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The AIM-65 microcomputer as a laboratory control device

C. DONALD HETH
University of Alberta, Edmonton, Alberta T6G 2E9, Canada

The AIM-65 microcomputer is a self-contained system equipped with several useful peripheral devices. Its low cost and versatility make it an attractive device for the control of laboratory equipment. This article describes the AIM-65 and illustrates some possible applications.

Although microcomputers have significant potential as inexpensive and efficient laboratory control devices, many psychological experiments require elaborate input and output media beyond the capacity of low-cost systems. For example, a conditioning experiment might require a trial-by-trial printout of acquisition data, or a memory study might involve typewritten responses to lines of text. The peripherals required to implement these procedures rapidly escalate the cost of a microcomputer-controlled installation. A teletype to provide a printed record of an experiment or a video terminal to present stimuli can easily involve several hundred to $1,000 each, making the entire system a significant expenditure.

A recent addition to the microcomputer market, however, goes a long way toward solving this dilemma. The AIM-65 microcomputer, by Rockwell International,[1] is a complete microcomputer that contains a typewriter keyboard, a 20-character alphanumeric display, interfaces for storing information on magnetic recording tape, and a 20-column hard-copy printer. The total cost of the system is $375.

The low-cost and impressive versatility of this microcomputer make it ideal for many psychological research applications. In this report, I will describe some of the salient features of the AIM-65 and illustrate its potential with sample applications.

HARDWARE OVERVIEW

The AIM-65 consists of an alphanumeric keyboard connected by a ribbon cable to the "master module." The master module contains a printer, visual display, various interface circuits, and the computer.

The central processing unit (CPU) is the 6502 microprocessor, an 8-bit CPU used in a variety of microcomputers, most notably the KIM-1 computer board and the PET and Apple II home computer systems. The unit has a total of 56 instructions and a memory addressing capacity of 65K. It contains an 8-bit accumulator, two 8-bit index registers, and three interrupt lines. In the AIM-65 system, the 6502 operates at 1 MHz.

The standard AIM-65 package contains 1K of random-access memory (RAM), expandable on board to 4K. The package also has 8K of read-only memory (ROM), containing a monitor program to be described below. Additional sockets allow expansion of ROM and programmable ROM to 20K

The visual display consists of 20 16-segment characters. This font will display the complete set of uppercase ASCII characters and can be controlled through the monitor or through user-called monitor subroutines. The 20-column alphanumeric thermal printer can print 120 lines/min. The printer can also be operated through the monitor or through subroutine calls.

The AIM-65 contains an interface for controlling a standard Teletype and interfaces for recording and playing back data on audio recorders. Thus, data or programs in memory can be stored in a high-density medium. In addition, the AIM-65 has a general-purpose interface chip that contains two interval timers (one of which can serve as an event counter), a shift register for serial-parallel conversions, and two 8-bit bidirectional I/O ports. The latter can be used to sense switch closures or to operate relays. In addition, major control lines and busses are brought out to a 44-pin connector to allow for further expansion.

Thus, the AIM-65 has the hardware to receive input from a typewriter keyboard and to record it permanently on paper or magnetic tape. It can also respond to external signals and set voltage levels to control other equipment.

SOFTWARE OVERVIEW

The AIM-65 contains an 8K monitor program that allows the user to interact with the various components of the system. For example, the monitor program will display the contents of a memory location on command; another command will change the contents of a location. Microcomputer programs, of course, are stored as a sequence of coded instructions in memory. The monitor thus allows the user to write the program for his particular application.

Requests for reprints should be sent to the author, Department of Psychology, University of Alberta, Edmonton, Alberta T6G 2E9, Canada.

The AIM-65 monitor is especially useful to less-than-full-time microcomputer programmers. Its commands and operations are easy to remember and use, yet they are quite powerful. For example, a programmer might wish to transfer the contents of Memory Location 0001 into the accumulator. With the 6502 CPU, this is accomplished by the sequence A5 01 (hexidecimal notation) in two successive 8-bit memory locations. The AIM-65 monitor, like others, allows a programmer to write these numbers (machine language) directly into memory. However, the AIM-65 also contains another command ("I") that permits the programmer to type a mnemonic symbol for an instruction. In the above example, the programmer could type LDA 01, and the AIM-65 monitor would convert the mnemonic to machine language. The mnemonics are much easier to remember and to format. The monitor can also translate from machine language to the mnemonic ("disassembling"), which is an especially convenient way to examine and debug a program.

The monitor will also run a selected program. The user merely instructs the monitor where to begin and commands the execution of the program. At the user's option, the monitor will display or print each instruction and/or the contents of the registers as each instruction is executed. Furthermore, the monitor can be given commands to stop execution at selected points in the program (software-controlled break points). The monitor is therefore an extremely useful tool for debugging programs.

Another feature of the monitor is a text editor, which allows the user to type large sections of text for later use in program construction. Lines of text can be inserted or deleted later. Upon command, the editor searches the entire block of text for a specific character. At the user's command, this character can be changed. The text editor is especially useful for construction of assembly language programs.

Finally, the monitor can read from and transfer data to various storage media. Information can be read into areas of memory from the keyboard, from a simple tape recorder, or from a Teletype. Areas of memory (e.g., programs or data) can be printed on the printer, recorded on tape, or transferred to a Teletype. The operations are controlled by the user in a sequence of commands prompted by the monitor.

In summary, the AIM-65 monitor permits the easy interaction of user with computer. It seems to be ideally suited for the development and testing of microcomputer programs by both novice and experienced programmers.

INTERFACING

As mentioned, the principal interface component of the AIM-65 is a general-purpose device that can be used to sense events such as switch closures and to control equipment such as relays. However, the voltage levels and currents of the computer ordinarily require a specialized interface. Input to the computer, for example, must be modified to eliminate spurious voltage changes (e.g., "switch bounce"). The simplest technique is to use 5-V currents to operate latches or flip-flops. Possible designs for such circuits have been described by Criswell and Babcock (1978), Murray and Lawler (1978), and Parks (1978). These circuits were designed for the KIM-1 microcomputer and are readily adaptable to the AIM-65.

The most common output application is likely to be the control of relays or other electromechanical devices. The interface of the AIM-65 is very similar to the interface chip on the KIM-1 microcomputer; therefore the circuits described by Murray and Lawler (1978) and Parks (1978) for the KIM-1 can be adapted.

SAMPLE APPLICATIONS

The AIM-65 is extremely versatile. Like the KIM-1 described by Criswell and Babcock (1978) and Parks (1978), it can be used to count events or to measure temporal intervals. Two such applications are illustrated in Tables 1 and 2.

Table 1 describes a subroutine designed to count events. This program assumes that the event causes a transition from 0 to 5 V on one of the AIM-65 interface lines (line PA-7 is used in this example). For maximum generality, no limit is placed upon the time the input is held at 5 V (e.g., a rat may hold an operant lever down for a variable time). Whenever the subroutine detects a transition, it increments the number stored in Locations 0010 and 0011. For convenience in recording the data, the cumulative total of events is stored as a decimal number. The subroutine can be used as part of a "scan for response" loop, or it can be called in response to an interrupt signal. The main program should initialize the counter by clearing the contents of Locations 0010, 0011, and 0012, and by clearing Bit 7 of Location A003.

Table 1
Subroutine to Count Responses

Address	Instruction	Comment
0200	PHA	Save accumulator
0201	PHP	Save processor status flags
0202	SED	Set decimal mode
0203	LDA A001	Load input port
0206	PHA	
0207	PHA	
0208	EOR 12	Check for change
020A	STA 12	
020C	PLA	
020D	AND 12	Check for high level
020F	ASL .A	Increment counter
0210	LDA #00	
0212	ADC 11	
0214	STA 11	
0216	LDA #00	
0218	ADC 10	
021A	STA 10	
021C	PLA	
021D	STA 12	Store last response status
021F	PLP	Restore processor status
0220	PLA	Restore accumulator

Table 2
A Free-Running Clock

Address	Instruction	Comment
0240	LDA #40	Set timer to recycle mode
0242	STA A00B	
0245	LDA #C0	Enable timer interrupt
0247	STA A00E	
024A	LDA #00	Define 0300 as interrupt address
024C	STA A400	
024F	LDA #03	
0251	STA A401	
0254	LDA #00	Clear locations 0000 and 0001
0256	STA 00	
0258	STA 01	
025A	LDA #0E	Load constants into timer
025C	STA A004	
025F	LDA #27	
0261	STA A005	
0264	CLI	
	(Continue with main program)	
0300	PHA	
0301	PHP	
0302	LDA #40	Test if timer has caused interrupt
0304	BIT A00D	
0307	BEQ 031A	
0309	SED	
030A	CLC	
030B	LDA #01	Add one to location 0001
030D	ADC 01	
030F	STA 01	
0311	LDA #00	Add any overflow to location 0000
0313	ADC 00	
0315	STA 00	
0317	LDA A004	Clear interrupt
031A	PLP	
031B	PLA	
031C	RTI	

Table 3
Program to Print the Contents of Locations 0000, 0001, 0010, and 0011

Address	Instruction	Comment
0280	PHA	
0281	PHP	
0282	JSR EB44	Jump to clearing subroutine
0285	CLD	
0286	LDA 00	
0288	JSR EA46	Jump to display subroutine
028B	LDA 01	
028D	JSR EA46	
0290	JSR E83B	Jump to double space subroutine
0293	LDA 10	
0295	JSR EA46	
0298	LDA 11	
029A	JSR EA46	
029D	JSR EA24	Jump to print subroutine
02A0	PLP	
02A1	PLA	

Note—Printer must be turned on.

Table 2 lists a program to keep track of time. The program has two components. The first initializes one of the AIM-65 timers and programs it to interrupt the computer every 10 msec. The second part is the routine that is called when the timer interrupt occurs. This routine tabulates, in decimal notation, every 10-msec interval in Locations 0000 and 0001. These locations therefore form a free-running clock with which the experimenter can time intervals between events.

An extremely useful feature of the AIM-65 is the capacity to use portions of the monitor within the experimenter's program. Table 3, for example, lists a short subroutine that will display and print the contents of Locations 0000 and 0001 in the left columns of the printout and the contents of Locations 0010 and 0011 to the right. In conjunction with the programs of Tables 1 and 2, this routine allows an experimenter to print a time and response record upon command.

Similarly, other monitor subroutines allow a programmer to scan the keyboard for a subject's response or to present a message on the 20-character LED display. In this fashion, the AIM-65 can be programmed as a smart memory drum.

EXPANSION

The AIM-65 contains a 44-pin connector that can be used to expand the standard system. Rockwell International manufactures a motherboard that can be plugged into the AIM-65. The AIM-65 can also be ordered with several options on-board. The standard configuration contains 1K of memory; a 4K version is available. Rockwell International also sells a two-pass assembler and an 8K BASIC program in ROM. Both of these can be mounted on the AIM-65 board.

REFERENCES

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NOTE

1. Rockwell International Corporation, Microelectronic Devices, P.O. Box 3669, Anaheim, California 92803.

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