Special Issue: Microprocessors and Microcomputers

Introduction

Microcomputers in psychology

JOSEPH B. SIDOWSKI

University of South Florida, Tampa, Florida 33620

A simple introduction to microcomputers is provided. References are provided for more detailed descriptions of some systems and applications in psychology.

The purpose of this issue of *Behavior Research Methods & Instrumentation* is to provide the behavioral scientist with some selected examples of uses and applications of microprocessors and microcomputers.

MICROCOMPUTERS

In the past few years, much has been written in both popular and technical publications on microcomputer-based technology. So I shall provide relatively superficial coverage. The interested reader can refer to the following articles, which are written simply and clearly and require no technical background for understanding

Frenzel, L. How to choose a microprocessor. *Byte*, 1978, 3, 124-139.

Gray, S. B. Selecting a micro. *Creative Computing*, 1977, 3, 31-33.

Isaacson, P. Personal computers for small-business applications. *Popular Electronics*, 1978, 14, 53-57.

North, S. The ABCs of microcomputers: What the beginning computer hobbyist needs to know. *Creative Computing*, 1978, 4, 83-92.

Anonymous. Special focus on home computers: Basic guide to computer buying. *Popular Electronics*, 1977, 12, 57-72.

A more technical explanation of microcomputers may be found in a special tutorial issue on fundamentals of microcomputer systems. The reference is *Mini-Micro Systems*, 1977, Volume 10 (Mini-Micro Systems, 5 Kane Industrial Drive, Hudson, Massachusetts 01749). Readers interested in the specifics of microcomputer technology will find a relatively detailed list of books presented in tabular form in: Osbourne, A. What's what in personal computing software. *Mini-Micro Systems*, 1978, 11, 107-111. The same reference contains tabular listings of available software for various microsystems as well as software vendors. An excellent source of information on microcomputers and microprocessors is the "Special Issue on Microcomputers—From Chips to Systems" of the Cashner publication, *EDN*, November 20, 1977, Volume 22. Included is the Fourth Annual Microprocessor Directory, the First Annual Microcomputer Support Chip Directory, the Third Annual Microcomputer Systems Directory, and an

article on "Microcomputer Programming Languages: When to Use Which and Why?" (*EDN*, 270 St. Paul Street, Denver, Colorado 80206).

The introductions to some of the articles in this issue also present elementary information concerning this area. Additional information on microprocessor technology directed to the psychologist may be found in the April 1978 issue of *Behavior Research Methods & Instrumentation*, which reports on the Seventh National Conference on the Use of On-Line Computers in Psychology (listing provided in References section of this paper).

I believe that the first attempt by a psychologist to educate psychologists about microcomputers was a talk presented by McLean to the 1973 meetings of the national computer conference noted above. The reprinted version of that presentation is also tutorial (McLean, R. S. Microcomputers for experimental psychology. *Behavior Research Methods & Instrumentation*, 1974, 6, 155-158). A clearly written follow-up was published by: Kehoe, E. J., Frei, L. J., Tait, R. W., & Gormezano, I. On microprocessor-based computers. *Behavior Research Methods & Instrumentation*, 1975, 7, 183-186). Krausman writes of his experiences with a microcomputer kit (Krausman, D. T. The microcomputer kit: An excellent small system development tool. *Behavior Research Methods & Instrumentation*, 1976, 8, 501-507). His system was used with heart rate biofeedback.

The overwhelming influences of electronics and microelectronics are covered in special issues of two publications: The microelectronics issue of *Scientific American* (September 1977, Volume 237) and the issue on the electronics revolution in *Science* (March 1977, Volume 195, No. 4283).

The Computing Systems: Some Definitions, Explanations, and Descriptions

A microcomputer consists of several components tied together; the microprocessor is only one of these components. As with other computers, a memory is required, inputs and outputs needed, and interconnections wired. Basically, the microprocessor coordinates activities and input/output devices. It performs operations on data

stored in memory and determines the external devices that might provide or have access to the data. Memories include random-access memory (RAM), which can be written into and read from by the computer, and read-only memory (ROM), which can have information read from it, but itself cannot store new information. ROM is preprogrammed with a set of instructions. If your microcomputer comes with software programmed in ROM (e.g., BASIC), the language is operating as soon as the system is connected. Unprogrammed ROMs can be purchased and permanently programmed as required (programmable read-only memories, PROMs). Erasable programmable read-only memories (EPROMs) allow the user to reprogram, but both PROMs and EPROMs act basically like unprogrammed ROMs once in the system. RAM is required to reprogram during computer operation. Inexpensive audio-cassette recorders appear to be the most popular peripheral memories, but there are a number of audio-cassette interfaces and they are rarely compatible. Using one of the more common interface standards allows the user more freedom in trading or buying software, but some are used only by users of that manufacturer's system. If random-access, high-speed operation is required, as it is in many research applications, a floppy-disk unit is needed, and this greatly increases the cost of what might otherwise be a relatively inexpensive system.

At present, most microprocessors are 8 bit. The most widely used in microcomputers is the Intel 8080, probably the best documented and upward-compatible device available. The Zilog Z-80, discussed elsewhere in this issue of the journal, is newer and more powerful and designed to include the 8080 instructions. The software written for the 8080 also runs on the Z-80. The Z-80 has the advantage of being faster with more instructions than the 8080 and requires only one 5-V power supply. The 8080 requires three, although the newer Intel 8085 microprocessor uses a single power supply and fewer support chips than the 8080. The Intel 8080 microprocessor is used in microcomputer systems provided by Digital Group, E & L Instruments, Heath Company (H8), IMSAI (8080), MITS (Altair 8080B), PolyMorphic, Processor Technology, and Vector Graphic. Except for the Heathkit and Digital Group systems, the S-100 bus is used. Bus systems will be explained shortly.

The Motorola 6800 microprocessor has a superior instruction set, architecture, and addressing modes, but it is slightly slower than the 8080 or Z-80. The MOS Technology 6502 is somewhat similar to the 6800 and is incorporated into the KIM-1 microcomputer, which is described elsewhere in this issue. The 6502 microprocessor is incorporated into microcomputers marketed by Ohio Scientific Instruments, Apple Computer, MOS Technology (KIM-1), and Commodore PET. Microcomputers built around the Z-80 include the Radio Shack system, Technical Design Labs, Cromemco, and the

Digital Group. There are, of course, other microprocessors, but the systems mentioned above are the most popular. Mentioning incorporated systems is merely intended to indicate the commonality of subsequent function and peripheral requirements.

Sixteen-bit systems. In this issue, Hansen discusses 16-bit microcomputers. Sixteen-bit systems include the National Semiconductor PACE, 8900, the General Instruments 1600, the Data General MicroNOVA, the Digital Equipment Corporation LSI-11, the Texas Instruments 9900, and the Fairchild 9440. At present, prices are higher for the 16-bit systems than for the 8-bit systems and supportive software is not as readily available, but the advantages of the 16-bit systems will be felt shortly. The DEC LSI-11 is the most widely used; the Heath Company offers a version called H11. Virtually any of these systems can call on the software backing of the PDP-11 library.

The 16-bit MicroNOVA can run all software of the Data General NOVA line minicomputers. And the Intersil 6100, a 12-bit microprocessor, runs on software written for the DEC PDP-8/e minicomputer.

Obviously, software cannot be overemphasized. Some of the non-8-bit microprocessors have excellent software bases. For 8- and 16-bit systems, BASIC is the most common language, but software is being developed at a very rapid rate, and FORTRAN and other languages are becoming available. PASCAL for small computers is discussed in this issue by Bowles and Hollan; COBOL-60 was recently developed by MICROSOFT of Albuquerque, New Mexico, to run on the Intel 8080 and 8085 microprocessors and on the Z-80; and SKED is available for micros in psychology laboratories. But the present availability of software for psychological applications is limited. Minicomputers offer a tremendous advantage in this respect. (Arguments could be developed for recommending minis over micros for reasons other than software, but the issue is not covered in this volume.)

Addresses of the microcomputer companies mentioned above, as well as others, are listed in Table 1.

Bus. A much discussed element is the bus, a collection of wires or lines that serve as connecting links that carry signals. Microcomputers have bus systems to tie components together whether the system is on one or more than one printed circuit board. The bus itself may be part of a "motherboard" that contains connections for different circuit cards that can be plugged in. On a single-board system, the bus is arranged to connect the same sort of elements, that is, memories, processor, and input/outputs. The sets of wires going to different places have the following functions: Power lines supply the operating voltages (as noted earlier, some microprocessors, such as the Intel 8080, require three separate power voltages, others require only one); data lines generally carry data in or out of the central processor; address lines are most often driven by the central

Table 1
Names and Addresses of Some Microcomputer Companies

Apple Computer Co., Inc. 10260 Bandley Drive Cupertino, CA 95104	Fairchild Semiconductor 464 Ellis St. Mountain View, CA 94040	Ohio Scientific 11679 Hayden Hiram, OH 44234
Central Data P.O. Box 2484 Station A Champaign, IL 61820	General Instrument Corporation Microelectronics Division 600 West John Street Hickville, NY 11802	Pertec Computer Corporation Microsystem Division 20630 Nordhoff Street Chatsworth, CA 91311
Commodore Business Machines, Inc. (PET) 901 California Avenue Palo Alto, CA 94305	Heath Company Benton Harbor, MI 49022	Poly Morphic Systems, Inc. 460 Ward Drive Santa Barbara, CA 93111
Computronics 19824 Ventura Blvd. Woodland Hills, CA 91364	IMSAI Manufacturing Corporation 14860 Wicks Blvd. San Leandro, CA 94577	Processor Technology Corporation 6200 Hollis Street Emeryville, CA 94608
Compucolor Corporation P.O. Box 569 Norcross, GA 30091	INTEL Corporation 3065 Bowers Avenue Santa Clara, CA 95051	Radio Shack 2617 West Seventh Street Ft. Worth, TX 76107
Compucorp 1901 S. Bundy Drive Los Angeles, CA 90025	Intelligent Systems Corporation 5965 Peachtree Corners East Norcross, GA 30071	RCA Corporation RCA Solid State Somerville, NJ 08876
Computer Data Systems 5460 Fairmont Drive Wilmington, DE 19808	Intersil Corporation 10900 North Tantau Avenue Cupertino, CA 95014	Southwestern Technical Products 219 West Rhapsody San Antonio, TX 78216
Cromemco, Inc. 2400 Charleston Road Mountain View, CA 94043	Midwestern Scientific Instruments 220 West Cedar Olathe, KS 66061	Technical Design Labs Research Park Princeton, NJ 08040
Data General Corporation Microcomputer Division Westboro, MA 01581	MITS 2450 Alamo, Southeast Albuquerque, NM 87106	Technico Incorporated 9130 Red Branch Road Columbia, MD 21045
Digital Equipment Corporation One Iron Way Marlborough, MA 01752	MOS Technology, Inc. 950 Rittenhouse Road Norristown, PA 19401	Texas Instruments, Inc. Microcomputer Products Houston, TX 77001
The Digital Group P.O. Box 6528 Denver, CO 80206	Mostek 1215 West Crosby Road Carrollton, TX 75006	Vector Graphic, Inc. 717 Lakefield Road West Village, CA 91361
E & L Instruments 61 First Street Derby, CT 06418	Motorola Semiconductor 5005 East McDowell Road Phoenix, AZ 85008	VideoBrain Computer Company 150 Wolfe Road Sunnyvale, CA 94086
Equinox Division Parasitic Engineering Box 6314 Albany, CA 94706	National Semiconductor Corporation 2900 Semiconductor Drive Santa Clara, CA 95051	Zentec Corporation 2400 Walsh Avenue Santa Clara, CA 95050
	North Star Computers 2547 Ninth Street Berkeley, CA 94710	Zilog 10460 Bubb Road Cupertino, CA 95014

processor and received by other parts of the system; control signal wires have various functions, but as their title indicates, various component outputs are controlled by them.

The S-100 bus has been called a "standard" because it is used in so many systems, rather than because it satisfies the technical definition of the term (Ogdin, C. A. Microcomputer buses. *Mini-Micro Systems*, 1978, 11, 97-104). It was introduced in about 1975, with the Altair 8800 microcomputer. Due to its early introduction and subsequent popularity, rather than enthusiastic acceptance, many companies marketing support equipment designed equipment to work with the S-100

bus; in fact, new supportive companies continue to sprout.

When the Heath Company announced its H8 microcomputer, it introduced a bus with 50 lines (the S-50) rather than the 100 of the S-100 Altair. The designers of the 50-line bus claimed a number of advantages resulting from their past experiences with the S-100. These will not be covered here, but detailed information is provided by: Lees, J., & North, S. Heath H8 system. *Creative Computing*, 1978, 4, 38-40; and Arnold, R. S. A buyer's and builder's guide to the Heathkit H8 system. *Interface Age*, 1978, 3, 128-141.

The KIM-1 microcomputer has most of its subsystems

on one board. A 44-pin edge connector brings the central processor unit bus out. A motherboard is available to expand the bus, so converting the KIM-1 bus to a S-100 permits use of the many S-100 connections. The ability to convert from one bus to another obviously offers many advantages for any system.

The GPIB is a general-purpose interface bus that has been adopted as a standard by IEEE. The maximum effective bus length for this system is said to be about 16 ft, which provides some advantage in connecting to peripherals. The three buses mentioned earlier have their operational speeds restricted to an overall length of about 2 ft, which generally means that interface boards must be plugged into the bus at the cabinet. The GPIB connector is on the back of the Commodore PET microcomputer, one of the most inexpensive and best selling complete systems on the market today.

Additional information on bus systems may be found in articles or advertisements covering individual microcomputer systems. Also refer to the following:

Duncan, M. Some guidelines for users of the RS-232 or the UART. *Interface Age*, 1977, 2, 46.

Notari, R. A 16-bit system for the S-100 bus that holds its own against a mini. *Interface Age*, 1977, 2, 72-74.

Purser, R. E. S-100 compatible computer kits. *Creative Computing*, 1977, 3, 41-44.

Purser, R. S-100 bus compatible systems—OEM supplement and price list. *Interface Age*, 1977, 2, 76-87.

Chamberlin provides an easy-to-read article on bus systems in a recent issue of *Popular Electronics* (Chamberlin, H. Computer bit: Bus systems. *Popular Electronics*, January 1978, p. 77-79).

Fortunately, a number of converters have been designed and continue to be introduced by commercial firms that allow microcomputers with one type of bus to use other interface boards. In this issue, R. N. Johnson notes one such supplier for the PET system. An increasing number of others are available, including Pickles and Trout of Goleta, California (S-100 to IEEE-488 interface for \$325).

Ogden states that only three buses are contenders in the contemporary popularity race: These are the LSI-11 (DEC), the MULTIBUS (INTEL) originally used in the Intel microcomputer development system, and the S-100. The Heath H8 bus scheme, she states, is "doomed to a long, slow and painful death as technology marches on." The same fate is predicted for the S-100 because both are dedicated to the Intel 8080 microprocessor control signals.

Becoming involved. Becoming acquainted with microcomputers is a relatively simple matter: You merely go to the local Radio Shack store or to a computer store and examine one. Computer stores that specialize in micros are located in virtually every large or medium-size city in the country. The world's first computer store was opened in Los Angeles, California, in 1975. Byte, Inc. is

the first computer store chain and now numbers over 30 stores. So the situation for the beginner is much different than it was for the individual interested in purchasing a minicomputer. A micro not only may be purchased at the corner store, but the salesperson may also supply local maintenance and advice on setting up the system for specific applications. Local clubs are numerous, and extensive information is exchanged in the more popular publications, such as *Creative Computing* (P.O. Box 789-M, Morristown, New Jersey 07960), *Byte* (70 Main Street, Petersborough, New Hampshire 03858), *Interface Age* (P.O. Box 1234, Cerritos, California 90701), and *Dr. Dobb's Journal of Computer Calisthenics and Orthodonta* (El Camino Real, Box E, Menlo Park, California 94025). Of course, a great deal of the information concerning applications will not be of interest to the research-oriented psychologist, but these publications carry much information of value on software, hardware, technological developments, evaluations of systems, and so on. More of the efforts of the National Conference on the Use of On-Line Computers in Psychology are being directed to microcomputers, so that organization can be expected to act as a prime source of information for the behavioral scientist.

CONTENTS OF THIS JOURNAL ISSUE

An attempt has been made to provide the reader with a sample of the work now being done with microcomputers in psychology. The first three sections deal with three different systems, the PET, the KIM-1, and the LSI-11. Another use of the PET may be found in the section on observational research; Durrett (1978) discusses the PET and the Radio Shack (Tandy Corporation) TRS-80 systems in a recent issue of this journal. Murray and Lawler (1978) describe a KIM-1 interface for aversive conditioning applications in the same issue.

It is obvious that only a small sample of the available microcomputer systems are mentioned in this volume. At present the PET is probably the best selling complete system on the market; it was introduced as a stand-alone system in 1977, at the National Computer Conference in Dallas, Texas, and caused a stir throughout the computer industry because of the price (\$595 and \$795) and package (keyboard, display, cassette system, processor, memory, interface, and software). The Heath systems were announced but not shown at the same meetings. I suspect that a reasonable number of Heath systems will be adopted by research psychologists because of individual satisfaction with Heathkit products in general in the past. But the H8 system built around the Intel 8080 is priced at \$1,239.75 with 4K memory, serial I/O and cassette interface, a video terminal, and cassette recorder-player. The Heath System IV costs \$3,350 with the H11 (LSI-11-based) computer, 4K memory, parallel interface and serial interface, paper-

tape reader-punch, and DECwriter. The TRS-80 from Radio Shack is comparable in price with the PET with somewhat similar built-in features. It will be sold eventually at 2,100 stores, which should make the system a relatively popular laboratory adjunct. Additional information on the PET and TRS-80 may be found in the following sources:

- Brown, L. Commodore PET. *Creative Computing*, 1978, 4, 24-26.
 Fylstra, D. User's report: The PET 2001. *Byte*, 1978, 3, 114-127.
 Gray, S. B. Radio Shack TRS-80. *Creative Computing*, 1978, 4, 35-37.

The DEC LSI-11 and other 16-bit microcomputers obviously have advantages, and these are covered in this issue by Hansen. Palya in this volume provides an invaluable source for LSI-11-compatible products.

Timesharing, interfacing, and networks are of concern to microcomputers as they were and continue to be to minicomputerists. Four articles cover some aspects of these in this volume.

The five experimental articles cited are merely samples of the many ways in which the technology is being used in the laboratory; Hale and his coverage of British psychology departments provides a number of others as he reports on the state of the art in the behavioral sciences in Great Britain.

The gathering of data in naturalistic settings is being revolutionized by electronic developments. The three articles covering observational and field research technology provide illustrations. Microprocessor-based systems are allowing for limited but immediate analysis of the data. Development of battery-operated microcomputers may offer enhanced data-handling capabilities in the field. A battery-operated system has recently been

advertised (battery-operated Model 600 microcomputer, Adaptive Systems, Inc., P.O. Box 1481, Pompano Beach, Florida 33061).

Finally, three groups of authors address the uses of microsystems for psychological testing and assessment, reflecting the potential for the immediate use of this technology in clinical settings.

REFERENCES

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