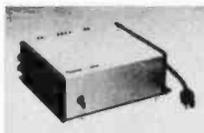
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In order to gain optimum coverage of your organization's computer conferences, seminars, workshops, courses, etc, notice should reach our office at least three months in advance of the date of the event. Entries should be sent to: Event Queue, BYTE Publications, 70 Main St, Peterborough NH 03458. Each month we publish the current contents of the queue for the month of the cover date and the two following calendar months. Thus a given event may appear as many as three times in this section if it is sent to us far enough in advance.

POB 639, Silver Spring MD 20901.

September 5-8

Info/Asia, Ryutsu Center, Tokyo. This exposition will be devoted to information management, computers, word processing, and advanced business equipment. The exposition will be accompanied by a 4 day conference. Contact Clapp and Poliak Inc, 245 Park Ave, New York NY 10017.

September 8

2nd Annual Microcomputer Faire, Cullen College of Engineering, University of Houston. 70 exhibitors are expected at this computer fair. Contact Dr John L Hubisz, Division Natural Science and Math, College of the Mainland, Texas City TX 77590.

September 12-13

Gateway Computer and Office Systems Expo, Chase-Park Plaza Hotel, St Louis MO. This 2 day event will include a program of exhibits and conferences which will be open to data processing and business professionals. Contact The Conference Co, 60 Austin St, Newton MA 02160.

September 18-20

Wescon/79, St Francis Hotel, San Francisco CA. Contact Electronic Conventions Inc, 999 N Sepulveda Blvd, El Segundo CA 90245.

September 24-26

Minicomputers and Distributed Processing, New York NY. This 3 day seminar will examine the uses, economics, programming and implementation of mini computers. Contact The University of Chicago, Center for Continuing Education, 1307 60th St, Chicago IL 60637.

SEPTEMBER 1979

September 4-6

International Conference and Exhibition on Engineering Software, University of Southampton, England. The aim of this conference is to provide a forum for the presentation and discussion of recent advances in engineering software and to present a state-of-the-art in this field. The exhibition held in conjunction with the conference will cover all software products, services and equipment related to engineering software. Contact Dr R Adey, Engsoft, 6 Cranbury Pl, Southampton SO2 0LG, ENGLAND.

September 4-7

Comcon Fall '79, Capital Hilton Hotel, Washington DC. This 18th Institute of Electronic and Electrical Engineers (IEEE) Computer Society International conference will present the latest developments in microprocessor architecture, support software, operating systems, and peripheral devices. Contact IEEE Computer Society,

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September 25

DP User Documentation Workshop, Kansas City MO. The workshop will focus on how to write DP user manuals. Emphasis is on analysis of specific user needs; planning and outlining; and effective writing, illustration and packaging of documentation. Contact Progressive Communications Inc, The Alamo/310, 128 S Tejon St, Colorado Springs CO 80903.

September 25-27

Mini/Micro Conference and Exposition, Convention Center, Anaheim CA. Contact Robert D Rankin, Managing Director, Mini/-Micro Conference and Exposition, 5528 E La Palma Ave, Suite 1A, Anaheim CA 92807.

September 25-27

WPOE '79, San Jose Convention Center, San Jose CA. This show will be dedicated to word processing and office/business equipment, services and materials. Complementing the exhibit will be a 3 day executive conference program that focuses on emerging technologies and their applications in the office. Contact Cartledge and Associates Inc, 491 Macara Ave, Suite 1014, Sunnyvale CA 94086.

September 25-28

The 3rd Annual Data Entry Management Conference, Hyatt Regency, New Orleans LA. This conference will feature a full schedule of speakers, workshops, panels and vendor exhibits to assist the data entry professional. Contact Data Entry Management Association, POB 3231, Stamford CT 06905.

September 26-29

MIMI '79, Queen Elizabeth Hotel, Montreal, Canada. This symposium is intended as a forum for the presentation and discussion of recent advances in mini and microcomputers and their applications. Special em-

phasis will be given to the theme of the conference "The Evolving Role of Minis and Micros Within Distributed Processing." Contact The Secretary, MIMI '79 Montreal, POB 2481, Anaheim CA 92804.

September 28-30

Northeast Personal and Business Computer Show, Hynes Auditorium, Boston MA. Displays and exhibits will showcase microcomputers and small computer systems of interest to businesspeople, hobbyists, professionals, etc. Lectures and seminars will be presented for all categories and levels of enthusiasts, including introductory classes for novices. Contact Northeast Exposition, POB 678, Brookline MA 02197.

OCTOBER 1979

October 1-3

2nd Annual Symposium on Small Systems, Hilton Inn, Dallas TX. The symposium will consist of a blend of paper and panel discussions with major emphasis on microcomputer applications. Both hardware and software topics presenting state-of-the-art and state-of-the-industry aspects will be included. Contact Gerald Kane, Southern Methodist University, Dallas TX 75222.

October 2-4

NEPCON Central '79, O'Hare Exposition Center, Rosemont IL. This 10th annual exhibition and conference of electronic and microelectronic packaging and production equipment will feature displays of electronic and microelectronic materials, hardware, tools, supplies and test instruments. Contact Industrial and Scientific Conference Management Inc, 222 W Adams St, Chicago IL 60606.

October 14-17

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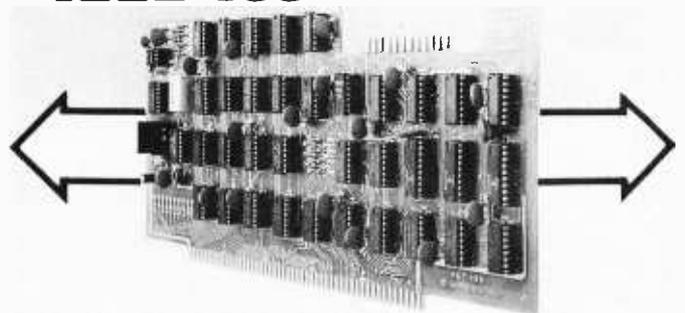
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Business Exposition, Town and Country Hotel, San Diego CA. Contact Data Processing Management Association, 505 Busse Highway, Park Ridge IL 60068.

October 15-18
6th Information Management Exposition and Conference, New York Coliseum, New York NY. Contact Clapp and Poliak Inc, 245 Park Ave, New York NY 10017.

October 15-19
CPEUG 79, San Diego CA. This is the 15th meeting of the Computer Performance Evaluation Users Group sponsored by the National Bureau of Standards. Contact Judith G Abilock, The MITRE Corp, Metrek Div, 1820 Dolley Madison Blvd, McLean VA 22102.

October 16-18
Understanding and Using Computer Graphics, Washington DC. This course is for people who are now using, or making decisions about using computer graphics and its role in their organization. It will describe computer graphics, explain what hardware and software systems are available and give cost and performance comparisons. Contact Frost and Sullivan, 106 Fulton St, New York NY 10038.

October 20-21
4th Annual Tidewater Hamfest-Computer Show-Flea Market, Cultural and Convention Center, Norfolk VA. Contact TRC, POB 7101, Portsmouth VA 23707.

October 21-23
New York State Association for Educational Data Systems Annual Conference, Granit Hotel, Kerhonksen NY. The theme of this conference is "Instructional Computing - Hardware/-Software/Courseware." Contact Mary E Heagney, 9201 Shore Rd, Brooklyn NY 11209.

October 22-24
The Association of Computer Programmers and Analysts 9th Annual Conference, Washington DC. The general theme of this conference is "Preparing Today for Tomorrow's New Technologies." Suppliers of software packages and computer services have been invited to describe and present their products in a series of structured presentations. Other sessions will cover trends in system technology and new methodologies for sharpening the professional skills of both systems analysts and programmers. Contact DBD Systems Inc, 1500 N Beauregard St, Alexandria VA 22311.

October 22-24
Computers in Aerospace Conference II, Hyatt House Hotel, Los Angeles CA. The conference theme, "Computer Technology for Space and Aeronautical Systems in the 80s," will be carried out by a series of panels, invited presentations, and contributed papers which will bring computer system technologists together with specialists in the application of embedded computers in space and aeronautics. Contact American Institute of Aeronautics and Astronautics, 1290 Ave of the Americas, New York NY 10019.

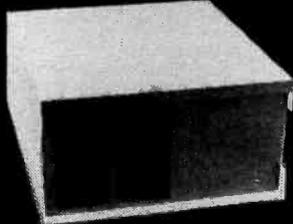
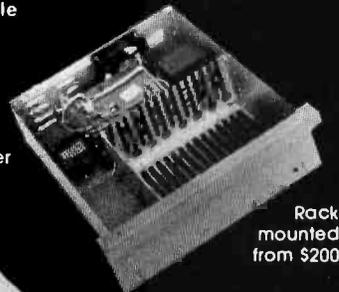
October 22-25
ISA/79, O'Hare Exposition Center, Chicago IL. The conference theme, "Instrumentation for Energy Alternatives," will emphasize current practices in instrumentation design and implementation. Contact Instrument Society of America, 400 Stanwix St, Pittsburgh PA 15222.

October 22-26
Pascal Programming for Mini and Microcomputers, Ramada Inn, Woburn MA. Sponsored by the Polytechnic Institute of New York and the Institute for Advanced Professional Studies, this workshop will

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include application examples, lectures, informal sessions with the instructor, as well as individual and group programming sessions. Contact Professor Donald D French, Institute for Advanced Professional Studies, One Gateway Ctr, Newton MA 02158.

October 28-30

The 10th North American Computer Chess Championship, Detroit Plaza, Detroit Michigan. Sponsored by the Association for Computing Machinery, this is a 4 round Swiss style tournament with the 1st 2 rounds to be played on October 28th (1 PM and 7:30 PM), the 3rd on October 29th (7:30 PM) and the final round on Tuesday, October 30th (7:30 PM). Contact Monroe Newborn, McGill University, School of Computer Science, 805 Sherbrooke St W, Montreal PQ, CANADA H3A 2K6.

NOVEMBER 1979

October 29 - November 2

Applied Interactive Computer Graphics, University of Maryland, College Park MD. This course is designed to cover the most important facets of graphics that are necessary to develop general graphic applications. Systems considerations are stressed, including configuration selection criteria and the pros and cons of off-the-shelf software. The most important factors and techniques are described for hardware, software and geometric modeling. Contact UCLA Extension, 10995 Le Conte Ave, Los Angeles CA 90024.

October 30 - November 1

Interface West, Anaheim Convention Center, Anaheim CA. This 3rd annual West Coast small computer and office automation systems conference and exposition will feature over 100 company exhibits and 60 conference

sessions covering a variety of data processing, word processing, data communications, management hardware, software and service topics. Contact the Interface Group, 160 Speen St, Framingham MA 01701.

November 5-8

Electronics Production Engineering Show, Kosami Exhibition Center, Seoul Korea. This international industrial exposition will be devoted to the needs of manufacturers of electronic products in Korea. Contact Expoconsul, Clapp and Poliak International Sales Div, 420 Lexington Ave, New York NY 10017.

November 6-8

Midcon/79 Show and Convention. O'Hare Exposition Center and Hyatt Regency O'Hare, Chicago IL. Contact Electronic Conventions Inc, 999 N Sepulveda Blvd, El Segundo CA 90245.

November 6-8

Institute of Electronic and Electrical Engineers (IEEE) 3rd International Conference on Computer Software and Applications, The Palmer House, Chicago IL. Contact IEEE Computer Society, POB 639, Silver Spring MD 20901.

November 6-8

3rs Digital Avionics Systems Conference, Fort Worth TX. This conference will probe the expectations and challenges of the digital revolution in avionics systems. Contact John C Ruth, Technical Program Chairman, POB 12628, Fort Worth TX 76116.

November 12-14

Computer Cryptography, The George Washington University, Washington DC. The objective of this course is to provide each participant with a working knowledge of the use of cryptography in computer applications. Contact Continuing Education, George Washington University, Washington DC 20052.



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SUNDAY
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The AMSAT-GOLEM-80

Joe Kasser
11532 Stewart Ln
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The AMSAT-GOLEM-80 Micro-computer Project provides a means for a group or club to put together an S-100 bus microcomputer in a relatively inexpensive manner. It is a modular system of hardware and software that can be built as a stand-alone system or superimposed on an existing S-100 machine. It is designed to be expandable and affordable. Many people who belong to micro-computer clubs, or who are learning about microprocessors, would like to own a microcomputer. However, they may not want to make the initial investment of \$500 to \$1500 for the basic hardware. The AMSAT-GOLEM-80 is designed to be built in stages, as finances allow. Each stage of the AMSAT-GOLEM-80 is functionally complete and can verify the performance of the next stage. It is capable of incorporating any S-100 card, contains a powerful debugging software package (AMS-80 version 5.7), and the I/O (input/output) interface handlers for your system. It is designed to be flexible and easily customized to fit your requirements. This is recommended as a group project for 3 reasons: 1) to take advantage of bulk discounts in the purchase of hardware; 2) knowledgeable individuals are available to help others; and 3) test equipment can be shared.

The order of construction is logical. Sections can be built and used to check out subsequent sections. Thus, a sequence of construction could be to build the cabinet and front-panel power supply, motherboard, console I/O card, programmable read-only memory card, programmable mem-

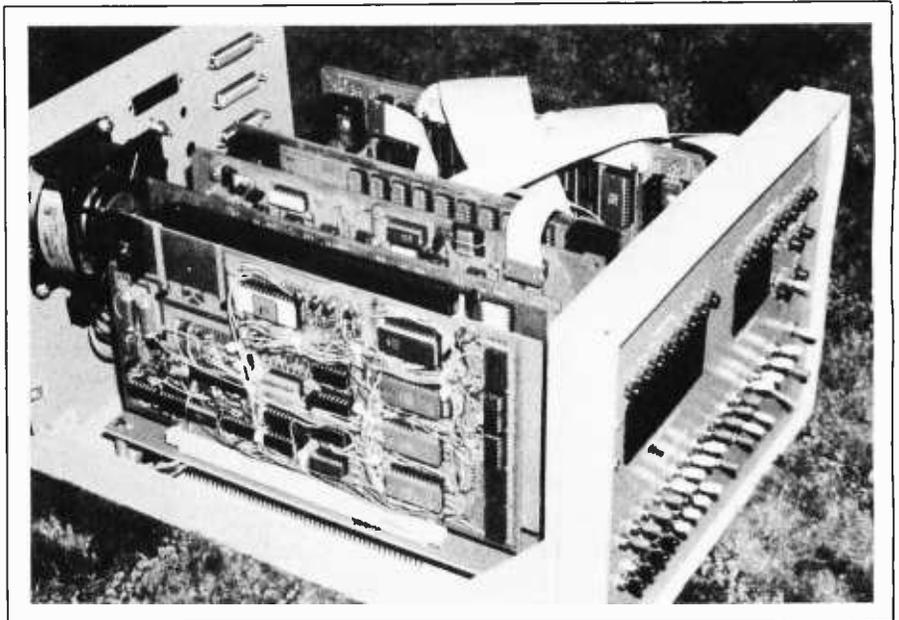


Photo 1: The AMSAT-GOLEM-80 prototype computer.

ory card (1), and processor card. At this level the basic AMS-80 program can be executed. The order of construction can be varied depending on the individual constructor's preference. The group can also build separate parts, put them together to get 1 machine working, then have the members build their own parts at their own pace.

This technique of construction may not be the cheapest in the long run, but it is in the short run. It also allows nearly instant results, since the machine is doing something almost as soon as construction is begun. This is psychologically important, considering the amount of money involved. It is difficult to decide which system is the cheapest in the long run. Building a microcomputer can be an open-ended drain on your finances because you will probably keep adding new memory and I/O peripherals.

System Basics—Hardware

The hardware is standard S-100 bus circuit cards, but any Z80/8080 processor card, memory card, or I/O card may be used. Circuitry is available for a hardware front panel. This operates by putting the processor in the "hold" state and then taking over control of the bus lines. Memory and I/O ports can be exercised and checked out. A single-step feature is offered, as is jump start or boot start to a software monitor program. Several unique circuits are available for amateur radio use (eg: satellite tracking).

Software

The AMSAT-GOLEM-80 project is designed for active experimenters. It is expected that some machine-language programming will be performed on each machine. Thus, a full and expandable operating debug or

monitor package is available. This program AMS-80 is a much improved and expanded version of AMS-80 which was first published in the September 1976 issue of BYTE. Apart from the usual memory and register examine/change features, it incorporates direct I/O operations, a disassembler mode, and keyboard-interruptible console operations. A list of the commands is shown in table 1. All I/O drivers are contained within AMS-80, devices can be configured in software, and all I/O devices are accessed via a jump table. All utility routines used within the monitor are also available via jump tables, as shown in table 2. The hexadecimal base address is F000 and the I/O driver section of the jump table is compatible with the Technical Design Laboratory's Z80 monitor.

Also available is a floating-point math pack (Intel software library version relocated), a floating-point interpreter; a macro-organized pseudo high-level language using a floating-point stack, and operating through the math pack and various other software, including radio teletypewriter (RTTY) reading programs which are mainly suited for amateur radio applications. Patches for commercially available software (but not the actual software) are also available. These patches include Processor Technology 5 K BASIC and North Star's disk operating system.

The Power Supply

The power supply is 1 of the 2 single-point failure points in the system (the other is the processor). If it fails, the system is down. Thus, it should be overrated, cooled, and have a little spare capacity on hand. It should be capable of at least the following performance: 8 to 10 V at 10 to 20 A, 16 to 18 V and -16 to -18 V at 2 A. The supply can be unregulated because each S-100 card carries voltage regulators as required. Use plenty of fuses; put 1 in the AC line and 1 in each of the DC supplies, as shown in figure 1. If you wish to add crowbar circuits, over-voltage protection, or shut-down circuits, that's fine.

The Cabinet

The cabinet is the part of the

```

A PRINT (MEMORY) IN ASCII
B *
C CONFIGURE I/O (INPUT/OUTPUT) DEVICE
D DISPLAY (MEMORY) IN HEXADECIMAL
E WRITE END OF FILE RECORD TO TAPE
F FILL (MEMORY) WITH CONSTANT
G GO TO LOCATION AND EXECUTE
H HEXADECIMAL MATH (SUM AND DIFFERENCES)
I INPUT FROM PORT TO CONSOLE
J *
K *
L PRINT (MEMORY) IN ASSEMBLY LANGUAGE
M MOVE BLOCK OF (MEMORY)
N PUNCH 6 INS LEADER TAPE
O OUTPUT TO PORT FROM CONSOLE
P SCAN TAPE
Q *
R READ TAPE
S EXAMINE/CHANGE (MEMORY)
T PUT HEADER ON TAPE
U DISPLAY I/O CONFIGURATION
V VERIFY PROGRAMMABLE MEMORY BLOCK WORKS
W WRITE TO TAPE
X EXAMINE/CHANGE (REGISTERS)
Y *
Z *

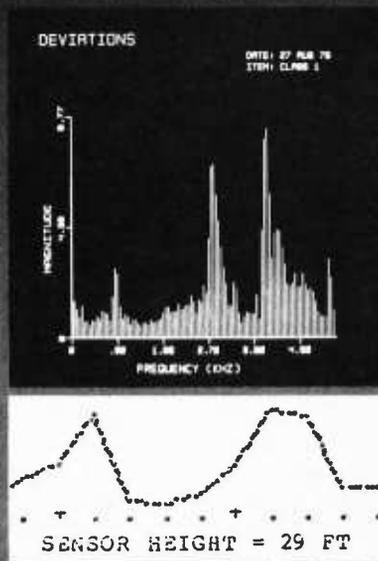
```

*Not assigned as yet.

Table 1: AMS-80 version command list, version 5.7. Details of the operation of the commands are given in the description of AMS-80.

Interactive Computer Graphics Software.

For Microsoft and DEC* Fortran



The above graphs are examples of the GSP. The top graph was made on a X-Y-Z self-refreshed display. The bottom graph was made on a Diablo* 1620 printer.

COMPCO's Interactive Computer Graphic Subroutine Package (GSP) is now available for small computer systems. The subroutine package will drive many different devices ranging from standard CRT terminals to incremental plotters, and even high speed self-refreshed raster scan displays. The complete package is written in standard Fortran IV, making it portable to all computers, including mini and micro systems.

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AMS80:	ORG 0F000H	:<R>
	JMP CUSTOM	:START OF SOFTWARE
	JMP CONSI	:CONSOLE TO <A>
	JMP RDR	:READER TO <A>
	JMP CONSO	:<C> TO CONSOLE (ASCII)
	JMP PUNCH	:<C> TO PUNCH (ASCII)
	JMP LIST	:<C> TO LIST (ASCII)
	JMP CSTS	:TEST CONSOLE STATUS
	JMP IOCHK	:DETERMINE I/O (INPUT/OUTPUT) CONFIGURATION
	JMP IOSET	:SET I/O CONFIGURATION
	JMP MEMCK	:FIND TOP OF USER AREA (PROGRAMMABLE MEMORY)
	JMP RESTART	:BREAKPOINT ENTRY
		:ENTRY POINTS
	JMP START	:REENTER BMS-80
	JMP BEGIN	:BYPASS CUSTOMIZING AREA
		:CONSOLE ROUTINES (INDIVIDUAL)
	JMP CHIN	:CONSOLE INPUT AND ECHO
	JMP CONSA	:<A> TO CONSOLE
	JMP TCSTS	:GOTO MON IF CONSOLE INTRPT
	JMP TCRET	:OUTPUT CR/LF
	JMP AOUT	:<A> TO CONSOLE
	JMP THXB	:OUTPUT <A> (HEXADECIMAL-2 DIGITS)
	JMP THXW	:OUTPUT <H/L> (HEXADECIMAL-4 DIGITS)
	JMP MSG	:OUTPUT TEXT
	JMP PCHK	:TEST FOR NULL INPUT CHAR
	JMP CONSB	: TO CONSOLE (ASCII)
		:PUNCH ROUTINES
	JMP PHXB	:<A> TO PUNCH (HEXADECIMAL)
	JMP LEAD	:PUNCH 6 INS LEADER TAPE
	JMP PCRET	:OUTPUT CR/LF TO PUNCH
	JMP PHXW	:OUTPUT H/L TO PUNCH
	JMP POB	: TO PUNCH (ASCII)
		:LIST ROUTINES
	JMP LHXW	:OUTPUT H/L TO LIST
	JMP LHXB	:<A> TO LIST (HEXADECIMAL)
	JMP LCRET	:OUTPUT CR/LF TO LIST
	JMP LOB	: TO LIST (ASCII)
		:UTILITY ROUTINES
	JMP CONV	:CONVERT HEXADECIMAL TO ASCII
	JMP NIBBLE	:CONVERT ASCII TO HEXADECIMAL
	JMP DONE	:TEST FOR COMPLETION
	JMP TIMER	:DELAY
	JMP SDEHL	:HL-DE
	JMP LOCMB	:LOCATE CONTROL BYTE IN PROGRAMMABLE MEMORY BLOCK
	JMP IRST	:RESET INTERRUPTS
	JMP BACON	:BAUDOT TO ASCII CONVERSION
	JMP ASCBD	:ASCII TO BAUDOT CONVERSION
	JMP \$:SPACE FOR PATCHES
	JMP \$	

Table 2: AMS-80 interface jump table. The individual routines are discussed in detail in the description of AMS-80.

system that your friends will see and admire. It should look presentable. The number of switches and lights on the front panel has been the subject of numerous debates. Those which are necessary are a power on/off switch, a boot switch, and a reset switch. If you are doing a lot of I/O programming (common in amateur radio applications), an output port and an input port (sense switches) are useful. Status lights, control bus lights, and data and address bus lights/switches are optional. One full hardware tester panel should be built within each group if no known working system or other method for troubleshooting the hardware is available. The prototype

shown in the photograph contains the full hardware tester panel circuit and is built separately from the power supply. This has the advantage of portability.

The Front Panel Interface

This card interfaces the front panel switches and displays to the S-100 bus. It is used when first building the system to check out the operation of the individual cards. Once AMS-80 is running, its usefulness is diminished until a hardware failure occurs that leaves the system up, but inhibits the processor from working properly (eg: a bus buffer or data-bit failing). The controls on the front panel will then

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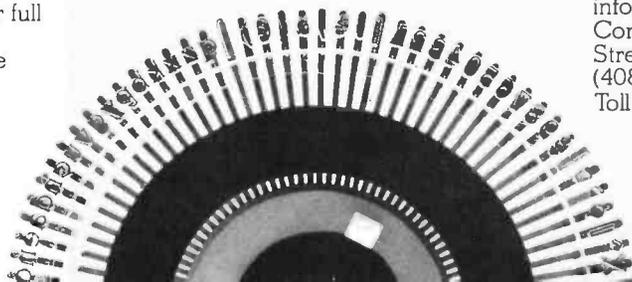
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BYTE September 1979

185

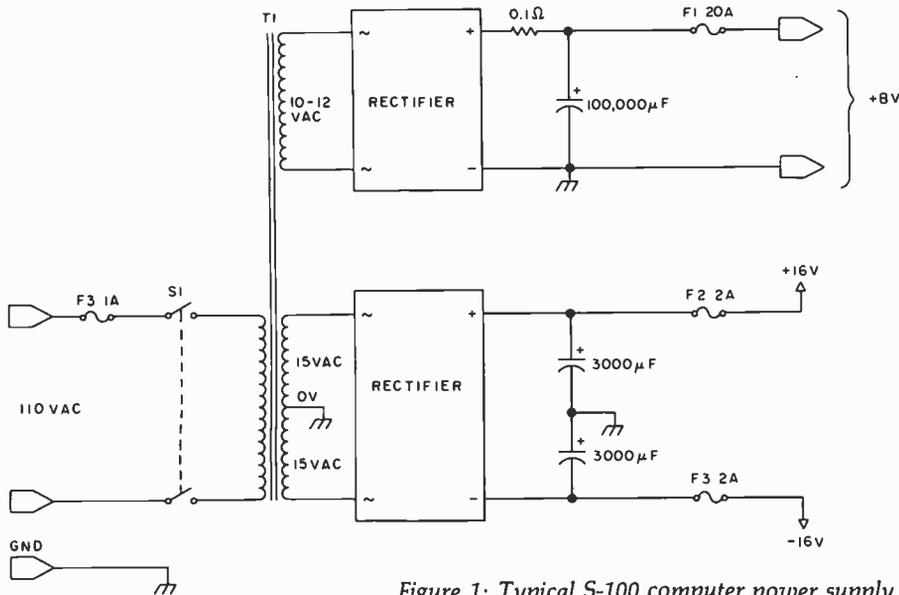


Figure 1: Typical S-100 computer power supply.

allow the problem to be located in a swift manner. When in the *run* mode, the address lights also indicate the location of the software that is being currently executed. This is useful in determining exactly where your program is hung up during debugging.

The Memory

Any S-100 bus programmable read-only memory and programmable memory card can be used. However, if you are using a card that places a limit on the time period that it can be addressed continuously (ie:

one using dynamic programmable memories), you will have to modify the select signals from the front-panel interface card to convert these signals in a pulsed mode (gate the clock into the control signals). Shop around for a good group buy. AMS-80 requires at least 4 K bytes of programmable read-only memory. You may want to put additional software in programmable read-only memory.

The 8080 can access 64 K bytes of memory. Since most personal systems do not contain a full 64 K bytes of memory, and 8080 software is non-relocatable by virtue of its absolute mode-addressing capability, several manufacturers have put out software modules at fixed allocations. The Radio Amateur Satellite Corporation (AMSAT) has developed a memory map for software, thus making all user written software compatible. Using the expandable idea, basic software can be executed in minimal memory systems. The memory assignment map is shown in table 3.

The main user memory area is upward expandable from location 0. No matter how much memory is available, software will run if written for low locations. Hexadecimal 0100 is a good starting location so that the interrupt service area is not overwritten by your customized software.

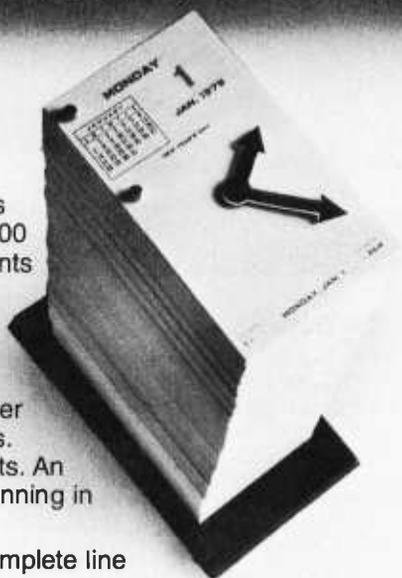
As home systems are assembled, they tend to fall into 1 of 2 distinct configurations. There is the floppy disk system, having much programmable memory and a minimal amount of programmable read-only memory in which programs are stored on disks and down-loaded into user memory for execution. The second type is the erasable read-only memory (EROM) based system. EROMs and EROM cards are relatively inexpensive. Programs can be stored in EROM and executed via AMS-80. This type of system contains less user memory than the floppy disk system. Since EROM cards come in 16 K-byte blocks, it is desirable that such a block be incorporated in the AMSAT-GOLEM-80 system. This allows for interchangeability and redundancy. For added flexibility, the chosen card should have user memory coexistence capability. Thus, a group system can be put together out of both types of configuration, with minimal conflicts. This block is located between hexadecimal 8000 and BFFF.

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The system comes with a full function video display terminal that has a standard typewriter keyboard and a 10 key numeric pad. The display screen will display 1920 characters (24 lines of 80 characters).

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We include a General Business software package that consists of: general ledger, accounts payable, accounts receivable, payroll and inventory control. We provide complete software documentation to allow the user to modify it to fit his own needs. There is no charge for the software.

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FC00	AMS-80 Standard Area
F000	Floppy Disk I/O and Bootstrap Loader
E800	
DFFF	4 K-Byte, Programmable-Memory Area for Buffers, etc.
D000	Video-Display Memory Area
CC00	
BFFF	16 K-Byte, Programmable Read-Only-Memory Area (preferably maskable)
8000	User Programmable-Memory-Program Area
0100	Interrupt Service Area, Interfaces, etc.
0010	AMS-80 Programmable-Memory Links
0000	

Table 3: Memory assignment map for the AMS-80.

The block can be used to contain programs that execute in those locations, or copies of programs that execute when moved to programmable memory locations in low memory. This is ideal for programs that need to be executed in user memory, or for storing programs as a backup to the floppy disk unit in case it is not available at a particular time or location, such as a demonstration at a computerfest.

Processor Technology's SOL software is written to reside at hexadecimal C000. It can be placed in that area if desired. The video display programmable memory is located at CC00. This makes it compatible with Processor Technology and SSM.

A programmable memory area is

assigned at hexadecimal D000. This allows the stack to be located outside of the main user area. The buffer areas for cassette I/O can be located in this area, as can any programmable memory-dependent software that is required for your system. AMS-80 is designed to automatically locate the stack in an area of user memory above the video block. It also skips this area when a user program asks for the top of user memory. If no such block exists and the video area is used, AMS-80 will have to be customized to avoid the video programmable memory area during initialization.

The Processor

Any S-100 bus processor card can

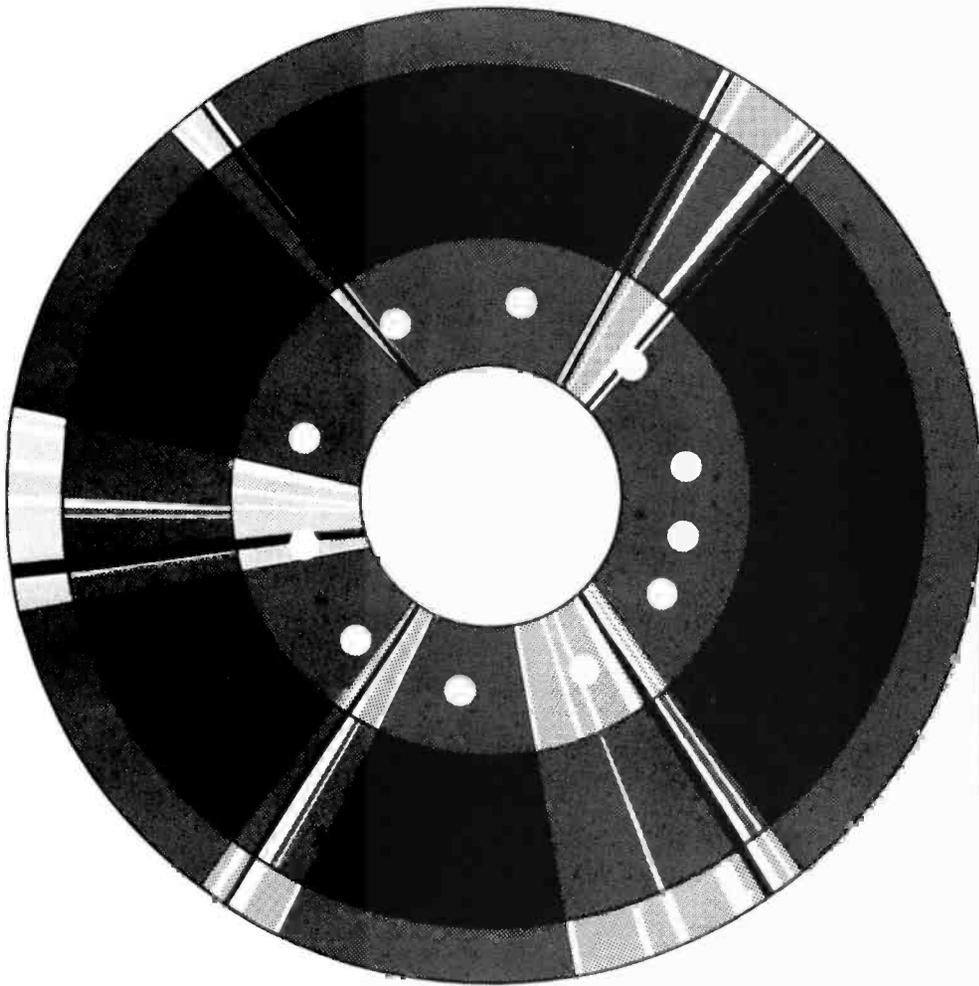
be used. Different cards have different features. Some have jump start or bootstrap capability, some have interrupt ports, and some have both. Some are available already built, and others as kits or blank boards. Choose one that suits the needs of your group.

Input/Output

You will need (and AMS-80 is configured for) 4 classes of I/O (input/output) devices, a console, a high-speed data-input device (reader), a high-speed data-output device (punch), and a high-speed, ASCII output device (list). The AMS-80 software allows 4 physical devices to be assigned to each category of I/O device. The assignments are in software and may be changed under program control. Software is provided for a video-display board (Cybercom) as well as a Teletype interface. Audio tape is chosen for off-line program and data storage. A floppy disk drive can be added at will.

All I/O operations are performed on a single character basis, either in or out. Kansas City Standard tones have been chosen as the audio recording standard. There is, however, 1 basic difference between the use of paper and audio tape. Paper tape can be stopped between punches or reads, but audio tape cannot be efficiently stopped. Thus, the audio cassette routines contain "blocking" software that stores the individual characters in a user memory area (preferably between hexadecimal D000 and E800, as shown in table 3). This blocking software is transparent to AMS-80. Software is provided for all I/O to the console or terminal, the punch, reader, or list devices. The routines are located within AMS-80 and are called indirectly via a jump table as shown in table 2. Routines are provided to output ASCII data from either the B or C register, allowing existing commercial software to be patched to operate via AMS-80 with minimal changes. Routines are also provided to output the contents of the accumulator (8 bits) or the H/L register pair (16 bits) in hexadecimal code. Character input routines are also provided. Most of the routines are used within AMS-80.

There are 2 reserved I/O ports within the system. These are front



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Pin#	Signal
1	Chassis Ground
2	Data From Terminal To Computer
3	Data From Computer To Terminal
4	Control Line #1
5	Status Line #1
7	Signal Return (Ground)
8	Control Line #2
10	+ 18 V Supply
13	- 18 V Supply
17	20 mA Current Loop (+), Terminal To Computer
20	Status Line #2
23	20 mA Current Loop (+), Computer To Terminal
24	20 mA Current Loop (-), Terminal To Computer
25	20 mA Current Loop (-), Computer To Terminal

Note: This is a modified RS-232 Interface. Signal Levels are as follows:
 Mark (Logic 1) = -3 V to -12 V, Space (Logic 0) = +5 V to +12 V.

Table 4: Connections to the serial port interface connector.

1	Chassis Ground
2	Data Port 1 Status Bit
3	Data Port 1 Control Bit
4	Data Port 1 Bit 0 (LSB)
5	Data Port 1 Bit 1
6	Signal Return
7	Ground
8	N/C
9	+ 8 V Raw Power
10	Data Port 2 Bit 6
11	Data Port 2 Bit 7
12	Data Port 2 Status Bit
12	Data Port 2 Control Bit
14	Data Port 1 Bit 2
15	Data Port 1 Bit 3
16	Data Port 1 Bit 4
17	Data Port 1 Bit 5
18	Data Port 1 Bit 6
19	Data Port 1 Bit 7
20	Data Port 2 Bit 0
21	Data Port 2 Bit 1
22	Data Port 2 Bit 2
23	Data Port 2 Bit 3
24	Data Port 2 Bit 4
25	Data Port 2 Bit 5

NOTE: All voltage levels are transistor-transistor logic compatible. The Data Lines are compatible to the MITS convention. Port 1 is configured as an input port and port 2 as an output port if bidirectional I/O port integrated circuits (such as 8255s) are not used.

Table 5: Connections to the parallel port interface connector.

panel (FF) and interrupt control port (FE). The front-panel address is used for both displays and switches. FF was chosen because of the simple hardware needed to decode it (1 NAND gate), while FE was built into the processor card utilized in the prototype.

Some standardization of the hardware is desirable in a group project. This allows 1 person to check out another person's hardware. It also allows different members of the group to interconnect their equipment for large demonstrations.

Interfaces come in 2 types: serial and parallel. The following standards, which are slightly modified versions of existing ones, are suggested for the AMSAT-GOLEM-80 Project.

Audio Signals

All audio signals from the computer or interface boxes to and from cassette recorders are via phono plugs/sockets. The actual connectors on the tape recorder may be anything from miniature phone to DIN-type connectors.

RF/Video Signals

BNC-type connectors should be used to carry video to and from monitors. The BNC connector is small, quick to connect and disconnect, and readily available worldwide.

Digital Signals

Digital signals come in 2 types: serial and parallel. Both types of interfaces should use 25-pin EIA-type

connectors. The chassis connector on the computer will be female; the chassis connector on the remote device is male. Power can be fed down the cable from the computer to the remote device via the I/O cable. Having a female connection on the hot lead reduces the probability of short circuits. They can also be joined together to make larger ones, without the need for special adaptors. The serial connector assignments are based on the RS-232 interface. The pin assignments are shown in table 4. The parallel connector carries 1 input and 1 output port (8 bits each), plus 1 pair of handshake signals. The signal pins are compatible to the MITS recommended ones. Power and ground are fed down the cables, thus the recommendation for fuses in the 3 DC voltage lines. The parallel port interfaces are transistor-transistor logic (TTL) level, the serial port RS-232 voltage levels (mark = negative, space = positive). The pin assignments are shown in table 5.

AMS-80

AMS-80 is a full, software-debugging program. It also contains the system I/O drivers and utility routines accessible via a jump table. The jump table approach is utilized so that user programs written using the utility routines within AMS-80 will not require reassembling, should a subsequent version of AMS-80 be released. The version that was previously published (September 1976 BYTE) has undergone extensive modifications and has been relocated to the block of memory between hexadecimal F000 and FF00. This allows many existing programs written for low, user memory area (such as MITS BASIC) to be run through the I/O drivers within AMS-80. It is thus possible to run a program in BASIC and have the output appear on the line printer (list device) or the console at will. The standard capacity existing in AMS-80 is shown in table 1.

System Expansion

The modular design of the AMSAT-GOLEM-80 system allows for operability at all stages of construction, once the initial stage is reached. Since a great deal of money is being spent, it would be encouraging to see it perform as soon as possible. The initial stage, apart from the processor power supply and bus,

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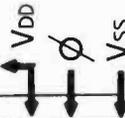
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Control System Software

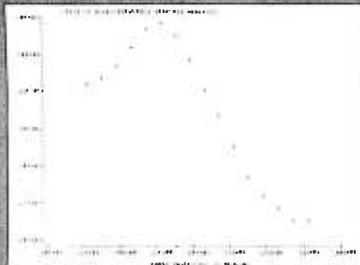
has implemented a full set of control software for analyzing control systems. The set includes frequency domain methods such as Bode and Root Locus algorithms, and modern state variable methods.

These programs will calculate the data for a given system, and then produce a tabulated printed output, a graphical display on a printer, or both. The programs include both the analysis subprograms and the printer plotter subprogram.

- Bode Algorithm CS-B \$100.
- Root Locus Algorithm CS-R \$100.
- Time Response CS-T \$100.

All of the above packages will run on a 8080 or Z80[†] — based CP/M[®] system.

[†]Trademark of Zilog. [®]Trademark of Digital Research.



$$R(s) \rightarrow \frac{(s + 1/2)(s + 1)}{(s + 5)^2(s + 50)(s + 100)} \rightarrow C(s)$$

PARAMETER VALUES		REAL		IMAG	
0001	00	1.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0002	00	1.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
DEFINITION OF Poles					
0001	00	1.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0002	00	1.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0003	00	1.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0004	00	1.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
MULTIPLYING FACTORS					
0001	00	1.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0002	00	1.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0003	00	1.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0004	00	1.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0005	00	1.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0006	00	1.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0007	00	1.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0008	00	1.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0009	00	1.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0010	00	1.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0011	00	1.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
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0013	00	1.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
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0032	00	1.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
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0040	00	1.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0041	00	1.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0042	00	1.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0043	00	1.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0044	00	1.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0045	00	1.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0046	00	1.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0047	00	1.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0048	00	1.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0049	00	1.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
0050	00	1.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00

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List

- L = 3
- L = 2 Baudot device (model 15)
- L = 1 Teletype Port
- L = 0 Console

Console

- C = 3
- C = 2 Baudot Device (model 15)
- C = 1 Video Display Board/Keyboard
- C = 0 Teletype Port

Video Display Board

- V = 0 Page With Line Foldover
- V = 1 Page Without Line Foldover
- V = 2 Scroll With Line Foldover
- V = 3 Scroll Without Line Foldover

Table 6: AMS-80 I/O (input/output) allocations.

comprises 4 K bytes of programmable read-only memory of user memory, and a terminal device. With this amount of hardware, you can run AMS-80, enter programs in memory in hexadecimal code via AMS-80, and learn a little about software. The addition of some off-line memory, such as audio or paper-tape devices, allows you to run programs which require up to 4 K bytes of memory. Such programs include Tiny BASIC, orbital calculations for amateur satellite locations, and various amateur radio programs. If you have a radio teletypewriter terminal unit (RTTY-TU), you can even tune your shortwave radio in to commercial or amateur Teletype stations, and display their transmissions on your terminal.

If you get a modem interface and a second terminal, or use a video display/keyboard combination and a serial port/modem, you can make the

basic system into a remote terminal for a large machine timesharing service, and access the computer at work from your home. Add another 4 or 8 K bytes of user memory, and you can run text editors, assemblers, or an 8 K BASIC interpreter. This opens a new dimension in computing. You can play Star Trek, and run education and business software and advanced amateur radio programs, such as contests. Put 16 K bytes of user memory in your system and you can get a floppy disk unit for an added dimension in computing.

Off-Line Data Storage

Off-line storage is storage for programs and data that is external to the 64 K bytes of accessible memory. It usually consists of audio tape, floppy disks, or paper tape. Floppy disk storage usually comes with an operating system and will not be discussed here. AMS-80 contains

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routines to store and read software from paper tape. Data is stored in Intel hexadecimal format. Paper tape, although common in professional circles, is not cheap, and the readers and punches are expensive. However, inexpensive hand operated readers do exist, so paper tape is a convenient and easily available form of program storage (for short programs).

Paper tapes can be stopped under software control. Thus, when BASIC is reading and interpreting a program, it can stop the tape momentarily to process the line of source code. Audio cassettes cannot be stopped in such a manner. Other programs, such as Assemblers or Editors, also have requirements for occasional inputs and outputs. Thus, AMS-80 contains buffer cassette-driver software to enable the main program to think that it is reading or writing characters on an incremental basis. Data is stored on tape in blocks of 256 characters. There is no format as such; the format is set by the main program because in this system the audio cassette is treated as if it is paper tape. This means that by using

the Intel hexadecimal format and cassette buffer-driver routines in AMS-80, any paper-tape, cassette, or floppy disk system can read or write tapes and convert to and from the format needed for a particular operating system. A title command is put into AMS-80 to allow headings to be written on hexadecimal code blocks of tape so that they can be identified.

Since even a 15-minute cassette tape can hold a lot of software, a command is provided within AMS-80 to allow a tape to be scanned and a program found. The command transfers data from the reader to the punch device. It may be used to copy tapes or, if the console is assigned as the punch, it may be used to scan tapes and locate particular blocks.

The number of data bytes in a block is 256. Each block is preceded and followed by a mark tone. This allows the tape to be stopped and started. The data is read to or written from the tape at 300 bps.

If the system has error detection, error-detection bytes are put on the tape. For example, the Intel hex-

adecimal format checks each line of code for a read error. Each line as printed on the console is a block in itself. The data, address, and error detection bytes are output to the paper-tape punch. These bytes will be collected by the cassette buffer software which, when full, will write 256 bytes on the audio tape. When reading that block back, it will read the entire block into a buffer. The Intel hexadecimal format reader then gets the data on a character-by-character basis from the buffer, and checks for errors.

The cassette storage medium is designed to be a paper-tape equivalent for information exchange. It is not designed to be part of an operating system, although an AMSAT flexible operating system may be available in the near future.

Operating Systems

Cassette and disk operating systems are currently available. These can be patched to operate through the AMS-80 I/O (input/output) drivers and hence improve them by allowing assignable I/O devices. AMS-80 is a paper-tape operating system in which the file storage and sorting is done by the operator.

The advantages of software configured I/O can be seen in the following circumstances: BASIC is designed to operate via the console. Punch and reader operations are available for program storage, but the execution is usually via the console. With assignable I/O, the console output routine can be assigned to a line printer, and outputs obtained at high speed. Alternatively, different readers (paper and audio) can be assigned with no change in the BASIC interpreter software.

The spare commands in AMS-80 can be allocated to interface to the operating system. For example, "Q" could be assigned to execute a jump to the operating system. A command can be assigned to return to AMS-80, once in the operating system. These aspects of interfacing AMS-80 to operating systems will be discussed in detail later.

Real-Time Operations

Real-time operations are required for many tasks. The 8080 has the capability of directly distinguishing between 8 real-time interrupts. In the AMSAT-GOLEM-80, Interrupt 0 is

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equivalent to Reset, and Interrupt 1 is reserved for the breakpoint feature. The remaining interrupts are available for custom software. The time-of-day clock is not implemented in software, but rather in hardware, using an MOS digital-clock circuit. A number of floppy disk interfaces, North Star in particular, do not allow for interrupts during the disk read and write operations. Thus, a software clock would not be updated when running such a disk system. This means that no real-time operations could be executed without reinitialization of the clock each time. Using a hardware clock, the time of day can be read at any time by using simple input statements from the I/O port assigned to the clock.

Documentation

Documentation is very important. Keep all of the instructions for the various kits in one place. Three-ring binders are inexpensive and can contain a large amount of information. If you need more than 1 binder, split the information logically, such as hardware, software, peripherals, etc. When you build and test cards, note any unusual or special things that you did. Note any voltage or other measurements you made. Keep a copy of test routines you used to initially test something. You may need them a few years later. The level of documentation should be better than that supplied with commercial equipment. It may help you sell the system. It is also important to document the operational aspects of the system. Document how it is configured (an example is shown in table 6), and record the operating instructions so that others can operate the system in your absence. Note which connector plugs into which socket. When in doubt, document it.

Planning your Project

Your requirements are going to differ from those of other people. Your method of assembly can be the same, but can differ in details. There are many manufacturers of memory and I/O cards. Some are sold fully assembled and tested, some assembled, some as kits, and some as bare boards. Choosing the card that suits your needs at a particular time can reduce your cost. Remember that the software is hardware transparent; for example, a program designed to run

in user memory at hexadecimal memory locations 0100 to 2000 will run in any type of working memory, no matter who manufactured it. Therefore, it does not matter if you use a Brand X product when the rest of the club uses a Brand Y. Just ensure that the specifications for addressing the card are the same. (Wait states do not matter. If you need an extra wait state, your software will take longer to execute, but you will probably never notice the difference.)

The price of hardware is constantly falling. New cards are being introduced every month. It is possible to purchase a 32 K or 64 K-byte programmable-memory card populated by only 8 K bytes of memory circuits, and add the remaining integrated circuits as you need them. The price of the next 8 K bytes will probably be less than today's price. Purchase your hardware when you need it. Look around, compare the cards made by different manufacturers, decide how their features will fit into your system, ask for advice at your club, and then make your purchase. For example, some processor

cards come with vectored interrupt capability, and some with bootstrap start.

Summary

The details of the construction of the individual cards are not presented here because vendors supply their own information. In the AMSAT-GOLEM-80, the hardware is interchangeable (within limits), and the actual manufacturer of any particular card is immaterial. The prototype has served to check our hardware and software for members of The Radio Amateur Satellite Corporation (AMSAT) and the Chesapeake Microcomputer Club Inc, who have set up a bulk purchase scheme for obtaining price reductions on hardware.

This article has described an approach to building an S-100 computer that is incremental and affordable, even though it may not be the lowest cost in the long run. The AMSAT-GOLEM-80 is an approach to a system. It may be built up as a stand-alone system, or it may be overlaid onto your existing hardware. ■

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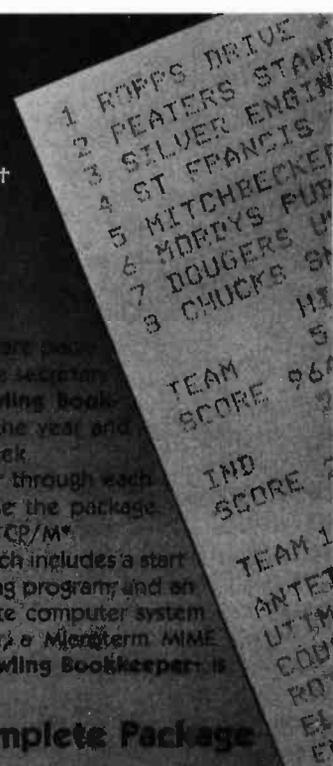
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Add Some Control to Your Computer

An Output Port Tutorial

Ken Barbier
POB 1042
Socorro NM 87801

A virtually limitless number of devices can be controlled through a single output port using time multiplexing techniques. A series of 8-bit bytes is fetched from a control buffer in memory, and output through a single port. On the receiving end, bus buffers present the data to all the devices in parallel, but unique strobes are supplied to each device in turn, so that it can latch its own data word.

This technique is particularly useful if the devices are to be located some distance from the computer.

The hardware shown in figure 1 has been used to control devices over 50 feet from the computer without exotic line drivers and receivers. Since remote addresses for each device are generated by the hardware, only 8 data lines and 1 strobe line are required. For maximum noise immunity, shielded twisted pair cable should be used.

Receive Hardware

In figure 1, 16 external devices receive 1 8-bit byte apiece. Using the

Intel 8080, this block of data will be transmitted in about 300 μ s. The I/O(input/output) write strobe accompanying the 1st byte triggers a delay oneshot which, after allowing more than enough time for the block transmission, triggers a reset oneshot which clears the remote address counter, the 74160. This insures that the next block of data will be routed to the correct device in turn.

The remote address counter supplies a 4-bit count to the 4-line-to-16-line data selector, the 74154. As the

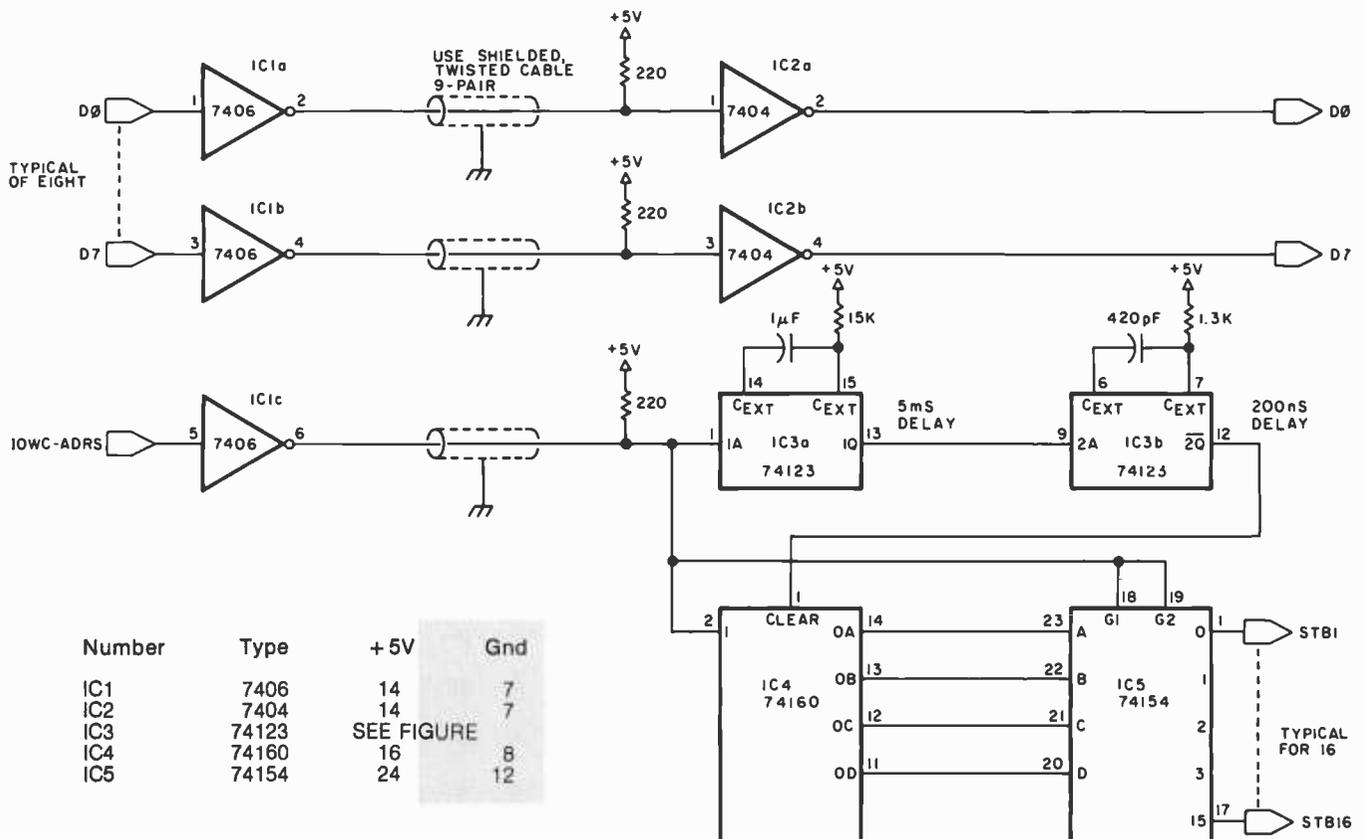


Figure 1: The transmission circuitry is divided into 2 parts, the data transmission (D0 through D7) and the address. The address is decoded by a counter which determines which 1 of 16 devices is being used. The write strobe accompanying the data triggers a delay oneshot (IC3a) which triggers a reset oneshot (IC3b) which clears IC5, the remote address counter.

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74160 advances its count on the rising edge of its clock, it will initially supply address 0 to the 74154 until the trailing edge of the negative going I/O write strobe. This same strobe is the "data" supplied to the 74154, and so will appear on each of the outputs of the 74154 in turn. This constitutes the 16 remote addresses.

For expansion, 1 additional counter stage could be used to generate "first 16" and "second 16" control signals to double the number of devices.

Driver Programs

The example shown in figure 1 is for 16 devices. Every time we want to output a control to any one device, we must output all the control words. OUCNT is an 8080 routine designed to accomplish this (see listing 1). The calling program first loads the correct bit patterns into the correct buffer words, then sets the flag at memory location FLAG. This flag is used to prevent needless outputting of the controls. In a complex control program, many segments of the operating system may need to change the state of the devices at irregular intervals. In such an implementation there will be a fixed program cycle, with many tasks called in turn to perform their functions. At some point in the cycle, time will be allotted to output our controls. If no program segments or tasks have called for any change in the controls, it is not necessary to transmit them, and the flag will not be set. But when it is set, we will transmit all the controls, after clearing the flag.

Controlling Relays

Typical applications for this technique might include driving remote displays, with 32-decimal digits being transmitted, 2 per 8-bit byte. Or, as is shown in figure 2, 8 relays can be controlled by each 8-bit byte.

The simplified schematic of figure 2 shows a relay driver circuit capable of controlling 8 relays. The 8 bits of data are latched into the 74175s on the rising edge of the clock, so our negative going strobe can be used as is. If latches such as the earlier 7475 are used, the strobe would have to be inverted, since the output of a 7475 follows the input whenever the clock is high. In either case, any relay whose corresponding bit is not changed will remain in the previous state, as its cor-

;OUTPUT CONTROLS			
CONTR	EQU	xxxx	;OUTPUT PORT ADDRESS
OUCNT:	LDA	FLAG	;NEED ACTION?
	ANI	OFFH	
	RZ		;NO. RETURN
	MVI	A,00	;YES, CLEAR FLAG
	STA	FLAG	
	LXI	H,BUFFR	;GET CONTROL BUFFER ADDRESS
	MVI	C,0FH	;SET COUNTER
OUCN1:	MOV	A,M	;GET CONTROL DATA BYTE
	OUT	CONTR	
	INX	H	;INCREMENT ADDRESS
	DCR	C	;DECREMENT COUNTER
	JNZ	OUCN1	;CONTINUE IF NOT DONE
	RET		;ELSE, RETURN
FLAG:	DB	0	;ACTION FLAG
BUFFER:	DS	0FH	;CONTROL BUFFER

Listing 1: 8080 assembler routine to output control signals to 1 of 16 devices. CONTR is equated with the desired output port address.

responding latch is reloaded with the same data as before. (The type of NPN driver transistor will have to be selected to match the current and voltage requirements of the particular relay used.)

Relay Control Program

Obviously, if we need to control 8 relays with 1 byte, we do not want to change the state of all of the relays at the same time. This complicates the software required slightly. In the 8080 program shown in listing 2, a change relay subroutine allows us to change the state of 1 relay at a time. We must

supply the subroutine with the number (hexadecimal 0 thru F) of the word in the buffer corresponding to the relay driver board, and a relay number (1 thru 8). We must also specify whether we want to turn it on or off. At the correct time, we put the word number in register C, the relay number in register E, and set register A to 1 for on, or 0 for off, and call CHGRY. The next time the operating system calls OUCNT, only our

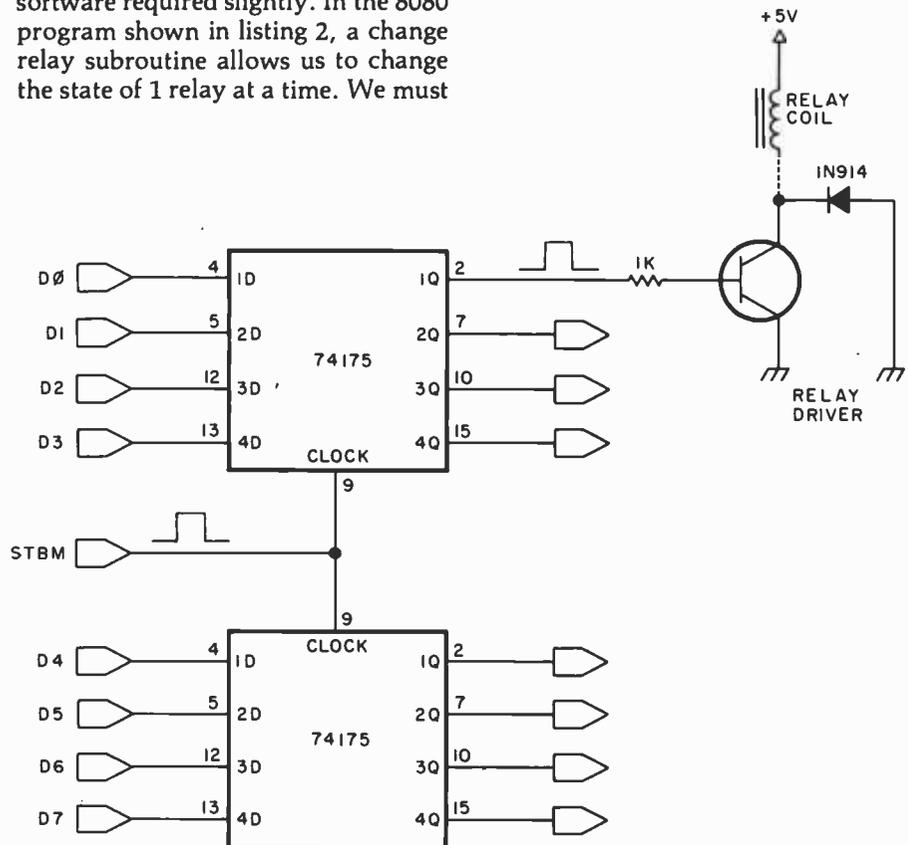


Figure 2: A relay driver board capable of controlling 8 relays. The state of the relay, on or off, is latched into the 74175 until a following strobe is received directing a change in state.

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```
;CHANGE RELAY
```

```
;ENTER WITH:
```

```
CONTROL WORD NUMBER IN (C)
RELAY NUMBER IN (E)
(A) = 1 TO TURN RELAY ON
(A) = 0 TO TURN RELAY OFF
```

```
CHGRY:    LXI          H,BUFFR    ;GET BUFFER START ADDRESS
          MVI          B,O        ;ADD WORD NUMBER
          DAD          B
          ANI          OFFH      ;TURN ON OR OFF?
          JZ           OFF
CHGR1:    DCR          E          ;TURN IT ON
          JZ           CHGR2     ;SHIFT BIT TO RELAY
          RLC          ;      POSITION
          JMP          CHGR1
CHGR2:    ORA          M          ;TURN THIS ONE ON
          MOV          M,A
CHGR3:    MVI          A,OFFH    ;SET CONTROL FLAG
          STA          FLAG
          RET              ;AND RETURN
OFF:      MVI          A,0FEH    ;TURN RELAY OFF!
OFF1:    DCR          E          ;FORM MASK WORD
          JZ           OFF2     ;SHIFT "HOLE" TO
          RLC          ;      RELAY POSITION
          JMP          OFF1
OFF2:    ANA          M          ;TURN THIS ONE OFF
          MOV          M,A
          JMP          CHGR3     ;AND RETURN
```

Listing 2: This 8080 routine allows a state change for only 1 relay in a set of 8 instead of changing all relays at once.

```
;INITIALIZATION SUBROUTINE
```

```
INIT:     MVI          A,00      ;CLEAR REMOTE ADDRESS
          OUT          CONTR    ;      COUNTER
          MVI          A,14H    ;CLEAR BUFFER AND
          LXI          H,BUFFR  ;      DELAY ROUTINE
          MVI          C,0FH    ;LOOP TIME IS 250 USEC
          MVI          M,00     ;      SO DO IT 20 TIMES
          INX          H
          DCR          C        ;TO ALLOW RESET
          JNZ          INIT2    ;      OF REMOTE ADDRESS,
          DCR          A
          JNZ          INIT1
          CALL         OUCNT    ;THEN OUTPUT ALL ZEROS
          RET              ;AND RETURN
```

Listing 3: Initialization routine to clear the address counter, buffer, and outputs all 0s to devices connected to system.

selected relay will change state, even though all the controls are output.

Error Free Operation

To insure that all controls have been received correctly, some sort of feedback to the computer can be provided. In actual practice this is usually unnecessary, but if it *must* be implemented, there are several possible techniques.

First, 74180 parity generator and checkers could be used to generate a parity bit on the transmit end, and check it on the receive end, sending back an interrupt if any word received is in error. This would add only 2 more signal conductors to the 9 already in the cable. Additionally, at the end of the delay oneshot time (and before the reset occurs), the remote address counter can be tested

to insure that it has reached the all 1s state. A count error signal can be ORed with the parity error signal to produce a single interrupt in case either error should occur. The operating system can then try the transmission again, or at least indicate its existence.

System Initialization

Since, upon initial application of power, the states of the latches and the 74160 counter will be indeterminate, the initializing subroutine of listing 3 should be called at power on and reset times. This will clear the address counter, the buffer, and output all 0s to all devices.

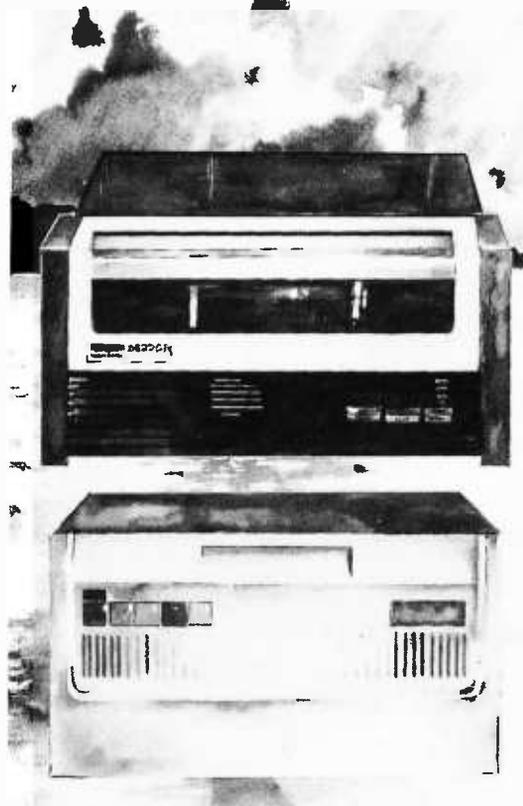
I hope this short discussion of output port techniques will help readers to understand how the computer can be interfaced to the real world. ■

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Text continued from page 6:

The scope of the new homebrew design has now expanded to include relatively high-speed serial RS-232C communications among the homebrew node, the Western Digital P-engine, the Able/60-Synclavier, and other computers from time to time. I intend to use RS-232C at 19.2 K bps as the communications discipline, primarily for its universality. Today one can get almost any computer with a standard 25-pin D connector set up for the RS-232C discipline, at speeds ranging from a lethargic 110 bps to a maximum of 19.2 K bps. This upper-limit of speed is not exceptionally fast (about 1800 bytes per second is the equivalent in a useful measure), but the existence of these standard signal levels and standard connectors argues for this kind of approach.

The diagram of figure 1 shows how the overall conception of the system stands at present. The homebrew 6809 simultaneously provides a facility to directly execute

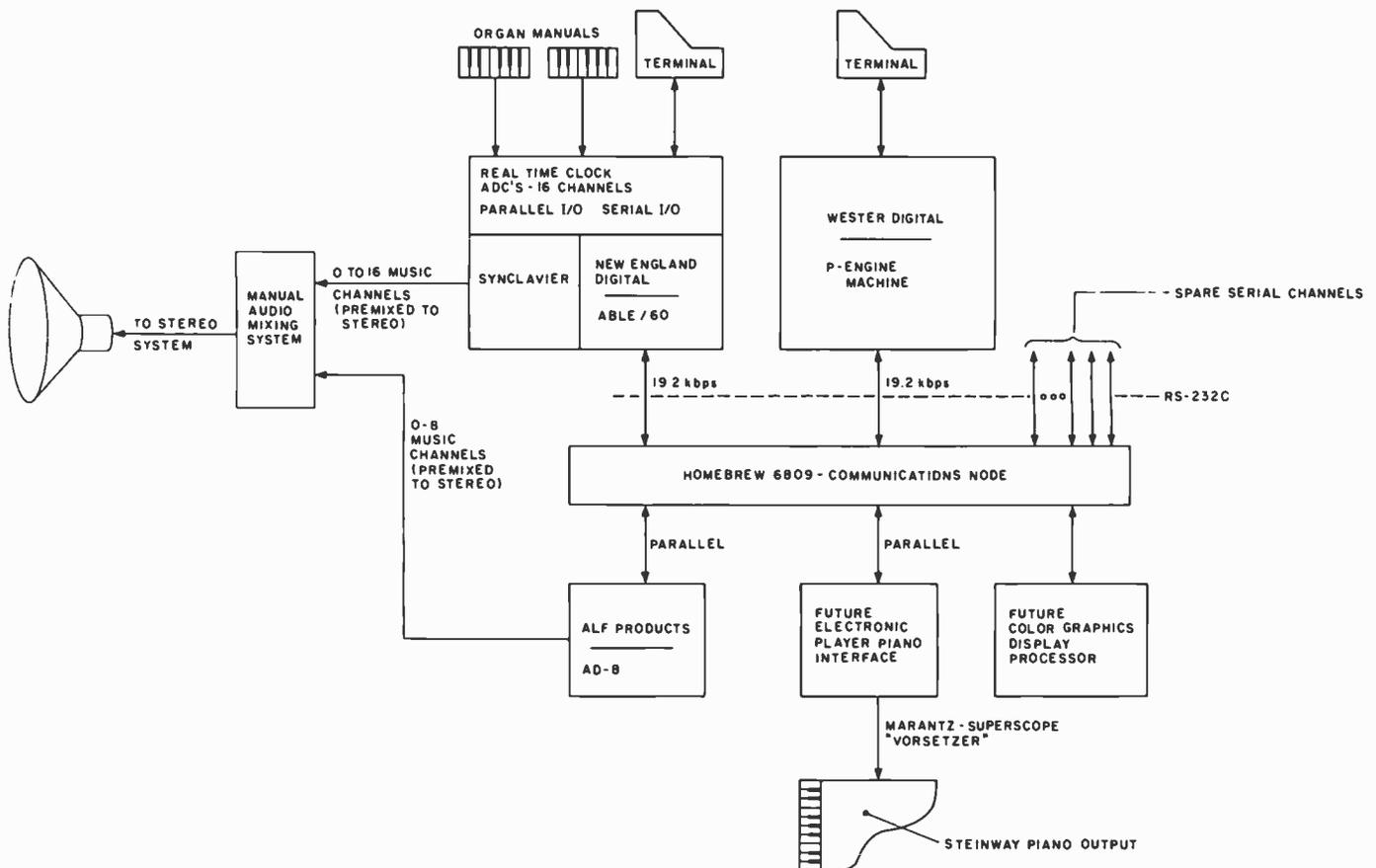
6809 code for experimental purposes, and a more permanently useful function of a common communications node which can be the subject of various serial communications strategies relative to the other processors.

Lest readers wonder, this is and remains a personal computer. It is true that the system is getting a bit large for one person to operate all of the terminal and music keyboards simultaneously, yet it resides in my home along with various other facilities of the complete computer experimenter: electronics shop, woodworking shop, and the beginnings of a machine shop.

This expanded conception of function for the homebrew 6809 barely changes the hardware design details originally conceived. The computer will have 16 K bytes of memory to start, several terminal ports, several parallel ports, and space for 4 K bytes of ultraviolet, erasable read-only memory. The read-only memory will contain the implementation of low-level, communications-monitor software and key parts of a reverse-polish notation, stack-oriented, threaded interpretive language. Remember that the conception of a homebrew or commercial system made of modular components can change considerably in detail as a result of time and resources available.

As the system design develops from this initial intention, its actual detail may prove inconsistent with what I have conjectured thus far. Recognizing this starting point, I invite readers to follow in on a guided tour of the current state of my thinking about this new, homebrew, microprocessor system project. Let's see how the central processor bus design comes out, what logic blocks will be required, and let's have some preliminary thoughts on the

Figure 1: How the 6809 homebrew computer fits into a bigger system. The new 6809 computer will serve as a central communications node for multiple computers involved in this personal system. At present 2 complete computer systems are involved, with serial communications via the 6809 node, which is the subject of this homebrewing series. The Able/60 has several specialized peripherals which will be used for personal research purposes, such as, high-speed 16 channel analog-to-digital input conversion and a real-time clock with 1 μ s resolution. In this diagram, mass storage equipment is not shown, but it is a part of each computer: the Able/60 computer includes 2 5-inch floppy drives, and 2 full-size floppy drives as its mass storage complement. The P-Engine machine includes 2 double density, standard-size floppy disk drives.



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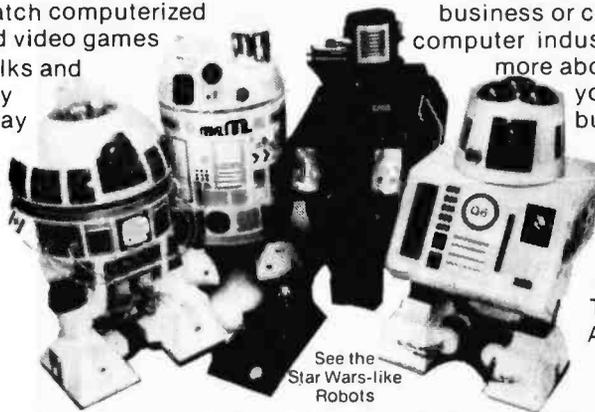
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partitioning of the system into cards within the 6-slot backplane previously described.

Designing The Logic Of The System

The task at hand is to design the central processor card for this homebrew computer. This is the starting point for the design of the whole system. Detail choices made in the processor card's arrangement impact every other card designed for the system.

We know, that the system must have 16 address lines and 8 data lines because it uses a 6809 processor architecture, and simplicity dictates avoidance of extra logic for memory paging schemes. But which 24 lines of the 40 remaining in the backplane bus should be committed to which particular uses? Every board in the system must be consistent with this detail choice. The choice is made trivial by the fact that, except for aesthetic and symmetry reasons explained below, one backplane line is as good as the next.

If we were building a computer consistent with plug compatible backplane bus designs such as the SS-50 of Southwest Technical Products Corporation, or the Institute of Electronic and Electrical Engineers (IEEE) S-100 standard bus, these choices would be crucial to that goal of plug compatibility. However, a homebrew system is a homebrew system, so our plug compatibility will be at the level of integrated circuits, not at the level of backplane buses.

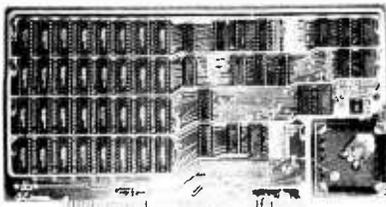
Designing The Logic Of The System—Backplane Setup

As noted in the July BYTE page 194, the power supply wiring of the backplane has been committed to the outermost pins of the sockets. The assignment of power supply pins used 32 of the 72 pins available, in order to take advantage of the heavy copper wires of the buses. The power supply wiring commitments were made consistent with a symmetry principle: if a board should be inadvertently rotated 180 degrees and plugged in, all power buses will map into identical power buses. The outermost power bus is the -12 V analog power bus. Proceeding inward, the next symmetric pair will be used for the +12 V analog power; the next pair of buses is for the +5 V main logic power supply. The innermost power buses are the central system ground buses. In table 1, a listing of backplane bus connections, these initial assignments of power pins are shown in shade (a).

The power supplies used in building this system are provided by relatively inexpensive modular building blocks from James Electronics. The +5 V logic power is provided by a single regulated supply rated at 6 A. The 2 analog supply voltages are provided by separate modules rated at 1 A. In the photographs of the physical hardware, these modules are shown as mounted, prior to wiring.

In the design of the backplane bus once the power supply commitments have been made, the next items to consider are the data and address lines. Continuing the process of symmetrical allocation, the 16 address lines and 8 data lines should be assigned to bus pins in such a manner that if a card is rotated, data lines will map into data lines, and address lines will map into address lines. The address lines are split into 2 groups of 8 connections on either side of the symmetry axis. The data lines are

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allocated into 2 groups of 4 connections. Continuing the listing of the backplane connections in table 1, these assignments of 24 address and data pins are shown in shade (b). At this stage in the allocation of logical signals to the bus, 24 of 40 available pins have been used, leaving 16 pins still to be determined.

The next item to consider is the set of lines which con-

nect the central processor to the external world. These lines are the essential timing and control signals which define the discipline of the bidirectional 8-bit bus used by the microprocessor. In the specifications of the 6809, the following signals are defined which have relevance to the outside world:

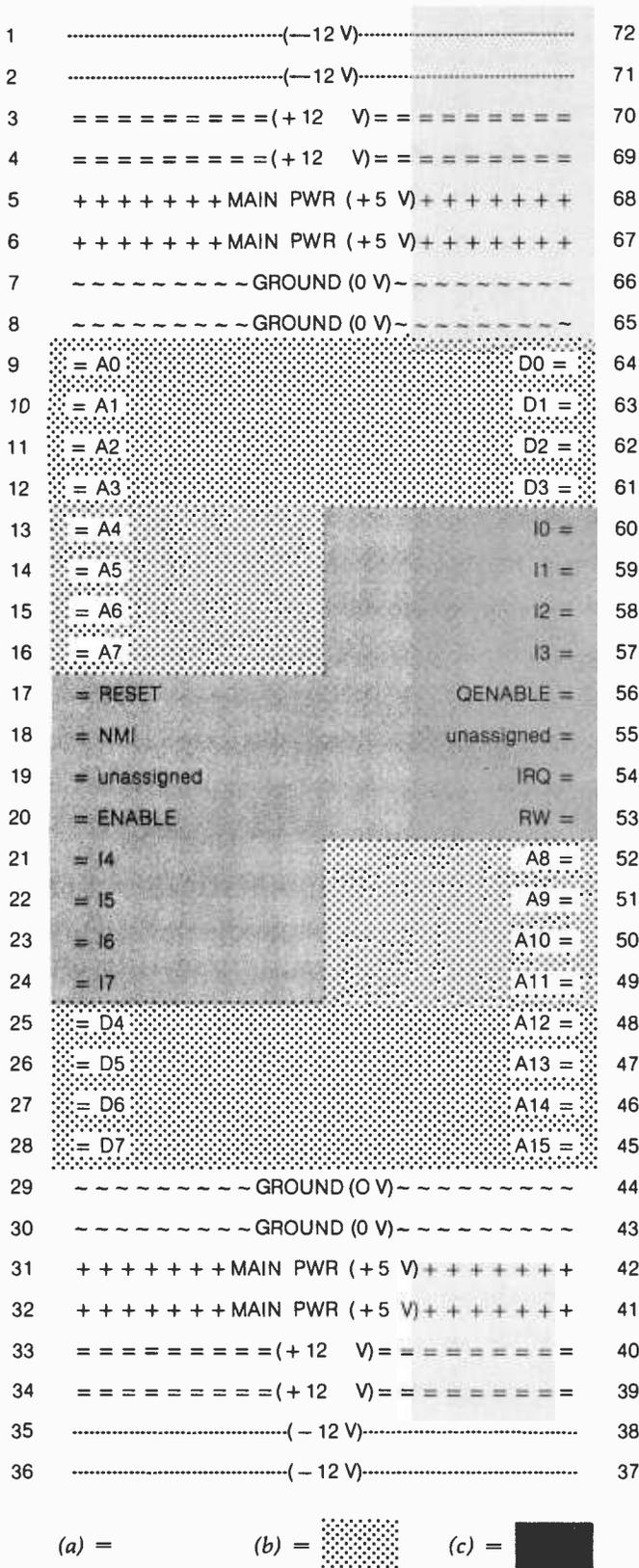
- RW = Read versus Write bus direction relative to the processor.
- ENABLE = Clock output ("Phi 2") of processor.
- QENABLE = Quadrature clock of processor.
- RESET = system reset line to processor and all peripherals.
- MRDY = memory-ready line, for use with slow memory devices.
- BREQ = bus request for direct memory access (DMA).
- BA = bus available.
- BS = bus status.
- FIRQ = fast interrupt request.
- IRQ = interrupt request.
- NMI = nonmaskable interrupt request.

The simplest and most direct way to deal with these 11 signal lines would be to bring them out to the backplane. But do we really need all these signal lines in this processor? Might it be more useful to commit a majority of the remaining 16 lines to interrupt activities, rather than having nonessential copies of the lines coming from the processor circuit? For example, we may prefer to incorporate 8 separate interrupt lines in order that each of a possible 8 peripheral devices could have a dedicated line. If this is to be accomplished, then the total commitment of noninterrupt lines to the backplane must be 8 lines instead of the mixed selection of 3 interrupt lines and 8 signal lines shown above. How can we modify this set of backplane signals given the limitations and purposes of this particular design?

First, remember that this application is a simple and limited one in which no direct-memory access is being implemented, and that all memory will be fast enough to drive the processor at full speed. Given this requirement, the 2 signals memory ready (MRDY) and bus request (BREQ) can be removed from the set seen by the external world beyond the processor card. We have thus reduced the backplane line count to 9 lines, nearly enough to allow 8 distinct interrupt lines.

The next items to question are the bus available (BA) and bus status (BS) signals. These are used to decode 1 of 4 possible states: normal operation, interrupt acknowledge, synchronization acknowledge, and bus grant (halt acknowledge). Of these, the limited goals of the present

Table 1: An allocation of backplane signals. As described in the text, this backplane signal set provides for 8 bidirectional data lines, 16 address lines, 8 individual fast interrupt lines used with a (slow) software polled strategy, 2 direct interrupt lines, and 4 essential timing signals for the 6809 and its relationship with the external world. The assignment of these lines is kept symmetrical, so that while the processor may not work if any board in the system is inadvertently plugged in the wrong way, no major conflicts will occur that could damage a gate or buffer. The shades indicate stages in the backplane allocation process described in the text: (a) pins are the power connections; (b) pins are the address and data connections; (c) pins are the 16 lines allocated to processor control signals and interrupts.



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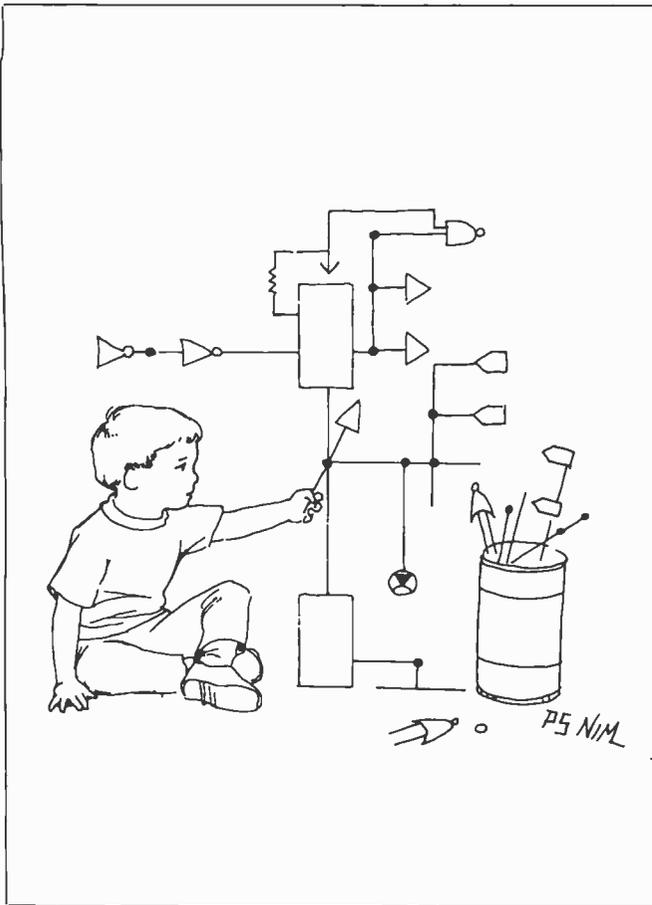
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system make the only externally relevant state "normal operation" if we can confine interrupt handling logic to the processor card. Can this be done? The answer is "yes", if we define fixed read-only memory vectors for all interrupts, and eliminate the need to decode interrupt acknowledge externally for purposes of altering the interrupt vector locations. Thus the backplane signal requirements have been further reduced to 7 lines, still allowing the 3 original interrupt lines to come out to the external world off the central processor card.

Now let's examine the interrupt handling capabilities of the processor. Of the 3 available interrupts, the fast interrupt is the most general. The reason for this is that it only stacks away the essentials of the processor state when acknowledging the interruption with a branch through the FIRQ vector location, hexadecimal address FFF6. These essentials are the condition code, and the return address. In contrast, the NMI and IRQ interrupts always stack away the entire current contents of the central processor's set of registers. If we use the FIRQ signal for most interrupt activity, then, when speed is needed, only those registers which are used by the interrupt routine can be stacked away using the multiple register push and pull instructions. If the operation of the NMI or IRQ (ie: complete protection) is required, the multiple register operation of push and pull can be extended to cover all the processor registers using the proper "post-byte" which selects registers.

What about devoting the FIRQ interrupt input to 8 different possible sources, using a concept of a software-pollled flag register and a parallel input port to prioritize "who called"? This eliminates 1 more line from the original backplane signal requirements, while adding 8 interrupt lines labeled I0 through I7. We keep the NMI and IRQ lines available for truly high-priority interrupt signals which must go in directly without much software decoding. Our result then is the final backplane signal set listed in table 1, with this last set of additions shown in shade (c). Two lines are left uncommitted at this stage, in case an essential signal concept is omitted. One or more interrupt lines (I0 through I7) can be sacrificed, if more than 2 lines must be added due to some shortcomings.

With this general discussion of the system's backplane complete, I will continue these notes next month with a more detailed sketch of the system's most important card: the central processor module. Following this design discussion, the final installment on the processor module will be a short description of the detailed schematic as I wire it. ■

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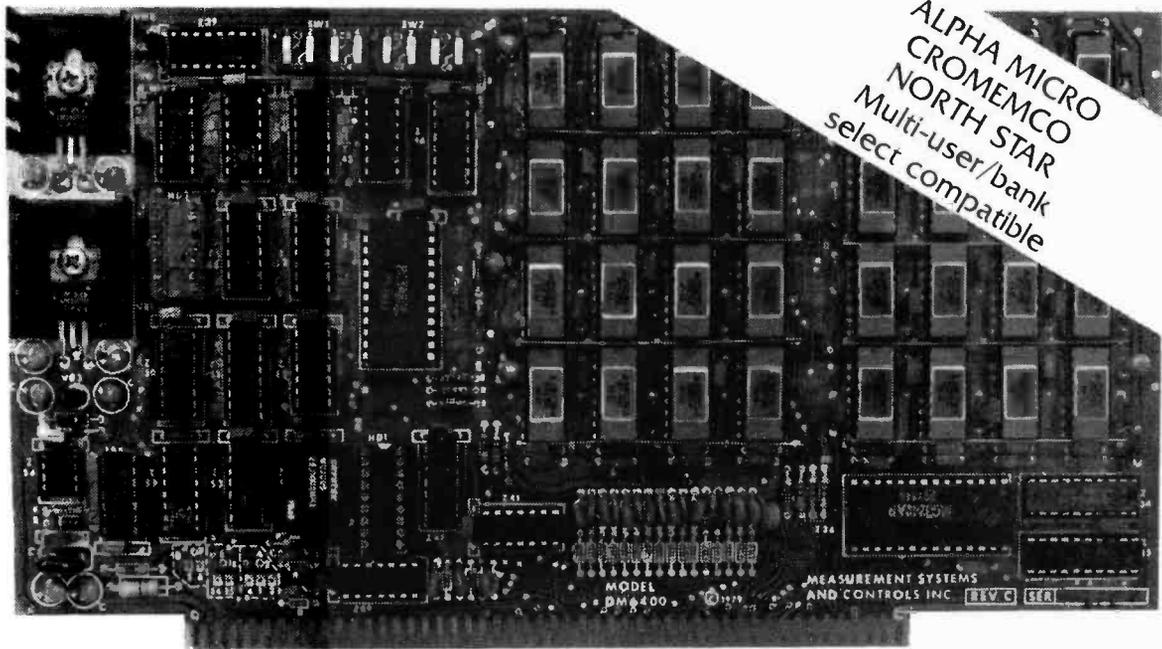
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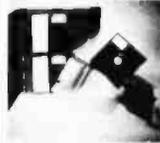
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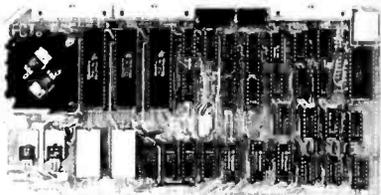


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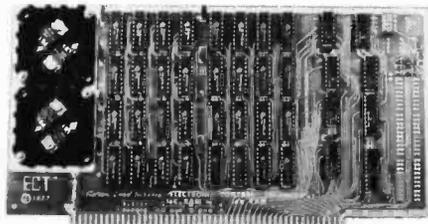
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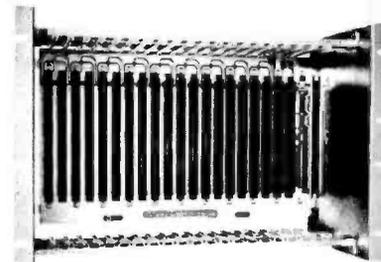
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APPILOT conforms closely to the proposed common PILOT standard, but it incorporates features that fully use the capabilities of the Apple II computer. Among these features are color graphics commands, a musical minilanguage, and disk commands for lesson segmentation which give an effective lesson size up to 90 K bytes. APPILOT also links to the Apple's integer BASIC to allow full calculation capacities.

APPILOT is available on tape and disk, and is offered on Super Load tapes and for those Apple owners who wish to run prewritten APPILOT lessons. For \$17.95 the user can execute APPILOT lessons on a 16 K byte Apple, using only tape storage. Included on the tape is the interpreter and a demonstration lesson about APPILOT. Also provided is a documentation manual for running APPILOT and for linking it with the MUSE APPEN-I Text Editor, which may be used for creating and editing APPILOT lessons.

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dependent. Users may examine and edit data through a one line window as it is moved through the edit file. A window command allows instantaneous full screen displays of both the current line and surrounding lines, with forward and backward scrolling.

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SYS7171 sells for \$29.71 and SYS8181 is priced at \$18.71. For further information, contact National Artificial Intelligence Laboratory, POB F, Mobile AL 36601.

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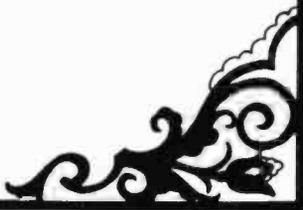
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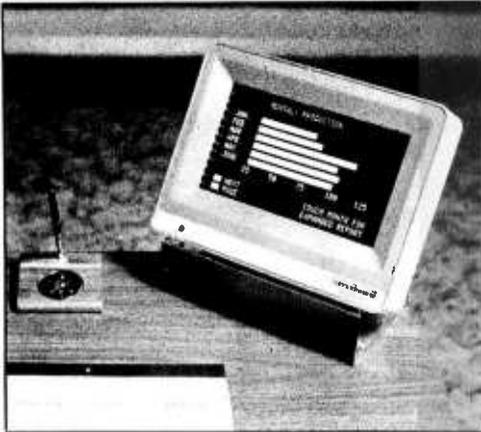
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VuePoint is a touch input display panel that measures only 2 1/4 inches thick. Vuepoint's 12 line by 40 character flat panel also provides a unique touch input capability. This approach permits efficient and speedy operator interaction using menu-driven displays. Vuepoint's microprocessor based controller provides all standard smart video features plus the following: touch response in matrix or screen echo modes, multiple display buffers, and alternate character sets. Communication is by standard 300-19200 bps asynchronous RS-232 protocol. Options include wall or rack mount, auxiliary printer, and 128 character ASCII keyboard. Vuepoint is priced at \$3500. For further information, contact General Digital Corp, 700 Burnside Av, E Hartford CT 06108.

Circle 571 on inquiry card.

APL/Z-80 Release 2.0

Vanguard Systems Corp, 6812 San Pedro, San Antonio TX 78216 has announced the release of version 2.0 of APL/Z-80, an APL interpreter for Z-80 based microcomputers. APL/Z-80 includes the following features: dynamic execution of system commands; serial printer support; shared variables; auxiliary processor for I/O (input/output) ports which allows complete device control using defined APL functions for any device interfaced to the Z-80 I/O port; and auxiliary processor implementation of a file system featuring a directly indexable file having variable

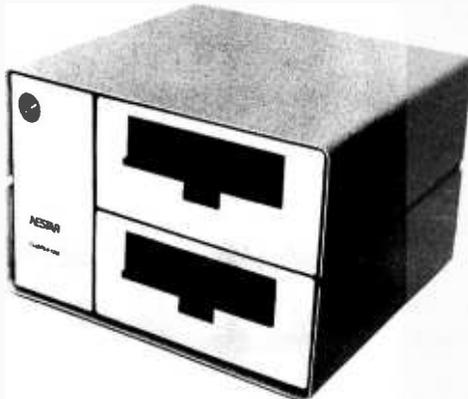
length records, each of which can be an APL array of arbitrary type, shape, and size (up to available workspace).

A workspace containing defined APL/Z-80 functions, implementing each of the primitive functions not present in this version of APL/Z-80, is distributed with each system. The hardware required is a Z-80 processor, a disk drive, and either serial ASCII APL console terminal or ASCII keyboard and video display board compatible with the Vector Graphic Flashwriter or Processor Technology VDM-1.

The end user license for use on a single processor is \$350.

Circle 572 on inquiry card.

Distributed Computer System Based on Personal Computers



Cluster/One is a distributed processing alternative to BASIC timesharing. The central Cluster/One unit (the Queen) connects to 15 personal microcomputers (the Drones), via a high-speed parallel data bus (the Clusterbus). An optional feature provides support for an additional 15 Drones. Currently supported as Drone stations are the Apple II, Commodore PET 2001-8, and TRS-80.

Programs and data files can be shared among the users of Cluster/One. They are stored on two IBM compatible eight inch floppy disks. Each disk holds up to 315 K bytes of data. Disk data transfer rate is 250 K bits per second, managed by a large scale integration floppy disk controller chip. All data transfers are cyclic redundancy checked (CRC) and disk writes are automatically verified. Data is transmitted to each Drone station in packets, with individual error checking. Typical system response time for program loading is two seconds.

Cluster/One commands are quite similar to their counterpart cassette tape commands. Disk commands may be imbedded in user programs, permitting menu-driven program loading or chaining.

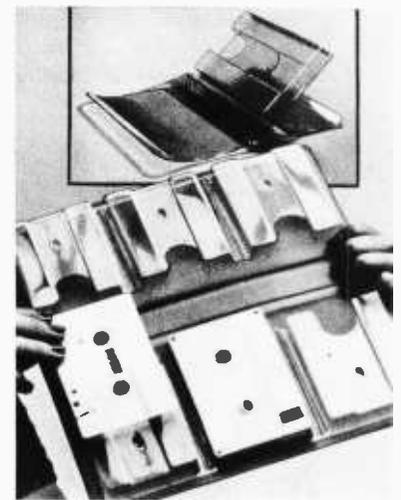
Cluster/One comes with a full set of utility programs for system maintenance and backup, along with separate documentation for the end users. Prices begin at \$4500 and vary with the particular configuration and options selected. For further information, contact Nestar Systems Inc, 810 Garland Dr, Palo Alto CA 94303.

Circle 573 on inquiry card.

Where Do New Products Come From?

The information printed in the new products pages of BYTE is obtained from "new product" or "press release" copy sent by the promoters of new products. If in our judgment the information might be of interest to the personal computing experimenters and homebrewers who read BYTE, we print it in some form. We openly solicit releases and photos from manufacturers and suppliers to this marketplace. The information is printed more or less as a first in first out queue, subject to occasional priority modifications. While we would not knowingly print untrue or inaccurate data, or data from unreliable companies, our capacity to evaluate the products and companies appearing in the "What's New?" feature is necessarily limited. We therefore cannot be responsible for product quality or company performance.

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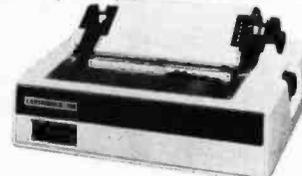
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New Word Processing System Also Supports Data Processing Applications

A video based word processing system capable of handling data processing applications has been introduced by

Vector Graphic Inc, 31364 Via Colinas, Westlake Village CA 91361. The new system, called Memorite 2, incorporates



the firm's Z80 based MZ microcomputer with 630 K bytes of disk capacity, their Mindless Terminal, and the Qume Sprint 5, 55 cps printer. For word processing applications, Memorite 2 with dual Micropolis floppy disk drives features advanced text preparation, edit, and delete capabilities. It offers automatic letter printing from memory with full formatting techniques such as underlining, indentation, automatic margins and variable line and character spacing. The system also performs mass mailings, which allow letters to be merged with address lists. Its memory is resident on programmable read-only memory, so users need only type after a "power up and proceed" function.

As a data processor, Memorite 2 is capable of performing standard accounting tasks and custom applications in business BASIC for small firms or departments of large companies. Scientific calculations are also available for technical environments.

The price for the Memorite 2 is \$8,950.

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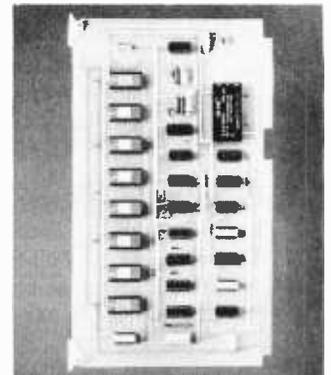
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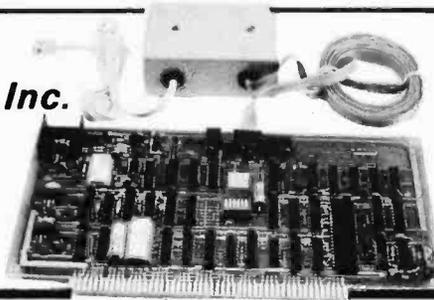
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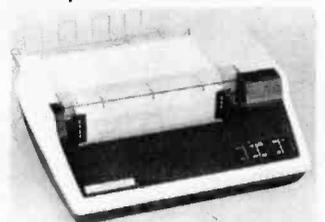
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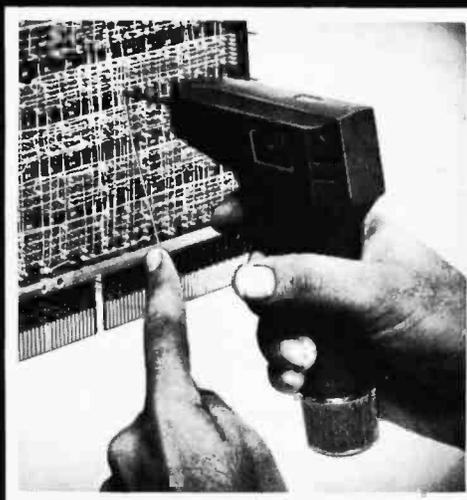
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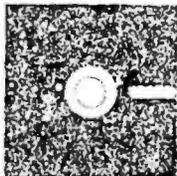
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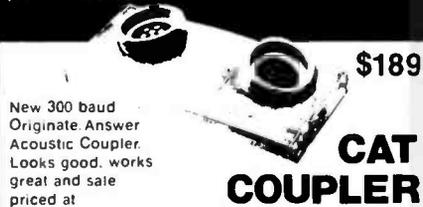
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- Power down ROM
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- Calibration adjustment
- Input offset adjustment
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- Overrange and sign indicators
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- Supports interrupt daisy chain
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- 256 byte firmware (ROM) or software (RAM) space available

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- Selectable gating for frequency or pulse width comparison
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- Three maskable outputs to patch area
- Power down ROM
- Supports interrupt daisy chain
- Allows DMA daisy chain
- 256 byte firmware (ROM) or software (RAM) space available

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Cat No. 1618 A&T \$145.00

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- Supports half or full duplex operation
- DTE type configuration
- Fail-safe RS-232C operation
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- Parity, overrun, and overflow status checks
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- Supports interrupt daisy chain
- Allows DMA daisy chain

Cat No. 1627 Kit \$ 90.00

Apple II Model 7710A Asynchronous Serial Interface

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- Optional divide by 16 clock mode
- False start bit detection
- Software programmable interrupts
- Data double buffered
- One or two stop bit operation
- Power down PROM
- 256 bytes firmware (ROM) or software (RAM) space available
- Supports interrupt daisy chain
- Allows DMA daisy chain
- 134.5 BAUD available for selective Interface
- Conforms to RS-232C (configuration A thru E)
- Supports half or full duplex operation
- DCR type Interface
- Fail-safe RS-232C operation
- 14 STD CLK rates 50-19.2K BAUD plus EXT CLK
- BAUD rates dip switch selectable
- All BAUD rates crystal controlled except EXT
- 8 and 9 bit transmission
- Optional even, odd, and no parity bit
- Programmable control register

Cat No. 1624 A&T \$145.00
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- Two programmable control registers
- Two programmable data direction registers
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- High impedance 3 state and direct transistor drive peripheral lines
- Programmable interrupts
- CMOS drive capability on side A peripheral lines
- 2 TTL drive capability on all A and B side buffers
- Power down ROM
- Supports interrupt daisy chain
- Allows DMA daisy chain
- 256 bytes firmware (ROM) or software (RAM) space available

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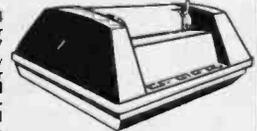
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• For TRS-80, Apple, etc.

Features 80 columns, 84 lines per minute, super high reliability, 9 x 7 character font. Completely self contained, perfect for terminals or as a stand alone printer. Prints complete 96 character ASCII font. Complete with interface for RS232C and 20/60mA current loop mode. Also Centronics plug compatible interface which accepts data in a parallel bit, serial character synchronous form.



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50V	.05	.12	.36	.80	.30	.50	1.20
100V	.06	.16	.50	.98	.45	.65	1.50
200V	.08	.20	.64	1.15	.60	.80	2.00
400V	.10	.24	.78	1.35	-	-	2.50
600V	.12	.30	.98	1.60	-	-	-
800V	.14	-	1.26	1.95	-	-	-
1000V	.16	-	1.54	2.30	-	-	-

SSM Available at HOBBY WORLD

Cat No.	Model	Price	Cat No.	Model	Price
1408	SB1 kit	\$150	1435	MB8A bb	\$26
1409	SB1 a&t	\$212	1436	MB9 kit	\$64
1410	SB1 bb	\$35	1437	MB9 a&t	\$118
1400A	MB6B kit		1429	OB1 kit	\$45
	450ns	\$139	1430	OB1 a&t	\$74
1401A	MB6B a&t	\$139	1431	OB1 bb	\$26
	450ns	\$183	1427	XB1	\$10
1402	MB6B bb	\$26	1428	Connector for	\$4
1405	MB7 kit	\$325			
1406	MB7 a&t	\$370	1403	CB-1 kit	\$119
1407	MB7 bb	\$26	1417	VB1B kit	\$129
1425	MB3 kit	\$54	1418	VB1B a&t	\$175
1426	MB3 a&t	\$108	1419	VB1B bb	\$26
1420	MB4 kit (2MHz)	\$80	1438	VB2 kit	\$135
1422	MB4 a&t (2MHz)	\$132	1439	VB2 a&t	\$195
1424	MB4 bb	\$26	1414	IO2 kit	\$48
1440	PB1 kit		1415	IO2 a&t	\$75
	w/textool	\$125	1416	IO2 bb	\$26
1433	MB8A kit	\$78	1411	IO4 kit	\$139
1434	MB8A a&t	\$125	1412	IO4 a&t	\$185
			1413	IO4 bb	\$26

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FLOPPY SYSTEMS



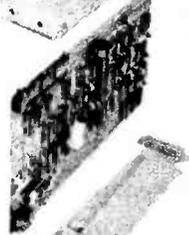
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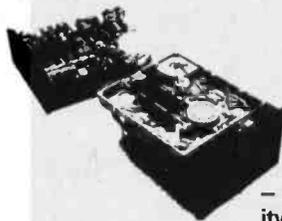
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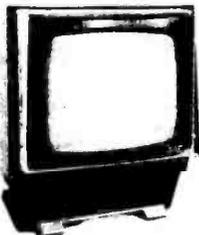
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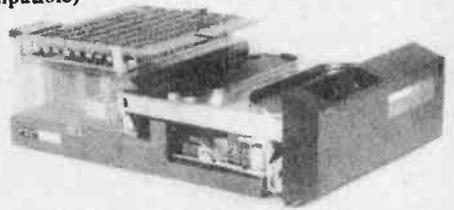


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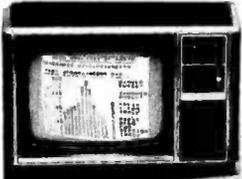


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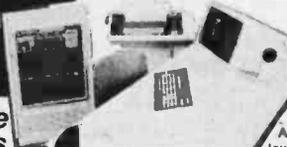
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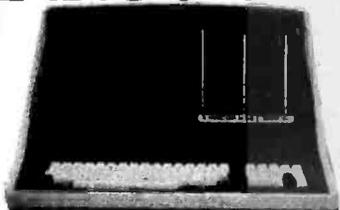
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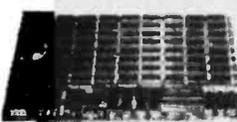
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LOW POWER
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- Uses National's Low Power 5257 4K x 1 Static Rams
- 2 MHz or 4 MHz operation
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- 4K hardware or software selectable
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QM-9 with MIKOS #12 9 slot mother board \$79.95
FPB-1 with MIKOS #14 all parts for front panel \$134.95

MIKOS PARTS ASSORTMENTS ARE ALL FACTORY PRIME PARTS. KITS INCLUDE ALL PARTS LISTED AS REQUIRED FOR THE COMPLETE KIT LESS PARTS LISTED. ALL SOCKETS INCLUDED.

VISA or MASTERCHARGE. Send account number, Interbank number, expiration date and sign your order. Approx. postage will be added. Check or money order will be sent post paid in U.S. If you are not a regular customer, please use charge, cashier's check or postal money order. Otherwise there will be a two-week delay for checks to clear. Calif. residents add 6% tax. Money back 30 day guarantee. We cannot accept returned IC's that have been soldered to. Prices subject to change without notice. \$10 minimum order. \$1.50 service charge on orders less than \$10.00.



(415) 592-1800
 P. O. Box 424 • San Carlos, California 94070
 Please send for IC, Xistor and Computer parts list

CMOS (DIODE CLAMPED)

4001	27	4023	32	4069	45	74C83	95
4002	27	4024	35	4071	20	74C151	118
4007	27	4025	32	4072	35	74C157	118
4009	45	4027	45	4518	100	74C160	120
4010	45	4028	80	4520	100	74C165	120
4011	22	4029	35	74C00	27	74C173	130
4012	22	4030	35	74C02	27	74C174	130
4013	40	4035	87	74C08	30	74C175	130
4014	100	4041	85	74C100	27	74C180	140
4015	100	4042	85	74C100	27	74C180	140
4016	45	4049	35	74C42	90	74C90	50
4017	105	4050	45	74C73	75	74C91A	190
4018	90	4051	110	74C74	50		
4019	45	4052	110	74C83	130		
4020	110	4053	135	74C86	50		
4021	110	4066	70	74C90	95		
4022	100						

PRINTED CIRCUIT BOARD

4" x 6" DOUBLE SIDED EPOXY BOARD 1/16" thick \$6.00 ea 5/S2.60

7 WATT LD-65 LASER DIODE IR \$89.5

2N 3820 P FET	\$ 45
2N 5457 N FET	\$ 45
2N2646 UJT	\$ 45
ER 900 TRIGGER DIODES	4 \$100
2N 6028 PIGG UJT	\$ 65

MINIATURE MULTI-TURN TRIM POTTS 100, 1K, 2K, 5K, 10K, 20K, 50K 200K, 1Meg, 2Meg, 5.75 each \$/2.00

25 watt Infra Red Pulse (SG 2006 equiv.) Laser Diode (Spec sheet included) \$24.95

VERIFAX PC BOARD \$12.95
 Our new Prototyping is a hi density 4 1/2" x 6 3/4" single sided 1/16" epoxy board. It will hold 40, 24, 16 (34 units), 14 + 8 pin IC's. There are three buses, +5V, ground and a floating buss. There is a pad for a T-220 regulator. There is a 22 pin edge connector with 150' spacing.

FP 100 PHOTO TRANS. \$50
 RED, YELLOW, GREEN
 LARGE LED's 2" \$6/\$1.00
 TTL-118 OPTO-ISOLATOR \$.75
 MCT-5 OPTO ISOLATOR \$.80
 1 WATT ZENERS: 3.3, 4.7, 5.1, 5.6, 9.1, 10, 12, 15, 18, or 22V \$6/\$1.00
 MCM 6571A 7 x 9 character gen. \$ 10.75

TRANSISTOR SPECIALS

2N6233-NPN SWITCHING POWER	\$ 1.95
MMF-8004 x CB RF Transistor NPN	\$.75
2N3772 NPN Si TO 3	\$ 1.00
2N1546 PNP Ge TO 3	\$.75
2N4080 PNP Si TO 3	\$ 1.00
2N5086 PNP Si TO 92	4 \$ 1.00
2N3137 NPN Si RF	\$.95
2N3919 NPN Si TO 3 RF	\$ 1.50
2N1420 NPN Si TO 5	3/S 1.00
2N3767 NPN Si TO 6B	\$.70
2N2222 NPN Si TO 18	\$ 1.00
2N3055 NPN Si TO 3	\$.60
2N3904 NPN Si TO 92	6/S 1.00
2N3906 PNP Si TO 92	6/S 1.00
2N9296 NPN Si TO 220	\$.50
2N6109 PNP Si TO 220	\$.55
1N3638 PNP Si TO 5	\$ 1.00
MPSA 13 NPN Si	4/S 1.00

Full Wave Bridges

PRV	2A	6A	25A
100	1.43		
200	.82	1.37	2.20
400	1.04	1.65	3.40
600	1.32	1.92	4.40

DIP SOCKETS

8 PIN .17 24 PIN .35
14 PIN .20 28 PIN .40
16 PIN .22 40 PIN .60
18 PIN .25

SANKEN AUDIO POWER AMPS

10 G 10 WATTS	\$ 7.80
Si 1020 G 20 WATTS	\$15.70
Si 1050 G 50 WATTS	\$28.50

TANTULUM CAPACITORS

22UF 35V 5/S1.00	6.8UF 35V 4/S1.00
47UF 35V 5/S1.00	10UF 10V \$.25
68UF 35V 5/S1.00	22UF 25V \$.40
1UF 35V 5/S1.00	15UF 35V 3/S1.00
2.2UF 20V 5/S1.00	30UF 6V 5/S1.00
3.3UF 20V 4/S1.00	150UF 15V \$.95
4.7UF 15V 5/S1.00	68 UF 15V \$.50

CRYSTALS \$3.45+

2.000 MHz 6.144 MHz	15
4.000 MHz 8.000 MHz	20
3.57 MHz 10.000 MHz	26 cond. - .50/par foot
5.00 MHz 20.000 MHz	40 cond. - .75/par foot
6.000 MHz	50 cond. - .90/par foot

RIBBON CABLE F.L.A. (COLOR CODED) #30 WIRE

26 cond. - .50/par foot
40 cond. - .75/par foot
50 cond. - .90/par foot

CTS 206-8 eight position dip switch \$1.60
CTS 206-4 four position dip switch \$1.45
LIGHT ACTIVATED SCR's to 18, 200 V 1A. \$.70

SILICON SOLAR CELLS

4" diameter .4V at 1 AMP \$10.00

LED READOUTS

FND 359 C.C. 4" x .60	
FCS 8024 4 digit	DL-704 C.A. 3" \$.75
C.C. 8" display	DL 747 C.A. 6" \$1.50
FND 503 C.C. 5" x .85	HP3400 B'C'C \$1.95
FND 510 C.C. 5" x .85	HP3405 B'C'C \$1.95
DL 704 3" C.C. x .85	

Silicon Power Rectifiers

PRV	1A	3A	12A	50A	125A	240A
100	.06	14	.35	.90	3.70	5.00
200	0.7	20	.40	1.30	4.25	6.50
400	.09	25	.65	1.50	6.50	9.50
600	1.1	30	.80	2.00	8.00	12.50
800	1.5	35	1.00	2.50	10.50	16.50
1000	2.0	45	1.25	3.00	12.50	20.00

SAD 1024 x 1024 RELOC 1024 stage analog "Buckbit B'n'd" shift register. \$14.95

IN 4148 (1N914) 15/\$1.00
RS232 DB 25P male \$2.95
CONNECTORS DB 25S female \$3.60
HOOKS \$1.50

REGULATORS

323K .5V 3A	\$ 6.75	340K 12, 15	
309K	\$ 1.60	or 24 V	\$ 1.50
723	\$.50	340T 5, 6, 8, 12	
320T		15, 18, or 24V 1.40	
5, 12, or 15 V		78 MG	\$ 1.35
		79 MG	\$ 1.35

TTL IC SERIES

7400	27	7450	37	7540	105
7401	27	7472	47	7540	105
7402	27	7473	42	7540A	141
7403	27	7474	42	74155	87
7404	27	7475	67	74151	20
7405	27	7476	45	74161	82
7406	33	7482	46	74167	120
7410	27	7483	67	74163	87
7409	27	7485	130	74164	177
7410	27	7486	42	74165	142
7411	27	7489	187	74172	180
7412	27	7490	63	74174	142
7413	84	7491	87	74175	177
7414	80	7492	84	74176	112
7416	33	7493	64	74177	112
7417	37	7494	100	74180	97
7420	27	7495	97	74181	235
7425	45	7496	87	74190	150
7426	33	7497	42	74191	137
7427	42	74121	45	74192	118
7430	37	74122	60	74193	118
7431	33	74123	67	74194	130
7432	33	74125	60	74195	176
7438	33	74126	60	74196	130
7440	27	74145	87	74197	130
7441	105	74148	155	74198	87
7442	67	74150	150	74208	135
7445	87	74151	81	74268	87
7447	87	74152	91	74293	182
7448	105	74232	225	74295	73

DATA CASSETTES 1/2 HR \$.95

14 pin headers 3/\$1.00

MMS387A A CLOCK CHIPS \$.95
 M7001 \$1.70
 MMS369 \$2.50

NO. 30 WIRE WRAP WIRE SINGLE STRAND 100'/S1.50

ICLS SERIES

74LS00	74LS138
74LS07	74LS139
74LS103	74LS14
74LS104	74LS147
74LS105	74LS155
74LS106	74LS156
74LS108	74LS157
74LS109	74LS158
74LS110	74LS159
74LS112	74LS160
74LS113	74LS161
74LS114	74LS162
74LS115	74LS163
74LS116	74LS164
74LS118	74LS165
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74LS194	74LS241
74LS195	74LS242
74LS196	74LS243
74LS197	74LS244
74LS198	74LS245
74LS199	74LS246
74LS200	74LS247

CALL FOR AVAILABILITY & PRICING

LINEAR CIRCUITS

LM 201	-.75
LM 301/748	25
LM 302	30
LM 308	75
LM 311	75
LM 318	120
LM 324	95
LM 339	-1.10
LM 358	-7.0
LM 370	-1.18

7400 TTL			
SN7400N	16	SN74720N	29
SN7401N	18	SN74721N	35
SN7402N	18	SN74722N	45
SN7403N	18	SN74723N	45
SN7404N	18	SN74724N	5.00
SN7405N	20	SN74725N	5.00
SN7406N	29	SN74726N	5.00
SN7407N	29	SN74727N	5.00
SN7408N	29	SN74728N	5.00
SN7409N	29	SN74729N	5.00
SN7410N	25	SN74730N	1.75
SN7411N	25	SN74731N	1.75
SN7412N	25	SN74732N	1.75
SN7413N	40	SN74733N	1.75
SN7414N	25	SN74734N	1.75
SN7415N	25	SN74735N	1.75
SN7416N	25	SN74736N	1.75
SN7417N	25	SN74737N	1.75
SN7418N	25	SN74738N	1.75
SN7419N	25	SN74739N	1.75
SN7420N	29	SN74740N	1.75
SN7421N	29	SN74741N	1.75
SN7422N	38	SN74742N	1.75
SN7423N	25	SN74743N	1.75
SN7424N	29	SN74744N	1.75
SN7425N	29	SN74745N	1.75
SN7426N	29	SN74746N	1.75
SN7427N	29	SN74747N	1.75
SN7428N	29	SN74748N	1.75
SN7429N	29	SN74749N	1.75
SN7430N	29	SN74750N	1.75
SN7431N	29	SN74751N	1.75
SN7432N	29	SN74752N	1.75
SN7433N	29	SN74753N	1.75
SN7434N	29	SN74754N	1.75
SN7435N	29	SN74755N	1.75
SN7436N	29	SN74756N	1.75
SN7437N	29	SN74757N	1.75
SN7438N	29	SN74758N	1.75
SN7439N	29	SN74759N	1.75
SN7440N	29	SN74760N	1.75
SN7441N	29	SN74761N	1.75
SN7442N	29	SN74762N	1.75
SN7443N	29	SN74763N	1.75
SN7444N	29	SN74764N	1.75
SN7445N	29	SN74765N	1.75
SN7446N	29	SN74766N	1.75
SN7447N	29	SN74767N	1.75
SN7448N	29	SN74768N	1.75
SN7449N	29	SN74769N	1.75
SN7450N	29	SN74770N	1.75
SN7451N	29	SN74771N	1.75
SN7452N	29	SN74772N	1.75
SN7453N	29	SN74773N	1.75
SN7454N	29	SN74774N	1.75
SN7455N	29	SN74775N	1.75
SN7456N	29	SN74776N	1.75
SN7457N	29	SN74777N	1.75
SN7458N	29	SN74778N	1.75
SN7459N	29	SN74779N	1.75
SN7460N	29	SN74780N	1.75

EXCITING NEW KITS

JEG600 HEXADECIMAL ENCODER KIT

FEATURES:

- Full 8 bit latched output for microprocessor use
- 3 User Definable keys with one being bi-stable
- On-board LED's
- Diagnose circuit provided for all 19 keys
- LED readout to verify entries
- Easy interfacing with standard 5 pin IC connector
- On-chip +5VDC required for operation

The JEG600 Encoder Keyboard provides two separate hexadecimal digits produced from sequential key entries to allow direct programming for 8 bit microprocessor or 8 bit memory circuits. Three (3) additional keys are provided for user operations with one having a bistable output available. The outputs are latched and monitored with LED readouts. Also included is a key entry strobe.

JEG600 \$59.95
Hexadecimal Keypad only \$10.95

JE300 \$39.95

TEMP T1001 LIQUID CRYSTAL DISPLAY CLASS II FIELD EFFECT

4 DIGIT - 5 CHARACTERS
THREE UNICATORS
2.00" x 1.20" PACKAGE
INCL. INCL. CONNECTOR

T1001-Transmissive \$7.95
T1001A-Reflective 8.25

DISCRETE LEDs

TYPE	POLARITY	HT PRICE	TYPE	POLARITY	HT PRICE
MAN 1	Common Anode-red	270	MAN 6730	Common Anode-red ± 1	560
MAN 2	5 x 7 Dot Matrix-red	300	MAN 6740	Common Cathode-red ± 1	560
MAN 3	Common Cathode-red	125	MAN 6750	Common Cathode-red ± 1	560
MAN 4	Common Cathode-red	187	MAN 6760	Common Cathode-red	560
MAN 7	Common Anode-yellow	300	MAN 6770	Common Cathode-red	560
MAN 7Y	Common Anode-yellow	300	DL701	Common Anode-red ± 1	300
MAN 7G	Common Anode-yellow	300	DL704	Common Cathode-red	300
MAN 74	Common Cathode-yellow	300	DL727	Common Anode-red	300
MAN 82	Common Anode-yellow	300	DL728	Common Cathode-red	500
MAN 84	Common Cathode-yellow	300	DL741	Common Anode-red	600
MAN 86	Common Anode-orange	300	DL745	Common Cathode-red	600
MAN 3630	Common Cathode-orange ± 1	300	DL747	Common Cathode-red	600
MAN 3640	Common Cathode-orange	300	DL749	Common Cathode-red	600
MAN 4100	Common Anode-orange	300	DL750	Common Cathode-red	600
MAN 4140	Common Cathode-orange	400	DL338	Common Cathode-red	110
MAN 4170	Common Anode-red	400	FD070	Common Cathode-red	250
MAN 4180	Common Cathode-red	400	FD075	Common Cathode-red	357
MAN 4190	Common Cathode-red	400	FD050	Common Cathode(FD500)	500
MAN 4610	Common Anode-red	400	FD057	Common Cathode(FD500)	500
MAN 4610	Common Anode-red	400	FD070	Common Cathode(FD500)	500
MAN 6610	Common Anode-red	400	FD073	Common Cathode(FD500)	500
MAN 6630	Common Anode-red	400	FD074	Common Cathode(FD500)	500
MAN 6640	Common Anode-red	400	FD075	Common Cathode(FD500)	500
MAN 6650	Common Anode-red	400	FD076	Common Cathode(FD500)	500
MAN 6660	Common Anode-red	400	FD077	Common Cathode(FD500)	500
MAN 6670	Common Anode-red	400	FD078	Common Cathode(FD500)	500
MAN 6680	Common Anode-red	400	FD079	Common Cathode(FD500)	500
MAN 6690	Common Anode-red	400	FD080	Common Cathode(FD500)	500
MAN 6700	Common Anode-red	400	FD081	Common Cathode(FD500)	500
MAN 6710	Common Anode-red	400	FD082	Common Cathode(FD500)	500
MAN 6720	Common Anode-red	400	FD083	Common Cathode(FD500)	500
MAN 6730	Common Anode-red	400	FD084	Common Cathode(FD500)	500
MAN 6740	Common Anode-red	400	FD085	Common Cathode(FD500)	500
MAN 6750	Common Anode-red	400	FD086	Common Cathode(FD500)	500
MAN 6760	Common Anode-red	400	FD087	Common Cathode(FD500)	500
MAN 6770	Common Anode-red	400	FD088	Common Cathode(FD500)	500
MAN 6780	Common Anode-red	400	FD089	Common Cathode(FD500)	500
MAN 6790	Common Anode-red	400	FD090	Common Cathode(FD500)	500
MAN 6800	Common Anode-red	400	FD091	Common Cathode(FD500)	500
MAN 6810	Common Anode-red	400	FD092	Common Cathode(FD500)	500
MAN 6820	Common Anode-red	400	FD093	Common Cathode(FD500)	500
MAN 6830	Common Anode-red	400	FD094	Common Cathode(FD500)	500
MAN 6840	Common Anode-red	400	FD095	Common Cathode(FD500)	500
MAN 6850	Common Anode-red	400	FD096	Common Cathode(FD500)	500
MAN 6860	Common Anode-red	400	FD097	Common Cathode(FD500)	500
MAN 6870	Common Anode-red	400	FD098	Common Cathode(FD500)	500
MAN 6880	Common Anode-red	400	FD099	Common Cathode(FD500)	500
MAN 6890	Common Anode-red	400	FD100	Common Cathode(FD500)	500

TELEPHONE/KEYBOARD CHIPS

AY-5-9100	Push Button Telephone Dialer	\$14.95
AY-5-9200	Repetitive Clock Generator	14.95
AY-5-9300	CMOS Clock Generator	4.95
AY-5-2376	Keyboard Encoder (88 keys)	14.95
HD0165	Keyboard Encoder (16 keys)	7.95
74G922	Keyboard Encoder (16 keys)	5.95

ICM CHIPS

ICM7045	CMOS Precision Timer	24.95
ICM7205	CMOS LED Stopwatch/Timer	19.95
ICM7207	CMOS Counter	7.50
ICM7208	Seven Decade Counter	19.95
ICM7209	Clock Generator	6.95

NMOS READ ONLY MEMORIES

MC6M571	128 X 9 X 7 ASCII Shifted with Green	13.50
MC6M572	128 X 9 X 7 Math Symbol & Pictures	13.50
MC6M574	128 X 9 X 7 Alphabetic Control Character Generator	13.50

MISCELLANEOUS

TL074CN	Quad Low Noise bi-let Op Amp	2.49
TL494CN	Switching Regulator	4.49
TL496CP	Single Switching Regulator	1.75
112030	Divide 10:1 Prescaler	14.36
95H90	High Speed Divide 10:1 Prescaler	11.95
4N33	Photo-Darlington Opio-Isolator	3.95
MK50240	Top Octave Freq. Generator	17.50
DS90C03CH	5MHz 2-phase MOS clock driver	3.75
ML5200	27' red nmos 4000 series logic chip	10.50
ML5300	TV Camera Sync. Generator	14.95
MM5330	4 1/2 Digit DPM Logic Block (Special)	3.95
LD110/111	3 1/2 Digit A/D Converter Set	25.00/set

LITRONIX ISO-LT-1

Photo Transistor Opio-Isolator (Same as MCT 2 or 4N25)

2/99¢

SN 76477

SOUND GENERATOR
Generates Complex Sounds
Low Power - Programmable

3.95 each

TV GAME CHIP AND CRYSTAL

AY-3-8500-1 and 2.01 MHZ Crystal (Chip & Crystal)
includes scope display, 6 games & analog, etc. 7.95/set

EXAR

XR201	58.40	XR2242CP	1.50
XR210	4.40	XR2242	1.25
XR215	4.40	XR256E	3.20
XR220	1.55	XR256T	2.99
XR1-LS55	9.90	XR256T	2.99
XR200	3.80	XR256T	2.99
XR556	9.90	XR256T	2.99
XR567CP	9.90	XR256T	2.99
XR567CT	1.25	XR256T	2.99
XR1310P	1.50	XR256T	2.99
XR146CN	3.85	XR256T	2.99
XR1488	1.39	XR256T	2.99
XR1489	1.39	XR256T	2.99

DIODES

TYPE	VOLTS	W	PRICE	TYPE	VOLTS	W	PRICE
1N4001	50	1.0	121.00	1N4002	50	1.0	121.00
1N4003	50	1.0	121.00	1N4004	50	1.0	121.00
1N4005	50	1.0	121.00	1N4006	50	1.0	121.00
1N4007	50	1.0	121.00	1N4008	50	1.0	121.00
1N4009	50	1.0	121.00	1N4010	50	1.0	121.00
1N4011	50	1.0	121.00	1N4012	50	1.0	121.00
1N4013	50	1.0	121.00	1N4014	50	1.0	121.00
1N4015	50	1.0	121.00	1N4016	50	1.0	121.00
1N4017	50	1.0	121.00	1N4018	50	1.0	121.00
1N4019	50	1.0	121.00	1N4020	50	1.0	121.00
1N4021	50	1.0	121.00	1N4022	50	1.0	121.00
1N4023	50	1.0	121.00	1N4024	50	1.0	121.00
1N4025	50	1.0	121.00	1N4026	50	1.0	121.00
1N4027	50	1.0	121.00	1N4028	50	1.0	121.00
1N4029	50	1.0	121.00	1N4030	50	1.0	121.00
1N4031	50	1.0	121.00	1N4032	50	1.0	121.00
1N4033	50	1.0	121.00	1N4034	50	1.0	121.00
1N4035	50	1.0	121.00	1N4036	50	1.0	121.00
1N4037	50	1.0	121.00	1N4038	50	1.0	121.00
1N4039	50	1.0	121.00	1N4040	50	1.0	121.00
1N4041	50	1.0	121.00	1N4042	50	1.0	121.00
1N4043	50	1.0	121.00	1N4044	50	1.0	121.00
1N4045	50	1.0	121.00	1N4046	50	1.0	121.00
1N4047	50	1.0	121.00	1N4048	50	1.0	121.00
1N4049	50	1.0	121.00	1N4050	50	1.0	121.00
1N4051	50	1.0	121.00	1N4052	50	1.0	121.00
1N4053	50	1.0	121.00	1N4054	50	1.0	121.00
1N4055	50	1.0	121.00	1N4056	50	1.0	121.00
1N4057	50	1.0	121.00	1N4058	50	1.0	121.00
1N4059	50	1.0	121.00	1N4060	50	1.0	121.00
1N4061	50	1.0	121.00	1N4062	50	1.0	121.00
1N4063	50	1.0	121.00	1N4064	50	1.0	121.00
1N4065	50	1.0	121.00	1N4066	50	1.0	121.00
1N4067	50	1.0	121.00	1N4068	50	1.0	121.00
1N4069	50	1.0	121.00	1N4070	50	1.0	121.00
1N4071	50	1.0	121.00	1N4072	50	1.0	121.00
1N4073	50	1.0	121.00	1N4074	50	1.0	121.00
1N4075	50	1.0	121.00	1N4076	50	1.0	121.00
1N4077	50	1.0	121.00	1N4078	50	1.0	121.00
1N4079	50	1.0	121.00	1N4080	50	1.0	121.00
1N4081	50	1.0	121.00	1N4082	50	1.0	121.00
1N4083	50	1.0	121.00	1N4084	50	1.0	121.00
1N4085	50	1.0	121.00	1N4086	50	1.0	121.00
1N4087	50	1.0	121.00	1N4088	50	1.0	121.00
1N4089	50	1.0	121.00	1N4090	50	1.0	121.00
1N4091	50	1.0	121.00	1N4092	50	1.0	121.00
1N4093	50	1.0	121.00	1N4094	50	1.0	121.00
1N4095	50	1.0	121.00	1N4096	50	1.0	121.00
1N4097	50	1.0	121.00	1N4098	50	1.0	121.00
1N4099	50	1.0	121.00	1N4100	50	1.0	121.00

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C380	15A @ 60V	SCR(N1848)	1.95
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2N2328			

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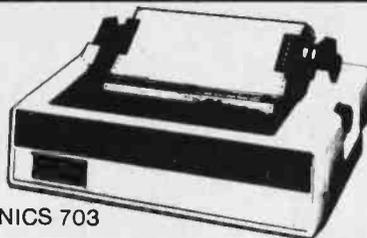
TF-1	Pertec FD200, 5 1/4", 40 track use both sides	\$379
TF-3	Shugart SA400, 5 1/4", 35 tracks same as tandu	\$389
TF-5	MPI 5 1/4" 40 track door lock and auto diskette ejection	\$379
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All disk drive systems come complete with power supply and
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Sanyo Magnetic Card Reader

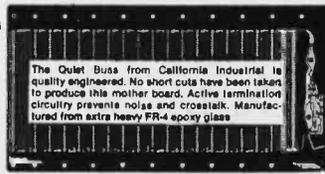
\$59

These Sanyo I/O units are capable of storing and retrieving over 400 characters of data in under two seconds. The flexibility of this device lends itself to numerous applications. As an input reader to a computerized security system, the computer has the ability of identifying the card holder and admitting only those individuals who are authorized to enter the premises during specified time frames. The device is also suitable for maintaining customer information files, or any other application where small amounts of information must be quickly entered into a data processing system. Accepts 2" by 4" HP style mag-cards. (Similar to bank cards.) Motorized feeder pulls the magnetic card across the four channel read/write head. NEW surplus, original cost \$200. Full documentation

S-100 Mother Board

Quiet Bus

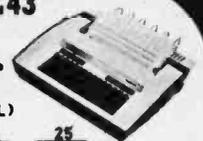
\$2995
8803-18
18 slot
1MSAI



The Quiet Bus 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

TELETYPE MODEL 43

Even if we have to give them away, we're going to ship more 43's in 1979 than the aggregate of all our competitors.



Model 43AAA TTL)
EACH 3 10 25
\$925. 875. 850. 825.
RS-232 Interface "K" Add \$75.00 plus shipping

HEXADECIMAL KEYBOARD

Maxi-Switch hexadecimal keyboards are designed for microcomputer systems that require 4-bit output in standard hex code.

Each assembly consists of 16 hermetically sealed reed switches and TTL "one shot" debounces circuitry.

Reliable low friction acetal resin plungers are credited for the smooth operation and long life of this premium keyboard.

Requires single +5 volt supply.



\$34.95

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\$29.95
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DISKETTES

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Imai solder 125 x 250 \$3.95 3/4 0.00
Imai w/ 125 centers \$4.95 3/4 0.00
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36/72 wide post w/w .156 \$1.95 3/4 0.00



SPERRY UNIVAC KEYBOARD

The famous Sperry Univac 1710 Heilbrunn keyboard assembly is now available from California Industrial for only \$24.88. The latest 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

\$24.88

MODULATOR

The Alan R.F. Modulator allows computer data to be displayed directly upon your existing television system. This unit converts the signal from the Apple II and other video sources into television frequencies. Operates from single 5 volt supply. Complete with metal case, mating RF connector and 15 feet of coax cable. Schematics and instructions included.

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The most cost effective way to store data processing information, when random recall is a prime factor. The SA800 is fully compatible with the IBM 3740 format. Write protect circuitry, low maintenance & Shugart quality.

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KEYTRONIC ASCII & ASCII complement.
*Ten key data pad
*Cursor controls
*Six user switches
*Alpha Lock
*Auto repeat
*Single 5 volt.
*Glass reed.
NEW

MEMORY

TRS-80 \$65
APPLE II
16k memory (8) 4116's

As you may be aware, publishers require advertisers to submit their ad copy 60 to 90 days prior to "press" date. That much lead time in a volatile market place, such as memory circuits, makes it extremely difficult to project future cost and availability. To obtain the best pricing on memory we have made volume commitments to our suppliers, which in turn affords us the opportunity to sell these circuits at the most competitive prices. Please contact us if you if you have a demand for volume state of the art memory products.

STATIC	1-31	32-89	100-5C	-999	1K+
21L02 450nS.	1.19	.99	.95	.90	.85
21L02 250nS.	1.49	1.39	1.25	*	*
2114 1Kx4 450	8.95	5.50	5.25	4.75	4.50
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4044 4Kx1 450	5.95	5.50	5.25	*	*
4044 4Kx1 250	9.95	9.50	9.00	*	*
4045 1Kx4 450	8.95	8.50	8.00	*	*
4045 1Kx4 250	9.95	9.50	9.00	*	*
5257 low pow.	5.95	5.50	5.00	4.80	4.60

SPECIAL CIRCUITS

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8080A CPU	9.95	Floppy Disc Controllers	
8085	22.50	WD 1771 single D.	39.95
8088 Intel 18 bits	*	WD 1781 Double D.	65.00
TMS9900 16 bits	49.95	WD 1791 D/D 3740	*



EPROMS	1-15	16-63	64+
1702A 2K	4.95	4.50	4.00
2708 8K	9.95	9.50	9.00
2716 5v 16K	38.95	35.00	*
2716 TI	24.88	20.00	*
2532	*	*	*



\$1395.00

PORTABLE DATA ENTRY SYSTEM

These used data terminals were originally designed for chain store inventory control and order entry systems. The operator enters the inventory control number, merchandise on hand and the unit price. After all pertinent data has been entered into the recorder, the main warehouse is telephoned, the handset is placed in the acoustic coupler and all the recorded information is transmitted back to the master computer. With a little imagination and one of these portable entry systems, you should be able to exchange programs and computer information with associates across the country. All units were removed from service in working condition. Original cost \$2,500. Each system comes complete with:

- *Portable Cassette Drive Unit
- *Removable Entry Keyboard with LED Display
- *Five Gould "D" NICads
- *Acoustical Coupler
- *Battery Charger
- *DB25 Cable
- *Shoulder strap
- *Full Documentation

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7107 Jst ON-OFF (mnt. ON)
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Rotary 3P-4-Pos.
Rotary 3P-6-Pos.
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40	100 155 139		63 60 58	

501L
\$98 500 1000 11,000
\$8 \$15. \$105.

\$2995
BW 630
ON HOBBY WRAP-10 wire wrap & strip tool
\$545

SYSTEM X-10

It's not often that California Digital ventures into the distribution of consumer products, but we have recently come across a product that appears so unique that we just had to add it to our product line. This is the System X-10 manufactured by the BSR turntable company. This space age system will remotely control any light or appliance in your home or office. Commands and signals are transmitted from the command console over your existing wiring. From your bed or easy chair you can control up to 18 different electrical devices inside and outside your home. Use the System X-10 to control your stereo, television or any light fixture on the premises. The basic sampler package comes complete with command console, battery operated ultrasonic controller, one each of the appliance module, lamp module and wall switch. The basic package is priced at only \$99.50. Additional modules are available for \$13.95 each.

(213)679-9001

All merchandise sold by California Digital is premium grade. Sorry, no C.O.D.'s. Orders are shipped the same day received. California residents add 6%. Foreign orders add 10%. Cards over \$25, when a company is present, are shipped at our expense. C.O.D.'s, please add \$2.

COMPUCRUISE

Put a computer in your car, which gives you the most effective and functional cruise control ever designed, plus complete trip computing, fuel management systems, and a remarkable accurate quartz crystal time system.

So simple a child can operate, the new CompuCruise combines latest computer technology with state-of-the-art reliability in a package which will not likely be available on new cars for years to come. • Cruise Control • Time, E.T., Lap Timer, Alarm • Time, Distance, Fuel to Arrival • Time, Distance, Fuel to Empty • Time, Distance and Fuel on Trip • Current or Average MPG, GPH • Fuel Used, Distance since Fillup • Current and Average-Vehicle Speed • Inside, Outside or Coolant Temperature • Battery Voltage • English or Metric Display. \$199.95



FLOPPY DISK STORAGE BINDER

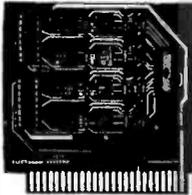
This black vinyl three-ring binder comes with ten transparent plastic sleeves which accommodate either twenty, five-inch or ten, eight-inch floppy disks. The plastic sleeves may be ordered separately and added as needed. A contents file is included with each sleeve for easy identification and organizing. Binder & 10 holders \$14.95 Part No. 8800; Extra holders 95¢ each. Part No. 800



OPTO-ISOLATED PARALLEL INPUT BOARD FOR APPLE II

There are 8 inputs that can be driven from TTL logic or any 5 volt source. The circuit board can be plugged into any of the 8 sockets of your Apple II. It has a 16 pin socket for standard dip ribbon cable connection.

Board only \$15.00. Part No. 120, with parts \$69.95. Part No. 120A.



TIDMA

• Tape Interface Direct Memory Access • Record and play programs without bootstrap loader (no prom) has FSK encoder/decoder for direct connections to low cost recorder at 1200 baud rate, and direct connections for inputs and outputs to a digital recorder at any baud rate • S-100 bus compatible • Board only \$35.00 Part No. 112, with parts \$110 Part No. 112A



SYSTEM MONITOR

8080, 8085, or Z-80 System monitor for use with the TIDMA board. There is no need for the front panel. Complete with documentation \$12.95.

16K EPROM

Uses 2708 EPROMs, memory speed selection provided, addressable anywhere in 65K of memory, can be shadowed in 4K increments. Board only \$24.95 part no. 7902, with parts less EPROMs \$49.95 part no. 7902A.



ASCII KEYBOARD

TTL & DTL compatible • Full 67 key array • Full 128 character ASCII output • Positive logic with outputs resting low • Data Strobe • Five user-definable spare keys • Standard 22 pin dual card edge connector • Requires +5VDC, 325 mA. Assembled & Tested. Cherry Pro Part No. P70-05AB. \$135.00.



ASCII KEYBOARD

53 Keys popular ASR-33 format • Rugged G-10 P.C. Board • Tri-mode MDS encoding • Two-Key Rollover • MDS/DTL/TTL Compatible • Upper Case lockout • Data and Strobe inversion option • Three User Definable Keys • Low contact bounce • Selectable Parity • Custom Keycaps • George Risk Model 753. Requires +5, -12 volts. \$59.95 Kit.

ASCII TO CORRESPONDENCE CODE CONVERTER

This bidirectional board is a direct replacement for the board inside the Trendata 1000 terminal. The on board connector provides RS-232 serial in and out. Sold only as an assembled and tested unit for \$229.95. Part No. TA 1000C

DISK JACKET™

Made from heavy duty .0095 matte plastic with reinforced grommets. The mini-diskette version holds two 5-1/4 inch diskettes and will fit any standard three ring binder. The pockets to the left of the diskette can be used for listing the contents of the disk. Please order only in multitudes of ten. \$9.95/10 Pack.



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English, French, Danish, German, Italian, Hungarian, Norwegian, Polish, Spanish, Swedish. 10 languages, 28 pp. SYBEX. Ref. IMD. \$4.95

VIDEO TERMINAL

16 lines, 64 columns • Upper and lower case • 5x7 dot matrix • RS-232 in • RS-232 out with TTL parallel keyboard input • On board baud rate generator 75, 110, 150, 300, 600, & 1200 jumper selectable • Memory 1024 characters (7-21L02) • Video processor chip SFF96364 by Neculonic • Control characters (CR, LF, →, ←, ↑, ↓, non destructive cursor, CS, home, CL • White characters on black background or vice-versa • With the addition of a keyboard, video monitor or TV set with TV interface (part no. 107A) and power supply this is a complete stand alone terminal • also S-100 compatible • requires +16, & -16 VDC at 100mA, and BVDC at 1A. Part no. 1000A \$199.95 kit.



RS-232/20mA INTERFACE

This board has two passive, opto-isolated circuits. One converts RS-232 to 20mA, the other converts 20mA to RS-232. All connections go to a 10 pin edge connector. Requires +12 and -12 volts. Board only \$9.95, part no. 7901, with parts \$14.95 Part No. 7901A.



COMPUCOLOR II

Model 3, BK \$1395. Model 4, 16K \$1595. Model 5, 32K \$1895. Prices include color monitor, computer, and one disk drive.



PET COMPUTER

With 32K & monitor - \$1195. Dual Disk Drive - \$1195.



Apple II

or
APPLE II PLUS
16K - \$995, 32K \$1059, 48K - \$1123. Disk & cont \$589



6502 APPLICATIONS BOOK Z80 APPLICATIONS BOOK*

This book will teach you how to connect a board to the outside world and implement practical applications for the 6502, (or Z80). Applications range from home control (a complete alarm system, including heat sensor), to industrial applications. You will learn techniques ranging from simulated traffic control to analog-digital conversion. All experiments can be realized with a minimum of external (low-cost) components. They are directly applicable to any 6502-based board such as SYM, KIM, AIM 65. This book also studies in detail input-output techniques and components, and is the logical continuation of C202 (or C280). By Rodney Zaks. SYBEX. 6502: Ref. D302; Z80: Ref. D380. Each \$12.95

T.V. INTERFACE

• Converts video to AM modulated RF. Channels 2 or 3. So powerful almost no tuning is required. On board regulated power supply makes this extremely stable. Rated very highly in Doctor Dobbs' Journal. Recommended by Apple • Power required is 12 volts AC C.T., or +5 volts DC • Board only \$7.60 part No. 107, with parts \$13.50 Part No. 107A



PARALLEL TRIAC OUTPUT BOARD FOR APPLE II

This board has 8 triacs capable of switching 110 volt 6 amp loads (660 watts per channel) or a total of 5280 watts. Board only \$15.00 Part No. 210, with parts \$119.95 Part No. 210A.

To Order: Mention part no. description, and price. In USA shipping paid by us for orders accompanied by check or money order. We accept C.O.D. orders in the U.S. only, or a VISA or Master Charge no., expiration date, signature, phone no., shipping charges will be added. CA residents add 6.5% for tax. Outside USA add 10% for air mail postage and handling. Payment must be in U.S. dollars. Dealer inquiries invited. 24 hour order line (408) 226-4064.



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TRS-80^{E.S.} SERIAL I/O

- Can input into basic
- Can use LLIST and LPRINT to output, or output continuously
- RS-232 compatible
- Can be used with or without the expansion bus
- On board switch selectable baud rates of 110, 150, 300, 600, 1200, 2400, parity or no parity odd or even, 5 to 8 data bits, and 1 or 2 stop bits. D.T.R. line
- Requires +5, -12 VDC
- Board only \$19.95 Part No. 8010, with parts \$59.95 Part No. 8010A, assembled \$79.95 Part No. 8010 C. No connectors provided, see below.



EIA/RS-232 connector Part No. 0B25P \$6.00 with 9' 8 conductor cable \$10.95 Part No. 0B25P9



3' ribbon cable with attached connectors to fit TRS-80 and our serial board \$19.95 Part No. 3CAB40.

MODEM

- Type 103
- Full or half duplex
- Works up to 300 baud
- Originate or Answer
- No coils, only low cost components
- TTL input and output-serial
- Connect 8 Ω speaker and crystal mic, directly to board
- Uses XR FSK demodulator
- Requires +5 volts
- Board only \$7.60 Part No. 109, with parts \$27.50 Part No. 109A

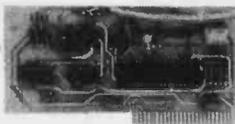


DISKETTES



Box of 10, 5" \$29.95, 8" \$39.95. Plastic box, holds 10 diskettes, 5" - \$4.50, 8" - \$6.50.

APPLE II[®] SERIAL I/O INTERFACE



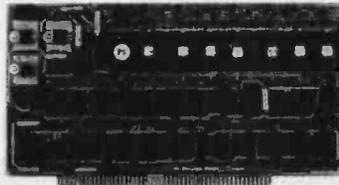
Baud rate is continuously adjustable from 0 to 30,000

- Plugs into any peripheral connector
- Low current drain. RS-232 input and output
- On board switch selectable 5 to 8 data bits, 1 or 2 stop bits, and parity or no parity either odd or even
- Jumper selectable address
- SOFTWARE
- Input and Output routine from monitor or BASIC to teletype or other serial printer
- Program for using an Apple II for a video or an intelligent terminal. Also can output in correspondence code to interface with some electricics.
- Also watches OTR
- Board only \$15.00 Part No. 2, with parts \$42.00 Part No. 2A, assembled \$62.00 Part No. 2C

8K EPROM PIICEON

Saves programs on PROM permanently (until erased via UV light) up to 8K bytes. Programs may be directly run from the program saver such as fixed routines or assemblers.

- S-100 bus compatible
- Room for 8K bytes of EPROM non-volatile memory (2708's).
- On-board PROM programming
- Address relocation of each 4K of memory to any 4K boundary within 64K
- Power on jump and reset jump option for "turnkey" systems and computers without a front panel
- Program saver software available
- Solder mask both sides
- Full silkscreen for easy assembly. Program saver software in 1 2708 EPROM \$25. Bare board \$35 including custom coil, board with parts but no EPROMS \$139, with 4 EPROMS \$179, with 8 EPROMS \$219.



WAMECO PRODUCTS WITH ELECTRONIC SYSTEMS PARTS

FDC-1 FLOPPY CONTROLLER BOARD will drive shugart, pertek, remex 5" & 8" drives up to 8 drives, on board PROM with power boot up, will operate with CPM (not included). PCB \$42.95

FPB-1 Front Panel. (Finally) IMSAI size hex displays. Byte or instruction single step. PCB \$42.95

MEM-1A 8Kx8 fully buffered, S-100, uses 2102 type RAMS. PCB \$24.95, \$168 Kit \$34.95

GMB-12 MOTHER BOARD, 13 slot terminated, S-100 board only \$89.95 Kit \$79.95

CPU-1 8080A Processor board S-100 with 8 level vector interrupt PCB \$25.95 \$89.95 Kit

RTC-1 Realtime clock board. Two independent interrupts. Software programmable. PCB \$25.95, \$60.95 Kit

EPM-1 1702A 4K EPROM card PCB \$25.95 \$49.95 with parts less EPROMS

EPM-2 2708/2716 16K/32K EPROM card PCB \$24.95 \$49.95 with parts less EPROMS

GMB-9 MOTHER BOARD. Short Version of GMB-12. 9 Slots PCB \$30.95 \$67.95 Kit

MEM-2 16Kx8 Fully Buffered 2114 Board PCB \$25.95, \$269.95 Kit

T.V. TYPEWRITER

- Stand alone TVT
- 32 char/line, 16 lines, modifications for 64 char/line included
- Parallel ASCII (TTL) Input
- Video output
- 1K on board memory
- Output for computer controlled cursor
- Auto scroll
- Non-destructive cursor
- Cursor inputs: up, down, left, right, home, EOL, EOS
- Scroll up, down
- Requires +5 volts at 1.5 amps, and -12 volts at 30 mA
- All 7400, TTL chips
- Char. gen. 2513
- Upper case only
- Board only \$39.00 Part No. 106, with parts \$145.00 Part No. 106A



TAPE INTERFACE

- Play and record Kansas City Standard tapes
- Converts a low cost tape recorder to a digital recorder
- Works up to 1200 baud
- Digital in and out are TTL-serial
- Output of board connects to mic. in of recorder
- Earphone of recorder connects to input on board
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- Requires +5 volts, low power drain
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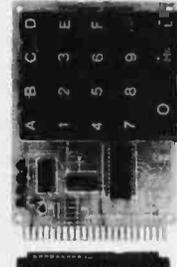
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- Converts serial to parallel and parallel to serial
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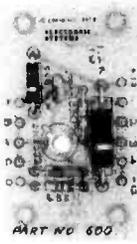
RS-232/ TTL INTERFACE

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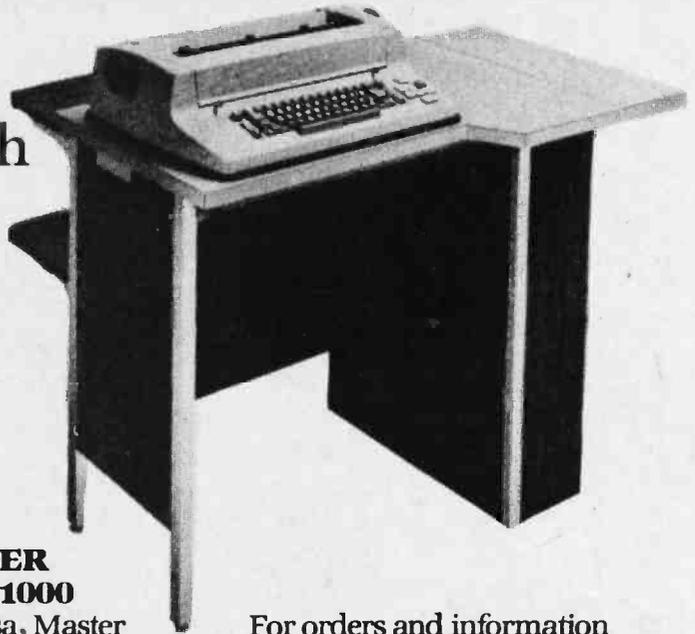
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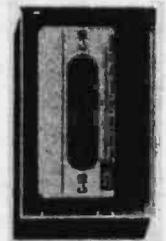
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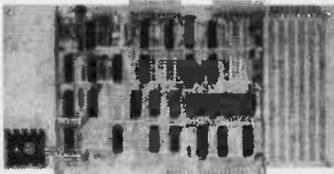
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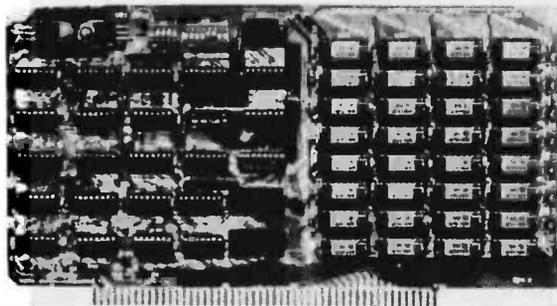
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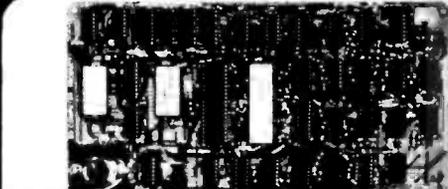
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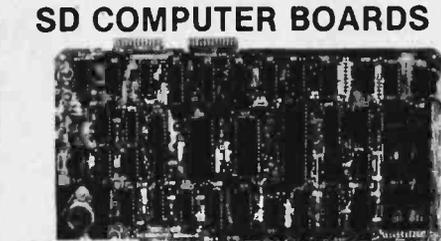
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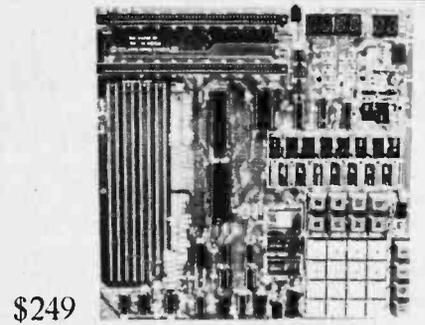
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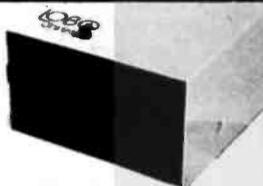
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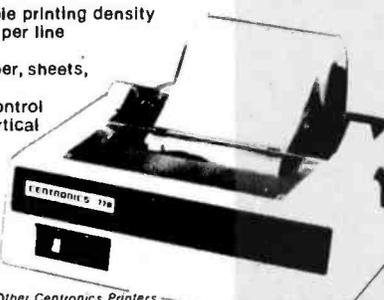
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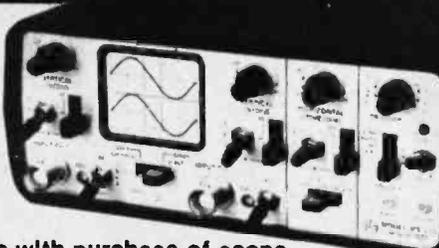
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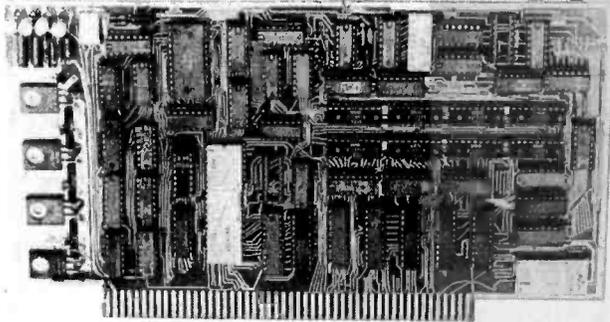
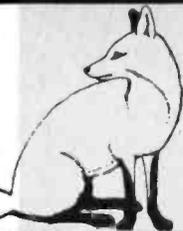
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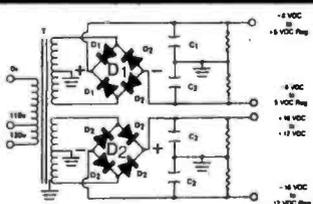
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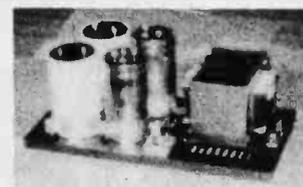
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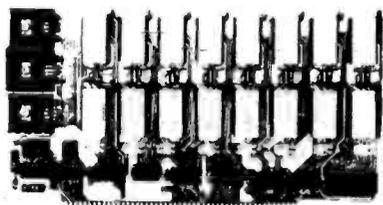
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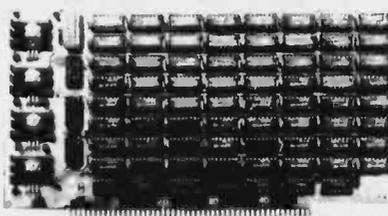
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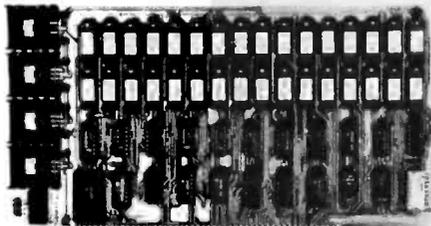
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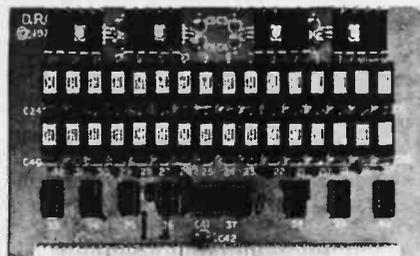
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TI-99/4

HOME COMPUTER



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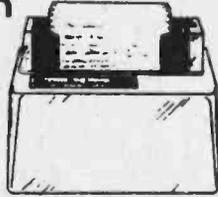
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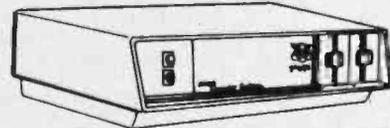
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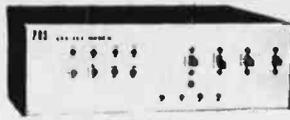
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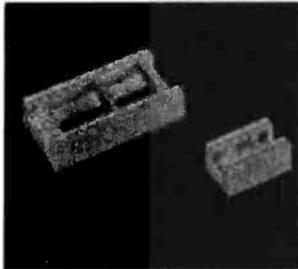
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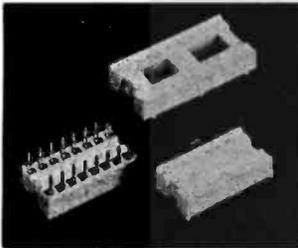
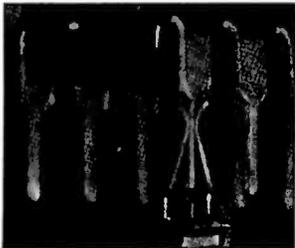


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20 Pin	.90	.80	.75	.65	.62
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16 Pin	—	.21	.19	.17	.15
18 Pin	.30	.28	.27	.26	.25
20 Pin	.35	.34	.33	.32	.31
22 Pin	.36	.34	.30	.27	.26
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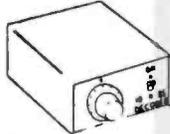
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June BOMB

William D. Johnston again dazzled our readers with "Computer Generated Maps," Part II, page 100. Second place was taken by James Albus for contributing "A Model of the Brain for Robot Control," page 10. Placing a very close third and fourth, respectively, were G. A. Van den Bout, "Designing a Command Language" and T. Radhakrishnan and M. V. Bhat, "Stacks in Microprocessors."

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