

**Using the H-8 Computer  
with the  
PAM-37  
Panel Monitor**

**Operation Manual**

## INTRODUCTION

This Manual describes the functions and operations of the Heath H-8 Panel Monitor Program, PAM-37, which resides permanently in a ROM on the H-8-6 Z80 CPU board. PAM-37 provides a sophisticated front panel display and keyboard emulation as well as handling master clear and interrupt operations. Some of the major features of PAM-37 are:

- Memory contents display and alteration.
- Register contents display and alteration.
- Program execution control (both breakpoint and single instruction operation).
- Self-contained bootstraps for program loading and dumping.
- Port input and output routines.

In addition to the above features, PAM-37 can be instructed (by means of a flag byte contained in the H-8 RAM) to bypass some or all of its normal functions so the sophisticated user can augment or totally replace them.

Communication with the Panel Monitor is accomplished through three devices: the keypad, the 7-segment displays, and the audio alert. The user enters commands and values through the 16-key keypad, and PAM-37 responds visually through the front panel displays. In addition to the front panel displays, PAM-37 provides the keypad entry and function feedback to the built-in speaker. Appropriate signals (short, medium, and long beeps) indicate that commands and data are accepted or rejected.

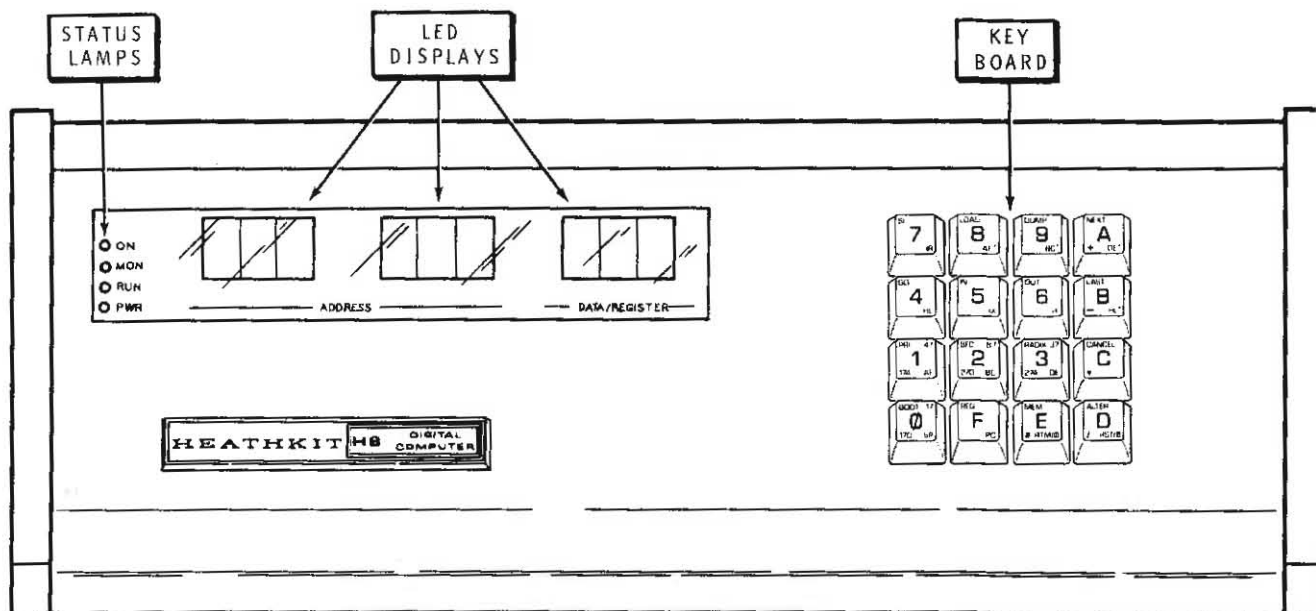


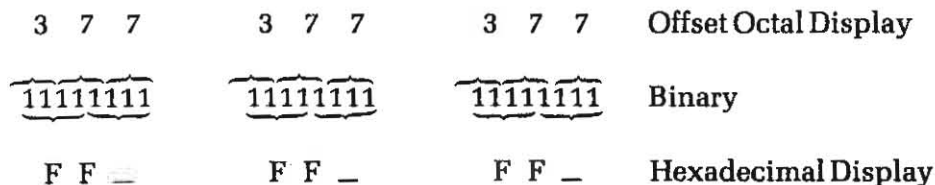
Figure 1

## H-8 FRONT PANEL

The following discussion requires that you understand binary, octal, and hexadecimal numbers. If you do not, see the Appendix for an introduction to these three number systems.

You must understand the front panel of the H-8 Computer to use PAM-37. The front panel is made up of nine LED displays arranged in groups of three, and a keyboard, as shown in Figure 1. The left two groups of three show the address of a memory location or the contents of a register. The right group of three shows the contents of the memory location or the name of the register.

Each group of three LED displays represents one byte (eight bits) of information, displayed as three octal or two hexadecimal digits. The relationship between binary numbers and the octal or hexadecimal number displays is shown below.



Notice that the most significant octal digit (the digit on the left) in each byte represents only two bits instead of three. When we use groups of three octal numbers to represent bytes, we are using offset octal. The consequences of this are that octal digits from 4 to 7 are not used in the most significant position in each group of three digits. Remember also not to confuse offset octal with true octal. The difference between the two is shown below.

3 7	7 3	7 7	Offset Octal
$\overbrace{1\ 1\ 1\ 1\ 1}$	$\overbrace{1\ 1\ 1\ 1\ 1}$	$\overbrace{1\ 1\ 1}\ \overbrace{1\ 1\ 1}$	Binary
1 7	7 7	7 7	True Octal

Note that offset octal may occasionally be written with a point mark separating each byte, such as in 377.377.

Only two hexadecimal digits are needed to represent a byte, because each hexadecimal digit represents four bits. The extra display in each group of three LED displays is simply not used.

Entering numbers via the keypad in both octal and hexadecimal formats is explained later in this Manual.

## H-8 Keypad

The H-8 Keypad consists of 16 keys, as shown in Figure 2. When the keypad is operating under the control of PAM-37, it exhibits a number of unique properties.

- Each keystroke is verified by a short beep from the audio alert.
- Octal digits are entered using the keys "0" through "7".
- Hexadecimal digits are entered using the keys "0" through "F".
- Holding a key down continuously repeats the key's function.
- The "NEXT" key increments memory port or register locations.
- The "LAST" key decrements memory port or register locations.
- The "CANCEL" key cancels previous keypad entries.
- The "ALTER" key causes PAM-37 to enter the alter mode.
- The "MEM" key causes PAM-37 to enter the display memory mode.
- The "REG" key causes PAM-37 to enter the register mode.

All of the keys on the keypad have multiple functions, depending on the PAM-37 mode being used. In the register mode, for example, the "0" through "B" keys call the register indicated in the lower right-hand corner of the key. When PAM-37 is in neither the register nor the memory mode, the keys perform the functions indicated in the upper left-hand corner of the key.

The "D" and "E" keys have additional special functions, as indicated earlier. When the "D" key is pressed simultaneously with the "0" key, the "RST" (master clear) sequence is initiated. When the "E" sign key is pressed simultaneously with the "0" key, the RTM (Return To Monitor) function is initiated, the user program is stopped, and PAM-37 regains control.

Each key is covered in greater detail as the various function are discussed.

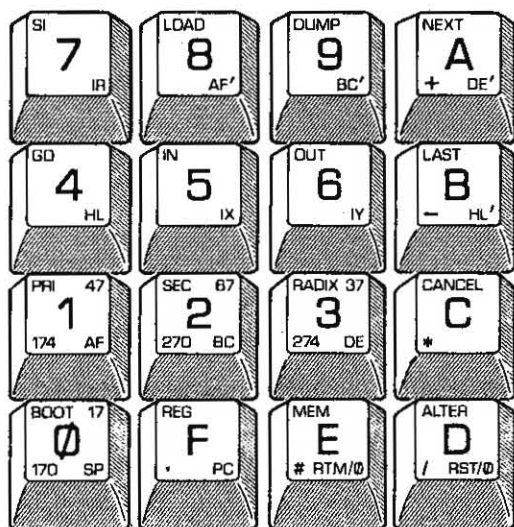


Figure 2

## DISPLAYING AND ALTERING MEMORY LOCATIONS

One of the major features of PAM-37 is its ability to examine the contents of any H-8 memory location and to modify the contents of that memory location if it is RAM.

When the H-8 is first powered up, PAM-37 is in the display memory mode. This mode is indicated by all digits displaying octal numbers and no decimal points being on.

### Changing Between Octal and Hexadecimal

PAM-37 allows you to enter numbers in either octal or hexadecimal. When the H-8 Computer is first turned on or when you perform a master reset by pressing the "D" and the "0" keys simultaneously, PAM-37 accepts only octal numbers. To enter hex numbers, press the "RADIX" button. (The button is called "RADIX" because changing number systems is known as changing the radix of the number.)

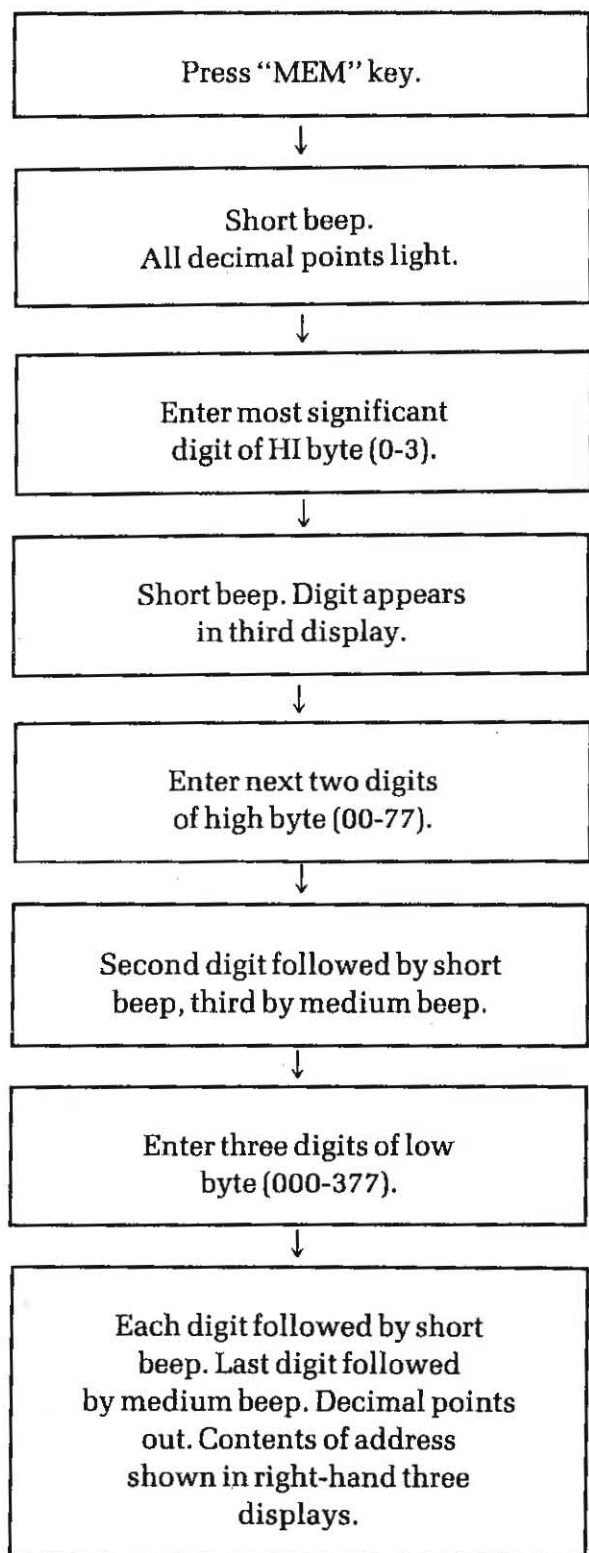
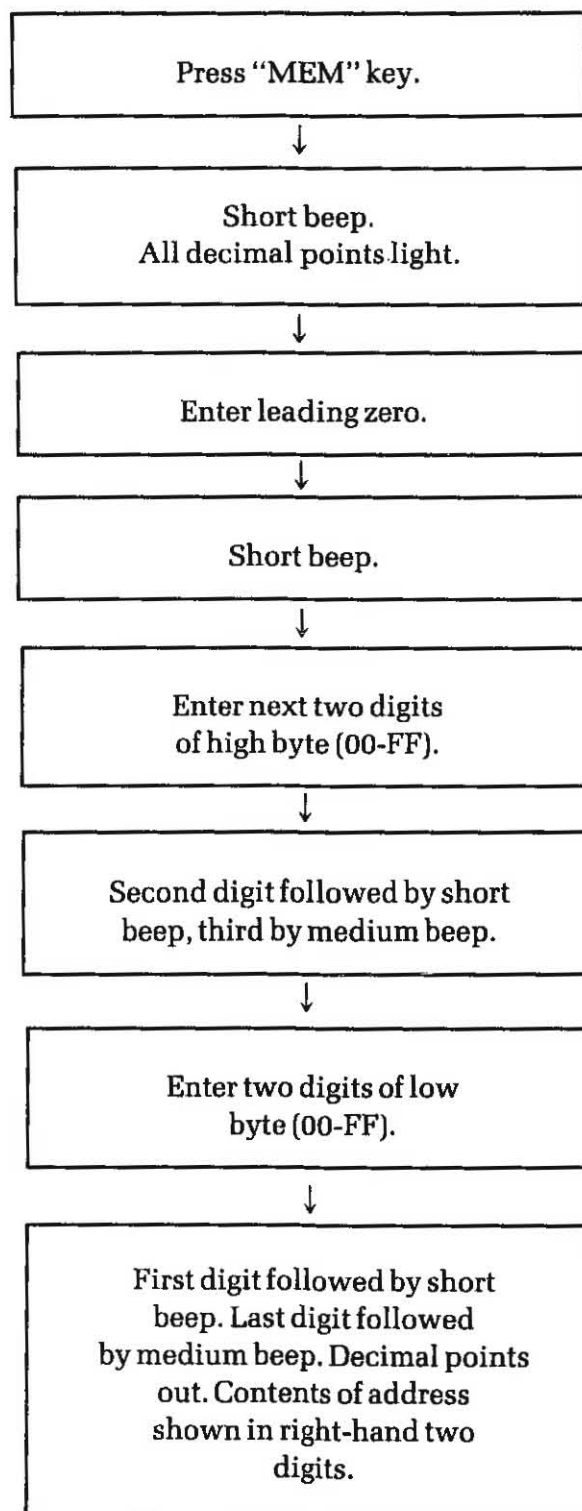
To return to octal numbers, press the "RADIX" key again.

### Specifying a Memory Address

If you wish to display or alter the contents of a memory location, you must first place PAM-37 in the memory address mode and then enter the desired memory address. Place PAM-37 in the memory address mode (if not already there) by pressing the MEM (Memory) key. Specify the address to be displayed or altered by entering the 6-digit offset octal address or the 5-digit hex address.

When you press the MEM key, all the decimal points will light. This indicates that the address may now be entered. Once the full address is entered, the decimal points turn off, indicating that address entry is completed. The address is displayed in the left-most six displays, and the contents of the addressed memory location are displayed in the right-hand 3 digits.

NOTE: As you press each key, including the MEM key, a short beep indicates successful entry. As each group of three octal digits is successfully entered, a medium beep is sounded. The sequence by which you specify a memory address is shown in Figure 3.

**OCTAL Procedure (Press D & 0)****HEX Procedure (Press RADIX)****Figure 3**

Entering a memory address through PAM-37.

**NOTE:** If you press a non-octal digit key as one of the six address digits while you are in the octal mode, an error is flagged (a long beep). Once this error is flagged, PAM-37 considers the address complete and extinguishes the decimal points. The entire sequence must be repeated. If you press any key other than zero when you are beginning a hex address, an error is also flagged and the entire sequence must be repeated.

## Altering Memory Contents

Before you can alter memory, you must first display the contents of the memory location by specifying the memory address as described in the preceding paragraphs. After you specify the memory address, press the "ALTER" key. This will cause PAM-37 to enter the memory alter mode.

When PAM-37 enters the memory alter mode, a single decimal point rotates from right to left through all 9 digits. You can now alter the contents of the displayed location by entering the new value. When the digits have been entered, a short beep is given **and the memory address is incremented**. You can then alter this new location by entering three more digits or pressing one of the following keys, causing the monitor to perform the indicated function:

<u>KEY</u>	<u>FUNCTION</u>
NEXT	Increment the address.
LAST	Decrement the address.
MEM	Specify a new memory address (leave the memory alter mode).
REG	Specify a register for display (leave the memory alter mode).
ALTER	Exit from the alter mode (into the display mode).

PAM-37 automatically increments the memory address as each entry (3 octal digits) is complete. Therefore, you may load a program in sequential locations very rapidly. Each location is modified by simply entering the three octal digits.



The following example shows how the value 345 octal is entered into the memory location 040.123 octal.

<u>OCTAL DISPLAY</u>			<u>COMMENTS</u>
X X X	X X X	X X X	The maximum memory address is displayed initially on power up or master reset. (This address will vary depending on how much memory your Computer has.)
X.X.X.	X.X.X.	X.X.X.	The "MEM" key is pressed to allow new addresses to be entered. All of the points light up.
X.X.0.	X.X.X.	X.X.X.	The "0" key is pressed, for the first number of the address.
X.0.4.	X.X.X.	X.X.X.	The "4" key is pressed.
0.4.0.	X.X.X.	X.X.X.	The "0" key is pressed.
0.4.0.	X.X.1.	X.X.X.	The "1" key is pressed.
0.4.0.	X.1.2.	X.X.X.	The "2" key is pressed.
0 4 0	1 2 3	X X X	The "3" key is pressed and the points go out.
0.4.0.	1.2.3.	X.X.X	The "ALTER" key is pressed to allow the contents of the location to be changed. The points move across the display.
0.4.0.	1.2.3.	X.X.3.	The "3" key is pressed, for the first number of the location value 345.
0.4.0.	1.2.3.	X.3.4.	The "4" key is pressed.
0.4.0.	1.2.4.	X.X.X.	The "5" key is pressed and the memory location increments by one.
0.4.0.	1.2.3.	3.4.5.	The "LAST" key is pressed and the address decrements by one.
0 4 0	1 2 3	3 4 5	The "ALTER" key is pressed and the points go out.

The next example shows how the value D5 hex is entered into the memory location 20 53 hex.

HEXADECIMAL DISPLAY

X X X    X X X    X X X

r A d    H

X X \_    X X \_    X X \_

X.X.\_.    X.X.\_.    X.X.\_.

X.X.\_.    X.X.\_.    X.X.\_.

X.2.\_.    X.X.\_.    X.X.\_.

2.0.\_.    X.X.\_.    X.X.\_.

2.0.\_.    X.5.\_.    X.X.\_.

2 0 \_    5 3 \_    X X \_

2.0.\_.    5.3.\_.    X.X.\_.

2.0.\_.    5.3.\_.    X.X.\_.

2.0.\_.    5.3.\_.    X.d.\_.

2.0.\_.    5.4.\_.    X.X.\_.

2.0.\_.    5.3.\_.    d.5.\_.

2 0 \_    5 3 \_    d 5 \_

COMMENTS

The maximum memory address is displayed initially on power up or master reset. (This address will vary depending on how much memory your Computer has.)

The "RADIX" key is pressed to convert to hex.

A fraction of a second later, the display changes to this.

The "MEM" key is pressed to allow the new address to be entered.

The "0" key is pressed. (When you enter hex memory locations, always enter a zero first.)

The "2" key is pressed, for the first number in the address 20 53.

The "0" key is pressed.

The "5" key is pressed.

The "3" key is pressed and the points go out.

The "ALTER" key is pressed to allow the contents of the location to be changed. The points move across the display.

The "0" key is pressed. (You must always have a leading zero when you are entering a new hex value into a memory location.)

The "D" key is pressed.

The "5" key is pressed and the memory location increments by one.

The "LAST" key is pressed, which decrements the memory location by one so that the contents may be viewed.

The "ALTER" key is pressed and the points go out.

## Stepping Through Memory

When PAM-37 is either in the display memory or alter memory modes, the "NEXT" and "LAST" keys increment and decrement the memory address. Each time you press the key, PAM-37 increments (or decrements) the memory address one location. If you hold the key down, the auto-repeat function of PAM-37 causes the memory address to increment or decrement repeatedly (approximately one location every second).

## DISPLAYING AND ALTERING REGISTERS

PAM-37 can display and alter the contents of the Z80 CPU registers, just as it displays and alters the contents of H-8 memory locations. Although the process is quite similar, a few special features should be noted.

### Specifying a Register for Display

Press the REG key to specify that a register is to be displayed. After you press the REG key, press a second key (see the Table below) to specify the desired register or register pair.

When the REG key is pressed, six points light, indicating that you must now select a register. NOTE: Simply pressing the REG key causes a register name to appear in the right-hand digits. However, you must select a register using the Register Select key before a register is definitely selected and its true contents are displayed. Once a register is selected, the decimal points are extinguished.

The contents of the selected register pair are displayed in the six left-most displays. The register name (or names) are displayed in the two right-most digits of the right-hand three displays. The registers are selected and displayed in accordance with the following table:

### Z80 ACCESSIBLE REGISTERS

<u>KEY</u>	<u>DISPLAY</u>	<u>COMMENTS</u>
SP (0)	SP	Stack pointer
AF (1)	AF	AF register pair
BC (2)	BC	BC register pair
DE (3)	DE	DE register pair
HL (4)	HL	HL register pair
IX (5)	IX	X index register
IY (6)	IY	Y index register
IR (7)	IR	Interrupt and refresh registers
AF' (8)	AF'	AF' register pair
BC' (9)	BC'	BC' register pair
DE' (A)	DE'	DE' register pair
HL' (B)	HL'	HL' register pair
PC (F)	PC	PC register pair

NOTE: The contents of any single eight-bit register may lie in the range of 000 to 377 octal or 00 to FF hex. The stack pointer (SP) and the program counter (PC) are 16-bit registers and are displayed as two sets of three octal numbers or two hex digits. Each set corresponds to one byte (8 bit number). When a register pair is displayed, the left set correspond to the left register and the middle set corresponding to the right register. For example:

256 312 AF

Register A contains 256 octal and register F contains 312 octal.

AE CA AF

Register A contains AE hex and register F contains CA hex.

## Altering Register Contents

To alter the contents of a register (or register pair), you must first specify it as described in the preceding paragraphs. After you select the register or register pair, press the "ALTER" key. This will cause the points to move across the display, indicating that you may enter digits to alter the contents of the indicated register or register pair.

The following command keys affect the registers.

<u>KEY</u>	<u>FUNCTION</u>
NEXT	Displays the contents of the next register or register pair.
LAST	Displays the contents of the previous register or register pair.
MEM	Specify a memory address.
REG	Specify a register for display.
ALTER	Enter or exit the register alter mode.

**NOTE:** Stack pointer register (SP) is not a direct display of the real stack pointer register, but simply a copy of the real stack pointer register and is used for display purposes only. The stack pointer cannot be altered from the front panel. To alter the stack pointer register, an SPHL (SPHL = 371 octal, or 5D hex) instruction must be written into memory. The desired new stack pointer value is then placed in the HL register pair. PAM-37 single instruction mode is used to execute the SPHL swap instructions, loading the stack pointer with the contents loaded in the HL register pair.

## Stepping Through the Registers

Use "NEXT" and "LAST" keys to change the register pair being displayed. For example, if the DE register pair is being displayed, pressing the "NEXT" key causes the next sequential register pair to be displayed (the HL pair). In the same manner, pressing the "LAST" key causes the register to decrement to the preceding pair. For example, if the DE pair is being displayed, pressing the "LAST" key displays the BC register pair. **NOTE:** Holding down either the "NEXT" key or the "LAST" key causes the display to continuously increment or decrement through all registers and register pairs.

## PROGRAM EXECUTION CONTROL

PAM-37 supports three basic program execution control facilities:

- Beginning or starting execution.
- Breakpointing.
- Single instruction.

Each of these execution controls permits the programmer to execute the desired portions of a program and examine its effects. He may execute the entire program, or a small group of instructions, or a single program instruction.

### Initiating Program Execution

To begin the execution of a program residing in H-8 memory, place the address of the first instruction to be executed in the PC (program counter). Use the methods described in "Displaying and Altering Registers" (Page 13). Once the address of this first instruction is placed in the program counter, press GO key and program execution will begin. NOTE: Unless the program disables the front panel, the display continues to be actively updated, although the front panel commands are no longer active (except for RST and RTM). If the program counter is displayed when you press the GO key, PAM-37 continuously monitors the program counter.

### Breakpointing

Breakpointing permits the programmer to execute small portions of a program and then return to PAM-37. Breakpointing is especially useful when a program is being "debugged." Small portions of the program may be executed and their results observed. If there is an error, it may be corrected before an entire program is involved.

When the H-8 executes a program and encounters a halt instruction, it re-enters PAM-37 and sounds a beep. All of the registers are preserved and the program counter points to the address **following** the address of the halt instruction. Thus, you can breakpoint a program from the front panel by inserting halt instructions (HLT = 166 octal, or 76 hex) at the desired points throughout the program. When a particular section of the program is tested and the breakpoint feature is no longer required, you can change the halt to a "no operation" (NOP = 000 octal, or 00 hex).

Once the halts are changed to NOPs, execution of the NOP simply passes control to the next successive instruction. Program execution for breakpointing uses the GO key as previously described.

**NOTE:** If you temporarily replace an existing instruction with a halt, you must restore the instruction before resuming program execution. The contents of the program counter point to the address **following** the halt. Therefore, if the instruction which replaced the halt is to be executed, when the program continues, the contents of the program counter must be decremented one location before execution is resumed.

## Single Instruction Operation

Any user program may be operated in the single instruction mode. This procedure is identical to the "GO" command, except that the "SI" key is pressed rather than the "GO" key. When the "SI" key is pressed, a **single instruction** (not a single machine cycle) is executed and then control is returned to PAM-37. Single instruction operation is available for careful inspection of program results and for executing special programs, such as swapping the HL register pair with the stack pointer as discussed in "Alternating Register Contents" (Page 15).

## Interrupting a Program During Execution

You can interrupt a running program (with all registers preserved at the point of interruption) by pressing the "RTM" and "0" keys simultaneously. You can then examine and/or alter the contents of various memory locations and all the registers as required. Resume execution of the program at the next sequential instruction by simply pressing the "GO" key. **NOTE:** It is almost impossible to stop a program exactly where you want to stop it using this method. Therefore, use the breakpoint feature if you want to stop the program at an exact location.

## LOAD/DUMP ROUTINES

PAM-37 contains a routine that lets you load and dump memory contents from or to a tape. This feature is especially important, as most computers require one of two successive "boot strap" routines to be hand-loaded before a desired program can be loaded into the main memory. All these "boot strap" routines are contained within the PAM-37 ROM, and use sophisticated error checking techniques. Thus, a program can be loaded or dumped by simply pressing a single key.

### Loading From Tape

Turn the Computer and recorder on, and connect the tape recorder to the Computer, as explained in the H-8-5 Manual. Load the tape into the recorder and press the recorder's PLAY button. Press the "LOAD" key on the Computer. PAM-37 will then start the tape recorder and scan the tape for the first file record.

No change will be seen on the front panel displays until PAM-37 finds the first file. When the first file record is located, PAM-37 checks it to see if it is the first (or only) record in a sequence, and the record is a memory dump record. If it is not a memory dump record, an error is flagged (see "Tape Errors" on Page 20).

Once a correct record is found, loading begins. The loading procedure places the entry point address of the program being loaded into the Computer's program counter. The Computer is then loaded. The display continuously shows the address and the data being loaded unless you have selected a register to be displayed instead of a memory location; in which case, the front panel will not change as the file is being read.

When the load is complete, PAM-37 sounds a long beep and displays the final memory address. If the load is faulty, an error number is displayed (see "Tape Errors" on Page 20) and the alarm continuously beeps.

NOTE: You may abort a load using the "CANCEL" key. Naturally, the load image resulting from this action is incorrect and should not be executed.



## Dumping to Tape

Before dumping a memory image onto tape, the following three dump parameters are required:

- The entry point address (the program starting address).
- The dump starting address.
- The dump ending address.

Set the desired entry point address by placing this value in the program counter (PC). This value will be placed in the program counter whenever you load the program so execution will begin at this address when you press the "GO" key.

Place the dump starting address into the first two H-8 RAM cells. These cells are: 040.000 and 040.001 octal or 2000 and 2001 hex. NOTE: The low order byte of the address should be placed into location 040.000 octal and the high order byte of the starting address should be placed into location 040.001 octal.

Enter the dump ending address as a memory address using the "MEM" key. Then ready the tape transport and press the "DUMP" key. As the tape dump takes place, the number of bytes left to be dumped and the contents of the memory location being dumped are displayed on the front panel. You can abort a dump by using the "CANCEL" key. If the "CANCEL" key is used, an incomplete dump image is left on the tape. This cannot be loaded at a future date. NOTE: A successful load automatically sets up the following three dump parameters:

- A. The program starting locations are stored in locations 040.000 and 040.001 octal.
- B. The program ending location is displayed.
- C. The program counter contains the program entry point.

The following is a typical memory image dump sequence. The sequence is shown in octal.

1. Set PC to 040.100; (040.100 = entry address).
2. Set 040.000 to 100 (100 = low byte of dump start).
3. Set 040.001 to 040 (040 = high byte of dump start).
4. Enter memory address 052.340 (052.340 = end address of dump).
5. Be sure tape is ready.
6. Press "DUMP".

The next two steps make up a typical memory image load sequence.

1. Be sure tape is ready.
2. Press "LOAD."

## Copying a Tape

The beginning and final address of the load image are placed at the appropriate points. Thus, to copy a tape, simply load the tape as described in "Loading From Tape" (Page 18). Then ready the dump tape drive and press the "DUMP" key. A dump then takes place, including entry point, initial address, and final address.

In a similar manner, to load, alter, and then dump, enter only the ending address. The other parameters are unchanged from the load if locations 040.000, 040.001 or the program counter have not been modified during the altering procedure.

## Tape Errors

PAM-37 detects two types of tape errors: record errors and checksum errors. In either case, when an error is detected, the tape transport is halted. The error number is then displayed in the center three digits (001 for a checksum error, 002 for a record error) and the alarm is repeatedly sounded. To halt the alarm and return to the command mode, press the "CANCEL" key.

## **RECORD ERRORS**

The following are typical causes of record errors.

- Attempting to load a file which is not a memory image. For example, loading an editor text file or a BASIC program file.
- Attempting to start a load in the middle of a load image. Therefore missing the initialization information at the start of the file.
- A tape error which causes a portion of the load image to be missed so the next record read is not in the proper sequence.

## **CHECKSUM ERRORS**

A checksum error is flagged when the CRC (Cyclical Redundancy Check) checksum following a record does not match the CRC calculated by PAM-37. This error means that the record is either incorrectly recorded or the load is faulty. In either case, the load should be attempted again. If successive loads result in repeated failures, the original tape must be suspected as faulty.

## DISK BOOT

PAM-37 contains the code necessary to boot up an operating system from the H-17, H/Z-37, H/Z-47, or Z-67 Disk Drive Systems. There are four booting methods. The first, called "Primary Boot," lets you boot up on drive 0 of the primary device with one keystroke. The second, called "Secondary Boot," lets you boot up on drive 0 of the secondary device with one keystroke. The third method, called "Universal Boot," lets you boot up on any drive of any device with four keystrokes. Finally, the fourth method, called "Auto Boot," boots up on drive 0 of the primary device automatically when you turn the power on.

### Primary Boot

Select the primary device by setting switch SW1 on the HA-8-6 Z-80 CPU Board as shown in "Switch SW1" in this Manual on Page 26. Press "1" on the keyboard.

The display will show *P r* and the name of the primary device.

To cancel the boot command, press the "CANCEL" key.

### Secondary Boot

Select the secondary device by setting switch SW1 on the HA-8-6 Z80 CPU Board, as shown in "Switch SW1" in this Manual on Page 26.

Press the "2" key. The display will show *S E* and the name of the secondary device.

To cancel the boot command, press the "CANCEL" key.

## Universal Boot

The single-key booting methods described earlier could access only drive 0 on either the primary or secondary device. To boot on other drives:

1. Press the "BOOT" key. The display will show *dEU*.
2. Press the device key, which can be either "0" for the H-17, "1" for the H/Z-47, "2" for the Z-67, or "3" for the H/Z-37. The display will show *Por*.
3. Press the address port key, which can be either "0" for 170 octal (78 hex), "1" for 174 octal (7C hex), "2" for 270 octal (B8 hex), or "3" for 274 octal (BC hex). The usual ports for disk drive devices, under Heath software, are shown in the following table.

<u>DEVICE</u>	<u>PORT</u>
H-17	174 octal (7C hex)
H/Z-37	170 octal (78 hex)
H/Z-47	170 or 174 octal (78 or 7C hex)
Z-67	170 or 174 octal (78 or 7C hex)

The display will show *Un*.

4. Press unit number, which can be 0, 1, 2, or 3. The boot will now begin.

To cancel the Universal Boot, press the "CANCEL" key.

## Auto Boot

If Switch SW1 section 7 is set to 1, the floppy disk will boot from the primary device automatically at power-up and master clear.

**NOTE:** We do not recommend auto-booting with a diskette in the drive and the door closed at power-up. Damage could occur to the diskette if you attempt to do so. Rather, power-up the H-8 and the disk device, insert the diskette, and close the door within 15 seconds.

## **Errors**

If any of the following conditions occur, the front panel will display the word *ERROR*, followed by the name of the device (or the word *dEU* if you attempt a Primary, Secondary, or Auto Boot on switch SW1):

1. The boot device does not respond within 15 seconds.
2. Switch SW1 is set to an undefined setting.
3. A disk error occurs.

When an error is detected, the device is reset, the error message is displayed on the front panel, and an alarm is repeatedly sounded until you press the "CANCEL" key.

## I/O FACILITIES

PAM-37 supports two commands that allow you to perform input and output functions on H-8 I/O ports. These front panel instructions permit simple manipulation of the H-8 I/O ports without your having to write extensive routines to perform these functions.

### Inputting From a Port

To input from a port, press the "E" key. Then enter three zero digits and the three-digit address (octal) of the desired port. NOTE: The front panel should now display 000 XXX, where XXX is the port address and 000 is meaningless. Press the "IN" key to read the port. The value is displayed in the three left-most digits of the front panel display.

### Outputting to a Port

To output to a specified port, press the "E" key. Then enter the value to be supplied to the port in the three left-most displays. The port address is entered into the middle three displays. The display is of the form VVV AAA, where V stands for value, and A for address. Pressing the "OUT" key causes the value to be outputted to the indicated port.

### Addressing Port Pairs

Frequently, ports are assigned in pairs, where one of the two port addresses is the control and status register and the other port is the data port. Address port pairs by using the "NEXT" and "LAST" key to change ports. Once the initial port has been defined, the "NEXT" key increments the port address to a new higher numbered port, and the "LAST" key is used to decrement to a lower numbered port.

## SWITCH SW1

The sections of SW1 (on the HA8-6 Z 80 CPU Board) have been defined as follows:

SWITCH SECTION	DESCRIPTION
7 6 5 4 3 2 1 0	
X X X X X X 0 0	Port 174/177 = H-17
X X X X X X 0 1	Port 174/177 = H/Z-47
X X X X X X 1 0	Port 174/177 = Z-67
X X X X 0 0 X X	Port 170/173 = H/Z-37
X X X X 0 1 X X	Port 170/173 = H/Z-47
X X X X 1 0 X X	Port 170/173 = Z-67
X X X 0 X X X X	Boot primary from port 174/177
X X X 1 X X X X	Boot primary from port 170/173
0 X X X X X X X	Normal
1 X X X X X X X	Auto-Boot

Note that sections 5 and 6 of SW1 are reserved.



## PAM-37 THEORY OF OPERATION

This section will supplement the information contained in the "Operation" and "Circuit Description" sections of your H-8 Operation Manual. In order to fully understand how PAM-37 operates, you must be familiar with the H-8 front panel and CPU. A thorough knowledge of the Z80 instruction set and its architecture is also essential.

### Power Up and Master Clear

PAM-37 initializes the H-8 whenever you power up or master clear ("RST"). You initiate the power-up operation by turning on the rear panel Power switch. You can master clear by simultaneously depressing both the lower right-hand ("RST") and the lower left-hand ("0") keys of the H-8 front panel keypad. Both power-up and "RST" cause a level zero (highest priority) interrupt and result in a long beep from the audio alert.

During initialization, PAM-37 enters a routine which determines the high limit of continuous RAM. Once the high limit of available RAM is determined, the H-8 stack pointer (SP) is set to this value. PAM-37 then determines if the RAM starts at 0, and copies itself from ROM into that RAM space. Control is passed to the front panel command loop. Using this feature, you can immediately determine the total amount of continuous memory above 8K by displaying the stack pointer value.

### Clock Interrupts

The Clock Interrupt is a crucial element in the operation of the H-8 front panel system. This level one interrupt is generated by the front panel hardware every 2 mS. PAM-37 uses this interrupt to check for some keyboard commands, to check for user program breakpoints, and to refresh the front panel displays.

PAM-37 performs these functions using a series of subroutines which are executed as necessary when indicated by the interrupts. For this reason, all user programs must maintain a valid stack (at high memory) containing at least 80 free bytes at all times. If this stack space is not available and PAM-37 is running (it can be disabled; see the Advanced Control Section), unpredictable software damage can occur in your program. In the same manner, if your program should execute a DI (Disable Interrupt) instruction, no front panel services including the RTM (Return To Monitor) function are available until an EI (Enable Interrupt) instruction is executed or until a master clear ("RST") is performed.

## **PAM-37 Modes (Using “RST” and “RTM”)**

PAM-37 is always in either the monitor mode or the user mode unless it has been disabled. In the monitor mode no user program is executing, PAM-37 loops reading the keypad and refreshing the displays. All commands entered via the keypad are valid; however, the “RTM” command is meaningless.

When your program is being executed, PAM-37 is in the user mode and the “MON”LED on the front panel is extinguished. Only two keyboard commands are valid in this mode: “RST” (master clear) and “RTM” (Return To Monitor). NOTE: Both of these commands are dual key commands. No single key command is recognized, so a user program may have free use of the entire keypad.

You can return PAM-37 to the monitor mode by using the “RTM” command (simultaneously press the “0” and the “E” keys). This command stops program execution at the end of the current instruction, stores the current value of each register, and returns PAM-37 to the monitor mode. You can then continue your program by pressing the “GO” key. The “RST” command (simultaneously press the “0” and the “D” keys) performs the master clear operation described earlier and does not save any register values.

Normally, when a user program is running, PAM-37 is also running. Thus, if PAM-37 is displaying the contents of the HL register pair and the user program is started, it continues to display the contents of this register pair as the program is run. If the user program changes the contents of the HL pair, the change is immediately reflected in the front panel displays. In a similar manner, if a memory location is displayed when a user program is started, it is displayed during the time the user program is run. If the user program changes the contents of the display memory location, the front panel display changes.

Since PAM-37 does not recognize keypad commands in the user mode, the "RTM" command must be used before the memory location or register being displayed is changed to a new location or a different register. Once you select the new location or different register, you can resume program execution by pressing "GO."

NOTE: PAM-37 requires about 20% of the H-8 CPU's resources to process the display interrupts. Programs which are compute-bound may be slowed down by simultaneous operation of PAM-37. In this situation, you may wish to turn off the clock interrupts to improve execution time. See "Using Interrupts" on Page 32.

## Memory Map

The lower 8K of memory is used as follows:

8K	H-17 ROM image
6K	UNUSED
4K	PAM-37
1K	PAM-8 COMPATABILITY Routines
0K	

## ADVANCED CONTROL

One of the advanced features of PAM-37 is its provisions allowing sophisticated users to augment or replace PAM-37 functions. Augmenting or replacing PAM-37 functions is usually done in conjunction with assembly language programs. Sometimes it is possible to implement these features by using the POKE and PEEK commands in BASIC.

### 16-Bit Tick Counter (TICCNT)

PAM-37 maintains a 16-bit (2 byte) tick counter known as TICCNT. The value of this counter is incremented each time a clock interrupt is processed. As an interrupt occurs once every 2 mS, the counter is incremented once every 2 mS. As long as clock interrupts are not disabled, this value can be used by any program to compute elapsed time. The tick counter may be set to any desired value, but it should not be frequently reset, as this interferes with the front panel refresh cycle. The contents of the tick counter are contained in memory locations 040.033 octal (the least significant byte) and 040.034 octal (the most significant byte).

### Using the Keypad

When your program is running, PAM-37 does not recognize any single key command. Thus, all single key patterns are available for your program. To read keypad patterns, you can use one of two routines. First, you may take an input from port IP.PAD; or second, your program may use PAM-37 RCK (Read Console Keypad) routine. The input port IP.PAD is permanently assigned to port location 360 octal. Inputting a binary number from this port detects which of the 16 keys are depressed.

The RCK routine provides keypad decoding, keypad debounce routines, auto-repeat routines, and acoustical feedback.

NOTE: If you use two key combinations, each key must reside in a separate bank. The first bank includes keys "0" through "7" and the second bank includes keys "8" through "F." RCK cannot decode two key combinations.

## Display Usage

When a user program is running, PAM-37 normally displays the contents of the selected register or memory location. However, you may disable this process and display any arbitrary segment pattern, or completely disable the display to provide greater computational through-put. The display usage is primarily controlled by setting various bits in the .MFLAG memory cell. This memory cell is found at location 040.010 octal.

### MANUAL UPDATING

By setting the UO.DDU bit in the .MFLAG memory location, you can instruct PAM-37 to continue refreshing the front panel displays and to disable updating. When this is done, PAM-37 continues to refresh the LED's from a 9-byte block of RAM cells found at locations 040.013 through 040.023 octal. When the UO.DDU bit is set in .MFLAG, the contents of these bytes are not altered in any manner by PAM-37.

You can use this technique to display numbers, letters, or arbitrary bar patterns on the front panel displays. For instance, your program may alter the display by inserting any value into FPLEDS.

### MANUAL DISPLAY REFRESHING

By setting the UO.NFR (User Option.No Front Panel Refresh) bit in the .MFLAG memory cell, you can instruct PAM-37 to stop refreshing the front panel displays. Setting the UO.NFR bit does not disable the clock interrupts; therefore, the tick counter (TICCNT) is still incremented. But PAM-37 does not refresh the displays from the information contained in the FPLEDS bytes.

**NOTE:** If you desire, you may write a program to refresh the front panel LED displays. Usually this is done using the clock interrupts. If you undertake an independent front panel refresh program, take extreme care to avoid burning the displays due to excessive refreshing. **The total power dissipated in the LEDs is determined by the refresh cycle, and too frequent refreshing will result in excessive display heating.**

## Using Interrupts

All H-8 interrupts cause control to be transferred into the low 64 bytes of memory. PAM-37 occupies this memory space so all interrupts are first processed by PAM-37. Except for level zero interrupts, which are used as master clears, you can supply an interrupt processing routine for each of the seven additional interrupts. The following sections explain the use of each of these interrupts.

### I/O INTERRUPTS

Interrupts numbered 3 through 7 are I/O interrupts. PAM-37 does not process these interrupts in any way. When a level 3 through level 7 interrupt is received, PAM-37 immediately transfers to the user interrupt vectors contained in memory locations 040.037 through 040.064 octal. Each location must contain a jump instruction pointing to the appropriate program location which processes these interrupts.

**NOTE:** If any of these interrupts occur, you must supply a processing routine for them. This routine must be complete including both entry and exit processing. When you use H-8 interrupts, you must use only the available vector, 6, to insure compatibility with other H-8 products. You may also use 2 if you will not be using BUG-8, or HDOS' DBUG.

### CLOCK INTERRUPTS

The level one interrupts are generated by the front panel hardware every 2 mS. PAM-37 normally processes these interrupts. However, by setting a processing vector in UIVEC and setting the UO.INT bit in the .MFLAG cell, PAM-37 enters the users routine each time a clock interrupt is generated.

### SINGLE INSTRUCTION AND BREAKPOINT INTERRUPTS

Level two interrupts are generated by the single instruction hardware contained on the CPU card. When a single instruction is requested, the result of the interrupt is processed by PAM-37. If the single instruction interrupt was generated by PAM-37 in response to a Monitor Mode Single Instruction register condition, PAM-37 processes it. Otherwise, PAM-37 jumps to the user level two interrupt vector (UIVEC). Since the level two interrupt does not affect PAM-37, a level two restart instruction can be used as a breakpoint instruction by the user programs.