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About the Cover

The conceptual target of the cover painting for September was a theme of music and sound. Taking this theme, Robert Tinney implemented this cover, entitled "Breaking the Sound Barrier." It was inspired by the legend of opera star Enrico Caruso breaking a wine glass through sympathetic resonances with his voice. The sound barrier we're referring to, of course, is the physical barrier between a program and the real world, which is crossed by one of a number of musical and audio output devices and software presently on the market or about to come to the marketplace.

In This BYTE

Experimenting with music on your computer can be very rewarding. If you're looking for a streamlined way to input musical material into your system, look no further. Hal Taylor shows you how in SCORTOS: Implementation of a Music Language. Who knows, with SCORTOS you could have your synthesized concerto for alpenhorn and orchestra up, running and debugged by next week.

A naked microcomputer board is unprotected from a harsh environment. In his article this month, R. Travis Atkins turns couturier as he fashions external garb in the form of A New Dress for KIM.

Steve Ciarcia returns this month with a combination of tutorial ideas and practical details so characteristic of his style. Read Steve's Control the World! (Or at Least a Few Analog Points) to review digital to analog conversion, and learn how BASIC can be used to compute and represent waveforms through a converter using a scope as a display.

A Tiny Assembler need not have tiny features, as Jack Emmerichs explains in his article on Expanding the Tiny Assembler. Jack adds structured programming features and incremental improvements to the Tiny Assembler design he described in April and May issues of BYTE this year. By reorganizing the symbol table to add the "begin" pseudo operation, "Tiny" takes on a number of "big" features while preserving practical operation as Version 3.1 in under 4 K bytes of memory.

Looking for a very simple way to build a wire wrap board? Ira Rampil has an idea in A One-Sided View of Wire Wrap Sockets.

Are you interested in making music with your computer? Hal Chamberlin's A Sampling of Techniques for Computer Performance of Music is one of the best ways to get acquainted with this fascinating field. The article will give you complete directions for creating 4 part harmony on your microprocessor for a very modest investment. Get out those 4 voice fugues that have been languishing in your music drawer and bring them to life!

Did you ever want your computer to sing you a lullaby? Well, as Ted Sierad points out, it's not too hard to do so if you Tune In With Some Chips, using the circuit and software he describes.

The roster of "complete" computer systems for the amateur computing person expanded considerably with the introduction of the Noval 760. Turn to an account by designers Lane T. Hauck and James D. Nash, System Description: the Noval 760, for details of the philosophy and overall design behind this product.

A double feature written by Carl Helmers and Chris Morgan of BYTE covers key details of an interesting musically oriented peripheral which can be added to the personal computer: acoustic pianos with pneumatic player actions. Notes on Anatomy: The Piano's Reproductive System gives global morphology of a Duo-Art upright reproducing piano. Notes on Interfacing Pneumatic Player Pianos covers some details of how to engineer a computer interface for the pneumatic control lines using valve elements manufactured for the pipe organ industry.

With this issue, readers will note the continued progression of information on APL, and several articles introducing the theme of music representation and performance with computers. Readers can look forward to further information on these themes in future issues.

APL is one of the most interesting high level languages around these days. If you want to continue learning what goes on in an APL interpreter, read part 2 of Mike Wimble's An APL Interpreter for Microcomputers. Here Mike covers the expression evaluation sections of the interpreter.

Many people are familiar with use of orthogonal basis functions such as sines and cosines to compute arbitrary waveforms. But how many readers have heard of Walsh Functions: A Digital Fourier Series which forms arbitrary repetitive waveforms as weighted sums of digital waveforms? Read Benjamin F. Jacoby's tutorial to find out a bit about these functions and their generation.
Announcing the West Coast's largest Personal Computing Show. April 28, 29, and 30, 1978 at California's brand new Long Beach Convention Center. This is a selling show with 180 booths (each draped, carpeted and with 500 watts of electricity). Three full days of conference sessions. There will be home brew exhibits, exhibitors lounge, inquiry badge system, computerized registration, a newsroom, and a full blown advertising and promotional campaign to bring you thousands of qualified buyers.

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Reflections on Entry into Our Third Year

By Carl Helmers

The September 1977 BYTE marks the end of the second year of our publication's existence in the public eye, although actual work on the magazine began at the end of May 1975. Since that time, the phenomenon of personal computing has expanded considerably as more people become aware of it through mass media publications, radio and television shows, trade fairs such as the First West Coast Computer Faire and the National Computer Conference. Good sense says a peak must be reached in any new and expanding marketplace, but to date we have seen no signs of the traditional "shakeout" (intense competition such as that which occurred recently in the calculator and watch marketplaces). For whatever reasons, a few firms have fallen by the wayside, but the general trend still remains one of expansion and exploration, to the ultimate benefit of the user of personal computing products who is presented with new options and lower prices for older options.

The "appliance" computer, a complete system presented in an assembled and tested package is on the threshold of its ultimate dominance in the general purpose personal computer field: from the high end, moving down in price, we find products like the Apple-II and the Commodore PET 2001 machines; from the low end, moving up in function at the same price, we find the increasing versatility and capability of programmable calculators such as the newly announced Texas Instruments SR-59 with its optional ROM software modules and expanded printing and magnetic card peripheral capabilities. And for the discrimi-
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 REGARDING INTERFACING THE IBM SELECTRIC KEYBOARD PRINTER

My congratulations to Mr Fylstra on a job well done in his June article in BYTE. I spent half a year, back in 1970, on designing the interface for the 735 Selectric to the Microdata 800 Mini-computer, and in the process went through many of the discoveries revealed in the article. As the man who serviced our IBM 10 printers (an ex-IBMer) said to me, that machine is a triumph of development over engineering!

One fruit of my work was a 2048 bit ROM which we custom programmed to do the ASCII to "ball code" conversion and back, without recourse to a software lookup table. It is still available as the MMS230KP from National Semiconductor. But note that it handles only the "correspondence" version of the Selectric: our machine needed full upper and lower case graphics.

Dan's comments on using the "a" and "b" contacts for figuring ready/busy of the printer are quite valid. One thing we learned was that allowing the clutch to stop between characters does lead to shortened life between adjustments. Back in 1970 we used a TTL voting circuit to read the contacts, because they bounced so much, and accurate timing is essential for "wide open" running.

One last point: the contacts are open reed, and must be "wetted" by using a current several times higher than the 5 mA shown, else they get dirty very quickly.

Good luck to all ye who pass this way again!

Richard Percival
National Semiconductor GmbH
Industriestrasse 10
808 Furstenfeldbruck GERMANY

IS BUS COMPATIBILITY NEEDED?

I have recently noticed that many people ascribe a certain importance to a product if it is "Altair (S-100) compatible." This should not be unusual; many people own Altair bus based systems and wish to buy only what is useful to them. But I am angered by people who automatically downgrade a product that is not S-100, even if they do not own a system themselves. They seem to think that compatibility and board interchangeability rank high on the list of priorities for a "good" computer system. This is typical of most of the hobby market. I feel that the next few years will bring a change in that viewpoint. As computers become more and more common, processor power and built-in features will take precedence over bus compatibility. This is especially true in the consumer market. Who, in the early days of radio, would buy a separate tuner, amplifier and speaker assemblies if they could buy a complete, assembled unit? Consumers would never consider buying and inserting full size printed circuit boards into a system; they will rarely care whether they have a separate video board or a video section or a single board computer if it works.

This is not to say that the Altair (S-100) design will vanish. The large number of systems and boards available makes it a great system for someone who knows what he or she is doing. For all others, a system that is self-enclosed and requires no expansion for basic IO devices (tape recorder, TV set) will be more popular.

If we are to go anywhere with home computers, as designers we must understand what consumers expect them to do; we must not force them to adapt to our insufficiencies; we must learn to provide a useful and well-integrated product.

C David Espinosa
21191 Gardens Dr
Cupertino CA 95014

The first automobiles were not truly consumer oriented, either, but as the public became educated in the uses of the product and as manufacturers learned more about the product and its design, the personal transporter became today's ubiquitous mechanism. In the continuing evolution of the personal computer, a similar user orientation is in the works and presently unfolding as innovative technological entrepreneurs gain experience and refine the product concepts.

IBM 360/370 EMULATIONS

Concerning Tom Koon's letter in the May 1977 BYTE about 360/370 emulation: this has already been done in at least one instance that I know of. Roger Appel of Interdata recently mentioned that his company took on this project a few years back. Interdata's Boston area phone is (617) 890-0537, and as to the price, don't count on it being cheap.

J Howell Mitchell Jr
Dynamics Research Corp
60 Concord St
Wilmington MA 01887

A PUZZLE: DELETING THE DELIMITER

I have comments to make regarding Dave Chapman's problems with deleting the delimiter (May 1977 BYTE). There is not much to say but even more annoying problem if you're working with an editor program which has a delete character.

The question is, how do you change

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a delete character, when typing the character deletes the previous character? A variation of this exercise is obtained when you suppose that somehow the character for “change” has been set to be the character for “delete.”

These are amusing puzzles, and it can be left to the reader to figure out how to get into and out of these situations.

E G Johnston
Computer Sciences Corporation
Silver Spring MD 20910

MORE ON SR-52/SR-51 INTERNALS

I am interested in interfacing the SR-52 with some other equipment and have gathered a little (very little) information which might help William D Lewis (letters of June 1977 BYTE) with his SR-52. First, the SR-52 and SR-51 terminal strips appear to be similar. The SR-52 has a TMC0501NL which they call U1 and a TMC0524NL which appears to be a version of the TMC-0523NS-5, but it is called U2.

The terminal strip connectors in the order shown in the June BYTE are: NC, D12, 02, Ext, IDLE, IRG, D15, DO, 01, KN, KP, KR. The pinouts of the TMC-0501NL are: (1)DPT), (2)SB), (3)SA), (4)SF), (5)SC), (6)SD), (7)SE), (8)KT), (9)KS), (10)KR), (11)KQ), (12)KP), (13)KX).

Continued on page 174

AN IMPORTANT WARNING ABOUT THE ELEMENT MERCURY AND ITS COMPOUNDS

The June 1977 issue of BYTE arrived recently and Mr Pasken’s letter on obtaining mercury caught my eye, causing me to go back and read Mr Firth’s article on weather prediction in the December 1976 issue, page 62, which I had not read the first time around. I fear that Mr Firth, and perhaps Mr Pasken, are under a misapprehension as to the nature of the hazards of contact with metallic mercury. As an industrial hygienist, I feel impelled to set the record straight and to comment on Mr Pasken’s method of obtaining mercury.

A note in Mr Firth’s article states that “mercury can be harmful if you breathe the vapors, swallow it or otherwise get it in your body. But there is little danger from . . . putting your hands in it.” It is true that mercury vapors are harmful; however, the rest of the statement I have quoted is, by and large, not true for metallic mercury, which is what one would use in a barometer. Metallic mercury is readily absorbed through the skin. On the other hand, if swallowed it passes virtually without absorption through the gastrointestinal tract and presents very little hazard to the individual. (One should, of course, try to avoid swallowing it anyway.)

Mr Pasken does not address the hazards of mercury, but his method of obtaining it is one which, in view of those hazards, I would not recommend. In breaking open mercury switches and cleaning the mercury by passing it through a hole in a filter paper, one’s tendency would be to work with the material rather close to the face. This could result in considerable breathing of mercury vapors. (Remember, most readers will not be doing this in a chemistry lab equipped with adequately performing fume hoods.) In addition, the potential for skin contact is obviously quite great.

Mercury, if spilled on a floor, can be quite difficult to clean up. Sweeping will only break it into smaller and smaller drops which will lodge in cracks and inCREASE the cleaning problem. Vacuuming is a preferred method. But most people don’t keep laboratory aspirators in their homes, and contaminating the family vacuum cleaner with mercury is hardly an ideal solution. There are also commercial materials which when sprinkled onto a mercury spill will halt the mercury compounds which can be swept up, but I doubt that many people have such things available to them at home. And frankly, should mercury be spilled on a rug, I can’t imagine how it could be cleaned up completely.

There are a few other points to consider. If mercury is spilled on your floor, it is a greater hazard to your small children and pets than to you. They are down there where the vapors are stronger and are in more intimate contact with the floor, and potentially with the spill. Also, mercury is fun to play with. Children, and adults too, like to coat coins with it or watch a droplet roll around the palm of a hand. Such recreation leads to skin contact, which should be avoided. Finally, should you be working with mercury in your home in winter, and your home is not heated with forced air, the room in which you work will not have much ventilation and the mercury vapor concentration will be higher than otherwise.

I should mention that the above statements on the hazards of mercury are made with respect to metallic, or elemental, mercury. Mercury compounds can also be hazardous in other modes of exposure.

In summary, metallic mercury is a hazardous material, both by breathing the vapors and by skin contact. If you must work with it, avoid skin contact, and if you don’t have access to a chemistry laboratory, work with it outside or in a well-ventilated room. Store mercury, and your open edge mercury barometer, where children, pets and other curious people cannot get at it, again, preferably in a well-ventilated room.

Peter L Zavon
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SCORTOS:

Implementation of a Music Language

Hal Taylor
Interactive Music
Box 11
Arlington VA 22210

Perhaps nowhere can technology better serve the creative end of the music arts than through the computer. The computer has a natural affinity for the application to music since it is capable of carrying out processes which create and perform music. It can be programmed to learn any language the composer wishes to use to describe his musical ideas. It can manipulate the symbols of that language to produce transformations of the composer’s original ideas. It can enlarge and improve the quality of the composer’s creative output by allowing him to work in an interactive mode where he can hear his musical works performed within minutes of their conception.

The computer owes this affinity to its unerring accuracy and high bandwidth, qualities which its human inventors do not possess. The human mind is slow and noisy and requires years of exercise to achieve the coordination necessary to perform complex musical passages. Although the computer may never be able to match the expressive subtleties of a concert soloist, it is in some cases more suitable for the performance of music than a human being.

If a program can be devised to convert musical symbols to the sounds they represent, then the computer can be of value to the composer as a means of developing composition prototypes, that is, preliminary designs of musical works that he could hear performed before he copied the parts and gave them to the orchestra. An editing capability would also be available to him to alter the music until it produced the desired results. When the computer performed the work to his satisfaction, the original score and the instrumental parts could be published on a computer controlled plotter. With such a system the composer could avoid the drudgery of hand copying parts, and would be encouraged to experiment
with new forms that he might otherwise hesitate to give to an orchestra.

The computer can also be useful to the composer as an originator of musical ideas since it can simulate the process by which the human mind creates music. A music composition consists of a series of musical events chosen from a minimum of about 200 different possibilities (consider, just 12 tones and 18 types of notes). Only certain of these combinations are pleasing to the human ear. The composer's job is to discover those combinations which produce aesthetic results. The manner in which he or she does this is personal, intuitive, and cannot by itself form the basis for a workable algorithm. It is possible, however, to infer some of the underlying rules of music by analyzing it. Whether we are composing with our minds or with a computer, we follow a set of rules that determine which pitches will be chosen, in what order they will be arranged, and how long each will last in time.

The set of rules describes the style and structure of the music and can be represented in a computer by a statistical model. A process can be programmed into the computer that uses the model to decide which musical events are suitable for use in the composition. The process is one in which random choices are discarded according to a stochastic model. According to Webster's, stochastic processes are processes based on the behavior of random variables. Random variables, in turn, are functions which are the result of statistical experiments in which each outcome has a fixed probability. For example, the number of spots showing if two dice are thrown is a random variable... CM/ In order to produce a musical event, the program generates a random number which it associates with a variable such as pitch or time. The number is then subjected to the constraints of the model. The model is constructed by feeding specimens to an analysis program which are representative of the desired compositional style. The specimens are analyzed according to pitch, time and chord structure, and a probability matrix of n dimensions is generated, where n is the degree of order desired and represents the extent to which the analysis was carried out. As n increases, progressively more order is imposed upon the process, since more information is available to describe the

Figure 1: A standard alphanumeric keyboard modified for the SCORTOS language. SCORTOS is a language dedicated solely to the processing of musical information. The keyboard is a standard ASCII unit which has been relabeled with music symbols. The user enters a musical composition by striking the keys which correspond to the symbols in the music score of the composition (see also photo 2).

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Photo 2: The modified ADM-III video terminal. The keytops on the ASCII keyboard have been modified to enable the user to easily encode musical compositions. See figure 1.
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SPECIFICATIONS

- **Microprocessor**: 6502 (1 MHz).
- **Video Display**: Memory mapped, 5 modes—all Software-selectable:
  - Text—40 characters/line, 24 lines upper case.
  - Color graphics—40h x 48v, 15 colors
  - High-resolution graphics—280h x 192v; black, white, violet, green (12K RAM minimum required)
- **Memory**: up to 48K bytes on-board RAM (4K supplied)
  - Uses either 4K or new 16K dynamic memory chips
  - Up to 12K ROM (8K supplied)
- **Software**
  - Fast extended integer BASIC in ROM with color graphics commands
  - Extensive monitor in ROM
- **I/O**
  - 1500 bps cassette interface
  - 8-slot motherboard
  - Apple game I/O connector
  - ASCII keyboard port
  - Speaker
  - Composite video output

Apple II is also available in board-only form for the do-it-yourself hobbyist. Has all of the features of the Apple II system, but does not include case, keyboard, power supply or game paddles. $598.

*Apple II plugs into any standard TV using an inexpensive modulator (not supplied).
Figure 2: A medium scale SCORTOS configuration. The 88-RCB units are relay boards which can be driven by the computer to operate organs, synthesizers or other similar instruments. Each board consists of two 8 bit data registers which can be loaded from the central processing unit. Each of these bits in turn drives a transistor which energizes a relay. One 88-RCB board can control 16 keys, or 1 1/4 octaves of a musical keyboard. The system can address (and therefore control) up to 256 keys.

desired composition and less is left up to chance.

Zeroth order stochastic control is no control at all. Random choices are used to build the composition without testing them against the model producing unlistenable music in most cases. In first order control, the transitions between pitches and rhythms are governed by the probability distribution of those transitions as they occurred in all the analyzed samples. Music produced in this manner still sounds amorphous, but will have fewer pitches that sound alien.

It is not until we impose higher order control that a melody as we know it will take shape with its symmetrical phrases and regular intervals. In second order control, the selection of an event depends upon the event that preceded it; in third order control the previous two notes, and so on. For example, if the previous note chosen was a B-flat and the random number generator has just produced a C, the program refers to that location in the probability matrix which gives the probability of a C following a B-flat. If there is no probability of this happening, the C is rejected. If the probability is 1.00 then a C always follows a B-flat in this style of music, and the program will reject all random numbers that are not Cs.

Of course the source of the information within the model need not be music specimens, as in this example, but may originate from mathematical functions, poetry or any one of a hundred other sources. It is this capability which makes the computer so intriguing as a composer's tool.

The Score to Sound System

The Score to Sound System (SCORTOS) was developed to provide the composer with an inexpensive means of conducting computer implemented music research and composition prototype development. The system has the capability to perform conventional music scores by allowing music symbols to be entered through a terminal keyboard by an operator. Music of computer generated specifications can be performed through user program calls to a set of subroutines that interface the user program to the SCORTOS system software.

Music is produced by the computer driving relays that are wired in parallel to the keyboard switches of electronic music instruments — organs, synthesizers, etc. This allows a simple and inexpensive interface between the composer's studio instruments and the computer. The limitation of this approach is in its inability to provide the computer with access to the timbre controls of the synthesizer, an encumbrance which may be tolerable to experimenters primarily interested in the musical variables of tonality and syntax. Also, there is a rich assortment of preset timbres available in commercial keyboard instruments, among them, the Orchestron which generates actual orchestral and choral sounds from a prerecorded optical disk.

The system consists of an Altair 8800 computer with 32 K bytes of memory, an ADM-Ill video terminal, a mass storage device (either cassette or floppy disk), one or more International Data Systems 88-RCB relay control boards and any electronic keyboard instruments the user wishes to connect to the 88-RCBs.

The ADM-Ill has a standard ASCII key-
You want to record your message verbatim—word for word—whether it's bits, bytes or "Dear Folks" translated into word processor language.

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board whose keytops have been relabeled with music symbols (see figure 1 and photo 2). The composer enters the composition into the computer by striking the key corresponding to each musical symbol as it appears in the score. This creates a music text file. The source text is passed to a language processor which maps each musical event represented in the source text into a physical IO address plus a timing value, and writes this to a binary output file. The result is a list of records each of which defines which key of which instrument will be turned on and for how long. The binary output of the language processor is read by a driver program which uses the IO addresses and timing values in each record to determine what data is to be loaded into the data registers of the 88-RCBs, and at what time it is to be loaded. The keyboard instrument responds by playing the piece just as if someone were playing on its keyboard. In fact, the system can be thought of as an organist with 16 very flexible fingers, because it is capable of performing 16 separate parts simultaneously.

Keyboard Instrument to Computer Interface

The 88-RCB is the interface between the computer and the electronic keyboard instruments. It was designed expressly for the SCORTOS system project, but is also useful for other low current switching applications. The board has two 8 bit data registers which are "write only" accessible to the central processing unit (CPU) through two output ports which are individually strappable to any address in the 8080 IO channel. The data register latches the contents of the CPU's A register when an OUT instruction has been executed to that register's output port address. The outputs of each bit of the data registers drive a transistor which in turn drives a board mounted DIP relay.

The complements outputs of the data register latches are used to drive light emitting diodes (LEDs) which can be mounted on the board or on a front panel to monitor the status of each relay. The relays are wired in parallel to the keyboard switches of the electronic music instruments which electrically isolate the peripherals from the computer and ensure plug-to-plug compatibility among most keyboard instruments. Each 88-RCB controls 16 keys, or 1 1/4 octaves of keyboard. To ensure an adequate tonal range, two 88-RCBs may be configured on any instrument (see figure 2).

The maximum number of keys the system can address is 256. In arriving at a figure of maximum connectivity, it was necessary to balance programming considerations against what was thought to be an adequate number of system-controllable sound producing peripherals. 256 keys are equal to about 20 octaves of keyboard (three full piano keyboards) which may be distributed among ten sound-producing peripherals, giving each instrument a 2 octave range. This maximum configuration seems adequate to provide for the largest studio application.
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A simple method of representing keyboard address was chosen to minimize the execution time of the DRIVER program. One byte is used to represent the keyboard address (pitch), and one byte contains the length of time the event will last (rhythm). Since a music piece consists of so many events, the size of the data record is critical. It affects the total performance of the system by limiting the length of any performance to the number of event records that will fit in available memory. For this reason, it is not practical to increase the size of the event data record to accommodate a connectivity greater than 256.

The Alphanumeric Representation of Music

The conventional music score format is not the most perfect method for entering music into computers. The music symbols must be somehow transformed into a code the computer understands. In the conventional method, the operator enters data from a music score into an alphanumeric keyboard. This method has two disadvantages: it often requires multiple alphanumeric symbols to define one musical event (one character for pitch, one character for rhythm, one character for dynamics). The second disadvantage is that the choice of alphanumeric symbols must relate in some way to the quality of the musical symbols they represent, which in the past has meant that the symbols were scattered about the keyboard with no regard to their qualitative value. As a result, the data entry process was a hunt and peck procedure which may have been too discouraging for all but the most enthusiastic.

The human to computer interface should provide maximum ease in data entry and data editing. There are four ways to accomplish this:

- Choose a set of alphanumeric symbols to represent the set of musical symbols that will enable music passages to be
best recognized in alphanumeric form.

- Eliminate all redundancies in the music score.
- Position the alphanumeric symbols on the keyboard logically in the order of their musical value and group them by type.
- Generate bar markings and bar numbers automatically during data entry.

Table 1 shows the alphanumeric symbols used to represent conventional music notation in the Score to Sound System. Note that each alphanumeric symbol alludes to the quality of the music symbol it represents. A musical event can be defined by one or two symbols, depending upon whether the event is a rest or a note. A numeric symbol which is not preceded by a letter character is recognized as a rest. Notes always occur as a pair of symbols, that is, a letter character followed by a numeric symbol. Figure 3 illustrates a portion of an actual orchestral score along with its corresponding SCORTOS code.

Since the characters generated by the SCORTOS keyboard hardware do not correspond to those desired to represent the music symbols, the data entry software echoes back the desired character with the terminal in full duplex mode.

System Software

The SCORTOS System Software consists of a group of programs written in 8080 assembler language which carry out the four major functions of the system:

- entry and manipulation of the symbolic music text.
- conversion of the text to binary data.
- conversion of events initiated by user programs to binary data.
- conversion of the binary data to music.

The interaction of these programs with each other is shown in figure 4.

The monitor allows the user to control the system's major functions. It recognizes three command verbs with one or more arguments per verb. Each verb calls a system module, and its arguments specify the data file which is to be operated upon by that module. Table 3 is a list of command verbs recognized by the monitor.

The editor allows the user to enter music text through the terminal keyboard and provides a means by which it may be easily manipulated.

As text is entered through the keyboard, the editor's data entry processor keeps a running count of the bar number and auto-

Continued on page 206
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Melanie Jubb's oil painting celebrates the idea of computers and music, emphasizing this issue's artistic themes.
A New Dress for KIM

At first I was reluctant to take KIM out in public because she was so small and homely compared to other systems her age. No one actually ever laughed at her in my presence, but I could sense the pity that they had for me. I wondered, would my KIM forever be overshadowed by those bristling brutish Altairs and IMSAs at every social gathering? I knew KIM's strengths and her weaknesses, and I wondered if there was anything that I could do to help her find acceptance in the world. Then, one evening, while talking to a friend whose IMSA was drawing considerable attention, as usual, it occurred to me that it wasn't his central processing unit's IQ that set it apart from my humble KIM. No, it was the way that it was dressed that did so much toward creating the image of great sophistication and power.

I resolved that very evening to give my KIM the same advantages that her peers had; after all, who wants to be accused of neglecting loved ones? If she was to be oooed and aaah'd over, then she'd have to be dressed up before I took her out again. Although I must say honestly that I doubted that her 8.5 by 11 by 5/16ths dimensions would ever win her a spot on the centerfold of BYTE.

I suspect that there are many other KIM owners around who have also wondered how to dress up their bare-bones KIM board to take them out to club meetings and such, so here's the way that I did it. I hope it gives you some good ideas for your own KIM-1.

First of all, I had two major constraints to deal with: namely, my budget and my own skill, or rather lack of skill in the field of beautifully sculptured fiberglass and metal enclosures and the like. So I knew that I would have to settle for a simple and cheap approach to this thing. One thing that the KIM had going for it was its small size, because that meant that it could be placed inside a reasonably sized package. But, what was a reasonably sized package? And, where could I get one cheap? A shoe box? . . . no, that's too big. Hey, how about that old briefcase in the back of my closet? . . . not a bad idea!

Much to my surprise and pleasure I discovered that those sneaky designers at MOS Technology must have been anticipating my train of thought, because when I opened that old briefcase and dropped the KIM in, it was a perfect fit! Great, now I knew what my enclosure was going to be, so the next question was how to support it inside the briefcase. Again, two constraints: first of all, protection for the
printed circuit board itself, and secondly, reasonable looks.

The briefcase's exterior would provide some rough handling protection for the KIM, but it would also need some solid support from the bottom; therefore, since the bottom of my briefcase was not flat, I would have to construct a flat platform for the KIM. As for the basic appearance, I really wasn't too crazy about an open frame power supply, nor would that be an awfully safe setup. So, I decided that the power supply would have to be placed inside a special enclosure, away from stray fingers. The chassis design, shown in figure 1, was the result of considerable study.

Some of the more notable yet less obvious features of this design are:

- A swing open door to provide access to the power supply compartment (pop rivet hinge).
- The 44 pin edge connectors (one of which is provided with the KIM-1) penetrate the chassis wall to give solid support and to protect the loose wires.
- PC board edge guides to hold the power supply and other auxiliary components on a removable card.
- An overall height selected to suit the briefcase depth (mine filled the lower half).
- Placement of the power cord, switches, and other auxiliary parts on the top surface of the power supply compartment to facilitate easy removal of the entire assembly for bench work or to change to a new briefcase.
- A large surface to place connectors, etc.
- A Plexiglas cover sheet to further protect the KIM-1 board and filter the LED displays may also be added.
- Use of the upper half of the briefcase to carry documentation, etc.

The KIM-1 board is recessed in this design, but it is not hard to get to the keyboard for programming it, although this was one thing that I thought might give me trouble at first. Being recessed does give the KIM an added amount of protection, and I have found that the recess over the board is a great place to carry my KIM-1 owner's manual. That spares me from having to explain what in the world I have in my briefcase every time I open it in public.

The auxiliary area on top of the power supply compartment is the place where you can customize your chassis to suit your own particular needs. On my chassis I put a surplus 50 pin connector which is wired to most of the pins of the A connector, and selected pins of the E connector of my KIM board. I use this to patch into a small prototype board which I also placed on that surface, and I must say this has proven to be a most useful setup. Of course, you will probably want to provide jacks for your audio cassette unit, and maybe one for a Teletype if you're fortunate enough to have access to one.

At any rate, my little KIM is no longer the club wallflower, and as I look into her future I see a handsome genuine calfskin briefcase waiting.

![Figure 2: The mechanical design of the chassis box is shown in this illustration. The depths of the two sections are dimensioned to fit the author's briefcase. This can be fabricated out of a piece of aluminum stock 1/6 of an inch thick and measuring 20.5 by 15.5 inches (or, in integral metric dimensions, 2 mm thick measuring 52 by 39 cm). The drawings show dimensions for the actual KIM-1 connector holes with metric dimensions in parentheses. The housing was cut, milled (the pin edge connector holes) and constructed at a local machine shop for under $15.](image-url)
A. VCP-80 Computer with 300 lpm printer.
B. PCS-80 with CRT, dual floppy disk & Intelligent Keyboard options.
C. Peripherals (clockwise from left) 45 cps daisy-wheel printer/terminal, 24x80 CRT terminal, 45 cps daisy-wheel printer, Intelligent Breadboard, 44 col. alphanumeric line printer.
D. Processor, Memory & Interface boards—shown MPU-A, 65K RAM, and floppy disk, line printer and serial I/O's.
E. PCS-80 System—sample component configurations.
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Control the World!

(Or at Least a Few Analog Points)

“Ka-chunk! OK, get the reading quick! Ka-chunk! Pop! Pop! Bang! The darn thing crapped out again! We’ll never get one of these detectors to pass a life test.”

The burly mechanic puffed his fat cigar and with a disgusted sigh continued, “The dime store engineers who design these kludges should be the ones who have to test them! That’s if you could ever get them out of that puzzle factory upstairs!”

That was my cue. I was indeed an engineer descended from the puzzle factory and my mission was to discover why we were having so much trouble life test qualifying one of the pressure detectors we intended for future manufacture. Hearing the preceding commentary as I approached the testing lab, I decided that an authoritative professional type would not be very popular at the moment, so I went into my innocent nonmanagerial mode and entered the lab.

This lab was not unlike any other small production qualification and testing lab. It had the usual machinery and instrumentation and many artifacts of former test programs lying about. The most prominent
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artifact was the leader of the instrumentation group, Ned. Ned's large frame amply filled the white lab coat though it was barely discernable in the dense cloud of cigar smoke. The combined scent of hydraulic oil, burned resistors, and cigar smoke convinced me that today was not going to be my day.

"Hi, Ned. What's the problem with the new detector?", I asked.

"It's about time one of you guys came down and asked. This has got to be the most fragile pressure detector I have ever tested. So far, we have wiped out four engineering prototypes and haven't gotten to 20,000 pressure cycles, let alone the 50,000 life test," he bellowed.

My eyes rolled slightly as he mentioned the failed units. These pressure detectors were not in the least bit fragile; they were ruggedized units with a prospective sale price of $4700 each. The four engineering prototypes were handmade and far more costly. Before it became too apparent that I was coming to a slow burn, I asked the obvious question. "Ned, are you following the engineering test specification?"

"You guys are really something! I've been in this business for 30 years. I was testing ... "

"OK, OK, Ned! Just tell me what your test procedure is. Pretend I'm a novice and tell me by the numbers." I was sure that he felt that was the way he had to work with any engineer, so I humored him and just listened.

"All right. The pressure detector is rated at 7500 PSIG and we are life testing it," he said with a cigar chomping smile. "The pressure is cycled between 0 pounds per square inch gauge (PSIG) and 10,000 PSIG every ten seconds and remains at 5,000 PSIG between cycles. [PSIG, or gauge pressure, is a differential pressure measurement using the ambient pressure as a reference. Usually, standard sea level pressure (14.7 pounds per square inch) is used as the reference ... CM/]

At the conclusion of each cycle, the detector reading is compared to an out-of-tolerance spec. Oven temp and other control parameters are constantly monitored. Every 10,000 cycles, a calibration run is taken and compared to the accuracy specification quoted. We just haven't been able to get one of the bloody things to hang together long enough to finish the test. The pressure diaphragm keeps breaking."

So far, what he was relaying was exactly the procedure I had outlined. Nothing sounded wrong, so the next obvious question was a description of the test apparatus.

"I decided to automate the testing procedure," he gleamed like a kid describing a new toy. "I made a sequencing circuit with relays to cycle the pressure automatically. All the operator does is record the data and run the calibrations. Here, let me draw you a diagram."

It was unbelievable! True, Ned was following the spec, but what a way to do it! Pressure transducers are expected to withstand a certain amount of overpressuring, which was the reason for the test. But over-pressure in combination with a 10,000 PSIG

![Figure 1: Configuration of a conventional impulse pressure calibration test setup. Note that the pressure detector under test receives what amounts to a square wave input. This type of violent pressure change can shorten the life of the detector and give a false indication of its long term life expectancy. PSIG, or "gauge pressure," is explained in the text.](image)
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Contact your local computer store or order directly from EXTENSYS.
impulse was like a jackhammer. The engineering group upstairs would be amazed that the test made it through 20,000 cycles. I wiped my brow, leaned against the concrete wall and asked with a pathetic whimper, "I suppose the failed detectors make good boat anchors."

"What?", he asked, not having heard what I had said.

"Ned, while I think your intention is fine, your method may be a little too rough on the unit. Why don't we change the square wave pressure being applied to the detector to a sinusoidal waveform." This was the method I had assumed he was going to use initially.

"I can't have a guy sitting there cranking a pressure controller knob ten hours a day. It's going to take two weeks to run this test as it is. That's why I automated it!" He seemed to get mad as I challenged his inventiveness.

"You don't have to compromise anything. Get a DC proportional control valve from the stock room and modulate the pressure sinusoidally. In fact, you can use the minicomputer which you ordinarily use for mathematical calculations over there in the corner to drive it directly, collect the data, and run the calibration automatically."

"You guys upstairs must be suffering from thin air. I know about computers; ones and zeros and all that stuff. We're talking about a DC voltage controlled valve. That isn't consistent with computer binary voltage levels. You would have exactly the same on and off situation as my relay controller," he stated.

It was going to be an uphill fight, but I knew I was going to introduce Ned to the world of analog to digital and digital to analog conversion. I first mapped out the life test circuit and diagrammed the waveforms.

Ned was no neophyte. He felt that he knew a lot about computers and in fact was quite familiar with the uses of BASIC and FORTRAN on the lab minicomputer. But Ned had never considered that this number crunching machine has the same logical abilities to control analog devices if properly interfaced.

General Considerations

While this may have been a lengthy introduction to computer analog interfacing, it often takes a real life situation to make one realize the added potential of the computer when it is combined with analog capabilities.

Since natural parameters such as displacement, temperature, volume and magnetic field strength are analog, and most practical methods of data acquisition, manipulation and visual presentation are digital, conversion between analog and digital qualities is a fundamental operation in computing and control systems. The basic building blocks are the digital to analog converter (DAC), and the analog to digital converter (ADC).

Because these converters are essentially interface devices, the basic conversion circuitry must be adapted to properly mate the application to the computer. Such variables include the possible necessity for buffers, registers, clock circuitry and reference voltages, all of which are external supports for the actual conversion device. The exact design requirements can be lengthy and are handled separately by necessity. Digital to analog conversion is the first topic to be discussed.

Digital to Analog Conversion

The digital to analog converter can be thought of as a digitally controlled programmable potentiometer which produces an analog output. This output value \(V_0\) is the product of a digital signal \(D\) and an

![Figure 2: The same pressure detector as in figure 1 being tested here with a computer controlled system which applies the test pressure sinusoidally. This approach gives a much better indication of the unit's true life expectancy, and incidentally shows one practical application of digital to analog conversion.](image)
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shown. The other sides of the switch es are co nn ected tog ether at the sum­
ing point of each switch with respect to its distance from the end of the ladder

proportional to the resistors are generated when th e s witc h es are closed. They

is in series w ith a resistor. The resistor va lu es ar e re lat e d as powe rs of 2, as

scr -a ight binary except that the binary n um­

ant bit is 1/4 or 2-2, a nd the least sign ifi­

binary fractions, the most significant bit h as

It is important to remember that the binary quantity presented by the computer is a representation of a fractional value to be multiplied by a reference voltage. In binary fractions, the most significant bit has a value of 1/2 or 2\(^{-1}\), the next most significant bit is 1/4 or 2\(^{-2}\), and the least significant bit is 1/2\(^{N}\) or 2\(^{-N}\). It can be seen that adding all the bits approaches a value of 1. (The more bits, the closer the value is to 1). The discrepancy between the binary value approaching 1 and the actual value 1 is the quantization error of the digital system. I'll discuss this later.

Offset binary is nothing more than straight binary except that the binary number zero is set to represent the maximum negative analog quantity. In the easiest terms, the most significant bit is a zero for negative analog values, and a one for positive analog values.

The conversion of digital values to proportional analog values is done by either of two basic conversion techniques: the weighted resistor digital to analog converter and the R-2R digital to analog converter. The weighted resistor digital to analog converter is by far the simplest and most straightforward. This parallel decoder requires only one resistor per bit. In the weighted resistor digital to analog converter, switches are driven directly from the signals that represent the digital number D. Currents with magnitudes of R, 2R, 4R, ..., 2NR between a reference voltage, -V\(_{\text{ref}}\), and the summing point of an operational amplifier by means of a set of switches. The various currents are summed and converted to a voltage by the operational amplifier (see figure 3).

While this may appear to be a simple answer to an otherwise complex problem, this method has some potentially hazardous ramifications. The accuracy of this converter is a function of the combined accuracies of the resistors, switches (since all switches have some resistance), and the op amp. In conversion systems of greater than ten bits resolution, the magnitudes of the resistors become exceptionally large and the resultant current flow is reduced to such a low value as to be lost in circuit noise.

A reasonable alternative to the weighted resistor digital to analog converter is the R-2R converter. This is often referred to as a resistor ladder digital to analog converter. The R-2R digital to analog converter is the most widely used type of digital to analog

Figure 3: A 4 bit weighted resistor digital to analog converter. A 4 bit word is used to control four single-pole single-throw switches. Each of these switches is in series with a resistor. The resistor values are related as powers of 2, as shown. The other sides of the switches are connected together at the sum­

Figure 4: A 4 bit "R-2R" ladder network digital to analog converter. This type of digital to analog converter makes use of a resistor ladder network constructed with resistors of values R and 2R. The topology of this network is such that current flowing into any branch of a 3 branch node will divide itself equally through the two remaining branches. Because of this, the current will divide itself in half as it passes through each node on its way to the end of the ladder. The four switches are again related as powers of 2. The position of each switch with respect to its distance from the end of the ladder determines its binary significance.
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Display of disassembled program flow.

Circle 212 on inquiry card.
Figure 5: A typical current output monolithic multiplying digital to analog converter. This Motorola integrated circuit contains an $R - 2R$ network like the one in figure 4 plus additional current switching logic. The relative accuracy of this 8 bit unit is ±1 least significant bit, or 0.19% of full scale.

A multiplying digital to analog converter, even though it uses more components. This circuit is illustrated in figure 4 and also contains a reference voltage, a set of binary switches and an op amp, but the basis of this converter is a ladder network constructed with two resistor values, $R$ and $2R$.

One resistor ($2R$) is in series with the bit switch, while the other ($R$) is in the summing line, so that the combination forms what electrical engineers call a "pi" network. This suggests that the impedances of the three branches of any node are equal, and that a current, $I$, flowing into a node through one branch flows out as $1/2$ through the other two branches. In other words, a current produced by closing a bit switch is cut by half as it passes through each node on the way to the end of the ladder. Simply speaking, the position of a switch, with respect to the point where the current is measured, determines the binary significance of the particular switch closure.

This type of converter is easy to manufacture because only two resistor types are needed and can be reduced to one value, $R$, if three components are used for each bit. Keeping matched resistor values with the same temperature coefficients contributes to a very stable design. Certain tradeoffs are required between ladder resistance values and current flow to balance accuracy and noise.

One form of the $R-2R$ ladder digital to analog converter is the multiplying digital to analog converter. Digital to analog converters are available with either a fixed reference or with an external variable reference. Multiplying digital to analog converters, which utilize external variable analog references, produce outputs which are directly proportional to the product of the digital input multiplied by this variable reference. Functionally, these converters are available as current or voltage output types. The current output devices are necessarily faster because they do not include output amplifiers which limit the bandwidth. Because this output amplifier is not included, current digital to analog converters tend to be a little less expensive than voltage types.

Probably one of the most useful and cost effective multiplying digital to analog converter, even though it uses more components. This circuit is illustrated in figure 4 and also contains a reference voltage, a set of binary switches and an op amp, but the basis of this converter is a ladder network constructed with two resistor values, $R$ and $2R$.

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converters available on the hobby market today is the Motorola MC1408L-8 8 bit digital to analog converter (see figures 5 and 6).

As previously mentioned, this monolithic converter contains an R–2R ladder network and current switching logic. Each binary bit controls a switch which regulates the current flowing through the ladder. If an 8 bit digital input of 11000000 (192) is applied to the control lines of the illustrated converter, the output current would be equal to (192/256) (2 mA) or 1.50 mA. Note that when binary 11111111 (255) is applied, there is always a remainder current which is equal to the least significant bit. This current is shunted to ground, and the maximum output current is 255/256 of the reference amplifier current, or 1.992 mA for a 2.0 mA reference current. The relative accuracy for the MC1408-L8 version is ±1/2 least significant bit, or 0.19% of full scale, and is more than adequate for most home computer analog control applications.

A Design with the User in Mind

I could actually stop right now and be satisfied that the reader has at least some idea of what a digital to analog converter is, but no mention has been made as to its uses. BYTE has published previous articles on digital to analog converters, but few actually using them in detail designs.

When we last left Ned in the testing lab, he was hooking up a voltage controlled pressure regulator and attaching it to the computer through a digital to analog interface. Though only the voltage requirement of the value was mentioned, the pressure detector is situated in an environmental control chamber with the temperature maintained by a setpoint controller.

At various times during the testing phase, the temperature is elevated. To adequately automate this test procedure, therefore, two analog output values are required: one for temperature setpoint and the other for pressure setpoint. It takes one digital to analog converter for the first voltage and we could add another separate digital to analog converter for the second voltage, but this is overly expensive and not necessary. The preferred method is to use multiplexed digital to analog conversion. This technique uses a single converter and switches it back and forth between the two channels doing the respective digital to analog conversion 50% of the time on each channel. To insure that each channel does not go on and off as the converter switches back and forth between them, a circuit called a sample and hold is employed on each channel to maintain the output at a constant level until the next refresh by the digital to analog converter. Figures 7a and 7b illustrate the
When the switch is closed, the capacitor begins to charge up exponentially to the value of the input voltage. Theoretically, the capacitor will maintain this value indefinitely after the switch is opened, but in reality a certain amount of voltage "droop" (exponential decay) will occur over time as the capacitor slowly discharges.

A sample and hold circuit is simply a charged capacitor analog storage device. Amplifier A1 is an impedance isolating buffer connected to the digital to analog converter or other voltage supply and connected to the capacitor through a switch. This switch is normally open in the "hold" state. When the output is to be updated, the switch is closed, the circuit enters the "sample" or acquisition mode, causing the capacitor to charge exponentially toward the new value present at the output of A1. When the switch is reopened and again in the "hold" state, the output of A2 will be equal to the capacitor voltage level.

The secret of good sample and hold is to use good high input impedance buffers to minimize the leakage from the capacitor and hold the output for long periods of time. No sample and hold can be designed without some droop during the holding period. The best that the designer can do to minimize this feature is to use precision components (usually more expensive) and refresh the sample and hold frequently enough to overcome decay problems.

Is There a Way to Overcome the Necessity to Refresh Sample and Hold Outputs?

For the home computer experimenter, sample and hold outputs, which require periodic refreshing, can become a bother.

This is especially true during step-by-step checkout of system software.

Refreshing a multiplexed digital to analog interface usually requires a separate digital to analog refresh subroutine which must be called at regular intervals while executing the program. Simple, inexpensive sample and holds may require updating tens of times per second, while the better designed circuits available to the hobbyist can do satisfactorily with a once per second update. The fact remains, though, that the refresh is a requirement. This can limit digital to analog interface applications.

Drive the Digital to Analog Converter with BASIC?

Many extended BASIC programs such as the Digital Group MaxiBASIC can directly interface with computer input and output ports. This means that analog devices can be driven with a digital to analog converter, analog data processed through an analog to digital converter, and the acquired data mathematically manipulated using BASIC. The implication is a pseudo real time analog control scheme utilizing BASIC. This is a realistic capability in slow process control applications where control feedback does not have to be activated within microseconds of an initiating event. Solar heating, low duty cycle repetitive machine functions, building environmental control systems, and supervisory control of setpoint controllers are examples of slow processes where slow computer response is of no major consequence.

The Final Configuration

Utilization of BASIC as a real time operating system does imply some constraints. If analog control is involved, the time between updates to an analog output interface can be on the order of tens of seconds, especially if the computer is required to do extensive calculations and record outputs to a printer. Of course, a special interrupt driver could be added to the BASIC and the processor interrupted frequently to service the external devices; but why make life difficult? The idea of using BASIC in the first place was to provide a control capability without adding special machine language drivers, a capability which would enable anyone to try his or her hand at closed loop control programming. This approach, though, tends to eliminate the classical sample and hold multichannel digital to analog method from consideration. It would also seem that the only approach left is the separate storage register and
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Circle 213 on inquiry card.
Figure 9. A "smart" 4-channel self-refreshing digital-to-analog converter. The circuit is self-refreshing and asynchronous in the sense that it maintains its analog outputs independent of computer timing. IC2 and IC3 form an address-decoding network which decodes the 8080 or 8085 processor's output port address and stores the computer data bus contents into IC4 and IC5.
which form an 8 bit random access scratch pad. IC7 performs the actual analog to digital conversion. The remaining portion of the circuit consists of timing generation and an analog multiplexer with sample and hold circuitry.

digital to analog converter combination previously illustrated. A more intelligent alternative is a combination of the two methods.

The necessary interface is essentially a smart multiplexed digital to analog converter which maintains its analog setpoints independent of the computer timing. The design of this interface is illustrated in figure 9. It is a hybrid system composed of separate digital storage sample and hold circuits for each of four output channels. Internal timing generators sequentially read the storage registers, initiate the digital to analog conversion, and refresh the sample and holds. Photo 1 shows how this card looks when built using a Vector board with 44 pin edge connector.

The key feature of this unit is the input storage buffer. Two 74170 4 by 4 bit registers are configured to form a 4 word by 8 bit random access scratch pad. An address decoding network composed of IC1, IC2, and IC3 decodes the processor’s output port address and strobes the computer data bus contents into the appropriate scratch pad location. These four jumper selectable port addresses can be set to be any four consecutively numbered output ports. The exact selection and jumping details are outlined in the check out procedure. This particular scratch pad can be written into and read from simultaneously. The interface is completely asynchronous and does not have to be synchronized with the computer in any way.

There are four basic sections to the interface: the scratch pad and port decoding, digital to analog converter, timing generator and analog multiplexer, and sample and holds. A basic timing diagram of the interface is illustrated as part of figure 9.

The timing section consists of a 200 kHz clock generator IC6 and address counter IC8. The 7493 counts down the 200 kHz clock and drives the address lines of the scratch pad and multiplexer at a 50 kHz conversion rate. Each channel is accessed, converted and sampled in a similar manner. When the address lines have settled on a particular channel, the output lines of the scratch pad (IC4 and IC5) present the respective stored digital word to the digital to analog converter IC7. The converter immediately starts moving towards the new value.

Since its settling time is dependent upon the magnitude of change from one channel to the next, the worst case being minus full scale to plus full scale, the 20 µs conversion period incorporates a 10 µs settling time. For the first 10 µs, the analog multiplexer IC10 is inhibited from conducting the signal to the sample and hold. After this settling time has concluded, the inhibit signal is dropped, and for the next 10 µs the sample and hold for that particular channel is in the sample mode. The circuit automatically sequences itself to the next scratch pad address and repeats the process over and over.

Anyone capable of a little quick math can realize that if the digital to analog conversion is proceeding at 50,000 conversions a second, each sample and hold is being updated at the fantastic rate of 12,500 times a second. This seems to be in direct disagreement with a “tens of times a second” statement made earlier. It is important to remember that this is an asynchronous analog interface. When new data is written into the scratch pad, the new value is not available at the sample and hold output until the next regular sampling period, controlled by the timing generator. The high sampling rate is more to increase the response of the interface than refresh the outputs.

At a 50 kHz conversion frequency, there is a worst case delay of 80 µs between a scratch pad update and an appropriate analog output response. This is of no consequence as far as this article is concerned. However, to maintain the ability to use BASIC as a real time operating system and yet not lose the capability to do high speed applications such as voice synthesis, a few simple modifications can be made. The interface clock rate can be increased from 200 kHz to 400 kHz. This has been successfully accomplished on the prototype and will increase the sampling rate on each channel to 25,000 samples per second. Unfortunately, it is far more demanding of the current to voltage converter IC9. Only one out of three LM301As may work successfully over the full range of 10 V. Another quick method is to remove the 7493 (IC8). This causes the interface to stay addressed on channel 4, doing 50,000 uninhibited conversions per second.

The converter itself is an 8 bit MC1408L-8 multiplying digital to analog converter. As previously outlined, “multiplying” means that it uses an external variable reference voltage. In this case, a 6.8 V zener diode regulated voltage is passed

Continued on page 156
Expanding the Tiny Assembler

(Increasing Function without Building More Memory)

It is worth noting that the group of people who have been using the Tiny Assembler since the end of 1976 as listed on page 133 of the March 1977 BYTE excludes the author. ME! Well, I have finally gotten my own computer system up and running and have been able to get some use out of the assembler myself. I soon found that there were a few things there that could be changed or added that would make the whole assembly process more convenient. I guess there is just no pleasing some people.

The problem is that, as predicted, I have a minimal configuration system. It is a SwTPC 6800 with (at the moment) no extras. The assembler just fits, so there is no place to put patches or additions except at the top of the symbol table. This of course reduces the capacity of the program. It became obvious that the proper approach to further modifications would be to increase the efficiency of the assembler so that additions could be made while maintaining or increasing the symbol table capacity. The first modification, therefore, would have to be the ability to delete symbols when no longer needed so that the symbol table space could be reused. This would allow a smaller table to handle a larger number of symbols.

As suggested in the article "Implementing the Tiny Assembler" (May 1977 BYTE, page 84), this has been accomplished by developing a "begin" statement (the assembler mnemonic is BGN). This statement causes the next available location in the symbol table to be pushed into a table stack and a structural level counter (which starts at 1 and keeps track of the nesting level of the BGN statements) to be incremented. Symbols entered beyond this point in the symbol table belong to this BGN block. A label on the BGN statement itself will not belong to the group of symbols entered beyond this point in the symbol table.

Listing 1: This simple in line BGN block shows the format of the BGN and END pseudooperations of the Version 3.1 Tiny Assembler. Any symbols defined within the block are deleted by the END statement for the block and can be reused without conflict by subsequent code. Thus the symbol GO at location 021E defined within block NEWBLOCK is not the same location as the later use of GO in the outer level of the hierarchy at location 0229. Note that the new version of Tiny Assembler still condenses symbols into 4 character names in the symbol table by using the first three and the last characters of the symbol as typed. Thus the NEWBLOCK name at location 200 condenses to NEWK in the symbol table.
symbols already in the table. The END statement must then be changed to pull a symbol table location out of the table stack and perform end of block processing on the symbols from this point to the end of the table. Everything relating to these symbols is then cleared from the assembler's tables. The structural level indicator is decremented, and if it becomes 0, end of program is signaled. Using this arrangement, the nesting level of BGN blocks is only limited by the space available for the table stack or the size of the structural level counter (256 in this case).

In practice, the BGN block is used to break a program into individual segments that can each be treated as single functions or routines. Labels and variable names within such blocks are local to the block and are not known outside the block in the rest of the program. This can be most useful when employing structured programming techniques such as those that have appeared from time to time in BYTE articles. A properly structured BGN block should have only one entry point and one exit point. It may be used in either of two different ways.

First, a section of in line code that is only used in one place in a program may be defined as a structural block. Such a block is entered by "falling into" the first statement, and exited by "falling out of" the last statement as program steps are executed in sequential order. There will usually be no label associated with the BGN statement for such a block.

The second possibility is to define a block as a subroutine which can be called from one or more places in the program. Such a block is entered by a jump or branch to subroutine and is exited by a return statement. In this case the entry point (which is usually the BGN statement itself) does require a label. In both cases, once a block has been completed, the internal structure is of no interest to the rest of the program, and any entries in the symbol table and the forward reference table for the current block may be removed when the block is ended.

An example of a small in line BGN block is shown in listing 1. Once this group of branch and jump instructions has been completed, the symbols defined within it may be reused without conflict. A more complex program structure using BGN blocks as subroutines is shown in figure 1. This is similar to the hierarchy diagrams discussed in the first of these articles (see "Designing the Tiny Assembler," April 1977 BYTE, page 84, for a discussion of hierarchies and networks). The pseudocode to implement this structure is shown in listing 2. Within any block, references can be made to entries in the symbol table for any already active block (ancestors), the entry point of any block at the same level (siblings), the entry point of any block at the next lower level (direct descendants), and the entry point of any block which is at the same level as currently active ancestor blocks (aunts and uncles). References cannot be made to items which are across any level of siblings and then down another branch of the "family tree" (nieces, nephews and cousins), or to items developed within a lower level of the tree. This is a fairly standard structuring scheme.

Listing 2: This is a structured pseudocode representation which shows how the hierarchy of figure 1 would be implemented in a normal coding sequence. The assembly starts with an initial (outer or global is an equivalent term) level so there is one more END statement than the number of BGN statements. This is required to finally terminate the assembly. In this listing, indentation of the code has been used to highlight the various levels of nesting of the blocks from figure 1.

Figure 1: This hierarchy diagram shows the relationships between the functional blocks used in the example of listing 2. Of the 12 blocks in the system of this program, only a maximum of five are ever active and using up space in the symbol table at any one time. Any entry point referenced at the beginning of block A during the 1 pass assembler's operation is available to any block in the hierarchy even if it is not defined until the end of the assembly.
This general arrangement is significantly modified, however, by the 1 pass nature of the Tiny Assembler. In this case, a symbol “belongs to” the first block that references it rather than the block that defines it as a label. Therefore, a symbol that is defined and used at a low level is inaccessible to higher levels as usual, but symbols that are first referenced in a low level block of code and then defined as a label in a later higher level block of code cannot be handled by the assembler. This is because the symbol belongs to the low level block, and both the forward reference table and the symbol table will be cleared of all references to such a symbol at the end of the low level block.

This problem of what level the symbol belongs to can be avoided by requiring such symbols to be first entered into the symbol table by a high level block of code (as a forward reference if need be). In this way the symbol and all references to it will belong to the high level block and will stay in the tables while low level blocks are created and ended. When the symbol is finally used as a label, all unresolved references to it will be resolved, even those which were made in blocks which have been terminated and no longer exist. In general, a symbol must be entered into the symbol table at a level equal to or higher than every reference that is made to it. It is therefore a good idea to define common subroutines early in the program or to make reference to their entry point names in the highest levels of the structure.

To illustrate how these rules are applied, consider what symbols are “known to,” or can be referenced by code within block G in the example in figure 1. Any items in A and E that have already been used can be referenced because they are ancestors. Any items within G itself can of course be referenced. This was the scope of the original versions of the Tiny Assembler. The entry points of H and I can be referenced because they are direct descendants. The entry point of B can be referenced because it is an ancestor’s sibling that has already been defined. The entry point of F can be referenced because it is a sibling that has already been defined. Any items first used within H, I, J or K cannot be referenced by G because they belong to a lower level. Any information about C and D that was not originally referenced in A is unavailable because they are cousins. The entry point of L (if not yet used) and any items in A and E that have not yet been used cannot be made a forward reference because they will not be defined until after references to them from G have been removed.

When a program is structured as a network instead of a simple hierarchy, things become a bit more complex because of relationships that cross between branches of the structural tree. The same rules apply when determining what can be referenced from what, however, so a program’s block structure should be planned so that multiple paths within the network can be contained within a single block to reduce or eliminate forward reference problems.

For programs with a moderate number of symbols or extremely complex forward references, the whole assembly may be considered a single block. In this case, no BGN statement need be used at all. The first END statement that is encountered ends the program much as it does in the original versions of the Tiny Assembler.

It should be pointed out that the entire table of currently active symbols is searched during symbol processing. Therefore, a block may not redefine a symbol used by an earlier but still active block. If this is tried, a duplicate symbol error will occur. This restriction is based on the fact that a 1 pass assembler allowing redefinition of symbols at a local level could not tell the difference between a forward reference to a redefined local symbol and a backward reference to an existing global symbol. Therefore, symbols may only be reused after they have been deleted from the symbol table by an END statement. As it turns out, the hierarchical structuring scheme of the Tiny Assembler is similar to other structural languages such as PL/I, but the restrictions on redefining symbols and the rules determining what level of the structure a symbol belongs to make the structuring of source programs for this assembler unique.

While developing the methods used to handle BGN and END statements it became evident that the deletion and possible reuse of symbols would make it very difficult to produce a complete symbol table dump at the end of the program. In fact, there may never be a complete symbol table during an entire assembly (a situation which requires a 1 pass design by the way). Therefore, each END statement terminates a structural block as if it were a complete program. All unresolved forward references to symbols first used in the current block are listed and the user is given a chance to abort the END statement. If it is aborted, the user will reenter the block, and may continue with corrections and additions as if the END had not been entered. If the user does not elect to abort the END statement, a sorted symbol table listing is provided for the completed block. In this way, every
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occurrence of every symbol and unresolved reference in an assembly is listed without requiring that they ever really exist at the same time.

Does this "virtual symbol table" mean that we have an assembler of unlimited capacity that will run in 4 K? Well, no, not really. While this may be theoretically true, there are some practical limits which are likely to be reached. All programs have a root segment and a list of global symbols which exist throughout the entire assembly. As the program increases in size, the root segment usually grows along with it, but at a slower rate. At some point it becomes impractical to try to fit ever larger programs into the Tiny Assembler. The current design provides for 150 symbols when running in a 4 K machine. This is large enough to assemble simple programs with ease, significant programs through moderate use of structural blocking, and large complex programs if need be. I don't really know what its practical limit would be now, because as noted earlier, I haven't really used the Tiny Assembler enough.

As an additional improvement, the Version 3.1 Tiny Assembler can now expand or contract to the user's requirements. If an 8 K machine were used, the symbol table could be increased to hold over 830 symbols. This could be effectively expanded into the thousands through the use of structural blocking. However, the sequential search times required to find symbols in such a table would no doubt start to become noticeable. Remember, this is supposed to be a TINY compiler, not competition for a full-scale standard assembler.

Having addressed the capacity problem, I then returned to the minor changes that started this whole modification project in the first place. Several items which did not work as one might expect in the previous version have been changed to process in a more normal manner, and a larger subset of the Motorola 6800 assembly language definition is now supported. The following is a list of some of the major changes which have been made. They are illustrated (where possible) in listing 3.

- The FCC pseudooperation will allow the use of character string delimiters as well as the previous string length operand.
- The FCB statement will allow the use of literals following an apostrophe, and the FCB and FDB statements may now forward references.
- Delimiters such as the comma (,), space ( ), plus (+) and minus (-) may be used as literals after an apostrophe. The apostrophe itself may be used as such a literal.
- If a label is used with an ORG statement, its value (as well as the program counter) is set to the value of the operand.
- Execution of the assembler after an assembly has been completed invokes the cold start rather than the warm

Listing 3: In addition to the reorganization of symbol table management and introduction of the BGN pseudooperation, a number of minor incremental improvements were added to Version 3.1 of the assembler. These are illustrated here, and are described in more detail in the text of the article.
start entry point so that different programs being assembled at the same time are completely separated. Within a given assembly, however, restarts are still from a warm start entry point. A warm start uses the old symbol table contents, and a cold start clears the entire symbol table before entry.

- The Tiny Assembler can now be stored in its entirety in ROM or PROM, and it is more easily relocatable.
- The forward reference and symbol tables can be redefined at a location and size determined by the user.
- A comment line starting with *P will produce a page break and a new heading (eg: *PAGE).

While modifying the assembler, I found the need for a simple, quiet (on a Teletype) loader to try out various program changes. As mentioned in previous articles, there are two types of loaders for the Tiny Assembler. Those handling complex forward references must first zero memory and then add each byte of generated code to the current memory value (a single memory location may have several components added to it). Those handling corrections made by the user when the assembler is used interactively must simply replace whatever is currently in memory with the generated code. Since I tend to have many more errors to correct than complex references to handle, the loader shown in listing 4 was developed to complement the one listed in the Tiny Assembler User's Guide. If the assembler's stack is relocated from A07F to A042 (which is easy to do: simply change locations 06D3, 06D4 of Version 3.1), the assembler and the loader can remain resident in a 4 K machine at the same time. The code:

```
LDAA #$3C
STAA $8007
```

will suppress the echo on input for any program using the standard Motorola MIKBUG input routines. In this case it allows the Teletype to read the Tiny Assembler load tape without having the print mechanism chattering away.

The current version (3.1) of the Tiny Assembler is quite a powerful assembly program which will operate within very tight memory restrictions. In larger machines this may mean more space can be made available for an input source buffer, monitor, editor, assembled object modules or other memory resident programs. In small machines it may mean the difference between being able to assemble anything at all or not.

Listing 4: A “quiet” loader is one which demurely purrs as it loads in from the reader of a Teletype, ignoring the noisy printer. This is a loader capable of residing in the Motorola MIKBUG program's scratch pad and loading object code from the Tiny Assembler. Note that there is no end of tape character, nor facilities for rereading the loader tape for verification, nor error handling outside of that provided by the Motorola MIKBUG monitor's routines.

```
LDAA $3C
STAA $8007
```

I should point out that the development of the Tiny Assembler was not a 1 person project, but rather a collective madness that infected quite a few individuals. Several sections of Version 3.1 reflect the ideas and work of Al Losoff, Chuck Bram and George Kuss. As the assembler evolves, I would like to hear from others who have found new and wonderful ways to improve, modify or adapt the program to different environments and requirements. By the way, I do not have the facilities to answer requests for copies of the Tiny Assembler. Contact BITS, 70 Main St, Peterborough NH 03458, for the PAPERBYTES™ edition of Tiny, or the Milwaukee Computer Store, 6916 W North Av, Milwaukee WI 53213, for an AC-30 cassette of the object code ($6).

Editor's note: As this article goes to press, Version 3.0 of Tiny Assembler 6800 is available as a 40 page book complete with user's guide, machine readable (bar code) object listing and complete assembly listing. The price of this book is $7 plus 35 cents postage and it may be ordered through BITS. In preparation as this article will go to press is the Version 3.1 supplement to the original book, which will contain documentation of these extensions, machine readable (bar code) object listing, a reprint of this article, and a complete Tiny Assembler 6800 Version 3.1 source listing. Write BITS at 70 Main St, Peterborough NH 03458.
A new star is born. The Heuristics voice input board for the Altair (S-100) bus is an interesting new option for personal computing enthusiasts. Now, for $250 one can add voice input to the computer.

The first thing I noticed about the Heuristics SpeechLab was the price, $250 in kit form, compared to huge sums for commercial equipment. After seeing a live demonstration at the Homebrew Computer Club in Palo Alto CA, I was convinced that the board worked. Horace Ennea and John Reykjalin, the principle designers, demonstrated the recognition of three words after a single training. Horace would type in a word and then pronounce it. The computer then used about 64 bytes to store a template for the word, "Apple, banana, mango...". The crowd at Homebrew stood in amazement as the computer typed out the spoken words.

Three weeks later I had my own SpeechLab kit. Surprise number two. The two documentation manuals are an order of magnitude better than anything else I've seen produced by the personal computer industry.

Hardware Manual

The hardware manual contains the standard sections: introduction, assembly, and theory of operation; but, the pages are numbered, paragraphs are tied together and the manual is actually readable. Several useful appendices are also included: troubleshooting, test program, warranty, schematics, etc.

Laboratory Manual

"Now what are you going to do with it?" is a question frequently asked by friends of personal computer owners. With this kit the question is the answer. The Heuristics people seem to be trying to create a Renaissance environment for scientific inquiry. The laboratory manual is a successful attempt to tie the diverse field of computer speech analysis together in a coherent fashion. The manual is bound to become popular among researchers in the field of speech recognition. The work is probably the best text material presently available on the subject.

The manual consists of 270 pages. The main body of the text presents 35 exploratory experiments to thoroughly acquaint the user with the problems and techniques of speech recognition. A sampling of experiments are: confusion matrix, compression amplifier, fricative consonants, and area averaging. A complete listing and explanation of Li Chen Wang's Palo Alto Tiny BASIC is included. The BASIC has been modified with a "Speech" command to access the speech input board through a high level interface. Most of the experiments are centered around Tiny BASIC, a wise design decision that makes experimentation easy and interesting. The experiments are clearly presented and should be easy to perform for anybody who can program in BASIC.

Assembly

The printed circuit board is silk-screened. Components are sequentially numbered as they appear on the board, from left top to bottom right. The layout appears to be flawless; no jumper patches are needed. I completed the assembly in two 2 hour sessions. Everything went smoothly except for two missing resistors which were supplied in four working days by mail. Like most small companies headed for success, Heuristics is bending over backwards to please customers. The hardware worked perfectly, so I didn't need the excellent troubleshooting section that is included.

One word of warning. The Heuristics board is intended for use with an Altair (S-100) bus 8080 computer, enough memory to run Tiny BASIC, and some application programs. A hardcopy terminal is not a must, but is useful for obtaining plots of waveforms.

Rick Parfitt
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**IMPORTANT NOTE:**
One of the most important features of the Challenger System is that it is not really "new". OSI has been delivering the basic circuitry of the Challenger since November 1975 and the floppy disk since June 1976. The only thing new is the total integration of the components as a complete, simple to use, fully-assembled, small computer system.

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One-Sided View of Wire Wrap Sockets

Ira Rampil
Dept of Electrical and Computer Engineering
University of Wisconsin—Madison
Madison WI 53706

Recently, while laying out the components for a new PDP-11 device controller, a devilishly simple construction technique revealed itself to me. Digital Equipment Corporation specifies that their printed circuit modules be restricted to component heights of 0.38 inch (0.97 cm), and on the solder side only 0.06 inch (0.15 cm) are allowed for the height of soldered and clipped off leads. These specifications enable boards to be mounted on half inch centers on a backplane. A problem arises, however, if wire wrap or Vector Slit-N-Wrap is the desired interconnection technique. DEC's solution to this problem is to provide a circuit board with soldered sockets for the integrated circuits. Each socket pin is connected by a foil trace to a wire wrap post staked and soldered to the component side of the board. Aside from meeting the DEC dimensional specifications, there is another important benefit. Since the wire wrapping is now done on the same side as the components, it's harder to get lost and make erroneous connections. The only caveat is to route the wires so they do not cross directly over any chip, otherwise you will have difficulties replacing defective components.

There are two difficulties in using DEC manufactured boards in my, or any other, microprocessor application. The first problem is flexibility; the layouts are prearranged and there is no provision for 40 pin chips. The second problem is cost; a so-called quad board which measures about 10.5 by 8.5 inches (26.7 by 21.6 cm) costs approximately $160.

The new technique which is described here retains all of the DEC board advantages with ultimate flexibility of layout, and very low cost. The best advantage is simplicity. The entire technique consists of bending the leads of a conventional wire wrap socket around so that they point upwards, and then gluing the socket down on a blank, unperforated board. The photos demonstrate the technique using a new Slit-N-Wrap pencil, by Vector Electronic Company.

For best result:
- Use quality sockets that have their posts solidly embedded in plastic, so they
will not be pulled out during the bending operation.

- Use a metal wire wrap pencil to do the bending. It is exactly the right size for the job. Slide the pencil down each post to a point about 0.1 inch (0.254 cm) from the socket base. Slowly bend the post out straight, away from the socket, and then up along the body. Remove the pencil and press the bent post flat against the socket to remove some of the remaining angle. The bent posts should be vertically aligned with each respective pin contact in the socket. Use of the wire wrap pencil leaves just enough room between the post and the socket for the wrapping operation.

- One method of gluing the sockets down is to mix a small solution of epoxy glue and briefly press each socket into the glue so that all of the bends in the posts receive a small dab of glue. After all of the sockets are in place, bake the board in an oven at approximately 140°F for an hour or until the glue hardens. A faster method is to use a hot glue gun as shown in photo 2. It will prove useful to roughen a smooth circuit board with a file or sandpaper prior to gluing to achieve a stronger board. If mechanical shocks are anticipated this is an essential consideration.

- Route all of the wires into the spaces between sockets. Never cross a socket. This will allow you to easily replace the individual integrated circuits.

- The Slit-N-Wrap tool is a very easy and inexpensive way to wire wrap. It is convenient for doing daisy chaining with. My only complaint with the system is the means of cutting the wire. I think a surgeon’s iris scissors or other small cutting tool would be much better than the tiny chisel provided by Vector.
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The PCNET (Personal Computer Network) Committee has been functioning in the Palo Alto area since the April 1977 West Coast Computer Faire. The committee's goal is the creation of regional (followed by national) personal computer networks for the computer to computer transfer of messages and files. A set of network protocols (sets of conventions defining all levels of intercomputer communication) is almost completely designed. These protocols should be operable in 8 K bytes of machine copy, and are designed to be implemented in string BASIC.

The committee believes this should be attractive to personal computer users. Participation will be voluntary; you can decide to participate (or not) on any given day of network operation. Network functioning will be relatively insensitive to the absence of an appreciable fraction of member computers.

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A message service: the ability to send a message (generally English text, although almost any file can be sent) is quite valuable. It doesn't sound very dramatic, but it is surprising how powerful and efficiency improving such a message exchange facility is. What keeps ordinary message services (telephone, telegraph, mail) from working well seems to be a combination of factors: too slow (mail); often hard to catch someone (phone); difficult or time consuming to use (mail, telegrams); expensive in terms

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<td>Fairchild</td>
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This text was supplied by Dave Fylstra.

## Adding New Transcendentals to Limited BASICs

Vince A Sempronio
PSC#2 Box 1451
BAFB DC 20332

As an avid reader of your periodical, and a devoted BASIC user, I discover that even the best of the many “tiny” BASICs that have hit the market still lack a few functions which I, as well as others, find useful. What do you do when you need some of the more complex math functions, more specifically the trigonometric functions? Well, if your BASIC has only the TAN (tangent), ATN (arc-tangent), and SQR (square root), most of the trigonometric functions are available

Continued on page 184
Computer music is probably one of the most talked about serious applications for home computers. By serious I mean an application that has a degree of complexity and open-endedness which can totally preoccupy experimenters and funded institutions for years. Computer performance of music is a discipline so vast that the final, "best" technique for its implementation or even a good definition of such a technique may never be discovered.

At the same time, computer music is an easy field to break into. With only minimal effort and expenditure a very impressive (to the uninitiated) music performance demonstration may be put together. With a little more work a system may be assembled which is of great value to other family members, particularly children just starting to learn music theory. Such a system could, for example, eliminate manual dexterity as a factor in a child's musical development. Finally, on the highest level, it is no longer very difficult to break into truly original research in serious performance of music by computer. The advances in digital and linear integrated circuits have made putting together the hardware system for supporting such research largely a matter of clever system design rather than brute financial strength. Programming, tempered with musical knowledge, is the real key to obtaining significant results. Thus, in the future, hobbyists working with their own systems will be making important contributions toward advancement of the computer music art.

While the scope of one article cannot fully cover such an extensive topic, it should serve to acquaint the reader with the more popular techniques, their implementation, strengths, weaknesses, and ultimate potential.

Generally, all computer music performance techniques can be classified into two generic groups. The first includes schemes in which the computer generates the sound directly. The second covers systems where the computer acts as a controller for external sound generation apparatus such as an electronic organ or sound synthesizer.

Early Techniques

Just as soon as standard commercial computers such as the IBM 709 and, later, the 1401 made their appearance, programmers started to do frivolous things with them after hours, such as playing games and music. Since elementary monotonic (one note at a time) music is just a series of tones with different frequencies and durations, and since a computer can be a very precise timing device, it did not take long for these early tinkerers to figure out how to get the machine to play such music. The fundamental concept used was that of a timed loop.

A timed loop is a series of machine language instructions which are carefully chosen for their execution time as well as function, and which are organized into a loop. Some of the instructions implement a counter that controls the number of passes through the loop before exiting.

Let's examine some fundamental
timed loop relationships. If the sum total execution time of the instructions in the loop is M microseconds then we have a loop frequency of

\[
\frac{10^6}{M} \text{ Hertz (cycles per second)}.
\]

If the initial value of the decrementing counter that controls the number of loop passes is N, then the total execution time before exit from the loop is (M\times N) microseconds. Thus what we really have is a "tone" with a frequency of

\[
\frac{10^6}{M} \text{ Hertz}
\]

and a duration of

\[
\frac{M\times N}{10^6} \text{ seconds.}
\]

Using different loops with more or fewer instructions will give us different Ms and thus different notes. Using different Ns when entering these loops gives different durations for the notes, and so we have satisfied the definition of elementary monotonic music.

Of course at this point the computer is merely humming to itself. Several techniques, some of them quite strange, have evolved to make the hum audible to mortals.

One such method that doesn't even require a connection to the computer is to use an AM portable radio tuned to a quiet spot on the broadcast band and held close to the computer. Viola! [Sic] The humming rings forth in loud, relatively clear notes. As a matter of fact, music programs using this form of output were very popular in the "early days" when most small system computers had only 256 bytes of memory and no IO peripherals except the front panel.

What is actually happening is that the internal logic circuitry with its fast rise time pulses is spewing harmonics that extend up into the broadcast band region of the radio spectrum. Since some logic gates will undoubtedly switch only once per loop iteration, the harmonics of the switching will be separated in frequency by the switching or loop frequency. Those high frequency harmonics that fall within the passband of the radio are treated as a "carrier" and a bunch of equally spaced nearly equal amplitude sidebands. The radio's detector generates an output frequency equal to the common differences of all these sidebands, which is the loop frequency and its harmonics. The timbre of the resulting tones is altered somewhat by the choice of instructions in the loop, but basically has a flat audio spectrum like that of a narrow pulse waveform. Noise and distortion arise from other logic circuitry in the computer which switches erratically with respect to the timed loops. One practical difficulty with this method is there is no clearly identifiable way to get the computer to "shut up" for rests or space between identical notes.

The Hammer-Klavier

Other early methods used some kind of output peripheral to make sound. In a demonstration of an IBM 1401 over a decade ago this was literally true: the computer played a line printer! It seems that the hookup between a 1401 central processing unit and the 1403 printer was such that software had control of the printer hammer timing. Each time a hammer was fired a pulse of sound was emitted upon impact with the paper. Using a timed loop program with a print hammer fire instruction imbedded in the loop gave a raspy but accurately pitched buzz. [It also tended to cause IBM customer engineers great trepidation . . .CH/ This same scheme should also be possible on some of the small, completely software controlled dot matrix printers that are now coming on the market.

A sane approach, however, is to connect a speaker to an output port bit through an amplifier. Instructions would then be placed inside the timed loops to toggle the bit and thus produce a clean, noise-free rectangular wave.

Timed Loop Example

Let's look at an example of a timed loop music playing program, not so much for its musical value (which is negligible), but for some insight into what is involved, and also to introduce some terms. The MOS Technology 6502 microprocessor will be used for these examples. These programs are designed to run on a KIM-1 system, and should run on most other 6502-based systems with very minor modifications. Motorola 6800 users should be able to easily convert the programs into 6800 machine language. 8080 users will benefit most because successful conversion indicates a thorough understanding of the concepts involved.

Figure 1: A basic tone generation subroutine. There are two nested loops in this routine: the first, or inner loop controls the frequency (or pitch) of the note to be generated, while the second, outer loop controls the duration of the note. A train of square waves is generated at the output port bit which is used to drive the circuit in figure 2 to produce an audible tone.

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The heart of the program is the tone generation subroutine which will be named TONE. Ideally, such a routine would accept as input two arguments: one related to the pitch of the note and the other controlling the duration. With such a subroutine available, playing a piece of music amounts to simply fetching the arguments from a "song" table in memory and calling the routine for each note to be played.

As mentioned previously, we could have a separate, carefully timed loop for each different tone frequency needed. TONE would then call the proper one based on the pitch parameter. Indeed this approach is very accurate (to within 1µs on the 6502) but a great deal of memory is consumed for the 30 or so notes typically required. It also lacks flexibility. (This will be discussed later.) A better approach is to embed a second, waiting loop to control the execution time of one pass through the outer loop, and thus the tone's frequency. Figure 1 is a flowchart illustrating this. When using this scheme, the frequency argument directly determines the number of times through the inner, waiting loop and the duration parameter directly determines the number of times through the outer, tone generation loop.

Now, how are the argument values determined to get the frequencies and durations desired? First the execution time of the nested loops must be determined. In the KIM-1 with a 1 MHz clock and a 6502 the tightest inner waiting loop that can be written is 5µs, assuming that the inner loop count (frequency argument) is 256 or less and that it is held in a register. The total time spent in the loop is \([5\times M]-1\) microseconds, where \(M\) is the frequency argument and the -1 is due to the shorter execution time of an unsuccessful branch. (The observant reader will note that the execution time of some 6502 instructions is altered if they cross a memory "page boundary"; thus, an assumption of no page crossing is made.) But there is still the time required for a pass through the outer loop to output a pulse and decrement the duration counter. This is termed "loop overhead." For an example, let's say that the loop overhead is 25µs. As a result, the total outer loop time is \([5\times M]+25\) or \([5\times M]+24\) microseconds which is the period of the audio waveform output. In order to determine the \(M\) required for a particular note, a table of note frequencies (see table 1) is consulted. Then the equation,

\[
M = \left( \frac{106 - 24}{F} \right) \times 5
\]

where \(F\) is the desired frequency, is solved for the nearest integer value of \(M\). Lower frequency notes are preferred so that the percentage error incurred due to rounding \(M\) is minimized. The duration argument is actually a count of the number of audio tone cycles which are to be generated for the note, and thus its value is dependent on the tone frequency as well as the duration. Its value can be determined from the relation \(N = D \times F\), where \(N\) is the duration argument, \(D\) is the duration in seconds, and \(F\) is the note frequency in Hertz.

As a complete example, let's assume that an eighth note G# an octave above middle C is to be played, and that the piece is in 4/4 time with a metronome marking of 80 beats per minute. Since an eighth note in this case is one half of a beat, the duration will be

\[
0.5 \times 60 = \frac{0.5 \times 60}{80} = 0.375 \text{ seconds.}
\]

or 0.375 seconds. The note table shows that the frequency of G# an octave above middle C is 830.6 Hz, which yields a frequency argument of 236. The duration argument is 311. So if TONE is called with these parameters, a nice G# eighth note will be produced.

As a step further and look at a practical "music peripheral" and TONE subroutine. Figure 2 shows a circuit for driving a speaker from any kind of TTL compatible
output port bit, including those found in the 6530 "combo chips" used in the KIM-1. When the output port bit is a logic 0 level, the transistor turns on and drives a current determined by the volume control setting through the speaker. When the bit is a logic 1, the current is interrupted. Larger speakers or even a high fidelity speaker system will give a richer timbre to the lower pitched tones. The AUX input to a sound system may also be used instead of the transistor circuit. Using a patch cord, connect the shield to the common terminal of the power supply and the center conductor to the output port bit through a 10 K to 100 K isolation resistor.

Listing 1 shows an assembled listing of a practical timed loop tone generation subroutine for the 6502 microprocessor. Several refinements beyond the flowcharted example have been made to improve tone quality and flexibility. The inner waiting loop has been split into two loops. The first loop determines the length of time that the output rectangular waveform is to be a logic 1 and the second loop determines the 0 time. If both loops receive the same frequency argument (which they do as written) and the loop time of both loops is the same, then a symmetrical square wave output is produced. However, if one or more "do nothing" instructions is inserted into one of the two loops, the output waveform will become nonsymmetrical. The significance of this is that the rectangular waveform's duty cycle affects its harmonic spectrum, and thus its timbre. In particular, there is a large audible difference between a 50%-50% duty cycle (square wave) and a 25%-75% duty cycle. Table 2 lists the harmonic structure of some possible rectangular waves. As a result, some control over the timbre can be exercised if a separate TONE subroutine is written for each "voice" desired. Unfortunately, if this is done the frequency arguments will have to be recomputed since the outer loop time will then be altered.

Real music also possesses dynamics, which are the changes in overall volume during a performance. Furthermore, the amplitude envelope of a tone is an important contributor to its overall subjective timbre. The latter term refers to rapid changes in volume during a single note. This is the case with a piano note, which builds up rapidly at the beginning and slowly trails off thereafter. Of course the setup described thus far has no control over either of these parameters: the volume level is constant, and the envelope of each note is rectangular with sudden onset and termination.

Listing 1: An assembled listing of a practical timed loop tone generation subroutine for the 6502 microprocessor. This routine is an elaboration of the flowchart shown in figure 1 which allows the user to generate nonsymmetrical rectangular waves. Experimenting with the wave's duty cycle affects the harmonic content of the resulting tone and creates many interesting aural effects.

Table 2: Harmonic amplitudes of rectangular waves. Note that, unlike square waves, asymmetrical rectangular waves contain even numbered harmonics. This simple technique of varying the duty cycle of such waves can have an appreciable effect on the timbre of the resulting sound.
By graduating to a more sophisticated music peripheral, control of dynamics and amplitude envelopes can be achieved with a timed loop music program. The secret is to use a digital to analog converter connected to all eight bits of the output port. A digital to analog converter (DAC) does just what its name implies: it accepts a binary number from the output port as input and generates a corresponding DC voltage as its output.

The circuit in figure 3, which can be used with any TTL compatible output port, gives an output voltage

\[ V = \left( \frac{1}{255} \right) \times 5 \]

where \( I \) is the binary number input between 0 and 255. When working with this kind of DAC, it is convenient to regard the binary number, \( I \), as a fraction between 0 and 1 rather than an integer. The benefit of this will become apparent later when calculations will be performed to arrive at the value of \( I \). The output of the DAC must be used with a sound system or the amplifier circuit in figure 8, not the simple transistor speaker driver circuit in figure 2.

As written, the TONE subroutine (see listing 1) alternately sends 0 and 255 to the output port with the music peripheral. With a DAC connected to that port, voltages of 0 and 5 V will be produced for the low and high portions of the rectangular wave. If instead 0 and 127 were output, the DAC would produce only 0 and 2.5 V giving a rectangular wave with about half the amplitude. This in turn produces a less loud tone, and so control over dynamics is possible by altering the byte stored at hexadecimal 101.

Arbitrary amplitude envelopes are also made possible by continuously exercising control over the amplitude during a note. Simple envelope shapes such as a linear attack and decay can be computed in line while the note is being sounded. A more general method is to build a table in memory describing the shape. Such a table can be quickly referenced during note playing. Great care must be taken, however, to insure that loop timing is kept stable when the additional instructions necessary to implement amplitude envelopes are added.

More Complex Techniques

Even if all of the improvements mentioned above were fully implemented, the elementary timed loop approach falls far short of significant musical potential. The primary limitations are a narrow range of tone colors and restriction to monotonic performance. The latter difficulty may be alleviated through the use of a multitrack tape recorder to combine separate parts, but this requires an investment in noncomputer hardware and is certainly not automatic. Also, unpitched percussive sounds such as drum beats are generally not possible. Musicians, too, will probably notice a host of other limitations such as lack of vibrato and

Figure 3: An 8 bit digital to analog converter (DAC). This circuit accepts an 8 bit binary number from the output port and generates a corresponding DC voltage as its output. The output voltage from this circuit is equal to \((I/255)\times5\) V, where \( I \) is the decimal equivalent of the 8 bit input which can take on any value from 0 to 225.
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other subtle variations. All of these shortcomings may be overcome by allowing the computer to compute the entire sound waveform in detail at its own speed.

The one fundamental concept that makes direct waveform computation possible is the sampling theorem. Any waveform, no matter how simple or complex, can be reconstructed from a rapid series of discrete voltage values by means of a digital to analog converter such as the one used earlier. As an example, let's try to generate an accurate sine wave using a DAC. If this can be done, it follows from the Fourier (harmonic) theorem that any other waveform may also be synthesized.

Figure 4 shows a sine wave as it would appear at the DAC output. Each step on the approximation to the sine wave is termed a sample, and the frequency with which these samples emerge from the DAC is the sample rate. An attempt is being made in the example to generate a 1.2 kHz sine wave at a sample rate of 25 kHz, or one sample every 40 µs. Obviously this is a very poor sine wave, a fact that can be easily demonstrated with a distortion analyzer.

Before giving up, let's look at the frequency spectrum of this staircase-like wave on a spectrum analyzer. The spectral plot in figure 5 shows a strong frequency component at 1.2 kHz which is the sine wave we are trying to synthesize. Also present are the distortion component frequencies due to the sampling process. Since all of the distortion components are much higher in frequency than the desired signal, they may be easily removed with a sharp low pass filter. After filtering, the distortion analyzer will confirm that a smooth, pure sine wave is all that remains.

What will happen if the sine wave frequency is increased but the sampling frequency remains constant? With even fewer samples on each sine wave cycle the waveform from the DAC will appear even more distorted. The lowest frequency distortion product is the one of concern since it is the most difficult to filter out. Its frequency is FD=(FS-f) Hertz, where FD is the lowest distortion component frequency, FS is the sampling frequency, and f is the sine wave signal frequency. Thus as f increases, FD decreases until they merge at f=FS/2. This frequency is termed the Nyquist frequency and is the highest theoretical frequency that may be synthesized. Any attempt to synthesize a higher frequency will result in the desired signal being filtered out and the distortion frequency emerging instead. This situation is termed aliasing because the desired signal frequency has been replaced by a distortion component alias frequency. Operating close to the Nyquist frequency requires a very sharp filter to separate the signal from the distortion. With practical filters, signal frequencies up to 1/4 to 1/3 of the sampling frequency are realizable.
Since any sound, whether it is a pitched tone or unpitched sound, is actually a combination of sine waves, it follows that any possible sound may be produced by a DAC. The only limitation is the upper frequency response, which may be made as high as desired by increasing the sample rate. The low frequency response has no limit, and extends down to DC.

There is another form of distortion in DAC generated sounds which cannot be filtered out, since it is spread throughout the frequency spectrum. Quantization noise is due to the fact that a DAC cannot generate voltages that are exact samples on the desired waveform. An 8 bit converter, for example, has only 256 possible output voltage values. When a particular voltage is needed, the nearest available value will have to be used. The theoretical signal to noise ratio when using a perfect DAC is related to the number of bits by the equation $S/N = (6xM)+4$ decibels where $M$ is the number of bits. A practical DAC may be as much as 6 db worse, but a cheap 8 bit unit can yield nearly 50 db, which is as good as many tape recorders. When using 12 bits or more, the DAC will outperform even the best professional recorders. Thus it is apparent that computed waveforms can, in theory, be used to generate very high quality music; so high, in fact, that conventional audio equipment is hard pressed to reproduce it.

Now that we have the tools, let’s see how the limitations of computer music mentioned earlier can be overcome. For tones of definite pitch, the timbre is determined by the waveshape and the amplitude envelope. Concentrating on the waveshape, it should be apparent that a waveform table in memory repeatedly dumped into the DAC will produce an equivalent sound waveform. Each table entry becomes a sample, and the entire table represents one cycle of the waveform. The frequency of the resulting tone will be $FS/N$ where $FS$ is the sampling frequency (rate at which table entries are sent to the DAC) and $N$ is the number of entries in the table. To get other frequencies, either the sample rate or the number of table entries must be changed.

There are a number of reasons why the sample rate should remain constant, so the answer is to change the effective table length. If the table dump routine were modified to skip every other entry, the result would be an effective halving of table size and thus doubling of the tone frequency. If the table is fairly long, such as 256 entries, a number of frequencies are possible by skipping an integer number of entries.

To get musically accurate frequencies, it is necessary to be able to skip a fractional number of table entries. At this point the concept of a table increment is helpful in dealing with programming such an operation. First, the table is visualized as a circle with the first entry conceptually following the last as in figure 6. A pointer locates a point along the circular table which represents the sample last sent to the DAC. To find what should be sent to the DAC next, the table pointer is moved clockwise a distance equal to the table increment. The frequency of the resulting tone is now

$$\frac{FS\times I}{N}$$

where $FS$ and $N$ are as before and $I$ is the increment.

---

**Figure 5:** The spectral plot of the staircase-like sine wave approximation shown in figure 4. This frequency versus amplitude graph indicates a strong frequency component at 1.2 kHz, the frequency of the sine wave. Normally, this would be the only frequency component to appear on a plot like this, but the presence of steeply rising steps in this waveform approximation introduces distortion components at higher frequencies, as shown.
Figure 6: Diagrammatic representation of the circular table used for storing the waveform “template.” The technique illustrated here is that of storing a large number of samples of one cycle of a musical waveform in memory as a table which wraps around itself in circular fashion. A pointer is used to point to the next sample to be extracted. In order to create a waveform with a given frequency, the program is designed to skip a fractional number of table entries to get the next sample value. This fractional number is called the table increment value. The process is continued around the table for one revolution to create a complete waveform. The cycle around the table is repeated until the duration counter decrements to zero.

With integer increments, the pointer always points squarely to an entry. With mixed number increments, the pointer also will take on a fractional part. The sensible thing to do is to interpolate between the table entries on either side of the pointer to arrive at an accurate value to give to the DAC. This is indeed necessary to assure high quality; but simply choosing the nearest entry may be acceptable in some cases, particularly if the table is very large.

There is one elusive pitfall in this technique. The table may contain the tabulation of any waveform desired, subject to one limitation: a nonzero harmonic component of the waveform must not exceed the Nyquist frequency, FS/2. This can easily happen with the larger table increments (higher frequency tones), the result being aliasing of the upper harmonics. Theoretically this is a severe limitation. Often a small amount of aliasing is not objectionable, but a large amount sounds like gross intermodulation distortion. High sample rates reduce the possibility or magnitude of aliasing, but of course require more computation. For the moment, we will ignore this problem and restrict ourselves to relatively smooth waveforms without a lot of high frequency harmonics.

Now that the DAC is used for generating the actual waveshape, how is amplitude control accomplished? If an amplitude parameter is defined that ranges between 0 and 1.0 (corresponding to amplitudes between zero and maximum), the desired result is obtained by simply multiplying each sample from the table by this amplitude parameter and sending the product to the DAC. Things are nice and consistent if the table entries are also considered as fractions between -1 and +1 because then the product has a range between -1 and +1 which is directly compatible with the DAC. (Note that the DAC in figure 3 is unipolar. It can be considered bipolar if +2.5 V output is the zero reference and the sign bit is inverted.)

The last major hurdle is the generation of simultaneous tones. Obviously, two simultaneous tones may be generated by going through two tables, outputting to two separate DACs, and mixing the results with an audio mixer. This is relatively simple to do if the sample rates of the two tones are the same. Actually, all the audio mixer does is to add the two input voltages together to produce its output, but a very important realization is that the addition can also be done in the computer before the output conversion by the DAC! The two samples are simply added together with an ADD instruction, the sum is divided by two (to constrain it to the range of -1 to +1), and the result sent to a single DAC. This holds true for any number of simultaneous tones! The only requirement is that the composite samples not overflow the -1 to +1 range that the DAC can accept. Rather than dividing the sum, it is best to adjust the amplitude factors of the individual “voices” to prevent overflow. So now we have the tools necessary to generate an ensemble of tones, each one possibly having its own waveform, amplitude envelope, and loudness relative to the others. Indeed, this is all that is necessary to simulate a typical organ.

Up to this point the timbre (waveform) of a tone has been determined by the contents of a fixed waveform table. Truly interesting musical notes change their timbre during the duration of the note. A reasonable alternative to switching between similar tables for implementing this is to build the tone from harmonic components. Each harmonic component of the tone is simply
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Listing 2: A program which, in conjunction with tables 3, 4 and 5, generates four simultaneous musical voices, each with a different waveform and volume level. The program is designed for use with the 6502 processor coupled to an 8-bit unsigned digital to analog converter (DAC) like the one shown in figure 3.

This program plays music in 4-part harmony on the KIM-1 or other 6502-based system using an 8-bit unsigned digital-to-analog converter connected to an output port. The program is designed to be used with the 6502 processor coupled to an 8-bit unsigned digital-to-analog converter (DAC) like the one shown in figure 3.

The program initializes the DAC and data direction register for DAC port. The address of extra 128 bytes of RAM in 6530 is set to point to the DAC memory space. The entry point to the KIM keyboard monitor is set to page 0 location 0.

The program contains a main music playing program and a subroutine to handle the individual voices. The music playing program sets the peripheral data direction and register to output. It then initializes the DAC and registers for the DAC port. It loads the waveforms, addresses of the song tables, and initializes the notes pointer and duration counter. The notes pointer is loaded with the address of the first note in the song.

The program then increments the notes pointer and checks if it is at the end of the song. If not, it increments the duration counter and saves the duration in the duration counter. If the end of the song is reached, the program jumps to the end of the song and returns to the monitor.

The subroutine for each voice handles the generation of the waveforms and the incrementation of the notes. It loads the note ID number, checks if it is at the end of the song, and increments the duration counter. If not at the end of the song, it increments the notes pointer and checks if it is at the end of the song.

What about other, unpitched sounds? They too can be handled with a few simple techniques. Most sounds in this category are based in part on random noise. In sampled form, random white noise with a uniform frequency spectrum is simply a stream of random numbers. For example, a fairly realistic snare drum sound may be generated by simply giving the proper amplitude envelope to pure white noise. Other types of drum sounds may be generated by using a digital filter to shape the frequency spectrum of the noise. A resonant type of digital filter would be used for toms and similar semipitched drums, for example. A high-pass filter is useful for simulating brush and cymbal sounds. An infinite number of variations are possible.

The sampling theorem works both ways also. Any waveform may be converted into digital samples with an analog to digital converter (ADC) with no loss of information. The only requirement is that the signal being sampled have no frequency components higher than half of the sampling frequency. This may be accomplished by passing the signal to be digitized through a sharp low pass filter prior to presenting it to the ADC. Once sound is in digitized form, literally anything may be done to it.

A simple (in concept) application is intricate editing of the sound with a graphic display, light pen and large capacity disk. The sound may be analyzed into harmonic components and the result or a transformation of it applied to a synthesized sound. Again, this is an area that deserves its own article.

The sound may be analyzed into harmonic components and the result or a transformation of it applied to a synthesized sound.
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Listing 2, continued:

0157 A000 PLAY: LDD #0 ; SET Y TO ZERO FOR DIRECT INDIRECT
0159 A61D LDX TEMPO ; SET X TO TEMPO COUNT
015B 18 PLAY: CLC ; CLEAR CARRY
015C 8101 LDA (VIPT+1),Y ; ADD UP A VOICE SAMPLES
015E 7104 ADC (V2PT+1),Y ; USING INDIRECT ADDRESSING THROUGH VOICE
0160 7103 ADC (V3PT+1),Y ; PUSH INTO WAVEFORM TABLES
0163 710A ADC (V4PT+1),Y ; STRAIGHT INDIRETS WHICH 1 INDEX - V
0154 8E0017 STA X',Y00 ; SEND X TO LIMIT-TO-ANALOG CONVERT
0157 A600 LDA VIPT ; ADD INCREMENT TO POINTERS FOR
0169 550C ADC Y'IN ; INC 4 VOICES
016B 850E STA VIPT ; FIRST FRACTIONAL PART
0170 8901 LDA VIPT+1 ; SECOND FRACTIONAL PART
0172 8501 STA Y'IN+1 ; THEN INCRAC PART
0173 8503 LDA Y'PT ; VOICE 2
0175 650E ADC Y'IN ; VOICE 3
0177 5503 STA Y'PT ; VOICE 4
0179 8504 LDA Y'PT+1 ; VOICE 5
017B 5507 ADC Y'IN+1 ; VOICE 6
017D 5504 STA Y'PT+1 ; VOICE 7
017F 4506 LDA Y'PT+2 ; VOICE 8
0183 6510 ADC Y'IN ; VOICE 9
0185 5506 STA Y'PT ; VOICE 10
0187 6507 ADC Y'IN+1 ; VOICE 11
0189 5507 STA Y'PT+1 ; VOICE 12
018B 8005 LDA VA'PT ; VOICE 13
018D 6512 ADC VA'IN ; VOICE 14
018F 6509 STA VA'PT ; VOICE 15
0191 8504 LDA VA'PT+1 ; VOICE 16
0193 8504 STA VA'PT+1 ; VOICE 17
0195 8504 STA VA'PT+2 ; VOICE 18
0197 2A DEX ; DEC taME & CHECK TEMPO COND.
019B 8908 BNE TIMAS ; BRANCH ID TIM THE.WAVE. GT 50 10, RAN OUT
019F 8914 DEC DUR ; DECRESMN & JOCK QUANT FOR LIMITER
019C 90C5 BEQ ENDBJT ; JUMP OUT IF END OF SEG
01A3 861D LDX TEMPO ; RESTORE TEMPO COUNT
01A6 0805 BNE PLAY1 ; CONTINUE PLAYING
01A7 D505 LDA BRT ; CONTINUE PLAYING
01A8 8D08 BNE #05 ; CONTINUE PLAYING
01AA 9502 STA V2PT ; CONTINUE PLAYING
01AC 8904 LDA Y'PT+1 ; CONTINUE PLAYING
01AD 650E ADC Y'IN ; CONTINUE PLAYING
01AE 7104 ADC Y'IN+1 ; CONTINUE PLAYING
01AF 7103 ADC Y'IN+2 ; CONTINUE PLAYING
01A9 PI END z ; END AND BEGINNING ADJUSTED FOR THIRD PART
0198 60 ENDBJT: RTS ; RETURN
019A 60 PLOT; RT$ ; TOTAL LOW TONE 1.8 HZ SINE X 84Hz
019B 60 PLT; RT$ ; TOTAL HIGH TONE 1.8 HZ SINE X 84Hz

Sampled Waveform Example

It should be obvious by now that while these sampled waveform techniques are completely general and capable of high quality, there can be a great deal of computation required. Even the most powerful computers in existence would be hard pressed to compute samples for a significant piece of music with many voices and all subleties implemented at a rate fast enough for direct output to a DAC and speaker. Typically the samples are computed at whatever rate the program runs and are saved on a mass storage device. After the piece has been "computed," a playback program retrieves the samples and sends them to the DAC at a uniform high rate.

Most microprocessors are fast enough to do a limited amount of sampled waveform computation in real time. The 6502 is one of the best 8 bit machines in this capacity due to its indexed and indirect addressing modes and its overall high speed. The example program shown in listing 2 has the inherent capability to generate four simultaneous voices, each with a different waveform and volume level. In order to make the whole thing fit in a basic KIM-1, however, only one waveform table is actually used.

This program could probably be considered as a variation of the timed loop technique, since the sample rate is determined by the execution time of a particular loop. The major differences are that all of the instructions in the loop perform an essential function and that the loop time is constant regardless of the notes being played. Using the program as shown on a full speed (1.0 MHz) 6502 gives a sample rate of 8.77 kHz, which results in a useful upper frequency limit of 3 kHz. The low pass filter in figure 7 coupled with the DAC in figure 3 and audio system or amplifier in figure 8 are all the specialized hardware necessary to run the program with full 4 part harmony.

The program consists of two major routines: MUSIC and PLAY. MUSIC steps through the list of notes in the song table and sets up DUR and V1IN thru V4IN for the PLAY routine. PLAY simultaneously plays the four notes specified by V1IN thru V4IN for the time period specified by DUR. Another variable, TEMPO, in page zero controls the overall tempo of the music independently of the durations specified in the song table. The waveform tables for the four voices are located at WAV1TB thru WAV4TB and require 256 bytes (one memory page) each. The actual waveform samples stored in the table have already been scaled so that when four of them are added up there is no possibility of overflow.

The song table has an entry for each musical "event" in the piece. An entry requires five bytes, the first of which is a duration parameter. By suitable choice of the TEMPO parameter in page 0, "round" (in the binary sense) numbers may be used for duration parameters of common note durations. A duration parameter of 0 signals the end of the song, in which case the program returns to the monitor. A duration parameter of 1 is used to specify a break in the sequential flow of the song table. In this case the next two bytes point to the continuation of the table elsewhere in memory. This feature was necessary to deal with the fragmented memory of the KIM-1, but has other uses as well. All other possible duration values are taken literally and are followed by four bytes which identify the notes to be played by each voice. Each note ID points to a location in the note frequency table which in turn contains a 2 byte frequency parameter for that note which is placed in V1IN thru V4IN.

The PLAY routine is optimized for speed,
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Figure 7: A sharp low pass filter with 3 kHz cutoff. This circuit is used to filter out the high frequency distortion illustrated in figure 5.

**Table 3: Note frequency table used in conjunction with listing 2.** This table is for a sample rate of 8.772 kHz. The range of the notes used is from 65.41 Hz (for C2) to 1046.5 Hz (for C6).

<table>
<thead>
<tr>
<th>NOTE FREQ. TAB.</th>
<th>RANGE FROM C2 (65.41 Hz) TO C6 (1046.5 Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>001F 0000</td>
<td>0 SILENCE</td>
</tr>
<tr>
<td>0021 0189</td>
<td>2 1.233</td>
</tr>
<tr>
<td>0023 0265</td>
<td>4 C2# 69.295 2.0224</td>
</tr>
<tr>
<td>0025 0225</td>
<td>6 D2 73.315 2.1427</td>
</tr>
<tr>
<td>0027 0245</td>
<td>8 E2# 77.783 2.7201</td>
</tr>
<tr>
<td>0029 0256</td>
<td>10 E2 82.408 2.9051</td>
</tr>
<tr>
<td>002B 028C</td>
<td>12 F2 87.388 2.5481</td>
</tr>
<tr>
<td>002D 02B3</td>
<td>14 F2# 92.994 2.6644</td>
</tr>
<tr>
<td>002F 02BC</td>
<td>16 G2 97.998 2.8601</td>
</tr>
<tr>
<td>0031 03CB</td>
<td>18 C2# 103.83 3.0032</td>
</tr>
<tr>
<td>0033 0316</td>
<td>20 A2 110.00 3.2104</td>
</tr>
<tr>
<td>0035 0367</td>
<td>22 A2# 116.54 3.4013</td>
</tr>
<tr>
<td>0037 039A</td>
<td>24 N2 123.47 3.6055</td>
</tr>
<tr>
<td>0039 03D1</td>
<td>26 C3 130.81 3.8176</td>
</tr>
<tr>
<td>003B 040B</td>
<td>28 C3# 138.59 4.0448</td>
</tr>
<tr>
<td>003D 0449</td>
<td>30 D3 146.83 4.2654</td>
</tr>
<tr>
<td>003F 048A</td>
<td>32 D3# 155.57 4.4002</td>
</tr>
<tr>
<td>0041 04CF</td>
<td>34 E3 164.82 4.6102</td>
</tr>
<tr>
<td>0043 0519</td>
<td>36 F3 174.62 4.9062</td>
</tr>
<tr>
<td>0045 0566</td>
<td>38 F3# 185.00 5.3992</td>
</tr>
<tr>
<td>0047 058B</td>
<td>40 G3 196.00 5.7203</td>
</tr>
<tr>
<td>0049 060F</td>
<td>42 G3# 207.55 6.0804</td>
</tr>
<tr>
<td>004B 066C</td>
<td>44 H3 246.94 7.2021</td>
</tr>
<tr>
<td>0051 071A</td>
<td>46 H3# 261.62 7.6356</td>
</tr>
<tr>
<td>0053 0747</td>
<td>48 H3## 277.18 8.0677</td>
</tr>
<tr>
<td>0055 0862</td>
<td>50 K3 293.66 8.5707</td>
</tr>
<tr>
<td>0057 0915</td>
<td>52 K3# 311.13 9.0804</td>
</tr>
<tr>
<td>0059 0983</td>
<td>54 L3 326.93 9.6203</td>
</tr>
<tr>
<td>0061 0A11</td>
<td>56 M3 344.93 10.1228</td>
</tr>
<tr>
<td>0063 0B2F</td>
<td>58 N3 363.93 10.6250</td>
</tr>
<tr>
<td>0065 0C1F</td>
<td>60 O3# 385.93 11.1272</td>
</tr>
<tr>
<td>0067 0D07</td>
<td>62 P3 407.93 11.6350</td>
</tr>
<tr>
<td>0069 0D99</td>
<td>64 Q3 429.93 12.1292</td>
</tr>
<tr>
<td>006B 0E84</td>
<td>66 R3 450.93 12.6305</td>
</tr>
<tr>
<td>006D 0F75</td>
<td>68 S3 471.93 13.1208</td>
</tr>
<tr>
<td>006F 0G6A</td>
<td>70 T3 492.93 13.6212</td>
</tr>
<tr>
<td>0071 133E</td>
<td>72 U3 513.93 14.1212</td>
</tr>
<tr>
<td>0073 1462</td>
<td>74 V3 534.93 14.6212</td>
</tr>
<tr>
<td>0075 1599</td>
<td>76 W3# 555.93 15.1212</td>
</tr>
<tr>
<td>0077 1726</td>
<td>78 X3 576.93 15.6212</td>
</tr>
<tr>
<td>0079 1863</td>
<td>80 Y3# 597.93 16.1212</td>
</tr>
<tr>
<td>007B 1924</td>
<td>82 Z3 618.93 16.6212</td>
</tr>
<tr>
<td>007D 1A1E</td>
<td>84 AA 639.93 17.1212</td>
</tr>
<tr>
<td>007F 1C1C</td>
<td>86 BB 659.93 17.6212</td>
</tr>
<tr>
<td>0081 1E88</td>
<td>88 CC 679.93 18.1212</td>
</tr>
<tr>
<td>0083 0000</td>
<td>90 DD# 699.93 18.6212</td>
</tr>
</tbody>
</table>

**Notes:**
- All resistors 1/4 Watt 5%.
- All capacitors except 100μF Plastic Film or NPO Ceramic preferably 5%.

This example demonstrates the use of a waveform table to set the tempo and duration of notes. The routine maintains four pointers (V1PT thru V4PT) to access each waveform table. Each pointer consists of three bytes in order of increasing significance. The first byte is the "fractional part" of the pointer, the second byte is the integer part which is also the lower half of an address in the waveform table. The third byte is the upper address which normally remains constant. The waveform table lookup is considerably simplified by using the indirect addressing mode of the 6502 with these pointers. Note that the fractional part of the pointer is ignored when the table lookup takes place, since interpolation is much too slow for a real-time routine.

During each sample, waveform table entries for each voice are fetched, added up, and sent to the digital to analog converter output port. Then the increment (VxIN) is added (double precision) to each pointer (VxPT). Wraparound from the end of a waveform table to the beginning is automatically taken care of due to the fact that the table occupies a full memory page. Finally, the tempo counter is decremented and checked. If the tempo counter is zero, it is restored and the duration counter is decremented and checked. If it is also zero, the note is finished and PLAY returns. The net result is that TxD samples are computed and sent out for the event, where T is the tempo parameter and D is the duration parameter. Note that, unlike the earlier timed loop example, there is no interaction between the duration parameter and the note frequencies being played.
How does it sound? With the waveform table shown and a reasonably good speaker system, the result sounds very much like an electronic organ, such as a Hammond. There is a noticeable background noise level due to compromises such as precompressed waveforms and lack of interpolation in the tables, but it is not objectionable. The pitches are very accurate, but there is some beating on chords due to compromises inherent in the standard equally tempered musical scale. Also there are noticeable clicks between notes due to the time taken by the MUSIC routine to set up the next set of notes. All in all the program makes a good and certainly controlled sound synthesizer. Since the incoming notes are usually assumed to be in the range of 0 to +10 volts, although some modules will have control voltages in the range of 0 to +12 volts, the signal is divided down to +5 volts by a circuit of unknown construction, when coupled with the circuits in figures 3 and 7, is all the experimenter needs to create music with his or her microprocessor.

Synthesizer Control Techniques

So far we have discussed techniques in which the computer itself generates the sound. It is also possible to interface a computer to specialized sound generation hardware and have it act as a control element.

The most obvious kind of equipment to control is the standard, modular, voltage controlled sound synthesizer. Since the interface characteristics of nearly all synthesizers are standardized, a computer interface to such equipment could be used with nearly any synthesizer in common use.

Generally speaking, the function of a voltage controlled module is influenced by one or more DC control voltages. These are usually assumed to be in the range of 0 to +10 volts, although some modules will...

**Table 4:** This song table is an encoding of “The Star Spangled Banner” in 4 part harmony which is used by the program in listing 2. Each musical event in the table consists of five bytes. The first byte represents the duration of the event in units, according to the value of the “tempo” (0 denotes the end of the song). The next four bytes contain the note identifications of the four voices (0 indicates silence for the voice).
have a predictable response to negative voltages as well. In a voltage controlled oscillator, for example, the output frequency is determined by a control voltage. For typical tuning, 0 V would correspond to 16 Hz (a very low C), and the frequency would increase one volt per octave for higher voltages. Thus, +4 V would produce middle C, and the maximum input of +10 V would produce a nearly inaudible 16.4 kHz. A typical oscillator module has two or three control inputs and a number of outputs. The voltages at the inputs are internally summed to form the effective control value (useful for injecting vibrato), and the outputs provide several different waveforms simultaneously.

A voltage controlled amplifier has as a minimum a signal input, a control input, and a signal output. The voltage at the control input determines the gain from the signal input to the signal output. In a typical setting, +8 V would correspond to unity (0 dB) gain, with lower voltages decreasing the gain by 10 dB per volt.

Many other voltage controlled devices have been developed during the approximately 12 year history of this field. In order to play music, the modules are first “patched” together with patch cords (like old style telephone switchboards) according to the desired sound characteristics. Manually operated control voltage sources such as potentiometers, joysticks and specialized organ-like keyboards are then manipulated by the player. The music is generally monotonic due to difficulties in the control elements (now being largely overcome). Multitrack tape recorders are universally utilized to produce the results heard on recordings such as Walter Carlos’s *Switched on Bach*.

A useful computer interface to a synthesizer can be accomplished with nothing more than a handful of digital to analog and optionally analog to digital converters. The DACs would be used to generate control voltages under program control and the ADCs would allow operator input from the keyboard, for example, to be stored. Since control voltages vary slowly compared to the actual sound waveforms, real time control of a number of synthesizer modules is possible with the average microprocessor. Due to the large number of DACs required and the relatively slow speeds necessary, a multiplexing scheme using one DAC and a number of sample and hold amplifiers is appropriate. The home builder should be able to achieve costs as low as $2 per channel for a 32 channel, 12 bit unit capable of controlling a fairly large synthesizer.

The routing of patch cords can also be computerized. A matrix of reed relays or possibly CMOS bilateral switches interfaced to the computer might be used for this task. The switches used for some contemporary synthesizer sounds resemble the program patch boards of early computers and thus are difficult and time consuming to set up and verify. With computer controlled patching, a particular setup may be recalled.

Table 4, continued:

<table>
<thead>
<tr>
<th>Time Code</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0240</td>
<td>1058D041C</td>
</tr>
<tr>
<td>0245</td>
<td>1058D031E</td>
</tr>
<tr>
<td>0250</td>
<td>1058D031E</td>
</tr>
<tr>
<td>0255</td>
<td>1058D031C</td>
</tr>
<tr>
<td>0260</td>
<td>1058D032C</td>
</tr>
<tr>
<td>0265</td>
<td>1058D032C</td>
</tr>
<tr>
<td>0270</td>
<td>1058D032C</td>
</tr>
<tr>
<td>0275</td>
<td>1058D032C</td>
</tr>
<tr>
<td>0280</td>
<td>1058D032C</td>
</tr>
<tr>
<td>0285</td>
<td>1058D032C</td>
</tr>
<tr>
<td>0290</td>
<td>1058D032C</td>
</tr>
<tr>
<td>0295</td>
<td>1058D032C</td>
</tr>
<tr>
<td>0300</td>
<td>1058D032C</td>
</tr>
</tbody>
</table>

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and set up in milliseconds, thus enhancing real time performance as well as reducing the need for a large number of different modules.

Other musical instruments may be interfaced as well. One well-published feat is an interface between a PDP-8 computer and a fair sized pipe organ. There are doubtless several interfaces to electronic organs in existence also. Even piano mechanisms can be activated, as noted elsewhere in this issue.

Recently, specialized music peripherals have appeared, usually oriented toward the S-100 (Altair) bus. In some cases these are digital equivalents of analog modules of similar function. For example, a variable frequency oscillator may be implemented using a divide-by-N counter driven by a crystal clock. The output frequency is determined by the value of N loaded into a register in the device, much as a control voltage affects a voltage controlled oscillator. Such an approach bypasses the frequency drift problems and interfacing expense of analog modules. The biggest advantage, however, is availability of advanced functions not feasible with analog modules.

One of these is a programmable waveform. A small memory in the peripheral holds the waveform (either as individual sample values or Fourier coefficients), which can be changed by writing in a new waveform under program control. Another advantage is that time multiplexing of the logic is usually possible. This means that one set of logic may simulate the function of several digital oscillators simultaneously, thus reducing the per oscillator cost substantially. Actually, such a digital oscillator may be nothing more than a hardware implementation of the PLAY routine mentioned earlier.

Digital/analog hybrids are also possible. The speech synthesizer module produced by Computalker Consultants, for example, combines a programmable oscillator, several programmable amplifiers and filters, white noise generator, and programmable switching on one board. Although designed for producing speech, its completely programmable nature gives it significant musical potential, particularly in vocals.

How do these various control techniques compare with the direct waveform computation techniques discussed earlier? A definite advantage of course is real time playing of the music. Another advantage is simpler programming, since sound generation has already been taken care of. However, the number of voices and complexity of subtle variations is directly related to the quantity of synthesizer modules available.

<table>
<thead>
<tr>
<th>WAVESTabe</th>
<th>EXACTLY ONE PAGE LONG ON A PAGE BOUNDARY</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAXIMUM VALUE OF AN ENTRY IS 03 DECIMAL OR 3F HEX TO AVOID</td>
<td></td>
</tr>
<tr>
<td>OVERFLOW WHEN 4 VOICES ARE ADDED UP</td>
<td></td>
</tr>
<tr>
<td>0300 . . X'300</td>
<td>START WAVEFORM TABLE AT 0300</td>
</tr>
<tr>
<td>0300 WAVETB = ,</td>
<td>VOICE 1 WAVEFORM TABLE</td>
</tr>
<tr>
<td>0300 WAVETB = ,</td>
<td>VOICE 2 WAVEFORM TABLE</td>
</tr>
<tr>
<td>0300 WAVETB = ,</td>
<td>VOICE 3 WAVEFORM TABLE</td>
</tr>
<tr>
<td>0300 WAVETB = ,</td>
<td>VOICE 4 WAVEFORM TABLE</td>
</tr>
<tr>
<td>. .</td>
<td>NOTE THAT ALL 4 VOICES USE THIS TABLE DUE</td>
</tr>
<tr>
<td>. .</td>
<td>TO LACK OF RAM IN BASIC KIM-1</td>
</tr>
<tr>
<td>. .</td>
<td>FUNDAMENTAL AMPLITUDE 1.0 (REFERENCE)</td>
</tr>
<tr>
<td>. .</td>
<td>SECOND HARMONIC .5, IN PHASE WITH FUNDAMENTAL</td>
</tr>
<tr>
<td>. .</td>
<td>THIRD HARMONIC .9, 90 DEGREES LEADING PHASE</td>
</tr>
</tbody>
</table>

Table 5: This table is an encoding of the samples of the waveform used in program listing 2. The table is exactly one memory page long on a page boundary. The maximum value of any entry is decimal 63 or hexadecimal 3F to avoid overflow when all four voices are summed.
For example, if more voices are needed, either more modules must be purchased or a multitrack tape recording must be made, which then takes us out of the strict real time domain. On the other hand, a new voice in a direct synthesis system is nothing more than a few bytes added to some tables and a slightly lengthened execution time. Additionally, there may be effects that are simply not possible with currently available analog modules. With a direct synthesis system, one merely codes a new subroutine, assuming that an algorithm to produce the effect is known.

A separate problem for the experimenter is that a "critical mass" exists for serious work with a direct synthesis system. To achieve complexity significantly beyond the 4 voice example program described earlier, a high speed, large capacity mass storage system is needed. This means an IBM type digital tape drive or large hard surface disk drive; usually at least $3000 for a new drive less interface. Used 7 track tapes and 2311 type disks (7.5 megabytes) are often available for $500 and certainly provide a good start if the user can design his own interface. Synthesizer modules or peripheral boards, on the other hand, can be purchased one at a time as needed.

Music Languages

Ultimately, software for controlling the sound generation process, whether it be direct or real time control, is the real frontier. The very generality of computer music synthesis means that many parameters and other information must be specified in order to produce meaningful music. One function of the software package is to convert "musical units of measure" into physical sound parameters such as conversion of tempo into time durations. Another part is a language for describing music in sufficient detail to realize the control power available from music synthesis without burdening the user with too much irrelevant or repetitive detail. With a good language, a good editor for the language, and real time (or nearly so) execution of the language, the music system becomes a powerful composition tool much as a text editing system aids writers in preparing manuscripts.

Music languages can take on two forms. One is a descriptive form. Music written in a descriptive language is analogous to a conventional score except that it has been coded in machine readable form. All information in the score necessary for proper performance of the piece is transcribed onto the computer score in a form that is meaningful to the user yet acceptable to the computer. Additional information is interspersed for control of tone color, tempo, subtle variations, and other parameters available to the computer synthesist.

A simple example of such a language is NOTRAN (NOt TRANslation) which was developed by the author several years ago for transcribing organ music. Listing 3 shows a portion of Bach's "Toccata and Fugue in D Minor" coded in NOTRAN. The basic thrust of the language was simplicity of instruction (to both the user and the interpreter program), rather than minimization of typing effort.

Briefly, the language consists of statements of one line each which are executed in straight line sequence as the music plays. If the statement starts with a keyword, it is

Listing 3: Bach's "Toccata and Fugue in D Minor" as encoded in NOTRAN, a music language developed by the author (NOTRAN stands for NOte TRANslation). The main function of the language is to transcribe organ music, but it will work equally well with other types of music. Program statements are used to encode duration, pitch, attack and decay rates, and loudness of each note.

```plaintext
* TOCCATA AND FUGUE IN D-MINOR BACH
*
VOICE1 40,0,0,0,0,30,0,0,0,0,0,0,90,0 10 30,30
VOICE2 37,0,0,0,0,0,0,0,50,0,0,0,0,50,0 10 60,60
VOICE3 0,0,38,0,38,0,0,0,38,19,0,0,0,28,0 15 100,250
TEMPO 1/4=1200

/~/
002 1A3,1/64; 2A2,1/64
1A#3,1/64; 2A#2,1/64
1A3,1/64; 2A2,1/8
R,1/32
1G3,1/64; 2G2,1/64.
1F3,1/64; 2F2,1/64.
1E3,1/64; 2E2,1/64.
1D3,1/64; 2D2,1/64.
1C#3,1/32; 2C#2,1/32
1D1,1/16; 2D2,1/16
R,1/4
3D2,1/16; R,1/4
2C#3,1/16; R,1/16
1E3,1/16; R,1/16
1G3,1/16; R,1/16
1B#3,1/16; R,1/16
1C#4,4/16; R,1/16
1E4,3/16

/~/
140 1B#4,1/8; 1G4,1/8; 1E4,1/8; 2E3,1/8; 3C#3,1/8
1E3,1/32
1D3,1/32
1C#3,1/32
1B#3,1/32
1G4,1/8
1B#4,1/8; 1G4,1/8; 1E4,1/8; 1C#4,1/8; 2E3,1/8; 3C#3,1/8
1E4,1/8; 1F4,1/8; 1D4,1/8; 2F#3,1/8; 3C3,1/8
TEMPO 1/4=950
1D3,1/32
TEMPO 1/4=1050
1A3,1/32
TEMPO 1/4=1150
1D4,1/32
TEMPO 1/4=1200
1F4,1/32
1A4,1/8
1A4,1/8; 1F4,1/8; 1D4,1/8; 2F#3,1/8; 3C3,1/8
1D4,1/2; 1B#3,1/2; 2G3,1/2; 3G2,1/4
1G4,1/4; 1C#4,1/4; 2B#3,1/4; 3D2,1/4
1F4,1/4; 1D4,1/4; 2A3,1/4; 3F2,1/4
1E4,1/4; 2A1,1/2; 3A2,1/2; R,1/4
1C4,1/2; R,1/4
1D4,1/2; 2F#1,1/4; 3B#2,1/4
2B#3,1/4; 2G3,1/4; 3G2,1/4
1A3,3/2; 2F#3,1/2; 3D3,3/2; 3D2,3/2
END
```

80
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a specification statement; otherwise, it is a note statement. Specification statements simply set up parameters that influence the execution of succeeding note statements and take no time themselves.

A VOICE statement assigns the timbre described by its parameters to a voice number which is used in the note statements. In the example score, the first group of parameters describe the waveform in terms that are implementation dependent, such as harmonic amplitudes. The next, isolated parameter specifies the overall loudness of the voice in relation to other voices. The last pair of parameters specifies the attack and decay times respectively for notes using this voice. Depending on the particular implementation, other parameters may be added without limit. For example, vibrato might be described by a set of three additional parameters such as vibrato frequency, amplitude, and a delay from the beginning of a note to the start of vibrato.

A TEMPO statement relates note durations in standard fractional terms to real time in milliseconds. The effect of a tempo statement lasts until another is encountered. Although the implementation for which this example was written required a sequence of tempo statements to obtain a retard, there is no reason why an acceleration or a retard set of parameters could not be added.

Note statements consist of one or more note specifications and are indented four spaces (the measure numbers are treated as comments). Each note specification begins with a voice number followed by a note name consisting of a letter, optional sharp (#) or flat (@) sign, and an octave number. Thus C#4 is one half step above middle C. Following the comma separator is a duration fraction. Any fraction is acceptable, but conventional musical fractions are normally used. Following the duration are two optional modifiers. A period (.) indicates a "dotted" note which by convention extends the note's duration by 50%. An "S" specifies a staccato note which is played as just an attack and decay (as specified by the corresponding voice statement) without any steady state. The presence of a semicolon (;) after a note indicates that additional notes which are intended to be part of the same statement are present, possibly extending to succeeding lines.

The execution sequence of note statements can become a little tricky due to the fact that note durations in the statement may not all be equal. The rule is that all notes in the statement start simultaneously. When the shortest one has ended, the notes in the next statement are initiated, even though some in the previous statement may be still sounding. This could continue to any depth such as the case of a whole note in the bass against a series of sixteenth notes in the melody. The actual implementation, of course, limits the maximum number of simultaneous tones that may be built up.

Also available is a rest specification which can be used like a note specification. Its primary function is to provide silent space between note statements, but it may also be used to alter the "shortest note" decision when a note statement is scanned. If the rest is the shortest then the notes in the next statement are started when the rest elapses even though none of the current notes have ended. A use of this property may be seen in the last part of measure 2 where an arpeggio is simulated.

As can be seen, NOTRAN is best suited for describing conventional organ music, although it could be extended to cover a wider area as well. One such extension which has been experimented with but not fully implemented is percussion instruments. First a set of implementation dependent parameters was chosen to define a percussive sound, and then a PERCUS statement similar to the VOICE statement was added to the language. To initiate percussive sounds, specifications such as "P3,1/4" would be interspersed with the note specifications in note statements. The "3" would refer to a percussive sound number 3 and the 1/4 would be a "duration" which would be optional. All percussive sounds in the same statement would start simultaneously with the regular notes.

A much more general music language is the well-known MUSIC V. It was designed to make maximum use of the flexibility afforded by direct waveform computation without overburdening the user. It is a massive program written in FORTRAN and clearly oriented toward large computers. Much significant computer music work has been done with MUSIC V, and it is indeed powerful. An excellent book is available which describes the language in detail and includes some background material on digital sound generation (see entry 1 in the list of references at the end of this article).

A different approach to music languages is a "generative" language which describes the structure of the music rather than the note by note details. In use, the structure is described by "loops," "subroutines," and "conditional branches" much as an algorithm is described by a computer language. The structure is "executed" to produce detailed statements in a conventional music language which is then played to produce sound. The intermediate step need not necessarily be visible to the user. One well
thought out system is described in reference 2. It was actually developed as a musicological analysis tool and so has no provisions for dynamics, timbre, etc. It could, however, be extended to include these factors. One easy way to implement such a language is to write a set of macros using a good mini-computer macroassembler.

Conclusion

By now it should be apparent that computer generated music is a broad, multidisciplinary field. People with a variety of talents can make significant contributions, even on a personal basis. In particular, clever system designers and language designers or implementers have wide open opportunities in this field. Finally, imaginative musicians are needed to realize the potential of the technique.

A Short Cut to a Singing KIM...

As his article was being finished by our production department, Hal Chamberlin notified us that he has completed the design of a board which accomplishes the digital to analog conversion and filtering functions described in this article. The board contains printed circuitry for an 8 bit digital to analog converter, low pass filter and power amplifier. Without components, the board may be purchased for $6; completely assembled and tested the price is $35. Orders should be mailed prepaid to Micro Technology Unlimited, 29 Mead St, Manchester NH 03104. In addition, a software package for the KIM-1 computer is available on cassette tape (KIM format) for $13 added to the price of the output board. A 7 inch 16 ohm speaker can be ordered for $5 prepaid, completing the required parts of a KIM's music system.

REFERENCES


Are you fascinated with the idea of computerized music, but find the mechanics of producing such effects too complex? I've come up with a simple technique which is the subject of this article, and which is well within the capabilities of the novice computer experimenter. With less than a dozen inexpensive integrated circuits, a few resistors, capacitors and a small prototyping board you can be well on the way to creating interesting music with your Altair, IMSAI or similar computer. My design creates a programmable music tone generator peripheral which has outputs that sound somewhat reminiscent of a clarinet when it is programmed by simple or complex software used to sequence notes in time. The first attempts I made at music generation required complicated programs and many integrated circuits. But as I gained more familiarity with the problem, the project reduced into a relatively simple solution as illustrated here.

The Hardware

The diagram of the melody box hardware is illustrated in figure 1. This hardware is the key to generation of tones from the computer. Software to be described later is responsible for sequencing the notes in time, thus creating a melody. The basic principle of operation of this melody box peripheral is use of a latched binary code in eight bits to select one of several adjustable resistors which will be switched into an oscillator circuit as the timing resistor. In the particular circuit shown in figure 1, I used a pair of 7475 latch circuits to hold the code sent from an 8080's IO instruction; then I decoded the 8 bit pattern with a pair of 7441 circuits which I happened to have on hand in my workshop. The 7441s separately decode two 4 bit codes into selection of one of ten open collector output lines. These output lines are low if the line is selected, and effectively disconnected if not selected. The software used to drive the IO port should be set up to select only one active line by giving out a "null code" such as binary 1111 in one half of the 8 bit word, while selecting a given tone in the other half of the 8 bit word. This guarantees that only one line is in the low state out of a possible 20 lines. The line which is in the low logical state will then affect the frequency of the oscillator implemented by the 555 timer integrated circuit, IC7 of figure 1. The pitch of the note selected is determined by the tuning of the potentiometer associated with a given binary code by the decoder.

The low logic level output of the decoder is similar to a ground or zero voltage. Since all the other lines are effectively floating as open collector outputs, a definite low state on the one line inserts the resistor selected

Figure 1: Schematic of the melody box. This circuit works by changing the timing elements of a 555 oscillator integrated circuit to set the pitch. One resistor sets the pitch of each note of the scale. To turn off the oscillator, the circuit detects a special case which turns off the power to the oscillator by raising its ground pin to the high logic level.
### Integrated Circuit Power Wiring

<table>
<thead>
<tr>
<th>Number</th>
<th>Type</th>
<th>+5 V</th>
<th>GND</th>
</tr>
</thead>
<tbody>
<tr>
<td>IC1</td>
<td>7475</td>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td>IC2</td>
<td>7475</td>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td>IC3</td>
<td>7441</td>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td>IC4</td>
<td>7441</td>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td>IC5</td>
<td>7404</td>
<td>14</td>
<td>7</td>
</tr>
<tr>
<td>IC6</td>
<td>7402</td>
<td>14</td>
<td>7</td>
</tr>
<tr>
<td>IC7</td>
<td>555</td>
<td>8</td>
<td>5</td>
</tr>
</tbody>
</table>

### Resistor Potentiometer Approximate Number Value Setting

<table>
<thead>
<tr>
<th>Resistor Number</th>
<th>Potentiometer Value</th>
<th>Approximate Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>R3</td>
<td>100 k</td>
<td>40 k</td>
</tr>
<tr>
<td>R4</td>
<td>100 k</td>
<td>48 k</td>
</tr>
<tr>
<td>R5</td>
<td>100 k</td>
<td>64 k</td>
</tr>
<tr>
<td>R6</td>
<td>100 k</td>
<td>68 k</td>
</tr>
<tr>
<td>R7</td>
<td>100 k</td>
<td>76 k</td>
</tr>
<tr>
<td>R8</td>
<td>100 k</td>
<td>80 k</td>
</tr>
<tr>
<td>R9</td>
<td>100 k</td>
<td>86 k</td>
</tr>
<tr>
<td>R10</td>
<td>200 k</td>
<td>90 k</td>
</tr>
<tr>
<td>R11</td>
<td>100 k</td>
<td>43 k</td>
</tr>
<tr>
<td>R12</td>
<td>100 k</td>
<td>66 k</td>
</tr>
<tr>
<td>R13</td>
<td>100 k</td>
<td>67 k</td>
</tr>
<tr>
<td>R14</td>
<td>100 k</td>
<td>76 k</td>
</tr>
<tr>
<td>R15</td>
<td>100 k</td>
<td>86 k</td>
</tr>
<tr>
<td>R16</td>
<td>200 k</td>
<td>108 k</td>
</tr>
<tr>
<td>R17</td>
<td>200 k</td>
<td>135 k</td>
</tr>
<tr>
<td>R18</td>
<td>200 k</td>
<td>152 k</td>
</tr>
<tr>
<td>R19</td>
<td>200 k</td>
<td></td>
</tr>
<tr>
<td>R20</td>
<td>200 k</td>
<td></td>
</tr>
</tbody>
</table>
into the 555’s timing circuit. The circuit is tuned by running a scale and adjusting the pitches by ear, or even by using a frequency meter.

But what about having no sound at all? Rests are important to music, and there must be some way to turn off the sound. Simply selecting none of the resistors is the first thought which comes to mind, but this does not work very well at all, as you’ll find out if you try it. What I did was to put in the NOR gate logic of IC6d to detect when both halves of the 8 bit output word are 0, as indicated by selection of the 0 output line of each decoder. When this happens, the output of the NOR gate is high. Since I use this NOR gate as the power and signal ground of the 555 oscillator, I have effectively removed power from the 555 and turned it off when the double 0 state is output to the port. This may not be optimal engineering, but it certainly works.

My hardware stopped at the point of generating the tones, but for a full range of musical effects, you would certainly want to add some digital controlled filters and amplifiers to this basic pitch generation facility. Some filtration can be accomplished, of course, by manipulation of the tone controls of your high fidelity amplifier.

Further Simplifications of Hardware

The circuit of figure 1 is how I built the melody box; but after building it, it occurred to me that several further simplifications could be made. For example, the latches and IO port decoding logic outlined by the dotted lines could easily be replaced by an existing IO port on a computer, such as those provided by the peripheral interface adapters (PIA) of typical IO port boards. The 7441 is not the only open collector decoder chip available, and if you want to make 32 or 64 notes, use of two or four 74159 circuits with a 5 or 6 bit binary code would be possible. The only major disadvantage I find with this circuit is that it has to be tuned individual note by individual note.

Construction

The melody box was built on a Radio Shack IC experimental breadboard, #276-154 (Archer), which plugs into their #276-151 card connector socket. This type of board has a foil pattern on one side. The integrated circuits or sockets are inserted from the nonfoil side and pins are then soldered to pads designed to take the DIP package pins as well as several connecting wires or components. See photo 1 for a look at my version. I used Molex pins to fabricate sockets for the integrated circuits, although solder tail sockets or no sockets at all could be used depending on your preferences and sources of supply. Wiring is done from the nonfoil side, with stripped ends of the wires going through the board to the appropriate pads. I used multiple colors for the wires in order to make tracing of the circuit easy. The space between the solder

Continued on page 91
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WHAT PEOPLE ARE NOT GOING TO DO WITH HOBBY COMPUTERS by Stephen Gray of Creative Computing
APPLICATIONS OF MICROCOMPUTERS: THE MYTH AND THE REALITY by David Aho of Creative Computing
INTRODUCTION TO COMPUTERS THROUGH THE BASIC LANGUAGE by Eri Golemba of Computer Mart of New Jersey
DYNAMIC DEBUGGING SYSTEM FOR THE 8080 CODE by Larry Stein and David Beney of Computer Mart of New Jersey
MICROPROCESSORS FOR THE HOBBY MARKET TODAY AND TOMORROW by Dr. Adam Osborne of Osborne and Associates
GETTING STARTED WITH MICROCOMPUTER SOFTWARE by Dr. Christopher A. Titus, author of the Bugbooks
COMPUTERS AND MUSIC by Carl Helmers of BYTE Magazine

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Heathkit

This new Heathkit H9 video terminal features data rates ranging from 110 to 9600 bps, EIA RS-232 and 20 ma current loop interfaces, a full ASCII keyboard and 12 lines of 80 characters per line.
Figure 2: Programming model for the melody box. The note pitch and length codes listed are interpreted by the program shown as a flowchart here. Each note is completely specified by a pitch code and a length code contained in two bytes of memory as shown by the example.
Figure 3: The melody box notes are tuned by running this chromatic scale through the program of figure 2. While listening to the scale, adjust each note's potentiometer until the sound is a correct musical interval.

A Set of Chromatic Scale Data for Tuning the Melody Box

<table>
<thead>
<tr>
<th>Relative Address</th>
<th>Note and Length Code</th>
<th>Relative Address</th>
<th>Note and Length Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>000</td>
<td>001 002</td>
<td>00</td>
<td>01 02</td>
</tr>
<tr>
<td>002</td>
<td>002 002</td>
<td>02</td>
<td>02 02</td>
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<tr>
<td>004</td>
<td>003 002</td>
<td>04</td>
<td>03 02</td>
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<tr>
<td>006</td>
<td>004 002</td>
<td>06</td>
<td>04 02</td>
</tr>
<tr>
<td>010</td>
<td>005 002</td>
<td>08</td>
<td>05 02</td>
</tr>
<tr>
<td>012</td>
<td>006 002</td>
<td>0A</td>
<td>06 02</td>
</tr>
<tr>
<td>014</td>
<td>007 002</td>
<td>0C</td>
<td>07 02</td>
</tr>
<tr>
<td>016</td>
<td>010 002</td>
<td>0E</td>
<td>08 02</td>
</tr>
<tr>
<td>020</td>
<td>011 002</td>
<td>10</td>
<td>09 02</td>
</tr>
<tr>
<td>022</td>
<td>020 002</td>
<td>12</td>
<td>10 02</td>
</tr>
<tr>
<td>024</td>
<td>040 002</td>
<td>14</td>
<td>20 02</td>
</tr>
<tr>
<td>026</td>
<td>060 002</td>
<td>16</td>
<td>30 02</td>
</tr>
<tr>
<td>030</td>
<td>100 002</td>
<td>18</td>
<td>40 02</td>
</tr>
<tr>
<td>032</td>
<td>120 002</td>
<td>1A</td>
<td>50 02</td>
</tr>
<tr>
<td>034</td>
<td>140 002</td>
<td>1C</td>
<td>60 02</td>
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<tr>
<td>036</td>
<td>160 002</td>
<td>1E</td>
<td>70 02</td>
</tr>
<tr>
<td>040</td>
<td>200 002</td>
<td>20</td>
<td>80 02</td>
</tr>
<tr>
<td>042</td>
<td>220 002</td>
<td>22</td>
<td>90 02</td>
</tr>
<tr>
<td>044</td>
<td>240 040</td>
<td>24</td>
<td>00 40</td>
</tr>
<tr>
<td>046</td>
<td>377 xxx</td>
<td>26</td>
<td>FF xx repeat code</td>
</tr>
</tbody>
</table>

Figure 4: A test string, shown in machine code form and in traditional musical representation, sans time signature, using note lengths as defined in figure 2.

A A Familiar Tune

<table>
<thead>
<tr>
<th>Relative Address</th>
<th>Note and Length Code</th>
<th>Relative Address</th>
<th>Note and Length Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>000</td>
<td>002 004</td>
<td>00</td>
<td>02 04</td>
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<tr>
<td>002</td>
<td>002 004</td>
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<td>004</td>
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<td>006</td>
<td>011 004</td>
<td>06</td>
<td>09 04</td>
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<tr>
<td>010</td>
<td>120 014</td>
<td>08</td>
<td>50 0C</td>
</tr>
<tr>
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<td>040 024</td>
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<td>20 14</td>
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<td>014</td>
<td>040 004</td>
<td>0C</td>
<td>20 04</td>
</tr>
<tr>
<td>016</td>
<td>007 004</td>
<td>0E</td>
<td>07 04</td>
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<td>011 004</td>
<td>10</td>
<td>09 04</td>
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<td>040 004</td>
<td>12</td>
<td>20 04</td>
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<tr>
<td>024</td>
<td>011 040</td>
<td>14</td>
<td>09 20</td>
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<td>026</td>
<td>002 004</td>
<td>16</td>
<td>02 04</td>
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<tr>
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<td>1A</td>
<td>06 04</td>
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<tr>
<td>034</td>
<td>011 004</td>
<td>1C</td>
<td>09 04</td>
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<tr>
<td>036</td>
<td>011 014</td>
<td>1E</td>
<td>09 0C</td>
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<td>040</td>
<td>004 024</td>
<td>20</td>
<td>04 14</td>
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<tr>
<td>042</td>
<td>006 004</td>
<td>22</td>
<td>06 04</td>
</tr>
<tr>
<td>044</td>
<td>007 004</td>
<td>24</td>
<td>07 04</td>
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<tr>
<td>046</td>
<td>006 004</td>
<td>26</td>
<td>06 04</td>
</tr>
<tr>
<td>050</td>
<td>004 004</td>
<td>2B</td>
<td>04 04</td>
</tr>
<tr>
<td>052</td>
<td>002 030</td>
<td>2A</td>
<td>02 18</td>
</tr>
<tr>
<td>054</td>
<td>000 001</td>
<td>2C</td>
<td>00 01</td>
</tr>
<tr>
<td>056</td>
<td>377 xxx</td>
<td>2E</td>
<td>FF xx stop</td>
</tr>
</tbody>
</table>
PUT A MACRO IN YOUR MICRO!

Imagine playing Star trek to kill time while you wait for your computer to print out a complicated listing—but using the same computer.

Hardware limitations of the 8080 have made microcomputer timesharing impractical for the personal computer enthusiast. The AM-100™ 16-bit microprocessor set puts at your command a system which easily accepts multi-tasking from a multiple user structure. In addition the AM-100™ system lets you control priorities and allocate memory requirements for each job activated. There is even a security system to prevent unauthorized access to the data files (a Macro Computer?).

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- Multiple pass macro level assembler and linking loader
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- Fully supports most S-100 peripherals without modification
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- Free-form text editor and letter-writing text formatter
- System generation program to create custom operating system monitors
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- Multi-user structured file system with passwords
- Multiple pass macro level assembler and linking loader
- Floppy disk file management system and utilities
- Up to 10 times the throughput of an 8080 system
- Fully supports most S-100 peripherals without modification
- ALPHA BASIC™ extended compiler and run system (not an interpreter)
- Free-form text editor and letter-writing text formatter
- System generation program to create custom operating system monitors
- Completely device independent with logical file I/O calls

WESTERN DIGITAL MICROPROCESSOR

The AM-100 is based on Western Digital's advanced WD-16 microprocessor chip set. It has been reprogrammed to give a more flexible macro instruction set while still maintaining the general architecture and source code format on the popular PDP-11 series.

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Tucson, Arizona 85716
(602) 327-4579
Photo 2: Installation of the melody box inside an Altair 8800 is accomplished by wiring various wires from the backplane of the computer. The power switch and volume control were mounted on the back panel of the computer, so that the melody box could be turned off.

Pads and bus lines of the card is relatively small, so care must be used to prevent solder bridges from forming. I recommend a low wattage iron with a pencil tip. 25 to 30 W will work well.

The 20 variable resistors used can typically be found at prices from $.20 to $.49 depending on how good you are at shopping around. I mounted the actual melody box inside my Altair 8800, as shown in photo 2. The circuit connections to the Altair bus were made as shown in figure 1. When mounting the circuit inside the computer cabinet, care should be taken to prevent damage to existing boards of the computer. I found that covering the boards with a layer of paper was a good precautionary measure to prevent any splatter of solder. In order to make the Altair connections, you must remove the mainframe backplane board (the one with all the edge connectors) so that you can solder to the underside.

Software for the Melody Box

The melody box requires instructions to tell it what to do. In an organ, piano or other instrument, a special purpose keyboard gives instructions about what note to play and for how long. Making the melody box play a tune consists of writing a program to generate a time sequence of instructions.

A programming model for the melody box is summarized in figure 2. The data required for each note is the pitch of the note, and the length of the note. In the program I wrote for my Altair, I used one 8 bit byte to represent the pitch, followed by a second 8 bit byte with an integer count giving the length. A table of the pitch codes, referenced to a music stave, and a table of length codes with equivalent note symbols are shown as part of figure 2. The flowchart in figure 2 shows an algorithm which is easy to implement on any small computer. In my own system, I enter these codes with the front panel toggle switches and the “deposit” function.

Once you have coded up the details of a program which will execute the flowchart of figure 2, the first step is to tune the melody box. In figure 3 I've shown the musical representation of an ascending chromatic scale, as well as the corresponding table of byte values (in octal and hexadecimal) for the 2 byte note pitch and length codes required to play this scale. An arbitrarily long rest follows the end of data before the repeat. Tuning is accomplished by ear (assuming you know what a scale sounds like) while playing this chromatic scale with the program. The potentiometers of the circuit in figure 1 should be adjusted until the scale sounds “right.”

As a second example, figure 4 shows a familiar tune, both in music notation and as a table of values for the music program to utilize. In the music notation, the table locations are written below in hexadecimal and octal to show how the two representations correspond. The limits on what tunes you can play are only dependent upon how much imagination you have and how big your Altair's memory is.
nating or experienced user, the wealth of options available in the many varieties and permutations of 8080, Z-80, 6502, 6800 and 9900 systems at reasonable prices make it less and less likely that our readers will continue to be frustrated and annoyed by such devices of torture as job control, account numbers, contention for the use of a system, and the host of limitations encountered when commercial and industrial systems are twisted to personal purposes in “off” hours.

During the coming year, our third as a magazine born out of and devoted entirely to personal computing, we expect to see continued evolution in the field. The last half of 1977 represents the entry of several relatively large concerns into the marketplace, in the form of Heathkit this summer and Commodore soon to follow. Rumors have it that companies ranging from Atari and Bally Manufacturing (arcade games) to Radio Shack and Texas Instruments are in the process of developing general purpose systems appropriate for personal computing uses. This sort of “confirmation” of the marketplace’s existence is bound to keep all firms on their competitive toes and ultimately benefit the user who is presented with more options and ways of achieving the personal computing function. (We even see the same phenomenon in our own sub-branch of the industry, the publications devoted to personal computing.) Like all industries, we can expect to see ups and downs in the trend, but for the moment we certainly relish and enjoy the heady expansion and growth evident all around us. Once again, technology in its application to human affairs is having its effect, and our lives as individuals are being improved as a result, despite the pessimists, gainsayers and prophets of doom chattering on about their usual maudlin spectres. We have yet to see large and useful personal data banks, practical automatons and similar challenges which have been projected by the writers of “hard” science fiction. But even if such are seen in our lifetimes, one thing is certain: the challenge of technology and invention which so marks the human race will continue with new horizons, just as today’s computer technology could scarcely have been envisioned 20 years ago.

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Chemistry with a Computer by Paul A Cauchon. People are always looking for details of applications for the computer. It is one thing to say “gee whiz wouldn’t it be nice if...” but such thoughts are but the stimulus to action. One result of a “gee whiz” idea is a series of educational and tutorial BASIC programs for use by teachers of chemistry, invented by Paul A Cauchon and published by Educomp Corporation. This book contains a collection of tutorial, simulation and problem generation programs which can be employed to advantage by teachers in high schools or colleges wherever a BASIC facility is available. If you’re a chemistry professor or teacher by trade, or just a hobbyist interested in chemistry, this book will prove to be an invaluable tutorial aid. $9.95.

APL—An Interactive Approach Second Edition, Revised, by Gilman and Rose. Here’s an excellent way to introduce yourself to the APL language. APL is rapidly becoming one of the most popular high level languages in the computer field because of its clarity and conciseness. Gilman and Rose have extensively updated their popular book to include the latest information about the language and the various forms of it which are now in use. Since the examples are all carefully spelled out, APL—An Interactive Approach is particularly recommended for those who do not have access to an APL terminal. Answers to all problems are included. $11.95.

The Underground Buying Guide, by Dennis A King. Here at last is a source book for all those hard to find suppliers! It’s designed especially for computer hobbyists, experimenters, hams and CB’ers, and can tell you where to buy items like connectors, discrete components, electronic music supplies, instrumentation, analog to digital and digital to analog converters, and synthesizers. The list goes on to include Teletype, speakers, microcomputer software, cassette units, floppy disks and many other items. It will be an invaluable addition to your reference library. $5.95.

PCC’S Reference Book of Personal and Home Computing. Ever try to find the addresses of some manufacturers of, say, tape cassette or floppy disk interfaces for micros? Frustrating, isn’t it? Well PCC has done something about it. This book lists hundreds of companies and stores selling hardware, software, and services. Survey articles on software, hardware, kits, applications and the future for the experienced and the not-so-experienced user of micros. Also included in this edition are bibliographies for further reference, book reviews, and an index of the articles from the major hobbyist magazines. $4.95.

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A NEW CHESS SPECIAL INTEREST GROUP

Recently three computer chess programs have become available to the computer hobbyist, and two dedicated chess playing machines have been announced. The newspapers carry news of the US and international computer chess tournaments.

With this growing interest, one would expect that there’d be some medium of communication among devotees of computer chess. But the only articles appear in obscure professional publications which the average reader never heard of. So, having tried to get someone else to do it, I decided to try to start a Computer Chess Newsletter, with the contents furnished by the readers, based upon a model provided by Hal Singer’s pioneering Micro-8 Newsletter for computer users. Now the problem is to get contributions. Anyone with any interest in computer chess playing or programming, please write. So far no price, size, or frequency of publication has been determined.

We need letters and articles about experiences with specific programs, on some campus computers and some timesharing systems. In fact, we need a list of known programs. How do they compare, for strength, for speed of response, for the way the moves are reported, the way the board is displayed?

Lots of hobbyists would like to try their hand at writing a chess program but don’t know how to get started. Any advice or experience in this would be most appreciated. Also, descriptions of chess programs and their philosophies would be most welcome. There is not exactly a surplus of material to read on things like this.

Anyone interested in receiving the first issue should send a letter enclosing a couple of 13¢ stamps to defray costs for the first try. I hope that a great deal of interest shows up in the form of contributions of material for the newsletter.

Doug Penrod
1445 La Cima Rd
Santa Barbara CA 93101

For an interesting news item on the subject of computer chess, readers should consult the June 1977 Scientific American, the “Science and the Citizen” column, page 56. This report covers the first computer program to answer chess master David Levy’s 1968 challenge (which is up in 1978). The program was Chess 4.5, a product of Lawrence R. Atkin and David J. Slate of the computation center at Northwestern University. In ordinary tournament play, the chess program lost; in “blitz” high speed play, the program won handily. The

INTERACTIVE COMMENTARY – APL ROMs CONTINUED

I have thoroughly enjoyed your magazine for some time now; even though I can’t really be termed a “home hacker” (I run on a PDP-11/45 under RSTS or UNIX), it is still interesting and very informative. Keep up the good work!

I would like to comment on a few letters from recent issues. First, on the APL character set ROMs: I would love to see this developed, and made available soon and relatively inexpensively. APL is a wonderful language, but is not widely enough available to be well known. I have worked on an APL interpreter for our 11, which is compatible with APL/360; however, we don’t have enough APL terminals, so I thought of getting some ROMs burned for DEC-writers, but it turned out to be too
No bells or whistles... just performance, a warranty and a low price.

For $107.00 take your choice; the 4K RAM board or the alpha video board. For $137.00 the video graphic board can’t be matched. ($K 4M and the more video on the way.)

These are not kits, but completely assembled, burned-in, tested boards with a 1 year warranty. No soldering, no messing, no chance of mis-connections... just plug ‘em in and you’re ready to go.

The 4K RAM has the same features and speed as what you’re used to (500 nsec, no wait states) but with a couple of extras you might not expect. Like a mechanical write protect switch that gives you positive memory protection. And a microprocessor handy to play with.

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Quality, assembled boards at less than kit prices. But what else would you expect from a company whose prime product is electronic test instrumentation and microprocessing components?

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Kent-Moore INSTRUMENT COMPANY

Continued on page 209

expensive. If some other people want to get together and get them done, count me in! Also, if anyone out there is working on a "tiny APL" for an 8080 or another microprocessor, contact me; I’d like to hear what you’re doing. I've given it some thought myself, but don’t have a microprocessor handy to play with.

Second, to P M Lashley in February 1977 BYTE, I must say that while FORTRAN may be a "virtual pterodactyl," it does have its merits, the biggest one being portability. I program in "C" mainly, a beautiful language, impressively cleanly structured; but how many of you out there have heard of it, much less know where you could run it? This is the one point in which FORTRAN outweighs its competitors; however, much better they may be if this is of no concern, be my guest and scrap FORTRAN! (I'll help!) Thanks for a fine mag. I'm sure I won't be disappointed in the years to come.

Christopher A Kent
935 Burney Ln
Cincinnati OH 45230

Having recently conversed with a representative of a firm planning an APL "black box" computer, we found that according to the gentleman in question a full APL Interpreter does not have to be an emulation of a 360 with several hundred thousands bytes (as is the case in IBM's 5100 APL). This caller claimed it was possible to implement APL for an 8080 or Z-80 in under 12 K bytes with clever programming. See Mike Wimble's articles for the algorithms.—

MORE BASIC QUESTIONS

In your March 1977 BYTE, you listed a Space War game in BASIC written by David Price (page 106). In his game he uses the instruction MAT. I have just purchased an SwTPC 6800 12 K byte computer with SwTPC's 8 K BASIC. SwTPC's BASIC does not have a MAT instruction. My question is: What can I use to substitute in place of the MAT instruction?

Steve Wright
13900 SE Highway 212, Spa74
Clackamas OR 97015

The MAT refers to "matrix" operations. In David Price's program, the concept of a matrix (often a two-dimensional one) is used to represent a two-dimensional array of values. For example, line 520:

\[
\text{MAT K} = \text{ZER} (3,3)
\]

The "MAT" at the beginning of a line is your cue that an array or "matrix" is involved. In the statement above, this would be equivalent to writing:

\[
\text{DIM K} (3,3) \\
\text{FOR I=1 TO 3} \\
\text{FOR J=1 TO 3} \\
\text{K (I,J)=0} \\
\text{NEXT J} \\
\text{NEXT I}
\]

(The DIM is only needed once in a program, at or near its beginning.) In David's program, the MAT statements are essentially used only to allocate storage for matrix data type arrays, followed by initialization similar to the example shown. There are other operations applicable to matrix data, but most uses of the matrices in David's programs refer to components, once values have been initialized. If you do not have a two-dimensional array facility, a much more difficult simulation of two-dimensions is also possible.—

SOME BASIC VARIATIONS

I put the March 1977 BYTE "Star Trek" program (page 106) on disk in an IBM VM 370 operating system with a timeshared terminal. I encountered several problems due to the differences between VM 370 BASIC and the version used by David Price in his program. Most were solvable with the help of a guide at the end of the article, but a few still have me stumped.

Continued on page 209
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System Description: The Noval 760

Here is the designer's eye view of a new product which represents one of the most complete ready to run computer packages seen to date. Introduced with a 4 page advertisement in June 1977 BYTE, this manufacturer's product description provides some more detailed information for readers' inspection and evaluation.

Lane T Hauck, Director of Research and Development
James D Nash, Senior Systems Programmer
Noval Inc
8401 Aero Dr
San Diego CA 92123

The first wave of personal computing hysteria seems to have subsided. A casual stroll through the West Coast Computer Faire last spring served as a pretty clear indication that the small computer user has grown up in a big hurry. We now hear these alleged "kids" rapping about relocatability, graphics generation and memory design, a far cry from the "dumb" user concept.

The Noval 760 computer was designed to fill the needs of the advanced hobbyist, who has a serious interest in learning about writing and using software. The system emphasis at Noval has been placed on provision of a unified hardware and software package which facilitates program development. The Noval 760 system does not allow the user to pick up a 4-year degree in computer science within two weeks by following the manual, but it does simplify some of the "dog" work required to design, write and debug programs written for amusement or more serious business.

The most startling aspect of the 760 is its package. The computer system is housed in an attractive desk, which in its "folded" position is a piece of contemporary furniture. It is, in fact, fully functional as a desk, complete with drawer space. However, lifting the rear half of the desk top (photo 1) reveals a computer console with video display and cassette mass storage. The center drawer pulls out to reveal a full alphanumeric keyboard.

The design philosophy of the 760 system is to provide a fully assembled and tested computer, with everything needed to develop and run programs. This philosophy is carried through all aspects of the hardware and software, and especially in the way the hardware and software work together.

Hardware

The Noval 760 computer is based on an 8080A microprocessor. The standard hardware includes:

- 16 K bytes of user program memory.
- 3 K bytes of PROM systems software.
- 12 inch (30 cm) solid state monitor.
- Full alphanumeric keyboard.
- 32 column printer.
- Digital cassette tape unit with full electronic control.
- Eight built-in IO ports (three user available).
- Heavy-duty power supply.
- Graphics system, including 1 K bytes of user programmable refresh memory, 2 K bytes of user programmable char-
character generator memory, and 1 K bytes of scratch pad memory.

Dynamic memories with invisible refresh are used for all programmable memory. No memory wait states are generated, and full refresh is maintained when the system is halted. An optional second memory board expands the system to 32 K, and PROM expansion to 16 K is optional.

The standard software PROM occupies 3 K bytes, with sockets for an additional 1 K bytes of user supplied PROM. The system uses a direct video monitor for a clear, crisp display. The wide bandwidth attained using the direct drive approach is especially important in the high resolution graphics mode.

The drawer mounted keyboard has all the standard ASCII keys, plus special control keys for video games, such as up and down arrows. The keyboard is scanned and encoded using software, so that key codes may be arbitrarily assigned, if desired.

The printer is a dot matrix impact printer, manufactured by LRC Products Inc. Rather than employing a standard ROM for character generation, the software creates the images to be printed. This allows user defined symbols to be created along with standard ASCII characters, a graphics mode which enhances the usefulness of the printer as a plotting device.

The tape mass storage unit is a PhiDeck, with Naval designed electronics, capable of reading and writing at 2500 bits per second. This allows a 4 K byte program to be loaded or saved in about 20 seconds.

The IO system is implemented using a distributed logic technique. One corner of the main printed circuit board is devoted to eight parallel connected Molex connectors of 20 pins each. All signals from the processor which are necessary to implement the first eight ports (ports 0 to 7) are bussed to these

Photo 1: The Nova 760 is shown in this picture as it appears in its natural setting for use: unfolded in a living room, office or den. The console with display and cassette drive folds into the desk and the drawer with its keyboard closes, so that when not in use the Nova 760 blends into the decor as a desk-like woodtone piece of furniture.
connectors. The cable for any peripheral is terminated by a small printed circuit board which contains four integrated circuits which actually implement the IO port.

The graphics system is one of the nicest aspects of the Nova! hardware. The display system contains its own 4 K byte volatile memory which is dedicated to image generation and display. Control of the screen is done using a memory mapped approach, so that every screen location has a unique memory address. This allows fast access to any screen location using any of the 8080A memory referencing instructions.

The graphics system is character oriented with user defined character graphics. 1 K bytes of the video memory are devoted to holding the character codes for the screen which are accessed every time the beam scans the CRT. The screen is organized as 28 rows of 32 characters each. The character codes span a full 8 bit range which gives the capability for defining 256 different characters. The characters are formatted as an 8 by 8 array of “dots.” The definition of these dot patterns is contained in a second 2 K byte image memory, also user programmable. (A little figuring shows that to represent 256 different images of 64 dots each requires 2 K bytes of memory.) Since, like the refresh memory, the image memory is treated like any other 8080A system memory, it can be directly accessed using conventional memory reference instructions. “Loading” the character generator is simply a matter of writing bit patterns (which will be displayed as dot pattern on the CRT) into consecutive memory locations.

What about color? This feature is built into the system, but an external color monitor is required to use it. The system allows the user to define four different color “schemes” for use with such a monitor, where each scheme consists of eight pairs of image and background colors. Although the color schemes themselves require burning a 32 by 8 PROM, selection of one of the four is done in software.

1 K bytes of memory physically located in the video system are available for general purpose use. In all Nova system software, the 8080A “overhead” variables such as the stack data and system flags are stored here, so that the user has maximum use of the 16 K byte (or 32 K with expansion) memory elsewhere in the system.

The development of hardware for the Nova! system was closely paralleled by intensive software development. It is the “co-operation” between these two disciplines which we feel has produced a successful integrated package.

Software

Nova software is organized around a number of utility and supervisory routines which are collectively referred to as the system “monitor.” In the minimum system configuration, a 3 K byte PROM resident segment of the monitor contains a command processor, a few utility routines and the software required to communicate with the front panel, keyboard, CRT and cassette tape. The primary function of this 3 K program is to load other monitor and system routines from cassette (unless a PROM option has preloaded this data).

Standard software includes an editor, assembler, debugger, and a graphics character generation package. As an option, all of the above software can also be installed in PROM. A BASIC interpreter is also available.

Editor, Assembler and Debugger

The Nova editor, assembler and debugger for 8080A code have many unique features. Before examining this system, however, let’s quickly outline what these development tools are traditionally designed to do.

An editor allows you to enter, format and modify ASCII text. Input to the editor is either old text which is to be modified or new lines of text which are typed in. Text output from the editor is used as input to the assembler. The assembler input is called a source program. The assembler translates the “source” into binary codes which are intelligible to your processor. Traditionally on large machines and many minicomputers, editors and assemblers are independent programs; text created by the editor must be saved somewhere while the assembler is being loaded. When the assembler has been loaded, the edited source program can be reloaded and assembled.

When assembly is complete, the assembler produces a listing of the source program and the associated binary codes. The binary codes are called the object program. The assembler output also includes a list of errors found in the source program. Perhaps you typed MOB A,B instead of MOV A,B, or maybe you forgot to define label “LOOP.” So back you go to the editor. Load, reedit, save, load, reassemble, ...

The Nova system uses an interactive approach to editor and assembler design. The Nova editor can be used in a mode which checks each line of proposed assembly language code for syntax errors as it is entered. Thus when you type “MOB A,B” and attempt to insert it into the text, the editor does not allow the line to be inserted. Instead, an error message is issued and the
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line must be retyped. The method used involves the editor and assembler working together; the assembler is called by the editor to check the syntax of each proposed instruction. The editor cannot check for every possible assembly error condition, but errors that are caught constitute a large percentage of typical assembly errors. The editor's interactive assembly mechanisms can, of course, be disabled to allow input of arbitrary text as well.

The mechanics of using the editor and assembler have been kept as simple as possible. A 2-letter keyboard command (ED) calls the editor from the monitor's command processor. The first 24 lines of text (if any) are displayed immediately. Each line of text has been automatically assigned a line number. One letter keyboard commands allow you to insert (I), erase (E) or change (C) lines. Up arrow (↑) and down arrow (↓) allow viewing of previous or upcoming pages of text. Any specific section of text can be displayed by simply typing the line number. A search command (S) allows capability to search for any ASCII string. All editor commands immediately display the results of command execution. An inserted line, for example, is immediately displayed along with its neighboring lines.

The "ESC" key causes exit from the editor and returns control to the monitor command processor. All assembler commands work directly on prescanned text created by the editor, with no need to save intermediate results. Assembler options include capabilities to assemble and list errors, assemble and print assembly listing on the printer, assemble and display a listing on the CRT, and execute the object program after assembly. When assembly errors are noted (most are undefined labels since syntax is checked during editing), the editor can be immediately recalled and the source program modified. The Noval editor and assembler interaction helps minimize the time spent in the program development cycle, a concern which is just as important to the amateur as it is to the professional programmer.

The monitor save text command allows saving any number of lines on the cassette tape. Special assembly commands allow segments of the large source program to be read into memory, assembled and linked to previously assembled segments. Very large programs can be assembled in this manner. The ultimate size limitation essentially depends only on the amount of available memory.

When the source program has assembled properly, typing OD transfers control to the Noval ODT (On-line Debug Technique) command processor. From here insertion of software breakpoints and use of the ODT jump command allow the user to execute any segment of object program. Before the jump all 8080A registers can be preset. Upon hitting a breakpoint (a dedicated restart instruction, "RST 2"), the breakpoint address is displayed along with all register values, the stack pointer address and previous elements on the stack. When the entire development procedure is complete, the debugged source and object programs can easily be saved on cassette tape.

Leave the Driving to Us

Communication between the central processor and peripheral equipment in this (or any) system is accomplished with software "drivers." Drivers deal with the detailed workings of system input or output, and, at best, are organized to make such communication an easy task. Drivers for all peripherals in the Noval system are included in the standard PROM monitor. Also included is extensive documentation on how to use each of them. Furthermore, the monitor includes a large number of utility routines which can be used for special purpose programming applications. Examples include a routine to print ASCII text on the screen; routines to create and display graphics characters; a routine to find a keyboard key "push" and return the ASCII code for the key. In total, the user of the Noval system has access to over 75 systems routines which can be used in a variety of applications.

An Eye Toward Revision

One problem with accessing drivers using subroutine calls is that absolute address of the subroutine must be known. As subroutine revisions are made, absolute addresses change and all references to subroutines must be modified. Typically, a reassembly of a large amount of user applications software is required each time system subroutines are modified. [Perish the thought!] Noval monitor utility routines can be called without knowing the absolute address of the routine. To call one of these routines, the programmer inserts an "RST 7" instruction followed by a 1 byte constant which identifies the desired routine. As an example,

\begin{verbatim}
RST 7 (Restart 007)
DB 17 (Define Byte 017)
\end{verbatim}
calls utility routine number 17, which erases the display screen. The restart 7 data (the "DB 17" above) is used by the monitor to
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index into a “call” or “jump” table. Entries in the table contain the absolute addresses of the utility routines, thereby freeing the programmer from having to deal with absolute addresses. This technique assures that programs which call the monitor system routines will execute properly with all (including future) versions of monitor software. RST 6 has been reserved for the user to construct a similar call table for his or her own use. Two dedicated locations in scratch pad memory are used to specify the starting address of the call table.

And an Eye to Graphics

Another 2 letter monitor command (GR) transfers control to the graphics character generator command processor. Simple keyboard commands allow the user to place any of 256 current character definitions at any screen line and column; create or modify character graphics by defining individual dots within an 8 by 8 matrix; erase the screen; select a graphics color scheme; or save a created set of characters on cassette tape. The characters created in this manner can be used by routines created by the editor and assembler.

Noval BASIC

Noval BASIC is available as a minimal cost option. However, a prerequisite for running this version of BASIC is that the entire system monitor (including the editor, assembler, etc) be installed on PROM. The reason for this requirement is that some of the extended features of Noval BASIC require use of editor and assembler subroutines. Noval BASIC itself occupies 6 K bytes of memory, and is available in both volatile memory and PROM versions. If the PROM version of BASIC is installed, a total of 16 K bytes of systems software resides in a Noval 760.

Consistent with the overall Noval design philosophy, BASIC has been enhanced to take full advantage of system flexibility. Some of the features are graphics character generation and display capabilities; color selection capability; saving and loading programs from cassette tape; listing programs on the printer; fast BCD floating point package; full control of display screen presentations, including cursor positioning; single and double dimensioned arrays; and the ability to call monitor and user assembly language subroutines.

Although the Noval BASIC interpreter is designed to be consistent with the 1974 ANSI standard (which presents a “standard BASIC”), the extra features of this system require some differences. Some of the most useful “extras” of this version concern the use of monitor subroutines and the development of user assembly language subroutines. Noval BASIC allows the user to preset all 8080A registers before a call to an assembly language routine whether it is in the monitor, or user created. Similarly, all registers can be read after the call has been completed. The statement SYS (n) calls system routine number “n.” The USER statement provides a similar facility for user defined routines.

About the Manufacturer

Noval was formed about a year ago as a sister company to Gremlin Industries, an established manufacturer of electronic arcade games. The goal of Noval is to provide the personal computing user with the microprocessor technology which Gremlin has developed in-house and refined over a 3 year period. This explains the heavy emphasis in the Noval system on assembly language, graphics and game-oriented features. Additionally, Noval is involved in a continuing research project with the San Diego school system, called Telemath, in which tutorial games are designed around mathematical learning objectives for grade levels 2 thru 6. Out of this effort has evolved a mathematical game library of over 50 programs to date. All Telemath programs are available to Noval system users, as are selected Gremlin Industries arcade games, which until now were rarely seen in homes and offices.
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Microsoft Announces 8080 FORTRAN IV Compiler

Microsoft has announced a FORTRAN IV compiler for the 8080 microcomputer. Called FORTRAN-80, the compiler is a full implementation of ANSI Standard FORTRAN with the exception of the double precision and complex data types.

FORTRAN-80 provides three data types including: logical (1 byte), integer (2 byte), and real (4 byte floating point). An extended version of FORTRAN-80 with double precision and complex data types is forthcoming.

The compiler generates pure, relocatable code which may be placed in ROM. The run time system package may also be placed in ROM. This 1 pass compiler requires less than 12 K bytes of memory, the run time system less than 6 K bytes. A relocating linking loader is included with the FORTRAN package so that subprograms may be compiled separately and linked at load time. This also means that only the specific subprograms required are loaded (including system subprograms).

Another part of the package is a relocating assembler and an assembly language programming package. The assembler may be used to produce FORTRAN compatible subprograms. The debugging system may be used with the load map produced by the loader to debug FORTRAN and/or assembly language programs.

Additional features of Microsoft FORTRAN-80 include:

- Multistatement code optimization.
- Mixed mode expressions.
- All standard FORTRAN library functions for reals and integers.

Individual copies of FORTRAN-80 may be purchased for $500 including documentation. The manual is $15; OEM (original equipment manufacturing) licenses are available. Contact Microsoft, 819 Two Park Central Tower, Albuquerque NM 87108.

Computer Warehouse Store Catalog

The Computer Warehouse Store, 584 Commonwealth Av, Boston MA 02215, is perhaps the largest new and used computer equipment store in the world. Their new catalog (of similar proportions) lists a wide range of brand name kit and assembled computer products. In addition, there is much tutorial information along with microprocessor comparison charts and a multitude of one-time bargains. This is a true computer hacker's "wishbook" of useful equipment and accessories. The catalog is available free from the above address.

Prototype Cards for SWTPC 6800 Bus

Two prototyping boards for either wire wrap or solder tape and wiring pencil are now available from Personal Computing Company, Dallas TX. These boards are either IO size or memory size. Since they use molex connectors at the bus interface, they are compatible with the SWTPC bus structure and mother board. In addition, other connectors are provided to allow off board and IO functions.

The cards are arranged in rows of holes with the holes on 0.1 inch (0.25 cm) centers and the rows on 0.3 inch (0.76 cm) centers; no pads are dedicated to either power or ground; however, power and ground buses are provided throughout the card. Bypass capacitors are provided to eliminate power line noise. Two regulators can be installed in special locations on the memory size board. The IO size board has provision for one regulator. The memory size board is $19.95, and the IO size board is $9.95. Contact Personal Computing Company at 3321 Towerwood, Dallas TX 75234.
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<thead>
<tr>
<th></th>
<th>Kit</th>
<th>Assm.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interface card kit and assembled and tested drive</td>
<td>$750</td>
<td>$850</td>
</tr>
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<td>Power supply—+24V at 2A</td>
<td>45</td>
<td>65</td>
</tr>
<tr>
<td>Cabinet—Optima, blue</td>
<td>85</td>
<td>85</td>
</tr>
</tbody>
</table>

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Photo 1: The object of the design exercise documented in this article is an interface between the computer in the basement and the Steinway baby grand player piano shown at the left in this picture. Using the interface of figure 1, and the solenoid valves of photo 2, electronic control of the restored piano will be completed by adding a motor driven bellows unit of later vintage than this 1910 piano. In the picture, various subassemblies have been placed at skewed angles atop the keyboard (spool box and 3 phase wind motor) and underneath (foot operated bellows and pedals). In the restoration of this piano, all the original mechanisms will be preserved, with the electronics interface consisting of an addition to the basic design.

Notes on Interfacing Pneumatic Player Pianos

Carl Helmers
Editor

Everyone is familiar with the concept of the player piano, a complex mechanical monstrosity which had its heyday in the early part of this century as the prime home entertainment device before the invention of electronic media which now dominate the home entertainment scene. But player pianos are far from dead. Just as there is an active subculture of computer aficionados, there is a whole cult of player piano and mechanical music freaks. Thanks largely to these people a working player piano is not an uncommon sight in the parlors, dens and living rooms of contemporary suburbia.

Many of the owners of player pianos may not recognize that these instruments can be a most interesting output device for a personal computer, an output device whose interface can be achieved with very little woodworking and mechanical skill as well as the usual hardware and software skills of the experienced computer hacker.

I have long had an interest in electronic music as generated and controlled by computers. It is this interest which started me on the road to learning electronics hard-
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Figure 1: The normal arrangement of a player piano's vacuum control system is illustrated here. A player piano roll moving past a "tracker bar," analogous to a magnetic tape recorder's read head, turns on and turns off a flow of air into the evacuated control line which goes to one of the pneumatic controls of the piano. For the key mechanisms, the leading edge of loss of vacuum cues the striking of a key, which is held down until vacuum is restored. This occurs when the roll passes to a point which closes off the particular line. For control of a full 88 notes, there are 88 separate "channels" in the tracker bars of the more sophisticated players, not counting additional channels to control dynamics, pedals and other special effects.

Figure 2 shows this adaptation of the usual vacuum line arrangement for electronic control. Figure 2 also shows schematically the physical arrangement of a flap valve. As I began looking into the problem of controlling air flow, I quickly learned about the existence of electrically controlled pneumatic devices used in pipe organ and piano technology. It turns out that there is a company called Reisner Inc, which among other items makes a specialty of manufacturing and selling control valves for player pianos and pipe organs. Photo 2 shows the model for the schematic rendition in figure 2, a Reisner No 601-90 magnet with 5/8 inch valve mounted for the purpose of testing on a scrap of pine board, with a metal standoff used as the junction fitting to connect to the vacuum line. The Reisner subassembly consists of everything you see attached to the metal frame which is screwed to the top of the wood block: the magnet, the upper valve seal with cushions for sound dampening, and the return spring. In adapting this unit to a player piano's purposes, a bank of these valves is required, with a number depending upon the details of the particular piano. (For more complete
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information on these valves, contact Reisner Inc, 240 N Prospect St, POB 71, Hagerstown MD 21740.) The physical mounting of the valve magnets, tubing, etc, depends upon the particular piano being converted. In the case of my baby grand player, an equipment chest will probably be attached under the sounding board in back of the presently installed pneumatics chest. Some woodworking ability and some mechanical handiwork are required in the fabrication of a bank of valves and in making the interconnections to the vacuum lines.

Electrical Drive and Interface

The era of integrated circuits simplifies the basic problem of controlling the sole-
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When we set out to build the new MSI 6800 Computer System, we knew we had our work cut out for us. It had to be at least as good as the now famous MSI FD-8 Floppy Disk Memory System which is also pictured below. So, the first thing we did was analyze all the problems and drawbacks we had encountered with other 6800 systems, and then put our engineers to work on solutions. The objective: Build a better computer.

We started with power supply. We had big ideas, so we used a hefty 18 amp power supply. You can run full memory and several peripherals without the worry of running out of juice. We also put it in the front of the cabinet so it’s out of the way.

The next step was the CPU Board. A separate baud rate generator with strappable clock outputs allows any combination of baud rates up to 9600. A separate strappable system clock is available and allows CPU speeds of up to 2 MHz. The new MSI monitor is MIKBUG software compatible, so you will never have a problem with programs. Additional PROM sockets are available for your own special routines and to expand the monitor. The CPU also contains a single step capability for debugging software.

When we got to the Mother Board, we really made progress. It has 14 slots to give you plenty of room to expand your system to full memory capability, and is compatible with SS-50 bus architecture. Heavy duty bus lines are low impedance, low noise, and provide trouble-free operation.

With all this power and potential, the interface had to be something special. So instead of an interface address in the middle of memory, we put it at the top... which gives you a full 56K of continuous memory. Interfaces are strappable so they may be placed at any address. An interface adapter board is compatible with all existing SS-50 circuit boards and interface cards. All MSI interface cards communicate with the rear panel via a short ribbon cable which terminates with a DB-25 connector. All baud rate selection and other strappable options are brought to the connector so they may be automatically selected by whatever plug is inserted into the appropriate interface connector. Straps may also be installed on the circuit board.

To complete the system, we used an MSI 8K Memory Board which employs low power 2102 RAM memory chips and is configured to allow battery back-up power capability. A DIP switch unit allows quick selection of a starting address of the board at any 8K increment of memory.

If you’re one of those people who understands the technical stuff, by now you’ll agree the MSI 6800 is a better computer. If you’re one who does not understand it yet, you’ll be more interested in what the system can do... play games, conduct research and educational projects, control lab instruments, business applications, or just about anything else you might dream up that a microcomputer can do. The point is... the MSI 6800 will do it better.

The MSI 6800 Computer System is available in either kit form or wired and tested. Either way, you get a cabinet, power supply, CPU board, Mother board, Interface board, Memory board, documentation, instructions, schematics, and a programming manual. Everything you need.

There is more to say about the MSI 6800 than space permits. We suggest you send for more information which includes our free catalog of microcomputer products.

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The basic magnet drive circuit used for the pneumatic player piano interface. The driver circuit shown here is a Texas Instruments SN75452, a dual peripheral driver which comes in a miniature 8 pin dual inline package. Each driver has a maximum capability of sinking 300 mA in the low level output state (logical 1 input which "turns on" the magnet). With the nominal 90 ohm coil and a low level output of 0.25 V the coil will have 11.75 V across it. The current through the coil is thus 130 mA, more than enough to actuate the valve based on experiments with the unit shown in photo 1 which was tested against a vacuum applied to valve through the rubber hose.

The solenoid coil has a resistance of nominally 90 ohms, and from the specification sheet (confirmed by tests in my laboratory) the valves can be actuated under load with a current higher than about 100 mA (about 9 V across the magnet). Using the Texas Instruments Linear and Interface Circuits Data Book as the source of information, it soon became apparent that the 75452 peripheral driver circuit (or its cousin, the 75451) would prove quite adequate for the job since it can sink 300 mA and has a maximum voltage rating well above the voltage required for the actuation of the magnets. The basic circuit for driving a solenoid with the 75452 integrated circuit is shown in figure 3. In this illustration, I have shown one of the two gate inputs as an inhibit signal (normally at logic level 1) and the other input pin as the control signal defined so that if it is low (logic 0) the magnet is off (valve closed) and if it is high (logic 1) the magnet is on (valve open). The diode mounted on the solenoid coil is an absolute requirement. These magnets have a considerable inductance, and as a result when the current is removed will generate a substantial back EMF which can damage the 75452 output transistor if it is not shorted out by the diode. (The inductance is sufficient to cause an impulse which can be felt by the observer if fingers are held across the coil while the voltage is removed. This suggests a minimum of 50 to 100 V of inductive "kick.")

Logic of a Practical Interface

The brute force technique of interfacing the piano would be to simply put one wire from a latched output bit to each driver of the piano magnets, resulting in roughly 80 to 100 twisted pair interface data paths in a monstrously thick cable. This is an unwieldy mess. The problem is shared by pipe organ aficionados, as I found out from Jeff Raskin's lecture at the First West Coast Computer Faire's session on computers and music in April of this year. At that time he suggested the use of a serial technique to define the state of a bank of control valves. Basically, the technique consists of using serial synchronous transmission from the computer to cut down on the immense number of lines which would otherwise be required. Figure 4 shows a detailed sketch of
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  - DIP switch selection of memory address assignment.
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### 8K 2708 EPROM Programmer Board

- **Price**: $145
- **Description**: 2708's not included

- **Features**:
  - S100 bus Altair/IMSAI compatible.
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Figure 4: Solving the problem of heavy interconnection cables. This diagram shows a synchronous serial transmission scheme which requires four twisted pair wires to connect a parallel output port with the piano for programmed serial transfers. One twisted pair cable is dedicated to the system reset line so that the local electronics in the piano will turn off all drivers when the system is reset. The other three lines are connected to three output bits. One bit is programmed with the successive bits of data for the various valves when an output transfer is done. After each data bit is defined, the shift clock line is toggled to push its value down the 88-100 or so shift register stages assigned to control the 88 to 100 valves used in the piano. Then, when all the bits have been defined in successive operations, the transfer clock line is toggled to parallel load all the control latches and define the state of the solenoids. With a programmed transfer loop on a typical microprocessor, no more than 50 µs per bit should be required, or an update time of 5 ms per 100 solenoid data transfer under program control. This gives the processor a limiting resolution of 1/200th of a second, well within the timing accuracy needed for music. Using specialized transmission hardware to automatically serialize the data from 8 bit bytes would speed up the typical data rates if needed.

the logic I designed which will enable this method of interfacing to be employed with three signal lines from a parallel output port of the control computer. In this scheme, each group of four valves is assigned one 4 bit shift register segment and a latch which can be loaded from the shift register. This module of four bits works out very well with

Continued on page 168
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Photo 1: The Duo-Art reproducing player piano as it is currently displayed in my home. Notice the electric motor at bottom center. It is original equipment. The vacuum pump is at the right; it is connected to the motor by a 1968 V8 Buick fan belt, which just happens to be a perfect fit.

The piano was built in 1925 and required extensive renovations. The binary dynamics control system is located at bottom left (see photos 3a and 3b).

The Piano's Reproductive System

By Chris Morgan, Editor

When was the binary number system first used for control purposes in a mass produced machine? The early nineteenth century Jacquard punch card controlled loom comes immediately to mind; but, surprisingly enough, a more widespread application occurred in the first quarter of this century: the reproducing player piano!

The reproducer was so-called because it went one step beyond the player piano in its ability to "reproduce" the dynamics and subtle shadings of the pianist who recorded the roll.

I have owned a Duo-Art upright reproducing piano for five years now (see photo 1), during which time I have restored it so that it can now play the specially encoded Duo-Art rolls which were made for it. The Duo-Art roll catalog was remarkably extensive, featuring such items as Chopin études and Beethoven sonatas in addition to a large selection of popular titles. (The pièce de résistance was a complete set of themes from Wagner's Ring cycle comprising some 30 odd rolls!).

Reproducers were a luxury item during the 1920s, and for good reason: they were built like fine watches and contained some fairly sophisticated features (for the time) to control dynamics, operate the pedals, and so on.

Photo 1 shows the Duo-Art with the bottom cover removed for clarity. The spool box (photos 2a and 2b) is located at the top and is the place where the piano roll is inserted. Immediately below the keyboard are the levers which are used to control the speed of the roll as it plays, as well as volume and roll rewind. At the bottom center is the original electric motor (built in 1925) which drives the vacuum pump at the right. No pedalling is required on this
model, a boon for the lazy experimenter. Like most player pianos, the Duo-Art works on a vacuum actuated system which opens and closes cloth covered "pneumatics," or bellows. These in turn do all the mechanical work inside the piano, such as playing keys and operating pedals.

But what makes the Duo-Art so interesting is its binary-based volume control system located in the lower left section of the piano (see photos 3a and 3b for a close-up). There are two independent volume control systems built into the Duo-Art. They are controlled by two sets of four holes per set, located above the main row of holes near each end of the tracker bar. Photo 4 shows the right-hand set of holes in enlargement. Notice that they are vertically in line with the four highest note sensing holes on the tracker bar. When a Duo-Art roll is played, therefore, a special pneumatic 8 pole double throw switch must be thrown to disable the lower two sets of four holes and allow the upper two sets of four holes to control piano dynamics (the volume of sound heard).

Each set of holes is connected to a set of "accordion" pneumatics, so-called because they open and close like vertical accordion bellows. A rod at the top of each pneumatic is connected to an air governor. As the pneumatics close, the governor admits more and more air to the system and the volume of the notes played on the controlled side of the keyboard goes up.

The spacings of the four sections of the pneumatics are 1/2, 1/4, 1/8 and 1/16 inch, so that 16 different volume levels can be achieved. This bellows is in fact a form of mechanical digital to analog converter. So we have two nybbles (or one byte) of information to control volume in a Duo-Art reproducer piano. Photo 3b shows a level corresponding to 1/2 + 1/8, or 10/16ths of maximum volume, and photo 3a shows a zero level for comparison. Photo 5 shows the roll positioned to produce the level of photo 3b; the most significant bit is to the left. Since an opening (hole) corresponds to a binary 1 level, the binary number here is 1010.

Counting from the right in photo 4, the first 3 holes are mute pedal control, automatic reroll and the "theme" hole. The theme hole is an ingenious feature. There are often cases when the piano must suddenly change volume levels for isolated notes or chords and then return to the previous level. It takes a finite time for this sort of change, so the rolls are designed to allow the
Photo 3a: One of the two Duo-Art accordion pneumatics used to control the volume of one half of the piano keyboard. Each of the four chambers can be individually exhausted under control of the piano roll. The pneumatic is connected by a rod on top to an air governor. The four chambers close by 1/2, 1/4, 1/8 and 1/16 inches, so that the air governor can be set to any of 16 different vacuum levels to power the keyboard pneumatics. The roll's 4 bit binary "word" is thus translated into a vacuum level: in effect, this is a digital (vacuum lines from tracker bar) to analog (mechanical position of governor) converter.

Photo 3b: The accordion pneumatic shown converting the integer value 10 into one of 16 possible mechanical positions. This corresponds to the binary number 1010 on the roll. See photo 5.

Photo 4: A closeup illustrating the four right hand dynamics control holes, located slightly above the center line of the rest of the holes.

Photo 5: The roll in this case is outputting level ten to the accordion pneumatics. Photo 3b indicates the resulting mechanical position output of the pneumatics.
coming volume change. When the roll triggers either or both of these holes, control of the respective sides of the keyboard is transferred for that instant to the theme control. Details of this theme control system are essential to the design of software drivers for Duo-Art players converted to computer control.

Numerous other fascinating features abound on this instrument. Take for example the automatic roll-centering negative feedback system. The curved vertical "finger" shown in photo 5 is one of two which are positioned to just touch the edges of the roll. If the roll wanders off to the right or left, the fingers tilt back, uncovering air tubes which are under vacuum. This sends a signal to a set of opposing bellows with a high damping ratio, which push the roll spool back until the air tube is covered again. The design is simple, yet effective. Long before Norbert Wiener made it explicit, servomechanisms as control systems were in practical daily use.

Just how good does the Duo-Art sound? Well, it has some obvious limitations (limited dynamic range, for one), but on the whole it sounds remarkably good. The sound quality is several orders of magnitude better than the "new fangled" phonograph which eventually supplanted it commercially.

In its heyday, the Duo-Art Company could afford to hire some of the most famous pianists of the age to record for them: Paderewski (see photo 6), Wanda Landowska, Vladimir Horowitz (when he was in his twenties), Igor Stravinsky (!), George Gershwin (playing his own four-hand arrangement of "Rhapsody in Blue" by overdubbing), and on and on. The rolls were beautifully decorated, too (see photo 6).

Readers wishing to find out more about the fascinating hobby of reproducing pianos should write to the Vestal Press, POB 97, Vestal NY 13850, and ask for their catalog. The Vestal Press specializes in books about player pianos and other musical automata. The Player Piano Company in Wichita KS is an excellent source of supplies for the do-it-yourself restorer. The current bible in the field is *Rebuilding the Player Piano*, by Larry Givens, published by Vestal. In it you'll find valuable material about the Duo-Art and about the other brands of competing reproducers like the Ampico and Wurlitzer models. But that's another story.

Photo 6: A Duo-Art roll of Chopin's "Polonaise, Opus 40, Number 1," as played by Paderewski, in position over the tracker bar. Note the extensive ornamentation, both visually and verbally, in the form of the performer's authorization of the work. This roll is approximately 55 years old. Paderewski was a link in a list of salon pianists which began in America with Louis Moreau Gottschalk, and which continues to this day with certain candelabra wielding virtuosos.
The Great APL Interpreter Contest

As an incentive to those experimenters who would like to try writing their own APL interpreters based on this series of articles, BYTE announces the Great APL Interpreter Contest. We will award prizes for APL interpreters (suitable for publication with royalties to authors) based on Mike's flowcharts (or independent of them if you prefer).

Contestants are free to write their interpreters for any microprocessor they choose. Entries will, however, be judged on their suitability for use on small systems with a minimum of 16 K bytes of memory, as well as on programming elegance and efficient use of space. All of these factors should therefore be kept in mind.

Entries should be addressed to BYTE, attn: The Great APL Interpreter Contest, 70 Main St, Peterborough NH 03458 and must be postmarked no later than midnight, February 28 1978. Entries must be in the form of a publication quality manuscript which describes the Implementation of the interpreter and which includes a listing of source code and object code. Contestants should also submit machine readable source and object code in the form of paper tape or cassette.

The winners (if any) will receive $1000 plus normal author payments, should the entry be chosen for publication in book form or as an article in BYTE. We reserve the right to choose more than one winner under the same terms.

Judging will be done by the editors of this magazine. Those seriously interested in entering this contest should call Carl Helmers or Chris Morgan at BYTE, 603-924-7217. May the midnight oil burn prosperously for all.

Backus-Naur Form (BNF)

BNF is a notation used quite often in the description of computer language grammar and semantic information. Many of the figures in this series of articles contain a short BNF description of the formal elements of APL treated by the flowchart in question. A BNF statement looks like:

\[ <A> ::= <B> | <C> | <A> <B> \]

In BNF, brackets ("[") and "]") are used to enclose tokens or "terminal elements," and the symbol ":=" means "may be composed of." The symbol "|" is the notation of a logical "or." This notation was first developed for the description of the ALGOL language, and has since been used widely in numerous books and papers on language design and compiler writing. The example statement above can be translated into words as follows:

"An A token is composed of either a single B token, or a single C token, or an A token followed by ("concatenated with") a B token."

There is no restriction against possible recursion in BNF syntax descriptions, a feature which allows very simple language constructs to form very complicated statements which can be correctly parsed by the interpreter or compiler.
Figure 7: The logic of the statement interpreter. At this level the interpreter recognizes the two valid forms of a statement: either an expression, or a right arrow followed by an expression. When interpretation begins, variable I points to the rightmost byte in table SP of the immediate statement to be executed. Subroutine E is invoked to recognize and interpret an expression, setting B to true if a valid expression is found, and setting B false otherwise. If an expression is found, a test is made for a right arrow occurring at the beginning of the statement. If found, subroutine BRANCH is invoked to interpret the program branch. Otherwise, subroutine SUCCESSOR is invoked to interpret an advance to the next statement.

<statement> ::= <expression> | →<expression>

Table 8: A table of tables built and used by the statement interpreter. Whenever a subroutine is invoked, SFP is incremented by 1 and table SF is modified. SFP then indicates the current level of nesting or of recursion. If SFP is 0, the interpreter is presently executing a syllable in the immediate mode statement. Pointers to the value of operands for the various operators are stacked in table SVAL much as in any stack-oriented expression evaluator. Tables SD1 and SD2 are used to hold pointers to the right and left arguments of a function call.

<table>
<thead>
<tr>
<th>Table</th>
<th>Indexed By</th>
<th>Element</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF</td>
<td>SFP</td>
<td></td>
<td>Holds information for subroutine calls.</td>
</tr>
<tr>
<td>S1</td>
<td></td>
<td>FTAB entry of subroutine invoked.</td>
<td></td>
</tr>
<tr>
<td>S2</td>
<td></td>
<td>Value of I (last interpreted syllable pointer) for calling subroutine.</td>
<td></td>
</tr>
<tr>
<td>S3</td>
<td></td>
<td>Statement number of calling subroutine at time of subroutine call.</td>
<td></td>
</tr>
<tr>
<td>SVAL</td>
<td>SV</td>
<td></td>
<td>Holds stacked pointers to value of operands.</td>
</tr>
<tr>
<td>SD1</td>
<td>P1</td>
<td></td>
<td>Holds stacked pointer of left actual parameter.</td>
</tr>
<tr>
<td>SD2</td>
<td>P2</td>
<td></td>
<td>Holds stacked pointer of right actual parameter.</td>
</tr>
</tbody>
</table>
Figure 12: The logic for interpretation of a program branch, i.e., a right arrow followed by an expression. A pointer to the result of that expression is in the top of stack SVAL. The result must be an integer equal to the statement number of the desired statement to be executed in the current subroutine. If the result is an empty vector, then the branch is simply to the next statement. A noninteger result is an error. An attempt to branch while not in a subroutine is ignored and control is returned to the statement scanner. Finally, a branch to a statement number not in the current subroutine results in a return from the subroutine.

Figure 13. The method for advancing to the next statement function. If there is no next statement while in a subroutine an automatic return from subroutine occurs. At completion of interpretation for the immediate mode statement control is returned to the statement scanner. Otherwise variable I is set to point to the rightmost syllable of the next statement to be interpreted.
Introducing **HEATHKIT** COMPUTERS

A new value standard in personal computing systems featuring two powerful computers with better software, full documentation and service support from the Heath Company.

Heath Company has been interested and involved with personal computing since we first marketed an analog computer system all the way back in 1957. This continuing interest, along with the recent technological advances that have brought personal computing to the forefront of the electronics marketplace, has given us the opportunity to think through the recent developments, and develop two “total design” computer systems that give the computer hobbyist, whether beginner or advanced, everything needed for REAL power, performance and reliability—at prices that give you MORE value and performance for your computer dollar!

**Total system design.** The Heathkit computer line, both hardware and software, has been designed from the ground up to be a total computing system that meets all the needs of the computer hobbyist. The two mainframes are based on performance-proven well-documented MP modules, the 8080A and LSI-11. Using these CPU’s was a conscious design decision, because of their proven performance, reliability and efficiency, and the tremendous amount of existing applications programs, documentation and source materials that are available. The Heath-designed CRT terminal, paper tape reader/punch, serial and parallel interfaces make total system setup easy and fast, and the Heath-designed software provided assures immediate usefulness and versatility.

**Superior documentation.** Heath Company is world-famous for the accuracy and clarity of its instruction manuals. The Heath computer line continues this well-deserved reputation. Assembly and operations manuals are written with easy-to-understand step-by-step instructions that leave nothing to chance. Simply follow the easy-to-understand instructions in the manual and you’ll be up and running fast. As in all Heathkit products, easy self-service and troubleshooting is a definite benefit that can result in substantial cost-savings over the life of a product. These considerations, along with nationwide service and technical assistance at Heathkit Electronic Centers or the Heathkit factory, mean that you have the most reliable protection for your computer investment available anywhere.

**System versatility.** Both Heathkit computers offer full expansion potential to provide outstanding flexibility and adaptability to meet any application. Mass storage capability is available in both audio cassette and paper tape format on the H8 and in paper tape format on the H11 for added convenience. Additional memory expansion boards can be added to either unit, along with an expanding number of I/O devices.

**Continuing Development.** Heath will continue to design and develop new compatible products for their computer systems. Coming in the future will be—floppy disk storage, line printer, additional applications programs, and self-instructional courses in programming and assembly languages. All Heathkit computer users are eligible to join HUG (the Heath User’s Group) and H11 customers are eligible to join DECUS, the Digital Equipment Computer User’s Society.

We’re confident you’ll find the Heathkit computer line one of the most intelligent, sensibly developed and complete product lines available today. It offers you total versatility and expansion capability to go wherever your imagination and computing prowess take you. And, in the Heathkit tradition, it offers the best price/performance and reliability combination you’ll find anywhere.
A unique, value-packed computer featuring an “intelligent” front panel with built-in extended ROM monitor, octal entry keypad and digital readout, exclusive Heath bus, a pre-wired and tested 8080A-based CPU, and complete systems software at no extra cost!

$375.00
HEATHKIT 8-BIT DIGITAL COMPUTER

A low-cost digital computer that's easier to build and to use! Features an intelligent front panel with keyboard entry and 9-digit display, a heavy-duty power supply with enough extra capacity for memory and I/O expansion and a 50-line fully buffered bus capable of addressing 65K bytes and a mother board with positions for up to 10 plug-in circuit boards. Includes BASIC, assembler, editor and debug software at no extra cost!

The Heathkit H8 computer is an 8-bit machine based on the popular 8080A chip. It is one of the lowest-cost general-purpose computers on the market, and thanks to Heath's exclusive design, one of the most versatile.

The interrupt controlled "intelligent" front panel gives you far more power and control than is found on conventional units with bit switches and indicators. The 16-digit keyboard allows octal data entry and control that's far faster and less error prone than binary switches. The 9-digit octal readout provides you with more information than conventional models too.

The octal keyboard and display emulate a true hardware front panel with complete access to memory, all registers and functions. The 8-digit seven-segment octal display has three readout modes: 6 digits of address and 3 digits data; 6 digits register data and 2 digits register identification; and three digits data with three digits port address. The front panel functions are defined by a panel monitor control program (PAM-8) stored in a 1K x 8 ROM on the CPU board. The complete access to 8080 internal circuits and functions makes the H8 an ideal trainer and learning tool.

Complete front panel functions include: display and alter of memory locations; display and alter of registers; dynamic monitoring of registers or memory during program execution; program execution control including break-point capability and single instruction step; automatic tape load and store through a built-in routine that allows programs to be loaded with a single button; and write or read any I/O port. The front panel of the H8 is so versatile it's like having a mini I/O terminal built right in!

Other features of the H8 front panel include status lights for power-on, run, monitor and interrupt enable; a built-in speaker for audible feedback on keyboard entry. The speaker also can be programmed for variable tones, permitting a variety of special effects to be generated.

The CPU board is fully wired and tested. It features the 8080A, clock, systems controller, ROM monitor and full bus buffering. Seven vectored interrupts are available on the bus for quick response to your I/O requests. A built-in clock lets you design and run in real time.

The H8 uses an exclusive, Heath-designed bus which incorporates many practical improvements over existing busses. The bus is fully buffered to reduce noise and crosstalk and is "glitch" free to eliminate timing problems. Three-state line drivers and receivers are used on all bus lines to eliminate loading problems. The 50 lines include address, data, control, clock and interrupt lines, plus all signals needed to support the 8080 MPU and virtually any I/O or memory accessory. The bus is implemented on a heavy-duty printed circuit mother board with wide, heavy copper foils for greater physical strength plus reduced crosstalk and noise. The board has 10 positions for installing connectors that accept the front panel, CPU, memory, I/O and accessory cards. All I/O bus connectors are included with the mother board for fast and easy expansion when you want it.

The H8's built-in power supply is convection cooled for adequate ventilation without the use of noisy fans. Separate IC regulators provide distributed regulation with a heat sink on each circuit board for excellent heat dissipation. Power supplies of +5, -10 and +18 volts are provided to handle up to 32k memory plus three I/O interfaces. Switch-selectable 120 V, 50 Hz or 240 V, 50 Hz AC increases versatility.

The H8 includes all system software in 1200 baud audio cassette form at no extra charge. The Benton Harbor BASIC® is an enhanced version of standard Dartmouth BASIC with unique statements and commands to extend usefulness. The efficient compression techniques of the Benton Harbor BASIC permit you to put more program in less space.

The TED-S software is a line-oriented text editor used for generating source programs for the assembler or general word processing. Requires a minimum of 8K memory.

The BUG-8 a powerful terminal console debug program, is an enhanced and extended version of the front panel monitor program to allow entry and debugging of user machine language programs via an external terminal. Requires 3K memory plus user program.

The H8 is housed in a rugged, heavy-duty cabinet, 16¾" W x 6½" H x 17" D. Requires at least one H8-1 Memory.

KIt H8, Shpg. wt. 30 lbs. ......................... 375.00

Suggested applications for the H8 computer: As a trainer—learn microprocessor operation, interfacing and programming. The powerful front panel lets you get at and use all parts of the unit. As an entertainment center—use game and other applications programs for entertainment the whole family can enjoy.

As a hobby computer—the H8 can be used to process any information you program into it—it's perfect for hobby experimentation and design. A variety of peripherals and interfaces let you use it with other equipment—run your Ham radio station, control your model railroad systems, etc.

As an educational system—the H8 is ideal for schools, community colleges, libraries, etc. Full H8 software permits teaching BASIC plus machine and assembly language programming.

As a home management center—use the H8 to keep telephone numbers, monitor your budget, keep your checkbook balanced, do your income taxes, inventory your personal belongings. There are hundreds of ways the H8 can make your life more convenient.

Comprehensive Heathkit assembly and operations manuals give you the superior documentation you NEED for a thorough understanding of your H8.

Systems software is supplied in audio cassette format.

HASL-8 The Heathkit Assembly language is a 2-pass absolute assembler that lets you program with easily understood mnemonics and generates efficient machine language code. A minimum of 8K memory is required.

The TED-8 software is a line-oriented text editor used for generating source programs for the assembler or general word processing. Requires a minimum of 6K memory.

The BUG-8 a powerful terminal console debug program, is an enhanced and extended version of the front panel monitor program to allow entry and debugging of user machine language programs via an external terminal. Requires 6K memory plus user program.

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As a home management center—use the H8 to keep telephone numbers, monitor your budget, keep your checkbook balanced, do your income taxes, inventory your personal belongings. There are hundreds of ways the H8 can make your life more convenient.
The unique Heath-designed 50-pin bus is implemented on a heavy-duty printed circuit board with heavy copper-foil bus lines. The 10-position mother board is complete with all connectors. The bus lines are fully buffered to eliminate noise and crosstalk, and "glitch-free" to prevent timing problems.

Modular circuit boards slide into the H8 mainframe for easy memory and I/O expansion, easy access for servicing. The boards are in a semi-vertical position with unconfined heat sinks to enhance convection cooling and improve heat dissipation.

Heavy-duty power supply, rugged steel chassis and securely mounted and braced circuit boards make the H8 a truly reliable and long-life machine.

Unique Heathkit Software.
The Heathkit software supplied with the H8 computer has a number of features that make it easier to use and more practical than conventional systems. Automatic "command completion" simplifies typing; dynamic syntax checking instantly alerts you to errors and a special user configuration lets you really personalize your system. H8 software pushes the state-of-the-art a generation ahead — it’s memory efficient to give you more computing power for your memory dollar, modular design for easy expansion, and thoroughly documented for easy programming and maximum effectiveness.

H8 "Intelligent" Front Panel
The H8 front panel digital readout is the most informative display available on any personal computer to date. All displays are continuously updated even while your program is executing, giving you instant access to registers and memory for direct monitoring of program activity.

MEMORY DISPLAY — Shows memory location and contents using 6 digits for address and 3 digits for data.
REGISTER DISPLAY — Shows CPU-register contents using 6 digits for data and 2 digits for register identification.
I/O PORT DISPLAY — Shows I/O port data and location using 3 digits for data and 3 digits for port address.
The HB CPU is fully wired and tested to insure quick and trouble-free system startup. It contains the performance proven 8080A microprocessor chip, a 1Kx8 ROM with monitor program for controlling the front panel and input-output (load-dump) routines. Other features of the CPU include: 7 vectored interrupts, DMA capability, crystal-controlled clock and fully buffered bus with three state drivers. Use of the 8080A, which has the largest software library of any microprocessor, along with Heath software and documentation, makes the HB one of the most practical and immediately useful computers you can own.

HB-1 Memory Board. 8Kx8 memory card supplied with 4K memory, plugs directly into HB bus. Features maximum storage capacity of 8192 8-bit words. Uses modern 4Kx1 static memory IC chips for easy assembly and service. Access time, less than 450 nS. With on-board regulators, heat sinks and full buffering. Expandable to 8K memory with HB-3 chip set below. Kit HB-1, Shpg. wt. 2 lbs. . . . . 140.00

HB-3 Chip Set. Kit of eight 4K static memory IC's. Expands HB-1 to full 8K storage. With sockets. Kit HB-3, Shpg. wt. 1 lb. . . . . . 90.00

HB-2 Parallel Interface. Connects HB to any parallel device such as a paper tape reader/punch (required for H10) or line printer. Has three independent parallel ports, each with 8 bits input and 8 bits output and universal handshaking capability. Compatible with all Heath software. 380 μS maximum transfer time. With diode-clamped inputs, buffered outputs and full interrupt capability. Kit HB-2, Shpg. wt. 3 lbs. . . . 150.00

HB-5 Serial I/O and Cassette Interface. Connects the HB to serial devices such as the HB video terminal (page 10) or the HB DEC Writer II (page 12). Features jumper selectable data rate from 110 to 9600 baud, plus common input/output interfaces including 20 mA current loop and EIA RS-232C compatible levels. The cassette recorder interface permits the use of standard cassette recorders (Heathkit ECP-3801, page 12). Uses the popular Byte/Manchester or “Kansas City” standard recording format with a 300 or 1200 baud read/record rate. Control lines for remote start and stop of two cassette units allow separate record and playback for easy program or file editing. Also has full interrupt capability. LED test circuit for easy board setup and overall system servicing. Fully compatible with all Heath software. Kit HB-5, Shpg. wt. 3 lbs. . . . . 110.00

NOTE: Proper operation of the HB-5 is assured only if you use the Heath ECP-3801 cassette player/recorder and Heath-recommended recording tape (ECP-3802, page 12). Heath is not responsible for improper operation associated with other cassette units.

Extended Benton Harbor BASIC

Extended Benton Harbor BASIC is an enhanced and more powerful version of the BASIC supplied with the HB. It provides even faster operation and includes character strings, additional convenience commands and math functions, dynamic storage allocation, access to real time clock, keyboard interrupt processing, expanded error messages and recovery ability, LED display control and key pad support. A minimum of 12K memory is required to run this BASIC, 16K is preferred if full use is to be made of its capabilities. HB-13 (1200 baud audio cassette) Shpg. wt. 1 lb. . . . . . . . . . . 10.00 HB-14 (fan fold paper tape) Shpg. wt. 1 lb. . . . . . . . . . . 10.00

Paper Tape Systems Software

A paper tape version of the systems software supplied with the HB computer. It consists of four fan fold paper tapes, one each for Benton Harbor BASIC, HASL-8 assembler, TED-8 editor, and BUG-8 debugger. For use with the H10 paper tape reader/punch or other paper tape I/O equipment. HB-15, Shpg. wt. 1 lb. . . . . . . . . . 20.00

You can get even more excitement and practical use from your HB by joining HUG, the Heathkit User’s Group. It will put you in contact with other Heathkit computer users, provide a program library and an informative newsletter to keep you up to date. A HUG application is enclosed with each Heathkit computer product. See page 12 for further details.
THE HEATHKIT

H11

DIGITAL COMPUTER

Two of the finest names in modern electronics, Heath and Digital Equipment Corporation (DEC) combine to bring you the world's first 16-bit computer priced within reach of the general public!

$1295.00

The H11 and all its accessories will be available November 10th, 1977.
The new Heath/DEC H11 personal computer is one of the most powerful and sophisticated units available today! It combines the advanced, performance-proven hardware and software of the LSI-11 with Heath's expertise in kit design and documentation to bring you a personal computer of almost incredible power and flexibility. Equivalent commercial versions of the H11 would cost over twice as much, and you still wouldn't get the superior documentation and support of the H11!

The LSI-11 bus is a mechanically and electrically superior bus with 38 high-speed lines containing data, address, control and synchronization lines. Sixteen lines are used for time multiplexing of data and addresses. All data and control lines are bidirectional, asynchronous, open-collector lines capable of providing a maximum parallel data transfer rate of 633K words per second under direct memory access operation.

The 16-bit CPU functions are contained on four MOS LSI integrated circuit chips. These chips provide all instructions, decoding, bus control, and ALU functions of the processor. The CPU has eight general registers which serve as accumulators, index, autoincrement/autodecrement registers or stack pointer.

The KD11F memory is a 4096-by-16 MOS semiconductor memory composed of LSI 4K dynamic RAM chips. These chips require little power, provide fast access time, and are refreshed automatically by the processor's microcode. Additional memory cards can be added to expand memory capacity up to 20K in the H11 cabinet (32K words total).

The backplane/card guide assembly holds the microcomputer and up to six I/O and memory modules. All LSI-11 bus data, control, and power connections are routed on the printed circuit backplane to each module location. The backplane/card guides are fully compatible with all standard DEC LSI-11 accessories.

An efficient, well-designed switching power supply provides the required DC voltage for the LSI-11 as well as all accessory modules. The supply features overvoltage and overcurrent/short-circuit protection, power fail/automatic restart and a built-in fan for quiet cooling. The dual primary power configuration can be connected for 115 V, 60 Hz or 230 V, 50 Hz input power.

Has single-level, vectored, automatic priority interrupt, real-time clock input signal line, ODT/ASCII console routine/bootstrap resident in microcode for automatic entry into debugging mode, replacement of panel lights and switches with any terminal device generating standard ASCII code, and the ability to automatically commence operation through resident bootstrap routines.

The H11 is supplied with versatile PDP-11 software including editor, relocatable assembler, linker, absolute loader, debug program, I/O executive program, dump routines, BASIC and FOCAL.

ED-11. Assists you in the creation and modification of ASCII source tapes, also used to write assembly language programs and for general text editing or word processing functions.

PAL-11S. Relocatable assembler converts ASCII source tapes into relocatable binary modules. This lets you create programs in small, modular segments for easier coding and debugging. These binary modules serve as inputs to LINK-11S.

LINK-11S. Link editor which links the modules created by the PAL-11S into a load module ready for execution on the H-11. The module is loaded into the H-11 via the Absolute Loader.
FULLY WIRED AND TESTED K11F BOARD

The "heart" of the H11 computer is the standard DEC LSI-11 microcomputer board. The 16-bit CPU functions are contained in four silicon gate N-channel MOS LSI integrated circuit chips for high reliability and superior performance. The 4096-by-16 read/write MOS semiconductor memory is composed of LSI 4K dynamic RAM chips that provide fast access time and require little operating power. The CPU executes the powerful PDP-11/40 instruction set with over 400 instructions. There are no separate memory I/O or accumulator instructions, so you can manipulate data in peripheral device registers as easily and flexibly as in memory registers. The LSI-11 board is supplied fully wired and tested to facilitate kit assembly and provide greater reliability and less chance of error.

Rugged steel chassis and extra-thick backplane with heavy, solid connectors for added strength and years of superior performance.

Compact, efficient switching power supply uses less power to operate and generates less heat than conventional supplies. Overvoltage and overcurrent/short circuit protection, along with automatic power-up and power-down sequencing, provide high reliability and long life operation.

Built-in quiet-running fan provides efficient cooling and prevents heat buildup.

Card cage with backplane accommodates up to six accessory cards in addition to LSI-11. The card cage swings up for easy access and service even while the H11 is operating. Accessory boards slide directly into card guides with all connectors supplied.

Front panel controls include DC power switch and run/halt switch. Status lights indicate processor activity.

Styled and sized to match Heathkit peripherals for total system continuity.

The H11 and all its accessories will be available November 10th, 1977.
H11 ACCESSORIES, SOFTWARE AND MANUAL SET

1. H11-1 4K Memory Expansion Module
Plugs into H11 backplane, adds 4K x 16-bit word capacity to H11 memory. Uses high-reliability 1Kx4 static MOS RAM chips. Access time is less than 500 nS. Has decode circuitry for operation on 4K address boundaries. Handle for easy removal and insertion. Compatible with PDP 11/03 and other LSI-11 backplane machines.
Kit H11-1, Shpg. wt. 2 lbs ........ 275.00

2. H11-2 Parallel Interface
General-purpose parallel interface featuring 16 diode-clamped latched data input lines, 16 latched output lines, 16-bit word or 8-bit byte data transfers. Has LSI-11 bus interface and control logic for interrupt processing and vectored addressing; control status registers compatible with PDP-11 software routines. Four control lines for output data ready, output data accepted, input data ready and input data accepted logic operations. Maximum data transfer rate, 90K words per second under program control. Maximum drive capability, 25-ft. cable. Plugs into H11 backplane, can be used with DEC PDP-11/03 and other LSI-11 backplane machines. Also compatible with TTL or DTL logic devices. The H11-2 is required for interfacing the H11 to the H10 Paper Tape Reader/Punch.
Kit H11-2, Shpg. wt. 2 lbs ...... 95.00

3. H11-5 Serial Interface
Universal asynchronous receiver/transmitter serial interface module for use between LSI-11 bus and serial devices such as the Heathkit H9 video terminal (page 10) or LA36 teleprinter (page 12). Has optically isolated 20 mA current loop and EIA interfaces; selectable baud rates of 50, 75, 110, 134.5, 150, 200, 300, 600, 1200, 1800, 2400, 4800 and 9600. Plugs into H11 backplane, fully compatible with PDP 11/03 and other LSI-11 backplane machines. With all mating connectors.
Kit H11-5, Shpg. wt. 2 lbs ...... 95.00

4. H11-6 Extended Arithmetic Chip
Adds powerful arithmetic instructions to the LSI-11, including fixed point multiply, divide and extended shifts plus full floating point add, subtract, multiply and divide. Helps minimize or eliminate arithmetic sub-routines, speeds up program execution and eases program development. Saves memory space too. 40-pin dual-inline package IC plugs into socket on KD11 F board.
H11-6, Shpg. wt. 1 lb .......... 159.00

5. Manual Set for H11 Computer
HM-1100 Manual Set, Shpg. wt. 12 lbs ........ 25.00
NOTE: The price of the manual set can be deducted when you order an H11.
NOTE: DEC, DIGITAL, FOCAL and PDP are registered trademarks of Digital Equipment Corporation.

Special DEC Software License Requirement
H11 purchasers are required to fill out and sign the DEC license agreement on page 15. Please do so and include with your H11 order. Heath cannot ship merchandise without this license agreement.
H9 LONG AND SHORT-FORM VIDEO DISPLAY TERMINAL

The H9 video terminal is a general-purpose computer peripheral designed for use with the Heathkit H8 or H11 computers. It provides keyboard input and a CRT for the convenient entry and display of computer programs and data. The H9 can be used with any digital computer in dedicated stand-alone applications or in time-sharing systems.

Character format is standard upper case 5 x 7 dot matrix. The long form display is twelve 80-character lines. The short form display is forty-eight 20-character lines in four 12-line columns. The automatic line carryover feature executes line feed and return when line exceeds character count on both long and short form displays. A built-in oscillator/speaker generates a 4800 Hz tone and serves as audible end-of-line warning.

Auto-scrolling is featured in both long and short form. In the long form, as the line enters at bottom, the top line scrolls off-screen; in the short form, as new column enters from right, the left column scrolls off-screen. Auto-scrolling can be defeated with a front panel switch. The cursor mark indicates the next character to be typed for accurate positioning. Cursor control keys include up, down, left, right and home. Serial data baud rates are selectable from 110-9600. Baud rate clock output and reader control are available on the rear panel connector. The erase mode permits automatic full page erase or erase to end of line starting at cursor position. A transmit page function allows a full page to be transmitted as a block of continuous data.

Function keys are positioned away from characters to prevent miskeying and error.
Standard typewriter keyboard for easy, more accurate input.
Wide, easy-to-use space bar aids accurate typing.

Three separate modes give the H9 real display versatility

Long form - twelve 80-character lines
Short form - forty-eight 20-character lines
Plot mode - graphs, curves, simple figures

Control PC board is fully assembled and tested for added reliability and simplified kit assembly. A wiring harness with connectors helps reduce time-consuming point-to-point wiring. Ultra-compact size, only 12 1/2” H x 15 3/4” W x 20 3/4” D, makes the H9 ideal for desktop or console applications. For 110 VAC, 60 Hz or 230 VAC, 50 Hz.

Full ASCII 67-key Keyboard

The H9 serial interface provides EIA RS-232C levels, a 20 mA current loop or standard TTL levels. Parallel interfacing includes standard TTL levels, 8 bits input and 8 bits output and 4 handshaking lines.

Kit H9, Shpg. wt. 50 lbs. ........ $530.00
The H10 is a complete paper tape reader/punch mass storage peripheral using reliable low-cost paper tape. It's fully compatible and styled to match with the H8 and H11 computers. It also works reliably with any other computer through a parallel interface. The H10 uses standard 1" wide roll or fan-fold 8-level paper tape. Standard punched paper tape gives you the reliability, durability and trouble-free handling you need for effective mass storage of programs and data.

The reader reads tape at a maximum rate of 50 characters per second. A full sensitivity adjustment on each channel permits any color, thickness, quality (oiled or unoiied) paper tape to be used. Sensitive photo Darlington transistors and an incandescent lamp reader head provide reliable reading. The powerful stepper motor drive insures accurate tape positioning and movement.

The punch operates at a maximum speed of 10 characters per second. Precise ratchet/solenoid drive and reliable solenoid control of punches provide high-accuracy punching. The precision die-block punch head gives you positive and consistent punching.

Controls include power on-off, read and punch start. A feed control feeds blank paper tape through the punch to produce leader tape. A copy control on the rear panel permits tape being read to be duplicated by the punch for efficient and accurate tape copying.

Interface has parallel 8-bit input bus for punch, parallel 8-bit output bus for reader, standard TTL logic levels and handshaking lines for both reader and punch. A rear panel 24-pin interface connector and mating cable are supplied.

Accessories include holder for roll paper tape, chad collector tray, and collector box for fan-fold tape. With 8" roll (900 ft.) blank paper tape.

StyIed to match the Heathkit H8 and H11 computers. Cabinet with metal top and rugged steel chassis, 12½" H x 9½" W x 19½" D. For 110-130 VAC, 60 Hz, or 220-240 VAC, 50 Hz.

Kit H10, Shpg. wt. 29 lbs. ......... 350.00

H10-2, Three Blank Rolls Paper Tape, each 8" diameter, 900 ft. min.

H10-2, Shpg. wt. 5 lbs. ............. 10.00

H 10-3, Three Boxes Blank Fan-fold Tape. Approx. 1000 ft. each.

H10-3, Shpg. wt. 5 lbs. ............. 10.00
Cassette Recorder Storage Device

Has volume and tone controls, pushbuttons for record, play, rewind, fast forward, stop and eject, built-in 3-digit counter with reset button. Factory wired, not a kit.

ECP-3801, Shpg. wt. 6 lbs. $55.00

Heath recommended high output, low noise, premium grade audio recording tape. Pack of three 30-minute blank cassettes.

ECP-3802, Shpg. wt. 1 lb. per pack 5.00

NOTE: Proper operation of the HB-5 and H8 software is assured only when the ECP-3801 cassette recorder and ECP-3802 tape is used. Heath does not assume responsibility for improper operation resulting from the use of any other cassette units.

HUG—the Heathkit User's Group

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Figure 14: The procedure used to return from a subroutine. If the subroutine had an explicit result, an indirect pointer to the result must be stacked in table $SVAL$. Information stacked in table $SF$ by the call to the subroutine must be unstacked. Finally, before continuing the interpretation at the proper syllable, any actual parameter pointers stacked in tables $SD1$ and $SD2$ must be unstacked.

Statement branching and subroutine linkage is a relatively simple process compared with expression evaluation. The next few figures return us to our discussion of the interpreter itself by detailing the expression evaluation process.

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Figure 15: Subroutine E. This routine is called in figure 11 to recognize and interpret an expression. Five primary subroutines are invoked by E to interpret a valid expression. First _P_SUBR is called to test for a valid primary which must be the rightmost token in any valid expression. After a primary is found, subroutine FC is called to test for and interpret a valid function call. If found, subroutine E starts again; otherwise, AS is called to look for a valid assignment. Subroutines MOP and DOP may also be called to look for monadic and dyadic operators, respectively (see figure 17). The total result is that a valid expression will be interpreted and argument L will be set true. In the case of an invalid or a nonexistent expression, argument L will be set false.
Figure 16: Subroutine $p_{\text{SUBR}}$. A primary can be formed from a vector, a function call, a variable or an expression enclosed in parenthesis. The subroutines $\text{VEC}, \text{FN}, \text{V}_{\text{SUBR}}$ and $E$ are invoked to test for these tokens. Note the recursive call to subroutine $E$: subroutines which must handle recursive calls are so labelled on their flowcharts.
Figure 17: A collection of miscellaneous token recognition routines called by various routines in this APL interpreter. All subroutines in this figure have a single argument B which is set true if the particular token is found. B is set false otherwise.
Figure 78: Interpretation of a vector or constant. If the current syllable indicates a constant or a vector, the pointer to the associated value is stored in table SVAL.

CALL VEC(B)
B is set true if a constant or vector is recognized; the recognized constant/vector being stacked. B is set false otherwise.

Figure 79: Interpretation of a variable. This process is more complicated than the interpretation of a constant. A variable can be formed from a variable, a simple variable followed by an index expression, or a quad operator. Further, variables occurring to the left of an assignment operator are handled differently from those on the right. Subroutines STAK and LINK (figures 25 and 26) handle the stacking of operand pointers and the linking of results to a symbol table entry.
Figure 20: Interpretation of a function call.

RECURSIVE ENTRY ALLOWED

FC

L = FALSE

CALL FN(B)

FALSE

RETURN

CALL_SUBL

CALL

CALL_SUBL

L = TRUE

RETURN

Figure 21: Recognition of a call of a function. This subroutine is invoked to recognize a function name and to build an entry (if necessary) in table SF. If a function is found, the token to the left of the function name must be either a statement end or primary.

CALL FN(B)

B = FALSE

SP(1).C = SP

NO

RETURN

LOOKUP

{VTAB(SP(1).P).V1, FTAB.F1, Z}

Z = 0?

YES

SFP = SFP + 1

SF(SFP).SI = Z

SF(SFP).S2 = T

SF(SFP).S3 = NL

B = TRUE

I = I - 1

ERROR IT

LEFT ARGUMENT OF DYADIC FUNCTION CALL IS NOT A PRIMARY

CALL_SUBL

CALL

CALL_SUBL

L = TRUE

RETURN

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Figure 22: Call of function semantics. This routine is invoked to perform the linkages and table updates required in interpreting a function call. The last step is to set I to point to the rightmost syllable of the first statement in the called function.

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CALL AS(L)
L set true if valid assignment found and interpreted. L set false otherwise.

Figure 23: Interpretation of an assignment. This routine searches for a valid assignment which must be of the form “variable = expression.” Again, subroutines LARROW and V_SUBR are called to interpret the appropriate tokens. V_SUBR is also called by E_SUBR (see figure 19), but it functions differently for the two calls, since one is looking for a variable to the right of an assignment symbol, and the other is looking for a variable to the left of an assignment symbol. Variable ASSIGN is used to signify which mode to use.

CALL IND(L)
L set true if valid set of indices found. L set false otherwise.

Figure 24: Recognition of a list of indices. This routine, which is called when an index expression (an expression enclosed within square brackets) is encountered, calls subroutine E recursively to evaluate the expression for each index and to stack a pointer to the result in stack SVAL. Upon completion, variable NPV indicates the number of index expressions encountered. Similarly, the top NPV entries in stack SVAL point to the values of these indices.
Figure 25: Linkage for assignment. This subroutine (LINK) is called by subroutine VSUBR to link results to a symbol table entry (see figure 19).
Figure 26: Subroutine STACK. This subroutine is called by subroutine V\$U\$BR to stack operand pointers (see figure 19).
Figure 27: Linkage for a variable. This routine is called to recognize a simple variable. After it has been executed, variable GORD is set true if either a global or a dummy receiver is found. If the receiver is a formal argument, then RD is set true if the variable is the right argument of the function call, and set false if the variable is the left argument. For a simple variable to the left of an assignment, K is set to point to the associated VTAB entry; and for variables to the right of an assignment, PT is set to point to the D entry or value of the variable.

Figure 28: A subroutine used to input a constant vector. A value is read from the input device, an appropriate entry is made in table D, and a pointer to the D entry is stacked in table SVAL.

Note: No flowchart is shown for a quad denoting output, since the process is more or less implementation dependent (although simple). The element in the top of stack SVAL points to the table D entry to be listed.

That concludes part 2 of this 3 part series of articles describing an APL interpreter. Although the flowcharts may look awesome, the actual amount of code to be written is not overly great. My PL/I version of this interpreter is less than 1600 statements long.

Next month's concluding article describes the mathematical processing section of the statement interpreter, and describes the four arithmetic processing subroutines MOP, MONADIC, DOP and DYADIC. Since they define the number and use of the primitive operators, most of the tailoring of the interpreter will be done in these subroutines.
through a resistor that sets the current flowing into pin 14 to approximately 2 mA.

An additional resistor, \( R_1 \) (also in this current leg), allows the current to be varied by a small percentage and provides the ability to adjust the full scale range of the digital to analog converter. The output of the converter is a current which is equivalent to the product of this reference current and the binary data on the control lines. The current is converted to a voltage through IC9 and can be zero offset through the use of the offset adjustment pot, \( R_2 \).

The digital code stored in the scratch pad and presented to the digital to analog converter is in offset binary. A binary value of 00 000 000 produces an output of \(-5 \) V from the converter while 11 111 111 is equivalent to \(+5 \) V. In offset binary, if the most significant bit is a zero, the output is negative and if the most significant bit is a one, the output is positive. Since the converter has a range of 10 V, and is an 8 bit device, the resolution of the converter is 1/256 of 10 V, or approximately 40 mV. This means that the smallest output increments will be in 40 mV steps. To change this to finer increments requires that the range be shorter, such as \(+2.56 \) V to \(-2.56 \) V. By adjusting the span and zero pots, any reasonable range may be chosen, but the resolution will always be equal to the least significant bit or 1/256 of the range, and accuracy is estimated to be \( \pm 1/2 \) least significant bit.

### INTERFACE ASSEMBLY AND CALIBRATION

1. Be sure to build the circuit with good quality sockets for all integrated circuits. With all components except integrated circuits wired in place, and presuming that there are no shorts, apply power to the Interface. It should be noted that while the interface is shown with Altair (S-100) bus notation, there is no requirement that it be an S-100 configuration. The digital to analog conversion will work with any computer capable of providing an 8 bit data bus, 8 bit I/O address bus, and an output enable strobe. Computer cycle time and architecture are irrelevant. For use with a Digital Group 8080 system, the address and data buses are connected to the equivalent DGS pin numbers, S-100 pin 77 on the interface board is grounded, and the DGS pin 17 IO write signal is used on pin 45 of the Interface board in place of Sout.

2. Using a meter, check to see that the right supply voltages are on the appropriate integrated circuit pins and that \( V_{\text{ref}} \) on the digital to analog converter is approximately 6.2 V. If substituting parts, take care not to exceed 15 V between Vcc and Vee on the CMOS 4051.

3. Disconnect the power and attach the port decoding jumpers for the desired port addresses. Each of the six address lines, A7 thru A2, can be, by the appropriate placement of the jumpers, decoded as an inverted or noninverted signal. In building the circuit from scratch, an appropriate technique is to use a DIP socket with each pin, used as a jumper terminal. Selective wiring between the pins can then be done with wire wrap or Vector Slit-N-Wrap. The inverted choice is designated as a zero code, and the noninverted as a one. If all jumpers were set to the one position, channel 1's port address would be decoded as binary 11 111 100, or octal 374. Channel 4 would be 377 octal. If all jumpers were set to zeros, channel 1 would start at port address 0 and channel 4 would be port address 3 octal. Pick the binary code for whatever port assignment desired and wire the jumpers.

4. Insert integrated circuits IC1, 2, 3, 4, 5, 7 and 9. Apply the power, and with a short program which just outputs a value from the accumulator to an output port, output a binary 10 000 000 to the port address corresponding to channel 4 on the interface board. Using a meter to monitor the output of the LM301A, adjust the zero pot \( R_2 \) until the output is 0 V. With the same programming technique, load a binary 11 111 111 (octal 377) to channel 4 port address and adjust the span pot \( R_1 \) for a meter reading of \(+8.12 \) V. A binary setting of 00 000 000 should output \(-5.12 \) V. If you are unsuccessful at this point, with power off, remove the MC1408L-8 and the LM301A, and verify that the binary output of the scratch pad is correct. With the integrated circuits presently installed, the scratch pad is latched at an address of channel 4. Nine times of 15, problems like this can be attributed to choosing an incorrect port code. Turn off the power.

5. Insert the clock generator IC6, reapply power, and using a scope or frequency counter, verify an approximate 200 kHz clock rate. Turn off the power.

6. Next, insert IC8, the CMOS multiplexer IC10, and the sample and hold op amps IC11 and 12. Be very careful in handling the CMOS integrated circuit. It is very easily damaged by static charges. Turn on the power and then using the same simple program, output a binary value to one of the channel addresses and note with a meter that it is in fact the correct voltage. Using the program, vary the output of each channel separately across the range and note that no other channel outputs should change. Sym pathetic tracking usually indicates a bad multiplexer integrated circuit.

A few cautions: Don't use op amps with a frequency response less than the LM301A and use only the L8 version of the MC1408-L (not MC1408-L7 or MC1408-L6) if you want a guaranteed eight bits of precision.
80 REM THIS PROGRAM CALCULATES THE VALUES FOR A SINE WAVE AND
82 REM PUTS THEM IN PAGE 100 (OCTAL) OF MEMORY
90 PRINT "SINE WAVE POINT CALCULATOR"
100 LET A=3.14/180*360/256
110 FOR B=0 TO 255
120 LET W=INT(127.5+(127.5*SIN(A*B))
130 FILL 16384+B,W
160 NEXT B

Now How Do I Use It?

Once you have conquered the hardware and constructed an interface (see notes in the box) you should be ready to exercise it under program control. There are some interesting applications using the digital to analog interface alone, none the least of which is Ned's problem.

You will remember that my solution to the impulse response problem in Ned's test setup was to vary the pressure sinusoidally using a computer generated voltage to control a pressure regulator. Adding a computer sounds a bit unnecessary, but remember that an analog to digital interface will be attached for data acquisition.

With this particular digital to analog interface, programming an analog control voltage utilizing an extended BASIC such as the Digital Group's MaxiBASIC, is quite easy. To operate a real time sine wave that varies the pressure between 0 and 10,000 PSIG requires a control regulator with a control voltage range of -5 V to +5 V and the following very simple BASIC program:

90 REM THIS PROGRAM CALCULATES AND OUTPUTS A SINE WAVE.
100 LET A = 3.14/180*360/256
110 FOR B = 0 to 255
120 LET W = INT(127.5+127.5*SIN(A*B))
130 OUT 252,W
140 NEXT B
150 END

This program calculates 256 values of a sine wave with an amplitude of -5 to +5 V. When run in real time, the period of the waveform is about two seconds. The period is basically set by the time it takes to compute the expression on line 120 some 256 times. An alternative method is to calculate the points once, load the values in memory and call a subroutine which scans the table when directed to do so by the program.

The first time that the points are computed, it will take two seconds as before. Then they are available in a look up table. A program which constructs such a memory resident table is illustrated in listing 1. Photo 2 shows an oscilloscope trace of the synthesized sine wave created by the digital to analog converter in figure 9 using the table created by listing 1.

Listing 1: An extended BASIC program to compute and load a table in memory with 256 sample points of a sinusoidal waveform.

Digital Group MaxiBASIC interpreter.

Photo 2: An oscilloscope display of a sinusoidal waveform synthesized by using the BASIC program in listing 1 in conjunction with the digital to analog converter shown in figure 9.

<table>
<thead>
<tr>
<th>Split Octal</th>
<th>Octal Code</th>
<th>Operation</th>
<th>Commentary</th>
</tr>
</thead>
<tbody>
<tr>
<td>012/000</td>
<td>041 000 100</td>
<td>LXI H&amp;L</td>
<td>Set the program counter to page 100;</td>
</tr>
<tr>
<td>012/003</td>
<td>176</td>
<td>MOV A</td>
<td>Move addressed memory to accumulator;</td>
</tr>
<tr>
<td>012/004</td>
<td>323 375</td>
<td>OUT</td>
<td>Output accumulator to port 375;</td>
</tr>
<tr>
<td>012/006</td>
<td>054</td>
<td>INR L</td>
<td>Increment L register;</td>
</tr>
<tr>
<td>012/007</td>
<td>302 003 012</td>
<td>JMP COND.</td>
<td>Jump to 012/003 if L ≠ 0;</td>
</tr>
<tr>
<td>012/012</td>
<td>311</td>
<td>RET</td>
<td>Return to BASIC program;</td>
</tr>
</tbody>
</table>

Listing 2: A machine language program which is used to drive the digital to analog converter in figure 9. This program is called by the extended BASIC program in listing 3.

300 PRINT "THIS PROGRAM WHICH DRIVES AN 8 BIT D/A PRODUCES "
310 PRINT "ANY WAVEFORM FROM A BINARY TABLE"
400 REM THIS PROGRAM CALLS A SUBROUTINE AT 012/000 (OCTAL)
410 REM WHICH OUTPUTS THE 256 WAVEFORM VALUES TO
420 REM D/A ON OUTPUT PORT 375 (OCTAL)
430 REM OCTAL AT 012/000
440 REM 041 000 100 176 323 375 054 302 003 012 311
450 REM MAX SPEED FOR ADSR IS 4 MSBC
470 REM BINARY TABLE IS ON PAGE 100 (OCTAL)
502 PRINT "GENERATE THE WAVEFORM HOW MANY TIMES ?":INPUT E
505 FOR X=1 TO E
510 LET A=CALL(2560,0)
515 NEXT X
1000 END

Listing 3: An extended BASIC program which calculates 256 points of a given waveform which is to be synthesized and then calls the machine language routine in listing 2 to actually drive the digital to analog converter in figure 9. The call to the subroutine in listing 2 occurs at line 510 of this program. Digital Group MaxiBASIC interpreter.
A simple program which scans the table and drives the digital to analog converter is assembled into the memory of my particular system at split octal address 012/000 (hexadecimal 0A00) as shown in listing 2. This program can be called at any time with the BASIC command CALL (2560,0), and when driven at faster than 100 ms periods can be easily displayed on an oscilloscope. [Note that 2560 is decimal for split octal address value 012/000 or hexadecimal 0A00.] The program in listing 3 incorporates the routine in listing 2 as a called subroutine and can be used to display any waveform defined by the table located at address 100/000 in split octal notation (hexadecimal 4000).

On to Bigger and Better Applications

An obvious application of this programming technique is to mathematically compute and generate complex waveforms which would otherwise require extensive dedicated hardware to duplicate. Music application is an area which is being heavily infiltrated with computer technology. A composer interested in electronic music effects can design discrete waveforms, display and review them before committing them to a performance design.

An alternative approach is to use BASIC to generate all the tables defining envelope or waveform aspects of desired instruments and then let BASIC sit idle while a machine language program selects and calls the tables to produce a musical score.

It's often easier to illustrate one example rather than discuss volumes of theory. One of the least complicated musical envelope waveforms is the ADSR envelope. ADSR stands for Attack, Decay, Sustain and Release. Various combinations of these four variables produce unique sounds similar to such instruments as the piano or trumpet. In an electronic music application the composer would combine the necessary fundamentals and harmonics characteristic of a particular instrument and control the output amplitude with an ADSR waveform feeding a voltage controlled amplifier, or VCA. Both the envelope and harmonic content are separate elements of musical compo-

---

**Listing 4: An extended BASIC program which generates a table of sample points of the ADSR waveform whose graph appears in figure 10. Digital Group MaxiBASIC interpreter.**

```
80 PRINT "'ADSR MEMORY LOADER'
90 REM THIS PROGRAM COMPUTES DECIMAL VALUES FOR A PIECE-WISE
91 REM LINEAR ADSR WAVEFORM AND ILLUSTRATES THE METHOD
92 REM THE VALUES ARE THEN LOADED INTO PAGE 100 (OCTAL) OF MEMORY
93 REM THEY ARE THEN AVAILABLE FOR MACHINE SUBROUTINES
100 FOR X=0 TO 60
105 REM THIS IS THE "A" SECTION
110 LET Y=INT((255/60)*X)
115 FILL 16384+X,Y
120 NEXT X
125 LET W=61
130 FOR Z=0 TO 39
135 REM THIS IS THE "D" SECTION
140 LET Y=INT((-75/40)*Z+255)
145 FILL 16384+W,Y
150 LET W=W+1
155 NEXT Z
160 FOR X=101 TO 220
165 LET Y=180
170 NEXT X
175 LET N=221
180 FOR X=0 TO 34
185 REM THIS IS THE "S" SECTION
190 LET Y=INT((-180/35)*X+180)
195 FILL 16384+N,Y
200 LET N=N+1
205 NEXT X
210 LET W=221
215 FOR X=0 TO 60
220 REM THIS IS THE "R" SECTION
225 LET Y=INT((255/60)*X)
230 FILL 16384+W,Y
235 NEXT X
240 LET W=255
245 FOR X=0 TO 34
250 LET Y=180
255 NEXT X
260 FOR X=221 TO 255
265 LET Y=180/35*X+180
270 NEXT X
275 LET N=221
280 FOR X=0 TO 60
285 LET Y=255/60*X
290 NEXT X
300 N=0
305 END
```

---

**Figure 10: A simple ADSR (Attack, Sustain, Decay and Release) envelope waveform along with the line equations necessary for digital to analog waveform synthesis (see photo 3 and listing 4).**
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90 PRINT "WAVEFORM BEING CALCULATED"
92 REM THIS PROGRAM CALCULATES THE COORDINATES OF A COMPLEX WAVEFORM
93 REM THE POINTS ARE IN PAGE 100 (OCTAL)
100 LET B=3.14/180*360/256
110 FOR A=0 TO 255
120 LET E=-((255/3.14)*SIN(A*B))
125 LET F=-((255/(2*3.14))*SIN(2*A*B))
130 LET G=-((255/(3*3.14))*SIN(3*A*B))
140 LET Y=INT(127.5+E+F+G)
150 PRINT A,Y
160 NEXT A
500 END

Listing 5: An extended BASIC program which calculates sample points of the Fourier series illustrated in figure 11 and stores them in a table. Digital Group MaxiBASIC interpreter.

Photo 4: An oscilloscope display of the waveform resulting from the synthesis of a typical complex waveform using the program in listing 5 and the digital to analog converter in figure 9. The waveform is the result of summing three terms of a Fourier series (see figure 11).

Figure 11: A typical complex waveform which is the sum of three terms of a Fourier series. These equations were used by the program in listing 5 to generate the oscilloscope trace of photo 4.

Note From the Author

This article is an attempt to introduce the computer experimenter to more thought-provoking applications for his or her computer so that the question of its usefulness in the non-industrial environment will seldom if ever be questioned. I'm shortly to begin a regular feature in BYTE on applications systems (hardware and software), and invite correspondence from you, the reader, on possible topics, ideas you would like to see implemented. My address is given at the beginning of this article.
thesizer involves the same point plotting methods as previously outlined, with the exception that the equations become more involved.

Consider the trigonometric series for the complex waveform with a peak amplitude of B=127.5 as illustrated in figure 11.

The Fourier series approximating a triangular waveform can be plugged into an extended BASIC program which calculates the points, while the program in listing 3 can be used to display the tabulation. Photo 4 shows the resulting oscilloscope display.

Conclusions

What started out to be just a simple interface for an analog output can be incorporated into control, music and educational applications. The extent and direction of an experimenter's system expansion is of necessity governed by price performance. This is an inexpensive interface which connects an otherwise isolated digital computer to the analog world. When coupled with a high level language such as extended BASIC, its potential is limited only by the programmer. To think that the home computer is an expensive toy useful only to bide time between monopoly games is equivalent to thinking that a building is only used to hold the sidewalk down.

REFERENCES

1. Digital to Analog Converter Handbook, Hybrid Systems Corporation, Crosby Dr, Bedford MA.

The 4 channel self-refreshing digital to analog converter pictured in figure 9 is available in the following forms from Pinnacle Products, POB 3155, Talcottville CT 06066:

<table>
<thead>
<tr>
<th>Product Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blank PC board</td>
<td>$34</td>
</tr>
<tr>
<td>Postpaid in the Continental US</td>
<td></td>
</tr>
<tr>
<td>Complete kit</td>
<td>$69</td>
</tr>
<tr>
<td>Assembled and Tested</td>
<td>$99</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th></th>
<th>One Tutorial</th>
<th>Two Tutorials</th>
<th>Three Tutorials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students (with ID)</td>
<td>$30</td>
<td>$50</td>
<td>$75</td>
</tr>
<tr>
<td>IEEE Members</td>
<td>$40</td>
<td>$70</td>
<td>$100</td>
</tr>
<tr>
<td>Non-Members</td>
<td>$50</td>
<td>$90</td>
<td>$125</td>
</tr>
</tbody>
</table>

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Member of the ACM and IEEE, and chairman of the 1977 National Computer Conference.
Author of many articles in professional journals and magazines.
Received a Ph.D. in Computer Science from the Southern Methodist University.

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Teacher of electronics and computer programming at a community college
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Author of several books, home study courses and numerous magazine articles in electronics and computing.
Received a BS in electronics from the University of Houston and a MEd from the University of Maryland

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Editor-in-Chief and co-founder of BYTE magazine.
Obtained computing experience as a personal way to accomplish artistic and technological goals in music.
Graduated in 1970 with a BS in Physics from the University of Rochester, NY.
Worked for several years at Intermetrics, Inc. in Cambridge, Massachusetts on the NASA Space Shuttle Project.
Prior to working with BYTE, publication of a small computer newsletter on a part-time basis.
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- network design and architecture
- data communications aspects
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2. Development of Microcomputer Systems for Home Use
Cory Ringel, Con Edison
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- programming and software aids
- interfacing: A/D and D/A conversion
- examples: design of a home control system; microcomputers for a music synthesizer; computer TV games.
- case study: use of the Motorola 6800 in design of a microcomputer system

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- current applications
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- vendor survey
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- interfacing to cassette and floppy disk drives
- interfacing to display devices
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5. Microprocessor Programming and Software
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- software design: flow-charting, setting breakpoints, documentation, etc.
- assembly language for the Intel 8080, 8085, Z-80, Motorola 6800
- instruction types and addressing techniques
- use of the stack
- interrupt handling and direct memory access (DMA)
- software development aids
- high level languages for microcomputers

6. Technology Analysis and Forecast of Future Microprocessor Structures
and Will Mathys, MOS Technology Inc.
- emergence of specialized computational elements (SCE)
- architectural evolution (stack processors, reconfigurable architectures, multi-level logic)
- resource management techniques
- software evolution (nano-programming, extensible instruction sets, structured programming modules, very-high-level languages)
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Dr Iverson’s “Thought Experiment” Answered

Last month we published an article by Dr Kenneth Iverson entitled “Understanding APL” (August 1977, page 36), in which readers were challenged to solve the following APL expressions:

\[
(2+/0=1 \div (1N) •. \div (1N)//1N)
\]

The answer, which only becomes apparent for \( N = 7 \) or greater, is the set of prime numbers from 1 through \( N \)! To show how this unexpected result comes about, let us evaluate the expression for \( N = 7 \). Since expressions are evaluated from right to left in APL, the first step is to evaluate \( 1N \):

\[
1N = 1 2 3 4 5 6 7
\]

Next we evaluate everything to the left of the compression operator (\( / \)). Expressions in parentheses are evaluated first, so we start with \((1N) •. \div (1N)\), which becomes

\[
1 2 3 4 5 6 7 •. \div 1 2 3 4 5 6 7
\]

for \( N = 7 \). Performing the residue operation (\( \div \)), we get:

\[
\begin{align*}
0 & 0 0 0 0 0 0 \\
1 & 0 1 0 1 0 1 \\
1 & 2 0 1 2 0 1 \\
1 & 2 3 0 1 2 3 \\
1 & 2 3 4 0 1 2 \\
1 & 2 3 4 5 0 1 \\
1 & 2 3 4 5 6 0
\end{align*}
\]

Before we can transpose this array, we must first perform the "0=" operation:

\[
\begin{align*}
0 & 0 0 0 0 0 0 \\
1 & 0 1 0 1 0 1 \\
1 & 2 0 1 2 0 1 \\
1 & 2 3 0 1 2 3 \\
0 & 1 2 3 4 0 1 2 \\
1 & 2 3 4 5 0 1 \\
1 & 2 3 4 5 6 0
\end{align*}
\]

This gives:

\[
\begin{align*}
1 & 1 1 1 1 1 1 \\
0 & 1 0 1 0 1 0 \\
0 & 0 1 0 0 1 0 \\
0 & 0 0 1 0 0 0 \\
0 & 0 0 0 1 0 0 \\
0 & 0 0 0 0 0 1 \\
0 & 0 0 0 0 0 0
\end{align*}
\]

Next, we transpose this array using the transpose operator (\( \sim \)). The result is:

\[
\begin{align*}
1 & 0 0 0 0 0 0 \\
1 & 1 0 0 0 0 0 \\
1 & 0 1 0 0 0 0 \\
1 & 1 0 1 0 0 0 \\
1 & 0 0 1 0 0 0 \\
1 & 1 1 0 0 1 0 \\
1 & 0 0 0 0 0 1
\end{align*}
\]

Performing the \( +/- \) operation on this array gives:

\[
1 2 3 4 2 4 2
\]

The expression has thus been reduced to

\[
2 \div (1 \div 2 \div 3 \div 4 \div 2) / (1 \div 2 \div 3 \div 4 \div 5 \div 6 \div 7)
\]

and this reduces to

\[
2357
\]

This vector is indeed the set of prime numbers between 1 and 7, inclusive. The algorithm works for all integer values of \( N \). (Note that the algorithm excludes 1. If you happen to take the position that 1 is a prime number, try writing an APL statement which includes it!) For readers totally unfamiliar with APL, any of Dr Iverson’s many writings on the subject should help. See the references listed in last month’s BYTE.
TSC's Software Catalog...

We've received a 1977 catalog from Technical Systems Consultants, Box 2574, W Lafayette IN 47906. While a lot of people have been just talking about personal computing, TSC have gone out and done what a growing number of entrepreneurs are doing: publishing and selling software at reasonable prices. The TSC Software Catalog, which has a nominal price of 25 cents to cover postage, is available from the company. Most items are sold as completely commented, assembled machine code source listings for the 6800, 8080 or 6502 processor of your system. The prices for typical items from the catalog are:

- A BCD floating point package for the 6800 processor is $6.50 for the documentation, plus $1 for a MIBUG format paper tape.
- A scientific functions extension of the above package runs $10 plus $4 for a paper tape. This gets you transcendental, and other goodies.
- And of course, the firm will give you a high level language for the 6800 in the form of "Micro Basic Plus" which runs $15.95 for the documentation, plus a paper tape at $6 or cassette tape at $6.95.

The catalog is packed full of numerous items, with most programs written for the 6800 so far (but don't ignore the availability of several 6502 and 8080 packages).

The following quotation from the catalog regarding copyrights and pricing is well worth considering as a philosophy for personal use software marketing:

Yesterday's successful marketing of software for very little is now today's most successful marketing of software available at a reasonable price. Marketing software to lots of people with personal computers requires high volume production at low margin because of mass production and distribution. The low pricing is to encourage the hobbyist to buy from us instead of paying close to the same amount for a copy at the local copying machine.

We heartily agree with this approach, since the world of the personal use computer cannot support the concept of unit sales of custom written hand crafted programming of extremely expensive software. The automobile was a success because of mass production and distribution. Marketing software to lots of people with personal computers requires high volume production at low margin as with any mass market, an enterprise which TSC is proving quite realistic.

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Musical Micros, and More

---Fingertip Math from Texas Instruments. The subtitle of Fingertip Math reads: "How to use an electronic calculator to put speed, accuracy and confidence into everyday mathematics." It includes chapters on how to use a calculator, reciprocals, powers and roots, number systems, geometric applications, interest and mortgage calculations, and more. Fingertip Math is dedicated entirely to applications of the conventional 4 function calculator. Beginners and professionals alike will find it to be a useful, self-contained tutorial manual. Only $2.95.

---Bipolar Microcomputer Components Data Book from Texas Instruments. If you like to build computers from scratch, or are just interested in finding out what is available to the enterprising hacker, Texas Instrument's Bipolar Microcomputer Components Data Book is for you. Included are detailed data sheets covering Schottky and Injection Logic (12L) 4 bit slice processor elements, plus the SBP9900 16 bit microprocessor. A wide range of bipolar memory components is also covered, as well as bipolar microcomputer support function circuits such as latched bus transceivers, shift registers, programmable logic arrays (PLAs), and so on. With the aid of this handbook, the enterprising experimenter can create a variety of high-powered designs. Only $2.95.

---Microcomputer Handbook by Charles J Sippl. We often hear people say, "I'd like to find out more about microcomputers. I'm not a technical type, but I feel I can handle a fairly rigorous approach as long as it's well-written. What's available?" Charles J Sippl's Microcomputer Handbook is one answer to this question. The book covers the present state of computer technology very well, concentrating on both hardware and software. Lucid and complete glossaries are combined with a variety of illustrations. Topics covered include: microcomputers: where they are, what they are doing, and what is next; kits; distributed intelligence; and why the new systems are easier to use. The book was written by a computer industry lecturer and consultant and is highly recommended for the intelligent layman as well as for professionals and experimenters. The glossaries alone are worth the price of the book—don't miss this one! This hardcover reference is only $19.95.

---The Technology of Computer Music by Max Mathews, published by the MIT Press. If you're interested in creating music on your microcomputer, here is an excellent source book on the subject written by Max Mathews, often called the "Father of Computer Music." The book includes sections covering the fundamentals of digital sound generation, including the sampling theorem, digital to analog converters, sample-rate change, and storage of musical data. A significant portion of the book is devoted to a description of MUSIC V, the well-known high level music language. The sections of the book have been graded so that readers new to the field can approach the material systematically, $16 hardcover.

---On the Sensations of Tone by Herman Helmholtz and published by Dover Publications. This remarkable book is a reprint of the original 1865 edition, reprinted with Dover's usual attention to detail. Despite its age, On the Sensations of Tone is still a standard text for the study of the physics and physiology of music. Part 1 explains the sensations of sound in general, vibrations, sympathetic resonances, etc. Part 2 covers combinations of tones and beats. Part 3 concludes the book with Helmholtz's theory of the aesthetic relationships of musical tones. This book will make a valuable addition to the library of anyone interested in the production of music on microcomputers. $6.95.

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A Bit of the BASIC

---Computer Resource Book-Algebra by Thomas A Dwyer and Margot Critchfield is an exciting new way to learn about algebra and the interesting things you can do with it using a computer. The book uses the BASIC language, and flowcharts are used throughout to show the structure of programs. There are 60 applications programs including straight line graphs, polynomial equations, a space probe navigator, temperature profiles, computer generated animation, the ultrasonic root finder, random number generation and many more. Although it is particularly suitable for students, just about everyone will find some intriguing and easy to use applications in this entertaining book. $4.80.

---Basic BASIC by James S Coan. If you're not already familiar with BASIC, James Coan's Basic BASIC is one of the best ways to learn about this popular computer language. BASIC (which stands for Beginner's All-purpose Symbolic Instruction Code) is easy to learn and easy to apply to many problems. Basic BASIC gives you step-by-step instructions for using a terminal, writing programs, using loops and lists, solving mathematical problems, understanding matrices and more. The book contains a wealth of illustrations and example programs, and is suitable for beginners at many different levels. It makes a fine reference for the experienced programmer, too. $7.95.

---Advanced BASIC by James S Coan. Advanced BASIC is the companion volume to James Coan's Basic BASIC. In this book you'll learn about some of the more advanced techniques for programming in BASIC, including string manipulation, the use of files, plotting on a terminal, simulation and games, advanced mathematical applications and more. Many useful algorithms are covered, including some clever sorting techniques designed to reduce program execution time. As with Basic BASIC, there are many illustrative example programs included. BASIC doesn't have to be basic with Advanced BASIC! $6.95.

---Some Common BASIC Programs by Lon Poole and Mary Borchers, published by Adam Osborne and Associates. At last, a single source for all those hard to find mathematics programs! Some Common BASIC Programs combines a diversity of practical algorithms in one book: matrix multiplication, regression analysis, principal on a loan, integration by Simpson's rule, roots of equations, operations on two vectors, chi-square test, check writer, geometric mean and variation, coordinate conversion and a function plotting algorithm. These are just some of the many programs included. For only $7.50 you can buy the kind of programs previously available only as part of software math package systems for large scale computers. All the programs are written in a restricted BASIC suitable for most microcomputer BASIC packages, and have been tested and debugged by the authors. $7.50.

---A Guided Tour of Computer Programming in BASIC by Thomas A Dwyer and Michael S Kaufman. Colorful graphics abound in this lively introduction to the BASIC language. The authors have tried to present a rigorous, yet entertaining approach to the subject. Written for the novice, A Guided Tour begins with a section on how to recognize a computer, followed by some tips on working at a terminal. By the end of the book readers are writing their own programs and solving elementary problems in finance and business. The emphasis throughout is on learning by doing. Anyone interested in computer programming should benefit from A Guided Tour of Computer Programming in BASIC. $4.50.
The Best of BYTE, Volume 1

The volume we have all been waiting for! The answer to those unavailable early issues of BYTE. Best of BYTE, edited by Carl Helmers Jr and David Ahl. This 384 page book is packed with a majority of material from the first 12 issues. Included are 146 pages devoted to "Hardware" and how-to articles ranging from TV displays to joysticks to cassette interfaces, along with a section devoted to kit building which describes seven major kits. "Software and Applications" is the other side of the coin: on-line debuggers to games to a complete small business accounting system is included in this 125 page section. A section on "Theory" examines the how and why behind the circuits and programs. "Opinion" closes the book with a look ahead, as to where this new hobby is heading. It is now available through BITS Inc for only $11.95 and 50 cents postage.

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PAPERBYTES

Tiny Assembler 6800 — Design and Implementation of a Microprocessor Self Assembler

Originally described in the April and May 1977 BYTE, PAPERBYTES is now offering Jack Emmerichs' Tiny Assembler 6800. This book contains the complete Tiny Assembler source listing plus object code in cross assembly format (space restrictions prevented printing of this material in BYTE). A bar code version of Tiny Assembler is included for convenience, as well as reprints of Jack's two articles and additional user manual materials. Tiny Assembler will run on any machine with MIKBUG and 4K of memory starting at address 0000, and is an excellent tool for the interactive development of functional blocks for a large structured program. Add it to your 6800 system and you'll have a valuable programming aid which can free you from the drudgery of machine language. The best part is the price: only $7. Order yours today!

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See MERLIN ad on previous page.

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Super Bug #1

Thanks to inputs from Allen Evans (2 Munsell St, Binghamton NY 13901), Adrian Cammelot (Bell & Howell, Dept 8540, 7100 McCormack Rd, Chicago IL 60645), and several other readers, it became obvious to us that the July 1977 issue of BYTE had a rather important defect in our presentation of "Jeu de NIM, Peut Etre?" by Alain Chancé on page 90. The listing of the TI SR-52 program printed on page 91 included only one half of the total information which came with the article. Presented here then is the complete listing of the program as received with the article. Note that the listing has only two sheets and that these are numbered "2" and "4" in the images printed here, which are photo copies of photo copies of the originals.
Blackjack Bug

Master Steve Viterwyk of 4402 Meadow Wood Way, Tampa FL 33624, told us at the National Computer Conference show in Dallas TX about his discovery of a small bug on page 150, "SR-52 Card BLACKJACK," line 036, of the June 1977 BYTE. The present sign should be a division sign. Thanks, Steve.

A Sour Note in "Sweet Auto Line"

I loved that "Sweet Auto Line" article in your February 1977 BYTE, page 12. Mr. Nico is to be congratulated on a job well done. I am anxiously looking forward to future "goodies" comparable to this article.

While working with the information presented in "Sweet Auto Line," I believe I have discovered a slight bug at the tags ONOFF AND UNAUTO: reference is made to NEXT-1; I had to use NEXT-2 instead of NEXT-1. NEXT-1 plumped me back in mainline in the middle of an instruction.

If no one else has discovered this bug maybe you can advise everyone in general through an editorial comment.

Walter R. Norwood, manager
Computer Hobbies Unlimited
9601 Kendrick Rd
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We've had several other verbal comments by readers, but yours was the first written comment.
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PASCAL PRESSURE

In his article "All This Just to Print a Quotation Mark?" in May 1977 BYTE, page 132, the author offers us a mind bending case that is worse than the disease. Since the BASIC language he was using did not allow the user to represent a quote within a string delimited by quotes, he created an entire scratch file for the sole purpose of storing a quote which he subsequently read up as a variable and used.

The language I use, PASCAL, features a simple and straightforward solution: a quote mark within a string is represented by a pair of quote marks. Thus, in PASCAL you might say that the problem of quotes is "THE LANGUAGE" "'S PROBLEM".

George Cohn
Indiana University
Wrubel Computing Center
Memorial Hall West, Room 013
Bloomington IN 47401

Right you are. But no one has any small computer PASCAL compilers (or interpreters) yet, and when a user has to put up with what he's got, some mind bending contrivances may result out of sheer necessity.

COMMENTS ON PASCAL AND STACK MACHINES

The rumor of a Z-200 from ZILOG (April 1977 BYTE, page 140) seems to have triggered a groundswell in the small computer industry (and among personal computer enthusiasts) that cannot be ignored.

The concurrent article (page 128) by Donald J Stavely in your Technical Forum pages adds weight to the concept of using PASCAL (or a PASCAL subset) as a high level language for microprocessor users. The problem, of course, has been core. For example, PASCAL on a PDP 11/45 typically resides in 16 K of 16 bit words and takes seven passes to produce code for an abstract machine.

There is an additional overhead of 2 K words for an operating environment.

The ZILOG product, if it exists, would go a long way to bringing the small computer industry to a mature basis by providing it with a structured language. If the Z-200 does not exist the clamour of interest in such a product which your publication has generated must surely bring about its existence.

Keep up the good work, BYTE.

John S Perryn
Hartley Computer Applications Pty Ltd
39 Sherwood Rd
POB 365
Toowoong Qld 4066 AUSTRALIA

It turns out that Z-200 (later Z-800) rumor was untrue as of the spring of this year, but Zilog (and other companies) are not resting on past laurels. One design idea we heard at the West Coast Computer Fair from an LSI designer employed by a semiconductor laboratory was the idea of a fairly conventional processor design (at the machine language level) with built-in hooks to higher level functions implemented by fast machine language routines built into a ROM located in the processor. The suggestion was made that such routines could be made to run faster than if they were in external ROM segments due to the lack of any need to go through the external interfaces of the chip, and also due to short cuts in the addressing of operands. In essence, the concept is one of some "vertical" microprogramming extensions of the instruction set built into the

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design, using the basic instruction set of the processor to implement the functions. As for Zilog, it was the faster Z-80A which was announced this past spring, although representatives of the firm do not deny work upon a machine appropriate for high level language representations of programs. One comment, though, was that it would most likely be a machine which made it easy to generate high level language object code, rather than a design which in any sense could be said to directly execute high level language code.

COMPLAINTS ABOUT BYTE IN THE NUDE.

Now that BYTE is arriving with labels pasted on the cover, I (and probably others) would like to know a simple chemical method of removing the labels.

H W Neff
American Microsystems Inc
3800 Homestead Rd
Santa Clara CA 95051

My May issue of BYTE was really messed up in the mail. By coincidence or not, May also happened to be the first issue I got without a wrapper. Is there any way you could put my copy in a wrapper and (hopefully) keep it from being shredded?

J A Beuckman
11889 Creste Verde
St Louis MO 63141

The labels on the cover (May and June 1977) of BYTE were a temporary deviation from standard practice due to the disruptions of a strike at our printer. We like wrappers on magazines as much as you do, and will restore them as soon as possible.

OVERLY PRODUCT ORIENTED?

The LED display as suggested by Mr James Hogenson in his article “Multiplex Your Digital LED Displays” [March 1977 BYTE, page 122] seems unnecessarily complicated and expensive, at least for use as a digital readout for a microcomputer. A good alternative would be the use of two (hexadecimal) or three (octal) Hewlett-Packard alphanumeric displays 5082-7300 series. As noted by the attached data sheet, these displays have their own decoder drivers with memory and are DTL and TTL compatible. They can easily be inserted into a small breadboarding socket and hand wired to the bidirectional data bus as follows:

The latch enable should be set to OUT in order to monitor read in and instruction results, and set to ground when single stepping.

I would like to take the opportunity to say that your magazine has been a disappointment. Your publication is overly product oriented. In fact, many of your articles are simply reprints of product fliers. How about more emphasis placed on inexpensive computer projects, e.g.: simple interfacing involving different low priced memories, parallel to serial interfacing, etc?

Also a section devoted to simple software implementation and not necessarily involving BASIC or a high level language would be of interest. An educational series devoted to interested beginners would be helpful. Many of your articles are so difficult to understand that the novice is simply confused.

Considering the rapid advances being made in computer technology, it would behoove the hobbyist with restricted funds to stay with a low cost modular approach with software replacing hardware wherever possible. I think that much of what we see today as being the latest thing in microcomputer products will be obsolete within five years.

Don Woods
12012 Pebblebrook Ln
Carmel IN 46032

You make some good points. But as to “Your publication is overly product oriented. In fact, many of your articles are simply reprints of product fliers,” you are out on a proverbial limb sawing rapidly at the nearest node in the root direction. Our articles convey information about the theory and operation of computers, how to build same, designing software, etc. Surely we put in new product releases as well, but that’s all part of balancing the complicated equation of customers that is involved in any commercial magazine such as ours...
MORE HIDDEN GOLD:
PC-100 OPERATES WITH SR-51

This letter is in response to that from William D. Lewis in June 1977 BYTE. Perhaps I am not the typical BYTE reader because I have acquired over the last several months the Texas Instruments Models SR-51, SR-56, SR-52 and PC-100A. The last is a printer for the SR-56 and SR-52. If one removes the batteries from these calculators, the appearances of the battery compartments are similar (but quite different from that for the SR-50). For all, in addition to the battery terminals, there is a 12 pad connector strip as pictured by Lewis.

I have been tempted for months to put the SR-51 onto the PC-100A just to see what would happen. I was inhibited from this by two facts: The first is that the compartment on the SR-51 is shallow as compared with the others, and second the PC-100A has a position switch marked SR-52, SR-56, "other." After Lewis' letter I said, "I'll do it," and jammed the SR-51 onto the printer. I say "jammed" because it did not go on quite as smoothly as either the SR-56 or SR-52. Naturally I chose the "other" position for the PC-100A selector switch.

The SR-51 is not an "other" device and a next test showed it was not an SR-56. A third shows the SR-51 to be an SR-52 as far as the printer is concerned. And, talk about hidden gold, the results were fantastic (see reproduction of a printout). Before I discuss them let me point out that the inner workings of the SR-56 and SR-52 are very different as viewed by the PC-100A and things go to hell if the PC-100A selector switch does not match the calculator.

Texas Instruments is very inconsistent in its various machine features and their modes of operations as compared with those from Hewlett-Packard, thus the SR-51 has many functions not offered on the SR-52 and a few not offered on the SR-56. But, surprise, the PC-100A knows about them (unless it is the SR-51 which has more goodies than have been announced). In any case, when the PC-100A is adjusted for the SR-52 but actually gets the SR-51, the printer works as one would hope it would. Actually it works better than one would reasonably expect. One can press the PC-100A PRINT button to print the displayed value at any time, but the operation is most interesting when the PC-100A is in the TRACE mode; here one gets a complete audit trail of all operations and results from operations. The operations printed out include SINH, COSH, SLOPE, INTC and other functions which do not even exist on either the SR-56 or SR-52. Where does this information come from? Will some Texas Instruments engineer please tell us?

The many owners of the SR-51 know that it has the most preprogrammed functions and built-in conversions of all the pocket calculators built by Texas Instruments to the present time. Now that the price for the PC-100A printer is dropping, many of these owners might wish to make a spiffy equipment upgrade by buying one for their SR-51. And, of course, the printer will be usable for a subsequent SR-56 or SR-52. Note: SR-51A might be different from the SR-51.

Webb Simmons
1559 Alcala Pl
San Diego CA 92111

To carry this research further, we need a reader with an SR-51A to try the trick described here. Chances are that the trick will still work, since Texas Instruments probably was consistent in one respect: the design programmers most likely used a common coding scheme for all the arithmetic and transcendental functions of the calculator just to minimize the probability of software error.

POPULAR COMPUTING REPLUGGED

We do appreciate the plug for Popular Computing in Peter Travisano's Clubs and Newsletters column in your...
June 1977 issue, and no doubt it will trigger a flood of inquiries. All the subscription information was meticulously correct.

But where did the other material come from? We have produced 52 issues to date, with exactly two games all told. "Schwartz on Calculators" was one article; hardly a monthly feature. And except for one issue devoted to the Altair, there has never been any information about the micro field. In fact, we rather avoid printing any news at all, with the objective of making our issues sort of timeless. Gee, other than that, everything was correct.

*Popular Computing* is for people who want to compute, and it contains lots of computing problems, articles on how to compute and a series on the Art of Computing.

We'll explain all this to those who write, since we don't want anyone subscribing under a misconception.

Just think of the fun I could have describing BYTE in the same way!

But we do like being mentioned, very much.

Fred Gruenberg
*Popular Computing*
POB 272
Calabasas CA 91302

Oops! Your letter should correct things a bit.

**COPE OUT**

About computers there is no question that the coming of the chip computer heralds a new age. Science fiction writers have long foretold of the personal and personable computer. It is becoming fact. Yet, we who are about to enter the copse must needs reflect upon our passage first, and not as an afterthought.

Your rebuke of Mr. Garner's argument, (Ask BYTE, May 1977) was thoughtless and without point. Mr. Garner correctly points a finger in the direction of the dike that leaks: our technology. He questions the moral quality of a course of action that is new and untold. And you, obviously lacking human standard of value, computers and robots are not highly desirable technology. I do not argue that human beings are the measure of morality; but I must contend that automation of men and physical drudgery is not necessarily ethical. If I may, I shall submit an analogy. A man who thinks to build a box by hand; the more versatile person might use either method of construction depending upon mood and ends other than physical creation of a particular box.

**COMMENTS ON CERTIFICATION OF TAPES**

Judging from David Allen's article on saturation recording, personal computing is about to discover some of the benefits of professional digital recording techniques, of which high storage capacity and faster access time are but a few. Mr. Allen may be optimistic, though, in stating the cassette used need not be certified. Of course, an uncertified tape will work if there happen to be no dropouts in a critical area, but are you prepared to trust a laboriously debugged program or critical data to an uncertified cassette? If you can afford to gamble the recovery time and effort against the small additional cost for a certified product it may not matter; but most people, especially those using their systems in a commercial environment, would find the certified cassette well worth the investment. Some of the newer cassette subsystem suppliers, such as Microdesigns, have also discovered the desirability of using a certified cassette. Incidentally, most certified cassettes are usually more.

I think (if I may be so bold) that Mr. Garner poses this question to each of us. We strive, I no less that others, to produce artificial intelligence. Is it right that this intelligence supplant human intelligence? And is the definition of drudgery to be equated with that of effort? The man who built (euphemistically speaking) the box did not have to reason to build it. His mind was not exercised, nor were his hands. He needed only a rudimentary education and rudimentary expectations to build a box. If he worked in a factory he probably didn't even fully know how to use that wonderful tool which supplanted his own intelligence, and most likely his pride in himself.

In closing I shall ask a question posed once before. Is the definition of drudgery to be equated with that of effort? Take care in your answer, if any, for there are no easy solutions which you might glibly offer.

Nelson E Ingersoll
1620 Carlisle NE Apt C
Albuquerque NM 87110

*We'd have a boring world indeed if everything remained constant (and incidentally, regimented) by superstitious fears of the unknown. Progress in technology, good with the bad. Is a living manifestation of a viable sentient species, the human race. Attempting to build the dike around technology in the first place is probably one root cause of your metaphorical leak. I claim it is no less a mark of craftsmanship to give the robot system specifications of one box or many boxes to build than it is to design and build the box by hand; the more versatile person might use either method of construction depending upon mood and ends other than physical creation of a particular box.*

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Robert H. Katzive, Product Manager - Marketing Information, Terminals Corp., 323 Sequel Way, POB 9077, Sunnyvale, CA 94086

MODES OF EXPRESSION IN ENGLISH IDIOM

Please don't be intimidated by the likes of Lawyer Welborn, "Windmill Jousting Department" in your June Letters. He's obviously too intelligent to claim that BYTE has no female readers, since that argument could be knocked down by one counterexample, and law school has taught him the fallacy of strict majority rule ("Let's vote on what everybody's favorite color is"), so he resorts to ridicule and appeals to his own definition of reason. But it's easy enough to tell where his heart is when he categorizes your readers as "gals" and "men." Why not "women" and "guys?"

I'll admit that there are places where a simpler construction could be used. For example, in BYTE'S Bits, the phrase "the user plays the record on his or her phonograph" could have been tightened up by substituting "a phonograph." But it never struck me that you folks were on any kind of "crusade" (unless that's how you define good manners). All that I've noticed is that yours is just about the only technical publication I can read without wincing every so often.

Carol J. Pruitt, 1621 18th St NW, Cedar Rapids, IA 52405

PATCHING INFO NEED

In your write-up of SWTPC 4 K and 8 K BASIC in the What's New? column on page 72 of January 1977 BYTE, the following sentence appeared: "These packages should work on any 6800 computer system with MIBUG." I have discovered that the key word in that sentence is "should.

My system is based on a Motorola MEK6800D1 Evaluation Kit with MIBUG, and neither 4 K nor 8 K BASIC will "play" on it. I have observed one problem with 8 K BASIC: by changing the instruction at hexadecimal address 08D0 to 7E 0841, the program jumps around some unwanted PIA initialization routines. Now I can execute the commands and some simple programs, but the IF...THEN and FOR...NEXT statements, along with most of the functions, don't work.

If anyone has successfully modified SWTPC 8 K BASIC for a Motorola Evaluation Kit I would appreciate hearing from him or her.

Paul E. Pennington, 1503 Park Av, El Dorado KS 67042

The "should" evaluation was made based on the design of the SWTPC computer system, which has a fairly straightforward adaptation of the Motorola design information. However, as we have found from assembly of an MEK-6800D1, the ROM which comes with that system is for "MIBUG," a new monitor which differs from MIBUG in several key areas.

SR-52 INFORMATION SOURCE

The BYTE readership may be interested to know that there is now an SR-52 Troubleshooting Guide available for $12 plus local tax plus $1 shipping from Texas Instruments, POB 53, Lubbock TX 79408.

The artificial intelligence and robotics articles in the past couple of issues were great!

David B. Lamkins, DBL Electronics, 502-12 Sherman St, Canton MA 02021

ATTENTION AUTHORS:

Please get some of your contributors to write a few articles on trouble-shooting a nonfunctioning microcomputer. Those articles should be pitched to the level of the poor fellow with limited electronic troubleshooting experience who bravely assembled a microcomputer kit only to have it quit working on him. Don't let them say check to see if the assembly was done correctly. The kit documentation already says that. Have them start with the assumption that the assembly has been checked or that the computer was operating and then failed.

Some sample questions that the articles should answer:

- What instruments are necessary and what additional ones are nice to have?
- How does one use the schematics to determine what signals and voltages will be found at various points in the circuits?
- How can one narrow the malfunction down to a particular part of the computer?
- Does one need a stock of replacement parts to use in substitution tests and, if so, how does one determine which ones?
has been around for some time due to the widespread use of the IBM System 360 and its cousins. An earlier version with similar media, the 1311 drive, should also prove useful to homebrewers.

ARTICLES WANTED

Would appreciate article on use of small computer (Altair 8800b) for routine office tasks such as bookkeeping, payroll, taxes, and also on engineering calculations (lighting, heat loss, heat...
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Circle 263 on inquiry card.
design. It's also the story of a labor of love. His pictures and descriptions lend the little fellow personality. I chuckled as I read the article, thinking of Tom Paxton's song, "The Marvelous Toy."

The words of this fanciful song, written well over a decade ago, seem to describe Newt. Here is the song; perhaps you'll agree:

When I was just a wee little lad
Full of health and joy,
My father homeward came one night
And gave to me a toy.
A wonder to behold it was
With many colors bright.
And the moment I laid eyes on it
It became my heart's delight.
The first time that I picked it up
I had a big surprize,
For right on its bottom were two big buttons
That looked like big green eyes.
I first pushed one—then the other
Then I twisted its lid,
And when I sat it down again
Here is what it did . . .
It went zip when it moved,
Bop when it stopped,
Whirrr when it stood still.
I never knew just what it was
And I guess I never will.
It first marched left, then marched right
Then marched under a choir.
And when I looked where it had gone
It wasn't even there.
I started to cry and my daddy laughed
For he knew that I would find,
When I turned around, my marvelous toy
Achuggin' from behind.
Now the years have gone by, too quickly it seems,
I have my own little boy.
And yesterday I gave to him
My marvelous little toy.
His eyes nearly popped right out of his head,
He gave a squeal of glee.
Neither one of us knows just what it is,
But he loves it just like me.
It still goes zip when it moves,
Bop when it stops,
Whirrr when it stands still,
I never knew just what it was,
And I guess I never will.

Is Ralph Hollis a pseudonym for Tom Paxton, or is Tom Paxton a pseudonym for Ralph Hollis?

J Tom Badgett
1917 Washington St
Bluefield WV 24701

"The Marvelous Toy" by Tom Paxton. © Copyright 1961, Cherry Lane Music Company. Used with permission. All rights reserved. (For interested readers, this song is available on an Elektra recording, The Complete Tom Paxton, 7E-2003.)

MONITOR?

I recently received my first issue of

Circle 264 on inquiry card.
BYTE. Congratulations! This is one of the finest computer hobbyist oriented magazines I have read to date.

I will come right to the point of this letter. I am looking for a TV monitor that has a 9 inch diagonal screen, perhaps in kit form. I would also be interested in just the CRT and associated electronics so I could design my own terminal cabinet.

All of the monitors (assembled) that I have seen have been over $100. My question is: why buy a $125 monitor and watch nothing but your computer readout, when you could buy a 9 inch TV and get the networks also?

Is there anything that BYTE is aware of that might fill my needs?

Rick Downs
205 Shelton Beach Rd
Apt 53
Saraland AL 36571

Look on page 144 of The Best of BYTE Volume 1 (see the BITS advertisement in this issue) for a reprint of Kenneth Barbier’s article “The Ignorance is Bliss Television Drive Circuit.”

A LETTER OF THANKS TO RALPH BURHANS AND ASSOCIATES

Many thanks for the series on Omega navigation. I have been experimenting with analog Omega devices for years; now, thanks to your series, I have embarked on a digital version.

I have coded the phase lock loop program for the 6800 already. Currently I am developing a simulator to drive it for test and evaluation. Let’s have more on digital radio receivers and coherent CW.

Roy Murphy
System Development Corporation
REM 500
Macara CA 94086

APL CHARACTER GENERATION INTEREST

In reading February 1977 BYTE, I noticed a letter of interest dealing with character ROMs for APL. At the end of the letter, you said something about creating a demand. I’d like to say that I would be willing to purchase two or three such generators, but not five.

Thomas Curley
POB 69
Morrisville NY 13408

A note of interest regarding visual representations: systems with re-definable programmable memory buffer areas for character generation will prove quite useful to APL hackers. Two examples are currently on the market: the Naval computer first seen in BYTE in the June 1977 issue, and the ECD Micromind computer which has been advertised since January of this year. With such redefinable graphics sets, there
is no need to have a ROM at all; one simply creates a table in software with the needed definitions, and changes the definitions "on the fly" if the total number of symbols exceeds the re-definable character generation buffer memory capacity.

ATTENTION AUTHORS:
16 BIT PROCESSOR INFORMATION NEEDED

I have every issue of BYTE and I feel that it's the best magazine going in the field. I'm presently stationed in Korea, and I repair computers for the Army. I have a delay of a month in receiving my issues, since I have the family send them to me from home. This keeps them from disappearing before I get them, and it gives them an excuse to write. But, to the point.

I find that there is a definite lack of information in the 16 bit processor area. Although there has been a 16 bit chip or two described, the information is very general and, with the exception of the PACE chip, they are hard to find. I prefer to use the PACE chip and associated family of circuits, but any 16 bit chip will suffice.

Examples of information for those wanting a 16 bit system might be:

1. Are there any kits using the 16 bit chips available? [Yes: A system with the Texas Instruments 9900 has been seen in two forms to date.]
2. Since the majority of the peripherals are set up for use with 8 bit processors, can they easily be interfaced with the 16 bit ones? (A logical approach would be to divide the 16 bit word into two 8 bit words, putting the upper half to the device first, then the lower.) [Yes: by emulating the 8 bit bus, as you suggest.]
3. With all the readily available memory for 8 bit processors, can they be used? (Again, with each board using half a 16 bit word?)
4. What software is available? [It varies.]
5. More articles on 16 bit systems are needed, especially those pertaining to the problems of constructing a system.

SP/5 Bernard J Steeves
047-46-6241
169th Sig Co
APO SF 96218

RCA 1802 BASIC WANTED

I am running a homebrew CDP 1802 for which I have not seen an edition of BASIC. If there is such an edition, please let me know.

David Fansler
710 Ward St
Graham NC 27253

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David Fansler
710 Ward St
Graham NC 27253
to you. The formulas below will implement their respective functions.

By using the TAN and SQR functions, the sine, cosine, secant and cosecant may be found. The formulas are as follows, with $x$ in radians.

\[
\begin{align*}
\sin(x) &= \frac{\tan(x)}{\sqrt{1 + (\tan(x))^2}} \\
\cos(x) &= \frac{1}{\sqrt{1 + (\tan(x))^2}} \\
\sec(x) &= \sqrt{1 + (\tan(x))^2} \\
\csc(x) &= \frac{\sqrt{1 + (\tan(x))^2}}{\tan(x)}
\end{align*}
\]

Note: could cause a division error when $x$ approaches 0.

From the ATN and SQR function, the Arc-sine and Arc-cosine may be calculated.

\[
\begin{align*}
\arcsin(x) &= \text{ATN}(x/\sqrt{1 - x^2}) \\
\arccos(x) &= \text{ATN}(\sqrt{1 - x^2}/x)
\end{align*}
\]

For values of $x < 0$, normalize by adding $2\pi$ to $x$.

For still other formulas, try looking in any engineering and math handbook. TAN and SQR can often be found in such books expressed as series approximations which can be expressed even in limited 16 bit integer BASICS.

---

**On Finite State Machines and Their Uses**

Gerald Owens  
POB 9038  
Tucson AZ 85720

The two articles by M Wimble in the May and June 1977 *BYTEs* entitled "Artificial Intelligence, An Evolutionary Idea" provided much food for thought for me, as well as many others I'm sure. If I had a personal computer, I'd try a crack at the earthquake prediction model.

However so much that I hate to dampen anyone's spirits, I must point out a basic limitation to what the system that Wimble outlines has. The implementation is based on what is called a deterministic finite state automation. It's finite, since there are only so many states, and it's deterministic, since when one goes from one state to the next there is no ambiguity or uncertainty as to which state to go to next. Certain properties can be proved about what a finite state automation can do and what it can't do.

First, what it can do. Recurrent patterns are its forte. Given a recurrent pattern, the
method Wimble outlines will construct a finite state automaton that will predict what will happen next.

Now, what it can't do. The deterministic finite state automaton cannot recognize, or act upon, all computer languages. You cannot use the method to teach your computer BASIC and expect it to digest your Star Trek program. The language level is of a higher sort than what a finite state automaton can recognize. You should have somebody write up an article on the four levels of grammar, as outlined by Noam Chomsky, and the machines used to recognize sentences in those grammars. I may suggest that there are more fruitful lines of endeavor (like perpetual motion machines or faster than light travel) than teaching a deterministic finite state machine a language.

Comments on Floating Point Representation

Sheldon Linker's article on "What's in a Floating Point Package?" [page 62, May 1977 BYTE] needs a refinement that might make a difference.

He states that the base of the exponent controls the dynamic range of the arithmetic. What he did not state is that the base also effectively controls the precision. The bigger the base, the greater the dynamic range and the poorer the precision. And this has nothing to do with stealing bits from the mantissa. Choosing the base is not an arbitrary matter of picking a hefty dynamic range.

The problem is illustrated when you attempt to add a single lowest order bit to a mantissa that has all the bits turned on. You can either up the exponent by 1 and renormalize (which is the procedure I read into Linker's article) or you can just not perform the addition. If the exponent is based on 2, then increasing the exponent causes a change in magnitude equal to the change that would be found if a bit were added to any other number. If the base is 16, the change is much greater. The net result is that the precision is much closer to six digits rather than seven.

Another way to look at it is to acknowledge first that all integer arithmetic takes place in finite steps; there are gaps between the numbers. Next, observe that the machine doesn't, through processes unknown, convert over to a continuous number machine when floating point is implemented. With floating point we just get the option of choosing the gap size as well as scaling the numbers.

The difference between base 2 and base 16 may seem trivial to the novice, and indeed must have seemed trivial to enough of the right people at IBM when they went hexadecimal. With base 2 you get seven digits throughout the dynamic range. With base 16 you seem to get seven digits most of the time, but are bound to get six now and then. In fact, with 2 and 16 as bases you get four and three digits of precision if your computations have any sophistication (like multiplication and summing) at all. The exact results, of course, depend on the numbers involved, but if you're interested in floating point and want precision, then base 2 cannot be beat. But remember that if you go double precision, then the range will probably be extended and you will have to extend the exponent field.

As an historical note, I heard somewhere that IBM put the exponent up front just to be different from Burroughs or Univac who had the exponent on the right.

R A Baker
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Nov 28, 29, 30, (Dec 1, 2)* (Boston, MA
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Conducted by
Peter Travisano

Space Coast Microcomputer Club
The second edition of the Space Coast Microcomputer Club Newsletter is out,
with an interesting feature by Paul Rainosek, a tabulated comparison of some of the
different microprocessor chips available. The various advantages and disadvantages
are clearly listed. The comparison includes Intel 8080, Motorola M6800, MOS Techno-
logy 6502, Fairchild F8, Signetics 2650, and Cosmac 1801. To find out more about
the Space Coast Microcomputer Club contact Ray Lockwood, 1825 Canal Ct,
Merritt Island FL 32952.

West Virginia Computer Society
We hadn’t heard anything from the West Virginia Computer Society in
quite some time. Their newsletter Oscilla-
tions came in a few days ago to inform
us that they are alive and very well at 167
Iroquois Trail, Ona WV 25545.

Indian River Computer Society, Melbourne
FL
The Indian River Computer Society meets every Thursday at 7 PM in room 621
of the Science Tower on the campus of FIT, Melbourne FL.
Membership is open to the general public.
For more information call Bill Carter at
(305) 773-7837, or Frank Canova at (305)
724-4751, or write: Indian River Computer
Society, FIT Electrical Engineering Dept,
Country Club Rd, Melbourne FL 32901.

Montreal Area Computer Society
Over the past year the Montreal Com-
puter Society has grown from 12 members
to over 90. The club meets once a month,
usually on the second Tuesday evening of
the month, at Vanier College, 5160 Decarie
Bldv. For further information contact John
Erikson, the club president at (514) 932-
2344 or write: Montreal Area Computer
Society, POB 613, Stock Exchange Tower,
Montreal, Quebec, CANADA.
Indianapolis Small Systems Group

The Indianapolis Small Systems Group meets on the second Tuesday of each month at the Union Building, Medical Center, IUPUI. Recording secretary T O Whitaker has voiced a strong desire to apply small computers systems to practical business and technical applications. Among such applications is a computerized "newspaper" now under development which would allow the user to receive news over the telephone via a modem. If you have experience with this type of application or would like to find out more about the organization, contact the Indianapolis Small Systems Group at 4719 Squire Dr, Indianapolis IN 46241, or call (317) 241-7396.

IEEE Computer Society

The IEEE Computer Society is one of the most vigorous wings of the Institute of Electrical and Electronics Engineers, the world's largest professional engineering society. Computer magazine is published by the computer society; editor and publisher True Seaborn and staff produce this high quality technical magazine every month and cover the microcomputer scene in some detail.

Useful features of the magazine include a monthly column listing all of the new integrated circuits which appear each month from the various manufacturers, and the Repository, a listing of new technical papers about computers. The serious experimenter would do well to consider joining this important organization.

We received the following from Merlin Smith, president of the IEEE Computer Society:

The IEEE Computer Society is really a subset of a much larger organization—the Institute of Electrical and Electronics Engineers, whose antecedents reach back into the 19th century and whose history is closely connected with the evolution of electrotechnology in the US. The IEEE, with 180,000 members worldwide, is organized geographically into regions and sections. It is organized by technical interest areas into groups and societies, the largest of which is the Computer Society, with 26,000 members.

Like the IEEE, the Computer Society is mainly in the business of dissemination of technical information through conferences, tutorials, workshops, periodicals, and other publications. Its major conferences are COMPCON Spring, held annually in...
San Francisco, COMPCON Fall, held annually in Washington DC, and COMPSAC, held annually in Chicago.

The major periodicals of the Computer Society are the scholarly Transactions on Computers, Transactions on Software Engineering, and Computer, which appeals to a broader readership. Of specific interest to computer hobbyists and personal computing enthusiasts, Computer has recently inaugurated a new section, "Microsystems," which carries papers and articles on the whole field of small scale computing.

The Computer Society has chartered some 18 technical committees corresponding to the various technical specialties within the field of computer engineering. Included among them is the Technical Committee on Minis and Micros, which is of special interest to the personal computing community. The Mini/Micro TC has inaugurated a series of microcomputer workshops (see May Computer); these likewise may be of interest to your readers.

The traditional orientation of the IEEE Computer Society has been to the computer designer or the sophisticated computer user, and our membership qualifications entail fairly specific academic and/or professional requirements. However, computers are becoming increasingly "friendly to the uninitiated," and the lines separating the professional from the nonprofessional are tending to blur, at least in some areas. One way for a BYTE reader to find out whether the Computer Society has anything to offer is to pick up a copy of Computer at one of our conferences or tutorials, at one of our local chapter meetings, or even at the local computer store.

Another way is to write our Publications Office at 5855 Naples Plz, Long Beach CA 90803, and request a membership application.

Micro-8 Computer Club, Lompoc CA

Micro-8 is a loosely organized, nonhierarchical, extremely enthusiastic group. Originally, it was known as the Central Coast Computer Users Group but recently the name has been changed to perpetuate the memory of the pioneering, now defunct Micro-8 Newsletter. The membership includes Hal Singer, former editor of that publication.
Drop in sometime. Visitors are welcome. The club usually has a number of systems on display and lectures by club members are not infrequent.

You can contact Micro-8 at 2497 Lompoc-Casmalia Rd, Lompoc CA 93436, (805) 735-1023. Meetings are held on the third Wednesday of each month at the Cabrillo Computer Center, 4350 Constellation Rd, Lompoc CA, at 7:30 PM.

BAMUG: Bay Area Microprocessor Users Group

The Bay Area Microprocessor Users Group meets on the first Thursday of each month at the Hayward Regional Occupational Center, Hayward CA, at 7 PM.

Like many hobbyist clubs, BAMUG is looking for microcomputer oriented lecturers willing to share their knowledge for little or no fee. Literature from microprocessor manufacturers is especially welcome. Contact BAMUG, 1211 Santa Clara Av, Alameda CA 94501, (415) 523-7396.

Amateur Computer Society of Columbus OH

ACSC meets the first Wednesday of every month at the Center of Science and Industry beginning at 7:30 PM. Dues are $5 per year and include a monthly newsletter I/O.

To get in touch with the Amateur Computer Society of Columbus, write: Fred Hatfield K8VDU, Computer Data Systems, 1372 Grandview Av, Columbus OH 43212, (614) 486-3347.

New England Computer Club

New England hobbyists who haven’t done so already should investigate the advantages of membership in a first class computer club, the New England Computer Society, or either of its two affiliates, the Southern New England Computer Society and the New Hampshire Computer Society. Contact Robert M Tripp, POB 3, S Chelmsford MA 01824. A newsletter, The Computerist, is available at the same address by subscription at $6 per year or 60 cents for a single copy.

Crescent City Computer Club

Crescent City is an active club, sponsoring monthly lectures, classes in BASIC, Assembly Language, and PL/M. The club also includes homebrew and calculator groups. Meetings are held at 8:00 PM at the Science Building, University of New Orleans, second floor, on the second Friday of each month. Write POB 1097, New Orleans LA 70122 or call (504) 722-6321.

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Walsh Functions:

A Digital Fourier Series

Figure 1: The Walsh Functions WAL(0) Through WAL(15). The fact that Walsh functions lend themselves to digital generation is evident in the nature of the basic wave forms. The notations SAL and CAL emphasize the resemblance of Walsh functions to the Fourier series trigonometric functions SIN and COS.

Using a mathematical technique called Fourier analysis, it is possible to build arbitrary wave forms by adding together various "components."

While a full appreciation of the inner workings of the Fourier series requires a knowledge of advanced mathematics far beyond the capacity of many persons interested in electronics, that in no way deters them from using the concepts or even simplified portions of the math in practical applications. Even beginners are aware that wave forms can be broken into a set of harmonics and that a set of sinewaves of integer multiple frequencies can be summed to build up a complex wave form. In a like manner, Walsh function concepts can be put to work once a few fundamental ideas are mastered. A key to generating complicated sounds in computerized music and voice outputs is the ability to generate arbitrary wave forms from digital codes.

In these days of digital computers, a person familiar with Fourier concepts might ask the question: Is it possible to build up any wave form out of a sum of square waves of some type? Such a system would be ideal for use with digital logic. This question has been answered in the affirmative by the German mathematician H. Rademacher, not in 1972 or 1962, but in 1922. His set of square waves, called "Rademacher functions," consists of a fundamental square wave of 50% duty cycle at some frequency
Fourier series are used to create wave forms as the sum of pure sine and cosine waves at selected frequencies; this leads to the obvious question: Is it possible to use a similar mechanism which builds a complex wave form out of digital wave forms with sharp edges?

plus harmonics of square waves of 2, 4, 8, 16, 32 and higher powers of two times the fundamental frequency. A deficiency of this system, however, is that it is not possible to generate any arbitrary wave shape from only a simple sum of these square wave harmonics.

Also in 1922, J.L. Walsh presented his independently developed system to the American Mathematical Society. His system was later shown by the Polish mathematician Kaczmarz in 1929 to include the Rademacher system as a subset of the Walsh complete set of orthonormal functions, which, in plain English, says that some of the Walsh functions are square waves and that if all Walsh functions are allowed (you may not need to use them all, however) then any arbitrary periodic wave form can be built up by adding them together in a manner totally analogous to sine wave summation in Fourier series.

Interest in the engineering applications of Walsh functions was sparked by an article in the IEEE Spectrum by Dr H. F. Harmuth of the University of Maryland in 1968 and is continuing because of the suitability of Walsh functions to generation by digital systems.

The fastest way to understand what Walsh functions are is simply to look at a picture of some wave forms. Figure 1 shows the Walsh functions WAL(0) through WAL(15). It is seen that WAL(0) is merely a DC level which we will usually ignore in practical applications since offsets are easily handled by other means and that WAL(1), WAL(3), WAL(7), and WAL(15) are really the square wave Rademacher functions. You will note that in addition to the WAL(n) designation, the functions are also labeled with CAL or SAL. These labels are also commonly used and are acronyms for the terms Cosine WALsh and Sine WALsh by analogy to Fourier analysis. In short all WAL (even n) are called CAL and all WAL (odd n) are called SAL. CAL and SAL are also numbered but the numbers do not correspond to the WAL designation though they are easy to figure out. Also by analogy to Fourier analysis, a Walsh spectrum is called a sequency spectrum as opposed to a Fourier frequency spectrum.

Enter Mr Gray and His Code

However, knowing what Walsh functions look like and knowing how to generate them digitally are two different things. It is clear that the generation of WAL(1), WAL(3), WAL(7), WAL(15), etc., is a snap since they are simple square waves. A string of flip flops does the job, as shown in figure 2. The generation of the remaining functions, while a little more difficult, is not impossibly complex once the mathematics is shaken down into a few simple rules:

1. To generate WAL(n), first write the number n in Gray code. Gray code is a modified binary code having only one bit changing at a time when going to the next higher or next lower number. A table of Gray code numbers is shown in table 1; and with a little

In translating a mathematical summation into a physical circuit, the operational amplifier provides the summing element and the resistors from inputs to the summing node form the coefficients of the component signals.

Walsh functions are the digital answer to sines and cosines used in Fourier analysis.
sistors of values derived from the Walsh function approximation of coefficients and the output of sine wave? Calculate the Walsh coefficients using a tabulator method. Then wire in the circuit will be a step function. So you want to produce a sine wave? Calculate the values at 16 evenly spaced locations in the period, then use these values to calculate the Walsh coefficients using a tabulator method. Then wire in resistors of values derived from the Walsh coefficients and the output of the circuit will be a step function approximation of the desired sine wave.

Table 1: Gray Code Bit Patterns for the Walsh Functions WAL(0) Through WAL(31). The corresponding SAL and CAL notation of each WAL function is shown down the right hand column of the table.

<table>
<thead>
<tr>
<th>WAL FUNCTION</th>
<th>DIGIT</th>
<th>WAL(31)</th>
<th>WAL(15)</th>
<th>WAL(7)</th>
<th>WAL(3)</th>
<th>WAL(1)</th>
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<tbody>
<tr>
<td>WAL(0)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>WAL(1)</td>
<td>1</td>
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<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
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<td>WAL(2)</td>
<td>2</td>
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<td>0</td>
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<td>1</td>
<td>0</td>
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<td>3</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
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<td>4</td>
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<td>0</td>
<td>1</td>
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<td>0</td>
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<td>1</td>
<td>1</td>
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<tr>
<td>WAL(6)</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>WAL(7)</td>
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<td>1</td>
<td>0</td>
<td>1</td>
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<td>0</td>
<td>0</td>
<td>1</td>
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<td>WAL(9)</td>
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<td>1</td>
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<td>0</td>
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<td>1</td>
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<td>0</td>
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<td>1</td>
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<td>WAL(12)</td>
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<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
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<tr>
<td>WAL(13)</td>
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<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>WAL(14)</td>
<td>14</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>WAL(15)</td>
<td>15</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>WAL(16)</td>
<td>16</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>WAL(17)</td>
<td>17</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
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<tr>
<td>WAL(18)</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
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<td>WAL(19)</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
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<td>1</td>
<td>1</td>
<td>1</td>
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<tr>
<td>WAL(21)</td>
<td>21</td>
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<td>0</td>
<td>1</td>
<td>1</td>
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<td>WAL(22)</td>
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<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
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<td>WAL(23)</td>
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<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
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<td>WAL(24)</td>
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<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>WAL(25)</td>
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<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
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<td>WAL(26)</td>
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<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>WAL(27)</td>
<td>27</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>WAL(28)</td>
<td>28</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
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<tr>
<td>WAL(29)</td>
<td>29</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
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<tr>
<td>WAL(30)</td>
<td>30</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
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<tr>
<td>WAL(31)</td>
<td>31</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

So you want to produce a sine wave? Calculate the values at 16 evenly spaced locations in the period, then use these values to calculate the Walsh coefficients using a tabulator method. Then wire in resistors of values derived from the Walsh coefficients and the output of the circuit will be a step function approximation of the desired sine wave.

study, the pattern can easily be extended to any value.

2. Starting with the least significant bit, assign a square wave Rademacher function to each bit. Assign WAL(1) to the LSB, WAL(3) to the next, WAL(7) to the next, etc.

3. Any Rademacher function whose bit is 0 is not used. Those whose bits are 1 are combined by modulo 2 addition, which is to say by exclusive OR gates to give the Walsh output of that order.

4. All Walsh functions must begin positive so that the composite Walsh output may need to be inverted depending upon how many exclusive OR gates were used to produce it.

A couple of examples are shown in figure 2 and a complete generator producing all Walsh functions from WAL(1) through WAL(15) is shown in figure 3.

It should be noted that although a Walsh function is mathematically defined as going from +1 to −1, and it is possible to obtain positive and negative swings with CMOS logic with positive and negative supplies, in practice little is gained by going this route since all that is involved is a DC offset which is easily handled by the summing amplifier. Thus, 0−5 volt TTL logic outputs are fine.

Now that a set of Walsh functions has been generated, it only remains to add them in a summing amplifier with appropriate magnitudes and signs to simulate any wave form with a stair step approximation. The general expression of a Walsh function representation is a summation analogous to that found in Fourier analysis:

\[ X(t) = \sum_{i=1}^{\infty} \left( A_i \cdot \text{SAL}(i) + B_i \cdot \text{CAL}(i) \right) \]

where \( A_i \) and \( B_i \) are weighting constants which correspond to the resistors used in the summing amplifier inputs. The size of the steps and the number present will be determined by how many harmonics are combined. The more you use, the smaller and more numerous the steps, hence the better will be your approximation to your original wave form. The determination of these combining coefficients from the wave form desired requires a bit more detailed consideration.

Wave Form Synthesis

Before proceeding any further into the theoretical aspects of Walsh applications, a review of what we are attempting to do and how we intend to do it will help get our feet on solid ground. The device we wish to build using Walsh functions could be called "a square wave to arbitrary wave form converter." It will be a circuit into which you put a square wave of some frequency and out of which comes a periodic analog signal with a frequency related to that of the input wave (perhaps some submultiple) and a wave form that can be made to take any shape desired by adjusting a set of controls, switches or internal resistors. With such a device, digital logic could be used to synthesize a frequency and the converter could then be set to produce a sinewave for use in standard applications, or given sufficient accuracy of conversion, a computer could be made to talk or even sing. Both have been done by engineers working in this area.

The converter consists of two parts: The first is the digital expander which expands the input square wave into a variety of
digital wave forms, and the second is the analog combiner which adds up these wave forms to produce the periodic analog output. The expander is, of course, the Walsh generator shown earlier and the combiner will be discussed below.

All of the Walsh outputs will be fed into the summing junction of an operational amplifier, but they will not have the same strength or sign. It is the strength and sign of each component which will determine the net analog output so that once we have chosen the analog output we desire, the relative strength and sign of each Walsh harmonic must be calculated from that desired wave form. Once these values are known, a negative sign can be handled with a digital inverter and the magnitude by the choice of the resistor value into the summing junction. The net output will then be a stair step approximation to the desired output which can then be made more perfect by low pass filtering to smooth the wave shape.

Theoretically, the calculation of the coefficients from the analog wave form desired involves complex operations with the integral calculus; but it turns out that it is possible to shortcut the high powered math by starting, not with the analog signal, but rather with the stair step approximating function itself. This function can be easily determined by eyeball or by just taking the height of each step to be the value of the analog output at the center of each time interval. Figure 4 shows two examples: a linear ramp and a sinewave with 16 step approximations. The height of each step is shown.

Before proceeding to an actual calculation we will give some time and work saving rules, which are illustrated in figure 5.

1. The waveform to be synthesized must be repetitive (as in Fourier synthesis), although it is easy to start and stop at any point by control of the digital input.

2. It is especially advantageous to use $2^n$ steps in one period as this gives an automatic cutoff to the number of Walsh harmonics required

   Thus: With a 4 step output no functions beyond WAL(3) are required

   " 8 " WAL(7) "

   " 16 " WAL(15) "... etc.

3. If the coefficients for a higher order...
Figure 4: By picking a series of weighting constants for each Walsh function term, the outputs of figure 3 can be summed by an operational amplifier to produce arbitrary waveforms. Here are examples of the ramp and sine wave approximations generated by the Walsh function method. The smooth curve is the desired one in each case, obtained by filtering the output of the summing amplifier.

approximation are calculated (say 16 steps), and a less accurate approximation can be used (say 8 steps) then one only need disconnect WAL(8) through WAL(15) since the lower order coefficients will have the same value in either case (or nearly so). This effect is demonstrated in the sine generator circuit.

If your waveform to be synthesized possesses certain symmetries or can be made to do so by a DC baseline shift, many Walsh component coefficients will be zero which will not only simplify the calculations, but the circuitry as well.

4. If the waveform to be synthesized is even, which is to say that any value that the function takes to the left of center is the same as the value an equal distance to the right of center, then only CAL functions will be used and all SAL coefficients will be zero.

5. If the waveform is odd, or can be made so by a baseline shift, then only SAL functions will be used and all CAL coefficients will be zero. Here any value to the left of center equals minus the value to the right of center.

6A. If the waveform is even as in point 4 above and in addition it is even about the 1/4 point, then only CAL(k) where k is an even number will be present and all CAL(k) where k is an odd number will be zero.

6B. If the waveform is even as in point 4 above and in addition is odd about the 1/4 point, then only CAL(k) where k is an even number will be present and all CAL(k) with k an even number will be zero.

7A. If the waveform is odd as in point 5 above and in addition is even about the 1/4 point, then only SAL(k) where k is an odd number will be present and all SAL(k) where k is an even number will be zero.

7B. If the waveform is odd as in point 5, and in addition is odd about the 1/4 point, then only SAL(k) with k an even number will be present and all SAL(k) where k is an odd number will be zero.

In the calculations that follow it will also be observed that if a waveform is even or odd, the signed sums of the step values need only be calculated for the first half of the waveform since that value will be exactly half the sum of all steps. This is probably best understood by examining some practical examples.

Two Examples

The first example will be the linear ramp. This function can be made odd by adjusting the baseline, so by rule 5 it is seen that only SAL coefficients need be calculated and no CAL functions need be generated.

The best way to get your mind right in calculating coefficients is to make a table as shown in Table 2. The value desired for each step comprising the output function is written in order along the top of the table. Since we are attempting to produce a linear ramp, our output will be a rising staircase with a fixed increase with each step (we used two
units per step). This staircase will eventually be filtered to remove the jogs and give a linear ramp.

The body of the table shows the sign (positive or negative) each particular Walsh function takes in each of the 16 time intervals into which one period of the output wave form has been divided. As indicated earlier, we need not go past \( \text{WAL}(15) \) in this case. The Walsh sign values can be taken from the wave forms of figure 1 or from table 3 which is good for up to 32 segment approximations.

The numbers to the far right are the sums of the upper values when all signs are taken into account. Thus, for \( \text{WAL}(1) \) we see that it is positive in the first half period, but the step values are negative, so we get:

\[ (-15) + (-13) + (-11) + (-9) + (-7) + (-5) + (-3) + (-1) = -64 \]

and in the second half period where \( \text{WAL}(1) \) is negative and the values positive we get:

\[ (+1) - (+3) - (+5) - (+7) - (+9) - (+11) - (+13) - (+15) = -64 \text{ or a total of } -128. \]

This number gives the relative strength of \( \text{WAL}(1) \) in the output summa-

---

Table 2: A computational table used to help determine the Walsh function coefficients for the linear ramp. The relative strength of the SAL or CAL term in question is obtained by summing horizontally the +1(P) or -1(N) Walsh function value multiplied by the actual wave form value desired for that element of time. After figuring out the value of the signed sum for each term, the values should be normalized so that the largest magnitude is 1 (regardless of sign). Thus the normalized ratios shown below this picture were computed assuming -128 corresponded to -1.
The Sign of CAL and SAL in Each 1/32 Interval of Their Period

| CAL(1) | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP |
| SAL(1) | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP |
| CAL(2) | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP |
| SAL(2) | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP |
| CAL(3) | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP |
| SAL(3) | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP |
| CAL(4) | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP |
| SAL(4) | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP |
| CAL(5) | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP |
| SAL(5) | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP |
| CAL(6) | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP |
| SAL(6) | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP |
| CAL(7) | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP |
| SAL(7) | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP |
| CAL(8) | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP |
| SAL(8) | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP |
| CAL(9) | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP |
| SAL(9) | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP |
| CAL(10) | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP |
| SAL(10) | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP |
| CAL(11) | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP |
| SAL(11) | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP |
| CAL(12) | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP |
| SAL(12) | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP |
| CAL(13) | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP |
| SAL(13) | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP |
| CAL(14) | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP |
| SAL(14) | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP |
| CAL(15) | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP |
| SAL(15) | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP |
| CAL(16) | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP | PPPP |

Table 3: A larger computational table giving 32 Walsh function components and their signs during a 32 interval period.

Table 4: Using the computational table to calculate the resistor values for a 16 step sine wave approximation. The specialized sine wave generator of figure 6 uses these results, subject to a further approximation shown in table 5.

Table 5: The EIA resistor equivalents for the calculated values of table 4. The 5% tolerance resistance values shown at the right were used in the circuit of figure 6.
Inverted by simultaneously inverting all Walsh components. It is interesting to also note that if the components below the dotted line are removed, an 8 step sine wave approximation results. The feedback capacitor and output low pass filter can be added to smooth up the wave form to give a nearly perfect sinusoid.

The Walsh methods presented here would seem to have wide application for experimentation and engineering. Although these concepts are based on advanced mathematics, nevertheless, as the philosopher Seneca observed so many years ago, “The language of truth is simple.”

Walsh Functions for Music Synthesis?

Some background information on the use of orthogonal functions in music wave form synthesis has been generated by Hal Chamberlin, and published in Electronic News Letter, Volume 4, Number 25, July 20 1973. Hal also sent along a copy of a portion of a report by B A Hutchins, 60 Sheraton Dr, Ithaca NY 14850, on the use of Walsh functions in wave form generation. According to Hal, there was considerable analysis of Walsh functions in electronic music circles during a period of time approximately centered on 1973, but complexities of controlling the Walsh harmonic amplitudes digitally led to the demise of that interest. Hal’s current approach is to employ a real time Fourier series evaluation module which digitally linearizes terms of the first 32 components of a Fourier series, specified to 8 bit accuracy both in amplitude and phase.

Glossary

The following terms may be unfamiliar to some readers and are highlighted with further explanations.

Baseline: It is possible to add a fixed DC level to an analog signal, which will not affect its wave form. Using the 0 V and +5 V levels obtained with TTL circuits (using pull up resistors) as “Walsh functions” corresponds to a baseline adjustment of +2.5 volts to the ideal case of a symmetric positive or negative voltage value.

CAL: An acronym derived from Cosine wALsh. The CAL functions are the “even” Walsh functions, analogous to the Fourier cosine functions.

Duty cycle: For a digital wave form, the duty cycle is the percentage of time spent in the high state relative to the full period of the wave form.
Even function: An even function (or wave form) is one which is symmetric about the center point of its period. This means that its value a certain distance to the left of center is the same as its value the same distance to the right of center.

Fundamental: The lowest frequency in a Fourier or Walsh function summation.

Gray code: A binary code modified so that only one bit changes when going to the next higher or lower number. It is often used to de-glitch position encoders.

Harmonic: A frequency which is a multiple of the fundamental frequency.

Integral calculus: The mathematical formalism used to calculate the area under a curve. The integral calculus is used together with the theory of orthogonal functions to evaluate analytically the coefficients of Fourier and Walsh function expansions. The example of Walsh function coefficient calculation in this article uses properties of Walsh functions to simplify the process of calculating integrals required for the coefficients. There is no such simplification for the Fourier coefficients of a wave form, thus making the application of Fourier analysis a more complicated problem.

Odd function: An odd function (or wave form) is one which is antisymmetric with respect to the center point of its period. This means that if at a fixed interval before the center point its value is \( X \), then at the same interval past the centerpoint the value will be \(-X\).

Orthonormal functions: The mathematical theory of orthonormal functions is one of the most powerful tools used by physicists, theoretical chemists and engineers. Among other applications, it provides the tools needed to analyze complex wave forms and synthesize such wave forms using the principle of superposition: That the whole is a linear sum of its parts. Fourier series and Walsh function analysis mentioned here are two particular choices of a set of orthonormal functions which have useful practical applications. (See also spectrum below.)

Periodic wave form: A periodic wave form is one which has a fixed shape which is constantly repeated. A simple example would be the clock oscillator signal of a typical home brew central processor. A more complicated example (subject to imperfections) would be a long steady tone played on a musical instrument.

Rademacher functions: The subset of Walsh components consisting of only the unmodified square waves.

SAL: An acronym derived from Sine WAlsh. The SAL functions are the "odd" Walsh functions, analogous to the Fourier sine functions.

Sequence: Walsh function terminology referring to the Walsh components of a wave form in exactly the same way that frequency is used to refer to the Fourier components. Example: Sequence spectrum.

Spectrum: When orthonormal functions are used to analyze a wave form, the result frequently is a set of coefficients which weigh each of the basic functions found in a (theoretically) infinite sum which represents the wave form. Each coefficient corresponds to some parameter of the orthonormal functions, which might be, for example, a number "\( n \)." Whatever the parameter is, a spectrum for the analysis is obtained by plotting the coefficient values versus the parameter value for a large number of coefficients. For a Fourier analysis, the result is a plot of coefficient versus frequency (which at the low end corresponds to a small integer value). A Walsh spectrum would plot the coefficient of \( W(\text{AL} \text{n}) \) versus \( n \).

Wave form: For the purposes of this article, a signal’s wave form is a value of (for example) voltage as a function of time.

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Some Candid Photos Shot in Benton Harbor

As noted in August 1977 BYTE, the Heathkit product line was introduced to the press June 1, to prime the publicity pumps in time for the August introduction of the line in public at the Personal Computing '77 show in Atlantic City. Here are some candid photos taken in the Heath plant in Benton Harbor MI during the press party.

Photo 1: Perhaps a key element of the Heath line is this H9 video terminal, used with either the H8 or H11 systems. It is a full ASCII terminal (but with upper case only in the display section) and a wide range of data rates.

Photo 2: Flipping up the front panel of the demonstrator of the Heathkit H8 computer (an 8080 based product) in the press room revealed this lower level structure.

Photo 3: Here is an H8 computer used in a production and test situation at the Heathkit plant, with its memory board mounted on an extender. The boards in the H8 are mounted at an angle with respect to vertical, which keeps the height of the cabinet down while allowing bigger boards to be designed.

Photo 4: The "guts" of the H11 product by Heathkit are represented by the two boards shown here on the table in the press room. The DEC LSI-11 board and several peripheral and memory cards are mounted in the back plane assembly at right, and the switching regulated power supply for the system is shown at the left.

Photo 5: One point which many might overlook, but technology freaks can't ignore, is the specialized equipment which gets built: when a firm has a large manufacturing operation. Here is a prime example of several very interesting cases of manufacturing automation at Heath: a machine which collates resistors prior to packing. Each reel holds a supply of resistors mounted on tape strips which many readers may have seen occasionally in surplus houses. The reel feeds a mechanism which removes the resistors from the tape on command and drops the resistor into a bin on a conveyor belt moving horizontally in a loop around the machine. The net result is that the human bag packers (not seen in this photograph) simply dump the properly collated resistor assortment from a bin into a bag and seal it, and have no need to physically handle each resistor. Such automation is possible only due to the uniformity of the resistors, and even then a machine tender is required to monitor occasional exception conditions.
NYU Conference

A conference on Computing in the Arts and Humanities will be held from Friday evening to Sunday noon, October 21 to 23 1977, at Warren Weaver Hall, New York University. Sponsored by ACM/SIGLASH (Association for Computing Machinery/Special Interest Group on Language Analysis and Studies in the Humanities) and the NYU Departments of Computer Science, Linguistics, Art and Art Education, Music and Music Education, the program will include:

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Friday evening: computing in the visual arts and presentations of video and film works.

Saturday evening: concert of music composed with the aid of computers.

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NYU Conference

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For details, write: Survey Grants, United States Robotics Society, Box 26484, Albuquerque NM 87125.

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We recently received a terse note:

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This book will prove immensely useful to anyone interested in sophisticated logic design. Like the author's earlier RTL and TTL Cookbooks, it covers everything from basic principles and practical usage tips to relatively complete applications in a style that is informal, understandable, and very easy to read. If you want to learn about CMOS from the ground up, or if you want a handy reference source of CMOS circuit ideas, this book is for you.

The reader who is comfortable with TTL may doubt the book's claim that "CMOS is the first hassle-free digital logic family," but Don makes a good case. He cites its very low cost, low power requirements and wide power supply voltage ranges, open circuit inputs and wide output voltage swings, very high fanout, and tolerance of system noise. He doesn't neglect the disadvantages of CMOS, though, and warns about its sensitivity to input capacitance and its speed limitations. After reading this book, you will undoubtedly appreciate CMOS as a very practical alternative to TTL.

The following categories are among the subjects covered in the book:

- basic logic elements and transmission gates
- power supplies and the relationship between voltage, current and speed
- CMOS usage rules
- breadboarding techniques
- tools
- testing and monitoring states
- interfacing CMOS to TTL, LEDs and other devices.

Also included is a minicatalog of 100 devices, including such interesting packages as a frequency synthesizer, touch-tone dialer, modem, top octave music generator, TV numeric display, wristwatch and frequency counter.

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Besides covering basic gates and deMorgan's theorem, Don describes features unique to CMOS, such as transmission gate logic and his own "Mickey Mouse Logic" (M^2L). He goes on to discuss advanced logic design techniques using data selectors, read only memories (ROMs) and programmable logic arrays (PLAs). Finally Don gives some approaches to creative logic design, something for which he is famous. Although some of his suggestions, such as "use nonobvious codes or timing sequences," may make the reader shudder, this short section on design philosophy is very valuable.

Following the organization of his earlier books, the focus shifts to multivibrators. Basic astable and monostable multivibrators are covered, of course, but since he starts with more sophisticated CMOS packages, Don is able to present more interesting applications like data rate and touch-tone generators, equally tempered music and voltage controlled oscillators.

Succeeding chapters deal with clocked logic: flip flops, counters and shift registers. Although the basics are still covered, the more interesting examples exploit the special properties or the more sophisticated packages available with CMOS: touch and proximity sensors, phase detectors, character generator serial video and Teletype transmitters, and digital sine wave generators.

A very special chapter describes CMOS op amps, analog switches, and phase locked loops. The application examples for all three devices should give the reader a good grasp of their capabilities. The section on analog switches is especially interesting.

The final section of the book, "Getting It All Together," presents some larger scale designs, as well as challenges to the reader. Here you will find circuits for a video game, a digital wristwatch, and even a complete basic circuit and key waveforms for Don's TVT-4 television typewriter.

All in all, this book packs a lot of ideas into its 400 pages, and forms a superb introduction to an important new logic family. If you want to keep up-to-date on integrated circuit technology, you should not pass up this book.

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Continued from page 21

Control Character | Meaning
--- | ---
$\text{Pnn}$ | musical part number declaration, where $n = a$ number from 00 to 16
$\text{Knc}$ | key signature declaration, where $n$ is a number and $c$ is a "+" or a "−"
$\text{Tn/n}$ | time signature declaration: ie: "T4/4" means 4/4 time
$\text{Onn}$ | positions the CDEFGAB scale on the terminal keyboard to octave $n$ of the external instrument's keyboard
$\text{[ Jnn}$ | repeat text within parens $n$ times
$\text{<>=C}$ | equate all text within brackets to symbol C
$\text{Q+n}$ | transpose all subsequent text up $n$ steps
$\text{Q−n}$ | transpose all subsequent text down $n$ steps
$\text{CTRL A}$ | marks the end of the MUSIC TEXT FILE

Table 2: Control characters used by the SCORTOS language processor.

Table: Control characters used by the SCORTOS language processor.

matically informs the user when he has come to the end of a bar by displaying a slash and the next bar number on the terminal. This provides a checksum for each bar and a milestone to keep the operator informed of his position in the score. Listing 1 shows a sample of the dialog between the operator and the editor as the operator enters the score fragment in figure 3. The italicized type is supplied by the editor, the bold type by the operator.

Conventional string oriented text editors are inconvenient for use with music text since music is prone to have too many occurrences of any given string. Allowing the user to access the text by part number and bar number is more suitable since he refers to a written score in the same way. Various commands are available within the editor which allow a user to list selected bars and make insertions and deletions in the music text at selected bar boundaries.

The converter is the system's music language processor. It scans the text of the music text file and translates the logical entities of rhythm and pitch to the physical values of time and keyboard address. For each event described in the file the converter outputs a 2 byte record which contains the duration of that event in standard system timing units, and the location of the event on the system controlled music keyboards.

Table 2 is a list of control characters recognized by the converter. In keeping with the design goal of eliminating redundancies in the music score, an equate (=) statement was developed. Using equate, repeated groups of notes need only be typed in once and equated to a symbol. Thereafter they may be brought into the music source text by typing the symbol to which they have been equated.

The driver interface subroutines allow the user to communicate with the DRIVER by providing him access to the binary output file. Through their use, a sequence of musical events may be generated from within the computer by a user written program. For example, the researcher may have made an analysis of a particular composer's style (following the procedure described earlier in this article) and may wish to write a program in BASIC which creates a composition based upon the properties of that style. The sequence of events that constitute the composition would be produced by calls to the driver interface subroutines.

The EVENT subroutine is the principal interface subroutine. Its calling sequence is:

\[\text{CALL EVENT} \]
\[\text{DS ARG1} \]
\[\text{DS ARG2} \]
\[\text{DS ARG3} \]
\[\text{DS ARG4} \]

where:

- ARG1 = part number.
- ARG2 = duration of event.
- ARG3 = address of keyboard switch.
- ARG4 = slur code (0= no slur, 1= slur this event to next event).

The DRIVER is a software representation of the inner workings of a player piano where the binary output file, subroutine CLOCK, and the DRIVER's main code are the respective analogs of the piano roll, sprocket drive and mechanical read head. All of the control features of its mechanical counterpart are available within the program, including start performance, pause, and stop performance, and some which are unique to a software simulation, such as discrete tempo control and part selection.

The DRIVER causes music to be performed by initiating and terminating musical events according to the information contained in the binary output file. The program keeps a timer for each part that is participating in the performance. When an event is initiated, the address data in the event's data record is output to the appropriate 88-RCB data register. This causes sound to emanate from the instrument to which the 88-RCB is connected. The timer is set to zero, then incremented 20 times per second and compared at each incrementation to the event duration field of the event's data record. When these two quantities are equal, the event is terminated by a logical exclusive OR of that event's keyboard address data with the 88-RCB data register. The DRIVER then proceeds to the next event record and repeats the process.

Timing is provided internally by subroutine CLOCK which contains a timing loop and which also interprets control commands from the terminal. When a call is
made to CLOCK, the caller will not receive control back until a specified interval of time has passed. In this way it can be used as a time source. The time interval provided by CLOCK is used as the basic unit of time in the system. An interval of 1/20 of a second is sufficient to provide the resolution necessary to perform the most complex musical passages.

The internal generation of timing is less expensive and permits the tempo of the performance to be easily varied on line. By striking the keys labeled "rit" or "accel" on the terminal keyboard, the operator can retard or accelerate the tempo of the performance by 2.5% for each stroke of the key.

The use of processor cycles to generate timing puts a great strain on the DRIVER. It must complete its work so quickly that the listener is not aware of any delay between music parts that are supposed to be occurring simultaneously. Musicians can time a musical event to within 10 ms of its desired occurrence. This imposes on the DRIVER the specification that, for worst case condi-

### Table 3: A list of command verbs recognized by the system monitor. Each verb calls a system module, and its arguments specify the data file which is to be operated on by that module.

<table>
<thead>
<tr>
<th>Command</th>
<th>Meaning</th>
</tr>
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<tbody>
<tr>
<td>*E ab</td>
<td>Call the EDITOR and load the source text file identified by the characters ab</td>
</tr>
<tr>
<td>*C ab,cd</td>
<td>Load the file identified by the two character code ab and use it as input to the CONVERTER. Write the output of the CONVERTER to file cd</td>
</tr>
<tr>
<td>*P cd</td>
<td>Load the file identified by the characters cd. Call the DRIVER and perform the music described by the data in file cd</td>
</tr>
</tbody>
</table>

### Listing 1: A sample of the dialog between the operator and the system editor as the operator enters the score fragment in figure 3. The italicized type is supplied by the editor.

```
EDITOR
COMMAND? N
FILE CODE? S5
ENTER PART NO. P01
0001 "SYMPHONY NO 5 (PROKOFIEV)****OBOE" K2· T3/4 (2.)03
0005 P02
0001 "1st FLUTE " K2-T3/4 O3 F4 G4 A8. F16 /
0002 O4 C8. O3 B16 O4 F4 B4 /
0004 F8 E8 D8 C8 O3 B8 O2 C8 /
0005 P03
0001 "2ND FLUTE " K2· T3/4 . . . . .
```
This 63 key ASC II Encoded Keyboard kit was designed and manufactured by Electronics Warehouse Inc. Features: Single 5 volt D.C. supply, utilizing only TTL Logic elements (no MOS devices to blow). TTL drive capability (each of the eight bits of ASC II output will drive the equivalent of ten standard TTL inputs without external buffer drivers), de-bouncing, upper and lower case fully ASC II, 8 bit parallel. In addition to the alpha-numeric and symbol keys available on a regular keyboard, the following keys are utilized: Escape, back-space, tab, line-feed, delete, control, shift-lock, shift (2 keys), return. All 128 ASC II characters are generated.

Kit includes: 63 key keyboard, P.C. board, all required components and assembly manual with ASC II code list.

Optional: Parity bit - add 50¢ • Enclosure - $25.00 • Serial output - add $2.00 • 18 Pin edge connector - $2.00 • Sockets - $4.00

Note: If you already have this teletype keyboard you can have the kit without it for $39.00. Dealer inquiries invited.

## Conclusion

The functional possibilities addressed by the SCORTOS system are, of course rudimentary. In its present state it provides a foundation on which additional application programs can be built, notably a music language which treats the performer of the music as a computer and not a human. Other possibilities include a set-complex processor to analyze music and statistically model its characteristics, and a plotter interface that will draw musical scores on a plotter. Some of these programs already exist and need only be converted from FORTRAN to BASIC.

I am presently developing a macro capability that allows the user to equate a rhythm sequence to a symbol, and then associate different pitches with each note in the rhythm sequence by means of an argument list in a macro declaration.

The implications of this macro capability go further than just providing a way to eliminate redundancy. The composer often deals in "primitives" which are at a higher level than those allowed by his conventional music language. That is, the composer often thinks in terms of whole musical phrases and note groupings rather than individual notes of which he is compelled to construct those phrases and groupings. In using this higher level language, the composer is able to construct his compositions of larger building blocks and may easily vary the tonal parameters within those building blocks to achieve various aesthetic effects.

The purpose of the SCORTOS system project is to foster computer implemented composition among individuals and institutions whose financial and talent resources have prevented them from undertaking such projects in the past. Over the years various projects of this nature have been conducted at the larger educational centers of the country. The adoption of these projects by individuals and poorer institutions has not been widespread due to the large hardware costs involved, or lack of programming experience within the music departments. I hope that more modestly endowed music institutions will respond to a turnkey installation costing less than $10,000, and that we may shortly see the computer joining the synthesizer and tape recorder as standard equipment in every electronic music studio.
What is the equivalent of the LIN(x) command, the GO TO ... OF ... command, the PRINT USING, and the IMAGE statements used in the program as listed? Also, when the program is compiled in VM 370 BASIC, lines 1520, 1600, 3370 and 3600 give the error message "NO. OF DIMENS. INVALID"; line 140 gives a "SYNTAX ERROR IN EXPRESSION" message. Can you suggest revisions to eliminate the problems and tell me where to get hold of a VM 370 BASIC manual?

Glen Bullmann
2218 E Gatehouse Dr
Metairie LA 70001

LIN(x) is a built-in function in the BASIC version used by David Price, a function which is used for formatting control on the terminal. Its semantics are most likely: "advance the terminal by x lines."

PRINT USING and IMAGE are related statements, used to establish a format for output similar to the FORTRAN "FORMAT" statement in the version of BASIC used in David Price's article. The manual for VM 370 would have to be consulted to find the equivalent, or you could dispense with formats entirely (and get a much cruder output) by using PRINT instead of PRINT USING as a temporary measure.

The GO TO ... OF ... is the logical equivalent of a computed GO TO in FORTRAN, and probably exists also in the VM 370 BASIC. If you must implement it yourself, the semantics should be satisfied by a series of "IF" statements, as in the following conversion of line 780 of listing 1 of David Price's article, page 107 of the March 1977 BYTE:

New Line 720 code...

IF A+1 = 1 THEN GO TO 890
IF A+1 = 2 THEN GO TO 1520
IF A+1 = 3 THEN GO TO 1640
IF A+1 = 4 THEN GO TO 1800
IF A+1 = 5 THEN GO TO 2200
IF A+1 = 6 THEN GO TO 3010
IF A+1 = 7 THEN GO TO 3550

Of course, this example could be made more efficient by calculating the expression A+1 first and assigning its value to a variable; to avoid picking another variable name, we show this version of the logic.

The problems with lines 1520, 1600, 3370 and 3600 are due to the fact that the program as written by David Price uses a "substring" feature of the BASIC version he has access to. The notation A$(x,y) is (from the context of the version of the program we printed) a reference to the characters in string A$ starting at location x and extending to location y. Thus if A$(3,5) has the value "YTH" by this interpretation. No simple conversion is possible; however, you can often achieve the same effect by using a FOR...NEXT loop scanning the required range of characters within the string and referencing the characters one at a time using A$(i) as a form which is most likely allowed in the VM 370 version of BASIC. (Check the manual on this, and possibly use an alternate substring notation if it exists). As for line 140, figuring out why it gives a syntax error would require reference to the manual; however, noting that many times exponentiation is indicated by a double asterisk (**), one likely place to start would be by replacing the up arrow exponentiation symbol by a double asterisk. (This symbol is the upward pointing caret (^) seen in line 140 as printed in March 1977 BYTE).

As for getting hold of the manual for VM 370 BASIC, the most likely place to start is a trip to your local computer center which supports your terminal. Most computing centers for timesharing networks have some form of user accessible documentation library. Alternatively use the formal channels at your center to order a manual from IBM, or contact IBM yourself. The company is usually only too happy to satisfy such requests for documentation, and the charges are nominal.*
A Self Refreshing 4 Channel Digital to Analog Converter

Pinnacle Products has announced a self-refreshing 4 channel digital to analog converter that is Altair bus compatible. Instructions are included for alternate connection to Digital Group Systems. Features include complete output port address decoding and a 3-state bus connection. The converter has eight bits of resolution and can be set to cover any range within -10 to 10 V. It operates at a rate of 50,000 conversions a second, updating the four sample and hold outputs from a scratch pad register. Circuit operation as seen from the computer is completely static; no software refresh or wait states are required. A 4-byte computer program is used to set up the unit. The printed circuit board alone sells for $34. The complete kit is $69, and the assembled and tested board is $99. Contact Pinnacle Products, POB 3155, Talcottville CT 06066.®

Circle 647 on inquiry card.

A New Personal Computing Catalog

Sized at 11 by 14 inches (27.9 by 35.6 cm), the Byte Shopper catalog is hard to miss. Published by the Byte Shop of Arizona, 813 N Scottsdale Rd, Tempe AZ 85281, the new catalog describes a variety of microcomputers, video terminals, floppy disks and other personal computing items. A unique feature of the catalog is the tutorial information about personal computers, including a glossary of terms and short articles like: "What Can a Computer System Do?", "The Magic Bus" and "What Makes a Computer Smart?". The catalog is free for the asking.®

Circle 649 on inquiry card.

A Timely Kit for HP-45 Owners

Egbert Electronics, 1514 S 320 East, Orem UT 84057, has announced a new kit to improve the accuracy of the stopwatch function on the HP-45 calculator. As most owners of the unit know by now, the HP-45 can be turned into a stopwatch by first pressing RCL, and then simultaneously pressing CHS, 7 and 8. The kit provides a quartz crystal to stabilize the internal oscillator, plus associated electronics. Kit price is $13. Egbert Electronics will do the installation for $23.®

Circle 646 on inquiry card.

The Nova 760 Operating Manual

Nova Inc, 8401 Aero Dr, San Diego CA 92123, (714) 277-8700, has completed the first edition of the Nova 760 Operating Computer Operating Manual. This 1 inch (2.5 cm) thick loose-leaf manual is available by itself for $20. The manual describes hardware characteristics of available modules, as well as the software of the firm’s interactive assembly and editing systems, BASIC interpreter, and utility routines. This computer was developed by Gremlin Industries for in-house use as a design system for video arcade game and educational software, and should make an excellent option for many readers interested in graphics and complete systems with "turn key" characteristics. Use the manual alone if you want to investigate what this system package contains.®

Circle 647 on inquiry card.

A New Wire Dispenser-Stripper for Wire Wrap and Other Applications

A new wire dispenser from OK Machine and Tool Company, 3455 Conner St, Bronx NY 10475, combines cutting and stripping ability in one unit. Wire is drawn out of the dispenser to the desired length, cut with the built-in plunger, and pulled through the stripping blades. Dispenser includes 50 feet (15 meters) of AWG 30 insulated solid copper wire available in four colors. People who use conventional wire wrap will find this to be an excellent addition to the tool kit.®

Circle 648 on inquiry card.

Data General Enters the Personal Computing Market

The Computer Store, a chain of retail personal computer outlets in the Northeast, has announced that they will be distributing the entire line of Data General’s Micro-NOVA microcomputers, peripherals and software. Free catalogs are now available from The Computer Store, 120 Cambridge St, Burlington MA 01803, which describe the full line of products, including expansion memories and interfaces; DOS, RTOS, BASIC, FORTRAN and development software; the DASHER matrix printer and the 6000 line of video terminals.®

Circle 649 on inquiry card.

Digital Equipment’s Comments on the Heathkit H11

The following information was received from Digital Equipment Corporation, one party to the synergistic two-some of Heath Company and DEC.

Digital Equipment Corporation announced the signing of a multimillion dollar contract for LSI-11 microcomputers and related products by Heath Company, a subsidiary of Schlumberger, Ltd. The microcomputers, to be delivered over a 3 year period, will be incorporated into Heath’s H11 computer.
**NEW! ELECTRONIC TOUCH ORGAN KIT**

Fantastic new design uses CMOS I.C. and a total of 38 semi-conductors to give you a touch control keyboard, all the electronic parts in one PC Board. This organ is easy to build, yet has features like a full octave range to touch keyboard, variable tremolo, two voices; built-in I.C. amplifier with peak limiter, complete with speaker and a specially designed print-label case.

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PC Board For 10" TV Screen.

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Circle 303 on inquiry card.
the instruction set of the LSI-11 is virtually identical to that of other PDP-11 computers, such as the PDP-11/34. Thus, sophisticated program development is achievable with the Heath H11.

Purchasers of the H11 will be eligible to join DECUS (the Digital Equipment Computer Users Society). DECUS functions as a clearing house for more than 28,000 members worldwide who wish to exchange programs and information. "DECUS holds special symposia and publishes a journal. The DECUS library contains over 800 programs designed for the PDP-11 family of computers, many of which were developed for or can run on the LSI-11," he said.

A New Chip on the Block

We received an interesting preliminary product description for a television raster scan display controller recently, sent in by a gentleman at SMC Microsystems Corporation, 35 Marcus Blvd, Hauppauge NY 11787. The product involved is a 40 pin N-channel MOS LSI device called the CRT 5027 Video Timer-Controller.

This device will be of some interest to those homebrewers and designers who are interested in a minimum hassle path to a raster scan display (where minimum is relative to homebrewing the same logic out of SSI and MSI parts).

We have tried to establish all frame formatting, character scanning and sync timing for a video display (with the single exception of the dot address counter which cannot be practically implemented in MOS integrated circuits). The video display functions use seven 8-bit control registers connected to a bi-directional byte oriented data bus with appropriate select lines allowing easy integration in the typical microprocessor system. The boxes entitled "Operation" and "Additional Features" accompanying this note are copied from page 3 of the SMC document, and summarize the salient features of the product.

Persons interested in seriously pursuing homebrew (or commercial) designs with this device are advised to write SMC for a copy of the brochure. Who will be the first reader to homebrew a high resolution graphic display using this chip for timing, about 16 K bytes of memory, and a good black and white monitor? Find out when (sooner or later) the task is accomplished and a construction project is documented as an article. Circle 631 on Inquiry card.

A New Bar Code Reader

Here is one answer to the question, "Where can I buy a bar code reader to read the bar code listings published in BYTE?". Jeffersonville Engineering Co, 605 E 10th St, Jeffersonville IN 47130, phone (812) 288-8246, has announced its new bar code reader. Priced at $39.95, the unit outputs +5 V on a bar and 0 V on a space; timing and translation are software dependent. 6502 and 8080 software is said to be currently available for use with the unit. The company can also print bar code versions of customers' software. Contact them for further details.

Circle 655 on inquiry card.

Operation

The design philosophy employed was to allow the device to interface effectively with either a microprocessor based or hardware logic system. The device is programmed by the user in one of two ways: via the processor data bus as part of the system initialization routine, or during power up via a PROM tied on the bus and addressed directly by the Power Select output of the chip (see figure 4). Several 8-bit words are required to fully program the chip. Bit assignments for these words are shown in Table 1. The information contained in these seven words consists of the following:

| Character/Data Flow | Horizontal Formatting | 3 bits assigned providing up to 8 character times for generation of 'front porch'
|---------------------|-----------------------|-------------------------------------------------------------------------------------------------------------------
| Horiz. Sync Delay   | 3 bits assigned providing up to 8 character times for generation of 'front porch'
| Horiz. Sync Width   | 4 bits assigned providing up to 16 character times for generation of horizontal sync width
| Horiz. Line Count   | 8 bits assigned providing up to 256 character times for total horizontal formatting
| Sync Bits           | A 2 bit code providing a 0 to 2 character skew between the horizontal address counter and the horizontal blank and sync signals to allow for reaming of video data prior to generation of composite video signals. The Cursor Video signal is also skewed as a function of this code.
| Interlaced/Non-interlaced | The bit provides for data presentation with odd/even field formatting for interlaced systems. It modifies the vertical timing counters as described below
| 8 bits assigned, defined according to the following equations: |
| Scans/Frame          | 1) in interlaced mode—scans/frame = 2X - 513 Therefore for 525 scans, program X = 6 (00000010). Vertical sync will occur precisely every 256 ± scans, thereby producing two interlaced fields. Range = -513 to 2025 scans/frame, even counts only.
| Data Rate Start      | 2) in non-interlaced mode—scans/frame = 2X - 256. Therefore for 262 scans, program X = 3 (00000011). Range = 256 to 768 scans/frame, even counts only.
| Vertical Data Start  | In either mode, vertical sync width is fixed at three horizontal scans ( 3H4)
| Scans/Data Rate      | 8 bits assigned providing scan line resolution in vertical data positioning with respect to vertical sync. The Data Flow Counter is reset at vertical sync and will not begin counting until the scan line selected by these eight bits.
| Data Down/Frame      | 6 bits assigned providing up to 64 data rows per frame
| Data Down/Row        | 6 bits to allow up or down scrolling via a protocol defining the count of the last displayed data row.
| Scans/Data Row       | 4 bits assigned providing up to 16 scan lines per data row.

Additional Features

Device Interface

Under microprocessor control—The device can be reset under system or program control by presenting a 0101 address on AD-3. The device will remain reset at the top of the even held page until a start command is executed by presenting a 0111 address on AD-3.

Via Self-Loading—In a non-processor environment, the self loading sequence is effected by presenting the 1111 address on AD-3 and is initiated by the receipt of the strobe pulse (DS). The 1111 address should be maintained long enough to insure that all seven registers have been loaded (in most applications under one microsecond). The timing sequence will begin one line scan after the 1111 address is removed. In processor based systems, self loading is initiated by presenting the 1111 address to the device. Self loading is terminated by presenting the start command to the device which also initiates the loading chain.

Scrolling—in addition to the Register 6 storage of the last displayed data row a scroll command address 1101 presented to the device will increment the first displayed data row count to facilitate up scrolling in certain applications.

212
GOBDOUT'S INTRODUCES 24K OF MEMORY FOR $450; HOBBYISTS REJOICE!

EXCLUSIVE TO THE GAZETTE!

It is now possible to equip your computer with three 8K Economics II boards for $450. A single 8K board, the fanciest selling computer in Godbout's history, is still available for $125.

"We wanted to make it possible for the hobbyist to stuff a little more memory into his machine at a reasonable price," Godbout commented today. Judging from the response, he appears to have succeeded.

However, a representative for the company stressed that price was not the only attractive feature of this year's crop, citing the low current consumption (1.5A guaranteed, 1.25A typical) and high speed (60 wait states). For users of 8-bit processors driven by a 4 MHz clock, there is even an onboard clock for implementing wait states.

He added, "the vector interrupt feature, which lets you know if you are trying to write into protected memory, is very handy. Also, the board was designed to be configured as two separate, non-interfering 4K blocks, which adds considerably to the versatility of the system."

A poll of users, undertaken by Godbout, shows that hobbyists are pleased with the all-static design, which eliminates dynamic characteristics such as pulse carry and output delays. Users find the three-state outputs and fully buffered inputs and outputs as their favorite features. All agree that the quality is exceptional, from the legendary solder marked box to the low profile sockets.

Those wishing to take advantage of the special 3/$50 offer should ask for PSC-24. The standard 8K board ($163.84) is stock number CS-008; an assembled version, PSC-101, is available for $185.80. A deversion of the board costs $100 in kits (PSC-009) and $125 assembled (PSC-008).

1980 Processor Prices Plummet

The workhorse 8080A, darling of the chip set, has reached a new low in the past month. The full spec unit costs only $12.86 regardless of quantity purchased for $12.86.

In a parallel development with 8085, full spec units are now available for $25.00.

Computer Strike Averted

Things looked tough at the negotiations table, but all sides are ready to resume talks in the hope of averting a strike..."
This 0-15 VDC 05 per card digital meter features the Motorola 74189 7-segment display. The DC VDC DVM contains a single +5 VDC power supply. The unit is provided complete with an injection molded block plastic case assembly with fixed 90° pin connectors which fit into the same space as the 0-15 VDC allowing 117 VDC operation.

A. 0-15 VDC with Case $49.95

B. 5V Power Supply $14.95

**SLIT-N-WRAP WIRE WRAP TOOL**

Tightens and tranfers stranded wire into a single strand wire wrap tool. This tool is designed with a 100-200 spool of #26 AWG wire. Model 305A $24.95

**HEXDECIMAL ENCODER 19-KEY PAD**

- 19 Key Encoder
- 2-3.5mm Mounting Holes

Model 19 $10.95 each

**63 KEY KEYBOARD**

- This keyboard features 115 keys
- 2-3.5mm Mounting Holes
- 200-500 spool of #26 AWG wire

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**TOOL**

- A9786S - Digital Cutters w/20 in. Wire Cut, $8.95 ea.
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- 1A - Wire Stripper w/18 to 26 gauge, 3.75 ea.
- 510B - Wire Stripper w/32 to 22 gauge, 3.75 ea.
- CS-3 - Duct-Cutter Tool - 8" long, 8.95 ea.
- Notching Tool - 6" long, $6.95 ea.
- Notching Tool Replacement Punch, $3.75 ea.

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- 6 DIGIT ASSEMBLY $9.95

**DIGITAL STOPWATCH**

- 30 Second Timer
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**JE700 CLOCK**

- 115 Vac
- 1 2 3 4 5 6 7 8 9 0

**JE803 PROBE**

- $9.95 Per Kit

**CIRCLE 305 ON INQUIRY CARD**
New Printer Features Novel Printing Technique

A new 80 column dot matrix printer from Axлом Corporation, 5932 San Fernando Rd, Glendale CA 91202, has been announced which features an operating speed of 160 characters per second. The EX-800, shown at the NCC show in June, features an unusual electrosensitive printing technique: the nonimpact printing is done by passing a high current through fine wires in the print head for about 1 µs to remove the upper layer of aluminum from a 5 inch wide electrosensitive paper. This exposes a layer of black ink underneath.

The unit is 9.625 inches (24.45 cm) wide, 3.875 inches (9.84 cm) high and 10.825 inches (27.62 cm) deep. The price is $655, which includes case, power supply, parallel interface and 96 character ASCII character set, programmable character size, built-in self-tester, bell, and infrared low power indicator.

Cassette Terminal Interface for SwTPC 6800 Operates at 120 bps

Bell & Howell Offers New Microprocessor Course

Many people have expressed interest in microprocessor correspondence courses. Now, Bell & Howell offers a new source of such courses. Their new microprocessor correspondence course is available for $99. The course materials consist of two study units contained in loose-leaf binders.

Topics covered include an introduction to microprocessors, computer languages, system architecture, IO instructions, flowcharts and so on. For more information, contact Bell & Howell, 209 W Jackson Blvd, Chicago IL 60606.

New Learn-at-Home Electronic Circuits Course from Heath

Heath Company, Benton Harbor MI, has introduced a new learn-at-home electronics course covering basic electronic circuits. The course, EE-3104, is one of four basic electronics courses which use programmed instructions plus audio records. The course comes complete with electronic parts for "hands on" experiments. Other courses in the basic electronics series include AC Electronics, DC Electronics, and Semiconducotor Devices. An advanced course in Digital Techniques is also available.

Course EE-3104 covers basic and operational amplifiers, power supplies, oscillators, pulse circuits, modulation and demodulation with emphasis on integrated circuits. An optional final exam can be taken for Continuing Education Units (CEUs), a nationally recognized means of acknowledging participation in noncredit adult education.

Courses are mail-order priced at $39.95. For a free catalog write to Heath Company, Dept 350-18, Benton Harbor MI 49022.

A New Analog Multiplier Series

Analog Devices, Route 1 Industrial Park, POB 280, Norwood MA 02062, has announced a new series of monolithic analog multipliers called the ADS534 series. The ADS534L, in particular, offers a maximum multiplication error of ±0.25%, said to be the lowest of any integrated circuit multiplier. Small signal bandwidth of these units is 1 MHz, making them ideal for a variety of applications ranging from music synthesis to modulation and demodulation in communications systems. One real advantage for the experimenter is that these multipliers require no external components: simply feed in two analog signals within the input specs and get out their product. Single quantity price for the ADS534L is $26.

Mini-L Lor-Loran-C Receiver Announced

A limited number of circuit boards and a user's guide will be available from R.W. Burhans, 161 Grosvenor St, Athens OH 45701 or PAIA, 1020 W Wilshire Blvd, Oklahoma City OK 73116, for experimental study of the Lor-Loran-C, 100 kHz, navigation system with microprocessor data reduction systems. Mini-L is designed to generate 10 µs interrupt request pulses locked to the Lor-Loran-C carrier frequency to help eliminate local area interference, and has a very wide range automatic gain control (AGC) level for hard limiting on signals received. The level control can be arranged to

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## VIATRON CASSETTE DECKS

The computer cassette deck alone $35 Set of 2 boards read/write amp & serve control boards for this deck $40.00

## PORTABLE FIRE ALARM

Operates on 3 internal AA cells (not furnished) On temp rise of approx 150 Sonalert type alarm sounds off. Push to test switch makes nice sounding code practice oscillator $6.00

## SPECTRA FLAT TWIST

50 conductor, 28 gauge, 7 strands/conductor made by Spectra. Two conductors are paired & twisted and the flat ribbon made up of 25 pairs to give total of 50 conductor. May be peeled off in pairs if desired. Made twisted to cut down on “cross talk.” Ideal for sandwiching PC boards allowing flexibility and working on both sides of the boards. Cost originally $13.00/ft

<table>
<thead>
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<th>Wire Type</th>
<th>Price/ft</th>
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## WIRE WRAP WIRE

TEFZEL blue #30 Reg. price $13.28/100 ft. Our price 100 ft $2.00; 500 ft $7.50.

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Great savings as these are about 1/4 book prices. All fresh & new.

## MULTI COLORED SPECTRA WIRE

Footage 10' 50' 100'

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</table>

## TOUCHTONE ENCODER CHIP

Compatible with Bell system, no crystal required. Ideal for repeaters & w/specs. $6.00

## CHARACTER GENERATOR CHIP

Memory is 512x5 produces 64 five by seven ASCII characters. New material w/data $6.00

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operate either manually or under software control from an external digital to analog converter. The wideband antenna preamplifier may also be used with the Mini-O system as described in March 1977 BYTE. An improved Mini-O circuit board is being developed.●

A New Series of 16 Bit Microprocessors from Texas Instruments

Texas Instruments has announced a new series of 16 bit single board microcomputer modules based on the 9900 chip which feature upward and downward software compatibility with the rest of the 9900 series. The TM990/100M is the first module to be made available in the new TM990 series. It features 1 K by 16 bits of erasable read only memory expandable to 4 K by 16 bits (the memory will include a self-contained software monitor called TIBUG), plus a 256 x 16 bit volatile user programmable memory expandable to 512 by 16 bits on the board.

Sixteen lines of programmable parallel IO and a selection of either a current loop or RS-232 terminal interface are available. In addition, the TM990/100M offers two programmable interval timers, 15 external hardware interrupts and a blank board area with extra sockets for user prototyping, etc. The TM990/100M sells for $450, assembled, in single quantities.

This will provide an excellent starting point for the experimenter desiring a 16 bit minicomputer-like processor which features hardware (integer) multiply and divide, real shift instructions and a general register architecture.

For further information, contact Texas Instruments Inc, Inquiry Fulfillment, POB 1443, M/S 653 (Attn: TM990), Houston TX 77001.●

Get Some Pizza Mind

“Big Stan,” a new version of the MARK III line of electronic point-of-sale systems by FasFax Corporation, is currently in trial with prospects in the pizza and taco segments of the fast food industry. The new system automatically prices add-on ingredients to speed counter service and eliminate loss caused by incorrect pricing procedures. It uses its microcomputer intelligence to increase the productivity of food vendors. [Oh! The power of user oriented firmware...CH] Big Stan is programmed to allow for many basic carriers, such as different sizes of pizza shells and a wide variety of ingredients. The ingredients can be assigned to as many as 15 different price classes, thus assuring accuracy regardless of the way clerks enter the order. The unit maintains a complete record of all transactions, labor hours and inventory changes; this information is used to automatically compile management reports. For more information, contact FasFax Corporation at Ledge St, POB H, Nashua NH 03060.●

Small Business Software from Synchro-Sound

Synchro-Sound, 193-25 Jamaica Av, Hollis NY 11423, has announced an accounts receivable system for the small business owner. The system is expressly designed to be run on an 8080 microcomputer using an Altair floppy disk with Altair BASIC, video terminal and printer. Features include: adding new customer accounts, deleting dormant accounts, transaction processing and report generation. The monthly statements include both current and aged balances. Other reports generated are aged accounts receivable and delinquency notices.

The system is said to require little operator training. All communication is in interactive mode. Operator errors are easily corrected, and accidental data base deletions are prevented by requiring additional confirmation.

This system may be modified to include special installation dependent functions. All major programs are written in high level language to facilitate program additions and alterations. This program module is designed to serve as the basis for a complete accounting package. Provisions are included for linking billing control and general ledger modules. The latter will be available in the near future.●

A New Smart Terminal from Economy Terminals

Economy Terminals has announced their Model ET1 microprocessor-based video terminal for the experimenter market priced at $895 each. Hardware features include:

- 24 by 80 display of a 64 character ASCII subset (but a full 96 character set is transmitted)
- 12 inch (30.5 cm) industrial video monitor
- RS-232 and 20 mA current loop interface
- 16 switchable data transfer rates
- Switch selectable odd or even parity with one or two stop bits
- 63 key keyboard with all functions identified on key caps

Software features include:

- Page or scrolling mode of operation
- XY placement of cursor either from keyboard or remotely
- Automatic repeat of any key after a 0.3 second delay

For further information, write Economy Terminals, POB 12261, Minneapolis MN 55412.●

A Most Useful Catalog

Here at last is a source for all those hard-to-get accessories and supplies for mini and microcomputers: Minicomputer Accessories' new 1977 catalog. Small systems enthusiasts will enjoy paging through this compendium which features such things as binders for computer printouts, flowchart design templates, printer paper, cassette storage boxes, cordless paper tape winders, paper tape splicers and trays, myriads of special interconnection cables, extension boards, cable bridge systems for covering floor runs of computer cables, storage cabinets, and so on. The catalog is free for the asking from Minicomputer Accessories, 1015 Corporation Way, POB 10056, Palo Alto CA 94303.●

Page 218
K-rations for your computer

K-Ration™ 8Kx8 memory with SynchroFresh™.

$188 assembled and warranted.

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7441 - 9c

7442 - 10c

7443 - 10c

7445 - 10c

7446 - 10c

7447 - 20c

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ASTROLOGY: I am interested in getting in touch with someone doing astrological chart computation and regression on minicomputer systems. P. Pierce, Bone and Joint Surgery Association, Data Processing Dept, 2704 Marshall Ct, Madison WI 53705.

HELP: I need schematics and electrical specs for a Friden Selecta data tape reader, Model STR. Also need schematics and specs of a "Technical Manual" for a Friden Programmable Flexwriter, Model SPD. I will buy the manuals or pay for copies. John Kane, US Enterprises, AIMD 1M3 W3C03, FPO San Francisco CA 96001.

WANTED: January, February, March, April, May and June 1976 BYTES. Will pay any reasonable price. Send offers and lists to Reuven Plant, 43 Avista Ct, St Augustine FL 32084.

FOR SALE: One ASR-33 friction feed Teletype complete with reader, punch, and stand, $700. One ASR-33 sprocket feed Teletype with stand and punch, but no reader, $400. One ASR-33 sprocket feed Teletype with stand, no reader or punch, $350. Daniel Skret, 2485 Painted Rock Dr, Santa Clara CA 95051, (408) 296-9784 or (408) 246-8869.

FOR SALE: Video data terminal, RCA Model 70-752, 12 inch screen, 20 lines by 54 Characters. Full editing capability and cursor control, data input: RS232, 1200 baud, ASCII. Self-contained power supply, turning clock, and two IQ boards. ASCII keyboard included, also schematics, specs, etc, $600 or offer. Dick Amsley, 1121 Lafayette Park, Oakland CA 94611, (415) 539-9178.

WANTED: I am a high school student in need of an inexpensive TTY. I wish to use it as an output device for my COBOL 1980 system and would appreciate any information that would lead to the purchase of such a device. If you can help with this or other devices, please contact: Darcy Roberts, 660 Lauren Blvd, Brockton, Ontario K5B 5X9, CANADA.

WANTED: Eclectic IBM Selectric as equivalent quality terminal for high quality hand copy. Must have upper and lower case character set, but can be any standard one and a board need not be operative, Steve Goldblatt, 150 Autumn Av, Buffalo NY 14212.

SUMMER 1978: German student microtechniques, 3rd half-year now seeks opportunity to get some practical experience on computer systems and technical English in the USA. Geert Kluge, Lorelystrasse 93, D6230 Frankfurt 80, W Germany.

WANTED: IMSAI 8080, 22 stn mother board with 9 exxms, 8 C Vector Graphics programmable memory, details, send SASE to Roger Lewis, 1477 Harrington #17, Los Angeles CA 90025.

WANTED: I am a high school student in need of an inexpensive TTY. I wish to use it as an output device for my COBOL 1980 system and would appreciate any information that would lead to the purchase of such a device. If you can help with this or other devices, please contact: Darcy Roberts, 660 Lauren Blvd, Brockton, Ontario K5B 5X9, CANADA.

FOR SALE: PAL-Morale, POLY 80 computer, $490. Saku BKSC-2, 8 K high speed memory board, $250. Several IMSAI boards, Tabelfi, and Poly-Morale boards. Call 737-9478 to arrange details, or send SASE to Roger Lewis, 1477 Harrington #17, Los Angeles CA 90025.

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WANTED: Software, Resident assembler and Tiny BASIC on my 1408. If I receive, I will pay for cost of duplication and mailing. If there is somebody out there who is interested in exchanging programs and hardware information for the Motorola 6800, please write. R Veenen, Paul Krugler 113, Den Haag HOLLAND.

FOR SALE: Data Reference Card for RCA 1802 microprocessor. Send $1 plus self-addressed stamped envelope to R W Moell, 5905 Daywood Ct, Raleigh NC 27609.

FOR SALE: E and L instruments MMD-1808A based microcomputer complete with keyboard, 256 bytes programmed memory, 2 X PROM programmed for keyboard entry and execution of programs, power supply, interfacing and troubleshooting sockets, keyboard connector for expansion. Includes modular, self-taught microprocessor course. Assembled, tested, excellent condition, $350 Edward D Paradise 3 Vola Ln, New Britain CT 06052, (203) 223-2683.

IBM 1620: Being modified; additional core, peripheral, printer. Our printer is not to be attached; any comments, suggestions as to probable problems etc, will be appreciated. Please contact: T K Maki, 120 Minnet Rd, Westminster MA 01473.

GAMERS: I have compiled a book of BASIC games. Most are new games. If you wish to have a copy, send $10 in the form of a check or money order to Mike Blanchard, 7213 Spring Valley Rd, Bloomington IN 47401. Indiana residents add $40 for sales tax.

FOR SALE: New 102 switch keyboard printed circuit board double sided, plated through holes, 16x5 by 7 inch board. ASCII output or can be changed to 1725A PROM for any 7 bit code. All schematics, parts list, modifications (only left) $6. Also Motorola crystal oscillator K1091A (20 MHz, $10 new, $10 old). $4 for 5 MHz perfect for OSI video board optional oscillator. Also have miscellaneous parts: bridge rectifiers, filter caps, 600V, 800V, Mark 8 boards, C and mod-b boards, Monitor-8 ROM, 8008 manuals, books, etc. Send SASE for complete list to Ron Angradi, RD-2, Box 281, Kutztown PA 19530.

FOR SALE: 18 digital cassette tapes and cases by Wang Labs Inc. Like new $2 each. 30 Shufllt full size floppies, most barely used $4 each. Harry Morrow, 437 Barton Run Blvd, Marlton NJ 08053. Call anytime (215) 586-3600.

FOR SALE: Two G51 110 floppy disk drives, single or dual density, soft or hard sector drives. The electronics to the drives are complete, including a complete data separator, a complete set of documentation and all connectors and cables. $350 each or $650 for the pair. Jim Bannard, 6343 E Turney Av, Apt F-2, Buena Park CA, (714) 826-7056.

FOR SALE: Selectric 10 keyboard printer service manual, clean and barely used, $20 or early issues of BYTE in trade. Michael Craig, POB 895, West Asicto MA 01720.

FOR SALE: Teletype ASR-33 in very good condition, with manuals, 660, MITS RS-232C cassette interface, assembled and working, $120. I need more memory and an IO board (RS-232) for S-100 bus and would consider the above items. Donald Bailey, 19 Shaker Rd, Concord NH 03301.

CHESS BYTE readers interested in exchanging information about computer chess, finding postal connections for their computer chess programs and in organizing a tournament are invited to write me. R M Hord, 3407 N Third St, Arlington VA 22201.


FOR SALE: New Univac 30 cts 132 column 64 character printer with drive electronics board and motor (screw), and keyboard interface socket. Assembled and used, with documentation and interface information, cost $1800. Send $1000, receipt $695. D Kriewob 18 Nowarka Pl, Elizabeth NJ 07202.
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