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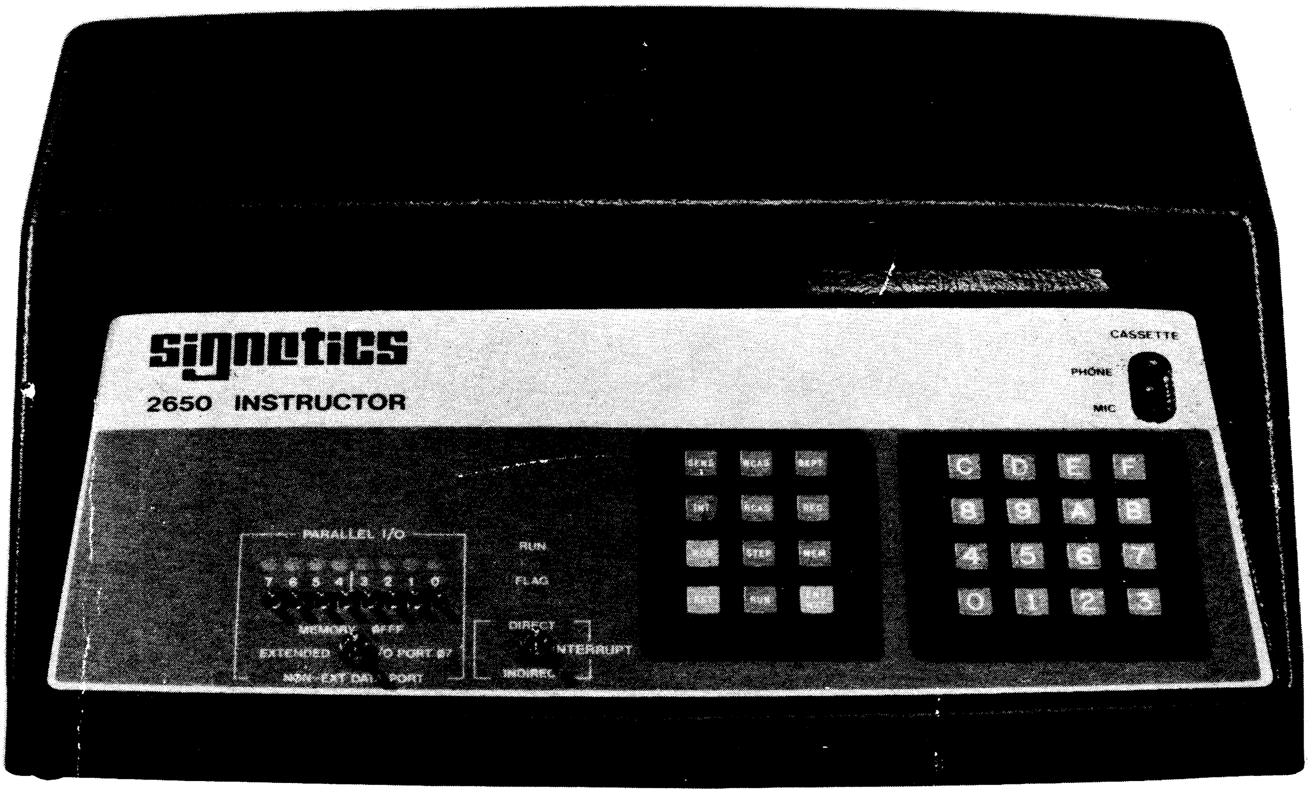
SIGNETICS INSTRUCTOR 50 USER GUIDE



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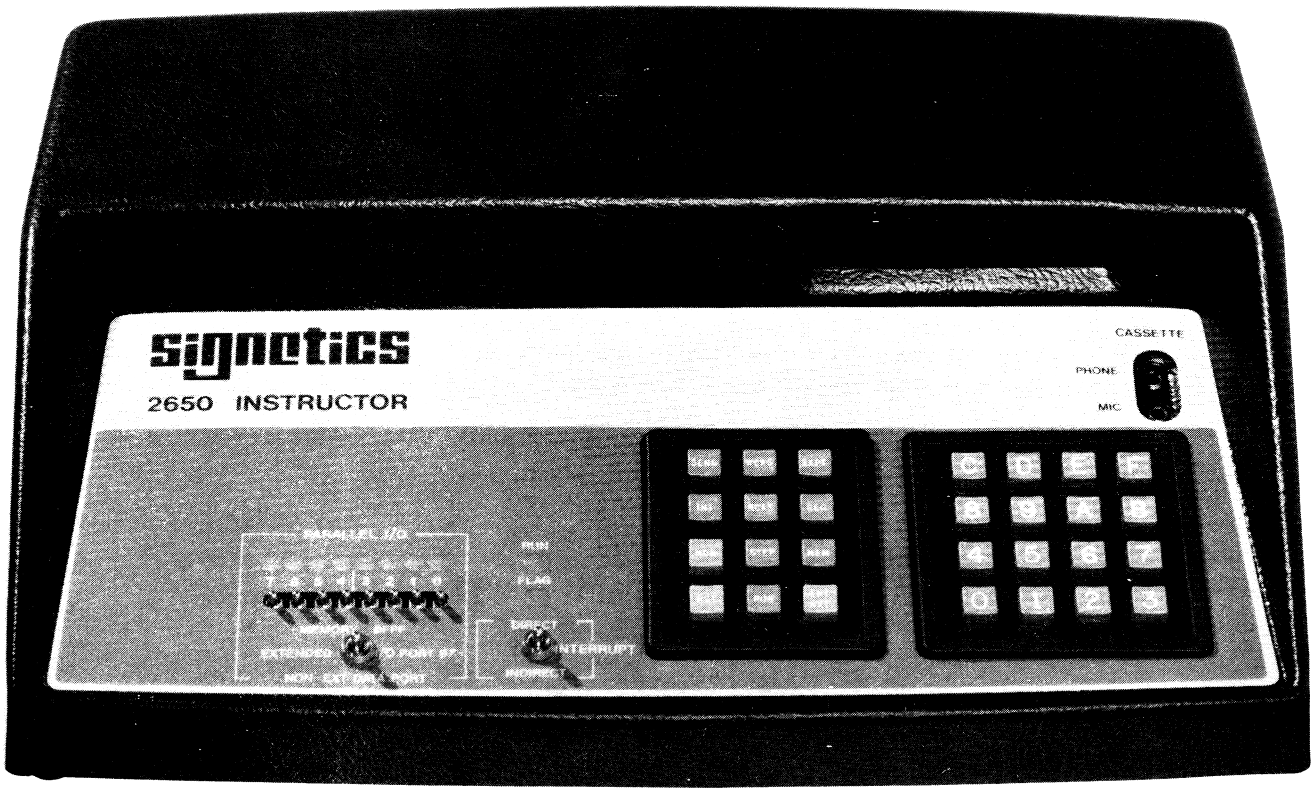

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PREFACE

This manual provides tutorial and reference information on the Signetics INSTRUCTOR 50--a complete, fully assembled and low cost microcomputer system. The INSTRUCTOR 50's computing power is enhanced by the Signetics 2650 Microprocessor which is described in detail in the 2650 manual accompanying this document.

INSTRUCTOR 50 is designed to assist you in learning programming and in writing, debugging, and testing the programs you develop. There is enough information here to get you started, whether or not you have ever written a program before. The only prerequisite is a familiarity with the 2650 microprocessor. Readers who are not familiar with the 2650's hardware structure and instruction set should read the 2650 Microprocessor Manual prior to using the INSTRUCTOR 50.

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1. INTRODUCTION

Welcome aboard the INSTRUCTOR 50--a unique and powerful training tool designed to introduce you to the world of microcomputers in the shortest possible time.

INSTRUCTOR 50 is for computer hobbyists, students, engineers or anyone who wants to learn how to use a microcomputer the easy way, without having to face the drudgery of a long and tedious training program.

INSTRUCTOR 50 is a stand-alone microcomputer based on the Signetics 2650 microprocessor. It includes everything that you need to write, run, and debug machine-language programs. A 12-key Function Control Keyboard and a 16-key Hexadecimal Keyboard are used to enter data and perform various system functions associated with the INSTRUCTOR 50. The INSTRUCTOR 50 User System Executive (USE) monitor program guides you in the use of the system by displaying prompting messages and responses on an eight-digit LED display. All facilities required for program development are built into INSTRUCTOR 50 -- you don't need anything else to start.

Before getting into the details of what makes the INSTRUCTOR 50 tick, let's first take a short shakedown cruise and write a few simple programs.

Power On and Initial Display

To apply power to the INSTRUCTOR 50, connect the power cord into the rear panel receptacle, and insert the power pack into any standard 115 VAC domestic wall socket. The INSTRUCTOR 50 does not have a power ON/OFF switch. The initial display is the message HELLO, indicating that the INSTRUCTOR 50 is in the monitor mode and ready for use. If the HELLO message does not appear, depress the MON key to initialize the INSTRUCTOR 50. Unplug the power pack to turn the INSTRUCTOR 50 off.

Operating Modes

The INSTRUCTOR 50 has two basic modes of operation, the MONITOR mode and the EXECUTION mode. The MONITOR mode is entered automatically on power up or by depressing the MON key on the function control keyboard. The monitor responds by displaying HELLO. While in the MONITOR mode, you may:

- Enter and alter a program.
- Read in a previously saved program from audio cassette tape.
- Display and alter the contents of the microcomputer's general-purpose working registers and/or Program Status Word (PSW).
- Examine and alter the contents of memory locations.

- Examine and alter the contents of the Program Counter.
- Specify and examine a program breakpoint.
- Step through a program one instruction at a time.
- Save a program on cassette tape.

The EXECUTION mode is entered by depressing the RUN key, the STEP key, or the RESET (RST) key on the function control keyboard. Depressing the RUN key terminates the MONITOR mode and causes program execution to begin at the address specified in the Program Counter. Depressing the STEP key causes the INSTRUCTOR 50 to execute a single instruction and return to the MONITOR mode. When the RST key is depressed, current INSTRUCTOR 50 activity is terminated, and the processor begins program execution at address H'0000'.

Keying in and Entering Values

The INSTRUCTOR 50 uses the hexadecimal number system with a base of 16 for entering values. The term "hexadecimal", or hex for short, refers to a shorthand method of expressing a group of four consecutive binary bits by a single digit. Valid digits range from 0 through F, where F represents the highest decimal value (15). See Table 1.1.

Since the INSTRUCTOR 50 uses 8-bit bytes, two hexadecimal digits can be used to specify a byte. The smallest hexadecimal number is 00_{16} (00000000_2) and the largest is FF_{16} (11111111_2). The INSTRUCTOR 50 still reads only binary numbers; hexadecimal is the user's shorthand, not the microcomputer's.

Decimal	Hexadecimal	Binary
0	0	0000
1	1	0001
2	2	0010
3	3	0011
4	4	0100
5	5	0101
6	6	0110
7	7	0111
8	8	1000
9	9	1001
10	A	1010
11	B	1011
12	C	1100
13	D	1101
14	E	1110
15	F	1111

Table 1.1: Relationship among decimal, hexadecimal, and binary systems.

To understand hex notation, take a decimal number like 107_{10}. In binary notation, this becomes 1101011_2. Breaking this number into two 4-bit nibbles (half-bytes), you get 0110_2 and 1011_2. The first and most-significant nibble is equal to 6_{10}, while the second and least-significant nibble is equal to 11_{10}. Thus, in hexadecimal notation, 107_{10} becomes $6B_{16}$ or H'6B'. To convert from decimal to hexadecimal, or vice versa, you must first convert the number into binary and then into hexadecimal as previously illustrated.

Address and data parameters are entered into the INSTRUCTOR 50 via the hexadecimal keyboard using the hex notation described earlier. When entering an address, you may enter as many as four hex digits starting with the most significant digit of the address. Leading zeroes need not be entered; if less than four digits are entered, the leading digits are automatically zeroed. Data values consist of one or two hex digits, with the most-significant digit entered first. If only one digit is entered, the most-significant digit is automatically zeroed.

Correcting Entry Errors

The numbers keyed in appear in the address/data display field and can be edited prior to depression of a function key by simply keying in the correct characters. The display shifts to the left each time a new character is entered, and characters shifted out of the field are disregarded. Only the last digits entered are retained, so that an error in entry can be corrected by entering the correct data.*

For example, if you were entering an address and you depressed 121 instead of the correct value of 120, the display would read:

.Ad. = 121

To recover from this error, simply key in the correct value by depressing the following hex keys:

[0] [1] [2] [0]

The correct value would then be displayed as indicated below:

.Ad. = 0120

The Prompt Light

A dot or period in the left-most position of the display (e.g., .Ad. =) is a prompt signal. It indicates that the INSTRUCTOR 50 is ready to accept a data or address value.

---

*Data values entered during operation in the FAST PATCH command mode cannot be corrected in this manner. See description of the FAST PATCH command in Section 4 .

Entering and Executing a Simple Program

To demonstrate the use of the INSTRUCTOR 50, let's write a simple program, enter it, and execute it. Prior to writing the program, we must decide what task or operation we want the program to perform.

Let's say we want to "show the operation of an 8-bit binary counter on the INSTRUCTOR 50's output port indicator LEDs". The flowchart for performing this task is shown in Figure 1.1.

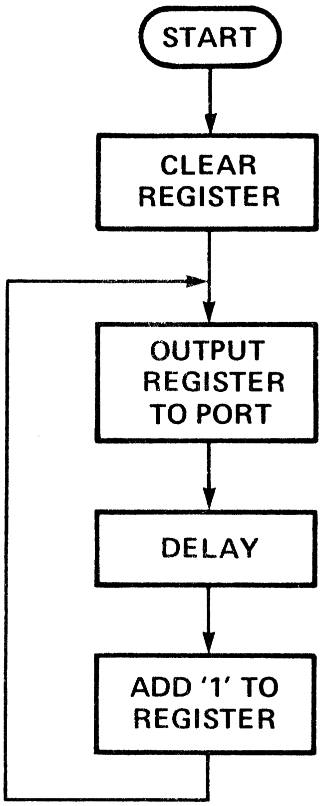


Figure 1.1: Flowchart for Binary Counter Program

The DELAY block shown in the flowchart provides a time interval between new values of the binary count in order to observe the counting action on the port indicators. This can be implemented in several ways, depending on the delay required.* We will use a double-loop technique, with the outer loop counting the number of excursions through the inner loop.

The next step is to select registers for the binary counter and the delay loop counters, and to select an output port for the display operation. Let's arbitrarily make the following assignments:

*See Signetics 2650 Applications Note AS52 - General Delay Routines.

Register 0	=	Binary counter
Register 1	=	Outer loop counter
Register 2	=	Inner loop counter
Port D	=	Output display port

We are now ready to write the program:

ADDRESS	HEX VALUE	LABEL	INSTRUCTION	COMMENTS
00	75,11	START	CPSL C + RS	Operations without Carry, Reg. bank 0
02	20		EORZ,R0	Clear R0
03	F0	OUT	WRTD,R0	Output R0 to D
04	05,20	LOOP1	LODI,R1 H'20'	Initialize outer loop
06	06,20	LOOP2	LODI,R2 H'00'	Initialize inner loop
08	FA,7E	SELF	BDRR,R2 SELF	Count inner loop
0A	F9,7A		BDRR,R1 LOOP2	Count outer loop
0C	84,01		ADD1,R0 H'01'	Add 1 to R0
0E	1F,00,03		BCTA,UN OUT	Go back to output

Let's begin entering the program using the INSTRUCTOR 50's FAST PATCH command, which is used for entering long hex data strings. The FAST PATCH mode is enabled by depressing the [REG] key followed by the [F] key:

KEY	DISPLAY		COMMENTS
[MON]	HELLO		Enter monitor mode
[REG] [F]	.Ad. =		Enter FAST PATCH
[0] [ENT/NXT]	.0000		Enter starting address
[7] [5]	.0000	75	Begin program entry.
[1] [1]	.0001	11	
[2] [0]	.0002	20	
.			
.			
.			
[1] [F]	.000E	1F	
[0] [0]	.000F	00	
[0] [3]	.0010	03	
[ENT/NXT]	0010	03	Terminate FAST PATCH

We will now verify correct entry by using the DISPLAY & ALTER MEMORY command:

KEY	DISPLAY		COMMENTS
[MEM]	.Ad. =		Display and Alter memory
[0] [ENT/NXT]	.0000	75	Address entered, data displayed
[ENT/NXT]	.0001	11	
[ENT/NXT]	.0002	20	
[ENT/NXT]	.0003	F0	
.			
.			
.			
[ENT/NXT]	.0010	03	Verification complete

If an error is detected during verfication, it can be corrected by entering the correct value before depressing the [ENT/NXT] key. For example:

KEY	DISPLAY	COMMENTS
.		
.		
[ENT/NXT]	.0003 F8	Error. Data should be F0.
[F] [0]	.0003 F0	Correct data entered.
[ENT/NXT]	.0004 05	New data deposited.
.		
.		

We are now ready to exercise the program. Before proceeding, make certain that the Interrupt Select Switch which is accessible from the bottom side of the case is in the keyboard position. (towards the center). The Port Address Select Switch is placed in the NON-EXTENDED Port D position, and, since the program begins at address zero, the [RST] key is depressed to initiate execution. The program operation can be observed on the I/O port indicators.

We can use the INSTRUCTOR 50 facilities to change the program parameters or to observe the internal operation of the program. For example, to change the delay time, we can change the delay constant at address H'05' with the DISPLAY AND ALTER MEMORY command.

KEY	DISPLAY	COMMENTS
[MON]	HELLO	Return to monitor mode.
[MEM]	.Ad. =	Display and Alter memory.
[5] [ENT/NXT]	.0005 20	Address entered, data shown.
[4] [0]	.0005 40	New constant entered.
[ENT/NXT]	.0006 06	New constant deposited.
[RST]		Program re-started.

The counter now operates about half as fast as before.

We can observe the internal operation of the program by using a breakpoint, which will stop program execution at a selected instruction and return to the monitor mode. Let's watch the outer delay loop operate by placing a breakpoint at address H'0A'. To enable the breakpoint during program execution, the program must be started via the RUN command. Before running the program, the starting address (H'00') must be entered by using the DISPLAY AND ALTER PROGRAM COUNTER (PC) command:

KEY	DISPLAY	COMMENTS
[MON]	HELLO	Return to monitor.
[BKPT] [A] [ENT/NXT]	b.P = A	Breakpoint entered.
[REG] [C] [0]	.PC = 0	Enter starting address.
[RUN]	-000A F9	Start execution. Program stops at breakpoint and returns to monitor.
[REG] [1]	.rl = 3F	Rl has decremented by 1.
[RUN]	-000A F9	Execute again.
[REG] [1]	.rl = 3E	Rl has decremented again.
[RUN] [REG] [1]	.rl = 3D	And again.
[BKPT] [BKPT]	b.P =	Breakpoint removed.
[RUN]		Program runs without stopping.

The simple program outlined above is designed to demonstrate some of the capabilities of the INSTRUCTOR 50 and to give you a feel for how the system works. More comprehensive programming examples are presented in subsequent sections of this manual.

2. SYSTEM OVERVIEW

Introduction

A simplified block diagram of the INSTRUCTOR 50 system is shown in Figure 2.1 Major system components include:

- 2650 8-bit, N-channel microprocessor
- 2656 System Memory Interface (SMI)
- Sixteen-key hexadecimal keyboard
- Twelve-key function selection keyboard
- Eight-digit, 7-segment display
- Audio tape cassette interface
- S100-compatible expansion bus
- User System Executive (USE) monitor
- Debugging aids
- On-board user Input/Output
- Forced jump logic
- 512 bytes of on-board user RAM
- Crystal-controlled system clock

2650 Microprocessor

The 2650 processor is a single-chip microprocessor made using an ion-implanted, N-channel silicon-gate process. It has a fixed command set of 75 instructions, operates on 8-bit parallel data and can address 32,768 bytes of memory. All bus outputs of the 2650 are three-state and can drive either one 7400-type load, or four 74LS loads.

The 2650 contains a total of seven general-purpose registers, each eight bits long. They may be used as source or destination for arithmetic operations, as index registers, and for Input/Output (I/O) data transfers.

The processor instructions are one, two, or three bytes long, depending on the instruction. Variable length instructions tend to conserve memory space since a one or two-byte instruction may often be used rather than a three-byte instruction. The first byte of each instruction always specifies the operation to be performed and the addressing mode to be used. Most instructions use six of the first eight bits for this purpose, with the remaining two bits forming the register field. Some instructions use the full eight bits as an operation code.

The 2650 has a versatile set of addressing modes used for locating operands for operations and an interrupt mechanism which is implemented as a single level, address vectoring type. Address vectoring means that an interrupting device can force the processor to execute code at a device-determined location in memory.

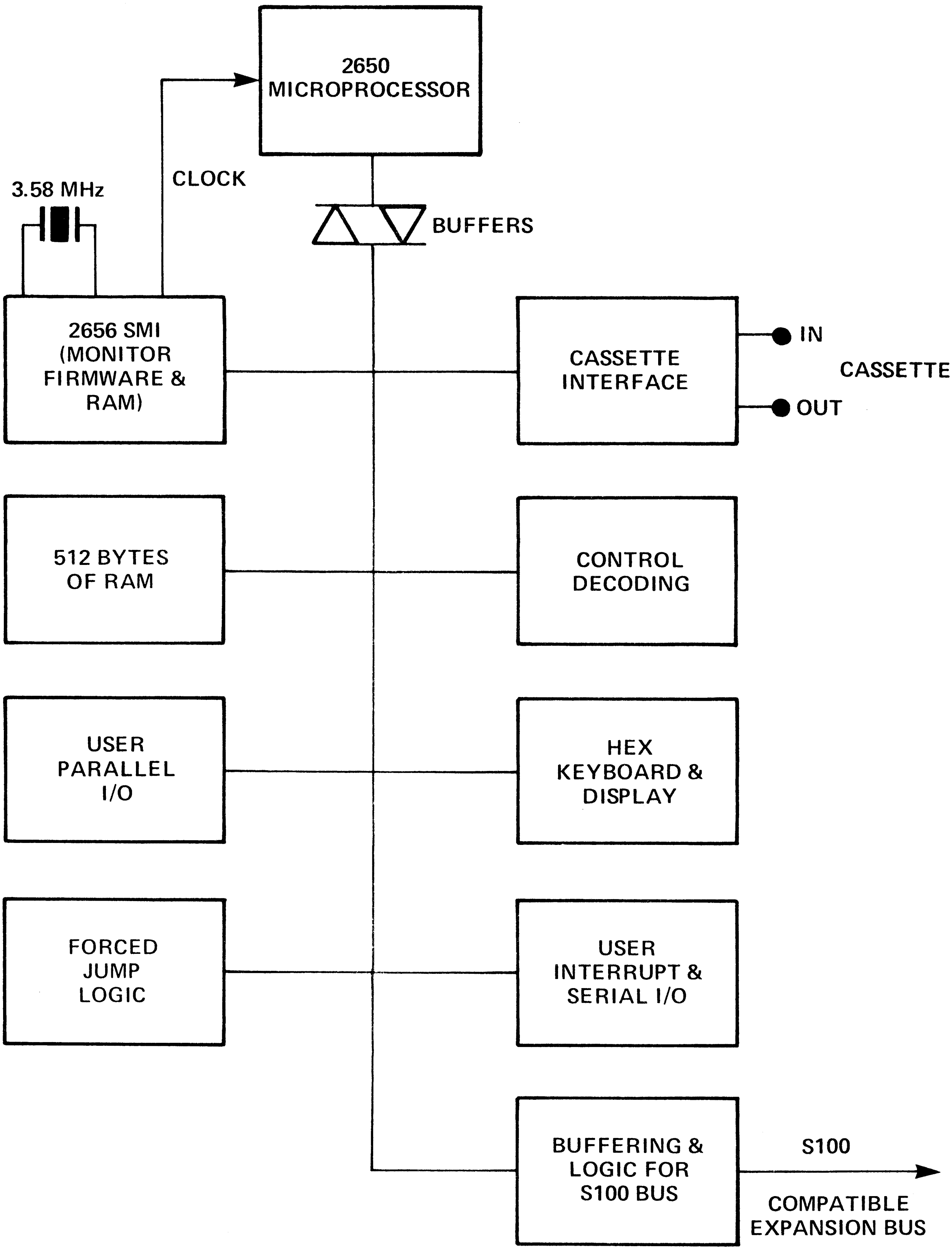


Figure 2.1: Instructor 50 Basic Block Diagram

Detailed hardware and software information on the 2650 microprocessor is provided in the accompanying Signetics 2650 Microprocessor Manual.

2656 System Memory Interface

The Signetics 2656 System Memory Interface (SMI) contains Read-Only Memory (ROM), Random-Access Memory (RAM), and a programmable I/O port. Two notable features are onboard decoders that make it possible to place the ROM and RAM anywhere in the memory space and an I/O port that can be set up as either a bidirectional port or as chip-select lines. The chip-select capability eliminates a great deal of the TTL that usually surrounds microprocessors. The 2K USE monitor, 128 bytes of scratch pad memory, I/O decode logic, and the system clock are housed in the 2656 SMI.

Keyboards

A 16-key hexadecimal keyboard and a 12-key function control keyboard enable you to communicate with the INSTRUCTOR 50. Both the hexadecimal keyboard and the function keyboard are under control of the USE monitor. The monitor performs a scanning process to determine what key has been depressed and what action is to be taken by the INSTRUCTOR 50 as a result of the depression. A functional description of the various controls and indicators is provided in Section 3.

Display Panel

The 8-digit, 7-segment display panel provides responses to input commands and guides you in the use of the INSTRUCTOR 50 by displaying prompting messages describing the data that must be entered.

Messages or responses are displayed using the seven-segment display font illustrated in Figure 2.2. Note that the characters 'b' and 'd' are always displayed with the right-hand decimal point attached in order to distinguish these characters from the number '6'.

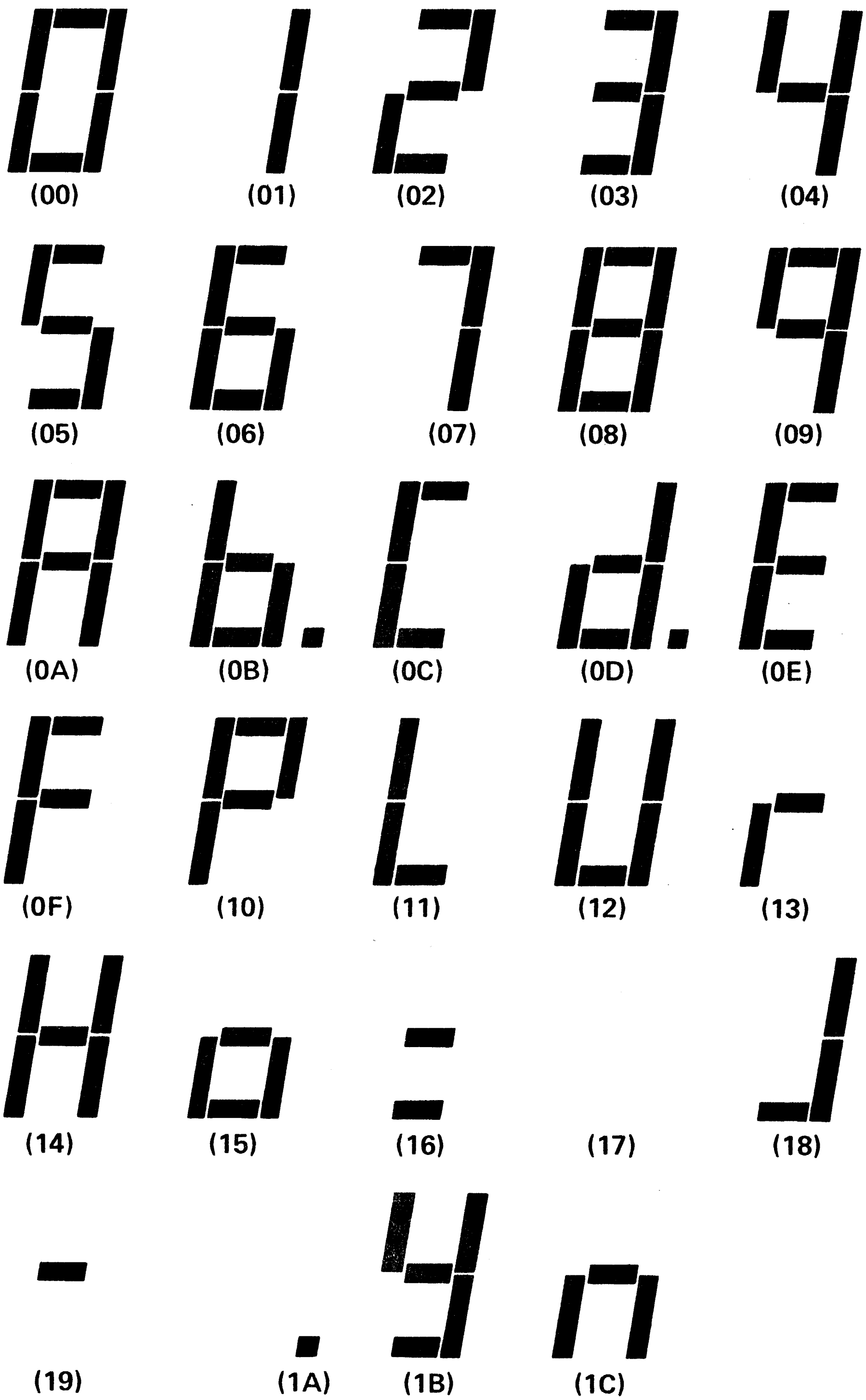
Figure 2.2 also shows the hexadecimal code required in the monitor's display buffer to display the character illustrated. To display a character with a right-hand decimal point attached, H'80' must be added to the value given. For example, H'07' will display '7', while H'87' will display '7.'. Refer to Section 5 for additional information on the use of the monitor's display subroutine.

Audio Cassette Interface

An audio cassette interface lets you load and store programs into and out of RAM. The storage medium is any audio cassette recorder.

S100-Compatible Expansion Bus

The INSTRUCTOR 50 includes an S100-compatible expansion bus connector so that other standard products, such as additional memory or prototyping cards, can be used with the system. This connector carries all of the 2650's I/O signals in addition to control signals required by the S100 bus. (See Section 6.)



( ) INDICATES THE HEX VALUE USED AS THE INTERNAL DISPLAY CODE.

NOTE: IF 80_{16} IS ADDED TO ANY CODE, A DECIMAL POINT WILL APPEAR WITH THE CHARACTER.

Figure 2.2: Instructor 50 Display Font

Monitor Firmware

The USE (User System Executive) monitor supervises operation of the INSTRUCTOR 50 and allows you to enter and alter programs, execute these programs in continuous or single-step modes, and perform a number of auxiliary functions. Monitor commands are entered via the control keys and the hexadecimal keyboard, and responses are displayed on the monitor display.

A basic flowchart of the monitor is shown in Figure 2.3. The monitor normally idles in the scan display and keyboard mode. If a key closure is detected during the scan, the monitor verifies that this is a new key closure (that any previously depressed key had been released), extinguishes the display, performs a keyboard debounce function, and then performs the requested function. The monitor then resumes the display and keyboard scan.

Monitor functions are terminated by depressing a new function key. Interrupts are inhibited while the monitor is running.

Debugging Aids

Two key features incorporated into INSTRUCTOR 50 are designed specifically for program debugging. These features are:

1. The ability to set a breakpoint that automatically interrupts execution of programs at any point without loss of hardware or software status.

2. The ability to step through a program one instruction at a time.

When a breakpoint is encountered during program execution or when a single instruction is executed in the single-step mode, control is returned to the monitor at which time you may examine the 2650 registers, the Program Status Word (PSW), and the program counter to determine the status of the microcomputer. You can then continue execution, set a new breakpoint, or resume the single-step operation. While in the monitor mode, you may change any register value, including the PSW and program counter, and you may alter memory locations.

On-Board User I/O

Both parallel and serial I/O are available in the INSTRUCTOR 50. The parallel I/O port provides 8 switch inputs and 8 individual Light-Emitting Diodes (LEDs) as a latched output port. A single LED is attached to the processor's FLAG output, and the SENS key on the function control keyboard allows you to test the processor's SENSE input. Additionally, you may exercise interrupt operation by using the interrupt (INT) key on the function control keyboard. See Section 5 for a discussion of the INSTRUCTOR 50's I/O capabilities.

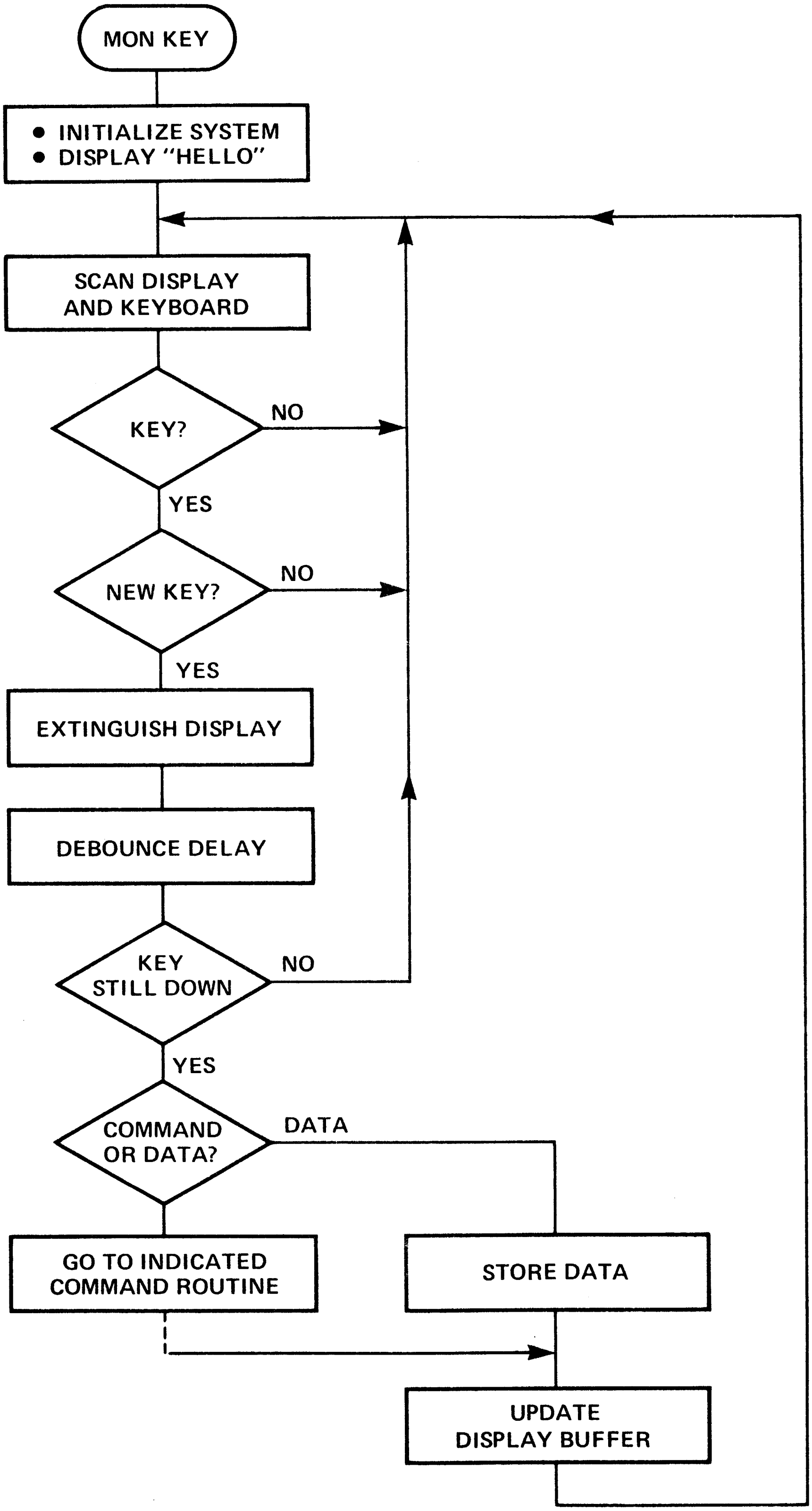


Figure 2.3: Basic Use Monitor Flow Chart

Forced Jump Logic

The Forced Jump Logic performs the following functions:

- Entry into the MONITOR mode when power is applied to the INSTRUCTOR 50 or when the MON key is depressed.
- Re-entry to the MONITOR mode after executing one instruction in single-step operation or upon detection of a breakpoint.

Memory and I/O Organization

512 bytes of RAM storage is provided for storing user programs and data. The RAM area may be expanded via the expansion bus connector.

Partitioning of the INSTRUCTOR 50's memory and I/O locations is illustrated in Figure 2.4. The supplied user memory occupies locations H'0000' to H'01FF' and may be expanded to occupy location H'0200' - H'0FFF' and H'2000' - H'7FFF'. The extended I/O ports from H'00' to H'F7' are available for program use. Ports H'F8' to H'FF' and memory locations H'1000' to H'1FFF' are reserved for the USE monitor.

An additional 64 bytes of RAM storage is available to user programs for storing data values. This additional storage space occupies memory locations H'1780' to H'17BF'. Because of the way the USE monitor operates, instructions should not be stored at these locations.

The INSTRUCTOR 50 I/O data port is assigned one of three locations, depending on the setting of the Port Address Select Switch. These are memory address H'0FFF', extended I/O address H'07', or non-extended Port D.

Clock Circuitry

The 2656 SMI provides the clock circuitry for the INSTRUCTOR 50. A 3.579545 MHz crystal is used to provide the reference frequency.

Internal Power Supply

The INSTRUCTOR 50 uses a self-contained A-C power pack that produces 8 VAC @ 1.5A. An on-board rectifier and regulator reduces this to 5 VDC. A jumper option permits the use of an alternate 8 VDC source. The INSTRUCTOR 50 may be plugged into any standard 115 VAC domestic wall socket. (European models require 220 VAC primary power).

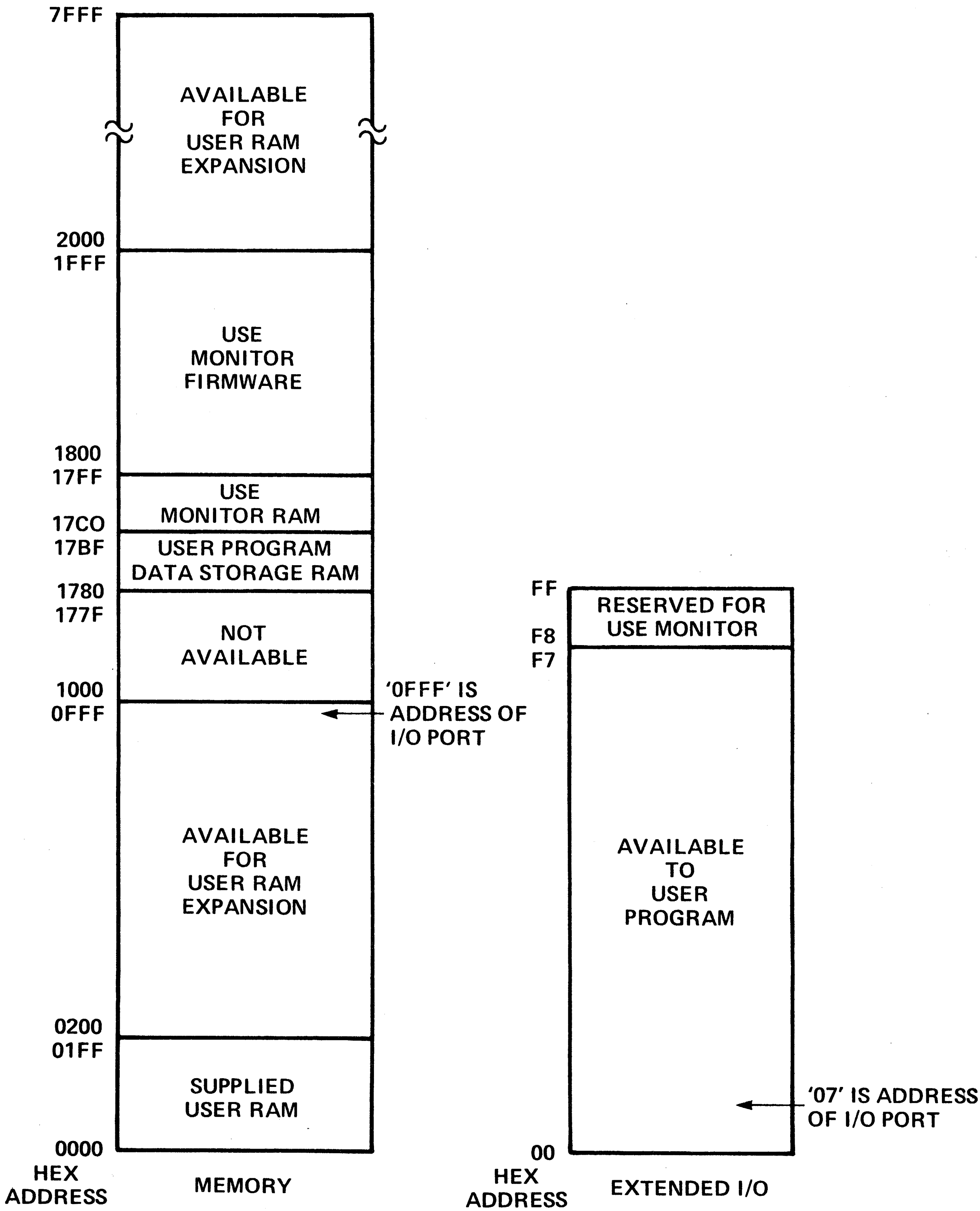


Figure 2.4: Memory And I/O Organization

3. CONTROLS AND INDICATORS

Introduction

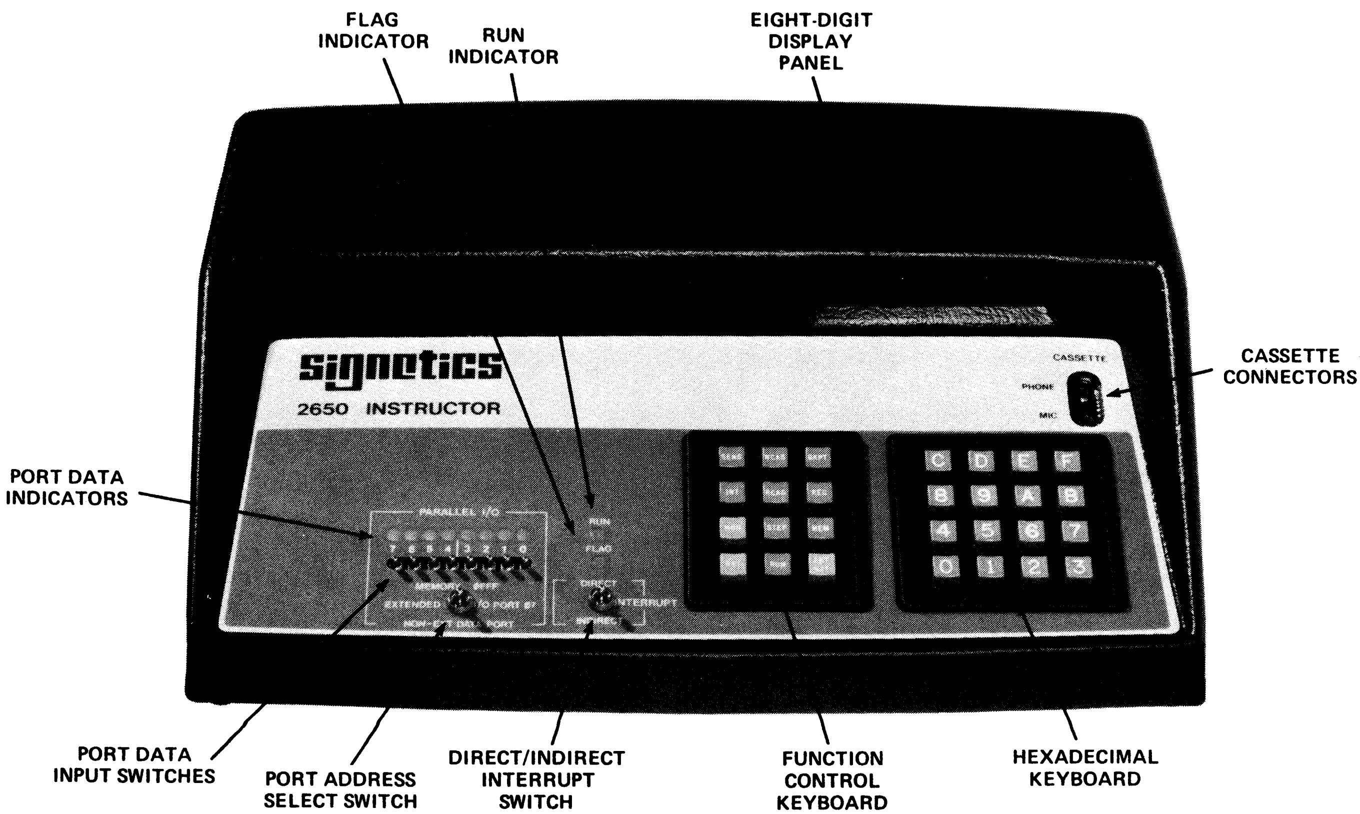
This section provides a brief functional description of the various keys, switches and indicators associated with the INSTRUCTOR 50. See Figure 3.1.

The 12-key Function Control Keyboard and the 16-key Hexadecimal keyboard enable you to communicate with, enter data, and perform the various system functions associated with the INSTRUCTOR 50. The 8-digit display is used by the USE monitor to display responses to keyed input commands. The other switches and indicators are associated with various INSTRUCTOR 50 facilities.

Function Control Keyboard

The keys in the left-most column of the function control keyboard (SENS, INT, MON, and RST) are used primarily for system control. All other keys on this keyboard perform functions associated with entry, execution, and debugging of programs.

The RST and MON keys are active at all times. All other keys except SENS and INT are normally active only during the monitor mode. Depressing these keys while executing your program has no effect. The SENS and INT keys are active only during execution of a program and have no effect on monitor operation.



However, you may take advantage of the INSTRUCTOR 50's keyboard and display facilities by incorporating calls to the monitor subroutines controlling these devices as part of your program. See section 5 for a description of these subroutines.

KEY	FUNCTION
SENS	Controls the SENSE input to the 2650 when executing a user program. The SENSE input is normally a logic '0'. Depressing the SENS key will set the SENSE input to a logic '1'.
INT	Allows you to manually interrupt the processor when executing a program. When this key is depressed, an interrupt sequence begins, resulting in the processor being vectored to or through memory location 07. The Direct/Indirect switch on the INSTRUCTOR 50 panel determines whether an instruction at location 07 is executed (Direct) or whether location 07 contains a branch address to another location in the user memory (Indirect). A switch accessible through a cut-out in the bottom panel permits interrupts to be controlled by the AC line input frequency. See Section 5 for more information on INT options.
MON	Terminates any operation in process and causes the forced jump logic to output a jump instruction sequence resulting in an entry to the monitor mode. The response to a depression of the MON key is the message HELLO on the display panel.
RST	When this key is depressed, any current operation is terminated, and a RESET signal is applied to the 2650 causing program execution to begin at address zero. The system does not enter the monitor mode when this key is depressed.
WCAS	Allows programs to be transferred from the INSTRUCTOR 50 memory to audio cassette tape.
RCAS	Allows programs to be transferred from audio cassette tape to the INSTRUCTOR 50 memory.
STEP	Causes the 2650 to execute a single program instruction and return to the monitor mode, displaying the address of the next instruction to be executed on the monitor display.

RUN	Depressing this key terminates the monitor mode and causes program execution to begin at a previously specified address. Program execution continues until (1) a breakpoint is encountered; (2) the RST or MON keys are depressed; or (3) the program executes a WRTC or HALT instruction.
BKPT	Allows you to specify and examine a program breakpoint.
REG	Places the INSTRUCTOR 50 in the Display and Alter Registers mode. In this mode, you may examine and alter the contents of the 2650 general-purpose registers, the program counter value, and the value of the Program Status Word (PSW). This key is also used to initiate entry into the ADJUST CASSETTE and FAST PATCH commands. See Section 4.
MEM	Places the INSTRUCTOR 50 in the Display and Alter Memory Mode. In this mode your may specify memory locations that you wish to examine, and you may alter the contents of these memory locations.
ENT NXT	Enters keyed-in data into memory or registers and also causes the contents of the next sequential memory or register location to be displayed. The use of this key during the various monitor operations is described in the detailed command descriptions, Section 4.

Hexadecimal Keyboard

The 16-key hexadecimal keyboard (0 through 9 and A through F) is used to enter address and data parameters as required. This keyboard is also used in conjunction with the REG key on the function control keyboard to enable certain commands. See detailed command descriptions, Section 4.

Eight-Digit Hex Display Panel

The 8-digit display panel is used by the monitor to display prompting messages and responses to keyed input commands. It also displays prompting messages to guide you in the operation of the INSTRUCTOR 50.

Port Data Input Switches

These eight switches are used to specify a byte of input data at the parallel I/O port. This value is read when the 2650 executes a read I/O port instruction.

Port Data Indicators

The eight I/O port LEDs reflect the current value in the parallel output port latch. This latch is loaded with the contents of an internal register by a write I/O port instruction.

Direct/Indirect Interrupt Switch

This switch determines whether the 2650 executes a direct or indirect branch to subroutine when it acknowledges an interrupt request.

Port Address Select Switch

This switch selects the manner in which the parallel I/O port is addressed. The three modes are: non-extended I/O - Port D, extended I/O at port address 07_{16}, and memory mapped I/O at address $0FFF_{16}$.

FLAG Indicator

This LED indicates the current value of the FLAG bit in the 2650's Program Status Word. If the FLAG bit is a one, the LED is on. If the FLAG bit is a zero, the LED is off.

RUN Indicator

The RUN indicator reflects the operating status of the 2650. When the 2650 is executing either the monitor program or a user program, the RUN light is on. The RUN light is off when the 2650 has executed a HALT instruction or when the PAUSE line of the S100 interface has been driven low.

4. COMMAND DESCRIPTIONS

Introduction

This section describes the various commands available to the INSTRUCTOR 50 user. These commands include:

- DISPLAY AND ALTER REGISTERS
- DISPLAY AND ALTER MEMORY
- FAST PATCH
- DISPLAY AND ALTER PROGRAM COUNTER
- BREAKPOINT
- STEP
- WRITE CASSETTE
- ADJUST CASSETTE
- READ CASSETTE
- RUN
- RESET

In this section, each pair of facing pages discusses a single command. The left-hand page is devoted to text, while the right-hand page actually shows what is displayed on the monitor display panel when specific keys are depressed. The circled numbers imbedded in the text on the left-hand page correspond with the circled numbers on the right-hand page.

A discussion of the INSTRUCTOR 50's error messages is presented at the end of this section.

DISPLAY AND ALTER REGISTERS

FUNCTION: This command allows you to inspect and alter, if desired, the contents of the 2650's general-purpose registers and/or Program Status Word (PSW).

PROCEDURE:

1. Depress the [REG] key (1) followed by the register address corresponding to the first register to be inspected, (2) according to the following table:

REGISTER ADDRESS	REGISTER
0	RO
1	R1, bank 0
2	R2, bank 0
3	R3, bank 0
4	R1, bank 1
5	R2, bank ~~0~~ 1
6	R3, bank ~~0~~ 1
7	PSU
8	PSL

2. The contents of the register are displayed as two hex digits in the data field of the display. (2)
3. The register contents may be modified at this time by keying in a new value followed by [ENT/NXT] . The numbers keyed in and appearing in the DATA display field are displayed there only and can be edited by simply keying in the correct characters (9) . The display shifts to the left each time a new character is entered, and characters shifted out of the two-digit field are lost. The hex value appearing on the display is deposited in the register when the [ENT/NXT] key is depressed. (10)
4. When the [ENT/NXT] key is depressed after step 2 or 3, the next higher register in sequence will be displayed as in step 2 (3) unless the PSL is being displayed, in which case RO will be the next register displayed. (10)
5. The command is terminated by initiating any other command.
6. If the keys 9, B, D, or E are depressed following [REG] in step 1, the key depression will be ignored. If the keys A, C, or F are depressed, the INSTRUCTOR 50 will enter the ADJUST CASSETTE, DISPLAY AND ALTER PROGRAM COUNTER, or FAST PATCH commands, respectively. See appropriate command descriptions.

DISPLAY AND ALTER REGISTERS

EXAMPLES

	KEY	DISPLAY	COMMENTS
1	REG	r =	Awaiting register address
2	4	. r4 = 7E	R1, bank 1 = H'7E'
3	ENT NXT	. r5 = OF	R2, bank 2 = H'OF'
4	ENT NXT	. r6 = 13	R3, bank 1 = H'13'

Example A: Examine contents of R1 - R3 of bank 1

	KEY	DISPLAY	COMMENTS
5	REG	r =	Awaiting register address
6	7	. PU = 04	PSU = H'04'
7	ENT NXT	. PL = 53	PSL = H'53'
8	4 8	. PL = 48	Wrong data entered
9	4 0	. PL = 40	Correct data entered
10	ENT NXT	. r0 = 72	Entered data deposited in PSL and RO contents displayed.

Example B: Examine contents of PSW and change contents of PSL to H'40'

DISPLAY AND ALTER MEMORY

FUNCTION: Allows you to examine and optionally alter the contents of memory locations individually. This command is particularly useful when you are debugging your program and wish to examine, verify and/or change the contents of memory locations.

PROCEDURE:

1. Depress the [MEM] key (1) followed by the address of the memory location to be inspected. (2) If fewer than four digits are entered, the digits entered are used as the least-significant hexadecimal digits of the address. (2) If more then four digits are entered, the last four digits are used as the address.
2. Depress the [ENT/NXT] key (3) to display the contents of the specified memory location. The contents is displayed as two hexadecimal digits in the data field of the display.
3. You may continue to examine the contents of sequential memory locations by depressing the [ENT/NXT] key. (4) If you wish to alter the content of any memory location, enter the new data via the hexadecimal keyboard. (8) Only the last two digits entered are retained, so that an error in entry can be corrected by entering the correct data. To deposit the new data into the specified memory location, you may either depress the [ENT/NXT] key or transfer control to a new function by depressing a function key. (9)

   Each time new data is specified, the monitor performs a read-after-write check to verify that you are not attempting to write into a ROM area or into nonexistent memory. If the check fails, error message 3 is displayed. To recover from this error, depress the [MEM] key and repeat the cycle correctly.

DISPLAY AND ALTER MEMORY

EXAMPLES

	KEY	DISPLAY	COMMENTS
1	MEM	.Ad. =	Awaiting memory address
2	1 0	.Ad. = 10	10 = Address of memory location to be examined
3	ENT NXT	.0010 02	H'02' = contents of memory location 0010
4	ENT NXT	.0011 FF	Address and contents of next sequential memory location

Example A = Examine contents of memory location 0010 and move to next sequential memory location

	KEY	DISPLAY	COMMENTS
5	MEM	.Ad. =	Awaiting memory address
6	2 2	.Ad. = 22	Address of memory location to be examined
7	ENT NXT	.0022 06	H'06' = Contents of memory location 0022
8	0 5	.0022 05	Desired contents of memory location 0022 entered and displayed.
9	REG	.r =	H'05' deposited into memory location 0022, Display and Alter Memory Command is terminated, and monitor enters Display and Alter Registers Command.

Example B: Examine contents of memory location 0022, change data, and transfer control to another function.

FAST PATCH

FUNCTION: The FAST PATCH command allows you to enter long strings of data into memory from the hexadecimal keyboard. Once the starting address is selected, data is loaded into memory sequentially--one byte for every two hex keys depressed. Once keyed in, data may not be changed in the FAST PATCH mode. To change data, you must use the DISPLAY AND ALTER MEMORY command or re-enter the FAST PATCH command starting at the address where the change is required.

PROCEDURE

1. To enter the FAST PATCH command, depress the [REG] key (1) on the function control keyboard followed by [F] on the hexadecimal keyboard. (2)
2. Enter the desired starting address on the hexadecimal keyboard. (3)

   NOTE: You may bypass this step and go directly to step 3 to begin at a known starting address. The starting address is known under any one of the following conditions:

   a) When a file has been read into memory from a cassette tape by the INSTRUCTOR 50. The file's starting address will be the beginning address for the FAST PATCH.

   b) The address from which the last exit from the DISPLAY AND ALTER MEMORY or FAST PATCH command took place.
3. Depress the [ENT/NXT] key (4) on the function control keyboard to set the starting address. Data may now be entered into the specified address.
4. Enter desired data for the displayed address as two hex digits. (5) Continue entering data in this manner until all data is entered. The INSTRUCTOR 50 automatically increments the memory address as data is entered. (6) (7) (8) (9)
5. Exit the FAST PATCH mode by depressing [ENT/NXT] or another function key. (10)
6. A read-after-write check is performed as each byte is deposited. The INSTRUCTOR 50 will display Error 3 if data cannot be stored.

EXAMPLE

	KEY(s)	DISPLAY	COMMENTS
(1)	REG	r =	
(2)	F	.Ad. =	Awaiting starting memory address
(3)	1 0	.Ad. = 10	Starting address entered
(4)	ENT NXT	.0010	Starting address set
(5)	1 2	.0010 12	Data entry
(6)	1 3	.0011 13	
(7)	1 4	.0012 14	
(8)	1 5	.0013 15	
(9)	1 6	.0014 16	
(10)	MEM	.Ad. =	Exit from FAST PATCH mode

Enter Data String "12 13 14 15 16" into Successive Memory Locations Starting at Address H'10'

DISPLAY AND ALTER PROGRAM COUNTER

FUNCTION: The DISPLAY AND ALTER PROGRAM COUNTER command allows you to examine or change the address of the first instruction to be executed by the 2650 during execution of a RUN or STEP command.

PROCEDURE:

1. To enter the DISPLAY AND ALTER PROGRAM COUNTER command, depress the [REG] key (1) on the function control keyboard followed by [C] on the hexadecimal keyboard. (2)
2. The display will show the current Program Counter (PC) value as four hexadecimal digits. (2)
3. If you want to change the PC address, enter the desired address on the hexadecimal keyboard. (3)

   NOTE: For a multiple-byte instruction, the address entered is the address of the first byte.
4. Depress any command key (4) on the function control keyboard to set the desired starting address. If the [ENT/NXT] key is used, the INSTRUCTOR 50 transfers control to the DISPLAY AND ALTER REGISTERS command.

DISPLAY AND ALTER PROGRAM COUNTER

EXAMPLE

	KEY	DISPLAY	COMMENTS
1	REG	r =	
2	C	.PC = 0015	0015 = present contents of Program Counter
3	1 7	.PC = 17	Starting address changed to 0017
4	ENT NXT	r =	Sets new starting address, and transfers control to DISPLAY AND ALTER REGISTERS Command

Set Starting Address for RUN Command to H'0017'

BREAKPOINT

The BREAKPOINT COMMAND allows you to enter, clear, or examine a program breakpoint. A breakpoint returns system control from the executing program to the monitor and enables you to examine the state of the memory and processor registers, make modifications, if desired, and continue program execution from the point of interruption.

PROCEDURE:

1. Depress the [BKPT] key on the function control keyboard (1) to place the INSTRUCTOR 50 in the breakpoint mode.
2. The monitor will display either:
   a) A blank data field if a breakpoint address was not specified previously. (1)
   b) The address of the breakpoint previously entered. (5)
3. Enter the desired breakpoint address on the hexadecimal keyboard. (2) If the desired address is already displayed, as in step (2b), re-entry is not required.

   NOTE: If a breakpoint is set at a multiple-byte instruction, the address specified for the breakpoint should be the address of the first byte.
4. Depress the [ENT/NXT] key (3) or another function key (4) to set the breakpoint at the address displayed.
5. To clear a breakpoint, depress the [BKPT] key twice in succession. (5) (6)

NOTE: The breakpoint is inserted into your program when you enter the execution mode via the RUN command. When the breakpoint is encountered during program execution, the breakpoint address and contents are displayed, preceded by a "-" (minus) sign. The instruction at the breakpoint address is restored and executed prior to this display, and the Program Counter is updated to the address of the instruction following the breakpoint.

ERROR MESSAGES

During specification of the breakpoint address, the INSTRUCTOR 50 may display one of the following error messages:

ERROR 1 If the user attempts to specify a breakpoint address in the INSTRUCTOR 50's ROM address space or in non-existent memory. To clear this error, depress [BKPT] once.

ERROR 2 If the user attempts to enter a new breakpoint address after having set a previous breakpoint address by depression of the [ENT/NXT] key. To clear this error, depress any function key. The original breakpoint address will be saved.

EXAMPLE

	KEY(s)	DISPLAY	COMMENTS
1	BKPT	.b.P =	No previous breakpoint specified. Waiting for breakpoint address.
2	4 4	.b.P = 44	Breakpoint address entered.
3	ENT NXT	b.P = 0044	Breakpoint address set.
4	REG	r =	Breakpoint address set by exiting to another function.
5	BKPT	.b.P = 0044	Breakpoint address displayed.
6	BKPT	b.P =	Breakpoint cleared.

Set Breakpoint at Address H'0044' and then clear it.

STEP

FUNCTION: Causes the 2650 to execute a single instruction and return to the MONITOR mode, displaying the address of the next instruction to be executed on the monitor display.

PROCEDURE:

1. Enter the address of the first instruction to be executed as described under DISPLAY AND ALTER PROGRAM COUNTER command. (1)
2. Depress the [STEP] key. (2) The INSTRUCTOR 50 will execute a single instruction and display the address of the next instruction to be executed and the data at that address.
3. At this point you may examine and alter memory and/or register values if desired by using the appropriate commands.
4. Continue as in step 2 to repeat the single-step operation. (3) (4)
5. To exit the single-step mode, depress any function key. (5)
6. Note that a breakpoint, if entered, is ignored during single-step operation.

The single-step sequencer and the forced jump logic are used in this mode of operation. Following is the sequence of operations executed by the monitor when the [STEP] key is depressed:

a) The monitor SINGLE STEP flag is set.
b) Register contents previously stored upon entry to the monitor are restored to the 2650.
c) The monitor executes a "hidden single step" to determine how many cycles are contained in the instruction to be stepped.
d) The monitor permits execution of one user program instruction by counting the predetermined number of cycles.
e) The registers (RO - R3, R1' - R3' and PSW) are saved.
f) The Program Counter is updated to the next instruction.
g) The address in the Program Counter and data at that address are displayed. The SINGLE STEP flag is cleared.
h) The monitor exits to the KBD SCAN routine to await user's input.

EXAMPLE

	KEY(s)	DISPLAY	COMMENTS
(1)	REG C 8 ENT NXT	r =	Starting address H'0008' entered
(2)	STEP	000A 42	Single step executed.* Next instruction is at H'000A', and op-code is H'42' (ANDZ, R2)
(3)	STEP	000B CC	Next instruction op-code is H'CC' (STRA, RO)
(4)	STEP	000E 20	Next instruction op-code is H'20' (EORZ, RO)
(5)	REG	r =	Exit single step

Single step three instructions starting at address H'0008

*Since the displayed address is two greater than the starting address (H'000A' - H'0008' = 2), the first instruction executed was a two-byte instruction.

WRITE CASSETTE

FUNCTION: The WRITE CASSETTE command allows you to write programs and data from memory onto cassette tape. Any good quality audio cassette tape recorder may be used as the output device. The data transfer rate is approximately 300 bits per second.

PROCEDURE:

General Installation

- Connect the INSTRUCTOR 50's Cassette-Out Jack to the microphone (MIC) input of the cassette deck using the appropriate cable supplied with the INSTRUCTOR 50 package.
- Install tape in transport.
- Make certain that the tape is positioned so that previously recorded files will not be destroyed when the WCAS command is issued.
- Adjust recorder's input level control, if one is provided, to normal recording level.

Operation

1. Depress the [WCAS] key (1) to place the INSTRUCTOR 50 in the WRITE CASSETTE mode.
2. Enter the lower (beginning) address of the file to be written. (2)
3. Depress the [ENT/NXT] key (3) to set the lower address.
4. Enter the upper (ending) address of the file to be written. (4)
5. Depress the [ENT/NXT] key (5) to set the upper address.
6. Enter the program start address (the address at which you want your program to begin executing). (6)
7. Depress the [ENT/NXT] key (7) to set the start address.
8. Enter the file identification (ID) number. (8)
   NOTE: The file ID may be any hex value between 00 and FF. If no ID is entered, the default file number is 00.
9. Place the cassette deck in the RECORD mode.
10. Depress [ENT/NXT] key. (9) This starts a five second delay prior to actual memory dump to tape. The INSTRUCTOR 50 flashes the FLAG Indicator at one-second intervals during this delay. The message HELLO is displayed (9) when data transfer to tape is completed.
11. During the recording process, a visual indication of the 'dump' can be observed on the I/O port indicators by placing the I/O Port Address Select Switch in the EXTENDED (center) position.

Tape Deck Shutdown

- Turn the audio tape recorder off.
- If the tape deck has a counter, note its value for future reference.
- Disconnect tape deck and remove and store tape cartridge.

Error Messages

The INSTRUCTOR 50 will display the message 'Error 7' if the value of the specified upper address is less than the value of the lower address.

EXAMPLE

	Key(s)	Display	Comments
①	WCAS	L.Ad. =	Waiting for lower address of file to be written onto tape
②	0	L.Ad. = 0	Lower address entered
③	ENT NXT	U.Ad. =	Lower address set. Waiting for upper address.
④	7 6	U.Ad. = 76	Upper address entered
⑤	ENT NXT	S.Ad. =	Upper address set. Waiting for start address.
⑥	10	S.Ad.= 10	Start address entered.
⑦	ENT NXT	. F =	Start address set. Waiting for file number.
⑧	1	. F = 1	File ID entered.
⑨	ENT NXT	HELLO	File address set. Write data to cassette tape completed.

Write a file to tape with the following parameters:

File Number = 1

Beginning Address = 0

Ending Address = H'76'

Program Start Address = H'10'

ADJUST CASSETTE

FUNCTION: The ADJUST CASSETTE command allows you to adjust the output level of a cassette recorder for proper interface to the INSTRUCTOR 50 during a READ CASSETTE operation.

While most conventional audio cassette recorders are compatible for use with the INSTRUCTOR 50, the playback volume control must be accurately adjusted to ensure proper detection of data by the INSTRUCTOR 50. Otherwise, the data signal may be distorted (volume too high) or may drop below detection thresholds (volume too low).

PROCEDURE:

General Installation

1. Check to ensure that the cassette recorder's playback heads and transport mechanism are clean and free from any obstructions.

2. Install tape in transport and rewind to an area known to contain a previously recorded file. Use of the sample tape supplied with the INSTRUCTOR 50 is recommended.

3. Connect the INSTRUCTOR 50's PHONE jack to the cassette deck's PHONE or SPEAKER output jack using the appropriate cable supplied with the INSTRUCTOR 50 package.

Operation

1. Place the INSTRUCTOR 50 in the ADJUST CASSETTE mode by depressing the [REG] key on the function control keyboard followed by [A] on the hexadecimal keyboard.(1)

2. Start playback of previously recorded data.

3. Adjust tape deck VOLUME or LEVEL control. The following three digits will be displayed intermittently during the adjustment process:

   U Increase volume

   d. Decrease volume

   \- volume control adjusted correctly

4. When a minus sign (-)(3) is displayed, the audio cassette's playback volume is properly adjusted.

5. During the adjust process, the I/O Port indicators can also be used to observe data being read by the INSTRUCTOR 50 if the I/O Port Address Switch is placed in the EXTENDED (center) position. The display has the following significance:

All LEDs OFF	Indicates proper operation or no data.
Some negative number (LED bit 7 ON)	Indicates that the playback level is too low - not enough pulses
Some positive number (LED bit 7 OFF)	Indicates that the playback level is too high. Tape "noise" is being detected - too many pulses.

6. When level is properly set, turn off the cassette deck.
7. Depress the [MON] key ④ to exit from the ADJUST CASSETTE routine.

EXAMPLE

	Key(s)	Display	Comments
①	[REG] [A]	U	Places INSTRUCTOR 50 in the ADJUST CASSETTE mode. Increase playback level.
②		d.	Decrease playback level
③		-	Playback level properly set
④	[MON]	HELLO	Exit ADJUST CASSETTE mode

READ CASSETTE

FUNCTION: The READ CASSETTE command allows you to read files previously stored on cassette tape using the WRITE CASSETTE command and store these files in the specified RAM locations.

PROCEDURE:

General Installation

1. Check to ensure theat the cassette recorder's playback heads and transport mechanism are clean and free from any obstructions.

2. Install tape in transport and rewind to desired file location.

3. Connect the INSTRUCTOR 50's PHONE jack to the cassette deck's PHONE or SPEAKER output jack using the appropriate cable supplied with the INSTRUCTOR 50 package.

4. Adjust playback level to setting previously determined to be proper by ADJUST CASSETTE operation (See ADJUST CASSETTE command).

Operation

1. Depress the [RCAS] key ① to place the INSTRUCTOR 50 in the READ CASSETTE mode.

2. Depress one or two hex digits ② corresponding to the file number desired to be read back.

   NOTE: the user may elect to read the first file encountered by omitting this step.

3. Depress the [ENT/NXT] key ③ to set the file ID number.

4. Start the cassette deck in playback mode. The reading of data by the INSTRUCTOR 50 can be visually observed on the I/O Port indicators by placing the I/O Port Address Switch in the EXTENDED (center) position.

5. When the reading of the specified file is completed, the INSTRUCTOR 50 will display the HELLO message. ④

6. Turn off the audio cassette deck.

7. Data read from tape will be placed at consecutive memory locations starting at the beginning address specified when the file was created. The Program Counter (PC) will be set to the address specified as the program start address when the file was created.

Error Messages

During the read-in process, any one of the following error messages may be displayed:

- Error 4 - Cassette Block Check Character (BCC) error
- Error 5 - Read Cassette Memory Write Error
- Error 6 - Read Cassette character from tape not ASCII HEX

EXAMPLE

	Key(s)	Display	Comments
①	RCAS	.F=	Places the INSTRUCTOR 50 in the READ CASSETTE mode. Waiting for file ID number
②	1	.F= 1	File ID number entered
③	ENT/NXT		Sets file ID number. Begins reading data into memory*
④		HELLO	File is fully loaded into memory

* Flashing I/O Port indicators at this point indicate that the file is being read.

RUN

FUNCTION: Terminates the monitor mode and causes program execution to begin at the address specified in the Program Counter. Program execution continues until 1) a breakpoint is encountered, 2) the RST or MON key is depressed, or 3) the user program executes a WRTC (Write to Port C) or HALT instruction.

The RUN command allows program execution to begin at any point in the user program. It is particularly valuable, when used in conjunction with a set breakpoint, for debugging sections of a program. When the RUN key is depressed, the INSTRUCTOR 50 performs the following actions:

1. If a breakpoint was set, the WRTC code is inserted at the specified breakpoint address and a monitor 'BREAKPOINT ENABLED' flag is set. This flag distinguishes a breakpoint 'WRTC' from any other 'WRTC' in the user program when control is returned to the USE monitor by the forced jump logic upon execution of a WRTC instruction.

2. The processor registers are restored to the last values existing when control was returned to the USE monitor after a breakpoint or single step, or to the values specified by you in a DISPLAY AND ALTER REGISTERS operation.

3. The INSTRUCTOR 50 switches to the execution mode by jumping to the address specified in the Program Counter. This address will be the address of the next instruction following a breakpoint or single step, or the address specified by you in a DISPLAY AND ALTER PROGRAM COUNTER operation.

RESET

FUNCTION: When the RST (RESET) key is depressed, current INSTRUCTOR 50 activity is terminated immediately, and the processor begins program execution at address H'0000'. Breakpoint and single-step flags, if set, are ignored. A high (logic one) level appears on the expansion connector RESET pin for as long as the key remains depressed.

When the RESET key is used to initiate program execution from location H'0000', the initial processor register values are unknown, and a breakpoint, if previously specified, is <u>not</u> inserted in the user program. Program execution continues until <u>any</u> one of the following occurs:

1. The RESET key is depressed again.

2. A HALT instruction (H'40') is executed. Upon detection of a HALT instruction, the processor halts until the RESET key is depressed again or, if the Interrupt Inhibit PSW bit was not set, until an interrupt occurs.

3. A WRTC instruction is executed or the MON key is depressed. Control is transferred to the USE monitor and the HELLO message is displayed. When control is returned to the monitor, the address of the last memory fetch is saved in the Program Counter, and register values are saved in monitor RAM. These may be examined by using the appropriate commands.

4. The processor's PAUSE input is raised high via the expansion connector. When this occurs, the RUN indicator light is extinguished. Program execution will begin at the next instruction when PAUSE goes low.

ERROR MESSAGES

The USE monitor incorporates extensive error checking firmware. If an error is encountered while attempting to execute a command, a message of the form 'Error n' is presented on the monitor display. Error messages are summarized in Table 4.1.

• Error 1	BREAKPOINT CANNOT BE SET
• Error 2	INVALID COMMAND
• Error 3	ALTER OR PATCH MEMORY WRITE ERROR
• Error 4	CASSETTE BCC ERROR
• Error 5	READ CASSETTE MEMORY WRITE ERROR
• Error 6	CHARACTER FROM TAPE NOT ASCII HEX
• Error 7	START ADDRESS GREATER THAN STOP ADDRESS
• Error 8	KEYBOARD HAS 2 KEYS IN COLUMN DOWN
• Error 9	NEXT SINGLE STEP IS INTO MONITOR

TABLE 4.1 Error Messages

Additional information on each of the above error messages is presented in the following paragraphs.

Error 1 *BREAKPOINT CANNOT BE SET*

The display message Error 1 indicates that an attempt was made to set a breakpoint at a memory address which is not RAM. A breakpoint is entered by inserting the WRTC,R0 code H'B0' into the memory address specified. A read-after-write check is then performed. If this test fails, the error message is displayed.

Error 2 *INVALID COMMAND*

The display message Error 2 indicates that an incorrect command sequence was entered via the keyboard.

Error 3 *ALTER OR PATCH MEMORY ERROR*

The display message Error 3 indicates that an attempt was made to change the data at a memory address which is not RAM. When changing memory data during an Alter Memory or Patch Memory operation, a read-after-write check is performed. If this test fails, the error message is displayed.

Error 4 *CASSETTE BCC ERROR*

When data is written on tape with the WRITE CASSETTE command, a Block Check Character (BCC) is appended to the end of the file. The BCC is re-calculated when data is read back with a READ CASSETTE command and compared with the BCC recovered from the tape. If the BCC's do not match, the message Error 4 is displayed, indicating that some problem has occurred in reading the tape.

Error 5 *READ CASSETTE MEMORY WRITE ERROR*

Data read back from the tape is stored in the INSTRUCTOR 50 at consecutive memory locations starting at the address specified in the tape file. A read-after-write check is performed on each byte stored. If the test fails, the message Error 5 is displayed.

Error 6 *CHARACTER FROM TAPE NOT ASCII HEX*

Data written on tape uses the ASCII code for the characters 0 through F. The display message Error 6 indicates that a non-hex character was recovered from the tape. Correct adjustment of playback level should be verified using the ADJUST CASSETTE command.

Error 7 *START ADDRESS GREATER THAN STOP ADDRESS*

The display message Error 7 indicates that the start address in the WRITE CASSETTE command is greater than the specified stop address. The operation cannot be performed. See Section 4.

Error 8 *KEYBOARD HAS 2 KEYS IN COLUMN DOWN*

The Error 8 message is displayed when the monitor detects that two keys are depressed simultaneously. The monitor cannot decode the action desired.

Error 9 *NEXT SINGLE STEP IS INTO MONITOR*

Single-step operation in the memory area reserved for the USE monitor (H'1000' - H'1FFF') is not permitted and will cause unpredictable results if executed. The display message Error 9 is a warning that such a single-step operation was attempted.

5. USING THE INSTRUCTOR 50

Restrictions on Using the 2650 Instruction Set

When writing programs, the INSTRUCTOR 50 user has the complete 2650 microprocessor instruction set at his disposal. However, because of the interaction between the USE monitor and user hardware and software, certain restrictions must be observed:

1) The USE monitor reserves the WRTC, Rx instruction (H'B0' - H'B3') to indicate the location of a breakpoint in a user program. If this instruction is executed in a user program, control of the system will return to the monitor, and the message HELLO will be displayed.

2) If a HALT instruction (H'40') is executed, processor operation will terminate. This is indicated by the RUN indicator being extinguished. The only ways to re-initiate operation are to depress the [RST] key or, if interrupts were not inhibited, to cause an interrupt by depressing the [INT] key.

   If a breakpoint is set at a HALT instruction location, the monitor will prevent execution of the HALT, and normal operation will continue.

3) The top of memory page zero is occupied by the USE monitor program. Therefore, the ZBSR and ZBRR instructions with negative displacements should not be used unless entry into the monitor program is desired. The same applies to interrupt vectors with negative displacements.

4) The USE monitor uses three levels of the 2650 subroutine Return Address Stack (RAS) in its operation. Since the RAS is limited to eight levels, user programs being developed under control of the USE monitor should be limited to a maximum of five levels of subroutines, including interrupt levels.

Using Interrupts

Interrupts provide a method of interfacing a synchronous program to asynchronous external events. An Interrupt Request forces the 2650 to temporarily suspend execution of the program currently running and branch to an interrupt service routine. Upon completion of the interrupt service routine, the 2650 resumes execution of the interrupted program.

The INSTRUCTOR 50 provides three methods of interrupting the 2650. The first method is a manual interrupt using the [INT] key on the function keyboard. The second method uses a 60Hz signal derived from the INSTRUCTOR 50's power supply to generate interrupt requests once every 16.7 ms. This option accommodates user programs that require a real-time clock. (For European systems, the real-time clock interrupts occur at a 50Hz rate or once every 20 ms). The third method of interrupting the INSTRUCTOR 50 is via the S100 bus interface. This section describes the 2650's interrupt mechanism and provides details on selecting the interrupt options.

The 2650's interrupt mechanism can be selectively enabled or disabled at various points in a user program by setting or clearing the Interrupt Inhibit (II) bit of the processor's Program Status Word (PSW). If the Interrupt Inhibit bit has been set, the 2650 ignores interrupt requests. The Interrupt Inhibit bit may be cleared (thus enabling interrupts) in any of the following four ways:

1) By reseting the processor (depressing the RST key);

2) By executing a Clear Program Status Upper (CPSU) instruction with the proper mask value;

3) By executing a Return from Subroutine and Enable Interrupt (RETE) instruction; or

4) By executing a Load Program Status, Upper (LPSU) intruction.

The interrupt mechanism of the 2650 operates with a vectored interrupt. When the processor accepts an interrupt request, it responds by issuing an INTerrupt ACKnowledge (INTACK). Upon receipt of INTACK, the interrupting device responds by placing an "interrupt vector" on the 2650 data bus. This vector is used as the address, relative to byte zero, page zero, of a branch to subroutine instruction. The interrupt vector may specify either direct or indirect addressing. A vector that specifies direct addressing causes the 2650 to execute a subroutine branch to the address specified by the vector. If an indirect address is specified, the interrupt vector points to the first of two successive memory locations (interrupt vector and interrupt vector + 1) where the address of the interrupt subroutine is stored. In this case, the processor first fetches the two interrupt subroutine address bytes and then branches to the subroutine. Thus, a direct interrupt vector transfers the program to any location from -64 to +63 relative to byte zero, page zero, and an indirect interrupt vector can transfer the program to any location within the 2650's 32K addressing range.

If the Interrupt Inhibit bit has been cleared, the INSTRUCTOR 50 responds to an interrupt request with the following sequence of events:

1) The 2650 completes execution of the current instruction.

2) The processor sets the Interrupt Inhibit bit of the PSW (=1)

3) The first byte of a Zero Branch to Subroutine Relative (ZBSR) instruction is inserted in the 2650's internal instruction register.

4) The processor issues INTACK and waits for an interrupt vector to be returned on the data bus.

5) The INSTRUCTOR 50's interrupt logic places the interrupt vector (H'07' or H'87') on the data bus. Whether the interrupt vector specifies direct (H'07') or indirect (H'87') addressing is determined by the setting of the Direct/Indirect switch on the front panel. If the switch is in Direct position, the next instruction executed is the instruction at address H'07'. If the switch is in the Indirect position, the next instruction executed is at the address contained in H'07' and H'08'.

6) The 2650 executes the ZBSR instruction. The address of the next instruction in the interrupted program is stored in the 2650's internal subroutine address stack, and the stack pointer is incremented.

7) When the interrupt subroutine is terminated with an RETE or RETC instruction, the 2650 decrements the stack pointer, replaces the current value of the Program Counter with the address previously stored in the subroutine stack, and resumes execution of the interrupted program.

Since the INSTRUCTOR 50 interrupt logic vectors interrupt requests through memory address H'07', user programs that support direct interrupts must place the first byte of the interrupt subroutine at this address. If indirect subroutines are used, the address of the interrupt subroutine must be stored at memory locations H'07' and H'08'.

As interrupts may occur at any point in a user program, it is entirely possible that they will affect the contents of the 2650's internal registers with unpredictable results for the interrupted program. This problem can be solved in two ways. The first way is to tightly control the portions of a user program that can be interrupted by selectively setting and clearing the Interrupt Inhibit bit in the PSW. The second method is to save the 2650's internal registers and Program Status Word upon entering the interrupt subroutine and restoring them before returning from the subroutine.

The INSTRUCTOR 50's interrupt modes can be selected by a combination of switch settings and a jumper option on the printed circuit board. As mentioned previously, the Direct/Indirect swtich on the INSTRUCTOR 50's front panel determines whether the interrupt vector generated by the interrupt logic specifies direct or indirect addressing. Whether the 2650 responds to the INT key or the 60 Hz real-time clock is determined by the setting of a slide switch located at the bottom of the INSTRUCTOR 50 case. Optionally, devices external to the INSTRUCTOR 50 can generate interrupt requests via the S100 bus interface. To accomplish this, a jumper option described in the last part of this section is used. Following are two programming examples that make use of the INSTRUCTOR 50's interrupt facilities:

FOLLOWING ARE TWO PROGRAMMING EXAMPLES THAT MAKE USE OF THE INSTRUCTOR 50's INTERRUPT FACILITIES:

Example 1 - Direct Interrupt

This example is a complete program that first clears the parallel I/O port lights and then maintains a binary counter at the I/O port lights. The count is incremented each time the [INT] key is depressed. Prior to running this program, you must place the Direct/Indirect switch in the Direct position, and the I/O port address select switch in the Non-Extended position.

Address	Data	Instruction Mnemonic	Comment
0000	76,20	PPSU H'20'	Set II - inhibit interrupts
0002	75,08	CPSL H'08'	Operations without carry
0004	1F,00,0A	BCTA,UN,H'000A'	Branch over interrupt subroutine
0007	84,01	ADD1,R0,H'01'	Increment R0 (counter)
0009	17	RETC,UN	Return from interrupt subroutine
000A	20	EORZ,R0	Clear R0 (counter)
000B	F0	WRTD,R0	Write R0 to the lights (non-extended)
000C	74,20	CPSU H'20'	Clear II (open interrupt window)
000E	76,20	PPSU H'20'	Set II (close interrupt window)
0010	1F,00,0B	BCTA,UN H'000B'	Branch back to WRTD

Example 2 - Indirect Interrupt

This example performs the same function as above but uses indirect interrupts. The interrupt subroutine starts at address H'100'. This address is contained in program locations H'07' and H'08'.

Address	Data	Instruction Mnemonic	Comments
0000	76,20	PPSU H'20'	Set II - Inhibit Interrupts.
0002	75,08	CPSL H'08'	Operations without carry.
0004	1F,00, 09	BCTA,UN H'0009'	Branch over interrupt address.
0007	01,00	ACON H'0100'	Interrupt routine address.
0009	20	EORZ,R0	Clear counter.
000A	F0	WRTD,R0	Write R0 to the lights.
000B	74,20	CPSU H'20'	Clear II - enable interrupts.
000D	1F,00, 0D	BCTA,UN H'000D'	Loop forever.
0100	84,01	ADDI,R0 H'01'	Increment counter.
0102	F0	WRTD,R0	Write R0 to the lights.
0103	37	RETE,UN	Return and enable interrupts.

Using the I/O Switches and Lights

The 2650 provides several methods for monitoring the status of and controlling the operation of external I/O devices. One such method unique to the 2650 is a serial I/O port formed by the SENSE input pin and the FLAG output pin on the processor. The 2650 also has provisions for two types of parallel I/O instructions, called extended and non-extended. The non-extended I/O instructions are one-byte instructions that allow a user program to read from and write to two eight-bit I/O ports: port C and port D. The two byte extended I/O instructions expand the 2650's I/O capabilities to 256 bidirectional I/O ports.

In addition to the 2650 instructions specifically intended for I/O operations, you may choose to use the memory mapped I/O mode. This mode is implemented by assigning a memory address to an I/O device. While a memory mapped I/O port requires more decode logic than either an extended or a non-extended port, it can be accessed by the full range of 2650 memory referencing instructions. (Refer to the 2650 Microprocessor Manual for a description of the 2650 I/O control modes.)

The INSTRUCTOR 50 includes features that demonstrate all of the 2650's I/O modes. These features are described as follows.

FLAG and SENSE I/O

The 2650's FLAG and SENSE pins are associated with the flag and sense bits of the processor's internal Program Status Word (PSW). The sense bit of the PSW always reflects the signal level on the SENSE pin. Likewise, the level on the FLAG pin always reflects the current value of the flag bit in the PSW.

The user may manually control the value of the sense bit in the PSW using the [SENS] key on the function control keyboard. When the [SENS] key is depressed, the sense bit is a one. Otherwise, the SENSE bit is a zero.

The INSTRUCTOR 50's FLAG indicator on the front panel is driven by the FLAG pin on the 2650, providing a visual indication of the flag bit's current value. The FLAG light is on if the flag bit is a one, and the light is off if the flag bit is a zero.

Non-Extended I/O

The 2650 can control two bidirectional I/O ports with four single-byte instructions: WRTC, WRTD, REDC and REDD. These instructions move data between port C, port D and the 2650's internal registers.

The INSTRUCTOR 50's front panel parallel I/O port can be assigned as non-extended port D by placing the Port Address select switch in the NON-EXTENDED position. In this position, the I/O port can be accessed with the WRTD and REDD instructions. This allows you to manually enter data with the input switches by including a REDD instruction in your program. Similarly, your program can write a data value to the output LEDs by executing a WRTD instruction.

Extended I/O

The 2650 can control up to 256 bidirectional I/O ports with the double-byte instructions WRTE and REDE. The second byte of these instructions specifies the extended I/O port address. The INSTRUCTOR 50's parallel I/O port can be assigned as extended address H'07' by placing the Port Address switch in the EXTENDED position. In this mode, the parallel I/O port can accessed with WRTE and REDE instructions that specify an extended address H'07' in their second byte.

Memory Mapped I/O

Memory mapped I/O is simply a matter of decoding a memory address for enabling an I/O port. To demonstrate this I/O mode, the INSTRUCTOR 50's Port Address select switch can be placed in the MEMORY position. This assigns the parallel I/O port a memory address of H'0FFF'. Thus, any memory reference instruction that specifies H'0FFF' as the source or destination will access the front panel parallel I/O port. When an instruction reads location H'0FFF', the value set in the port input switches is loaded into the specified register. If an instruction writes to memory location H'0FFF', the value contained in the specified register will appear in the port output LEDs.

CALLING MONITOR SUBROUTINES

Now that you are familiar with the 2650 instruction set and have successfully entered a few simple programs, you are undoubtedly ready and anxious to make use of some of the more powerful features provided by the INSTRUCTOR 50. For example, you might want to write a decimal add program using the INSTRUCTOR 50's keyboard and eight-digit display. By calling subroutines within the monitor program, the display can be used to request the two numbers to be added, and the hex keyboard can be used to enter the numbers. After the two numbers have been entered, and their sum calculated, another monitor subroutine can be called to display the results of the addition. This section describes these subroutines and provides examples in their use.

In addition to subroutines that provide easy access to the INSTRUCTOR 50's keyboard and display, the monitor program contains other subroutines that are useful in writing application programs. Refer to the program listing in the appendices for additional information on other subroutines.

The monitor subroutines are called with Zero Branch to Subroutine Relative (ZBSR) instructions. The ZBSR instruction specifies a subroutine relative to byte zero, page zero. The relative addressing range is -64 to +63. Since the 2650 uses an 8K page addressing scheme, ZBSR instructions with a negative offset (relative address) wraps back around to the top of the first 8K page. The top of the first 8K page in the INSTRUCTOR 50 is located within the monitor program and contains a table of indirect subroutine addresses. Thus, the monitor subroutines can be called by ZBSR instructions that specify indirect addressing and have the negative offset that points to the desired subroutine. The addresses required to call the various monitor subroutines are included in the description of each subroutine.

The subroutine descriptions include a list of the 2650 registers used in their execution. Unless otherwise specified, the contents of these registers will contain meaningless data when the subroutine returns control to the user program. Therefore, registers that contain important user program information must be stored in a memory location before the monitor subroutine is called.

When calling monitor subroutines, caution must be exercised to avoid overflowing the 2650's internal 8-level subroutine stack. Since some of the user-accessible subroutines call other subroutines within the monitor program, each subroutine description includes the number of other subroutines called during its execution. This information allows you to calculate the number of subroutine stack levels required by your program and insures that this number never exceeds eight.

MOVE SUBROUTINE

Calling Instruction:

Mnemonic	Hex Value
ZBSR *MOV	BB,FE

Registers Used:

R1 = Message Pointer -1 (high-order byte)
R2 = Message Pointer -1 (low-order byte)

Subroutine Levels Used: 0

Function:

MOVE fetches an eight-byte message within the user's program and stores the eight bytes in the monitor's display buffer. When combined with the DISPLAY subroutine, MOVE allows you to write messages on the INSTRUCTOR 50's eight-digit display. Any of the INSTRUCTOR 50's characters can be used in assembling a message.

Operation:

Before calling MOVE, you must store an eight-byte message within your program. The location of the sequential message bytes is transferred to MOVE by storing the address of the first message byte in R1 and R2 prior to calling the subroutine. Because of the algorithm used to implement the MOVE subroutine, it is necessary to subtract one from the message pointer before it is stored in R1 and R2. Following is an example of the MOVE subroutine call and a list of the hexadecimal values for the INSTRUCTOR 50's display characters.

EXAMPLE OF MOVE SUBROUTINE CALL

Address	Data	Instruction Mnemonic	Comments
•			
•			
•			
0010	05,00	LODI, R1 H'00'	Load message pointer -1 in R1 and R2
0012	06,FF	LODI, R2 H'FF'	(H'100' -1 = H'00FF').
0014	BB,FE	ZBSR *MOV	Call MOVE. The message bytes stored in locations 0100-0107 are transferred to the monitor's display buffer.
•			
•			
•			
0100	17		= blank **(first byte of message)**
0101	14		= H
0102	0E		= E
0103	11		= L
0104	11		= L
0105	00		= O
0106	17		= blank
0107	17		= blank (last byte of message)

Hex Values of Display Characters

Character	Value	Character	Value	Character	Value
*0.0	H'00'	*A	H'0A'	*H	H'14'
*1.I	H'01'	*B	H'0B'	*O	H'15'
*2	H'02'	*C	H'0C'	*=	H'16'
*3	H'03'	*D	H'0D'	*BLANK	H'17'
*4	H'04'	*E	H'0E'	*J	H'18'
*5.5	H'05'	*F	H'0F'	*-	H'19'
*6.G	H'06'	*P	H'10'	*	H'1A'
*7	H'07'	*L	H'11'	*Y	H'1B'
*8	H'08'	*U	H'12'	*N	H'1C'
*9	H'09'	*R	H'13'		

DISPLAY SUBROUTINE

Calling Instruction:

Mnemonic	Hex Value
ZBSR *DISPLY	BB,EC

Registers Used:

R0,R1,R2,R3

On entry R0 = Display Command
On exit R0 = Key Value (optional)

Subroutine Levels Used: 0

Function:

When used with the MOVE subroutine, DISPLAY writes messages on the INSTRUCTOR 50's eight-digit display. DISPLAY reads the message stored in the monitor's display buffer with MOVE and writes the message on the display. Optionally, DISPLAY can be used to read the function and data keyboards and return the value of a depressed key.

Operation:

DISPLAY has three modes of operation that are selected by writing a command byte in R0 prior to calling the subroutine. The DISPLAY commands and the functions they specify are summarized below:

Value Placed in RØ	Function
H'00'	Displays message in display buffer until a function or data key is depressed. Returns the value of the depressed key in R0.
H'01'	Makes one pass through the DISPLAY subroutine and does not read the keyboards. A single pass through the DISPLAY subroutine will not produce a visible display. Hence, when this command is used, it should be part of a loop that calls DISPLAY a sufficient number of times to illuminate the message.
H'80'	This command is identical to the H'00' command except that the decimal point of the most-significant (far-left) digit is illuminated.

The function and data key values returned in R0 when operating in response to commands H'00' and H'80' are listed in the following table. This is followed by an example of the MOVE and DISPLAY subroutine calls that displays the message HELLO until the [RUN] key is depressed.

Data Values for Command and Data Keys

Key	Value	Key	Value	Key	Value
Ø	H'00'	8	H'08'	WCAS	H'80'
1	H'01'	9	H'09'	BKP	H'81'
2	H'02'	A	H'0A'	RCAS	H'82'
3	H'03'	B	H'0B'	REG	H'83'
4	H'04'	C	H'0C'	STEP	H'84'
5	H'05'	D	H'0D'	MEM	H'85'
6	H'06'	E	H'0E'	RUN	H'86'
7	H'07'	F	H'0F'	ENT/NXT	H'87'

Example of Move and Display Subroutine Calls

Address	Data	Instruction Mnemonic	Comment
0010	05,00	LODI,R1 H'00'	Place message table pointer minus one in R1 and R2.
0012	06,FF	LODI,R2 H'FF'	
0014	BB,FE	ZBSR *MOV	Call the Move subroutine.
0016	04,00	LODI,R0 H'00'	Place command byte in R0.
0018	BB,EC	ZBSR *DISPLY	Call the DISPLAY subroutine.
001A	E4,86	COMI,R0 H'86'	Compare returned key code to RUN code. If equal,
001C	1C,XX,XX	BCTA,EQ H'XXXX'	branch to address H'XXXX'.
001F	1E,00,16	BCTA,UN H'0016'	If not equal, loop back and wait for next key.
⋮			
0100	17		First byte of message table = blank
0101	14		= H
0102	0E		= E
0103	11		= L
0104	11		= L
0105	00		= O
0106	17		= blank
0107	17		Last byte of message table = blank

USER DISPLAY SUBROUTINE

Calling Instruction:

Mnemonic	Hex Value
ZBSR *USRDSP	BB,E6

Registers Used:

R0, R1, R2, R3

```
On entry R3 = Display Command
         R1 = Message Pointer -1 (high order)
         R2 = Message Pointer -1 (low order)
On exit  R0 = Key value (optional)
```

Subroutine Levels Used: 2

Function:

USER DISPLAY combines the functions of MOVE and DISPLAY. That is, USER DISPLAY moves an eight-byte message from a user program to the display buffer and then displays the message. As with DISPLAY, this subroutine may be used to read the function and data keyboards.

Operation:

Before calling USER DISPLAY, you must load the first address of your message table (-1) in R1 and R2. Additionally, R3 must be loaded with the desired command as in the DISPLAY subroutine.

The following example of a USER DISPLAY subroutine call displays the message HELLO until the RUN key is depressed. (This example is functionally equivalent to the example for the DISPLAY subroutine).

<u>Example of a USER DISPLAY Subroutine Call</u>

Address	Data	Instruction Mnemonic	Comment
0010	05,00	LODI,R1 H'00'	Place message table pointer -1 in R1 and R2.
0012	06,FF	LODI,R2 H'FF'	
0014	07,00	LODI,R3 H'00'	Place command byte in R3.
0016	BB,E6	ZBSR *USRDSP	Call USER DISPLAY.
0018	E4,86	COMI,R0 H'86'	Compare returned key value to RUN's value.
001A	1C,XX,XX	BCTA,EQ H'XXXX'	Branch to XX,XX if equal.
001D	1F,00,10	BCTA,UN H'0010'	If not equal, loop back and get another key.
.	.		
.			
.	.		
0100	17		First byte of message table = blank
0101	14		= H
0102	0E		= E
0103	11		= L
0104	11		= L
0105	00		= O
0106	17		= blank
0107	17		Last byte of message table = blank

NIBBLE SUBROUTINE

Calling Instruction:

Mnemonic	Hex Value
ZBSR *DISLSD	BB,F4

Registers Used:

```
R0 and RZ
On entry:. R0 = byte (high-order nibble, low-order nibble)
on exit:   R0 = high-order nibble
           R1 = low-order nibble
```

Subroutine Levels Used: 1

Function:

NIBBLE takes an eight-bit byte and separates it into two bytes, each containing one of the original four-bit nibbles. This subroutine is useful in user programs that display a register or memory data value on the INSTRUCTOR 50 display.

Operation:

The byte to be separated is passed to NIBBLE in R0. NIBBLE then takes the least-significant four bits (low-order nibble) from R0 and places them in the four least-significant bits of R1. When NIBBLE returns program control to your program, R0 contains the low-order nibble, and R1 contains the high-order nibble. The most-significant four bits of both R0 and R1 contain zeros. A functional example of NIBBLE is shown below. This is followed by an example of a NIBBLE subroutine call.

Functional Example of NIBBLE

On entry: R0 = F3

On exit: R0 = 0F
R1 = 03

Example of NIBBLE Subroutine Call

Address	Data	Instruction Mnemonic	Comment
0000	70	REDD,R0	Read I/O port (Non-Extended) into R0.
0001	BB,F4	ZBSR *DISLSD	Call NIBBLE subroutine.
0003	CD,01,07	STRA,R1 H'01,07'	Store low-order nibble in message table.
0006	CC,01,06	STRA,R0 H'01,06'	Store high-order nibble in message table.
0009	05,00	LODI,R1 H'00'	Place message table pointer (-1) in R1 and R2.
000B	06,FF	LODI,R2 H'FF'	Place display command in R0.
000D	04,00	LODI,R0 H'00'	
000F	BB,E6	ZBSR*USRDSP	Call USER DISPLAY subroutine. Displays previous Port D value. Allows new I/O value to be set up in switches. Exits when any key is depressed.
0011	1B,6D	BCTR,UN H'6D'	Loop back to 0000 and get new I/O value.
:			
0100	13		= "R" (first byte of message table).
0101	0E		= "E"
0102	0D		= "D"
0103	0D		= "D"
0104	16		= "="
0105	17		= "blank"
0106	17		= "blank" (high-order nibble will be stored here).
0107	17		= "blank" (low-order nibble will be stored here).

INPUT DATA SUBROUTINE

Calling Instruction:

Mnemonic	Hex Value
ZBSR *GNP	BB,FA

Registers Used:

On entry: R0 = Input Command

On exit: R0 = Two Data Key Values
R1 = Two Data Key Values (optional)
R2 = Function Key Value
R3 = Data Entered Indicator

Subroutine Levels Used: 1

Function:

INPUT DATA displays the contents of the display buffer and scans the data keyboard for data entry. As data is keyed in, the subroutine writes the input data in the least-significant digits of the display. When a function key is depressed, USER DISPLAY returns to the main program with the input data and function key values in the 2650's internal registers.

Operation:

INPUT DATA has two selectable modes of operation. Mode selection is made by writing an input command byte in R0 before calling the subroutine. The input command bytes and the functions they specify are listed as follows:

Value Placed in R0	Function
H'00'	Displays a four-digit message and accepts four digits of data. As each data value is keyed in, it is displayed in the least-significant (right-most) display digit, and previously entered values are shifted left. Data entry is terminated and program control is returned to the user program when a function key is depressed. If less than four data values are entered, zeros are inserted in the non-entered digit positions.
H'01'	Identical to H'00' except that a five-digit message is displayed, and two digits of data are input from the data keyboard.

The four or five-digit message to be displayed by INPUT DATA must be placed in the monitor's display buffer before INPUT DATA is called. The message characters displayed are taken from the first four or five bytes of the eight-byte message table transferred to the display buffer by the MOVE subroutine.

The data values input to INPUT DATA are returned to the main program in R0 for the two-digit input mode and to R0 and R1 for the four-digit input mode. In the two-digit input mode, the most-significant data value entered is returned in the most-significant nibble of R0, and the least-significant data value is returned in the least-significant nibble of R0. In the four-digit input mode, the two most-significant data values are returned in R1, and the two least-significant data values are returned in R0.

When data entry is terminated with a function key depression, the value of the function key is returned to R2, and a data entered indicator value is returned to R3. If no data has been entered before a function key is depressed, R3 will contain the value H'7F'. If data has been entered, R3 will contain a value of H'00'. This allows you to insure that the data returned in R0 and R1 is valid data. The following example illustrates how data is returned to the user program. (This is followed by an example of an INPUT DATA call.)

Example of Data Entry and Register Contents on Return From Input Data Subroutine

Key	Display	Comments
[1][2][3][4]	P L U S	Initial display on subroutine entry.
[RUN]	P L U S 1 2 3 4	Data values entered.
		Data entry terminated and program control returned to user program.

Register Contents on Return from Input Data Subroutine

Register	Contents	Comments
R0	H'34'	Least-significant data values
R1	H'12'	Most-significant data values
R2	H'86'	Value of RUN key
R3	H'00'	Indicates valid data in R0 and R1

Example of Input Data Subroutine Call

Address	Data	Instruction Mnemonic	Comment
0050	05,00	LODI,R1 H'00'	Place message table pointer (-1) in R1 and R2.
0052	06,FF	LODI,R2 H'FF'	
0054	BB,FE	ZBSR *MOV	Call MOVE to transfer message table to display buffer.
0056	04,00	LODI,R0 H'00'	Place input command in R0 (H'00' = 4 digits).
0058	BB,FA	ZBSR *GNP	Call INPUT DATA subroutine.
⋮			
0100	10		First byte of message table = P
0101	11		= L
0102	12		= U
0103	05		= S
0104	17		= blank
0105	17		= blank
0106	17		= blank
0107	17		Last byte of message table = blank

NOTE: Since the input command requests four digits of input data, only the first four message table bytes (0100 - 0103) are displayed.

MODIFY DATA SUBROUTINE

Calling Instruction:

Mnemonic	Hex Value
ZBSR *GNPA	BB,FC

Registers Used:

R0,R1,R2,R3

On entry: R0 = Input command

On exit: R0 = Two Data Key Values
R1 = Two Data Key Values
R2 = Function Key Value
R3 = Data Entered Indicator

Subroutine Levels Used: 1

Function:

MODIFY DATA is very similar to INPUT DATA. The major difference is that the initial display message can use all eight digit positions on the INSTRUCTOR 50 display panel. MODIFY DATA enables a program to display data values that were previously entered with INPUT DATA and allows these data values to be modified.

Operation:

As with INPUT DATA, MODIFY DATA has two modes of operation that are selected by writing an input command byte in R0 prior to calling the subroutine. The input commands and their respective functions are listed below:

Value Placed in R0	Resulting Function
H'00'	Displays an eight-digit message and accepts four digits of data. After the first data key is depressed, the four least-significant digits of the display are cleared. Each new data value entered is then displayed in the least-significant display digit, and previously entered values are shifted left. Data entry is terminated when a function key is depressed.
H'01'	Identical to H'00' except that when the first data key is depressed, the three least-significant display digits are cleared, and two digits of data may be entered.

The eight-digit message to be displayed must be transferred to the monitor's display buffer with MOVE before MODIFY DATA is called. The values for the data entered indicator are the same for MODIFY DATA as for INPUT DATA. That is, R3 contains H'00' if R0 and R1 contains valid data and H'7F' if a function key was depressed before data was entered. The following example illustrates operation of MODIFY DATA. This is followed by an example of a MODIFY DATA subroutine call.

Data Entry and Register Contents on Return

From MODIFY DATA

Data Input Key	Display	Comments
	J O B = 0 1	Initial display on subroutine entry.
[2]	J O B = 2	Least-significant three digits are cleared and new data is displayed.
[R U N]		Data entry is terminated, and program control is returned to user program.

Register Contents on Return from MODIFY DATA

Register	Contents	Comments
R0	H'02'	Data entered is returned in R0.
R1	H'XX'	Data in R1 is meaningless.
R2	H'86'	Value of RUN key.
R3	H'00'	Indicates valid data in R0.

Example of MODIFY DATA Subroutine Call

Address	Data	Instruction Mnemonic	Comment
0034	05,00	LODI,R1 H'00'	Place message table poin-
0036	06,FF	LODI,R2 H'FF'	ter (-1) in R1 and R2.
0038	BB,FE	ZBSR *MOV	Call MOVE to transfer the message table to the dis- play buffer.
003A	04,01	LODI,R0 H'01'	Place input command in R0 (H'01' = 2 digits).
003C	BB,FC	ZBSR *GNPA	Call MODIFY DATA subroutine.
⋮			
0100	17		First byte of message table = "blank"
0101	18		= "J"
0102	15		= "O"
0103	0B		= "B"
0104	16		= "="
0105	17		= "blank"
0106	00		= "0" previously entered data value
0107	01		= "1" previously entered data value

Jumper Options

The INSTRUCTOR 50's versatility is enhanced by jumper options on the printed circuit board. These options allow you to modify the system's basic configuration. The jumpers are accessible through cut-outs at the bottom of the INSTRUCTOR 50's plastic housing. Figure 5.1 identifies the location of the various jumpers and their configuration. The factory supplied configurations are identified by asterisks (*) in the jumper pin description tables.

Jumper A - Interrupt Selection

As described previously, a switch at the bottom of the INSTRUCTOR 50 allows you to select interrupts from the interrupt key on the function keyboard or from the input line frequency clock. Jumper 'A' provides additional interrupt flexibility by allowing interrupt requests from external logic via the bus interface connector. If this option is exercised, interrupt requests from external logic will result in a vectored interrupt through memory address H'0007'. The setting of the DIRECT/INDIRECT switch on the front panel determines whether an externally generated interrupt request results in a direct or indirect subroutine branch. The pin descriptions for jumper 'A' are defined in the following table:

JUMPER A Pin Descriptions

Pins Connected	Description
1-2*	Normal operation. The 2650 recognizes interrupt requests from the interrupt key or the real-time clock, depending on the position of S6.
2-4	Bus interface. The 2650 recognizes interrupt requests from the interface signal VIO (pin 4). The interrupt latch is set on the rising edge of VIO.
2-39 3-4	Bus interface inverted. This configuration is identical to the 2-4 option except that the interrupt latch is set on the falling edge of VIO.

Jumper B - S100 Clock Select

The bus interface includes three pins for S100 interface clock requirements. The jumper 'B' option allows you to select between two clock signals generated by the INSTRUCTOR 50. The first clock is the same 895 KHz clock available to the 2650.

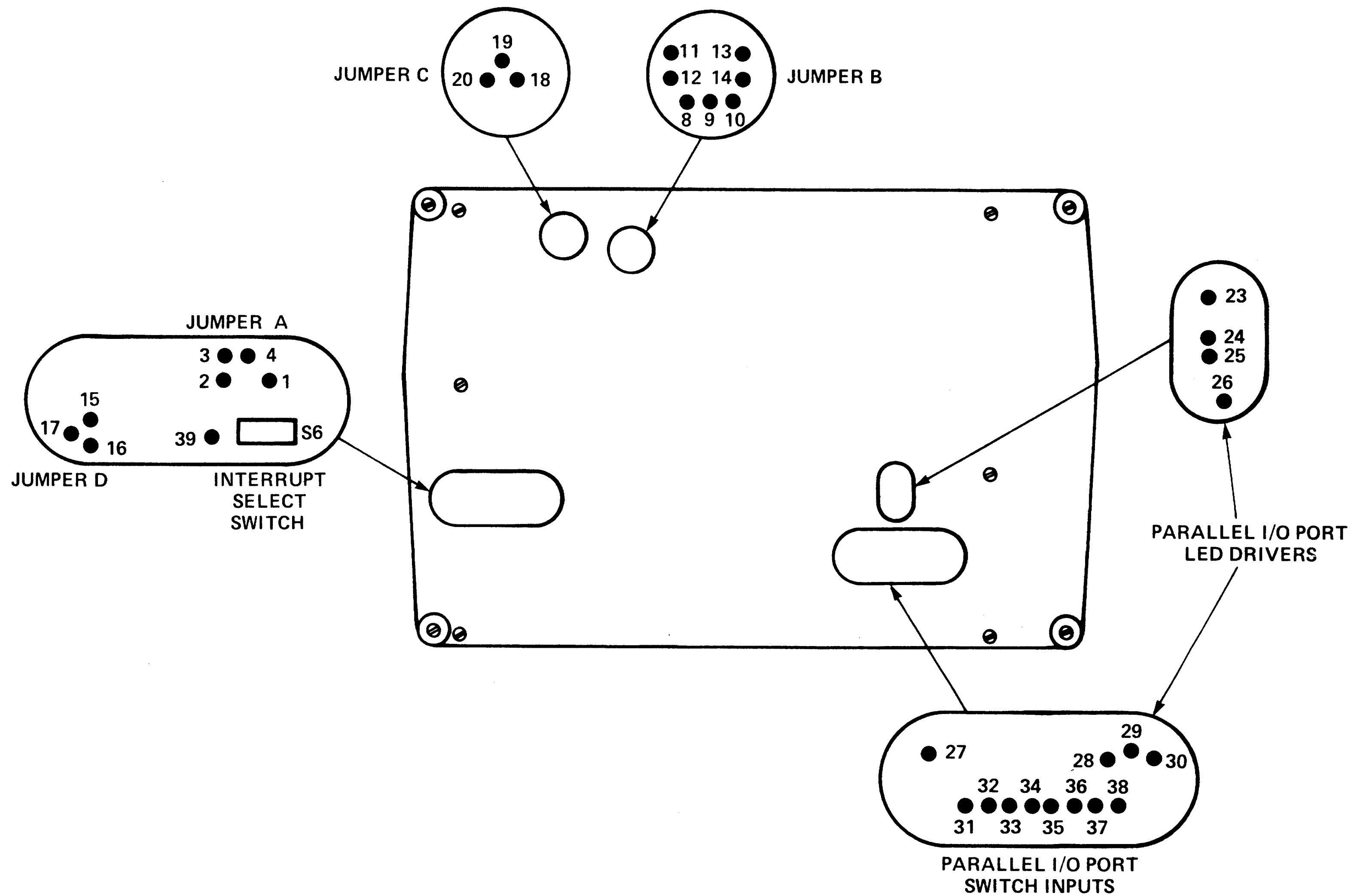


Figure 5.1: Jumper Locations

The second clock is the OPREQ signal generated by the 2650 gated by the forced jump logic enable (i.e., the OPREQ clock is inhibited whenever the forced jump logic has control of the 2650's address and data busses). The pin descriptions for jumper 'B' are defined in the following table:

JUMPER B Pin Definitions

Clock Source Pins

Pin Numbers	Description
11,12	These pins are driven by the INSTRUCTOR 50 895 KHz system clock.
13,14	These pins are driven by the conditioned OPREQ signal. The frequency is approximately 303 KHz. (NOTE: This clock is not a continuous frequency. Some 2650 instructions are executed without generating OPREQ).

S100 Clock Pins

Pin Numbers	Description
8	This pin is connected to the S100 bus signal Ø1, pin 25.
9	This pin is connected to the S100 bus signal Ø2, pin 24.
10	This pin is connected to the S100 bus signal CLOCK, pin 49.

Jumper C - Power Source Select

The INSTRUCTOR 50 is designed to operate with its own internal power supply used in conjunction with the wall transformer supplied with the system. Optionally, the input to the INSTRUCTOR 50's 5-volt regulator can be supplied from the interface bus connector. Jumper 'C' supports this option. The pin descriptions for jumper 'C' are defined in the following table:

JUMPER 'C' Pin Definitions

Pin Connected	Description
18-20*	Normal operation. The INSTRUCTOR 50 power requirements are supplied by the wall transformer.
18-19	The INSTRUCTOR 50 power requirements are supplied by an 8-volt unregulated D-C source applied via the bus interface connector.

Jumper D - Cassette Output Selection

The INSTRUCTOR 50's cassette interface provides two recording signal levels. Jumper 'D' selects between a 30mV rms record level and a 300mV rms record level. The pin descriptions for jumper 'D' are defined in the following table:

JUMPER 'D' Pin Definitions

Pins Connected	Description
15-17*	This option provides a 30mV rms record level to the cassette.
16-17	This option provides a 300mV rms record level to the cassette.

6. SYSTEM EXPANSION

Introduction

Microprocessors have had a tremendous impact on the hobbyist computer market. Beginning with Altair's 8800 home computer, the hobbyist market has literally exploded with new products. These new products include not only basic computers but a host of small support systems or peripheral boards. The first peripheral boards were simple memory expansion boards, but today there are a wide variety of peripherals available. There are television interfaces for computer graphics, floppy disc interfaces for mass storage, and even a board that synthesizes human speech.

The majority of these peripheral boards are designed to be compatible with the Altair 8800 bus. As more and more Altair 8800-compatible systems were introduced, this microcomputer bus was given an industry wide name, the S100 bus.

The INSTRUCTOR 50's S100 interface (an edge connector at the back of the unit) transforms a simple learning device into a small system computer limited only by the number and type of peripheral boards used. Moreover, the powerful program/data entry and debug facilities of the basic INSTRUCTOR 50 are extended to any device connected to the S100 bus interface.

Because the Altair 8800 home computer was based on the 8080, many of the S100 bus signals are essentially 8080 signals. Many of these signals, such as the two-phase clock and negative supply voltage, are not required by state-of-the-art microprocessors like the 2650. Hence, the INSTRUCTOR 50's S100 interface bus is not pin-for-pin compatible with Altair's original bus. However, the INSTRUCTOR 50's interface bus contains the most commonly used signals and can be easily connected to the majority of S100 peripherals. In addition to the common S100 bus signals, spare pins on the S100 pin bus have been assigned 2650 signals (e.g., OPREQ R/W and M/IO). Thus, custom interfaces can be designed with the 2650 control logic, instead of the more cumbersome 8080 interface logic. In short, the INSTRUCTOR 50's interface bus opens up the entire universe of home computer peripherals to owners of the INSTRUCTOR 50 training system.

The INSTRUCTOR 50 bus interface signals are described in Table 6.1.

TABLE 6.1

INSTRUCTOR 50 INTERFACE BUS SIGNALS

(* indicates a 2650 bus signal)

Pin #	Mnemonic	Signal Description
1	+8V	Positive 8 volts, unregulated. This line provides +8 volts to the INSTRUCTOR 50 when Jumper C selects the interface bus as the system power source.
2	+16V	Positive 16 volts. This line is reserved for +16 volts that may be required for a S100 peripheral board. +16V is neither required for or generated by the INSTRUCTOR 50.
3	XRDY	External Ready. XRDY is returned by an external device when it has completed a data transfer with the 2650. On board the INSTRUCTOR 50 XRDY becomes OPACK for the 2650.
4	VIO	Vectored Interrupt #0. VIO provides an external interrupt request when Jumper A is wired for external interrupts. VIO is latched and generates either an indirect or direct interrupt (selected by the DIRECT/INDIRECT switch) through address H'0007'.
5	not used	
6	not used	
7	not used	
8	not used	
9	not used	
10	not used	
11	not used	

12	R/W*	Read/Write. A 2650 control signal that indicates whether the processor is performing a read or write operation with an external peripheral board. As with all of the 2650 control signals, R/W is valid only when OPREQ is true. * NOTE: Indicates non-S100 2650 control signals.
13	WRP*	Write Pulse. A 2650 control signal that is generated during memory or I/O write sequences. WRP may be used to strobe data into the selected device.
14	M/IO*	Memory/Input-Output. A 2650 signal that indicates whether the address bus contains a memory or I/O address during a data transfer operation.
15	RESET*	Reset. When driven high, RESET performs the same operation as depressing the RST switch on the INSTRUCTOR 50 front panel. That is, the 2650 is reset and begins executing the user program at location H'0000'.
16	RUN/WAIT*	Run/Wait. A 2650 control signal that indicates whether the 2650 is in the wait state or is executing a program.
17	PAUSE*	Pause. This 2650 control signal input is provided for Direct Memory Access (DMA) operations. When driven high, this signal causes the 2650 to enter the WAIT state after completing the instruction currently being executed.
18	not used	
19	not used	
20	not used	
21	not used	
22	not used	
23	not used	
24	Ø1	Phase 1 Clock. Ø1 may be driven by the 895 KHz system clock or the 2650 OPREQ signal depending on the configuration of the Jumper B option.

25	Ø2	Phase 2 Clock. Ø2 may be driven by the system clock or OPREQ depending on the configuration of Jumper B.
26	not used	
27	not used	
28	not used	
29	A5	Address Bit 5
30	A4	Address Bit 4
31	A3	Address Bit 3
32	A15	Address Bit 15. Since the 2650 has an address range of 32K, this line is grounded.
33	A12	Address Bit 12
34	A9	Address Bit 9
35	DO1	Data Out Bit 1
36	DO0	Data Out Bit 0
37	A10	Address Bit 10
38	DO4	Data Out Bit 4
39	DO5	Data Out Bit 5
40	DO6	Data Out Bit 6
41	DI2	Data In Bit 2
42	DI3	Data In Bit 3
43	DI7	Data In Bit 7
44	not used	
45	SOUT	Output. SOUT indicates that the address bus contains the address of an output I/O device. The addressed device may accept the value on the data bus when PWR (pin 77) is active.
46	SINP	Input. SINP indicates that the address bus contains the address of an input I/O device. The selected device should return its data when PDBIN (pin 78) is active.

47	SMEMR	Memory Read. This signal indicates that the address bus contains the address of a memory location and that the 2650 is performing a memory read operation.	
48	not used		
49	CLOCK	System Clock. Depending on the configuration of Jumper B, this line is driven by the 895 KHz system clock or the 2650 OPREQ output.	
50	GND	System Ground.	
51	+8V	Positive 8 volts. This line provides +8V to the INSTRUCTOR 50 when Jumper C selects the interface bus as the system power source.	
52	-16V	Negative 16 volts. This line is reserved for -16 volts that may be required by a S100 peripheral board. Not supplied by INSTRUCTOR 50.	
53	not used		
54	not used		
55	DØ*	Data Bus Bit Ø -	In addition to the 2650 control signals, the INSTRUCTOR 50 Interface bus also includes a bidirectional data bus. The 2650 signals form a subset of the Interface Bus that can be used to interface the INSTRUCTOR 50 to breadboard peripherals with a minimum of interconnect wires.
56	D1*	Data Bus Bit 1 -	
57	D2*	Data Bus Bit 2 -	
58	D3*	Data Bus Bit 3 -	
59	D4*	Data Bus Bit 4 -	
60	not used		
61	D5*	Data Bus Bit 5 -	
62	D6*	Data Bus Bit 6 -	
63	D7*	Data Bus Bit 7 -	
64	UOPREQ*	User Operation Request - OPREQ is a 2650 control signal that indicates that the processor's address bus, data bus, and other control signals are valid. OPREQ may be used to latch the data bus for write operations and enable input device bus drivers for read operations.	

65	INTACK*	INTERRUPT ACKNOWLEDGE. The 2650 returns INTACK to an interrupting device in response to an INTERRUPT REQUEST. Upon receipt of INTACK, the interrupting device drives the data bus with a relative branch address and asserts either XRDY or PRDY (these signals become the 2650 status signal OPACK).
66	FLAG*	FLAG. This line contains the 2650 single bit output port.
67	USENSE*	USER SENSE. USENSE is the 2650 single bit input port. FLAG and SENSE are part of the PROGRAM STATUS WORD.
68	MWRITE	MEMORY WRITE. MWRITE indicates that data is to be written into the memory location addressed by the current value of the ADDRESS BUS.
69	not used	
70	not used	
71	not used	
72	PRDY	PROCESSOR READY. PRDY is logically OR'd with XRDY to form the 2650 status signal OPACK. PRDY is returned by an addressed device (either memory or I/O) or an interrupting device when the requested data transfer has been completed.
73	PINT	PROCESSOR INTERRUPT. PINT is an S100 signal that corresponds to the 2650 INTERRUPT REQUEST signal. The 2650 acknowledges PINT when it completes the instruction it was executing when PINT was driven low. The 2650 does not recognize PINT if it is in the WAIT state or if the INTERRUPT INHIBIT bit of the PSW is reset. PINT can be used to release the 2650 from the HALT state.
74	not used	
75	not used	
76	not used	
77	PWR	PROCESSOR WRITE. PWR indicates that the data bus is valid and may be accepted by the addressed memory location or output device.
78	PDBIN	PROCESSOR DATA BUS IN. PDBIN indicates that the 2650 is reading data from the addressed memory location or input device. PDBIN may be used to enable the selected device's data bus drivers.

79	AØ	Address Bit Ø
80	A1	Address Bit 1
81	A2	Address Bit 2
82	A6	Address Bit 6
83	A7	Address Bit 7
84	A8	Address Bit 8
85	A13	Address Bit 13
86	A14	Address Bit 14
87	A11	Address Bit 11
88	D02	Data Out Bit 2
89	D03	Data Out Bit 3
90	D07	Data Out Bit 7
91	D14	Data In Bit 4
92	D15	Data In Bit 5
93	D16	Data In Bit 6
94	D11	Data In Bit 1
95	D10	Data In Bit Ø
96	not used	
97	not used	
98	not used	
99	POR	POWER ON RESET. POR is an output signal that indicates that power has been applied to the INSTRUCTOR 50 and the system is being reset. POR may be used to reset peripheral boards on the Interface Bus
100	GND	GROUND. System Ground.

7. THEORY OF OPERATION

Introduction

The INSTRUCTOR 50 is typical of modern microcomputers, reflecting many of the recent advances in microprocessor technology. For example, the current trend in microcomputer design is to replace logic functions implemented with SSI and MSI circuits with complex LSI microprocessor support circuits. This trend is exemplified in the INSTRUCTOR 50 which makes use of the 2650 microprocessor and the 2656 System Memory Interface. These two chips alone constitute a basic microcomputer. Beyond this two-chip microcomputer, the remainder of the circuits on the INSTRUCTOR 50 Printed Circuit Board are devoted to providing the microcomputer with man-machine and machine-machine interfaces.

This section describes the hardware and software associated with the INSTRUCTOR 50 system. The intent is not to give a detailed exposition for maintenance purposes. The INSTRUCTOR 50 comes fully assembled and debugged ready to be plugged in and used and requires little or no maintenance. Rather, the intent is to introduce you to the basic fundamentals of modern microcomputer design.

Basic Concept

The functional heart of computers in general and microcomputers in particular is the system program. The program is a logical sequence of machine instructions that monitor system status, and, based on that status, decides what control actions to take. A computer's Central Processing Unit (CPU) is a device that reads instructions from program storage and, by executing the instructions, performs all of the arithmetic and logical operations required by the system program. The CPU also provides the system program with the physical means to access and control the system's I/O functions. The INSTRUCTOR 50's CPU is the 2650 microprocessor.

The 2650 fetches instructions from program storage and communicates with the system I/O circuits via its address bus, control bus, and data bus. As the 2650 executes each instruction, the address and control bus values specify the device to be communicated with (memory location, I/O device, etc.), and the data bus serves as an information conduit between the processor and the selected device. This information transfer scheme defines the system's basic architecture illustrated in Figure 7.1. Considerable savings in parts count was realized by decoding the I/O device addresses within the 2656 SMI.

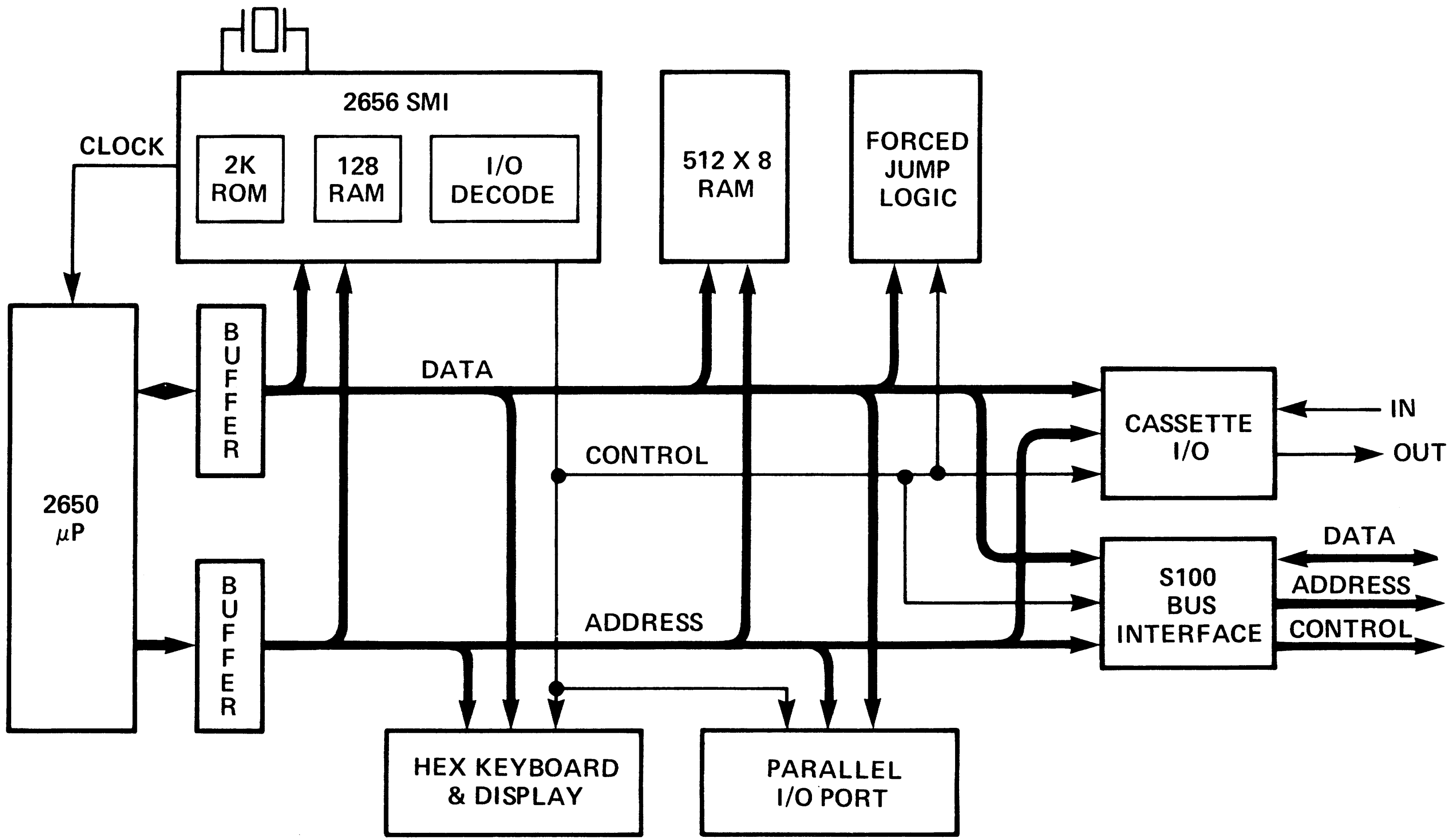


Figure 7.1: Basic Instructor 50 Architecture

Thus, when the 2650 executes an instruction that references an I/O device (e.g., the parallel I/O port), that device's address is asserted on the address bus, and the Programmable Gate Array within the SMI decodes the address and generates the I/O device's enable signal. Thus enabled, the selected I/O device either accepts data from or returns data to the 2650 over the data bus. As the 2650 executes each instruction, it selects the device specified by the instruction (program storage, user RAM, an I/O device, etc.) with the address bus and communicates with the selected device via the data bus.

Detailed Block Diagram Description

A detailed block diagram of the INSTRUCTOR 50 is presented in Figure 7.2. This section gives a description of each of the major functional blocks illustrated in Figure 7.2

The Microcomputer

As mentioned previously, the basic microcomputer consists of the 2650 microprocessor and the 2656 SMI. The 2650 provides the following functions:

8-bit ALU	The Arithmetic Logic Unit performs all of the arithmetic and logical operations required for program execution.
Program Counter	The program counter is used to generate program storage addresses.
Interrupt Logic	The interrupt logic performs all functions required to respond to an interrupt request from an external device.
Internal Registers	The 2650's seven internal registers provide temporary data storage and serve as a link between the ALU and external data storage, such as RAM locations and I/O devices.
Bus Interface Logic	The bus interface logic distinguishes between memory and I/O device addresses and specifies the direction of data transfers between the processor and external data storage.

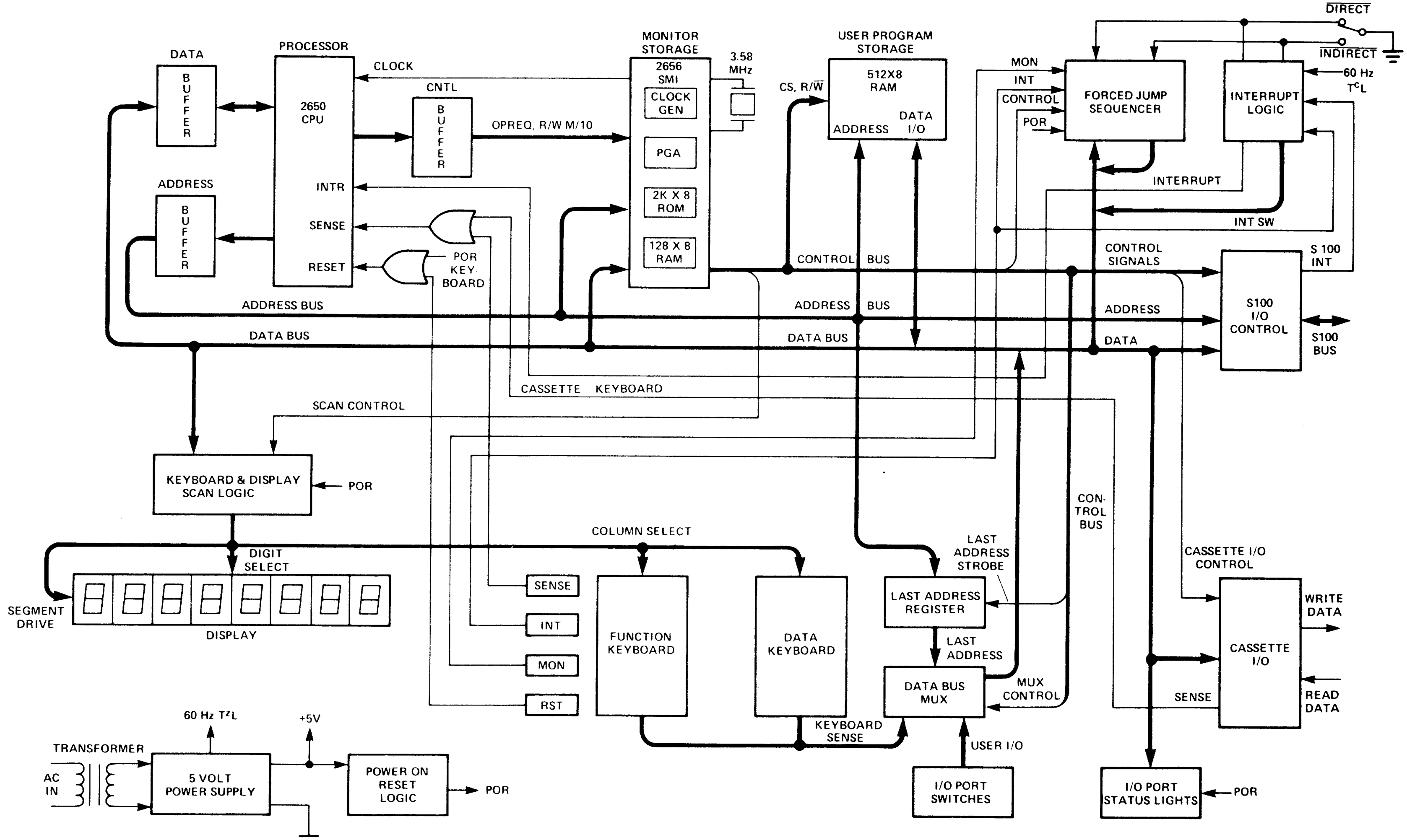


Figure 7.2: Instructor 50 Detailed Block Diagram

The 2650 microprocessor is surrounded with bus drivers (buffers). Because the 2650 is fabricated using an MOS process, its output pins can drive only one TTL load. The bus drivers buffer the 2650 outputs and are able to drive all of the loads on the INSTRUCTOR 50's busses.

The buffered 2650 data, address and control busses are connected directly to the 2650 SMI. The SMI contains the 2K monitor program, 128 bytes of scratch-pad RAM, a system clock generator, and an eight-bit I/O port. The eight-bit I/O port is controlled by a mask Programmable Gate Array (PGA). As configured for the INSTRUCTOR 50, the PGA decodes the address bus and provides eight I/O chip enables for the user RAM and I/O devices. Table 7.1 lists the functions of these outputs.

All of the monitor program's scratch-pad memory requirements are met by the SMI's 128 byte RAM. In fact, the monitor only requires 64 bytes, thus leaving the remaining 64 bytes for user storage. It should be noted, however, that while the INSTRUCTOR 50 enables the user to access these 64 bytes of the SMI's RAM with the DISPLAY AND ALTER MEMORY command and the FAST PATCH command, the SINGLE STEP and BREAKPOINT commands are not supported within this memory space. Hence, these 64 bytes should be used for data storage only. That is, user programs should be stored in user RAM or on an S100 memory expansion board.

INSTRUCTOR 50 Memory Allocation

Figure 7.3 is a memory map of the INSTRUCTOR 50's addressable memory space. The memory map is divided into four 8K pages reflecting the addressing architecture of the 2650. The first page, page zero, contains the user RAM and the SMI ROM and RAM. The second, third, and fourth pages are available for user memory expansion or memory mapped I/O.

The user RAM is formed by four 256 x 4 RAMs (Signetics 2112's) that are enabled by the SMI chip-enable lines mentioned previously. Section 6 describes how S100 memory boards can be added to the INSTRUCTOR 50.

TABLE 7.1

CONTROL SIGNALS GENERATED BY THE SMI

Signal	Function
RAM0CE	RAM 0 chip enable: this signal enables the lower 256 bytes of user RAM.
RAM1CE	RAM 1 chip enable: this signal enables the upper 256 bytes of user RAM.
PORTFX	PORTFX goes low whenever the 2650 executes an extended I/O instruction with an address between H'F8' and H'FF' inclusive. This signal enables the INSTRUCTOR 50's I/O device addresses to be decoded with just three address bits.
USRPORT	USRPORT goes low whenever the 2650 accesses the parallel I/O port with an extended I/O instruction (address H'07').
USRMEM	This signal goes low when the 2650 executes a memory reference instruction that specifies address H'0FFF' USRMEM enables the parallel I/O port when the port address select switch is in the MEMORY position.
DI/O	DI/O goes low when the 2650 executes a non-extended I/O instruction that specifies port D. If the port address select switch is in the NON-EXTENDED position, DI/O enables the parallel I/O port.
CI/O	CI/O goes low when the 2650 executes a WRTC instruction. This signal is used by the forced jump logic for breakpoint detection.
MON	MON goes low whenever the 2650 fetches an instruction or data value within the monitor's address space (H'17C0' and H'1FFF').

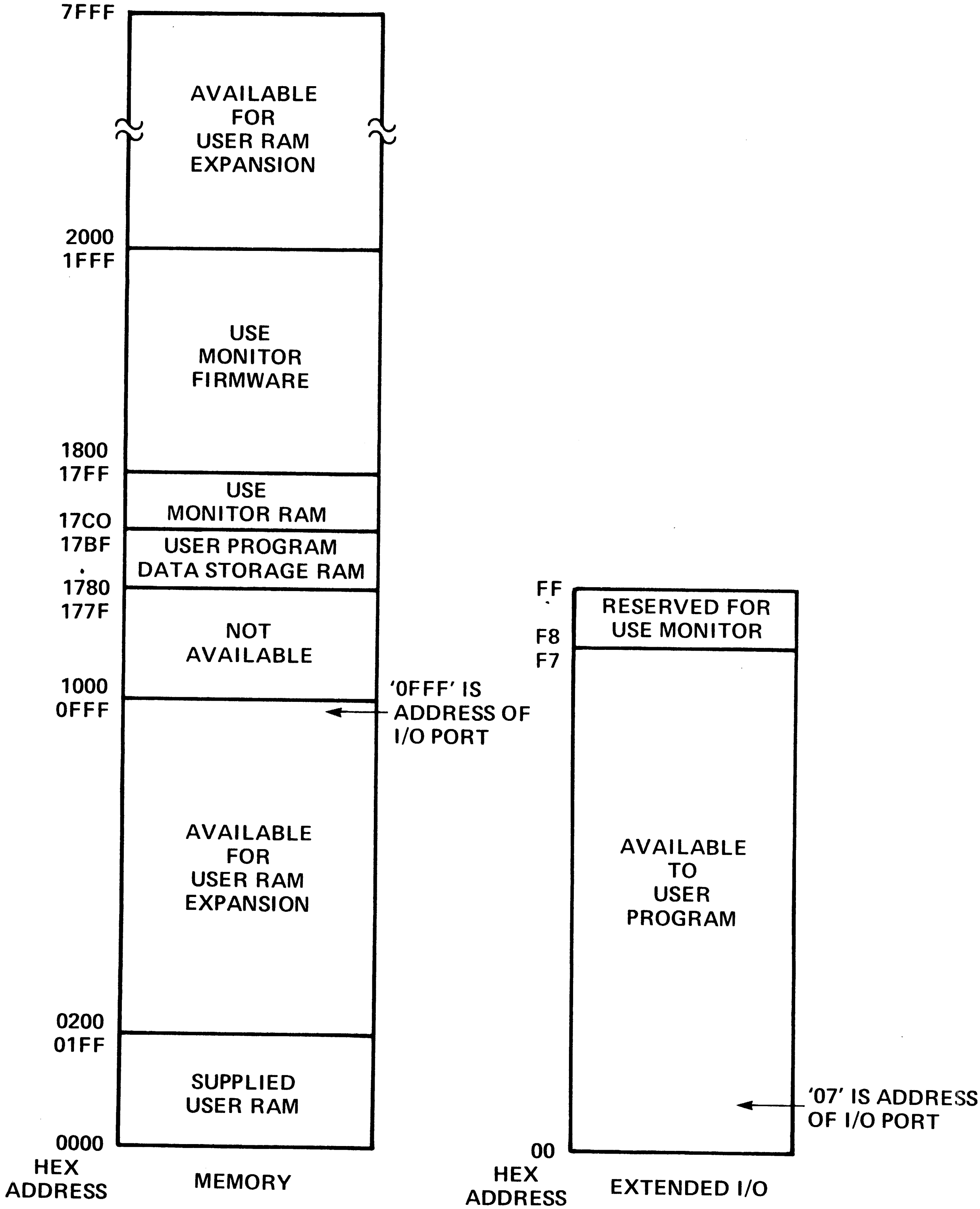


Figure 7.3: INSTRUCTOR 50 Memory Map

Parallel I/O Port

The parallel I/O port consists of an output latch, input switches, and port address decode logic. The port address decode logic generates a port enable whenever one of the three following conditions are met.

1) The 2650 executes a WRTD or REDD instruction.

2) The 2650 executes either a WRTE or REDE instruction that specifies H'07' as an extended I/O address.

3) The 2650 executes a memory reference instruction that specifies location H'0FFF'.

The Port Address switch selects one of these signals as the parallel I/O port enable.

Whenever the I/O port is enabled and the R/W control line specifies a write operation, the value on the data bus is strobed into the I/O port output latch. This latch drives the I/O port indicator LEDs.

The I/O port switches are one of four inputs to a data bus multiplexer. Whenever the I/O port is enabled and the R/W line indicates a read operation, the I/O switch levels are asserted on the data bus via the data bus multiplexer.

Keyboard and Display Logic

The INSTRUCTOR 50's primary man-machine interface consists of an output device, the eight-digit display, and two input devices — the function and data entry keyboards. Together they provide an inexpensive human interface to the microcomputer.

The display digits consist of seven discrete LEDs arranged in a rectangular array or bars and an eighth LED that serves as a decimal point. There are several methods of driving a seven-segment display with a microprocessor. The most straightforward approach is to provide a separate output port latch to drive each individual display. With this approach, the microprocessor simply writes a byte to each output port, corresponding to the segments required to form the desired character. While the direct drive approach is the simplest to conceptualize, it also requires the most hardware to implement. However, the basic rule of thumb in microcomputer design is to eliminate as much system hardware as possible with program logic. Toward this end, an alternate display drive method that requires only two output ports is used in the INSTRUCTOR 50.

The first output port is a latch that drives the segment select lines connected in parallel to each of the eight digits. The second output port, an eight-bit latch, enables only one digit at a time. With this structure, the segment select lines can be time shared among the eight digits. The 2650 first enables a digit with the digit select output port and then writes that digit's character segments in the segment select output port. The process is repeated for each digit in a sequential fashion. If each digit is illuminated at a sufficiently fast frequency, about 100 Hz, the entire eight-digit display appears flicker free. Thus, considerable savings in display drive hardware is realized by substituting program complexity for output ports.

Because of the display's high-current requirements, the two output port latches require current buffering. A darlington transistor array on the output of each latch supplies the required current.

There are several methods of interfacing a microcomputer to an input keyboard. Here again the primary objective is to minimize the system hardware by placing as much of the control logic in the program as possible. The keyboard scan approach used by the INSTRUCTOR 50 arranges the two keyboards in a matrix. Since each function and data key is actually a two-terminal switch, a matrix can be formed by grouping the terminals of each switch into columns and rows. This organization is illustrated in Figure 7.4.

Referring to Figure 7.4, the column select signals, COL 1-COL 6, are driven by an output port, and the two sense signals, KR0-KR3, serve as the inputs to an input port. Given this structure, the 2650 can scan the keyboards to detect a switch closure as follows:

1) The processor writes a byte to the column select output port that drives one of the column select lines low.

2) The processor reads the row sense input port. If any of the keys in the selected column are depressed, a low is sensed on the corresponding row sense line.

3) The process is repeated for each column.

The keyboard interface column select operation is identical to that of the display digit select. Hence, a single output port serves both interfaces. The row sense input port is another input to the data bus multiplexer. When the 2650 executes an REDE instruction that specifies the row sense input port, the row sense signals are returned to the processor on the data bus via the multiplexer.

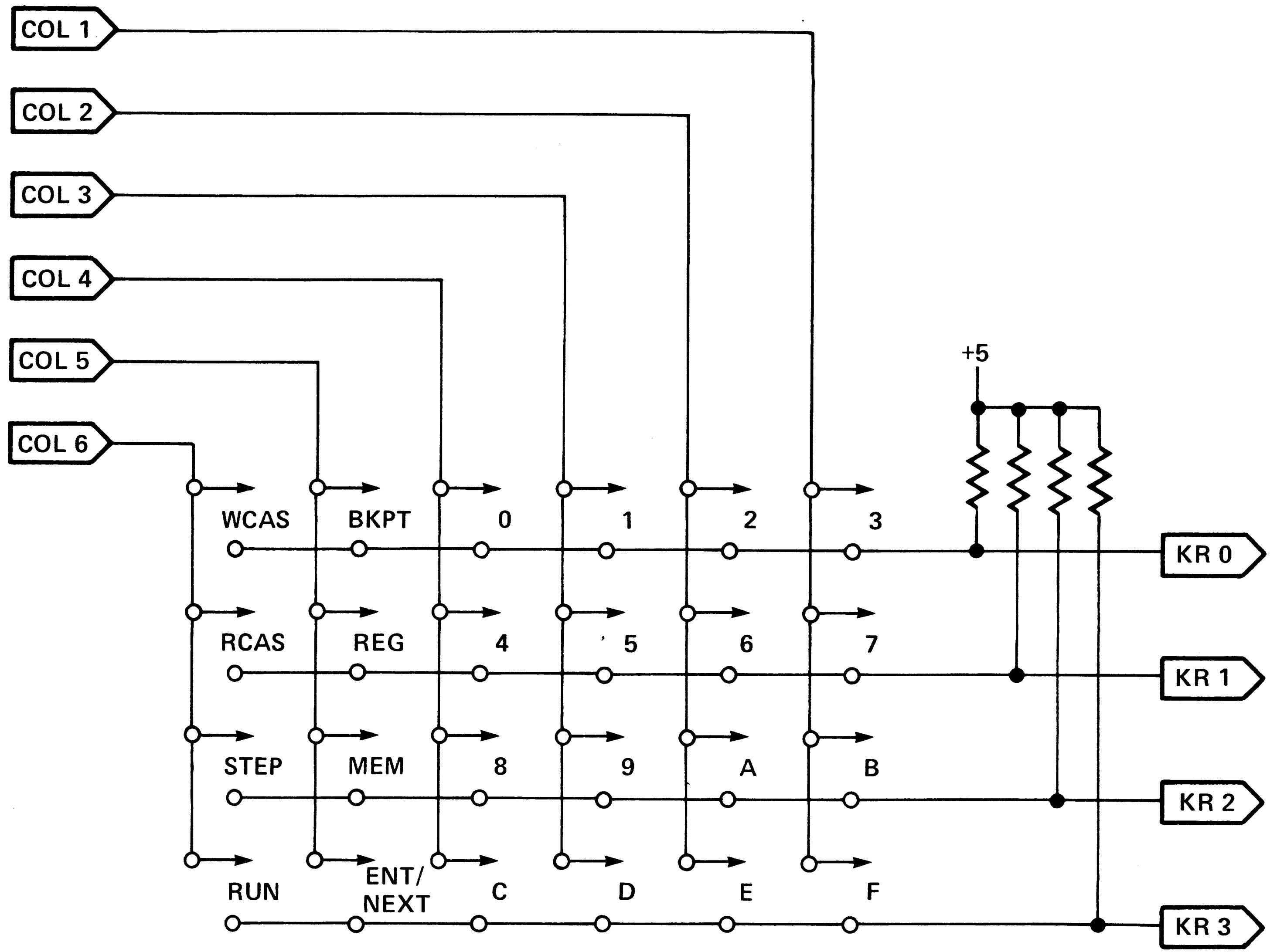


Figure 7.4: Keyboard Layout

Referring again to Figure 7.4, you will notice that four of the function keys, SENS, INT, MON, and RST, are not included in the switch matrix. The reason for their absence is that the functions they perform are independent of the monitor program. Since RST resets the 2650, this switch is connected to the 2650's RESET pin (after being OR'ed with the power on reset signal). Likewise, the SENS key is connected to the 2650 SENSE input pin. (Actually the 2650 SENSE pin is used for both the SENS key and the audio cassette interface. The signal presented to the 2650 depends on whether or not the 2650 is reading data from cassette). The INT key is connected directly to the INSTRUCTOR 50 interrupt logic, and the MON key is connected to the forced jump logic. The operation of these two keys is described under forced jump logic.

The Cassette Interface

The cassette interface is unique among the INSTRUCTOR 50's I/O devices in that it communicates with an analog system, a cassette tape recorder. In converts microprocessor-generated logic signals into an audio waveform for recording data, and converts the audio waveform returned from the recorder into a digital pulse stream that can be decoded by the processor when data is being read from the cassette.

The INSTRUCTOR 50 uses a two-bit output port for recording data onto cassette tape and a single-bit input port for reading the data back. Figure 7.5 illustrates the record waveforms required by this technique. The two signals, FREQ and ENV, are provided by a two-bit output port. These signals are combined with an open-collector NAND gate to form the write signal for the cassette. As shown in Figure 7.5, six pulses are used to record a 'zero' on the cassette, and three pulses to record a 'one'. The only exception to this recording format is the last bit of a byte. Six additional pulses are recorded for the last bit of a byte to mark byte boundaries (i.e., a one is nine pulses and a zero is twelve pulses).

Since only a single bit input port is required to read data back from cassette, the 2650's SENSE pin is used for this purpose. However, before the audio input is presented to the SENSE pin, it is digitized by a Schmidt trigger. The Schmidt trigger has about 1.5 volts of hysteresis that provides the read logic with necessary noise immunity.

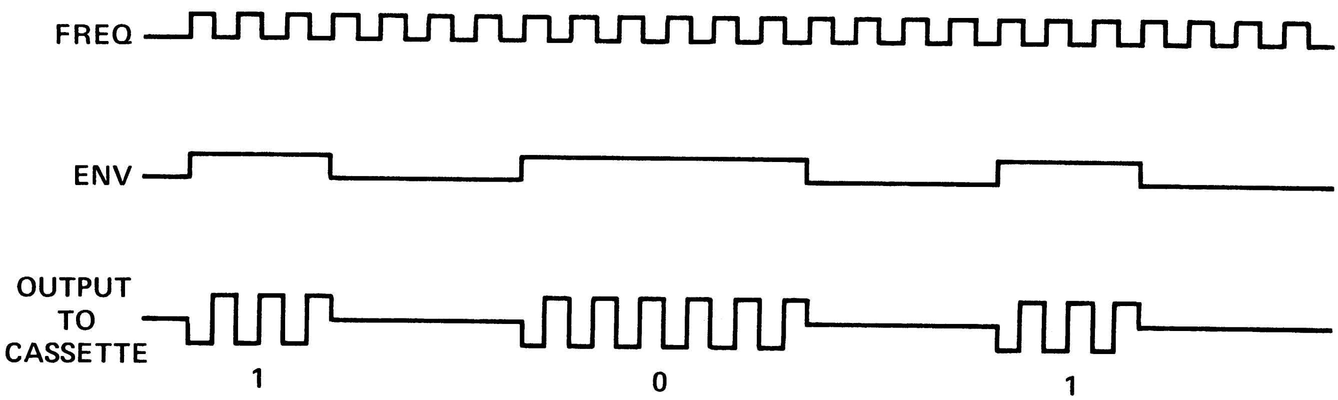


FIGURE 7.5: CASSETTE RECORD WAVEFORMS

Interrupt Logic

The INSTRUCTOR 50 can respond to interrupt requests from three possible sources: the INT key, the real-time clock derived from the power supply line frequency, or the S100 bus interface. As mentioned previously, interrupt source is determined by a switch located at the bottom of the INSTRUCTOR 50 case. This switch selects between the INT key and the real-time clock. A jumper option enables interrupt requests from the S100 bus interface.

The selected interrupt request source is input to a flip-flop that is set when an interrrupt request is received. The output of the flip-flop is connected to the INTREQ pin on the 2650. The 2650 responds to an interrupt request by asserting INTACK. INTACK, in turn, enables a tri-state drive that places the interrupt vector H'07' or H'87', depending on the position of the DIRECT/INDIRECT switch on the data bus. INTACK also resets the interrupt request flip-flop.

Forced Jump Logic

The INSTRUCTOR 50's Breakpoint and Single Step commands are implemented with a combination of firmware and hardware control. This hardware portion is called the forced jump logic. The forced jump logic returns program control to the monitor whenever a breakpoint is detected, after a single user instruction has been executed in the step mode, when the MON key is depressed, and when power is initially applied to the INSTRUCTOR 50.

The forced jump logic consists of the following logical elements:

1) The Return to Monitor Sequencer - This sequencer is responsible for returning program control to the monitor when the 2650 is executing a user program. The sequencer consists of a programmable counter and a 32 x 8 PROM. The PROM contains the data values of an absolute branch instruction. When the sequencer is active, the forced jump logic disables the INSTRUCTOR 50's normal instruction fetch mechanism and returns the absolute branch instruction stored in the PROM. The 2650 initializes the sequencer by loading the counter via an extended output port.

2) The Last Address Register - The Last Address Register (LAR) saves the last address issued by a user program before program control is returned to the monitor. This address points to the next instruction that the user program would execute if the return to monitor had not been activated. The monitor program reads the LAR to determine where the user program should resume execution after a STEP command has been completed or when a breakpoint is encountered.

3) Control Logic - The control logic performs general housekeeping functions such as loading the LAR, integrating interrupt requests with the return to monitor state sequencer, and loading the programmable counter.

The forced jump logic is enabled when power is first applied to the INSTRUCTOR 50, when the MON key is depressed, when a breakpoint is detected, and when the monitor program executes the STEP command. The resulting action taken by the forced jump logic when one of these events occurs is described below.

Power On (POR) or MON Key Depression

When power is applied to the INSTRUCTOR 50 or when the MON key is depressed, the 2650 is reset. The 2650 responds to a reset by clearing its internal program counter and fetching the instruction located at byte zero, page zero. However, when the 2650 places address H'0000' on the address bus, the forced jump logic disables the normal memory access mechanism and returns a NOP instruction value to the 2650 via the data bus. The 2650 executes the NOP and attempts to fetch an instruction at the next sequential address H'0001'. This instruction fetch generates an operation request (OPREQ). OPREQ is used to increment the sequencer counter. In this state, the return to monitor sequencer places the first byte of an unconditional branch instruction on the data bus. When the 2650 receives the BCTA, UN op-code, it generates two more OPREQs to fetch the branch address. Each OPREQ increments the counter and the PROM places the beginning address of the monitor, H'1800', on the data bus. At this point the 2650 executes the branch to monitor, and the forced jump logic returns to the idle state.

Breakpoint Detection

If the user has specified a breakpoint, the monitor program inserts a WRTC instruction at the breakpoint address specified. When the 2650 executes the WRTC instruction, a control signal is generated that produces the same results as the POR signal, and program control is returned to the monitor. A monitor software flag distinguishes this entry from a POR or MON key entry and causes a branch to the breakpoint routine.

Single Step

The execution of a single 2650 instruction in response to the STEP key is an excellent example of combined firmware/hardware control. When the STEP key is depressed, the monitor program fetches the instruction pointed to by the Program Counter and calculates the number of OPREQs required to execute the instruction. The OPREQ counter (an extended I/O port) is then loaded with a value that corresponds to the number of OPREQs. The monitor then restores the user's program registers and status and branches to the instruction to be stepped. When the 2650 executes the instruction, the OPREQ counter, beginning at the present count, addresses "dummy states" of the return to monitor sequencer. That is, the locations addressed are not output on the data bus. When the last OPREQ of the instruction occurs, the output of the return to monitor PROM is enabled, and subsequent OPREQs return the unconditional branch to monitor instruction bytes to the processor.

If an interrupt request should occur during execution of the STEP instruction, the 2650 waits until the instruction has been completed before asserting INTACK. Conditioned by the forced jump control logic, INTACK becomes an address bit for the return to monitor PROM. While INTACK is high, another address bit reflects the position of the DIRECT/INDIRECT switch. In concert, these two address bits force the sequencer into one of two interrupt handling sequences: one for direct interrupts and another for indirect interrupts.

S100 Bus Interface

The S100 bus interface consists of tri-state drivers and receivers and a Field Programmable Gate Array (FPGA) which produces the S100 bus signals from logical combinations of 2650 control signals. Unfortunately, the S100 bus is far from standardized. Many of the signals are repetitious and different peripheral manufacturers make different demands of the bus. The FPGA enables you to modify the bus interface to meet any specific needs you may encounter. A detailed description of the S100 bus interface is given in Section 6.

System Power

The INSTRUCTOR 50 obtains its system power from one of two possible sources. The first source is an A-C wall transformer supplied with the INSTRUCTOR 50. The transformer provides the INSTRUCTOR 50 with 8 VAC (rms). On board, the A-C input is rectified, and the resulting D-C voltage is applied to a three-terminal regulator. The regulator supplies 5 VDC at 1.5 amps - the system power requirements of the INSTRUCTOR 50. The user may optionally change a wire jumper at the bottom of the printed circuit board to select unregulated 8 VDC from the S100 bus interface as input to the regulator.

In addition to the rectifier, the A-C input to the system is also applied to the resistive divider network. The reduced A-C voltage is input to a comparator that outputs a 60 Hz real-time clock (50 Hz in Europe and Japan). This real-time clock is available to the interrupt request logic via a select switch at the bottom of the printed circuit board. The wall transformer can be used to drive the real-time clock even if system power is derived from the S100 bus interface.

The USE Monitor

Without question, the most important component of any microcomputer (or any computer for that matter) is the system program. Every function or operation performed by a microcomputer is accomplished by executing a sequence of instructions within the system program.

Basically, the USE monitor is a collection of separate routines — one routine for each system command. A brief functional description of several routines with illustrative examples is provided in Section 4. This section provides a brief description of the command executive - a section of the monitor program that links the various command routines into a cohesive system program.

Figure 7.6 is a flowchart of the command routine executive section of USE. Whenever the forced jump logic returns program control to the monitor, monitor execution begins at H'1800', the first address of the executive. Beginning at this address, the first operation is to save the 2650 registers and Program Status Word. (These values are restored before program control is transferred to the user program). The next operation is to check certain software flags to determine how the forced jump logic was enabled. If it was tirggered by a breakpoint (WRTC instruction), program control is returned to the breakpoint routine. Similarly, if the forced jump logic was activated by the completion of a single-step sequence, program control is returned to the single-step routine. The alternatives to these two entry modes are power on and MON key depression. If the executive was entered via either of these two modes, the executive clears the breakpoint and step flags, since they may be on even if entry to the monitor was via power-on. Next, the display buffer pointer is set to the "HELLO" message table, and the DISPLAY subroutine is called. The monitor remains in this routine until a function key is depressed.

Upon returning from the DISPLAY subroutine, R0 contains the function key value. This value is used as an index to fetch a command routine address from the command address table. The address thus accessed is used for an absolute branch to one of the command routines. The executive is re-entered from any command routine when a function key is depressed. Hence, a new

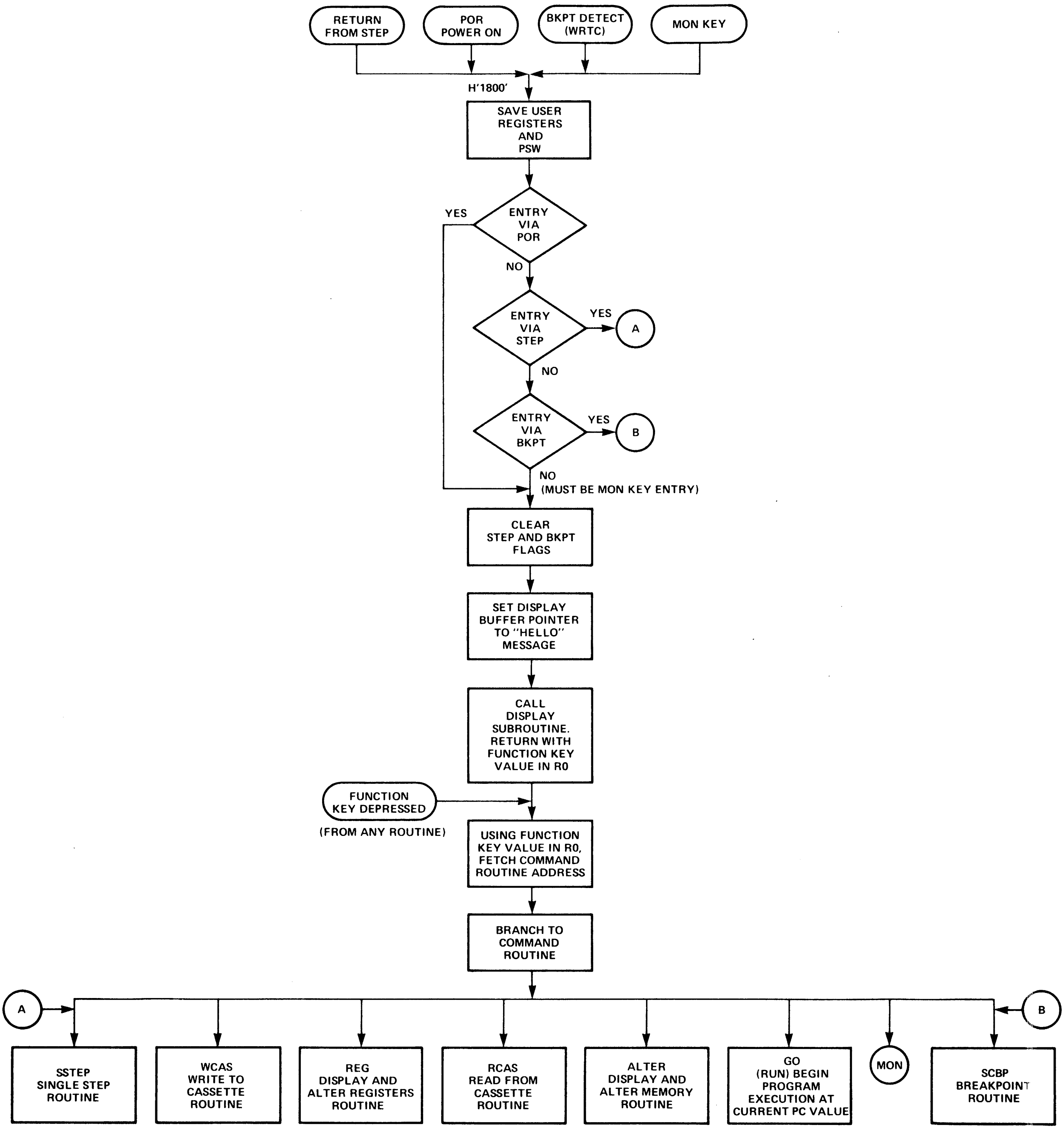


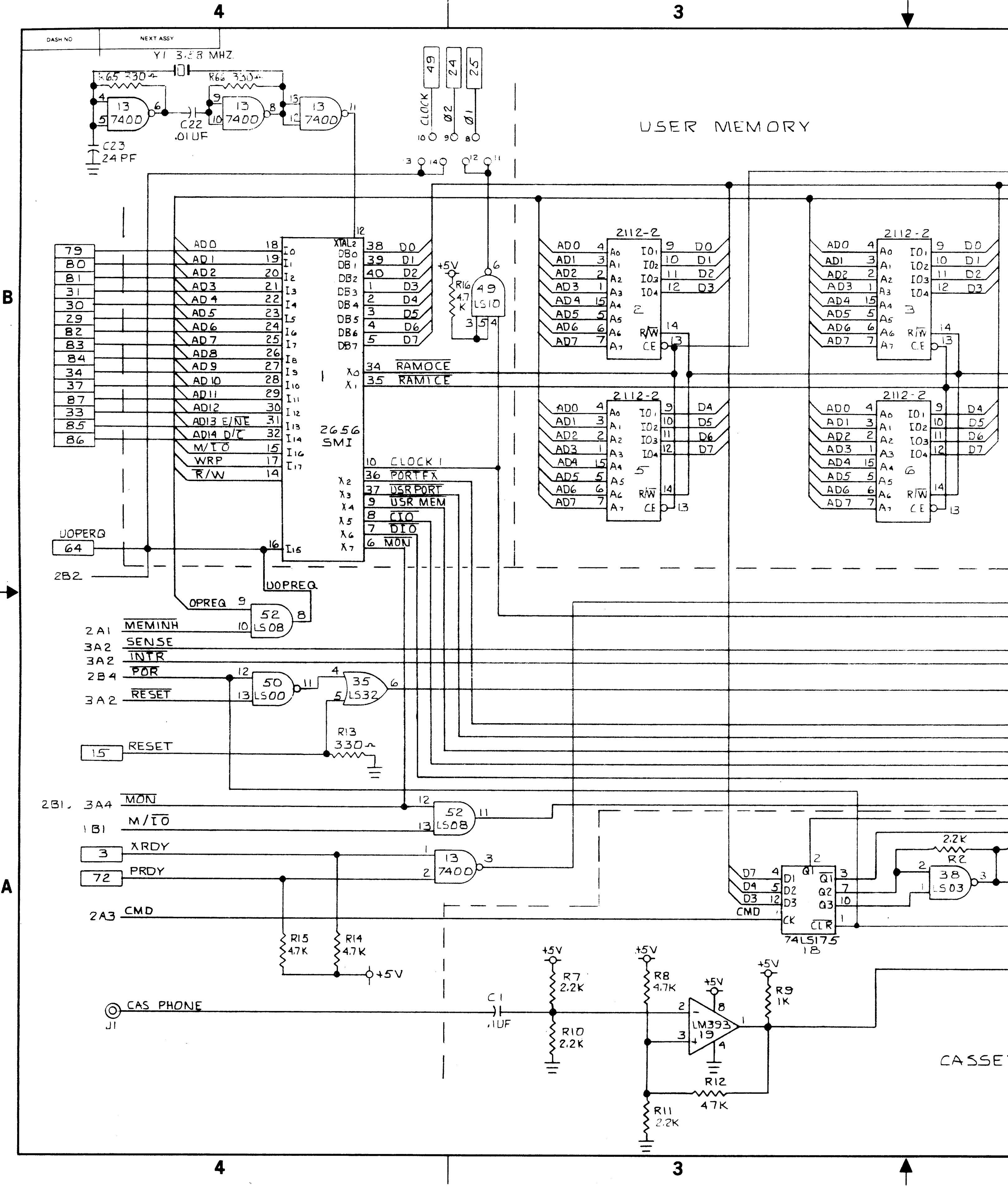
Figure 7.6: USE Command And Routine Executive

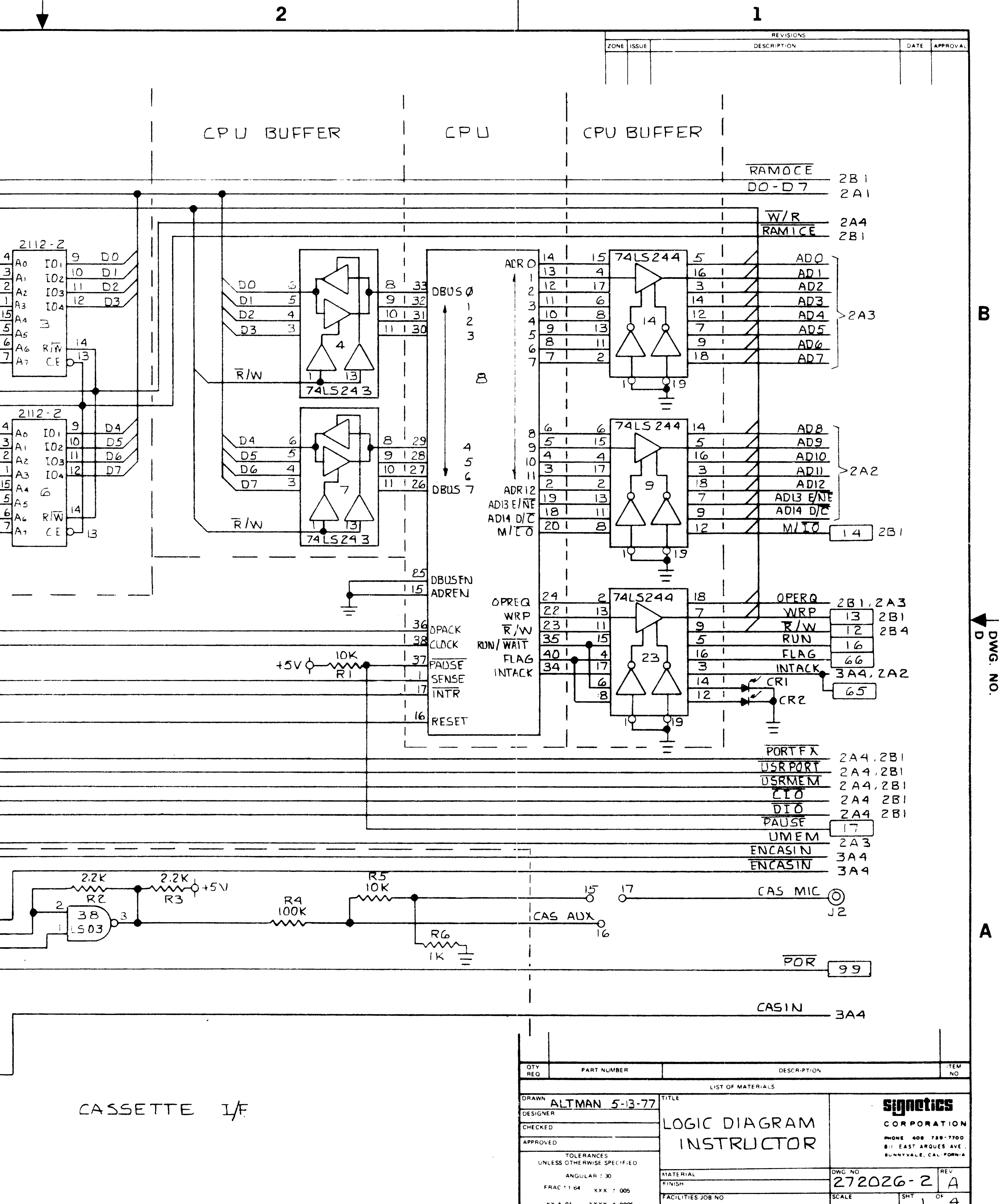
command address is accessed, and the monitor again branches to the specified command routine. Refer to the USE Program Listing in the appendices for detailed information on the USE routines.

APPENDIX A — THE 2650 MICROPROCESSOR

NOTE: Refer to the Signetics 2650 Microprocessor Manual accompanying this document.

APPENDIX B — INSTRUCTOR 50 SYSTEM SCHEMATICS


DASH NO
NEXT ASSY
USER MEMORY
Y1 3.58 MHZ
R65 330Ω
R66 330Ω
7400
C22 .01UF
C23 24PF
CLOCK
Ø2
Ø1
2656 SMI
XTAL2
RAMOCE
RAMICE
CLOCK 1
PORTFX
USR PORT
USR MEM
CIO
DIO
MON
2112-2
UOPERQ
2B2
UOPREQ
OPREQ
LS08
MEMINH
SENSE
INTR
POR
RESET
LS00
LS32
R13 330Ω
R16 4.7K
LS10
+5V
MON
M/IO
XRDY
PRDY
CMD
R15 4.7K
R14 4.7K
CAS PHONE
J1
C1 .1UF
R7 2.2K
R10 2.2K
R8 4.7K
LM393
R9 1K
R12 47K
R11 2.2K
74LS175
R2 2.2K
LS03
CASSE

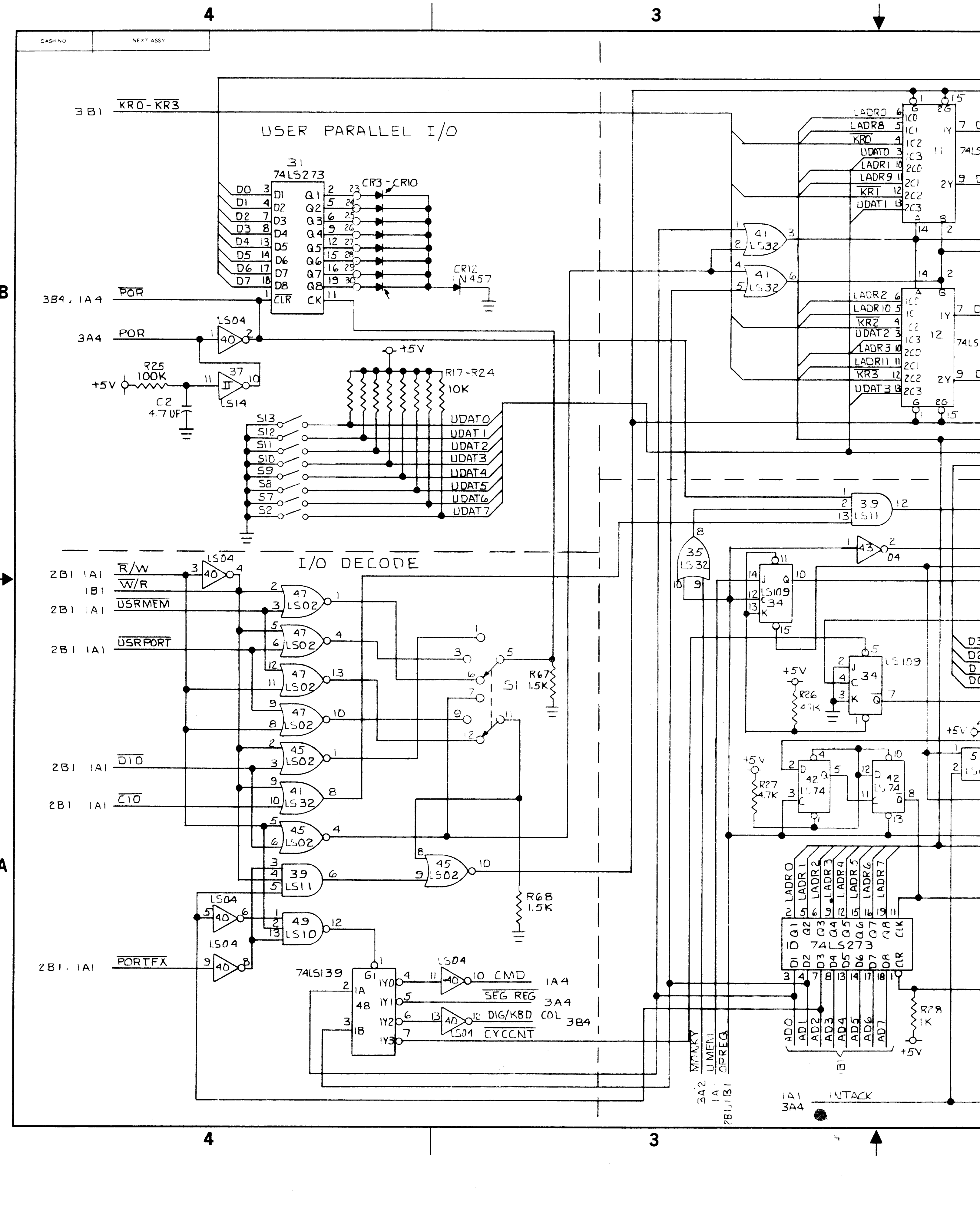


QTY REQ	PART NUMBER	DESCRIPTION	ITEM NO

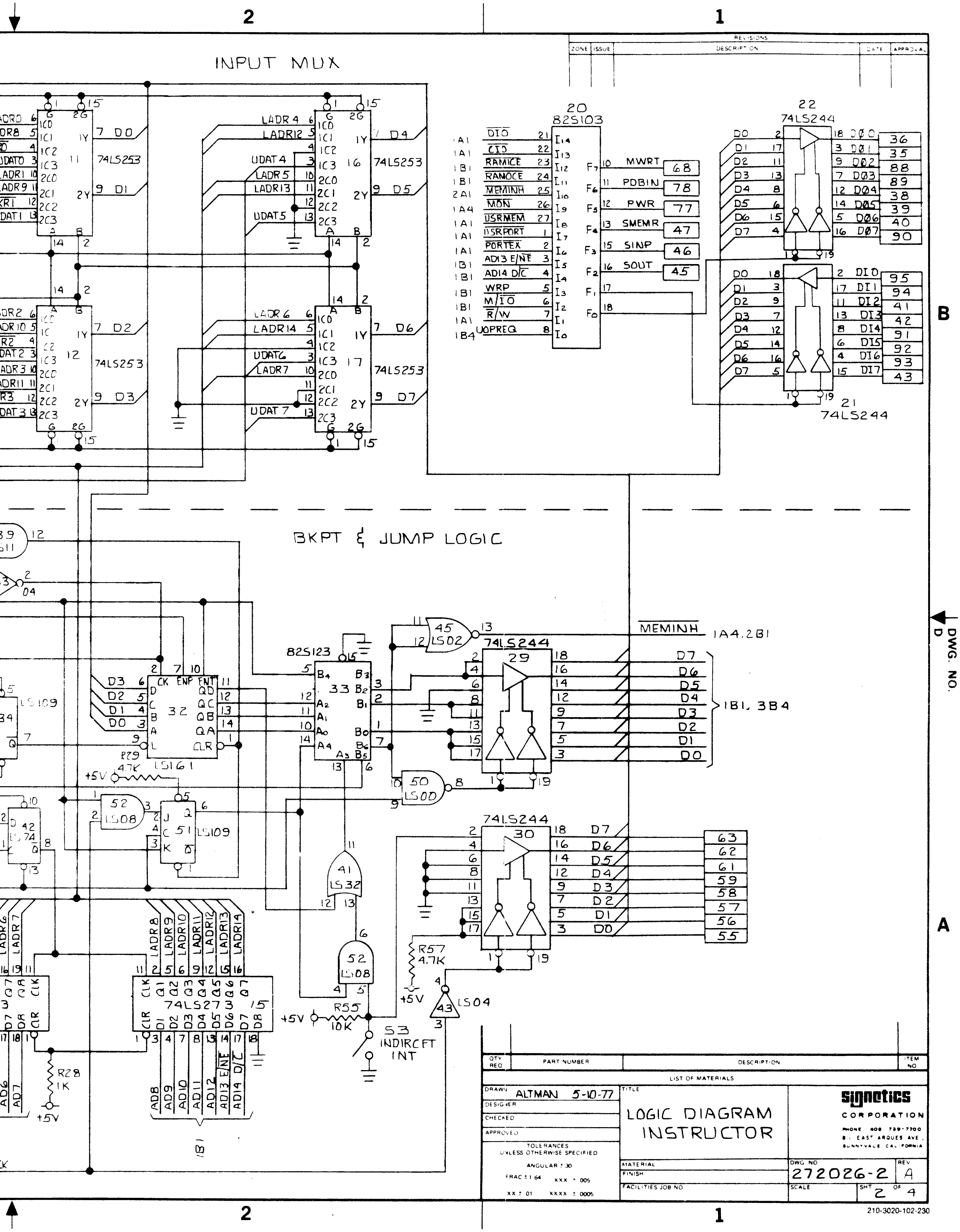
LIST OF MATERIALS

DRAWN ALTMAN 5-13-77	TITLE LOGIC DIAGRAM INSTRUCTOR	signetics CORPORATION PHONE 408 739-7700 811 EAST ARQUES AVE., SUNNYVALE, CALIFORNIA
DESIGNER		
CHECKED		
APPROVED		
TOLERANCES UNLESS OTHERWISE SPECIFIED ANGULAR ± 30 FRAC ± 1/64 XXX ± .005 XX ± .01 XXXX ± .0005	MATERIAL	DWG NO 272026-2 REV A
	FINISH	
	FACILITIES JOB NO	SCALE SHT 1 OF 4

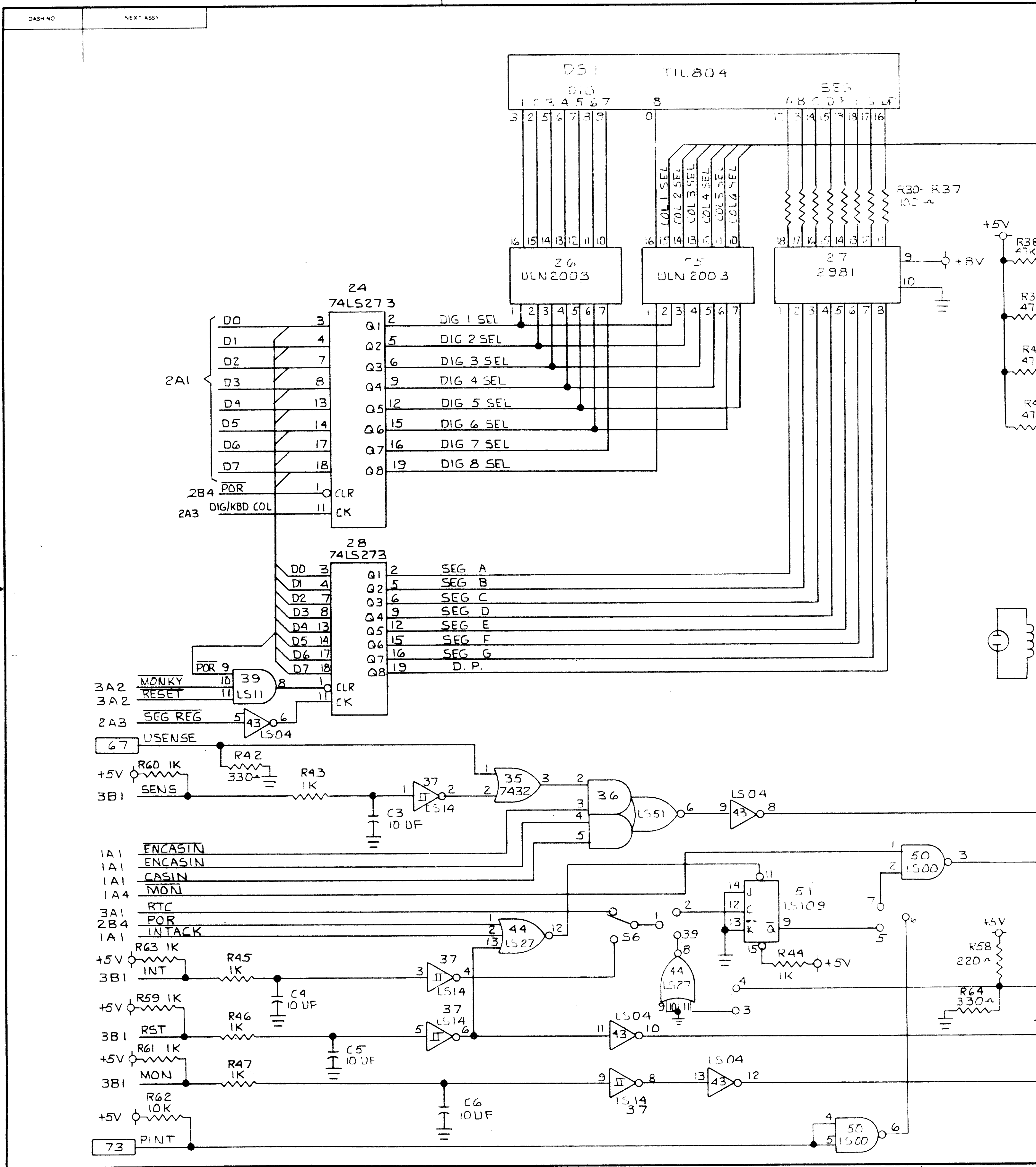
210-3020-102-230



4
3
DASH NO
NEXT ASSY
USER PARALLEL I/O
3B1 KR0-KR3
31
74LS273
CR3-CR10
CR12
1N457
3B4, 1A4 POR
3A4 POR
LS04
R25
100K
+5V
C2
4.7 UF
37
LS14
+5V
R17-R24
10K
S13
S12
S11
S10
S9
S8
S7
S2
UDAT0
UDAT1
UDAT2
UDAT3
UDAT4
UDAT5
UDAT6
UDAT7
I/O DECODE
2B1 1A1 R/W
1B1 W/R
2B1 1A1 USRMEM
2B1 1A1 USRPORT
2B1 1A1 DIO
2B1 1A1 CIO
2B1, 1A1 PORTFX
47 LS02
45 LS02
41 LS32
39 LS11
49 LS10
S1
R67 1.5K
R68 1.5K
74LS139
48
CMD 1A4
SEG REG 3A4
DIG/KBD COL 3B4
CYCCNT
LADR0
LADR8
KR0
UDAT0
LADR1
LADR9
KR1
UDAT1
LADR2
LADR10
KR2
UDAT2
LADR3
LADR11
KR3
UDAT3
74LS
41 LS32
39 LS11
35 LS32
43
LS109
34
R26 4.7K
R27 4.7K
42 LS74
R28 1K
74LS273
MMKY
UMEM
OPREQ
3A2
1A1
2B1,1B1
AD0
AD1
AD2
AD3
AD4
AD5
AD6
AD7
1B1
1A1 INTACK
3A4
B
A

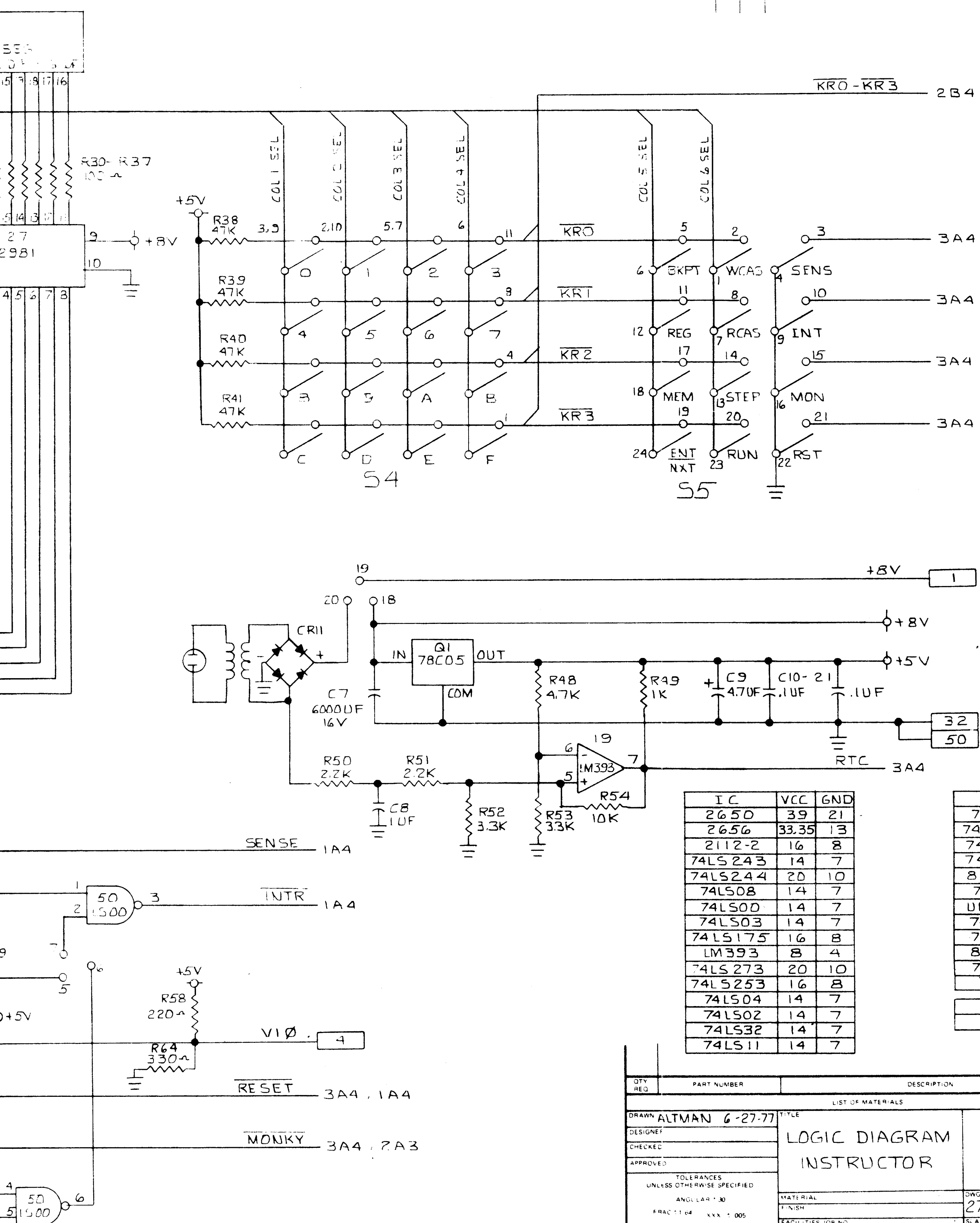


INPUT MUX
BKPT & JUMP LOGIC
LOGIC DIAGRAM
INSTRUCTOR
DRAWN ALTMAN 5-10-77
signetics
CORPORATION
DWG NO 272026-2
REV A
SHT 2 OF 4
210-3020-102-230



DASH NO
NEXT ASSY
DS1 TIL804
DIG
SEG
R30- R37
26 ULN2003
25 ULN2003
27 2981
+8V
+5V
R38 47K
24 74LS273
28 74LS273
2A1
D0
D1
D2
D3
D4
D5
D6
D7
2B4 POR
2A3 DIG/KBD COL
CLR
CK
DIG 1 SEL
DIG 2 SEL
DIG 3 SEL
DIG 4 SEL
DIG 5 SEL
DIG 6 SEL
DIG 7 SEL
DIG 8 SEL
COL 1 SEL
COL 2 SEL
COL 3 SEL
COL 4 SEL
COL 5 SEL
COL 6 SEL
SEG A
SEG B
SEG C
SEG D
SEG E
SEG F
SEG G
D. P.
3A2 MONKY
3A2 RESET
2A3 SEG REG
67 USENSE
3B1 SENS
R60 1K
R42 330
R43 1K
C3 10 UF
35 7432
36 LS51
LS04
LS14
1A1 ENCASIN
1A1 ENCASIN
1A1 CASIN
1A4 MON
3A1 RTC
2B4 POR
1A1 INTACK
44 LS27
S6
51 LS109
50 LS00
R44 1K
R58 220
R64 330
3B1 INT
R63 1K
R45 1K
C4 10 UF
3B1 RST
R59 1K
R46 1K
C5 10 UF
3B1 MON
R61 1K
R47 1K
C6 10 UF
R62 10K
73 PINT

4
3
4
3



IC	VCC	GND
2650	39	21
2656	33,35	13
2112-2	16	8
74LS243	14	7
74LS244	20	10
74LS08	14	7
74LS00	14	7
74LS03	14	7
74LS175	16	8
LM393	8	4
74LS273	20	10
74LS253	16	8
74LS04	14	7
74LS02	14	7
74LS32	14	7
74LS11	14	7

IC	VCC	GND
74LS10	14	7
74LS139	16	8
74LS109	16	8
74LS161	16	8
82S123	16	8
74LS14	14	7
ULN2003	—	8
74LS27	14	7
74LS51	14	7
82S103	28	14
74LS74	14	7
7400	14	7

IC	+8V	GND
2981	9	10

QTY REQ	PART NUMBER	DESCRIPTION	ITEM NO

LIST OF MATERIALS

DRAWN ALTMAN 6-27-77	TITLE LOGIC DIAGRAM INSTRUCTOR		signetics CORPORATION PHONE 408 739-7700 811 EAST ARQUES AVE SUNNYVALE, CALIFORNIA
DESIGNER			
CHECKED			
APPROVED			
TOLERANCES UNLESS OTHERWISE SPECIFIED ANGULAR ±30′ FRAC ±1/64 XXX ±.005 XX ±.01 XXXX ±.0005	MATERIAL	DWG NO 272026-2	REV A
	FINISH		
	FACILITIES JOB NO	SCALE	SHT 3 OF 4

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4 | 3

DASH NO	NEXT ASSY

2656 SMI PROGRAM CODING

	X0	X1	X2	X3	X4	X5	X6	X7			
FUNCTION SELECT	E	E	E	E	E	E	E	E			
	0	1	2	3	4	5	6	7	8	9	10
A0	X	X	X	1	1	X	X	X	1	X	X
A1	X	X	X	1	1	X	X	X	1	X	X
A2	X	X	X	1	1	X	X	X	1	X	X
A3	X	X	1	0	1	X	X	X	1	X	X
A4	X	X	1	0	1	X	X	X	1	X	X
A5	X	X	1	0	1	X	X	X	1	X	X
A6	X	X	1	0	1	X	X	X	1	X	X
A7	X	X	1	0	1	X	X	X	1	1	X
A8	0	1	X	X	1	X	X	X	1	1	X
A9	0	0	X	X	1	X	X	X	1	1	X
A10	0	0	X	X	1	X	X	X	1	1	X
A11	0	0	X	X	1	X	X	X	0	0	1
A12	0	0	X	X	0	X	X	1	1	1	1
A13	0	0	1	1	0	0	0	0	0	0	0
A14	0	0	X	X	0	0	1	0	0	0	0
OPREQ	1	1	1	1	1	1	1	X	1	1	1
M IO	1	1	0	0	1	0	0	X	1	1	1
WRP	1	1	1	1	1	1	1	X	1	1	1
	RAM 0 CE	RAM 1 CE	PORT FX	USR PORT	USR MEM	CIO	DIO	MON	SMI PORT	SMI RAM	SMI ROM

CLOCK SOURCE XTAL
CLOCK DIVIDE BY /4
NO DISABLE

82S123 PROGRAM TABLE

ADDRESS							OUTPUT								
HEX	OCTAL	A4	A3	A2	A1	A0	B7	B6	B5	B4	B3	B2	B1	B0	
00	00	0	0	0	0	0	0	1	1	1	0	1	0	0	CØ
01	01	0	0	0	0	1	0	1	0	1	0	0	1	1	1F
02	02	0	0	0	1	0	0	1	0	1	0	0	1	0	18
03	03	0	0	0	1	1	0	1	0	1	0	0	0	0	ØØ
04	04	0	0	1	0	0	0	0	0	0	0	0	0	0	IDLE
05	05	0	0	1	0	1	0	0	0	0	0	0	0	0	IDLE
06	06	0	0	1	1	0	0	0	0	0	0	0	0	0	
07	07	0	0	1	1	1	0	0	0	0	0	0	0	0	IDLE
08	10	0	1	0	0	0	0	0	0	1	0	0	0	0	SINGLE STEP
09	11	0	1	0	0	1	0	0	0	1	0	0	0	0	
0A	12	0	1	0	1	0	0	0	0	1	0	0	0	0	
0B	13	0	1	0	1	1	0	0	0	1	0	0	0	0	
0C	14	0	1	1	0	0	0	0	0	1	0	0	0	0	
0D	15	0	1	1	0	1	0	0	0	1	0	0	0	0	
0E	16	0	1	1	1	0	0	0	0	1	0	0	0	0	
0F	17	0	1	1	1	1	0	0	0	1	0	0	0	0	
10	20	1	0	0	0	0	0	0	0	1	0	0	0	0	
11	21	1	0	0	0	1	0	0	0	1	0	0	0	0	DIRECT INT VECT…
12	22	1	0	0	1	0	0	1	1	1	0	0	1	1	1F
13	23	1	0	0	1	1	0	1	0	1	0	0	1	0	18
14	24	1	0	1	0	0	0	1	0	1	0	0	0	0	ØØ
15	25	1	0	1	0	1	0	0	0	0	0	0	0	0	
16	26	1	0	1	1	0	0	0	0	0	0	0	0	0	
17	27	1	0	1	1	1	0	0	0	0	0	0	0	0	
18	30	1	1	0	0	0	0	0	0	0	0	0	0	0	
19	31	1	1	0	0	1	0	0	0	1	0	0	0	0	INDIRECT INT VECTO…
1A	32	1	1	0	1	0	0	0	0	1	0	0	0	0	HI ADDR BYTE
1B	33	1	1	0	1	1	0	0	0	1	0	0	0	0	LO ADDR BYTE
1C	34	1	1	1	0	0	0	1	1	1	0	0	1	1	1F
1D	35	1	1	1	0	1	0	1	0	1	0	0	1	0	18
1E	36	1	1	1	1	0	0	1	0	1	0	0	0	0	ØØ
1F	37	1	1	1	1	1	0	0	0	0	0	0	0	0	
								DATA BUS ENABLE	LAST ADDR LOAD	CNTR STOP		D6, D7	D3, D4	D0, D1, D2	

B

A

4 | 3

TABLE

TPUT

B3	B2	B1	B0		
0	1	0	0	CØ	
0	0	1	1	1F	
0	0	1	0	18	
0	0	0	0	ØØ	
0	0	0	0	IDLE	
0	0	0	0	IDLE	
0	0	0	0		
0	0	0	0	IDLE	
0	0	0	0		SINGLE STEP
0	0	0	0		
0	0	0	0		
0	0	0	0		
0	0	0	0		
0	0	0	0		
0	0	0	0		
0	0	0	0		
0	0	0	0		
0	0	0	0	DIRECT INT VECTOR	DIRECT / INTERRUPT SPACE
0	0	1	1	1F	
0	0	1	0	18	
0	0	0	0	ØØ	
0	0	0	0		
0	0	0	0		
0	0	0	0		
0	0	0	0		
0	0	0	0	INDIRECT INT VECTOR	INDIRECT
0	0	0	0	HI ADDR BYTE	
0	0	0	0	LO ADDR BYTE	
0	0	1	1	1F	
0	0	1	0	18	
0	0	0	0	ØØ	
0	0	0	0		
	D6, D7	D3, D4	D0, D1, D2		

82S1Ø3 PROGRAM TABLE

OUTPUT POLARITY		INPUT VARIABLE I0	I1	I2	I3	I4	I5	I6	I7	I8	I9	IA	IB	IC	ID	IE	IF	
FØ	L	H	H	–	–	–	–	H	H	H	H	H	H	H	H	H	–	ENABLE OUTPUT DATA
F1	L	H	L	–	–	–	–	H	H	H	H	H	H	H	H	H	–	ENABLE INPUT DATA
F2	H	–	H	L	–	–	–	H	H	H	H	H	H	H	H	H	–	$\overline{SOUT}$
F3	H	–	L	L	–	–	–	H	H	H	H	H	H	H	H	H	–	SINP
F4	H	–	L	H	–	–	–	H	H	H	H	H	H	H	H	H	–	$\overline{SMEMR}$
F5	L	H	H	–	H	–	–	H	H	H	H	H	H	H	H	H	–	PWR
F6	H	H	L	–	–	–	–	H	H	H	H	H	H	H	H	H	–	PDBIN
F7	H	H	H	H	–	–	–	H	H	H	H	H	H	H	H	H	–	MWRT
ACTIVE HIGH = H ACTIVE LOW = L		[illegible]	R/W	M/IO	WRP	ADR E/E	ADR E/NE	PORTEX	PERPORT	PERMEM	MON	MEMINH	RAMACE	RAMITE	CIO	DIO		

QTY REQ	PART NUMBER	DESCRIPTION	ITEM NO

LIST OF MATERIALS

DRAWN
DESIGNER
CHECKED
APPROVED

TOLERANCES UNLESS OTHERWISE SPECIFIED
ANGULAR ± 30
FRAC ± 1 64 XXX ± .005
XX ± .01 XXXX ± .0005

TITLE: INSTRUCTOR PROGRAM TABLES

MATERIAL
FINISH
FACILITIES JOB NO

signetics CORPORATION
PHONE 408 739-7700
811 EAST ARQUES AVE., SUNNYVALE, CAL. FORNIA

DWG NO 272062-2 REV A
SCALE SHT 4 OF 4

210-3020-102-230

REVISIONS

ZONE	ISSUE	DESCRIPTION	DATE	APPROVAL

APPENDIX C — USE PROGRAM LISTINGS

```
LINE ADDR  OBJECT  E SOURCE

                     *PROGRAM WRITTEN BY DAVE WOTRING
                     *****************************************************************
                     *   EQUATE TABLES
                     *
                     *   REGISTER EQUATES
     0000            R0      EQU     0       REGISTER 0
     0001            R1      EQU     1       REGISTER 1
     0002            R2      EQU     2       REGISTER 2
     0003            R3      EQU     3       REGISTER 3
                     *  CONDITION CODES
     0001            P       EQU     1       POSITIVE RESULT
     0000            Z       EQU     0       ZERO RESULT
     0002            NG      EQU     2       NEGATIVE RESULT
     0002            LT      EQU     2       LESS THAN
     0000            EQ      EQU     0       EQUAL TO
     0001            GT      EQU     1       GREATER THAN
     0003            UN      EQU     3       UNCONDITIONAL
                     *  PSW LOWER EQUATES
     00C0            CC      EQU     H'C0'   CONDITIONAL CODES
     0020            IDC     EQU     H'20'   INTERDIGIT CARRY
     0010            RS      EQU     H'10'   REGISTER BANK
     0008            WC      EQU     H'08'   1=WITH 0=WITHOUT CARRY
     0004            OVF     EQU     H'04'   OVERFLOW
     0002            COM     EQU     H'02'   1=LOGIC 0=ARITHMETIC COMPARE
     0001            C       EQU     H'01'   CARRY/BORROW
                     *  PSW UPPER EQUATES
     0080            SENS    EQU     H'80'   SENSE BIT
     0040            FLAG    EQU     H'40'   FLAG BIT
     0020            II      EQU     H'20'   INTERRUPT INHIBIT
     0007            SP      EQU     H'07'   STACK POINTER
                     *  IO PORT DEFINITIONS
     0007            LEDS    EQU     H'07'   USER EXTENDED IO PORT
                     *  INTERUPT VECTORS
     0007            UINTV   EQU     H'07'   USER DIRECT INTERUPT VECTOR
     0087            UINTVI  EQU     H'87'   USER INDIRECT INTERUPT VECTOR
                     * HARDWARE DEFINITIONS
     00FE            KBDIN   EQU     H'FE'   ADDRESS OF KBD IO PORT
     00F9            SEG     EQU     H'F9'   IO ADDRESS OF SEGMENT DRIVER
     00F9            DISP    EQU     SEG
     00FA            DIGIT   EQU     H'FA'   ADDRESS OF DIGIT ENABLE
     00F8            CTBYT   EQU     H'F8'   ADDRESS OF CONTROL BYTE
     00F8            CAS     EQU     CTBYT   ADDRESS OF CASSETTE INTERFACE
     00FB            OPRQCT  EQU     H'FB'   ADDRESS OF OPREQ COUNTER
     00FD            LADRH   EQU     H'FD'   ADDRESS OF LAST ADDRESS REG HI BYTE
     00FC            LADRL   EQU     H'FC'   ADDRESS OF LAST ADDRESS REG LO BYTE
```

```
LINE ADDR  OBJECT  E SOURCE

                     ****************************************************
                     *
     0000                   ORG     H'1800'-64     TRAINING CARD RAM AREA
                     *
     17C0            SCTCH  RES     8       8 BYTE SCRATCH AREA
     17C6            TEMP   EQU     SCTCH+6 TEMP STORAGE
     17C8            EAD    RES     2       STOP ADDRESS FOR WCAS
     17CA            BAD    RES     2       BEGINNING ADDRESS FOR WCAS
     17CC            BPD    RES     1       DATA TO BE RESTORED IN BREAK LOC
     17CD            BPL    RES     2       ADDRESS OF BREAK POINT LOC
     17CF            BPF    RES     1       BREAK POINT SET FLAG
     17D0            SSF    RES     1       SINGLE STEP SET FLAG
     17D1            DISBUF RES     8       8 BYTE DISPLAY REGISTER
     17D9            SAVREG RES     4       A PLACE TO SAVE R0 THRU R3 OF ONE BANK
     17DD            MEM    RES     2       ADDRESS FOR ALTER OR PATCH COMMAND
     17DF            FID    RES     2       FILE ID FLAG AND FILE ID
     17E1            BCC    RES     1       BLOCK CHECK CHAR
     17E2            BSTT   RES     1       SAVE UNITS DIGIT
     17E3            T      RES     2       TEMP REGISTER
     17E5            T1     RES     1       TEMP REGISTER
     17E6            T2     RES     1       TEMP REGISTER
     17E7            T3     RES     1       TEMP REGISTER
     17E8            LADR   RES     2       COPY OF LAST ADDRESS REGISTER
     17EA            SLADR  RES     2       SAVE LOCATION FOR LADR
     17EC            KFLG   RES     2       KBD SCAN FLAGS
     17EE                   RES     1       KBD DEBOUNCE COUNT
     17EF            ALTF   RES     1       DISPLAY AND ALTER FLAG
     17F0            RESTF  RES     1       RESTORE REGISTERS FLAG
     17F1            IFLG   RES     1       INTERUPT INHIBIT FLAG
     17F2            UREG   RES     12      STORAGE FOR USER REGISTERS
     17FE            PWRON  RES     2       WHEN POWER ON THESE LOC CONTAIN H'5946'
                     ****************************************************
```

```
LINE ADDR  OBJECT  E SOURCE

                     ************************************************************
     1800                   ORG H'1800'    BEGINING OF TRAINING CARD ROM AREA
                     ************************************************************
                     *
                     *SAVE ALL REGISTERS UPON ENTRY TO PROGRAM
                     *
                     *REGISTERS USED
                     *
                     *R0 THRU R3' PSU PSL
                     *
                     *SUBROUTINES CALLED
                     *
                     *NONE
                     *
                     *RAM MEMORY USED
                     *
                     *UREG  = R0
                     *UREG+1        = R1
                     *UREG+2        = R2
                     *UREG+3        = R3
                     *UREG+4        = R1'
                     *UREG+5        = R2'
                     *UREG+6        = R3'
                     *UREG+7        = PSU
                     *UREG+8        = PSL
                     *UREG+9        = PPSL INSTRUCTION OPCODE
                     *UREG+10       = PSL
                     *UREG+11       = RETC,UN      INSTRUCTION OPCODE
                     *
                     ****************************************************************
                     *
     1800 C870       SAVRG  STRR,R0 UREG    SAVE R0
     1802 13                SPSL            GET PSL
     1803 C875              STRR,R0 UREG+8  SAVE PSL
     1805 C875              STRR,R0 UREG+10 SAVE PSL         FOR RESTORE ROUTINE
     1807 12                SPSU            GET PSU
     1808 C86F              STRR,R0 UREG+7  SAVE PSU
     180A 7620              PPSU    II      SET INTERUPT INHIBIT
     180C 7510              CPSL    RS      CLEAR REGISTER SWITCH
     180E C963              STRR,R1 UREG+1  SAVE R1
     1810 CA62              STRR,R2 UREG+2  SAVE R2
     1812 CB61              STRR,R3 UREG+3  SAVE R3
     1814 7710              PPSL    RS      SET REGISTER SWITCH
     1816 C95E              STRR,R1 UREG+4  SAVE R1'
     1818 CA5D              STRR,R2 UREG+5  SAVE R2'
     181A CB5C              STRR,R3 UREG+6  SAVE R3'
     181C 75FF              CPSL    255     CLEAR PSL
     181E 7702              PPSL    COM     DO LOGICAL COMPARES
     1820 54FD              REDE,R0 LADRH   GET LAST ADDRESS HI BYTE
     1822 CC17E8            STRA,R0 LADR    SAVE IN MEMORY
     1825 54FC              REDE,R0 LADRL   GET LAST ADDRESS LO BYTE
     1827 CC17E9            STRA,R0 LADR+1  SAVE IT
     182A 20                EORZ    R0      GET A 0
     182B CC17F1            STRA,R0 IFLG    CLEAR INTERUPT INHIBIT FLAG
```

```
LINE ADDR  OBJECT  E SOURCE

                     ******************************************************************
                     *
                     *
                     *
                     *PROGRAM ENTRY ROUTINE
                     *
                     *
                     *DECIDES HOW REACHED ENTRY POINT OF PROGRAM
                     *
                     *1 POWER ON
                     *2 SINGLE STEP
                     *3 MONITOR PUSHBUTTON ON KEY BOARD
                     *4 BREAKPOINT
                     *
                     *
                     *
                     *
                     *****************************************************
                     *
     182E 084E       BEG    LODR,R0 PWRON   CHECK POWER ON FLAG
     1830 E459              COMI,R0 H'59'   AFTER POWER VALUE OF FLAG IS
                     *                      H'5946'
     1832 9813       BEG1   BCFR,EQ INIT    IF NOT CORRECT THIS IS POWER ON
                     *                      GO INITIALIZE THE MONITOR FLAGS
     1834 0849       BEG3   LODR,R0 PWRON+1 CHECK LO BYTE OF POWER ON FLAG
     1836 E446              COMI,R0 H'46'   IS SECOND BYTE CORRECT
     1838 980D              BCFR,EQ INIT IF NOT INITIALIZE THE PROGRAM
     183A 0C17D0            LODA,R0 SSF     CHECK THE SINGLE STEP FLAG
     183D 9C19C9            BCFA,EQ SGLSTP  IF FLAG THEN GO SINGLE STEP
     1840 0899              LODR,R0 *MON+1     SEE IF BREAK POINT ENABLED
     1842 9C197A     BEG2   BCFA,EQ BRKPT  GO EXECUTE THE BREAK POINT ROUTINE
     1845 1B13              BCTR,UN MON     MUST BE MONITOR KEY
                     *
```

```
LINE ADDR  OBJECT  E SOURCE

                     ***************************************************
                     *
                     *
                     *KEY BOARD MONITOR ROUTINE
                     *
                     *
                     *REGISTERS USED
                     *
                     *R0 SCRATCH
                     *R1 SCRATCH
                     *R2 SCRATCH
                     *R3 NOT USED
                     *
                     *SUBROUTINES USED
                     *
                     *MOV MOVE DATA TO DISPLAY BUFFER
                     *DISPLY DISPLAY MESSAGE AND KEY BOARD SCAN
                     *
                     *
                     *RAM MEMORY USED
                     *
                     *PWRON POWER ON FLAG
                     *SSF   SINGLE STEP FLAG
                     *BPF   BREAK POINT FLAG
                     *BPL   BREAK POINT LOCATION
                     *
                     ***********************************************
                     *
1847 0459            INIT   LODI,R0 H'59'    SET THE POWER ON FLAG
1849 CC17FE                 STRA,R0 PWRON    TO POWER ON VALUE H'5946'
184C 0446                   LODI,R0 H'46'
184E CC17FF                 STRA,R0 PWRON+1
1851 20                     EORZ    R0       GET A 0
1852 CC17DD                 STRA,R0 MEM      PRESET INDIRECT ADDRESS MEM
1855 CC17DE                 STRA,R0 MEM+1
1858 C881                   STRR,R0 *MON+1   CLEAR BREAK POINT FLAG
185A 0C17CF          MON    LODA,R0 BPF      GET BREAK POINT FLAG
185D 180F                   BCTR,EQ MON5     BREAK POINT NOT SET
185F 0C17CC                 LODA,R0 BPD      GET BREAK POINT DATA
1862 CC97CD                 STRA,R0 *BPL     CLEAR BREAK POINT
1865 EC97CD                 COMA,R0 *BPL     CHECK DATA STORED CORRECTLY
1868 1804                   BCTR,EQ MON5     BREAK POINT CLEARED OK
186A 0701                   LODI,R3 1        BREAK POINT DIDN'T CLEAR
186C 9BE8                   ZBRR    *ERR     GOTO ERROR
186E 20              MON5   EORZ    R0       GET A 0
186F D4F8                   WRTE,R0 CTBYT  CLEAR CONTROL BYTE
1871 CC17D0                 STRA,R0 SSF      CLEAR SINGLE STEP FLAG
1874 051F            MON3   LODI,R1 <HELLO-1        GET ADDRESS OF HELLO MESSAGE
1876 0694                   LODI,R2 >HELLO-1
1878 BBFE            MON1   ZBSR *MOV      MOVE MESSAGE TO DISBUF
187A 20              MON4   EORZ    R0       SET FLAG TO WAIT FOR ENTRY
187B BBEC                   ZBSR    *DISPLY DISPLAY MESSAGE AND SCAN KEYBOARD
187D F680            MON2   TMI,R2  H'80'    CHECK COMMAND FLAG
187F 9816                   BCFR,EQ ERR2      IF FLAG NOT SET ERROR
1881 460F                   ANDI,R2 H'0F'    MASK COMMAND VALUE
```

```
LINE ADDR  OBJECT  E SOURCE

1883 E607           COMI,R2 7       MAX COMMAND VALUE
1885 1910           BCTR,GT ERR2     ERROR CODE VALUE TO LARGE
1887 D2             RRL,R2          MULTIPLY INDEX BY 2
1888 0E78A4         LODA,R0 CMD,R2  SET UP AN INDIRECT ADDRESS
188B CC17E3         STRA,R0 T       TO THE FUNCTION WANTED
188E 0E78A5         LODA,R0 CMD+1,R2
1891 CC17E4         STRA,R0 T+1
1894 1F97E3         BCTA,UN *T      EXECUTE A COMMAND
               *
               *
1897 0702      ERR2  LODI,R3 2       INVALID COMMAND SEQUENCE
1899 051F      ERRI  LODI,R1 <ERROR-1  GET ADDRESS OF ERROR MESSAGE
189B 0684            LODI,R2 >ERROR-1
189D BBFE            ZBSR    *MOV    MOVE MESSAGE TO DISBUF
189F CF17D8          STRA,R3 DISBUF+7        WRITE THE ERROR NUMBER
18A2 1B56            BCTR,UN MON4    GO LOOK FOR NEW COMMAND
               *
               *COMMAND ADDRESS TABLE
               *
18A4 1C91      CMD   ACON    WCAS    WRITE CASSETTE COMMAND
18A6 1D61            ACON    SCBP     BREAK POINT COMMAND
18A8 1BAC            ACON    RCAS    READ CASSETTE COMMAND
18AA 1A7E            ACON    REG     REGISTER DISPLAY AND ALTER COMMAND
18AC 18B4            ACON    SSTEP      SINGLE STEP COMMAND
18AE 1A0C            ACON    ALTER     DISPLAY AND ALTER MEMORY
18B0 1E59            ACON    GO      GOTO COMMAND
18B2 187A            ACON    MON4    ENTR/NEXT KEY IS NOT COMMAND
               *
```

```
LINE ADDR  OBJECT  E SOURCE

                       *************************************************************
                       *
                       *
                       *SINGLE STEP ROUTINES
                       *THIS ROUTINE WRITTEN BY BBC
                       *
                       * PROCESSOR TRANSFERS CONTROL TO USER PROGRAM
                       * AFTER COMPUTING THE NUMBER OF OPREQ'S TILL
                       * THE NEXT INSTRUCTION FETCH.
                       *
                       *
                       *REGISTERS USED
                       *
                       *R0 THRU R3 SCRATCH
                       *
                       *
                       *SUBROUTINES CALLED
                       *
                       *RLADR RESTORE LAST ADDRESS REGISTER
                       *
                       *
                       *RAM LOCATIONS USED
                       *
                       *LADR  LAST ADDRESS REGISTER
                       *T3    TEMP REGISTER
                       *TEMP  TEMP REGISTER
                       *SCTCH SCRATCH REGISTER
                       *
                       ******************************************************************
     0000              OVHD   EQU     0      NEGATIVE NUMBER OF OPREQ'S
                       *
                       *
                       *CHECK IF NEXT SINGLE STEP IS IN MONITOR AREA
                       *
     18B4 0C17E8       SSTEP  LODA,R0 LADR    GET MSB OF LADR
     18B7 E410                COMI,R0 H'10'   IS ADDRESS LT H'1000'
     18B9 1A08                BCTR,LT SSTEP1  GO SINGLE STEP
     18BB E420                COMI,R0 H'20'   IS ADDRESS GT OR EQ H'2000'
     18BD 9A04                BCFR,LT SSTEP1  GO SINGLE STEP
     18BF 0709                LODI,R3 9       NEXT SINGLE STEP ENTERS MONITOR
     18C1 9BE8                ZBRR    *ERR    GOTO ERROR
     18C3 047F         SSTEP1 LODI,R0 127     SET SINGLE STEP FLAG
     18C5 CC17D0              STRA,R0 SSF     STORE IT
     18C8 0420                LODI,R0 H'20'   SET THE INTERUPT INHIBIT
     18CA CC17F1              STRA,R0 IFLG    SAVE IN INTERUPT INHIBIT FLAG
     18CD 7508                CPSL WC         CLEAR WITH CARRY IF SET
     18CF 0601         SSTEP2 LODI,R2 1       SET INDEX
     18D1 0EF7E8              LODA,R0 *LADR,R2        GET SECOND BYTE OF INSTRUCTION
     18D4 CC17E7              STRA,R0 T3      SAVE IT FOR LATER
     18D7 0F97E8              LODA,R3 *LADR   GET NEXT INSTRUCTION
     18DA 03                  LODZ    R3      SAVE INSTRUCTION IN R0
     18DB 471C                ANDI,R3 H'1C'   EXTRACT INSTRUCTION CLASS
     18DD 0500                LODI,R1 OVHD    SET OVERHEAD OPREQ COUNT
     18DF 0605                LODI,R2 5       SHIFT OR MOVE COUNT
     18E1 F420                TMI,R0  H'20'   TEST FOR ODD OPCODE IN CLASS4
```

```
LINE ADDR  OBJECT  E SOURCE

18E3 9F1902             BXA     CBRTB,R3        BRANCH TO CLASS PROCESSOR
                   *
                   * CLASS 5.     MIXED NUMBER OF OPREQ'S.
                   *
18E6 FA2F          CL5B  BDRR,R2 CL5A
18E8 4707                ANDI,R3 H'07'   MASK TO OPCODE
18EA 0F7967              LODA,R0 CL5TB,R3        GET NUMBER OF OPREQ'S FROM TABLE.
18ED C1                  STRZ    R1
                   *
                   * WRITE OPREQ COUNT AND EXIT TO USER
                   *
18EE 1F195E        EXIT BCTA,UN EXIT4    GOTO USER
                   *
                   * RETURN FROM TEST BRANCH, IF BRANCH TAKEN
                   *
18F1 3F196F        BRCH  BSTA,UN RLADR   RESTORE LAST ADDRESS REGISTER
18F4 0D17C6        BRCH1 LODA,R1 TEMP    GET OPREQ COUNT BACK AFTER TEST BRANCH
18F7 7508                CPSL    WC      CLEAR PSL WC BIT
                   *
                   * ROUTINE TO ADD 2 OPREQ'S IF INDIRECT APPLIES.
                   *
18F9 0C17E7        CIND  LODA,R0 T3      GET SECOND BYTE OF INSTRUCTION
18FC F480                TMI,R0  H'80'   TEST INDIRECT BIT
18FE 1806                BCTR,0  PLS2    SET, ADD 2 OPREQ'S
1900 1B6C                BCTR,UN EXIT    NOT SET, DO NOT ADD
                   *
                   * CLASS PROCESSOR TABLE.
                   *
1902               CBRTB EQU     $
                   *
1902 A501          PLS1  SUBI,R1 1       CLASS 0.        1 OPREQ
1904 1B68                BCTR,UN EXIT
1906 A502          PLS2  SUBI,R1 2       CLASS 1.        2 OPREQ'S
1908 1B64                BCTR,UN EXIT
190A A503                SUBI,R1 3       CLASS 2.        3 OPREQ'S + INDIRECT
190C 1B6B                BCTR,UN CIND
190E A504                SUBI,R1 4       CLASS 3.        4 OPREQ'S + INDIRECT
1910 1B67                BCTR,UN CIND
1912 1872                BCTR,EQ PLS2    CLASS4          2 OPREQS IF OPCODE ODD
1914 1B6C                BCTR,UN PLS1                    1 OPREQ IF OPCODE EVEN
1916 C3                  STRZ    R3      CLASS 5.        MIXED NUMBER OF OPREQ'S
1917 53            CL5A  RRR,R3          SHIFT OPCODE TO LOW BYTE
1918 1B4C                BCTR,UN CL5B    AND LOOK UP IN TABLE
191A 8501                ADDI,R1 1       CLASS 6.        2 OPREQ'S + IND IF BRANCH TAKEN
191C 6404                IORI,R0 H'04'   CONVERT TO CLASS 7.
191E A503                SUBI,R1 3       CLASS 7.        3 OPREQ'S + IND IF BRANCH TAKEN
                   *
                   * CLASS 6 AND 7.
                   * ADD 2 OPREQ'S IF INDIRECT AND BRANCH IS TAKEN.
                   *
1920 C9D3                STRR,R1 *BRCH1+1 SAVE PRESENT NUMBER OF OPREQ'S IN TEMP
1922 D5FB                WRTE,R1 OPRQCT  ALSO OUTPUT TO HARDWARE
1924 F440                TMI,R0  H'40'   TEST FOR REGISTER CLASS
1926 1804                BCTR,0  CL67B   IF SO, DO NOT TEST FOR UNCONDITIONAL
1928 F403                TMI,R0  H'03'   IS BRANCH UNCONDITIONAL
192A 184D                BCTR,0  CIND    IF SO, DO NOT TEST BRANCH
```

```
LINE ADDR  OBJECT  E SOURCE

192C F4E0       CL67B  TMI,R0  H'E0'   TEST FOR BDR INST
192E 1802              BCTR,0  CL67C   IF SO, DO NOT REMOVE 'SUBROUTINE' BIT
1930 44DF              ANDI,R0 H'DF'   REMOVE SUBROUTINE BIT FROM OPCODE.
1932 CC17C0     CL67C  STRA,R0 SCTCH   STORE IN TEST AREA
1935 0E7951     MVCODE LODA,R0 BRCD,R2 GET ROM CODE
1938 CE77C0            STRA,R0 SCTCH,R2  STORE IN RAM
193B FA78              BDRR,R2 MVCODE  DO UNTILL ALL HAS BEEN MOVED.
                *
                *SAVE LADR
                *
193D 0C17E8     SLAD1  LODA,R0 LADR    GET LAST ADDRESS REG
1940 C8AE              STRR,R0 *RLADR+1   SAVE IT
1942 0C17E9     SLAD2  LODA,R0 LADR+1
1945 C8AE              STRR,R0 *RLADR1+1
1947 0417              LODI,R0 <SCTCH  GET ADDRESS SCRATCH
1949 C8F3              STRR,R0 *SLAD1+1
194B 04C0              LODI,R0 >SCTCH
194D CC9943            STRA,R0 *SLAD2+1
1950 1B93              BCTR,UN *EXIT3+1      DO TEST BRANCH
                *
                *THIS IS CODE FOR TEST BRANCH
                *
1951            BRCD   EQU     $-1
1952 18F1              ACON    BRCH    ADDRESS FOR TEST BRANCH
1954 1F1957            BCTA,UN EXIT2      RETURN IF BRANCH NOT TAKEN
                *
1957 3B16       EXIT2  BSTR,UN RLADR   RESTORE LAST ADDRESS REG
1959 0D17C6            LODA,R1 TEMP    GET OPREQ COUNT
195C 7508              CPSL    WC      CLEAR WITH CARRY
195E D5FB       EXIT4  WRTE,R1 OPRQCT  SET THE OPREQ COUNTER
1960 20                EORZ    R0      CLEAR INTERUPT INHIBIT FLAG
1961 CC17F1            STRA,R0 IFLG    SAVE IN INTERUPT INHIBIT FLAG
1964 1F1E59     EXIT3  BCTA,UN GO
                *
                * CLASS 5 OPREQ TABLE
                *
1967 FF         CL5TB  DATA    OVHD-1      RETC
1968 FF                DATA    OVHD-1      RETE
1969 FD                DATA    OVHD-3      REDE
196A FE                DATA    OVHD-2      C-P PSW
196B FF                DATA    OVHD-1      DAR
196C FE                DATA    OVHD-2      TPSW
196D FD                DATA    OVHD-3      WRTE
196E FE                DATA    OVHD-2      TMI
                *
                *RLADR RESTORE LAST ADDRESS REG
                *
196F 0C17EA     RLADR  LODA,R0 SLADR   GET SAVED LADR
1972 C8CA              STRR,R0 *SLAD1+1
1974 0C17EB     RLADR1 LODA,R0 SLADR+1
1977 C8CA              STRR,R0 *SLAD2+1
1979 17                RETC,UN
                *
```

```
LINE ADDR  OBJECT  E SOURCE

0419                 ************************************************************************
0420                 *
0421                 *
0422                 *BREAK POINT AND SINGLE STEP RUN TIME CODE
0423                 *
0424                 *
0425                 *SINGLE STEP
0426                 *
0427                 *WHEN ENTERED AT SINGLE STEP. SINGLE STEP FLAG IS CLEARED
0428                 *AND DISPLAY IS ' ADDR DD'
0429                 *
0430                 *
0431                 *WHEN ENTERED AT BREAK POINT AND BREAK POINT IS SET AND MATCHES
0432                 *BREAK POINT REGISTER. THE DISPLAY IS '-ADDR DD'
0433                 *
0434                 *
0435                 *REGISTER USED
0436                 *
0437                 *R0
0438                 *
0439                 *SUBROUTINE CALLED
0440                 *
0441                 *DLSLD PREPARE BINARY DATA FOR DISPLAY
0442                 *
0443                 *
0444                 *RAM MEMORY USED
0445                 *
0446                 *DISBUF DISPLAY BUFFER
0447                 *BPF BREAK POINT FLAG
0448                 *BPL BREAK POINT LOCATION
0449                 *BPD DATA FOR BREAK POINT LOCATION
0450                 *LADR COPY OF LAST ADDDRESS REGISTER
0451                 *SSF SINGLE STEPFLAG
0452                 *
0453                 ************************************************************************
0454                 *
0455 197A 0C17E8     BRKPT  LODA,R0 LADR    GET LAST ADDRESS REGISTER
0456 197D 0D17E9     BRK3   LODA,R1 LADR+1
0457 1980 7709              PPSL    C+WC    SET CARRY AND WITH CARRY
0458 1982 A501              SUBI,R1 1       DECREMENT LAST ADDRESS REG
0459 1984 A400              SUBI,R0 0       SO CAN COMPARE TO BREAK POINT REGISTER
0460 1986 447F              ANDI,R0 H'7F    MASK OFF UNUSED BIT
0461 1988 7509              CPSL    C+WC    CLEAR CARRY AND WITH CARRY
0462 198A E8AF       BRK2   COMR,R0 *BRKPT2+1 COMPARE WITH BPL
0463 198C 9C185A     BRK1   BCFA,EQ MON    NO COMPARE
0464 198F E9AF              COMR,R1 *BRKPT1+1 COMPARE WITH BPL+1
0465 1991 98FA              BCFR,EQ *BRK1+1   NO COMPARE
0466 1993 C8E6              STRR,R0 *BRKPT+1        IF COMPARE UP DATE PC
0467 1995 C9E7              STRR,R1 *BRK3+1
0468 1997 0C17CC            LODA,R0 BPD     IF COMAPRE CLEAR BREAK POINT
0469 199A CC97CD            STRA,R0 *BPL
0470 199D EC97CD            COMA,R0 *BPL    ERROR CHECK OF DATA WRITTEN
0471 19A0 1804              BCTR,EQ BRK0    DATA STORED OK
0472 19A2 0701              LODI,R3 1       BREAK POINT NOT CLEARED OK
0473 19A4 9BE8              ZBRR    *ERR
```

```
LINE ADDR  OBJECT  E SOURCE

0474 19A6 E440        BRK0   COMI,R0 H'40'   HALT INSTRUCTION OPCODE
0475 19A8 1808               BCTR,EQ BRKPT9  IF HALT DON'T DO HIDDEN SINGLE STEP
0476 19AA 0480               LODI,R0 H'80'   SET FLAG FOR HIDDEN SINGLE STEP
0477 19AC CC17CF      BRKPT3 STRA,R0 BPF     SET FLAG IN BREAK POINT
0478 19AF 1F18B4             BCTA,UN SSTEP   EXECUTE ONE USER INSTRUCTION
0479 19B2 047F        BRKPT9 LODI,R0 127     SET BREAK POINT FLAG
0480 19B4 C8F7               STRR,R0 *BRKPT3+1
0481 19B6 0419               LODI,R0 H'19'   DASH SYMBOL FOR BREAK POINT
0482 19B8 C89A               STRR,R0 *BRKPT8+1  SET THE DASH SYMBOL IN DISBUF
0483 19BA 0C17CD      BRKPT2 LODA,R0 BPL     GET BREAK POINT ADDRESS
0484 19BD 3B32               BSTR,UN BRKPT7  SET THE DISPLAY
0485 19BF 0C17CE      BRKPT1 LODA,R0 BPL+1
0486 19C2 3B36               BSTR,UN BRKPT6
0487 19C4 0C97CD             LODA,R0 *BPL    GET INSTRUCTION OPCODE
0488 19C7 1B1A               BCTR,UN BRKPT5
0489                  *
0490                  *ENTRY POINT FOR SINGLE STEP
0491                  *
0492 19C9 20           SGLSTP EORZ    R0      GET A 0
0493 19CA CC17D0             STRA,R0 SSF     CLEAR SINGLE STEP FLAG
0494 19CD 08DE               LODR,R0 *BRKPT3+1       CHECK BREAK POINT FLAG
0495 19CF 1A61               BCTR,NG BRKPT9  DID A HIDDEN SINGLE STEP
0496                  *                      DISPLAY THE BREAK POINT
0497 19D1 0417        SGLST9 LODI,R0 H'17'   BLANK SYMBOL
0498 19D3 CC17D1      BRKPT8 STRA,R0 DISBUF  SET DISPLAY BUFFER
0499 19D6 0C17E8             LODA,R0 LADR    GET ADDRESS
0500 19D9 3B16               BSTR,UN BRKPT7  SET THE DISPLAY
0501 19DB 0C17E9             LODA,R0 LADR+1
0502 19DE 3B1A               BSTR,UN BRKPT6  SET THE DISPLAY
0503 19E0 0C97E8             LODA,R0 *LADR   GET INSTRUCTION DATA
0504 19E3 3B03        BRKPT5  BSTR,UN BRKPTI  SET UP DISPLAY
0505 19E5 1F187A             BCTA,UN MON4     GOTO MONITOR
0506                  *
0507                  *SET UP DISBUF 6&7
0508                  *
0509 19E8 BBF4        BRKPTI ZBSR    *DISLSD CONVERT TO BIN FOR DISPLAY
0510 19EA CC17D7             STRA,R0 DISBUF+6
0511 19ED CD17D8             STRA,R1 DISBUF+7
0512 19F0 17                 RETC,UN
0513                  *
0514                  *SET UP DISBUF 1&2
0515                  *
0516 19F1 BBF4        BRKPT7 ZBSR    *DISLSD CONVERT BIN TO DISPLAY
0517 19F3 CC17D2             STRA,R0 DISBUF+1
0518 19F6 CD17D3             STRA,R1 DISBUF+2
0519 19F9 17                 RETC,UN
0520                  *
0521                  *SETUP DISBUF 3&4
0522                  *
0523 19FA BBF4        BRKPT6 ZBSR    *DISLSD CONVERT BIN TO DISPLAY
0524 19FC CC17D4             STRA,R0 DISBUF+3        STORE DATA
0525 19FF CD17D5             STRA,R1 DISBUF+4
0526 1A02 0417               LODI,R0 H'17'   BLANK SYMBOL
0527 1A04 CC17D6             STRA,R0 DISBUF+5
0528 1A07 17                 RETC,UN
```

```
LINE ADDR  OBJECT  E SOURCE

                     ********************************************************
                     *
                     *
                     *DISPLAY AND ALTER MEMORY ROUTINE
                     *PATCH MEMORY ROUTINE
                     *
                     *
                     *REGISTERS USED
                     *
                     *R0 SCRATCH
                     *R1 SCRATCH
                     *R2 SCRATCH
                     *R3 SCRATCH
                     *
                     *SUBROUTINES CALLED
                     *
                     *GAD GET ADDRESS PARAMETER
                     *GNP GET NUMBER PARAMETER
                     *ROT ROTATE R0 1 NIBBLE LEFT
                     *BRKPT4        SETUP DISPLAY 6&7
                     *BRKPT6        SETUP DISPLAY 3&4
                     *BRKPT7        SETUP DISPLAY 1&2
                     *
                     *RAM MEMORY USED
                     *
                     *MEM INDIRECT ADDRESS MEMORY POINTER
                     *ALTF ALTER FLAG = 1 FOR DISPLAY AND ALTER
                     *                  3 OR 5 FOR PATCH
                     *
                     *******************************************************
                     *
                     *
                     *ENTRY POINT FOR PATCH COMMAND
                     *
     1A08 0403       PTCH   LODI,R0 3        SET ALTER FLAG TO PATCH
     1A0A 1B02              BCTR,UN ALTER5
                     *
                     *ENTRY POINT FOR DISPLAY AND ALTER COMMAND
                     *
     1A0C 0401       ALTER  LODI,R0 1        SET ALTER FLAG TO ALTER
     1A0E C8A4       ALTER5 STRR,R0 *ALTER1+1        STORE IN ALTF
     1A10 3F1B04            BSTA,UN GAD      DISPLAY AD= AND WAIT TILL DIGITS ENTERED
     1A13 E687              COMI,R2 H'87'    ENTR/NXT?
     1A15 9C187D            BCFA,EQ MON2     NEW FUNCTION ABORT ALTER COMMAND
     1A18 5B0E              BRNR,R3 ALTER4  NO ADDRESS ENTERED CONTINUE FROM LAST LOCATION
     1A1A C88D              STRR,R0 *ALTER4+1 MEM+1   SAVE ADDRESS DATA
     1A1C C981              STRR,R1 *AL1+1
     1A1E 0E17DD     AL1    LODA,R2 MEM      GET DATA
     1A21 0717              LODI,R3 H'17'       BLANK
     1A23 CF17D8            STRA,R3 DISBUF+7        CLEAR DISPLAY
     1A26 1B05              BCTR,UN ALTER2  SET UP DISPLAY
                     *
                     *NO ADDRESS CONTINUE FROM LAST ADDRESS
                     *
     1A28 0C17DE     ALTER4 LODA,R0 MEM+1   GET ADDRESS
```

```
LINE ADDR  OBJECT  E SOURCE

1A2B 0AF2                LODR,R2 *AL1+1 MEM
                    *
                    *UPDATE THE DISPLAY
                    *
1A2D 3B4B           ALTER2 BSTR,UN BRKPT6  SET UP ADDRESS DISPLAY
1A2F 02                    LODZ    R2      GET MSD
1A30 3F19F1                BSTA,UN BRKPT7  SET UP DISPLAY
                    *
                    *
1A33 0C17EF         ALTER1 LODA,R0 ALTF    CHECK ALTER FLAG
1A36 E401                  COMI,R0 1       PATCH COMMAND
1A38 1807                  BCTR,EQ ALTER8  NOT PATCH
1A3A 0417                  LODI,R0 H'17'   BLANK CHAR
1A3C CC17D7                STRA,R0 DISBUF+6
1A3F 1B05                  BCTR,UN ALTER9  PATCH COMMAND
                    *
1A41 0C97DD         ALTER8 LODA,R0 *MEM    GET THE DATA
1A44 BBEA                  ZBSR   *BRKPT4  SET UP DATA VALUE DISPLAY
1A46 08EC           ALTER9 LODR,R0 *ALTER1+1    SET FLAG TO SINGLE BYTE DATA
1A48 BBFC                  ZBSR *GNPA    DISPLAY BUFFER AND WAIT FOR NEW ENTRY
1A4A 5B0C                  BRNR,R3 ALTER3   NO DATA
1A4C CC97DD                STRA,R0 *MEM    CHANGE DATA IN LOCATION
1A4F EC97DD                COMA,R0 *MEM    CHECK DATA STORED OK
1A52 1804                  BCTR,EQ ALTER3  DATA STORED OK
1A54 0703                  LODI,R3 3       ALTER OR PATCH WRITE ERROR
1A56 9BE8                  ZBRR    *ERR    GOTO ERROR
                    *
                    *EXIT FROM COMMAND
                    *
1A58 08DA           ALTER3 LODR,R0 *ALTER1+1    EXIT FROM ALTER OR PATCH
1A5A E401                  COMI,R0 1       IS IT PATCH
1A5C 9807                  BCFR,EQ ALTER6  IF YES TAKE THIS BRANCH
1A5E E687                  COMI,R2 H'87'   IS IT ALTER NEXT KEY FUNCTION?
1A60 9C187D         AL2    BCFA,EQ MON2    GO TO MONITOR NEW COMMAND
1A63 1B08                  BCTR,UN ALTER7   GO UPDATE THE DISPLAY
                    *
                    *EXIT FROM PATCH
                    *
1A65 E60F           ALTER6 COMI,R2 H'0F'   WAS LAST KEY FUNCTION KEY
1A67 19F8                  BCTR,GT *AL2+1 MON2    FUNCTION KEY WAS LAST GO TO MONITOR
1A69 0405                  LODI,R0 5       RETURN ON SECOND DIGIT FLAG
1A6B C8C7                  STRR,R0 *ALTER1+1       SAVE IN ALTF
1A6D CE17D8                STRA,R2 DISBUF+7        SET DISPLAY
                    *
                    *INCREMENT INDIRECT ADDRESS
                    *
1A70 3F1C55         ALTER7 BSTA,UN INK     INCREMENT THE ADDRESS
1A73 1F1A2D                BCTA,UN ALTER2
                    *
                    *PREPARE BIN DATA FOR DISPLAY
                    *
1A76 C1             DISLSI STRZ    R1      SAVE NUMBER IN R0
1A77 44F0                  ANDI,R0 H'F0'   MASK FOR MSD
1A79 450F                  ANDI,R1 H'0F'   MASK FOR LSD
1A7B BBF6                  ZBSR    *ROT    ROTATE A NIBBLE
1A7D 17                    RETC,UN
```

```
LINE ADDR  OBJECT  E SOURCE

                     ************************************************************
                     *
                     *
                     *DISPLAY AND ALTER REGISTERS COMMAND
                     *
                     *THE DISPLAY AND ALTER REGISTERS COMMAND ALLOWS
                     *THE USER TO EXAMINE AND ALTER R0,R1,R2,R3,R1',R2',R3',PSU,PSL,PC
                     *
                     *THIS COMMAND ALSO PROVIDES ENTRY POINT TO ALTERNATE FUNCTIONS
                     *REG 9 NOT DEFINED
                     *REG A ADJUST CASSETTE COMMAND
                     *REG B NOT DEFINED
                     *REG D NOT DEFINED
                     *REG E NOT DEFINED
                     *REG F ENTER THE FAST PATCH MODE
                     *
                     *REGISTERS USED
                     *
                     *R0 SCRATCH
                     *R1 SCRATCH
                     *R2 SCRATCH
                     *R3 SCRATCH
                     *
                     *SUBROUTINES CALLED
                     *
                     *MOV   MOVE DATA TO DISBUF
                     *GNP   GET NUMERIC PARAMETERS
                     *ROT   ROTATE A NIBBLE
                     *GNPA  DISPLAY AND GET NUMERIC PARAMETERS
                     *BRKPT4        SET DISPLAY 6&7
                     *SCBP2 SET DISPLAY 4&5
                     *
                     *RAM MEMORY USED
                     *
                     *DISBUF        DISPLAY BUFFER
                     *UREG  USER REGISTERS
                     *LADR  LAST ADDRESS REGISTER PC COUNTER
                     *T2  TEMP REGISTER
                     *
                     **************************************************************
     1A7E 051F       REG    LODI,R1 <REQ-1  GET ADDRESS OF R= DISPLAY
     1A80 06A4              LODI,R2 >REQ-1
     1A82 BBFE              ZBSR *MOV     MOVE DATA TO DISBUF
     1A84 20                EORZ    R0      SET FLAG TO RETURN AFTER KEY PRESSED
     1A85 BBEC              ZBSR    *DISPLY
                     *
     1A87 F480              TMI,R0  H'80'   SEE IF FUNCTION
     1A89 1882              BCTR,EQ *REG14+1 MON2    GOTO MONITOR
     1A8B E409              COMI,R0 9       CHECK THE COMMAND
     1A8D 1E1AC2            BCTA,LT REG2    DISPLAY AND ALTER REGISTERS R0 THRU PSL
     1A90 E40A              COMI,R0 H'0A'   IS IT ADJUST CASSETTE COMMAND
     1A92 1C1F32            BCTA,EQ TCAS    TEST CASSETTE
     1A95 E40C              COMI,R0 H'0C'   IS IT DISPLAY AND ALTER PC
     1A97 1807              BCTR,EQ REG3    DISPLAY AND ALTER PC
     1A99 E40F              COMI,R0 H'0F'   IS IT THE PATCH COMMAND
```

```
LINE ADDR  OBJECT  E SOURCE

1A9B 1C1A08            BCTA,EQ PTCH    DO THE PATCH COMMAND
1A9E 1B5E              BCTR,UN REG     NOT DEFINED TRY AGAIN
                 *
                 *DISPLAY AND ALTER PROGRAM COUNTER
                 *
1AA0 051F        REG3  LODI,R1 <PCEQ-1 GET ADDRESS OF PC EQUALS DISPLAY
1AA2 06AC              LODI,R2 >PCEQ-1
1AA4 BBFE              ZBSR    *MOV    MOVE DATA TO DISBUF
1AA6 088E              LODR,R0 *REG4+1  GET CURRENT PC ADDRESS
1AA8 BBEA              ZBSR  *BRKPT4  SET UP DISPLAY
1AAA 0C17E8      REG11 LODA,R0 LADR    GET MSB OF CURRENT PC
1AAD 3F1D8A            BSTA,UN SCBP2   SET UP DISPLAY
1AB0 20                EORZ    R0      SET FLAG TO DOUBLE BYTE
1AB1 BBFC              ZBSR *GNPA    DISPLAY ADDRESS AND WAIT FOR ENTRY
1AB3 5B05              BRNR,R3 REG5    DON'T CHANGE DATA
1AB5 CC17E9      REG4  STRA,R0 LADR+1  UP DATE THE PC SAVE LSB
1AB8 C9F1              STRR,R1 *REG11+1 SAVE MSB OF PC
1ABA E687        REG5  COMI,R2 H'87'   ENTR/NXT TERMINATION
1ABC 9C187D      REG14 BCFA,EQ MON2    IF NOT NEW FUNCTION EXIT
1ABF 1F1A7E            BCTA,UN REG     GO ASK FOR NEW REGISTER
                 *
                 *DISPLAY AND ALTER REGISTERS
                 *
1AC2 CC17E6      REG2  STRA,R0 T2      SAVE IT
1AC5 C3                STRZ    R3      SAVE R0 TO USE AS INDEX
1AC6 0510              LODI,R1 H'10'   P CHAR
1AC8 E707              COMI,R3 7       IS IT PSU
1ACA 1A0A              BCTR,LT REG8    NOT PSU PSL
1ACC 1904              BCTR,GT REG10   NOT PSU
1ACE 0412              LODI,R0 H'12'   CHAR U
1AD0 1B06              BCTR,UN REG12    GO DISPLAY
                 *
1AD2 0411        REG10 LODI,R0 H'11'   CHAR L
1AD4 1B02              BCTR,UN REG12    GO DISPLAY
                 *
1AD6 0513        REG8  LODI,R1 H'13'      CHAR R
1AD8 CD17D3      REG12 STRA,R1 DISBUF+2        SET DISPLAY RN=
1ADB CC17D4      REG9  STRA,R0 DISBUF+3        SET UP DISPLAY
1ADE 0F77F2            LODA,R0 UREG,R3 GET REGISTER CONTENT
1AE1 BBEA              ZBSR  *BRKPT4  SET UP DISPLAY
1AE3 0401              LODI,R0 1       SET FLAG TO SINGLE BYTE
1AE5 BBFC              ZBSR *GNPA    DISPLAY REG CONTENT AND WAIT FOR ENTRY
1AE7 5B0C              BRNR,R3 REG7    NO DATA TERMINATE
1AE9 0BD8        REG6  LODR,R3 *REG2+1        GET THE INDEX VALUE
1AEB CF77F2            STRA,R0 UREG,R3 PUT NEW VALUE IN REGISTER
1AEE E708              COMI,R3 8       IS IT PSL?
1AF0 9803              BCFR,EQ REG7    NO CHECK TERMINATION
1AF2 CC17FC            STRA,R0 UREG+10 SAVE FOR RESTORE OF PSL
1AF5 E687        REG7  COMI,R2 H'87'   CHECK TERMINATION
1AF7 98C4              BCFR,EQ *REG14+1 MON2    NEW FUNCTION
1AF9 03                LODZ    R3      INCREMENT INDEX VALUE
1AFA D800              BIRR,R0 $+2     INCREMENT REGISTER COUNT
1AFC E408              COMI,R0 8       ROLL OVER?
1AFE 9D1AC2      REG13 BCFA,GT REG2    NO UP DATE DISPLAY
1B01 20                EORZ    R0      GET A 0 GO TO R0
1B02 1BFB              BCTR,UN *REG13+1    UPDATE DISPLAY
```

LINE ADDR OBJECT E SOURCE

```
*********************************************************
*
*
*GET NUMERIC PARAMETERS
*
*
*THIS ROUTINE GETS EITHER 2 OR 4 DIGIT NUMERIC PARAMETERS
*
*INPUT PARAMETERS
*
*R0 CONTAINS INPUT PARAMETER
*
*BIT0 = 0 DOUBLE BYTE
*BIT0 = 1 SINGLE BYTE DATA TO BE RETURNED
*BIT1 = 0 REQUIRES FUNCTION KEY DEPRESSION TO EXIT
*BIT1 = 1 WHEN SET WITH BIT0 EXIT IS AFTER ENTRY OF THIRD DIGIT
*         OF SINGLE BYTE DATA
*BIT2 = 1 WHEN SET WITH BIT0 EXIT IS AFTER SECOND DIGIT
*         OF SINGLE BYTE DATA
*
*SINGLE BYTE DATA USES DISPLAY BUFFER 5 THRU 7
*DOUBLE BYTE DATA USES DISPLAY BUFFER 4 THRU 7
*OTHER DIGITS OF DISBUF MUST BE INITIALIZED ON ENTRY
*
*RETURNS WHEN FUNCTION KEY DEPRESSED
*
*OUTPUT PARAMETERS
*
*R0 = LSB OF DOUBLE BYTE DATA OR SINGLE BYTE DATA
*R1 = MSB OF DOUBLE BYTE DATA OR 0 FOR SINGLE BYTE DATA
*R2 = FUNCTION KEY PRESSED CODE
*R3 = 0 DATA RETURNED IN R0(LSB), R1(MSB)
*R3 = NOT 0 NO DATA RETURNED R0,R1 = 0
*
*REGISTERS USED
*
*R0 SCRATCH
*R1 SCRATCH
*R2 SCRATCH
*R3 SCRATCH
*
*SUBROUTINES CALLED
*
*DISPLY       DISPLAY AND READ KEY BOARD
*CLR BLANK DIGIT DISPLAY
*
*RAM MEMORY USED
*
*T1 SAVE ENTRY FLAG
*DISPLY 4 THRU 7
*
**********************************************************
*
*
*DISPLAY AD= AND GET DATA
```

```
LINE ADDR  OBJECT  E SOURCE

                      *
     1B04 051F        GAD    LODI,R1 <ADR-1  GET ADDRESS OF AD= DISPALY
     1B06 068C               LODI,R2 >ADR-1
     1B08 BBFE               ZBSR *MOV     MOVE DATA TO DISBUF
     1B0A 20                 EORZ    R0      SET FLAG TO DOUBLE BYTE DATA
     1B0B 1B2E               BCTR,UN GNPI     GET THE ADDRESS DATA
                      *
                      *THIS ROUTINE CLEARS DIGIT DISPLAY
                      *
     1B0D 0517        CLR    LODI,R1 H'17'   BLANK SYMBOL
     1B0F F401               TMI,R0  1       SINGLE BYTE?
     1B11 1803               BCTR,EQ CLR1    ONE BYTE DATA
     1B13 CD17D5             STRA,R1 DISBUF+4        INITIALIZE DISPLAY TO BLANK
     1B16 CD17D6      CLR1   STRA,R1 DISBUF+5        GET HERE FOR ONE BYTE DATA
     1B19 CD17D7             STRA,R1 DISBUF+6
     1B1C CD17D8             STRA,R1 DISBUF+7
     1B1F 17                 RETC,UN
                      *
                      *THIS ENTRY POINT ALLOWS DISPLAY OF DATA IN DISPLAY
                      *BUFFER 4 THRU 7
                      *
     1B20 C8A6        GNPAI  STRR,R0 *GNP12+1        SAVE INPUT FLAG IN T1
     1B22 0480               LODI,R0 H'80'   TURN ON DECIMAL POINT FOR ENTRY
     1B24 BBEC               ZBSR    *DISPLY DISPLAY MESSAGE AND READ KEY BOARD
     1B26 08A0               LODR,R0 *GNP12+1       GET INPUT PARAMETER
     1B28 F680               TMI,R2  H'80'   FUNCTION KEY?
     1B2A 9809               BCFR,EQ GNP13   FIRST CHAR IS COMMAND TERMINATE
     1B2C E687               COMI,R2 H'87'   ENTR/NXT?
     1B2E 1802               BCTR,EQ $+4
     1B30 3B5B               BSTR,UN CLR     CLEAR DISPLAY
     1B32 1F1B74             BCTA,UN GNP4
     1B35 F404        GNP13  TMI,R0  4       PATCH COMMAND RETURN SECOND DIGIT?
     1B37 3A54               BSTR,NG CLR     CLEAR DISPLAY
     1B39 1B0C               BCTR,UN GNP12
                      *
                      *THIS ENTRY POINT CLEARS DISPLAY AND WAITS FOR ENTRY
                      *
     1B3B C88B        GNPI   STRR,R0 *GNP12+1        SAVE INPUT FLAG IN T1
     1B3D 3B4E        GNP11  BSTR,UN CLR     CLEAR DISPLAY
     1B3F 0480        GNP2   LODI,R0 H'80'   TURN ON DECIMAL POINT FOR ENTRY
     1B41 BBEC               ZBSR *DISPLY  DISPLAY MESSAGE AND READ KEY BOARD
     1B43 F680        GNP5   TMI,R2  H'80'   FUNCTION KEY PRESSED?
     1B45 182D               BCTR,EQ GNP4    GO TERMINATE
                      *
                      *MOVE DISPLAY 1 DIGIT LEFT
                      *
     1B47 0C17E5      GNP12  LODA,R0 T1      GET INPUT PARAMETER
     1B4A F483               TMI,R0  H'83'   THIRD DIGIT *EXIT ON THIRD ENTRY*SINGLE BYTE
     1B4C 1826               BCTR,EQ GNP4    GO TERMINATE
     1B4E F425               TMI,R0  H'25'   2ND DIGIT*EXIT ON 2ND DIGIT*SINGLE BYTE
     1B50 1822               BCTR,EQ GNP4    GO TERMINATE
     1B52 F401               TMI,R0  1       SINGLE BYTE DATA?
     1B54 180B               BCTR,EQ GNP3    ONLY TWO DIGITS
     1B56 0D17D6      GN1    LODA,R1  DISBUF+5       GET DIGIT
     1B59 CD17D5      GN2    STRA,R1 DISBUF+4        SHIFT IT
     1B5C 0D17D7      GN3    LODA,R1 DISBUF+6        GET DIGIT
```

```
LINE ADDR  OBJECT  E SOURCE

1B5F C9F6                STRR,R1 *GN1+1        SHIFT IT
1B61 0D17D8       GNP3   LODA,R1 DISBUF+7       GET DIGIT
1B64 C9F7                STRR,R1 *GN3+1        SHIFT IT
1B66 CAFA                STRR,R2 *GNP3+1        ENTER NEW DIGIT
1B68 08DE                LODR,R0 *GNP12+1      GET INPUT PARAMETER
1B6A 7508                CPSL    WC      CLEAR WITH CARRY
1B6C 8440                ADDI,R0 H'40'   SET BEEN HERE ONCE FLAG
1B6E 6420                IORI,R0 H'20'   SET SECOND DIGIT FLAG
1B70 C8D6         GN4    STRR,R0 *GNP12+1      RESTORE THE FLAG
1B72 1B4B                BCTR,UN GNP2    GET NEXT ENTRY
                  *
                  *SET UP DATA TO BE RETURNED
                  *
1B74 20           GNP4   EORZ    R0      GET A 0
1B75 C1                  STRZ    R1      CLEAR R1 DATA
1B76 C3                  STRZ    R3      CLEAR R3
1B77 08CF                LODR,R0 *GNP12+1      GET INPUT PARAMETER
1B79 F401                TMI,R0  1       CHECK FOR SINGLE BYTE
1B7B 1812                BCTR,EQ GNP7    IF EQ ONLY 1 DIGIT
1B7D 0C9B5A              LODA,R0 *GN2+1 DISBUF+4        GET MSD OF MSB
1B80 E410                COMI,R0 H'10'   SEE IF HEX DIGIT
1B82 9A03                BCFR,LT GNP6    IF NOT SKIP TO NEXT DIGIT
1B84 3B1F                BSTR,UN ROTI     ROTATE NIBBLE
1B86 C1                  STRZ    R1      SAVE IN R1
1B87 08CE         GNP6   LODR,R0 *GN1+1 DISBUF+5        GET LSD OF MSB
1B89 E410                COMI,R0 H'10'   SEE IF HEX DIGIT
1B8B 9A02                BCFR,LT GNP7    IF NOT SKIP TO NEXT DIGIT
1B8D 61                  IORZ    R1      INCLUSIVE OR MSD AND LSD OF MSB
1B8E C1                  STRZ    R1      SAVE IN R1
1B8F 08CC         GNP7   LODR,R0 *GN3+1 DISBUF+6        GET MSD OF LSB
1B91 E410                COMI,R0 H'10'   SEE IF HEX DIGIT
1B93 9A03                BCFR,LT GNP8    IF NOT SKIP TO NEXT DIGIT
1B95 3B0E                BSTR,UN ROTI     ROTATE THE NIBBLE
1B97 C3                  STRZ    R3      SAVE IN R3
1B98 08C8         GNP8   LODR,R0 *GNP3+1 DISBUF+7        GET LSD OF LSB
1B9A E410                COMI,R0 H'10'   SEE IF HEX DIGIT
1B9C 9A04                BCFR,LT GNP9    IF NOT RETURN
1B9E 63                  IORZ    R3      INCLUSIVE OR MSD WITH LSD OF LSB
1B9F 0700                LODI,R3 0    SET DATA IN R0,R1 FLAG
1BA1 17                  RETC,UN
1BA2 077F         GNP9   LODI,R3 127     NO DATA
1BA4 17                  RETC,UN
                  *
                  *THIS ROUTINE ROTATES A NIBBLE 4 BITS LEFT
                  *
1BA5 7508         ROTI    CPSL    WC      CLEAR WITH CARRY
1BA7 D0                  RRL,R0
1BA8 D0                  RRL,R0
1BA9 D0                  RRL,R0
1BAA D0                  RRL,R0
1BAB 17                  RETC,UN
```

```
LINE ADDR  OBJECT  E SOURCE

                    ********************************************************
                    *
                    *
                    *READ CASSETTE COMMAND
                    *
                    *
                    *
                    *THIS IS THE HEX OBJECT LOADER
                    *
                    *THIS ROUTINE REQUESTS A FILE ID AND THEN LOADS 2650 HEX OBJECT MODULES
                    *INTO MEMORY
                    *
                    *REGISTERS USED
                    *
                    *ALL
                    *
                    *SUBROUTINES CALLED
                    *
                    *IN CASSETTE INPUT ROUTINE
                    *MOV   MOVE DATA TO DISPLAY BUFFER
                    *GNP   GET NUMERIC PARAMETERS
                    *
                    **********************************************************************
                    *
                    *
     1BAC 051F      RCAS   LODI,R1 <FEQ-1  GET ADDRESS OF F= DISPLAY
     1BAE 06B4             LODI,R2 >FEQ-1
     1BB0 BBFE             ZBSR *MOV     MOVE DATA TO DISBUF
     1BB2 0401             LODI,R0 1      SET FLAG FOR SINGLE BYTE
     1BB4 BBFA             ZBSR    *GNP    GET THE FILE ID
     1BB6 180A             BCTR,EQ RCAS1   FILE ID SPECIFIED
     1BB8 E687             COMI,R2 H'87'   ENTR/NXT KEY?
     1BBA 988C             BCFR,EQ *RCAS4+1       GODO NEW FUNCTION
     1BBC 047F             LODI,R0 127     SET FILE ID FLAG TO FILE ID FOUND
     1BBE C8A4             STRR,R0 *RCAS5+1       STORE IN FILE ID FLAG
     1BC0 1B24             BCTR,UN LOAD
                    *
                    *
                    *FILE ID SPECIFIED
                    *
     1BC2 CC17E0    RCAS1  STRA,R0 FID+1   SAVE FILE ID
     1BC5 E687             COMI,R2 H'87'   ENTR/NXT KEY?
     1BC7 9C187D    RCAS4  BCFA,EQ MON2    GO DO NEW FUNCTION
     1BCA 20               EORZ    R0      SET FILE ID TO ID NOT FOUND
     1BCB C897             STRR,R0 *RCAS5+1       STORE IN FILE ID FLAG
     1BCD 75FD             CPSL    H'FD'     CLEAR PSL
     1BCF BBEE      RCAS2  ZBSR    *IN     LOOK FOR BEGINNING OF FILE
     1BD1 E416             COMI,R0 H'16'   BEGINNING OF FILE CHAR?
     1BD3 987A             BCFR,EQ RCAS2   LOOP TILL FIND BEGIN OF FILE
     1BD5 3F1C28           BSTA,UN BIN     GET THE FILE ID
     1BD8 E9E9             COMR,R1 *RCAS1+1  CHECK FILE ID FOR MATCH
     1BDA 1805             BCTR,EQ RCAS3   FOUND A MATCH
     1BDC 20               EORZ    R0      GET A 0
     1BDD C885             STRR,R0 *RCAS5+1 NO MATCH SAVE IN FID FLAG
     1BDF 1B05             BCTR,UN LOAD
```

```
LINE ADDR  OBJECT  E SOURCE

1BE1 047F        RCAS3  LODI,R0 127     SET FLAG TO FILE IS MATCH
1BE3 CC17DF      RCAS5  STRA,R0 FID     FILE ID FOUND
1BE6 75FD        LOAD   CPSL    H'FD'    CLEAR PSL
1BE8 BBEE               ZBSR    *IN     GET A CHAR
1BEA E43A               COMI,R0 A':'    START OF LINE CHAR?
1BEC 9878               BCFR,EQ LOAD    LOOP TILL FIND START FO RECORD
1BEE 20                 EORZ    R0      GET A 0
1BEF CC17E1             STRA,R0 BCC     PRESET BCC
1BF2 3B34               BSTR,UN BIN     INPUT A BYTE OF DATA
1BF4 CD17DD             STRA,R1 MEM HI ADDR
1BF7 3B2F               BSTR,UN BIN INPUT A BYTE OF DATA
1BF9 CD17DE             STRA,R1 MEM+1 LO ADDR
1BFC 3B2A               BSTR,UN BIN INPUT A BYTE OF DATA
1BFE 01                 LODZ    R1
1BFF 1C1C42             BCTA,EQ LOAD1  GO T0 START OF PROGRAM IF BYTE COUNT 0
1C02 C3                 STRZ    R3      SAVE BYTE COUNT
1C03 08DF               LODR,R0 *LOAD-2 GET FILE ID FLAG
1C05 185F               BCTR,EQ LOAD    FILE ID NOT FOUND SKIP TO END OF FILE
1C07 3B1F               BSTR,UN BIN INPUT A BYTE OF DATA
1C09 1804               BCTR,EQ BLOA    BCC OK READ THE RECORD
1C0B 0704        BLOA1  LODI,R3 4       BCC ERROR
1C0D 9BE8               ZBRR    *ERR    GOTO ERROR
1C0F 3B17        BLOA   BSTR,UN BIN INPUT A BYTE OF DATA
1C11 CD97DD             STRA,R1 *MEM STORE DATA IN MEMORY
1C14 ED97DD             COMA,R1 *MEM    DO THE ERROR CHECK
1C17 1804               BCTR,EQ BLOA2   DATA STORED OK
1C19 0705               LODI,R3 5       READ CASSETTE MEMORY WRITE ERROR
1C1B 9BE8               ZBRR    *ERR    GOTO ERROR
1C1D 3B36        BLOA2  BSTR,UN INK INCREMENT POINTER MEM
1C1F FB6E               BDRR,R3 BLOA LOOP TILL DONE
1C21 3B05               BSTR,UN BIN INPUT A BYTE OF DATA
1C23 9866               BCFR,EQ BLOA1 BCC ERROR
1C25 1F1BE6             BCTA,UN LOAD
                 *
                 * INPUT A PAIR OF HEX ASCII CHAR
                 *CONVERT TO BINARY
                 *OUTPUT IS IN R1
                 *CALCULATE BCC ON DATA
                 *
1C28 BBEE        BIN    ZBSR    *IN INPUT A CHAR
1C2A 7509               CPSL    C+WC    CLEAR CARRY AND WITH CARRY
1C2C 3B36        BIN1   BSTR,UN AHO3    LOOK UP VALUE
1C2E 02                 LODZ    R2      PUT VALUE IN R0
1C2F BBF6               ZBSR    *ROT    ROTATE VALUE
1C31 C1                 STRZ    R1      SAVE VALUE IN R1
1C32 BBEE               ZBSR    *IN     GET A CHAR
1C34 7509               CPSL    C+WC    CLEAR CARRY AND WITH CARRY
1C36 3B2C               BSTR,UN AHO3    LOOK UP VALUE
1C38 01                 LODZ    R1      GET SAVED VALUE
1C39 62                 IORZ    R2      MAKE THE BINARY BYTE
                 *
                 *CALCULATE BCC
                 *
1C3A C1          CBCC   STRZ    R1      SAVE VALUE
1C3B 2C17E1             EORA,R0 BCC     XOR WITH CURRENT BCC
1C3E D0                 RRL,R0          ROTATE LEFT
```

```
LINE ADDR  OBJECT  E SOURCE

1C3F C8FB                STRR,R0 *CBCC+2 UPDATE THE BCC
1C41 17                  RETC,UN
                   *
                   *
                   *FINISHED READING FILE
                   *
1C42 0C17DF        LOAD1  LODA,R0 FID     CHECK FILE ID FLAG FOR FILE ID FOUND
1C45 1C1BCF              BCTA,EQ RCAS2   NO LOOK FOR START OF NEXT FILE
1C48 088F                LODR,R0 *INK2+1 GET VALUE FROM MEM     PLACE START ADDRESS IN PC
1C4A CC17E8              STRA,R0 LADR
1C4D 0887                LODR,R0 *INK+1  GET VALUE FROM MEM+1
1C4F CC17E9              STRA,R0 LADR+1
1C52 1F1874              BCTA,UN MON3     GO TO THE MONITOR
                   *
                   *INCREMENT ADDRESS MEM
                   *
1C55 0C17DE        INK    LODA,R0 MEM+1   GET ADDRESS
1C58 0E17DD        INK2   LODA,R2 MEM
1C5B D802                BIRR,R0 INK1    INCREMENT IT
1C5D DA00                BIRR,R2 INK1
1C5F C8F5          INK1   STRR,R0 *INK+1   SAVE  IN MEM+1
1C61 CAF6                STRR,R2 *INK2+1 SAVE IN MEM
1C63 17                  RETC,UN
                   *
                   *LOOK UP ASCII HEX TO CONVERT TO BINARY
                   *
1C64 06FF          AHO3   LODI,R2 255     PRESET INDEX
1C66 EE3FC5              COMA,R0 ASCII,R2,+      CHECK THE VALUE
1C69 14                  RETC,EQ RETURN IF EQUAL
1C6A E610                COMI,R2 H'10'   CHECK FOR MAX COUNT
1C6C 9878                BCFR,EQ AHO3+2  LOOP
1C6E 0706                LODI,R3 6       CHAR NOT ASCII HEX
1C70 9BE8                ZBRR    *ERR    GOTO ERROR
                   *
                   *CARRAGE RETURN AND LINE FEED
                   *
1C72 040D          CRLFF  LODI,R0 13      CARRAGE RETURN
1C74 BBF0                ZBSR *OUT       PRINT
1C76 040A                LODI,R0 10      LINE FEED
1C78 BBF0                ZBSR *OUT       PRINT
1C7A 17                  RETC,UN
                   *
                   *CONVERT BINARY TO ASCII HEX AND PRINT
                   *
1C7B 7508          HOUTT   CPSL    WC
1C7D BBF4                ZBSR    *DISLSD CONVERT BIN TO NIBBLE
1C7F C2                  STRZ    R2      SAVE IN R2
1C80 0E7FC5              LODA,R0 ASCII,R2        TENS DIGIT
1C83 BBF0                ZBSR    *OUT    PRINT TENS DIGIT
1C85 0D7FC5              LODA,R0 ASCII,R1        GET UNITS DIGIT
1C88 BBF0                ZBSR *OUT       PRINT UNITS DIGIT
1C8A 17                  RETC,UN
```

```
LINE ADDR  OBJECT  E SOURCE

                   **********************************************************
                   *
                   *
                   *WRITE CASSETTE COMMAND
                   *
                   *THIS ROUTINE WRITES 2650 HEX FORMAT TO CASSETTE TAPE
                   *
                   *REGISTERS USED
                   *
                   *R0 SCRATCH
                   *R1 SCRATCH
                   *R2 SCRATCH
                   *R3 SCRATCH
                   *
                   *SUBROUTINES CALLED
                   *
                   *OUT WRITE CHAR TO TAPE
                   *HOUT CONVERT BINARY TO ASCII HEX AND WRITE TO TAPE
                   *INK INCREMENT POINTER MEM
                   *
                   *RAM USED
                   *
                   *BCC   BLOCK CHECK CHAR
                   *MEM   POINTER
                   *BAD   PROGRAM START ADDRESS
                   *SAD   DUMP STOP ADDRESS
                   *FID   FILE ID FLAG AND STORAGE
                   *
                   *THIS ROUTINE PUNCHES A HEX FORMAT TAPE
                   *
                   *
                   *   LEADER16ID:ADDRCTBCAADDCCRR........BC
                   *
                   *********************************************************************
                   *
                   *
     1C8B 20       WCAS4  EORZ    R0       GET A 0
     1C8C BBFA            ZBSR    *GNP     GET NUMBER
     1C8E E687            COMI,R2 H'87'    ENTR/NXT KEY
     1C90 17              RETC,UN
                   *
                   *
     1C91 051F     WCAS   LODI,R1 <LADEQ-1         GET ADDRESS OF LAD= DISPLAY
     1C93 06BC            LODI,R2 >LADEQ-1
     1C95 BBFE            ZBSR    *MOV     MOVE TO DISPLAY BUFFER
     1C97 3B72            BSTR,UN WCAS4    GET ADDRESS DATA
     1C99 988E            BCFR,EQ *WCAS6+1 MON2     IF NOT EXIT
     1C9B CD17DD          STRA,R1 MEM      SAVE START ADDRESS
     1C9E CC17DE          STRA,R0 MEM+1
     1CA1 0412            LODI,R0 H'12'    CHANGE DISPLAY
     1CA3 CC17D1          STRA,R0 DISBUF   DISPLAY 'UAD=    '
     1CA6 3B63            BSTR,UN WCAS4    GET ADDRESS DATA
     1CA8 9C187D   WCAS6  BCFA,EQ MON2     NOT ENTR/NXT MUST BE NEW COMMAND
                   *
                   *CHECK FOR START ADDRESS GT THAN STOP
```

```
LINE ADDR  OBJECT  E SOURCE

1136                 *
1137 1CAB ED17DD          COMA,R1 MEM     CHECK HI BYTE
1138 1CAE 1806            BCTR,EQ WCAS7
1139 1CB0 1909            BCTR,GT WCAS9
1140 1CB2 0707       WCAS8  LODI,R3 7       SET THE ERROR NUMBER
1141 1CB4 9BE8            ZBRR   *ERR     GOTO ERROR
1142 1CB6 EC17DE     WCAS7  COMA,R0 MEM+1   CHECK LO BYTE
1143 1CB9 1A77            BCTR,LT WCAS8
1144                 *
1145 1CBB D802       WCAS9  BIRR,R0 WCASA   INCREMENT STOP ADDRESS
1146 1CBD D900            BIRR,R1 WCASA   SO DUMP IS INCLUSIVE
1147 1CBF CD17C8     WCASA  STRA,R1 EAD     SAVE END ADDRESS
1148 1CC2 CC17C9            STRA,R0 EAD+1
1149 1CC5 0405            LODI,R0 H'05'   CHANGE DISPLAY
1150 1CC7 CC17D1            STRA,R0 DISBUF  DISPLAY 'SAD=    '
1151 1CCA 3F1C8B            BSTA,UN WCAS4   GET PROGRAM START ADDRESS
1152 1CCD 9C9CA9     WCAS3  BCFA,EQ *WCAS6+1 MON2   GOTO MONITOR NEW FUNCTION
1153 1CD0 CD17CA            STRA,R1 BAD     SAVE START ADDRESS
1154 1CD3 CC17CB            STRA,R0 BAD+1
1155 1CD6 051F            LODI,R1 <FEQ-1  GET ADDRESS OF F= DISPLAY
1156 1CD8 06B4            LODI,R2 >FEQ-1
1157 1CDA BBFE            ZBSR *MOV      MOVE DATA TO DISBUF
1158 1CDC 0401            LODI,R0 1       SET FLAG TO SINGLE BYTE
1159 1CDE BBFA            ZBSR *GNP     GET THE FILE ID
1160 1CE0 E687            COMI,R2 H'87'   ENTR/NXT KEY
1161 1CE2 98C5            BCFR,EQ *WCAS6+1 MON2    EXIT NEW COMMAND
1162 1CE4 C894            STRR,R0 *WCAS5+1   SAVE FILE ID
1163 1CE6 060A            LODI,R2 10      SET THE DELAY
1164 1CE8 0719       PUN10  LODI,R3 25
1165 1CEA 20               EORZ    R0       GET A 0
1166 1CEB BBF0            ZBSR    *OUT    OUTPUT A LEADER
1167 1CED FB7B            BDRR,R3 PUN10+2
1168 1CEF 12              SPSU        GET FLAG
1169 1CF0 2440            EORI,R0 H'40'   COMPLEMENT IT
1170 1CF2 92              LPSU        RESTORE IT
1171 1CF3 FA73            BDRR,R2 PUN10     DECREASE THE COUNT
1172 1CF5 0416            LODI,R0 H'16' START OF FILE CHAR
1173 1CF7 BBF0            ZBSR *OUT       PRINT
1174 1CF9 0C17E0     WCAS5  LODA,R0 FID+1   GET FILE ID
1175 1CFC BBF2            ZBSR *HOUT      CONVERT TO ASCII HEX AND PRINT
1176 1CFE BBF8       PUN2   ZBSR    *CRLF   OUTPUT CARRAGE RETURN AND LINE FEED
1177 1D00 043A            LODI,R0 A':'    START OF BLOCK CHAR
1178 1D02 BBF0            ZBSR    *OUT    PRINT
1179 1D04 20              EORZ    R0      GET A 0
1180 1D05 C8A3            STRR,R0 *PUN3+1      PRESET BCC
1181 1D07 0C17C8            LODA,R0 EAD CALCULATE NO OF BYTES TO OUTPUT
1182 1D0A 7709            PPSL    WC+C    SET CARRY AND WITH CARRY
1183 1D0C 0F17C9            LODA,R3 EAD+1   GET END ADDRESS
1184 1D0F ABAC            SUBR,R3 *BDUM1+1 MEM+1  SUBTRACT START ADDRESS FROM STOP ADDRESS
1185 1D11 A8A5            SUBR,R0 *BDUM+1 MEM
1186 1D13 7508            CPSL    WC      CLEAR WITH CARRY
1187 1D15 1E1CB2            BCTA,NG WCAS8   START > STOP
1188                 *
1189                 *
1190 1D18 581B       PUN4   BRNR,R0 ADUM    START ADDRESS GT THAN 256 AWAY FROM STOP
1191 1D1A 5B15            BRNR,R3 GDUM    START ADDRESS LT 256 AWAY FROM STOP
```

```
LINE ADDR  OBJECT  E SOURCE

     1D1C 0C17CA             LODA,R0 BAD THIS IS END OF FILE BLOCK
     1D1F 3B39               BSTR,UN EDUM SO OUTPUT START ADDRESS OF PROGRAM
     1D21 0C17CB             LODA,R0 BAD+1
     1D24 3B34               BSTR,UN EDUM    OUTPUT A BYTE AS 2 ASCII HEX CHARS
     1D26 20                 EORZ    R0      END OF FILE BLOCK
     1D27 3B31               BSTR,UN EDUM OUTPUT BYTE COUNT
     1D29 0C17E1      PUN3   LODA,R0 BCC     GET BCC
     1D2C 3B2C               BSTR,UN EDUM OUTPUT BCC
     1D2E 1F1874             BCTA,UN       MON3      GOTO MONITOR
                      *
                      *
     1D31 E71E        GDUM   COMI,R3 H'1E'   IS START LT 30 AWAY FROM STOP
     1D33 1A02               BCTR,LT BDUM    OUTPUT LAST BYTES
     1D35 071E        ADUM   LODI,R3 H'1E'   NO OF BYTES THIS RECORD IS 30
     1D37 0C17DD      BDUM   LODA,R0 MEM     OUT ADDR HI
     1D3A 3B1E               BSTR,UN EDUM    OUTPUT BYTE AS 2 ASCII HEX CHARS
     1D3C 0C17DE      BDUM1  LODA,R0 MEM+1   OUT ADDR LO
     1D3F 3B19               BSTR,UN EDUM    OUTPUT BYTE AS 2 ASCII HEX CHARS
     1D41 03                 LODZ    R3      OUT BYTE COUNT
     1D42 3B16               BSTR,UN EDUM    OUTPUT BYTE AS 2 ASCII HEX CHARS
     1D44 08E4               LODR,R0 *PUN3+1     OUT BCC FOR ADDR AND BYTE COUNT
     1D46 3B12               BSTR,UN EDUM    OUTPUT BYTE AS 2 ASCII HEX CHARS
     1D48 0C97DD      DDUM   LODA,R0 *MEM    OUTPUT DATA FROM MEM
     1D4B 3B0D               BSTR,UN EDUM    OUTPUT BYTE AS 2 ASCII HEX CHARS
     1D4D 3F1C55             BSTA,UN INK     INCREMEMT POINTER MEM
     1D50 FB76               BDRR,R3 DDUM    LOOP TILL DONE
     1D52 0C17E1             LODA,R0 BCC     GET BCC
     1D55 3B03               BSTR,UN EDUM    OUTPUT BCC FOR DATA
     1D57 1F1CFE             BCTA,UN PUN2
                      *
     1D5A 3F1C3A      EDUM   BSTA,UN CBCC    CALCULATE BCC
     1D5D 01                 LODZ    R1      GET VALUE TO OUTPUT
     1D5E BBF2               ZBSR    *HOUT   PRINT AS 2 ASCII HEX CHARS
     1D60 17                 RETC,UN
```

```
LINE ADDR  OBJECT  E SOURCE

                     *****************************************************
                     *
                     *
                     *SET OR CLEAR BREAK POINT
                     *
                     *
                     *TO SET BREAK POINT ENTR ADDRESS AND DEPRESS FUNCTION KEY
                     *TO CLEAR BREAK POINT DEPRESS FUNCTION KEY
                     *
                     *SUBROUTINES CALLED
                     *
                     *MOV MOVE DATA TO DISBUF
                     *GNPA DISPLAY AND GET ADDRESS DATA
                     *ROT ROTATE A NIBBLE
                     *SCBP2 SET DISBUF 4&5
                     *BRKPT4 SET DISBUF 6&7
                     *DSLSD CONVERT TO BINARY FOR DISPLAY
                     *
                     *RAM MEMORY USED
                     *
                     *BPF BREAK POINT FLAG
                     *BPL LOCATION OF BREAK POINT
                     *BPD DATA TO BE RESTORED IN BREAK POINT LOCATION
                     *
                     *
                     *
                     **************************************************************
                     *
     1D61 051F       SCBP   LODI,R1 <BPEQ-1  GET ADDRESS OF BP= DISPALY
     1D63 069C              LODI,R2 >BPEQ-1
     1D65 BBFE              ZBSR *MOV     MOVE DATA TO DISBUF
     1D67 0C17CF            LODA,R0 BPF     BREAK POINT SET?
     1D6A 180A              BCTR,EQ SCBP1   NOT SET GET ADDRESS
                     *
                     *BREAK POINT SET SET UP ADDRESS DISPLAY
                     *
     1D6C 0C17CE            LODA,R0 BPL+1   PREPARE THE ADDRESS
     1D6F BBEA              ZBSR  *BRKPT4  SET UP DISPLAY
     1D71 0C17CD            LODA,R0 BPL     GET MSB
     1D74 3B14              BSTR,UN SCBP2   SETUP DISPLAY
     1D76 20         SCBP1  EORZ    R0      SET UP GET NUMBER PARAMETER TO 4 DIGIT
     1D77 BBFC              ZBSR *GNPA    GET THE ADDESS IF ANY
     1D79 1818              BCTR,EQ SCBP4   SET THE BREAK POINT
                     *
                     *THIS SECTION CLEARS THE BREAK POINT
                     *
     1D7B 0B88              LODR,R3 *SCBP6+1     CHECK BREAK POINT FLAG
     1D7D 1889              BCTR,EQ *SCBP5+1    BREAK POINT NOT SET GO TO MONITOR
     1D7F E681              COMI,R2 H'81'   IS TERMINATION BKP?
     1D81 9885              BCFR,EQ *SCBP5+1    NO LEAVE BREAK POINT SET GO TO MONITOR
     1D83 20                EORZ    R0      GET A 0
     1D84 CC17CF     SCBP6  STRA,R0 BPF     CLEAR BREAK POINT FLAG
     1D87 1F1D7D     SCBP5  BCTA,UN MON2    GO TO MONITOR
                     *
     1D8A BBF4       SCBP2  ZBSR    *DISLSD CONVERT TO BIN FOR DISPLAY
```

```
LINE ADDR  OBJECT  E SOURCE

     1D8C CD17D6          STRA,R1 DISBUF+5
     1D8F CC17D5          STRA,R0 DISBUF+4
     1D92 17              RETC,UN
                    *
                    *THIS SECTION SETS THE BREAK POINT
                    *
     1D93 CC17CE    SCBP4 STRA,R0 BPL+1   SET BREAK POINT ADDRESS
     1D96 CD17CD          STRA,R1 BPL
     1D99 20              EORZ    R0      CLEAR BREAK POINT FLAG
     1D9A C8E9            STRR,R0 *SCBP6+1        CHECK THE BREAK POINT CAN BE SET
     1D9C 0C97CD          LODA,R0 *BPL    GET DATA FROM BREAK POINT LOCATION
     1D9F 05B0            LODI,R1 H'B0'   BREAK POINT INSTRUCTION..WRTC,R0
     1DA1 CD97CD          STRA,R1 *BPL    TRY TO SET BREAK POINT
     1DA4 ED97CD          COMA,R1 *BPL    DID IT SET OK?
     1DA7 1804            BCTR,EQ SCBP7   BREAK POINT CAN BE SET
     1DA9 0701            LODI,R3 1       CANT SET BREAK POINT ERROR
     1DAB 9BE8            ZBRR    *ERR    GOTO ERROR
     1DAD CC97CD    SCBP7 STRA,R0 *BPL    RESTORE USER DATA
     1DB0 047F            LODI,R0 127     SET THE BREAK POINT FLAG
     1DB2 C8D1            STRR,R0 *SCBP6+1        SET IT
     1DB4 1BD2            BCTR,UN *SCBP5+1    GOTO MONITOR
```

```
LINE ADDR  OBJECT  E SOURCE

                     ******************************************************
                     *
                     *
                     *MOVE 8 BYTES OF DATA POINTED TO IN R1 AND R2 TO DISBUF
                     *
                     *
                     *REGISTERS USED
                     *
                     *R0 SCRATCH
                     *R1 HI ADDRESS BYTE OF DATA ADDRESS-1
                     *R2 LO ADDRESS BYTE OF DATA ADDRESS-1
                     *R3 NOT USED
                     *
                     *SUBROUTINES CALLED
                     *
                     *NONE
                     *
                     *RAM MEMORY USED
                     *
                     *T TEMP INDIRECT ADDRESS
                     *
                     *********************************************************
                     *
     1DB6 CD17E3     MOVI   STRA,R1 T         SET INDIRECT ADDRESS
     1DB9 CE17E4            STRA,R2 T+1
     1DBC 0608              LODI,R2 8         SET INDEX TO MOVE 8 BYTES
     1DBE 0EF7E3     MOV1   LODA,R0 *T,R2     GET A BYTE
     1DC1 CE77D0            STRA,R0 DISBUF-1,R2         MOVE TO BUFFER
     1DC4 FA78              BDRR,R2 MOV1
     1DC6 17                RETC,UN
```

```
LINE ADDR  OBJECT  E SOURCE

                      **********************************************************
                      *
                      *
                      *KEY BOARD SCAN AND DISPLAY ROUTINE
                      *
                      *THIS ROUTINE WRITTEN BY ALEX GOLDBURGER
                      *
                      *
                      *TO USE THIS ROUTINE PLACE DATA TO BE DISPLAYED
                      *IN DISBUF (SEE CODES AT BEGINNING OF PROGRAM)
                      *
                      *ON ENTRY R0 CONTAINS A FLAG
                      *
                      *R0 = 0 NORMAL OPERATION
                      *       ON EXIT R0 = KEY PRESSED CODE
                      *R0 = 1-127 GO THRU SCAN ONCE AND EXIT
                      *           ON EXIT R0 = KEY PRESSED CODE
                      *R0 = H'80' TURN ON DECIMAL POINT FOR ENTRY MODE
                      *           ON EXIT R0 = KEY PRESSED CODE
                      *
                      *SEE KEY PRESSED CODES AT BEGINNING OF PROGRAM
                      *
                      *REGISTERS USED IN BANK ON ENTRY
                      *
                      *R0    SCRATCH
                      *R1    KEYBOARD FLAGS
                      *R2    DIGIT SELECT
                      *R3    DIGIT POINTER
                      *
                      *SUBROUTINES CALLED
                      *
                      *NONE
                      *
                      *RAM MEMORY USED
                      *
                      *DISBUF        DISPLAY BUFFER
                      *KFLG  KEY BOARD FLAG
                      *
                      **********************************************************
                      *
     1DC7 0406        DLOOP  LODI,R0 6       DELAY TO MAKE LOOPS EQUAL
     1DC9 F87E               BDRR,R0 $
     1DCB 52          DLOOP1 RRR,R2  ROTATE DIGIT SELECT
     1DCC 0F77D0             LODA,R0 DISBUF-1,R3       GET DATA TO BE DISPLAYED
     1DCF C1                 STRZ    R1      SAVE DISPLAY CODE
     1DD0 4580               ANDI,R1 H'80'   MASK FOR DECIMAL POINT
     1DD2 447F               ANDI,R0 H'7F'   MASK OFF DECIMAL POINT
     1DD4 0C7F68             LODA,R0 SEGTBL,R0       CONVERT TO SEGMENT DATA
     1DD7 61                 IORZ    R1      SET THE DECIMAL POINT IF NEEDED
     1DD8 F601               TMI,R2  H'01'   COL 7?
     1DDA 1A08               BCTR,NG DLOOP3  DONT PUT DECIMAL POINT HERE
     1DDC 0D17ED             LODA,R1 KFLG+1  GET FLAG
     1DDF 9A03               BCFR,NG DLOOP3  IF FLAG NOT NEG NO DECIMAL POINT
     1DE1 4580               ANDI,R1 H'80'   MASK DECIMAL POINT
     1DE3 61                 IORZ    R1      SET DECIMAL POINT
```

```
ADDR OBJECT  E SOURCE

1DE4 0500      DLOOP3 LODI,R1 0        GET A 0
1DE6 D5F9             WRTE,R1 SEG      TURN OFF SEGMENTS
1DE8 D6FA             WRTE,R2 DIGIT    ENABLE NEXT DIGIT
1DEA D4F9             WRTE,R0 SEG      AND DISPLAY IT
1DEC 0C17EC           LODA,R0 KFLG     SEE IF KEY IS DOWN?
1DEF 980B             BCFR,EQ DLOOP4   KEY UP DEBOUNCE
1DF1 1B1A             BCTR,UN DLOOP5   IS KEY DOWN?
               *
1DF3 FB52      DLOOP2 BDRR,R3 DLOOP    DECREMENT DIGIT PTR
               *                       TEST IF ONE SCAN IS DONE.
               *                       IF ONE SCAN DONE INITIALIZE SCAN
               *                       PARAMETERS AND KEY FLAGS
1DF5 0C17ED           LODA,R0  KFLG+1 CHECK FOR ONE PASS THEN EXIT MODE
1DF8 1933             BCTR,GT DISP3    IF ONE PASS EXIT
1DFA 1B23             BCTR,UN DISP4    RESET THE FLAGS
               *
               *
1DFC 3B28      DLOOP4 BSTR,UN GETKEY   GET A KEY
1DFE 9806             BCFR,EQ DLP0     KEY IS DOWN RESET DEBOUNCE
1E00 0887             LODR,R0 *DLP1+1 KFLG+2  GET COUNTER VALUE
1E02 F804             BDRR,R0 DLP1
1E04 1B14             BCTR,UN DISP1    SET FLAG TO ACCEPT KEY
1E06 0460      DLP0   LODI,R0 H'60'    SET THE DELAY COUNT
1E08 CC17EE    DLP1   STRA,R0 KFLG+2   SAVE DELAY COUNT
1E0B 1B66             BCTR,UN DLOOP2   DO THE NEXT SCAN
               *
               *
1E0D 3B17      DLOOP5 BSTR,UN GETKEY   IS A KEY DOWN?
1E0F 1862             BCTR,EQ DLOOP2     NO
1E11 1B24             BCTR,UN CODE
               *
               *ENTRY TO DISPLAY ROUTINE HERE
               *
1E13 CC17ED    DISPLI STRA,R0 KFLG+1   SAVE INPUT PARAMETER
1E16 0460      DISP2  LODI,R0 H'60'    KEY WAS DOWN - SET KFLG
               *                       NOT TO ACCEPT KEY NEXT SCAN
1E18 C8EF             STRR,R0 *DLP1+1 KFLG+2  SET KEY DEBOUNCE DELAY
1E1A CC17EC    DISP1  STRA,R0 KFLG     SAVE KFLG
1E1D 7509             CPSL    C+WC     CLEAR CARRY AND WITH CARRY
1E1F 0708      DISP4  LODI,R3 H'08'    INITIALIZE DIGIT POINTER
1E21 0601             LODI,R2 H'01'    AND DIGIT SELECT
1E23 1F1DCB           BCTA,UN DLOOP1   GO DISPLAY
               *
               *GET KEY CODE
               *
1E26 55FE      GETKEY REDE,R1 KBDIN    READ KEYBOARD
1E28 450F             ANDI,R1 H'0F'    MASK OFF UNUSED BITS
1E2A 250F             EORI,R1 H'0F'    INVERT THE INPUT
1E2C 17               RETC,UN
               *
               *SINGLE PASS EXIT
               *
1E2D 040A      DISP3  LODI,R0 10
1E2F F87E             BDRR,R0 $        DELAY
1E31 D4F9             WRTE,R0 SEG      TURN OFF SEGMENTS
1E33 0488             LODI,R0 H'88'    NO KEY PRESSED CODE
```

```
LINE ADDR  OBJECT  E SOURCE

     1E35 C2                  STRZ     R2      SAVE IN R2
     1E36 17                  RETC,UN
                    *
                    *CONVERT KEY LINE DATA TO KEY CODE
                    *
     1E37 20        CODE      EORZ     R0      GET A 0
     1E38 D4F9                WRTE,R0 SEG      TURN OFF SEGMENTS
     1E3A A701                SUBI,R3 1        DECREMENT COLUMN COUNTER
     1E3C D4FA                WRTE,R0 DIGIT    TURN OFF COLUMNS
     1E3E 0604      CODE1     LODI,R2 4        LOOP COUNT
     1E40 51        CODE4     RRR,R1           GET WEIGHT OF KEY LINE
     1E41 E580                COMI,R1 H'80'    CHECK FOR 1 KEY DOWN
     1E43 1808                BCTR,EQ CODE2    R0 = 0,4,8, OR H'C'
     1E45 8404                ADDI,R0 H'04'
     1E47 FA77                BDRR,R2 CODE4    CHECK FOR ONLY 1 KEY
     1E49 0708                LODI,R3 8        MORE THAN 1 KEY DOWN OR NO KEY DOWN
     1E4B 9BE8                ZBRR     *ERR    GOTO ERROR
     1E4D E704      CODE2      COMI,R3 H'04'    NUMBER OR FUNCTION KEY?
     1E4F 1A05                BCTR,LT CODE3    # KEY
     1E51 50                  RRR,R0           DIVIDE KEYLINE WEIGHT BY 2
     1E52 6480                IORI,R0 H'80'    FUNCTION KEY DESIGNATOR
     1E54 4701                ANDI,R3 H'01'    RETAIN LSB ONLY
     1E56 83        CODE3     ADDZ     R3      TO GET WHOLE KEYCODE
     1E57 C2                  STRZ     R2      SAVE KEY CODE IN R2
     1E58 17                  RETC,UN
```

```
LINE ADDR  OBJECT  E SOURCE

                     ****************************************************************
                     *
                     *
                     *GOTO ROUTINE
                     *
                     *
                     *REGISTERS USED
                     *
                     *R0 SCRATCH
                     *R1 SCRATCH
                     *R2 SCRATCH
                     *R3 SCRATCH
                     *R1' RESTORED
                     *R2' RESTORED
                     *R3' RESTORED
                     *PSU RESTORED
                     *PSL RESTORED
                     *
                     *SUBROUTINES USED
                     *
                     *NONE
                     *
                     *RAM MEMORY USED
                     *
                     *SSF   SINGLE STEP FLAG
                     *BPF   BREAK POINT FLAG
                     *BPL   BREAK POINT LOCATION
                     *BPD   BREAK POINT DATA
                     *LADR INDIRECT ADDRESS TO JUMP THRU
                     *
                     ***********************************************************
                     *
     1E59 0C17D0     GO     LODA,R0 SSF     GET SINGLE STEP FLAG
     1E5C 9819              BCFR,EQ GO1     NO SINGLE STEP GOTO USER
     1E5E 0C17CF            LODA,R0 BPF     GET BREAK POINT FLAG
     1E61 1814              BCTR,EQ GO1     BREAK POINT GO TO USER NO BREAK POINT
     1E63 0C97CD            LODA,R0 *BPL    GET USER DATA
     1E66 CC17CC            STRA,R0 BPD     SAVE USER DATA
     1E69 04B0              LODI,R0 H'B0'   WRTC,R0 BREAK POINT INSTRUCTION
     1E6B CC97CD            STRA,R0 *BPL    SET THE BREAK POINT
     1E6E EC97CD            COMA,R0 *BPL    CHECK BREAK POINT SET OK
     1E71 1804              BCTR,EQ GO1     GOTO USER
     1E73 0701              LODI,R3 1       ERROR BREAK POINT NOT SET OK
     1E75 9BE8              ZBRR    *ERR    GOTO ERROR
     1E77            GO1    EQU     $
```

```
LINE ADDR  OBJECT  E SOURCE

                     ***********************************************************
                     *
                     *
                     *RESTORE REGISTERS BEFORE GOING TO USER PROGRAM
                     *
                     *
                     *
                     *
                     *REGISTERS USED
                     *
                     *R0 THRU R3' PSU PSL
                     *
                     *SUBROUTINES CALLED
                     *
                     *UREG+9        RESTORE PSL
                     *
                     *RAM MEMORY USED
                     *
                     *UREG          = R0
                     *UREG+1        = R1
                     *UREG+2        = R2
                     *UREG+3        = R3
                     *UREG+4        = R1'
                     *UREG+5        = R2'
                     *UREG+6        = R3'
                     *UREG+7        = PSU
                     *UREG+8        = PSL
                     *UREG+9        = PPSL INSTRUCTION OPCODE
                     *UREG+10       = PSL
                     *UREG+11       = RETC,UN       INSTRUCTION OPCODE
                     *
                     ***************************************************************
     1E77 0577       RESTRG LODI,R1 H'77'   PPSL INSTRUCTION OPCODE
     1E79 CD17FB            STRA,R1 UREG+9  CREATE A SUBROUTINE TO RESTORE PSL
     1E7C 0517              LODI,R1 H'17'   RETC,UN INSTRUCTION OPCODE
     1E7E CD17FD            STRA,R1 UREG+11
     1E81 7510              CPSL    RS      CLEAR REGISTER SWITCH
     1E83 0D17F3            LODA,R1 UREG+1  RESTORE R1
     1E86 0E17F4            LODA,R2 UREG+2  RESTORE R2
     1E89 0F17F5            LODA,R3 UREG+3  RESTORE R3
     1E8C 7710              PPSL    RS      SET THE REGISTER SWITCH
     1E8E 0D17F6            LODA,R1 UREG+4  RESTORE R1'
     1E91 0E17F7            LODA,R2 UREG+5  RESTORE R2'
     1E94 0F17F8            LODA,R3 UREG+6  RESTORE R3'
     1E97 0C17F9     RESTR1 LODA,R0 UREG+7  GET PSU DATA
     1E9A 6C17F1            IORA,R0 IFLG    SET INTERUPT INHIBIT IF REQUIRED
     1E9D 92                LPSU             RESTORE PSU
     1E9E 0C17F2            LODA,R0 UREG    RESTORE R0
     1EA1 75FF              CPSL    255      CLEAR PSL
     1EA3 3F17FB            BSTA,UN UREG+9  RESTORE PSL
     1EA6 1F97E8            BCTA,UN *LADR   GOTO USER
                     *
```

```
LINE ADDR  OBJECT  E SOURCE

                    ************************************************************
                    *
                    *
                    *SUBROUTINE TO SAVE R1,R2,R3
                    *
                    *REGISTERS USED IN BANK ON ENTRY
                    *
                    *R1 SAVED IN SAVREG+1
                    *R2 SAVED IN SAVREG+2
                    *R3 SAVED IN SAVREG+3
                    *
                    *SUBROUTINES CALLED
                    *
                    *NONE
                    *
                    *RAM MEMORY USED
                    *
                    *SAVREG+1
                    *SAVREG+2
                    *SAVREG+3
                    *****************************************************
     1EA9 CD17DA    SAVR0  STRA,R1 SAVREG+1
     1EAC CE17DB    SAVR01 STRA,R2 SAVREG+2
     1EAF CF17DC    SAVR02 STRA,R3 SAVREG+3
     1EB2 17               RETC,UN
                    ***************************************************************
                    *
                    *
                    *SUBROUTINE TO RESTORE R1,R2,R3
                    *
                    *
                    *REGISTERS USED IN BANK ON ENTRY
                    *
                    *R1 RESTORED TO VALUE IN SAVREG+1
                    *R2 RESTORED TO VALUE IN SAVREG+2
                    *R3 RESTORED TO VALUE IN SAVERG+3
                    *
                    *SUBROUTINES CALLED
                    *
                    *NONE
                    *
                    *RAM MEMORY USED
                    *
                    *SAVREG+1
                    *SAVREG+2
                    *SAVREG+3
                    *****************************************************
     1EB3 09F5      RESTR0 LODR,R1 *SAVR0+1
     1EB5 0AF6             LODR,R2 *SAVR01+1
     1EB7 0BF7             LODR,R3 *SAVR02+1
     1EB9 17               RETC,UN
```

```
LINE ADDR  OBJECT  E SOURCE

1623                 *****************************************************
1624                 *
1625                 *
1626                 *CASSETTE IO ROUTINES
1627                 *PROGRAM WRITTEN BY BBC
1628                 *
1629                 * 04-27-77
1630                 *
1631                 * THESE ROUTINES WRITES OR READS ONE BYTE TO OR FROM
1632                 * THE CASSETTE IN SIMCA FORMAT.
1633                 *
1634                 * THE FREQUENCY IS DETERMINED BY FREQ
1635                 * (CYCLE TIME IS 3.333 MICRO-SEC.)
1636                 *
1637                 *
1638                 *ROUTINES SAVE AND REESTORE R1,R2,R3 OF CURRENT BANK
1639                 *
1640                 *IN RETURNS WITH DATA BYTE IN R0
1641                 *OUT REQUIRES BYTE TO BE OUTPUT TO BE IN R0
1642                 *
1643                 *TCAS IS THE CASSETTE READ TEST USED TO SET LEVELS ON PLAY BACK
1644                 *
1645                 *SEE FRONT OF PROGRAM FOR DISPLAYS AND INSTRUCTIONS
1646                 *
1647                 *
1648                 *REGISTERS USED
1649                 *
1650                 *R0,R1,R2,R3 ARE SCRATCH
1651                 *
1652                 *SUBROUTINES CALLED
1653                 *
1654                 *SAVR0 SAVES R1,R2,R3
1655                 *RESTR0 RESTORES R1,R2,R3
1656                 *
1657                 *RAM MEMORY USED
1658                 *
1659                 *TEMP  TEMPORARY STORAGE
1660                 *
1661                 ***********************************************************************
1662 0011            FREQ   EQU    17      PULSE TIME ( 0.2 MSEC. )
1663 0088            SPDLY  EQU    8*FREQ  INTER-BIT SPACE
1664 0013            TMDLY  EQU    19      TIME-OUT FOR INTER-BIT DETECTION
1665 0003            PULS1  EQU    3       NUMBER OF PULSES FOR A ONE
1666 0006            PULS0  EQU    2*PULS1 NUMBER OF PULSES FOR A ZERO
1667 0009            THRES  EQU    3*PULS1 TRANSITION THRESHOLD FOR DETECTION
1668 000F            EBIT   EQU    5*PULS1 TRANSITION THRESHOLD FOR END BIT
1669                 *
1670                 *
1671                 * SUBROUTINE OUT
1672                 * WRITES ONE BYTE FROM R0 TO CASSETTE
1673                 *
1674 1EBA 3B6D       OUTT   BSTR,UN SAVR0   SAVE R1-R3
1675 1EBC D407              WRTE,R0 LEDS    WRITE BYTE TO LEDS FOR DISPLAY
1676 1EBE 0708              LODI,R3 8       BIT COUNT
1677 1EC0 C8A8       OUT1   STRR,R0 *OUT5+1 TEMP    SAVE BYTE IN TEMP
```

```
ADDR OBJECT  E SOURCE

1EC2 CBAA                STRR,R3 *OUT6+1 TEMP+1  SAVE BIT COUNT IN TEMP+1
1EC4 0506                LODI,R1 PULS0   GET NUMBER OF PULSES FOR A ZERO
1EC6 F401                TMI,R0  H'01'   TEST FOR A ONE
1EC8 9801                BCFR,0  OUT2
1ECA 51                  RRR,R1          DIVIDE COUNT IF A ONE
1ECB FB02          OUT2  BDRR,R3 OUT3    CHECK FOR LAST BIT
1ECD 8506                ADDI,R1 PULS0   YES, ADD LAST BIT PULSES
1ECF 0611          OUT3  LODI,R2 FREQ    LENGTH OF PULSE
1ED1 0718                LODI,R3 H'18'   SET ENV AND FREQ
1ED3 D7F8                WRTE,R3 CAS
1ED5 FA7E                BDRR,R2 $       DELAY 10 MICRO-SEC PER ITERATION
1ED7 0611                LODI,R2 FREQ    LENGTH OF PULSE
1ED9 0710                LODI,R3 H'10'   RESET FREQ
1EDB D7F8                WRTE,R3 CAS
1EDD FA7E                BDRR,R2 $       DELAY 10 MICRO-SEC PER ITERATION
1EDF F96E                BDRR,R1 OUT3    DO NEXT PULSE
1EE1 0688                LODI,R2 SPDLY   INTER-BIT SPACE
1EE3 0700                LODI,R3 H'00'   TURN OFF ENV AND FREQ
1EE5 D7F8                WRTE,R3 CAS
1EE7 FA7E                BDRR,R2 $       DELAY 10 MICRO-SEC PER ITERATION
                   *
1EE9 0C17C6        OUT5  LODA,R0 TEMP    GET CHARACTER BACK
1EEC 50                  RRR,R0          ROTATE RIGHT ONE PLACE
1EED 0F17C7        OUT6  LODA,R3 TEMP+1  GET BIT COUNT
1EF0 FB4E                BDRR,R3 OUT1    CONTINUE IF COUNT NON-ZERO
1EF2 3F1EB3        OUT4  BSTA,UN RESTR0  RESTORE R1-R3
1EF5 17                  RETC,UN         ELSE, RETURN
                   *
                   * SUBROUTINE IN
                   * READS ONE BYTE FROM CASSETTE TO R0
                   *
1EF6 3F1EA9        INN   BSTA,UN SAVR0   SAVE R1-R3
1EF9 20                  EORZ    R0      SET R0 TO ZERO
1EFA 44FE          IN1   ANDI,R0 H'FE'   MASK OUT LOW BIT
1EFC C8EC                STRR,R0 *OUT5+1 TEMP    SAVE PARTIAL BYTE
1EFE 3B0A                BSTR,UN GBIT    GET NEXT BIT
1F00 88E8                ADDR,R0 *OUT5+1 TEMP    ADD IN PARTIAL BYTE
1F02 50                  RRR,R0          MOVE NEW BIT TO HIGH POSITION
1F03 5975                BRNR,R1 IN1     TEST LAST BIT FLAG
1F05 3BEC                BSTR,UN *OUT4+1  YES, RESTORE R1-R3
1F07 D407                WRTE,R0 LEDS    WRITE BYTE TO LEDS FOR DISPLAY
1F09 17                  RETC,UN         RETURN
                   *
                   * SUBROUTINE TO GET THE NEXT BIT FROM CASSETTE
                   * BIT IS RETURNED AS LEAST SIGNIFICANT BIT OF R0
                   *
1F0A 0580          GBIT  LODI,R1 H'80'
1F0C D5F8                WRTE,R1 CAS     SET SENSE TO CASSETTE
1F0E 12                  SPSU            GET PSU
1F0F 07FF                LODI,R3 -1      SET TRANSITION COUNT TO -1
1F11 06FF                LODI,R2 H'FF'   SET TIME-OUT TO MAX FOR FIRST TRANSITION
1F13 1B02                BCTR,UN GBT3
1F15 0613          GBT2  LODI,R2 TMDLY   SET END-OF-BIT DETECTION DELAY
1F17 C1            GBT3  STRZ    R1      SAVE LAST COPY OF PSU IN R1
1F18 8701                ADDI,R3 1       INCREMENT TRANSITION COUNTER
1F1A 12            GBT4  SPSU            LOOK FOR TRANSITION
```

```
LINE ADDR  OBJECT  E SOURCE

     1F1B E1                COMZ    R1
     1F1C 9877              BCFR,EQ GBT2    IF NOT EQUAL NEW TRANSITION
     1F1E FA7A              BDRR,R2 GBT4    IF EQUAL, TEST TIME-OUT
     1F20 20                EORZ    R0      SET R0 TO ZERO
     1F21 D4F8              WRTE,R0 CAS     SET SENSE BACK TO USER
     1F23 0501              LODI,R1 1       PRESET END FLAG TO 1
     1F25 E70F              COMI,R3 EBIT    ENDBIT THRESHOLD
     1F27 9903              BCFR,GT GBT5
     1F29 A70C              SUBI,R3 2*PULS0 LAST BIT, SUB ENDBIT PULSES
     1F2B C1                STRZ    R1      AND SET END FLAG
     1F2C E709        GBT5  COMI,R3 THRES   IS COUNT GREATER THAN THRESHOLD
     1F2E 15                RETC,GT         RETURN IF TRUE
     1F2F 0401              LODI,R0 1       NO, SET BIT TO ONE
     1F31 17                RETC,UN RETURN
                      *
                      *
                      * SUBROUTINE TEST CASSETTE READS
                      *
     1F32 0580        TCAS  LODI,R1 H'80'   SELECT LEAST SIGNIFICANT DIGIT
     1F34 D5FA              WRTE,R1 DIGIT
     1F36 0740        TCS0  LODI,R3 H'40'   OUTPUT '-' TO DISPLAY
     1F38 D407        TCS1  WRTE,R0 LEDS    OUTPUT VALUE TO LED'S
     1F3A D7F9              WRTE,R3 DISP    OUTPUT TO DISPLAY
     1F3C CF17C7      TCS10 STRA,R3 TEMP+1  SAVE UD CONDITION
     1F3F 060A              LODI,R2 10      RETURN AFTER 10 EXACT READS
     1F41 CE17C6      TCS2  STRA,R2 TEMP    SAVE R2
     1F44 3B44              BSTR,UN GBIT    GET A BIT
     1F46 0AFA              LODR,R2 *TCS2+1 TEMP    RESTORE R2
     1F48 050C              LODI,R1 2*PULS0 NUMBER OF TRANSITIONS FOR A ZERO
     1F4A 60                IORZ    R0      GET CONDITION CODE FOR R0
     1F4B 1801              BCTR,EQ TCS3    BRANCH IF A ZERO
     1F4D 51                RRR,R1          DIVIDE NOMINAL TRANSITION COUNT BY 2
     1F4E 03          TCS3  LODZ    R3      GET COUNT IN R0
     1F4F 1867              BCTR,EQ TCS1    BLANK DISPLAY IF 0
     1F51 A1                SUBZ    R1      TEST COUNT
     1F52 9804              BCFR,EQ TCS4    IF NOT EQUAL, RETURN
     1F54 FA6B        TCS35 BDRR,R2 TCS2    IF EQUAL AND COUNT NOT UP, GET NEW BIT
     1F56 1B5E              BCTR,UN TCS0
     1F58 190A        TCS4  BCTR,GT TCS5    DETERMINE POLARITY
     1F5A 08E1              LODR,R0 *TCS10+1        TEMP+1 GET UD CONDITION
     1F5C E4DE              COMI,R0 H'DE'   DOWN CONDITION
     1F5E 1874              BCTR,EQ TCS35   CANT GO DIRECT FROM DOWN TO UP
     1F60 073E              LODI,R3 H'3E'   OUTPUT 'U' TO DISPLAY
     1F62 1B54              BCTR,UN TCS1
     1F64 07DE        TCS5  LODI,R3 H'DE'   OUTPUT 'D' TO DISPLAY
     1F66 1B50              BCTR,UN TCS1
```

```
LINE ADDR  OBJECT   E SOURCE

                      ********************************************************************
                      *
                      *HEXTAB LOOKUP TABLE FOR HEX TO SEVEN SEGMENT
                      *
                      *THIS TABLE CONTAINS THE VALUES FOR LIGHTING THE
                      *SEGMENTS FOR THE DIGITS 0 THRU 9 AND LETTERS A TO F
                      *
     1F68 3F065B4F    SEGTBL DATA    H'3F,06,5B,4F,66,6D,7D,07,7F,67,77,FC,39,DE,79,71'
     1F6C 666D7D07
     1F70 7F6777FC
     1F74 39DE7971
                      *
                      *SEGMENT DATA FOR SYMBOLS P L U R H O = BLANK J - . Y N
                      *
     1F78 73383E50           DATA    H'73,38,3E,50,76,5C,48,00,0E,40,80,6E,54'
     1F7C 765C4800
     1F80 0E40806E
     1F84 54
                      *
                      *THIS TABLE CONTAINS THE DISPLAY ERROR
                      *
     1F85 170E1313    ERROR  DATA    H'17,0E,13,13,15,13,17,17'
     1F89 15131717
                      *
                      *THIS TABLE CONTAINS THE DISPLAY AD=
                      *
     1F8D 170A0D16    ADR    DATA    H'17,0A,0D,16,17,17,17,17'
     1F91 17171717
                      *
                      *THIS TABLE CONTAINS THE DISPLAY HELLO
                      *
     1F95 17140E11    HELLO  DATA    H'17,14,0E,11,11,00,17,17'
     1F99 11001717
                      *
                      *THIS TABLE CONTAINS THE DISPLAY BP=
                      *
     1F9D 170B1016    BPEQ   DATA    H'17,0B,10,16,17,17,17,17'
     1FA1 17171717
                      *
                      *THIS TABLE CONTAINS THE DISPLAY R=
                      *
     1FA5 17171317    REQ    DATA    H'17,17,13,17,16,17,17,17'
     1FA9 16171717
                      *
                      *THIS TABLE CONTAINS THE DISPLAY PC=
                      *
     1FAD 17100C16    PCEQ   DATA    H'17,10,0C,16,17,17,17,17'
     1FB1 17171717
                      *
                      *THIS TABLE CONTAINS THE DISPLAY F=
                      *
     1FB5 17170F16    FEQ    DATA    H'17,17,0F,16,17,17,17,17'
     1FB9 17171717
                      *
                      *THIS TABLE CONTAINS THE DISPLAY LAD=
```

```
LINE ADDR  OBJECT  E SOURCE

1823                 *
1824 1FBD 110A0D16   LADEQ  DATA    H'11,0A,0D,16,17,17,17,17'
     1FC1 17171717
1825                 *
1826                 *THIS TABLE IS THE ASCII LOOK UP TABLE
1827                 *
1828 1FC5 30313233   ASCII  DATA    A'0123456789ABCDEF'
     1FC9 34353637
     1FCD 38394142
     1FD1 43444546
1829                 *
```

```
LINE ADDR  OBJECT  E SOURCE

1831                 ************************************************************
1832                 *
1833                 *
1834                 *USER ENTRY TO DISPLAY ROUTINES
1835                 *
1836                 *
1837 1FD5 BBFE       USRDSI ZBSR    *MOV    SET UP DISPLAY
1838 1FD7 03                LODZ    R3      GET DISPLAY FLAG
1839 1FD8 BBEC              ZBSR    *DISPLY GO TO DISPLAY ROUTINE
1840 1FDA 17                RETC,UN
```

```
LINE ADDR  OBJECT  E SOURCE

1842                 ***********************************************************
1843 1FDB                  ORG 8192-26 THE ZBSR OR ZBRR VECTORS ARE HERE
1844                 ***********************************************************
1845 1FE6 1FD5       USRDSP ACON    USRDSI  USER ENTRY TO DISPLAY ROUTINES
1846 1FE8 1899       ERR    ACON    ERRI    ERROR MESSAGE
1847 1FEA 19E8       BRKPT4  ACON    BRKPTI SET DISBUF6,7 WITH CONTENTS OF R0
1848 1FEC 1E13       DISPLY ACON    DISPLI DISPLAY AND KEYBOARD ROUTINE
1849 1FEE 1EF6       IN     ACON    INN     CASSETTE INPUT ROUTINE
1850 1FF0 1EBA       OUT    ACON    OUTT    CASETTE OUT PUT
1851 1FF2 1C7B       HOUT   ACON    HOUTT   CASSETTE BINARY TO ASCII HEX OUTPUT
1852 1FF4 1A76       DISLSD ACON    DISLSI  CONVERT BYTE TO NIBBLE
1853 1FF6 1BA5       ROT    ACON    ROTI    ROTATE A  NIBBLE
1854 1FF8 1C72       CRLF   ACON    CRLFF   CARRAGE RETURN AND LINE FEED
1855 1FFA 1B3B       GNP    ACON    GNPI    GET NUMBERS
1856 1FFC 1B20       GNPA   ACON    GNPAI   GET NUMBERS AND DISPLAY
1857 1FFE 1DB6       MOV     ACON    MOVI    MOVE DATA TO DISBUF
1858                 *************************************************************
1859 1800                   END     SAVRG

 TOTAL ASSEMBLY ERRORS = 0000
```

APPENDIX D — ASCII CONVERSION TABLE

ACSII CHARACTER SET (7-BIT CODE)									
L.S. CHAR \ M.S. CHAR		0 000	1 001	2 010	3 011	4 100	5 101	6 110	7 111
0	0000	NUL	DLE	SP	0	@	P		p
1	0001	SOH	DC1	!	1	A	Q	a	q
2	0010	STX	DC2	"	2	B	R	b	r
3	0011	ETX	DC3	#	3	C	S	c	s
4	0100	EOT	DC4	$	4	D	T	d	t
5	0101	ENQ	NAK	%	5	E	U	e	u
6	0110	ACK	SYN	&	6	F	V	f	v
7	0111	BEL	ETB	'	7	G	W	g	w
8	1000	BS	CAN	(	8	H	X	h	x
9	1001	HT	EM	)	9	I	Y	i	y
A	1010	LF	SUB	*	:	J	Z	j	z
B	1011	VT	ESC	+	;	K	[	k	{
C	1100	FF	FS	,	<	L	\	l	|
D	1101	CR	GS	—	=	M	]	m	}
E	1110	SO	RS	•	>	N	↑	n	~
F	1111	SI	US	/	?	O	← or —	o	DEL

APPENDIX E — DECIMAL TO HEX CONVERSION TABLE

HEXADECIMAL COLUMNS											
6		5		4		3		2		1	
HEX	DEC	HEX	DEC	HEX	DEC	HEX	DEC	HEX	DEC	HEX	DEC
0	0	0	0	0	0	0	0	0	0	0	0
1	1,048,576	1	65,536	1	4,096	1	256	1	16	1	1
2	2,097,152	2	131,072	2	8,192	2	512	2	32	2	2
3	3,145,728	3	196,608	3	12,288	3	768	3	48	3	3
4	4,194,304	4	262,144	4	16,384	4	1,024	4	64	4	4
5	5,242,880	5	327,680	5	20,480	5	1,280	5	80	5	5
6	6,291,456	6	393,216	6	24,576	6	1,536	6	96	6	6
7	7,340,032	7	458,752	7	28,672	7	1,792	7	112	7	7
8	8,388,608	8	524,288	8	32,768	8	2,048	8	128	8	8
9	9,437,184	9	589,824	9	36,864	9	2,304	9	144	9	9
A	10,485,760	A	655,360	A	40,960	A	2,560	A	160	A	10
B	11,534,336	B	720,896	B	45,056	B	2,816	B	176	B	11
C	12,582,912	C	786,432	C	49,152	C	3,072	C	192	C	12
D	13,631,488	D	851,968	D	53,248	D	3,328	D	208	D	13
E	14,680,064	E	917,504	E	57,344	E	3,584	E	224	E	14
F	15,728,640	F	983,040	F	61,440	F	3,840	F	240	F	15