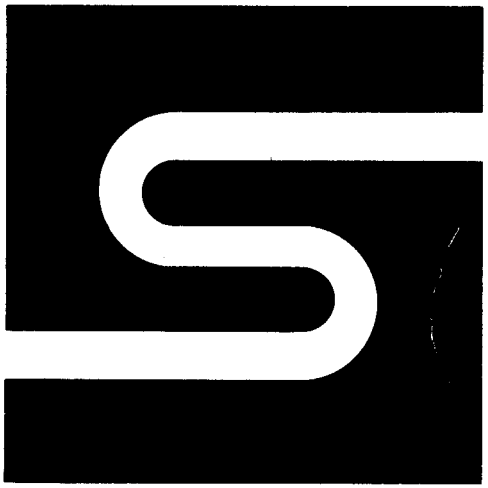

Synertek

Systems Corporation

SYM REFERENCE MANUAL

SYNERTEK SYSTEMS CORPORATION SYM REFERENCE MANUAL AUGUST 1978

SYM REFERENCE MANUAL

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SYM-1 REFERENCE MANUAL

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* KIM is a product of MOS Technology, Inc.

CHAPTER 1

INTRODUCTION TO THE SYM COMPUTER

Whether you're a teacher or a student of computer science, a systems engineer or a hobbyist, you now own one of the most versatile and sophisticated single-board computers available today. The Synertek Systems SYM-1 is an ideal introduction to the expanding world of microprocessor technology as well as a powerful development tool for design of microcomputer-based systems. Fully assembled and thoroughly tested, the SYM-1 comes equipped with a 28-key dual-function keyboard for input and a 6-digit light emitting diode (LED) display for output. All that's needed to make your computer operational is a single 5-volt power supply.

Based on the popular and reliable 6502 Central Processing Unit (CPU), the SYM-1 is designed to permit flexible solutions to a wide range of application problems. A system monitor (SUPERMON) is stored in 4K bytes of Read Only Memory (ROM) furnished with the SYM-1 so you're free to concentrate on the application itself. But should you require customized system software, sockets are provided on the board for three additional ROM or Erasable PROM (EPROM) packages that can expand total ROM to 24K bytes. And by changing connections on the jumpers that have been designed for this purpose, the SYM-1 can be set up to respond to your own system software as soon as the power is turned on.

For working with data and programs, SYM-1 comes equipped with 1K of Random Access Memory (RAM), and sockets are available on the board for plug-in expansion up to 4K. Should additional memory be required for your application, an expansion port is provided which will allow additional ROM, PROM, RAM or I/O to be attached to the system up to the 65,536 maximum addressable limit for an 8-bit microprocessor.

While the keyboard and LED display included on the SYM-1 board will be sufficient for most users, other users may require the additional storage capability of audio cassette tape or the hard copy output of an RS-232 or a teletype terminal. Not only the serial interface, but also the hardware and software necessary for control of these devices is included on the SYM-1. Adding them to your system is simply a matter of properly wiring the appropriate connectors. Similarly, SYM-1 allows an oscilloscope to be added to the system to provide a unique 32-character display under software control. (Or, with the addition of the SYM-2 KB/TV interface and a common and inexpensive Radio Frequency (RF) adapter, you can turn your television set into a video display terminal.)

And that's not all. A total of 51 active Input-Output (I/O) lines (expandable to 71 with the addition of a plug-in component) permit an almost endless variety of other peripheral devices to interface to the SYM-1, from floppy disk drives to full-ASCII keyboards and other computer systems.

Other key hardware and software features of SYM-1 include jumper-selectable and program-controlled write protection for selected areas of memory, four internal timers (expandable to six), four on-board buffers for direct control of high voltage or high current interfaces, and a debug facility that may be controlled either by a manual switch or by software. We could go on, but rather than merely list what the SYM-1 is capable of doing, let's move on to the rest of the manual and learn how to put it to work.

CHAPTER 2

HOW TO USE THE SYM REFERENCE MANUAL

This manual is designed both to help you get your SYM-1 running and to teach you to use it as fully as possible. Reading over the following chapter descriptions will give you an idea of how to proceed and where to look for help when you run into a problem. Although to get the most out of this manual you should read it thoroughly before attempting to operate your SYM-1, only Chapter 3 is essential before applying power and attempting simple operations.

You should read Chapter 3 before you even unpack your SYM-1. Following the handling instructions in that chapter will help insure that you do not inadvertently damage the microcomputer components. Chapter 3 also contains instructions for connecting the power supply, and a simple keyboard exercise to acquaint you with the SYM-1 and verify that the system is working properly. In addition, directions are provided for attaching an audio cassette recorder, teletype or any RS-232 compatible terminal to the system.

Chapter 4 provides you an overview of the hardware and software features of the SYM-1. The major Integrated Circuit (IC) devices are described, and the configuration of the various edge connectors is explained. Memory assignment is also discussed, as are the various hardware jumper options on SYM-1. A complete list of machine language and assembly language commands for the 6502 CPU is included in this chapter.

Chapter 5 provides complete operating instructions for the SYM-1. The color-coded keyboard layout is explained, the keys and their functions are defined, and you're shown how to form SYM monitor commands. Instructions for operating an audio cassette recorder, teletype terminal with paper tape unit, and RS-232 terminal are included with the appropriate monitor command descriptions. In addition, the features of the SYM-1 monitor are explained in detail.

Chapter 6 is where you'll learn to program the SYM-1 to handle your applications. We'll describe the program flow and assembly code for a small sample program and explain how to prepare it for entry to the SYM-1. Then we'll discuss how to execute it and how to find problems in it if it doesn't work the way you expected it to work. After you've completed this example program, you'll have a chance to try your hand at two more programs of increasing complexity.

Chapter 7 describes how to use an oscilloscope with your SYM-1 module to obtain a unique, 32-character display similar to that of a CRT. The hardware is present on your SYM-1 to allow this usage, and the software has been designed to allow you to write your own program to send characters to the oscilloscope. A sample program implementing this feature is discussed in the chapter.

Chapter 8 explains how to expand your SYM-1 system to include additional memory or peripheral devices. I/O techniques are also discussed, including how to configure an auxiliary expansion port.

Chapter 9 consists of a system flow chart and a discussion of advanced monitor and progamming techniques which will add flexibility and expandability to your SYM system. One of the unique things about the SYM-1 is its seemingly endless flexibility in software.

For example, you can create a sub-set of new monitor commands or an entirely new monitor by taking advantage of the way the system handles unrecognized commands. You can also make use of nearly all of the monitor as subroutines in your own programs, thus saving both programming time and memory space.

In addition to the chapters described above, several appendices located at the back of the manual include important service and other reference information. Appendix A explains what to do if your SYM-1 does not operate properly, becomes defective or requires service. Appendix B contains a complete parts list and a component layout diagram. Audio cassette tape formats are described in Appendix C, and the format for data stored on punched paper tape is outlined in Appendix D.

You will find that your SYM-1 will interface many devices designed to accompany the KIM computer. This compatability with KIM-related products is described in Appendix E. Appendix F explains how to create and use a sync tape for audio cassette operation. Appendices G and H contain Monitor Addenda and supplementary information relating to use of the SYM-1. Finally, Appendices I, J, K and L provide reference information on the SY6502, SY6522, SY6532 and SY2114 RAM IC devices.

The last item in the manual, which is not an appendix but an addendum, is a complete listing of the SYM-1 SUPERMON monitor program. Nothing is held back; you have the complete listing to allow you to use it any way you wish. Once you understand how the monitor works and the essentials of 6502 assembly language programming, this listing becomes an invaluable tool for implementing your own applications.

CHAPTER 3

PREPARING TO USE YOUR SYM COMPUTER

This chapter will take you, step-by-step, through the process of unpacking the SYM-1 and making it operational. After applying power and checking to see that the keyboard and display function properly, you will learn how to attach an audio cassette recorder, TTY, or CRT to the system.

3.1 PARTS CHECK

In addition to this manual, several other items are included with your microcomputer. Packed along with the SYM-1 microcomputer itself you should find a programming card containing a summary of 6502 instruction codes and SYM commands, a programming manual, a warranty card, which you should fill out and mail to Synertek Systems as soon as possible, an optional user club card and two edge connectors, one long and one short. Also included is a red plastic strip which serves as a faceplate over the lighted display. The terms of the warranty are explained on the warranty card. Also included with the computer is a packet of small rubber feet on which to mount your SYM-1 for table-top operation.

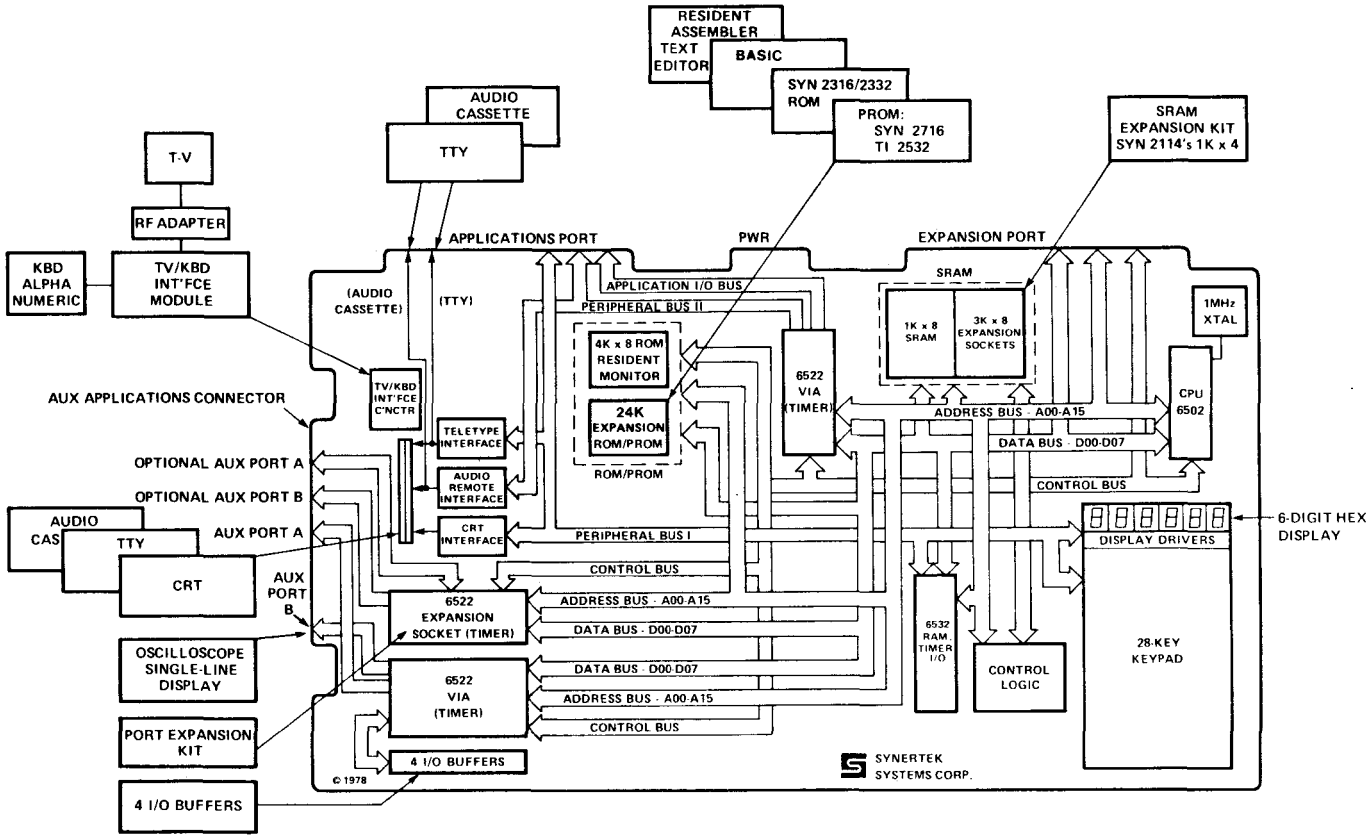
3.2 CAUTION ON MOS PARTS

The integrated circuits on your SYM-1 are implemented with Metal Oxide Silicon (MOS) technology and may be damaged or destroyed if accidentally exposed to high voltage levels. By observing a few simple precautions you can avoid a costly and disappointing mishap.

Static electricity is perhaps the least obvious, and thus most dangerous, source of voltage potential that can damage computer components. The SYM-1 is wrapped in special conductive material to protect it in shipping, and you should be careful to discharge any possible build-up of static electricity on your body before unpacking or handling the circuit board. Walking on a carpeted floor is especially liable to produce static electricity. Always touch a ground connection such as a metal window frame or an appliance with a three-pronged plug before handling your SYM-1, and avoid touching the pin connections on the back of the circuit board. Ungrounded or poorly grounded test equipment and soldering irons are other sources of potentially dangerous voltage levels. Make sure that all test equipment and soldering irons are properly grounded.

3.3 VISUAL CHECK

While observing the precautions described in section 3.2, take the SYM-1 from its box and remove the protective packing. Next, apply the small rubber mounting feet and place the SYM-1 on a flat surface with the keyboard facing you. Using Figure 3-1 you can identify the major system components and begin to familiarize yourself with the layout of the SYM-1 board. Chapter 4 describes the system in more detail, with appropriate schematics, but for now we're just concerned with powering-up and beginning operation.


RESIDENT ASSEMBLER TEXT EDITOR
BASIC
SYN 2316/2332 ROM
PROM: SYN 2716 TI 2532
SRAM EXPANSION KIT SYN 2114's 1K x 4
AUDIO CASSETTE
TTY
T-V
RF ADAPTER
KBD ALPHA NUMERIC
TV/KBD INT'FCE MODULE
APPLICATIONS PORT
PWR
EXPANSION PORT
(AUDIO CASSETTE)
(TTY)
APPLICATION I/O BUS
PERIPHERAL BUS II
SRAM
1K x 8 SRAM
3K x 8 EXPANSION SOCKETS
1MHz XTAL
4K x 8 ROM RESIDENT MONITOR
24K EXPANSION ROM/PROM
ROM/PROM
6522 VIA (TIMER)
CPU 6502
AUX APPLICATIONS CONNECTOR
TV/KBD INT'FCE C'NCTR
TELETYPE INTERFACE
AUDIO REMOTE INTERFACE
CRT INTERFACE
ADDRESS BUS - A00-A15
DATA BUS - D00-D07
CONTROL BUS
OPTIONAL AUX PORT A
OPTIONAL AUX PORT B
AUX PORT A
AUDIO CAS
TTY
CRT
AUX PORT B
PERIPHERAL BUS I
6-DIGIT HEX DISPLAY
DISPLAY DRIVERS
6522 EXPANSION SOCKET (TIMER)
6532 RAM, TIMER I/O
28-KEY KEYPAD
CONTROL LOGIC
OSCILLOSCOPE SINGLE-LINE DISPLAY
6522 VIA (TIMER)
PORT EXPANSION KIT
4 I/O BUFFERS
4 I/O BUFFERS
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SYNERTEK SYSTEMS CORP.

3.4 RECOMMENDED POWER SUPPLIES

The SYM-1 microcomputer requires only the addition of a power supply to become fully operational. Any unit that supplies +5 Volts DC @ 1.5 amps and has adequate overload protection is acceptable. Synertek Systems does not recommend any particular make or model. Rather than buy an assembled power supply, you may want to build your own from one of the many kits available from hobby stores and mail order houses.

3.5 POWER SUPPLY CONNECTION

Now that you've obtained a 5-volt power supply, you're almost ready to power-up the SYM-1. Find the power supply edge connector (the smaller of the two edge connectors packed along with the microcomputer), and wire it as shown in Figure 3-2. Next, slide the connector onto the power connector pins located in the middle of the top edge of the board. Check to make sure that the wiring is correct and that the connector is properly oriented before attaching it to the board.

3.6 POWER-ON CHECK

Turn on the power supply. The red light to the left of the power connection should glow to indicate that power is reaching the board. The LED display above the keyboard should be completely blank, and a tone should be heard. Press the Carriage Return (CR) key. You should again hear the audible tone that is emitted when power is turned on or a key depression is sensed, and the display should show "SY1.0 . .". Carriage Return (CR) is the key that "logs you on" to the computer when first powering up or after pressing Reset (RST). If your computer isn't responding properly, turn off the power supply. Remove the power connector from the board and make sure that all wires are connected to the proper locations and are securely attached, then repeat the power-up procedure.

If after you recheck and repeat the power-up procedure, your SYM-1 does not respond as described above, refer to Appendix A for information on returning the unit for service.

3.7 KEYBOARD EXERCISE

Now that your SYM-1 is operational, let's try a small program to verify that the system is functioning properly. The program will add together two 8-bit binary numbers and store the result. As you enter the program, addresses and data will appear on the LED display as hexadecimal digits. Addresses are 16 bits long and thus will be represented by four hexadecimal digits, while data bytes are 8 bits long and will appear as two hex digits. Before entering the program, you may want to review the following listing of assembler code for the test program. The process of converting assembler code to machine language will be explained in Chapter 6.

```
                          MONITR  =  $8000
                          VALUE1  =  $0200
                          VALUE2  =  $0201
                          RESULT  =  $0202
                            *     =  $0203
0203  18                   START     CLC
0204  D8                             CLD
0205  AD 00 02                       LDA  VALUE1
0208  6D 01 02                       ADC  VALUE2
020B  8D 02 02                       STA  RESULT
020E  4C 00 80                       JMP  MONITR
                                     END
```

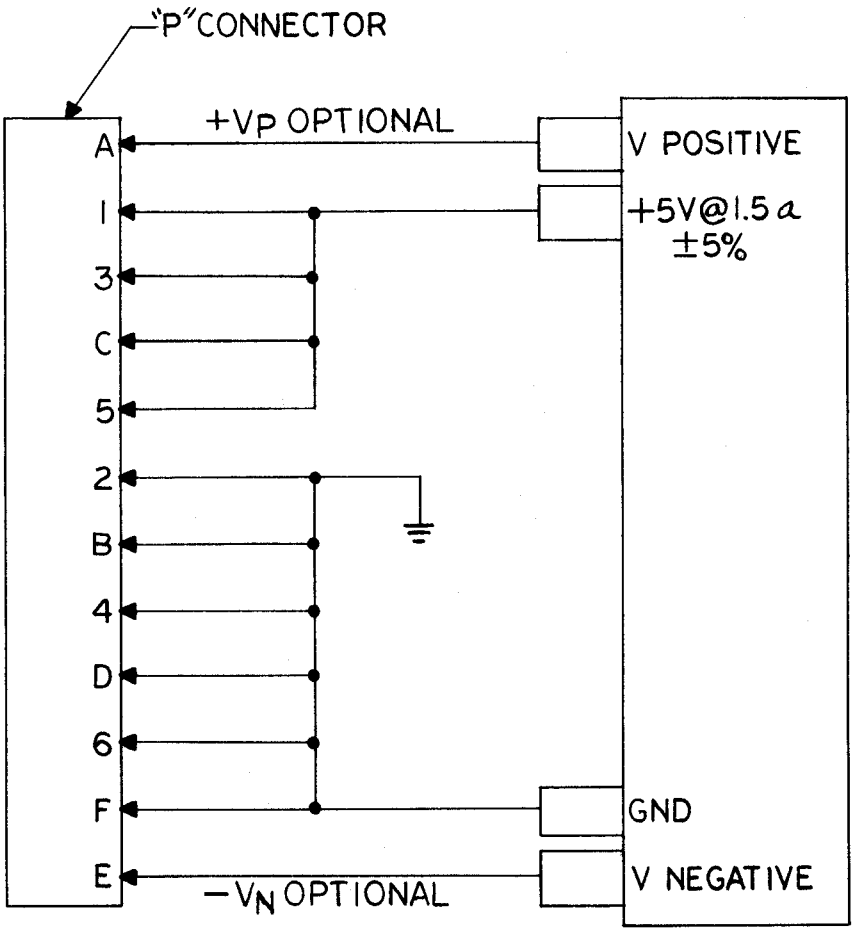


Figure 3-2. POWER SUPPLY CONNECTIONS

Now enter the program by following the steps listed below. Asterisks indicate the displayed data contained in the identified locations. Simulated key tops stand for function keys (e.g., (CR) for carriage return) The period displayed at the end of each entry sequence is SUPERMON's standard prompt character. As each data byte is entered, the address will automatically increment.

YOU KEY IN	DISPLAY SHOWS	EXPLANATION
(RESET)		
(CR)	SY1.0..	Keyboard log-on
(MEM) 200 (CR)	0200.**.	Display contents of location 0200.
C1	0201.**.	Store C1 (Hex) in 0200, display next location.
05	0202.**.	Store 05 (Hex) in 0201, display contents of 0202.
00	0203.**.	Store 00 (Hex) in 0202, display 0203
Enter Program:		
18	0204.**.	Store 18 (Hex) in 0203, display 0204
D8	0205.**.	Store D8 (Hex) in 0204, display 0205
AD	0206.**.	.
00	0207.**.	.
02	0208.**.	.
6D	0209.**.	.
01	020A.**.	
02	020B.**.	
8D	020C.**.	
02	020D.**.	
02	020E.**.	
4C	020F.**.	
00	0210.**.	
80	0211.**.	
(CR)	211.**..	
Check to see that program is entered correctly:		
(MEM) 200 (CR)	0200.C1.	VALUE1
(→)	0201.05.	VALUE2
(→)	0202.00.	RESULT
(→)	0203.18.	Clear carry flag
(→)	0204.D8.	Set status register for binary add
(→)	0205.AD.	Load VALUE1 into accumulator
(→)	0206.00.	Address of VALUE1, low order byte
(→)	0207.02.	Address of VALUE1, high order byte
(→)	0208.6D.	Add VALUE2 to accumulator
(→)	0209.01.	Address of VALUE2, low order byte
(→)	020A.02.	Address of VALUE2, high order byte
(→)	020B.8D.	Store accumulator
(→)	020C.02.	Address of RESULT, low order byte
(→)	020D.02.	Address of RESULT, high order byte
(→)	020E.4C.	JUMP to monitor
(→)	020F.00.	Address of monitor, low order byte
(→)	0210.80.	Address of monitor, high order byte
(CR)	210.80..	Exit from memory display and modify mode

Your program is now entered and ready to execute. The two numbers you will add together, C1 (Hex) and 05 (Hex), are stored in locations 0200 and 0201 respectively. The result will be stored in location 0202. The two digit hex codes you entered in

succeeding memory locations are the addresses, operands, and 6502 instruction codes necessary to add together two 8-bit binary numbers and return to the monitor program. To execute the program and display the result, perform the following steps:

YOU KEY IN	DISPLAY SHOWS	EXPLANATION
(GO) 203 (CR)	g 203 .	Execute program starting at location 0203
(MEM) 202 (CR)	0202.C6	Check result stored in location 0202
(CR)	202.C6. .	Exit from memory display and modify mode

Although this is a simple problem, it demonstrates the basic procedures for entering and executing a program on the SYM-1 as well as verifying that the system is operating properly.

3.8 ATTACHING AN AUDIO CASSETTE RECORDER

The program you entered in section 3.7 will remain stored in RAM memory only as long as the power remains on. As soon as the power is turned off, RAM data is lost, so to reuse the program you would have to enter it again from the keyboard. In order to provide you with a way to permanently store data and programs, SYM-1 is equipped with the hardware and software logic necessary to "talk to" an audio cassette recorder.

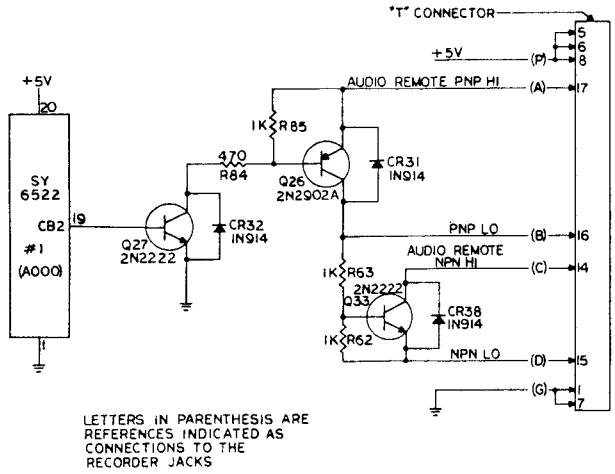
Since SYM-1 audio cassette operation involves high data transfer rates (185 bytes per second for HIGH-SPEED format), you should use a good quality recorder to ensure reliable performance. The unit should be equipped with an earphone jack for output, a microphone for input, a remote jack for remote control of the motor (optional), and standard controls for Play, Record, Rewind, and Stop. An additional feature that is useful but not essential is a tape counter. By keeping a record of counter values you can locate any program of data block manually without having to search the tape under program control at Play speed.

SYM-1 is designed to allow the cassette unit to be attached to either the Applications (A) or the Terminal (T) connector (requires a DB25 connector; see section 3.12). Refer to Figure 3-1 for the board location of these two connectors. Figure 4-3 shows how the Applications (A) edge connector should be wired for the cassette unit. The Terminal (T) connector should be wired as shown in Figure 4-3 if the unit is to be attached to the T connector. Keep the leads as short as possible and avoid running them near sources of electrical interference such as AC power cords. Always use the ground connection at the connector and do not ground directly to the power supply.

The remote control circuitry on the SYM-1 card allows a variety of cassette recorders to be used under software control. However, before you connect your remote control you must determine which type of connection is necessary for your particular recorder. Figure 3-3 illustrates the SYM-1 circuitry and eight different ways to hook it up. The following procedure can be used to determine which connection is necessary for your recorder:

1. Insert the remote control cable into your recorder. Install a tape in the unit.
2. Press play. The tape should not move. If it does, check the cable.
3. Measure the voltage at the center tip of the open end of the cable. (See Figure 3-4. Use ground reference from the EAR plug.) Record this as

AUDIO CASSETTE SYM REMOTE CONTROL CONNECTION



AUDIO CASSETTE RECORDER JACKS REMOTE CONTROL CONNECTIONS

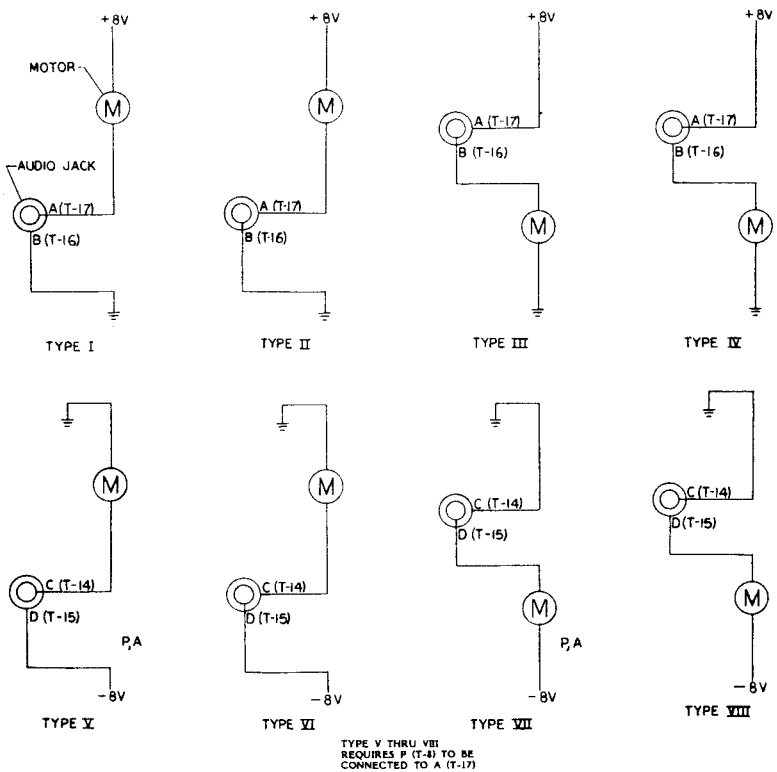


Figure 3-3. REMOTE CONTROL TYPES AND CONNECTIONS

Table 3-1. AUDIO CASSETTE REMOTE CONTROL TYPE DETERMINATION

READING B (shield voltage)	READING A (center tip voltage)		
	-6v to -8v	GND	+6v to +8v
-6v to -8v		READING C GND Type VIII -8v Type V	
GND	READING C GND Type VII -8v Type VI		READING C GND Type I +8v Type IV
+6v to +8v		READING C GND Type II +8v Type III	

Reading C (shorted)

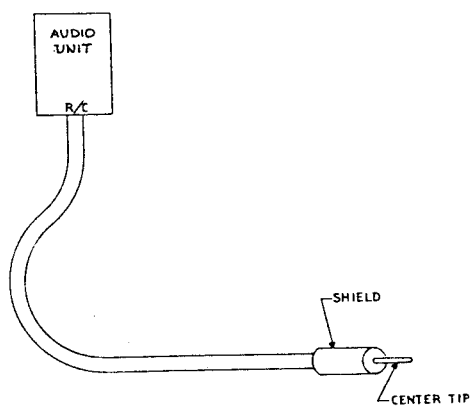


Figure 3-4. REMOTE CONTROL PLUG UNIT

Reading A. Typically this will be either +6 to +8 volts, -6 to -8 volts, or ground.

4. Measure voltage at the shield of the open end of the cable. Record this as Reading B. The same typical values stated in step 3 will apply. Readings A and B should not be the same.
5. Using a wire jumper, short the shield and center tip together. Your tape should now move. Measure the voltage at the center tip (do not remove the short). Record this as Reading C.
6. If your tape moves in step 2 or your tape does not move in step 5, check your cable for opens or shorts.
7. Use Table 3-1 to determine which type of connections to make for your recorder.
8. After you have found the proper category for your recorder, Figure 3-3 illustrates which connections to make.

3.9 SAVE AND LOAD EXERCISE

To check cassette unit operation, we'll "Save" on tape the program presented in Section 3.7, then load the program back into RAM. But before beginning tape operations, we must set the volume and tone controls on the recorder to the correct position. This is accomplished by creating and using a "sync" tape as described in Appendix F. Follow those procedures now, keeping in mind that we will save the program, and thus will also load it back into RAM, in HIGH-SPEED format.

After adjusting you recorder, enter the program from the keyboard as you did before. Insert a tape into the recorder. If your unit is equipped with remote control, place it in Record mode. Since the motor for the cassette is under software control, the tape will not advance. If your unit does not have remote control, do not place the unit in Record mode until just before pressing (CR) while entering the save command shown below including the carriage return, before placing the unit in Play Mode.

YOU KEY IN	DISPLAY SHOWS	EXPLANATION
(SAV 2) 3 (-) 200 (-) 210 (CR)	0-210.	Save locations 0200 to 0210 in a record with ID=03, in HIGH-SPEED format.

When recording starts the display will go blank. When recording is completed the display will re-light. All this should take approximately eight seconds. If your unit does not have remote control, stop the tape manually after the display re-lights.

Now rewind the tape to the starting point. If your unit has remote control, you will have to pull out the Remote jack from the recorder or keep your finger on the RST key.

To destroy the program stored in RAM, turn off system power, then turn it on again.

Log back onto the computer by pressing (CR), then place the cassette unit in Play mode if it is equipped with remote control. If you are operating the controls manually, you should first enter the load command shown below.

YOU KEY IN	DISPLAY SHOWS	EXPLANATION
(LD 2) 3 (CR)	..L3	Load HIGH-SPEED tape record with ID=03 into memory.

This command directs the SYM-1 to search for the tape record with ID=03. While the SYM-1 is searching, an "S" will be displayed. When reading begins, the AUDIO indicator LED will glow and the display should go blank. When the specified record has been loaded into memory the display will re-light.

If you are operating the controls manually, turn the recorder OFF. Under remote control, the motor will stop automatically.

Now follow the instructions in Section 3.7 for executing the program. The result of the addition, C6 (Hex), should appear on the display. If the "S" did not disappear when reading in the program, or if the cassette otherwise did not respond as described above, check all wiring connections, verify the settings of the volume and tone controls and repeat the recording and playback procedures, making sure that each step is performed correctly. If after rechecking connections and repeating the procedure you are still unsuccessful, refer to Appendix A.

3.10 ATTACHING A TTY

To enable you to add a hard copy output device to your system, SYM-1 interfaces to a TTY terminal. Since the Teletype Model 33ASR is widely used and easily obtained, it will be used in the procedures and diagrams in this section. To interface other terminals, use the information given in this section as a general guide and consult the terminal instruction manual for different wiring and connection options.

Your TTY should be set for 20 mA current-loop operation. If it is not, follow the manufacturer's instructions for establishing this configuration. In addition, check to make sure that your TTY is set up to operate in full-duplex mode. You need not concern yourself with the TTY data transmission rate. SYM-1 assumes 110 bits-per-second (baud) for TTY terminals.

Just like an audio cassette recorder, a TTY may be attached to either the Applications (A) connector or using a DB25 (see section 3.12), to the Terminal (T) connector connection (See Figure 3-1). Figure 3-5A shows how the edge connector should be wired if the TTY will be attached to the "A" connector. Figure 3-5B shows the proper connections if it will be attached to the "T" connector. Wire the edge connector as appropriate for your application, then slide it into position. To "log on" to the terminal enter the following command at the on-board keyboard (not on the TTY keyboard).

YOU KEY IN	DISPLAY SHOWS	EXPLANATION
(RESET)		
(CR)	SY1.0 . .	Log-on to keyboard
(SHIFT) (JUMP) 1 (CR)	blank	Log-on to TTY

The TTY should respond with a carriage return and the TTY prompt character, a period. If it does not, turn off the power and re-check your connections, then power-up again.

3.11 TERMINAL EXERCISE

After the TTY prints the prompting character (".") as shown on the first line of the chart below, perform the rest of the steps listed to become acquainted with TTY operation. You will be entering a portion of the program presented in Section 3.7.

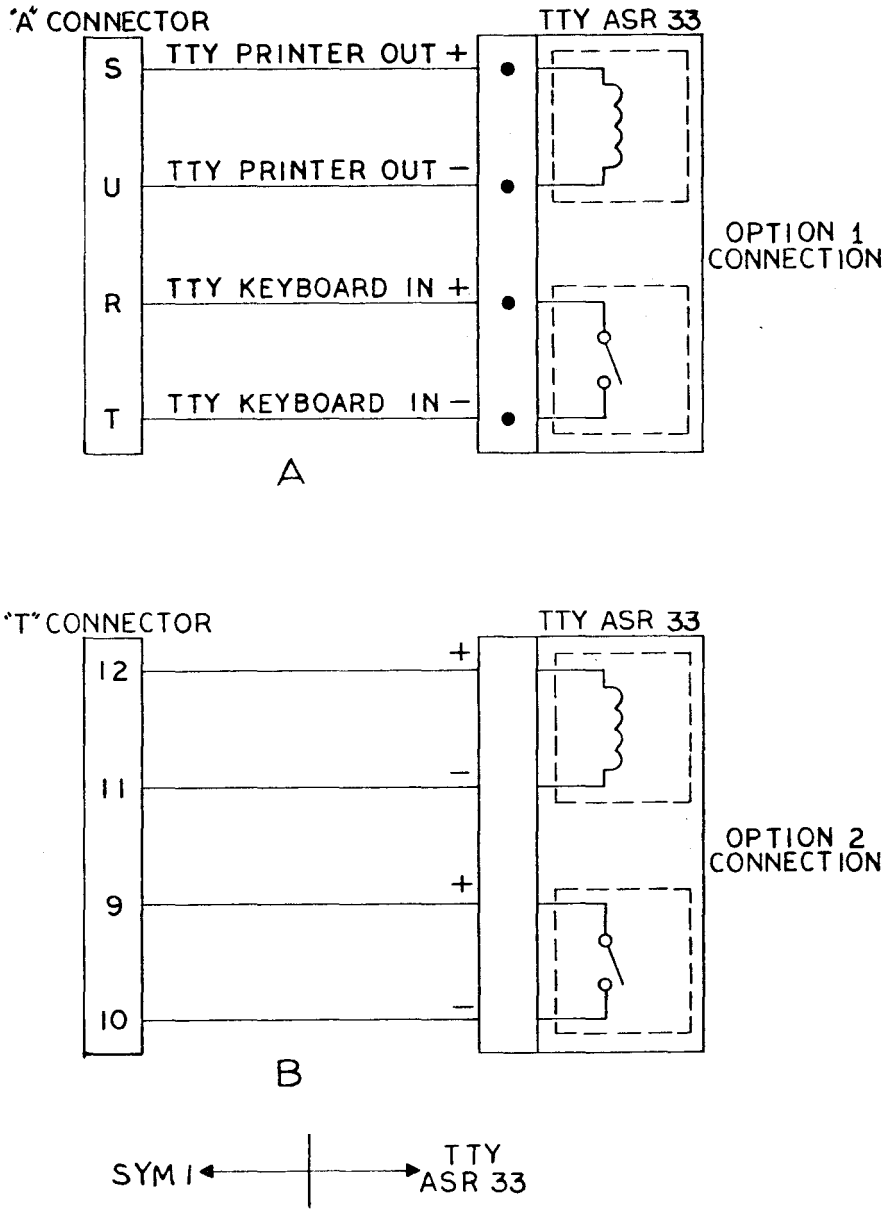


Figure 3-5. TTY I/O CONNECTIONS

YOU KEY IN	TTY PRINTS	EXPLANATION
	.	Prompt
M 200 (RETURN)	.M 200 0200,**,	Display contents of location 0200
C1	0200,**,C1 0201,**,	Store C1 (Hex) in 0200, display 0201
05	0201,**,05 0202,**,	Store 05 (Hex) in 0201, display 0202
(RETURN)	.	Return to monitor

3.12 ATTACHING A CRT

SYM-1 is equipped with an RS-232 interface to facilitate the use of such RS-232 devices as a full-ASCII keyboard and CRT display. Figure 3-6 shows how the proper DB25 connector, which may be easily obtained from an electronics supply house or computer hobby store, should be wired. The location of the interface on the SYM-1 board is show in Figure 3-1. Some older units may need to be wired differently. Refer to the section on jumper options in Chapter 4.

3.13 CRT EXERCISE

Operating a CRT terminal is very similar to operating a TTY. Names of keys and their functions may vary slightly depending on the device, so you should consult your CRT operating manual to find which keys correspond to the TTY keys used in the exercise in section 3.11. SYM-1 automatically adjusts to data transmission rates of 110, 300, 600, 1200, 2400, or 4800 baud for CRT operation. To set the baud rate, enter a "Q" on the CRT keyboard after powering-up (do not press any on-board keys). The CRT should respond with a ".", the terminal prompt character. Now repeat the exercise in Section 3.11 using the CRT keyboard.

In this chapter you have made your SYM-1 operational and learned how to attach several peripheral devices to the system. Let's move on to Chapter 4 and examine in detail the various features of SYM-1 hardware and software.

CRT I/O CONNECTIONS

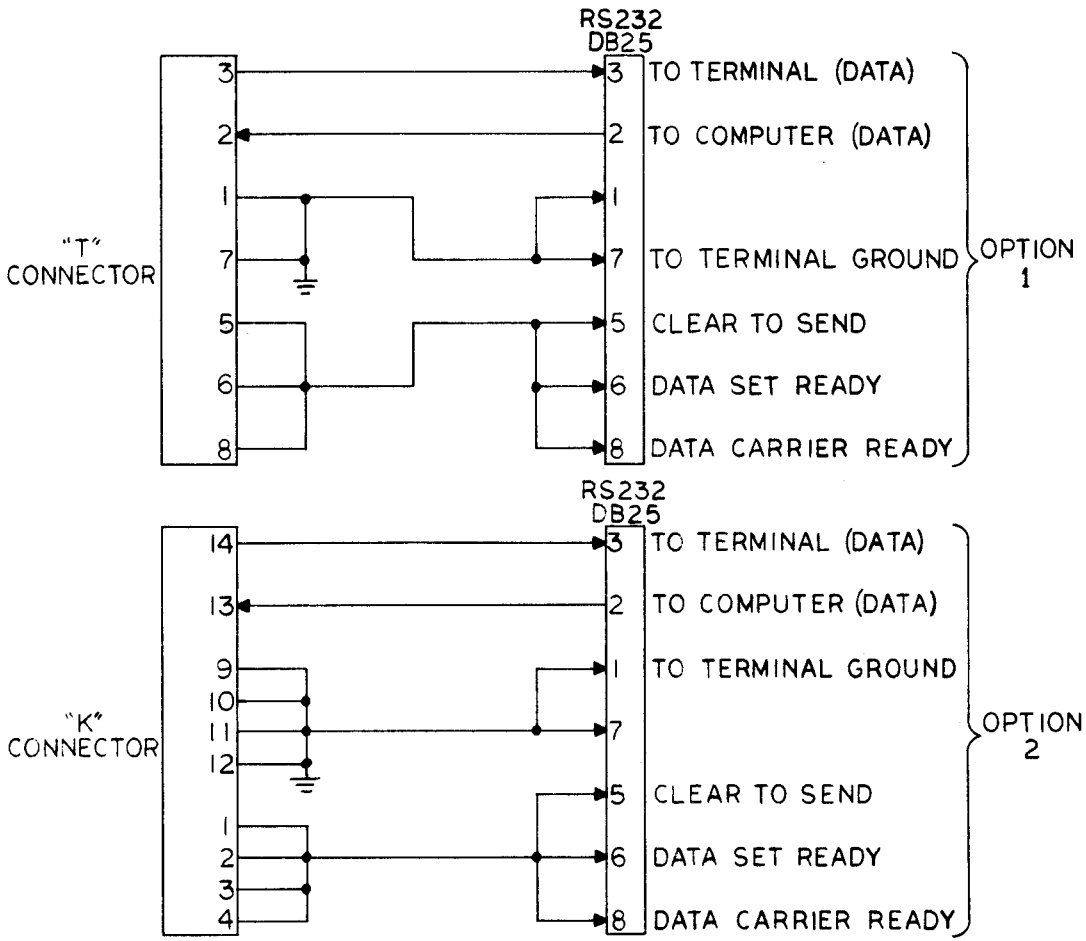


Figure 3-6. CRT I/O CONNECTIONS

CHAPTER 4

SYM-1 SYSTEM OVERVIEW

This chapter will describe your SYM-1 microcomputer system's hardware and software in sufficient detail to allow you to understand its theory of operation. Each Integrated Circuit (IC) component on the SYM-1 board is discussed and related to a functional block diagram. Each functional module is then discussed schematically and the I/O connectors are described. The system memory is then covered and the software is discussed briefly. Detailed data on the software itself is found in Chapter 5 of this manual.

4.1 HARDWARE DESCRIPTION

The SYM-1 microcomputer consists primarily of a 6502 CPU, one or more 6522 Versatile Interface Adapters (VIA), a 6532 Memory and I/O Controller and two types of memory involving any combination of several different components. Because of the flexibility of the memory structure, it is discussed in a separate section (4.2, below).

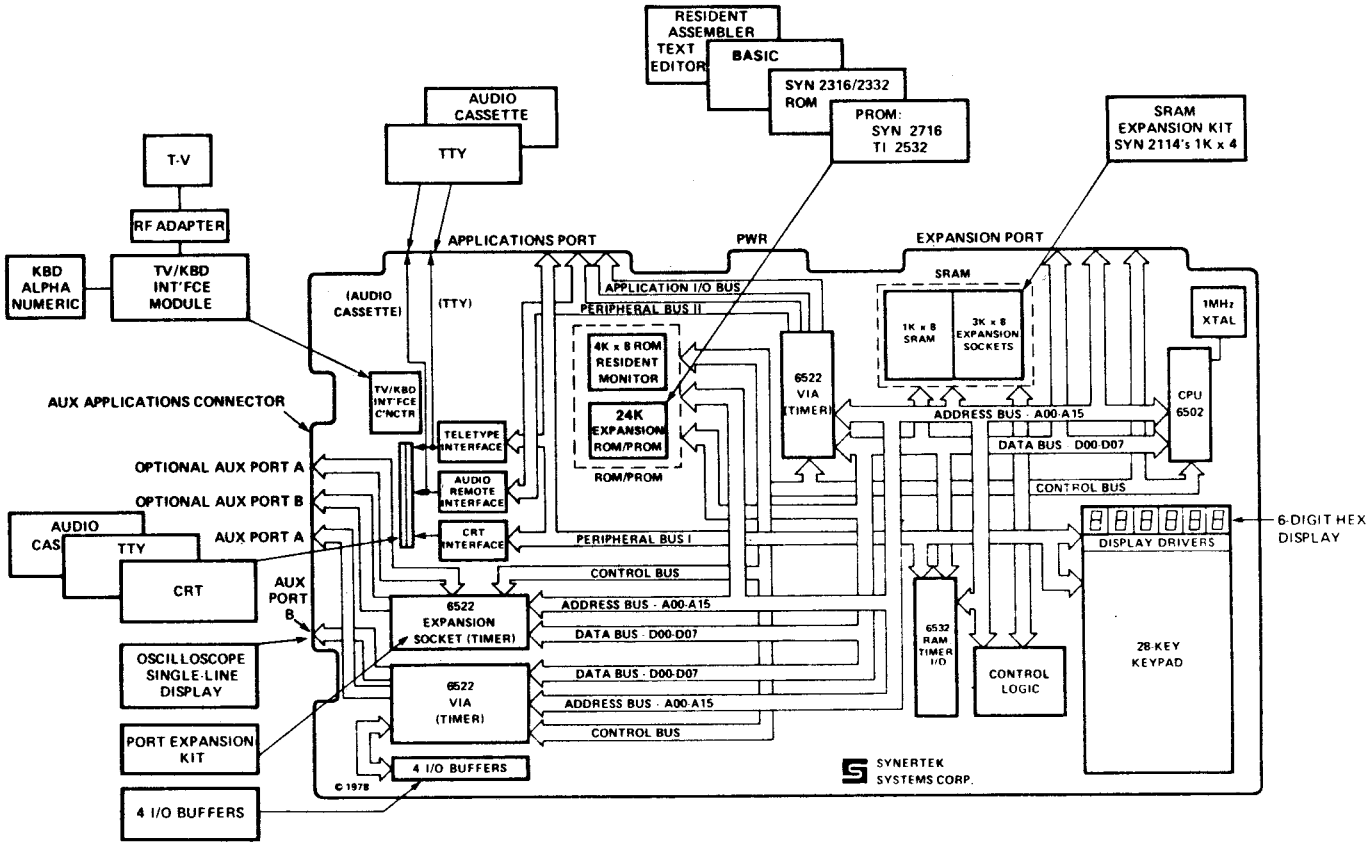
In any microcomputer system, all the components work together functionally as well as being physically interconnected. These connections are illustrated in Figure 4-1, a block diagram of the SYM-1 microcomputer system.

4.1.1 6502 CPU Description

The Central Processing Unit (CPU) of the SYM-1 microcomputer system is the 6502 microprocessor which is designed around a basic two-bus architecture--one full 16-bit address bus and an eight-bit data bus. Two types of interrupts are also available on the processor. Packaged in a 40-pin dual-in-line package, the 6502 offers a built-in oscillator and clock drivers. Additionally, the 6502 provides a synchronization signal which indicates when the processor is fetching an instruction (operation code) from program memory.

During the following discussion of the 6502, you should refer to the Data Sheets in this manual, which describe the pin connections for all three of the major types of devices present on the SYM-1 microprocessor system.

4.1.1.1 Bus Structure. The 6502 CPU is organized around two main busses, each of which consists of a separate set of parallel paths which can be used to transfer binary information between the components and devices in the SYM-1 system. The address bus transfers the address generated by the processor to the address inputs of the peripheral interface and memory devices (i.e., the 6522 and 6532 components). Note that in the Data Sheet for the 6502, the address lines originate at pins 9-20 and 22-25 of the 6502 CPU. These address lines go to pins 2-17 on the 6522 and/or to pins 2, 5-8, 10-15 and 34-40 on the 6532. Since the processor is almost always the only source of address generation in a system, an address bus is generally referred to as "unidirectional." That is the case with the SYM-1 microcomputer system. Since the address bus consists of 16 lines, the processor may read and write to a total of 65,536 bytes of storage (i.e., program memory words, RAM words, stack, I/O devices and other information), a condition which is normally referred to as a "64K memory capacity."



4-1. FUNCTIONAL BLOCK DIAGRAM

The other bus in the 6502 processor is called the data bus. It is an eight-bit bidirectional data path between the processor and the memory and interface devices. When data is moved from the processor to a memory location, the system performs a write; when the data is traveling from memory to the CPU, a read is being performed. Pins 26-33 on the 6502, 6522 and 6532 devices are all data lines connected to the data bus. The direction of the transfer of data between these pin connectors is determined by the output of the Read/Write (R/W, Pin 34) of the 6502. This line enables a write memory when it is "low" (when its voltage is below 0.4 VDC). Write is disabled and all data transfers will take place from memory to the CPU if the level is high (greater than 2.4 VDC).

One of the important aspects of the 6502 CPU is that it has two interrupt input lines available, Interrupt Request (labeled $\overline{IRQ}$ in the Data Sheet) and a Non-Maskable Interrupt (labelled $\overline{NMI}$).

Interrupt handling is one of the key aspects of microprocessor system design. Although the idea of interrupt handling is fairly simple, a complicating factor is the necessity for the processor to be able to handle multiple interrupts in order of priority (usually determined by the programmer) and not "losing track" of any of them in the process. These are concepts which you as a programmer-user of the SYM-1 will be concerned with only in advanced applications. The handling of user-generated interrupts is discussed elsewhere in this manual. If you do have occasion to alter pre-determined interrupt handling, it will be helpful for you to understand how the process works for the two types of interrupts in the 6502.

There are two main differences between the $\overline{IRQ}$ and $\overline{NMI}$ signals and their handling. First, $\overline{IRQ}$ will interrupt the CPU only if a specific flag--the Interrupt Disable Flag (I)--in the system's Processor Status Register is cleared, i.e., zero. If this flag is "set"--i.e., one--the $\overline{IRQ}$ is disabled until the flag is cleared. But an $\overline{NMI}$ request (as its name implies) always causes an interrupt, regardless of the status of the I-flag. The other main difference between the two types of interrupts is that the $\overline{IRQ}$ interrupt is "level sensitive." Any time the signal is less than 0.4 VDC and the Interrupt Disable flag is cleared, an interrupt will take place. In the case of $\overline{NMI}$, the interrupt is said to be "edge-sensitive" because it is dependent on a sequence of timing events. This interrupt will occur only if the signal goes "high" (i.e., exceeds 2.4 VDC) and then goes back to ground (less than 0.4 VDC). The interrupt occurs on the negative-going transition past 0.4 V.

The Data Sheet contains a summary of the 40 pins on the 6502 CPU and their function. Note that three of the pins--5, 35 and 36--are not connected on the 6502.

4.1.1.2 Summary. The 6502 CPU is a versatile processor. It was selected for your SYM-1 microprocessor system because of its overall functional characteristics, which facilitate its use in a wide variety of applications. Its role in the SYM-1 system will become clearer when we discuss programming and software in Section 4.3 and in Chapters 5 and 6.

4.1.2 6522 Description

The SY6522 Versatile Interface Adapter (VIA) is a highly flexible component used on the SYM-1 module to handle peripheral interfaces. Two of these devices are standard components on your SYM-1; a third may be added merely by plugging it into the socket (U28) provided. Control of the peripheral devices is handled primarily through the two eight-bit bi-directional ports. Each line of these ports can be programmed to act as

either an input or an output. Also, several of the peripheral I/O lines can be controlled directly from the two very powerful interval timers integrated into the chip. This results in the capability to 1) generate programmable frequencies, 2) count externally generated pulses, and 3) to time and monitor real time events.

A description of the pin designations on the SY6522 is contained in the Data Sheet enclosed with your SYM-1. It should be used in following the discussion of the operation of the component in the SYM-1 module which follows. The Memory Map of the SYM-1 module (Figure 4-10) will also be helpful during this discussion.

4.1.2.1 Processor Interface. Data transfers between the SY6522 and the CPU (6502) take place over the eight-bit data bus (DB0-DB7) only while the Phase Two Clock (Ø2) is high and the chip is selected (i.e., when CS1 is high and $\overline{CS2}$ is low). The direction of these data transfers is controlled by the Read/Write line (R/W). When this line is low, data will be transferred out of the processor into the selected 6522 register; when R/W is high and the chip is selected, data will be transferred out of the SY6522. The former operation is described as the write operation, the latter the read operation.

Four Register Select lines (RS0-RS3) are connected to the processor's address bus to allow the processor to select the internal SY6522 register which is to be accessed. There are 16 possible combinations of these four bits and each combination accesses a specific register. Because of the fact that the SY6522 is a programmable-addressable device, these RS line settings, in combination with the basic device address, form the specific register address shown in the 6522 Data Sheet.

Two other lines are used in the SY6522 interface to the 6502 processor. The Reset line ($\overline{RES}$) clears all internal registers to a logical zero state (except T1, T2 and SR), placing all peripheral lines in the input state. It also disables the timers, shift register and other on-chip functions and disables interrupting from the chip. The Interrupt Request line ($\overline{IRQ}$) generates a potential interrupt to the CPU when an internal interrupt flag is set and a corresponding interrupt enable bit is set to a logical "1." The resulting output signal is then "wire or'ed" with other similar signals in the system to determine when and whether to interrupt the processor.

4.1.2.2 Peripheral Interface. As we mentioned earlier, peripheral interface is handled largely over two eight-bit ports, with each of the 16 lines individually programmable to act as an input or output line. Port A consists of lines PA0-PA7 and Port B of lines PB0-PB7.

Three registers are used to access each of the eight-bit peripheral ports. Each port has a Data Direction Register (DDRA and DDRB), which is used in specifying whether the pins are to act as inputs or outputs. If a particular bit in the Data Direction Register is set to zero, the corresponding peripheral pin is acting as an input; if it is set to "1," the pin acts as an output point.

Each of the 16 peripheral pins is also controlled by a bit in the output register (ORA and ORB) and a similar bit in the Input Register (IRA and IRB). When the pin is programmed to act as an output, the voltage on the pin is controlled by the corresponding bit in the Output Register. A "1" in the appropriate Output Register causes the pin to go "high" (2.4 VDC or higher), and a zero causes it to go "low (0.4 VDC or lower).

Functionally, reading a peripheral port causes the contents of the appropriate Input Register to be transferred to the Data Bus.

The SY6522 has a number of sophisticated features which allow very positive control of data transfers between the processor and peripheral devices through the operation of "handshake" lines which involve the use of Peripheral Control Lines (CA1-CA2 and CB1-CB2). These operations are beyond the scope of this manual; if you are interested in further information, you should consult the data sheet enclosed.

4.1.3 6532 Description

Like the SY6522 described above, the SY6532 is used on the SYM-1 module to control peripheral interface. Only one SY6532 is furnished with your SYM-1 and no others are provided for.

From an operational standpoint, the SY6532 is quite similar to the SY6522. One key difference, particularly on your SYM-1 module, is the presence of a 128-byte x 8-bit RAM within the SY6532. This is the location referred to as "System RAM" in discussions of the software operation and in the Memory Map (Figure 4-10).

A description of the pin designations on the SY6532 is included in the enclosed Data Sheet. You will notice that, like the SY6522, the SY6532 contains 16 peripheral I/O pins divided into two eight-bit ports (lines PA0-PA7 and PB0-PB7). Each of these pins can be individually programmed to function in input or output mode. $\overline{IRQ}$ on the SYM-1 SY6532 is not connected.

The Address lines (A0-A6) are used with the RAM Select ($\overline{RS}$) line and the Chip Select lines (CS1 and $\overline{CS2}$) to address the SY6532. It is in this addressing that the SY6532 differs somewhat from the SY6522's on your SYM-1 module. To address the 128-byte RAM on the SY6532, CS1 must be high and $\overline{CS2}$ and $\overline{RS}$ must both be low. To address the I/O lines and the self-contained interval timer, CS1 and $\overline{RS}$ must be high and $\overline{CS2}$ must be low. In other words, CS1 is high and $\overline{CS2}$ is low to address the chip; $\overline{RS}$ is used to differentiate between addressing RAM and the I/O Interval Timer functions. Distinguishing between I/O lines and the Interval Timer is the function of Address Line 2 (A2), which is high to address the timer and low to address the I/O section. Again, the Memory Map in Figure 4-10 clarifies these operations since they are largely software-directed and address-dependent.

4.1.4 Functional Schematics

Understanding the electrical interfaces among the various components may be of some interest to you as you use and expand your SYM-1 microcomputer. The figures on the following pages include segmented schematics, where each figure provides an electronic overview of the interface between the CPU and its related component devices and peripherals.

Table 4-1 describes the contents of each figure in this group of schematic segments.

Table 4-1. INDEX OF SCHEMATIC SEGMENTS FIGURES 4-2 TO 4-9

Figure	Function/Segment Diagrammed
4-2	TTY and CRT Interface
4-3	Audio Cassette Interface
4-4	Audio Cassette Remote Control
4-5	I/O Buffer
4-6	Keyboard/Display
4-7	Control Section
4-8	Memory Section
4-9	Oscilloscope Output Driver

Table 4-2 provides, in summary form, a list of the connector points on the four SYM-1 connectors. This allows you to determine pin and connector configurations for various application options.

Table 4-2. CONNECTOR POINTS AND THEIR FUNCTIONS IN VIM-1

Key:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Component Side
	A	B	C	D	E	F	H	J	K	L	M	N	P	R	S	T	U	V	W	X	Y	Z	Solder Side

EXPANSION (E)

1	SYNC	A	AB0
2	RDY	B	AB1
3	$\overline{\phi 1}$	C	AB2
4	$\overline{IRQ}$	D	AB3
5	RO	E	AB4
6	$\overline{NMI}$	F	AB5
7	$\overline{RES}$	H	AB6
8	DB7	J	AB7
9	DB6	K	AB8
10	DB5	L	AB9
11	DB4	M	AB10
12	DB3	N	AB11
13	DB2	P	AB12
14	DB1	R	AB13
15	DB0	S	AB14
16	$\overline{18}$	T	AB15
17	DBOUT (1)	U	$\phi 2$
18	$\overline{POR}$	V	$\overline{R/W}$
19	Unused	W	$\overline{R/W}$
20	Unused	X	AUD TEST
21	+5V	Y	$\overline{\phi 2}$
22	GND	Z	Ram-R/W

APPLICATION (A)

1	GND	A	+5V
2	APA3	B	$\overline{00}$
3	APA2	C	$\overline{04}$
4	APA1	D	$\overline{08}$
5	APA4	E	$\overline{0C}$
6	APA5	F	$\overline{10}$
7	APA6	H	$\overline{14}$
8	APA7	J	$\overline{1C}$
9	APB0	K	$\overline{18}$
10	APB1	L	Audio In
11	APB2	M	Audio Out (LO)
12	APB3	N	RCN-1 (1)
13	APB4	P	Audio Out (HI)
14	APA0	R	TTY KB RTN (+)
15	APB7	S	TTY PTR (+)
16	APB5	T	TTY KB RTN (-)
17	KB ROW 0	U	TTY PTR (-)
18	KB COL F	V	KB ROW 3
19	KB COL B	W	KB COL G
20	KB COL E	X	KB ROW 2
21	KB COL A	Y	KB COL C
22	KB COL D	Z	KB ROW 1

AUXILIARY APPLICATION (AA)

1	GND	A	+5V
2	-VN	B	+VP
3	2 PA 1	C	2 PA 2
4	2 CA 2	D	2 PA 0
5	2 CB 2	E	2 CA 1
6	2 PB 7	F	2 CB 2
7	2 PB 5	H	2 PB 6
8	2 PB 3	J	2 PB 4
9	2 PB 1	K	2 PB 2
10	2 PA 7	L	2 PB 0
11	2 PA 5	M	2 PA 6
12	2 PA 3	N	2 PA 4
13	RES	P	3 CA 1
14	3 CB 1	R	SCOPE
15	3 PB 2	S	3 PB 3
16	3 PB 0	T	3 PB 1
17	3 PA 6	U	3 PA 7
18	3 PA 3	V	3 PA 0
19	3 PA 4	W	3 PA 1
20	3 PA 5	X	3 PA 2
21	3 PB 5 (B)	Y	3 PB 4 (B)
22	3 PB 7 (B)	Z	3 PB 6 (B)

(1) Jumper option
(B) Buffered

TABLE 4-2. CONNECTOR POINTS AND THEIR FUNCTIONS IN SYM-1 (Continued)

POWER (P)

1	+5V	A	+VP (optional)
2	GND	B	GND
3	+5V	C	+5V
4	GND	D	GND
5	+5V	E	-VN (optional)
6	GND	F	GND

TERMINAL (T)

1	GND
2	RS-232 IN
3	RS-232 OUT
4	N.C.
5	+5V
6	+5V
7	GND
8	+5V
9	TTY Keyboard IN +
10	TTY Keyboard IN -
11	TTY Printer OUT -
12	TTY Printer OUT +
13	N.C.
14	Audio Remote NPN HI
15	Audio Remote NPN LO
16	Audio Remote PNP LO
17	Audio Remote PNP HI
18	Audio IN
19	Audio GND
20	N.C.
21	Audio Out (HI)
22	N.C.
23	Audio Out (LO)
24	N.C.
25	Audio GND

KEYBOARD (K)

1	+5V
2	+5V
3	+5V
4	+5V
5	+VP
6	+VP
7	-VN
8	-VN
9	GND
10	GND
11	GND
12	GND
13	RS-232 IN
14	RS-232 OUT

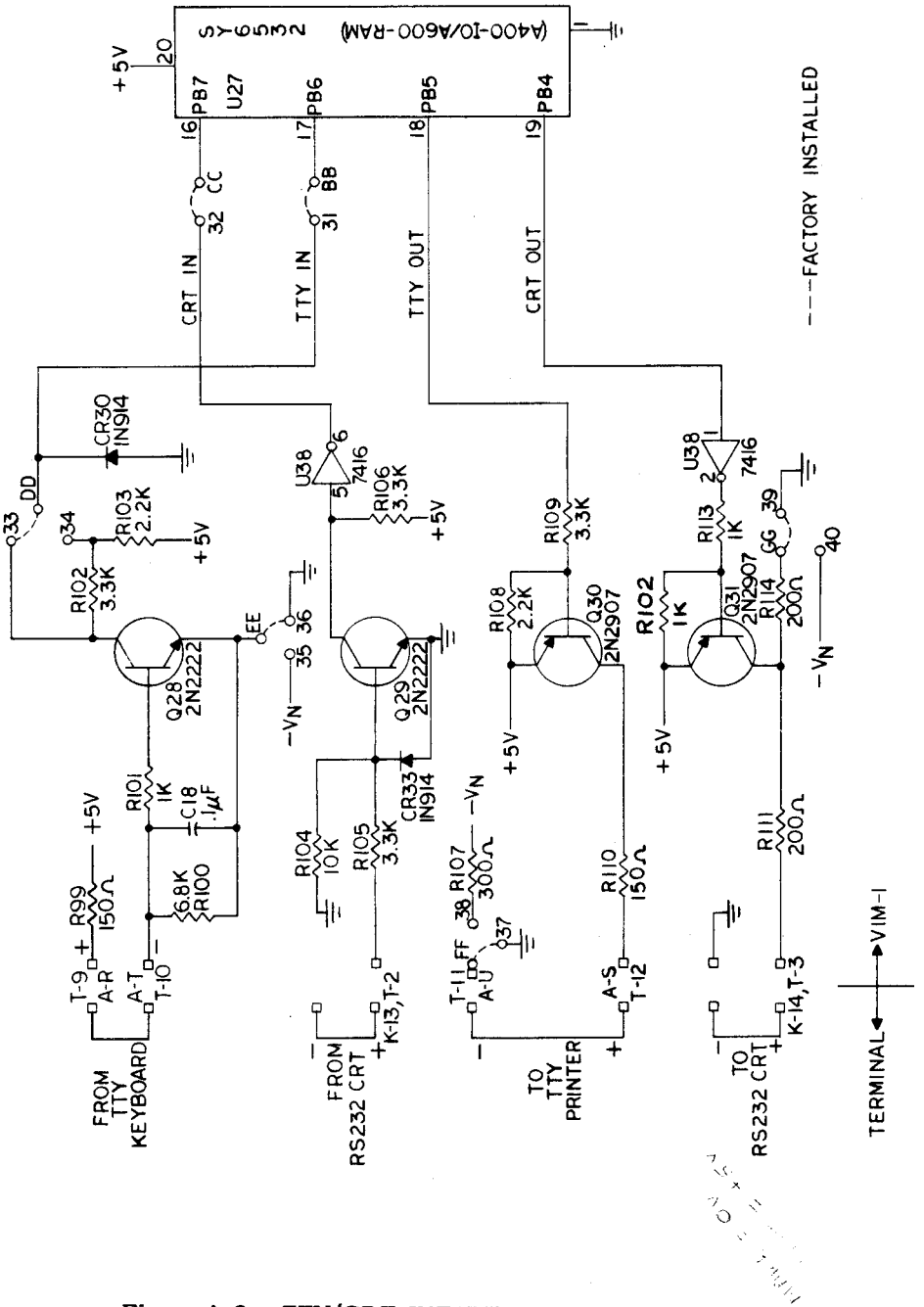


Figure 4-2. TTY/CRT INTERFACE SCHEMATIC

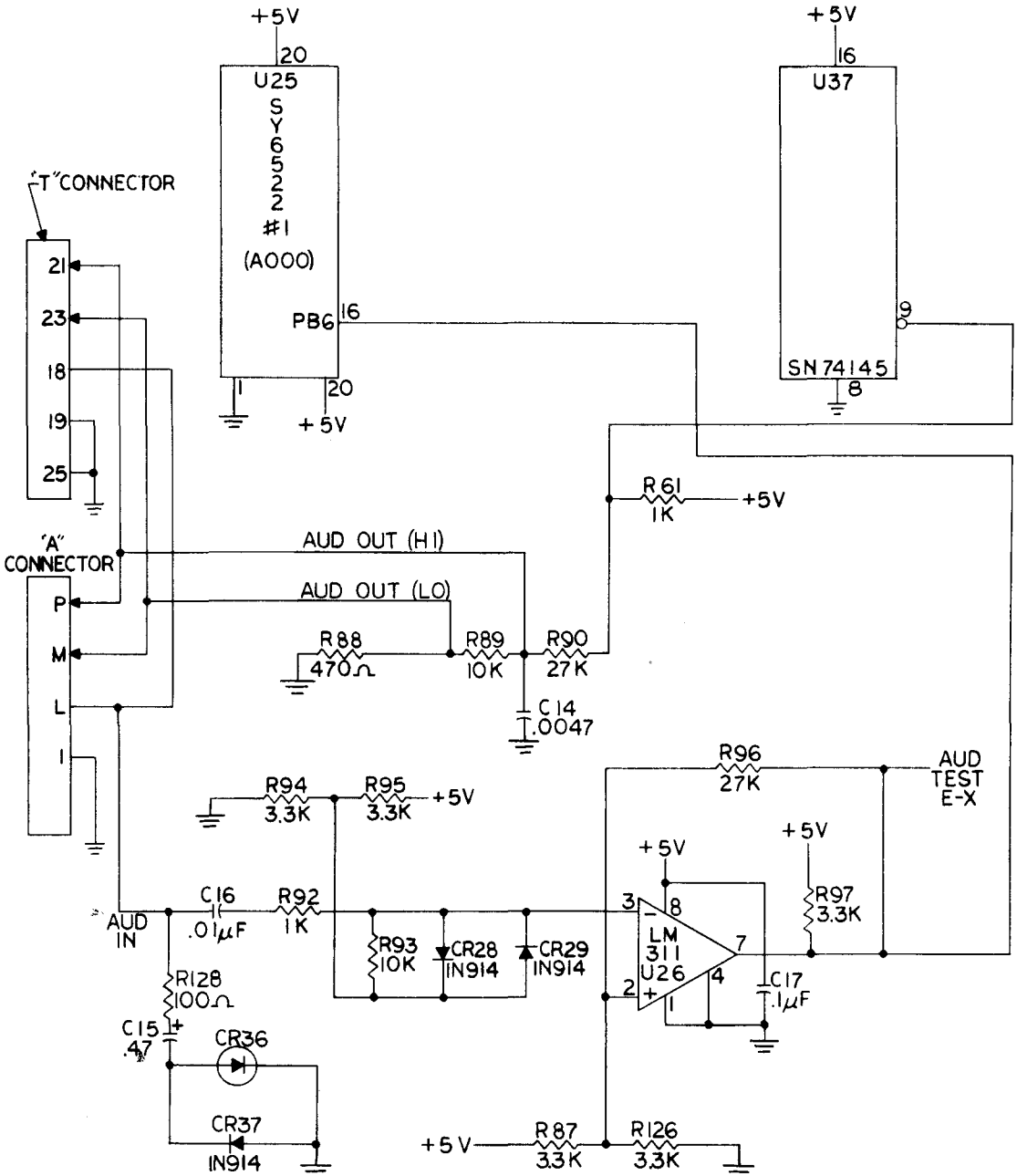


Figure 4-3. AUDIO CASSETTE INTERFACE SCHEMATIC

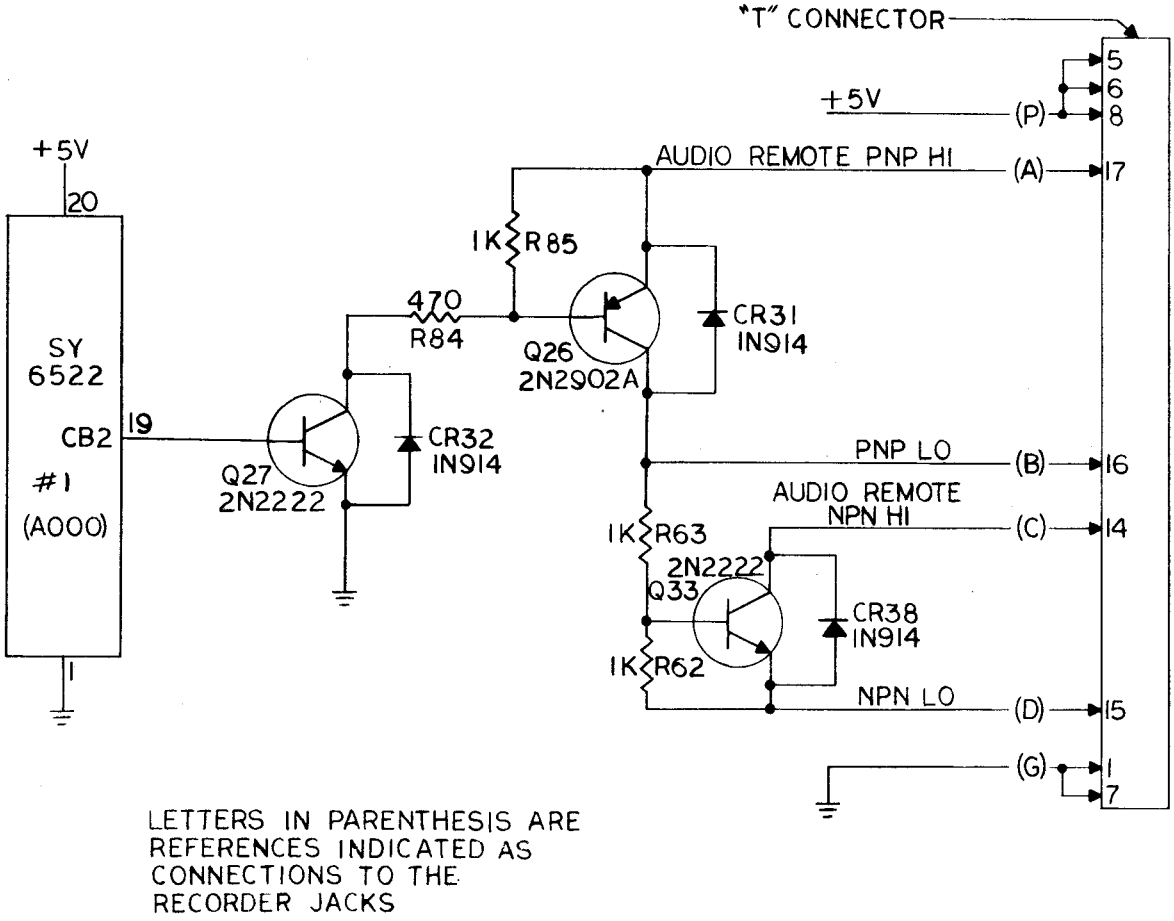
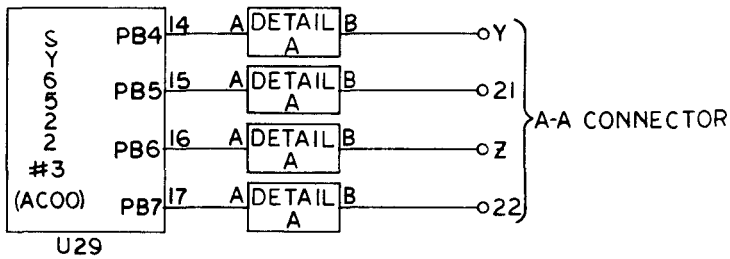


Figure 4-4. AUDIO CASSETTE REMOTE CONTROL

I/O BUFFERS



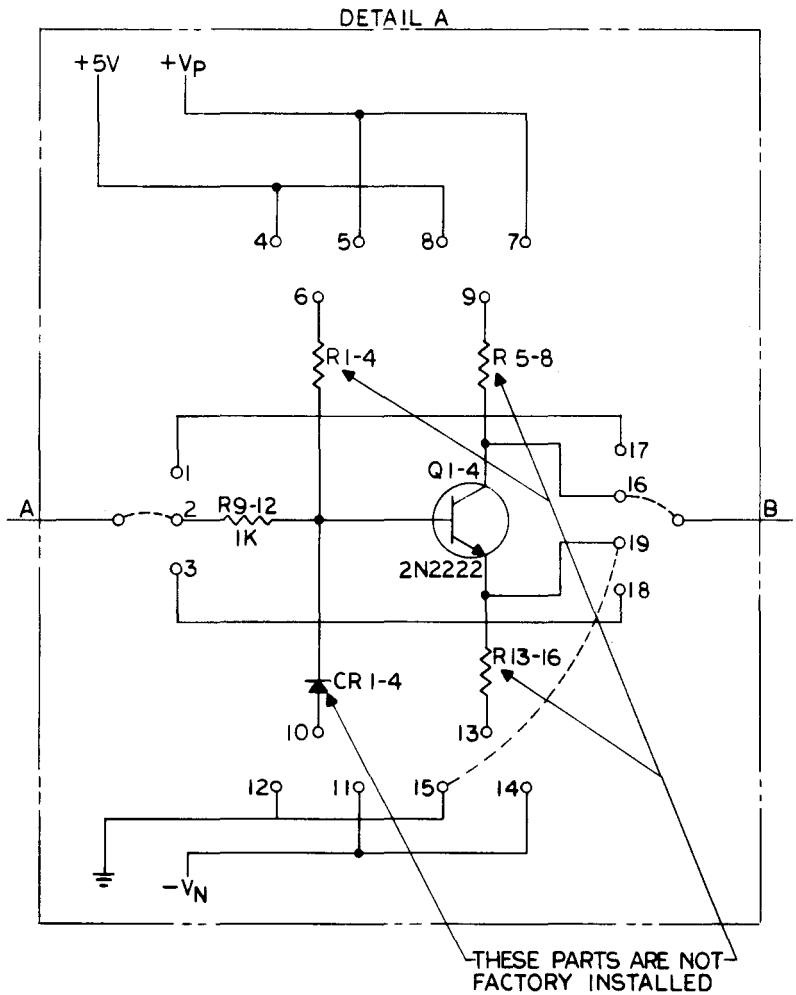


Figure 4-5. I/O BUFFERS SCHEMATIC

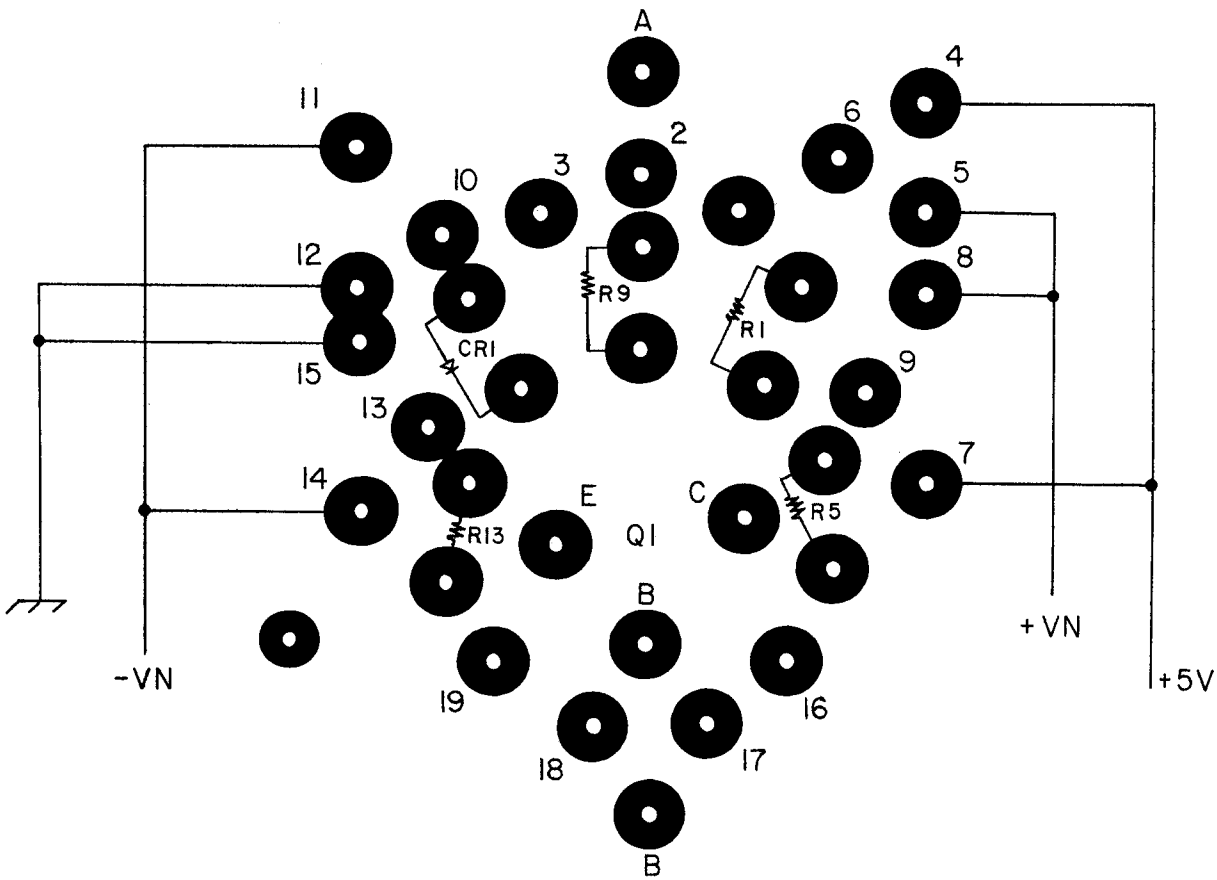


Figure 4-5a. I/O BUFFERS, PC LAYOUT BLOW-UP

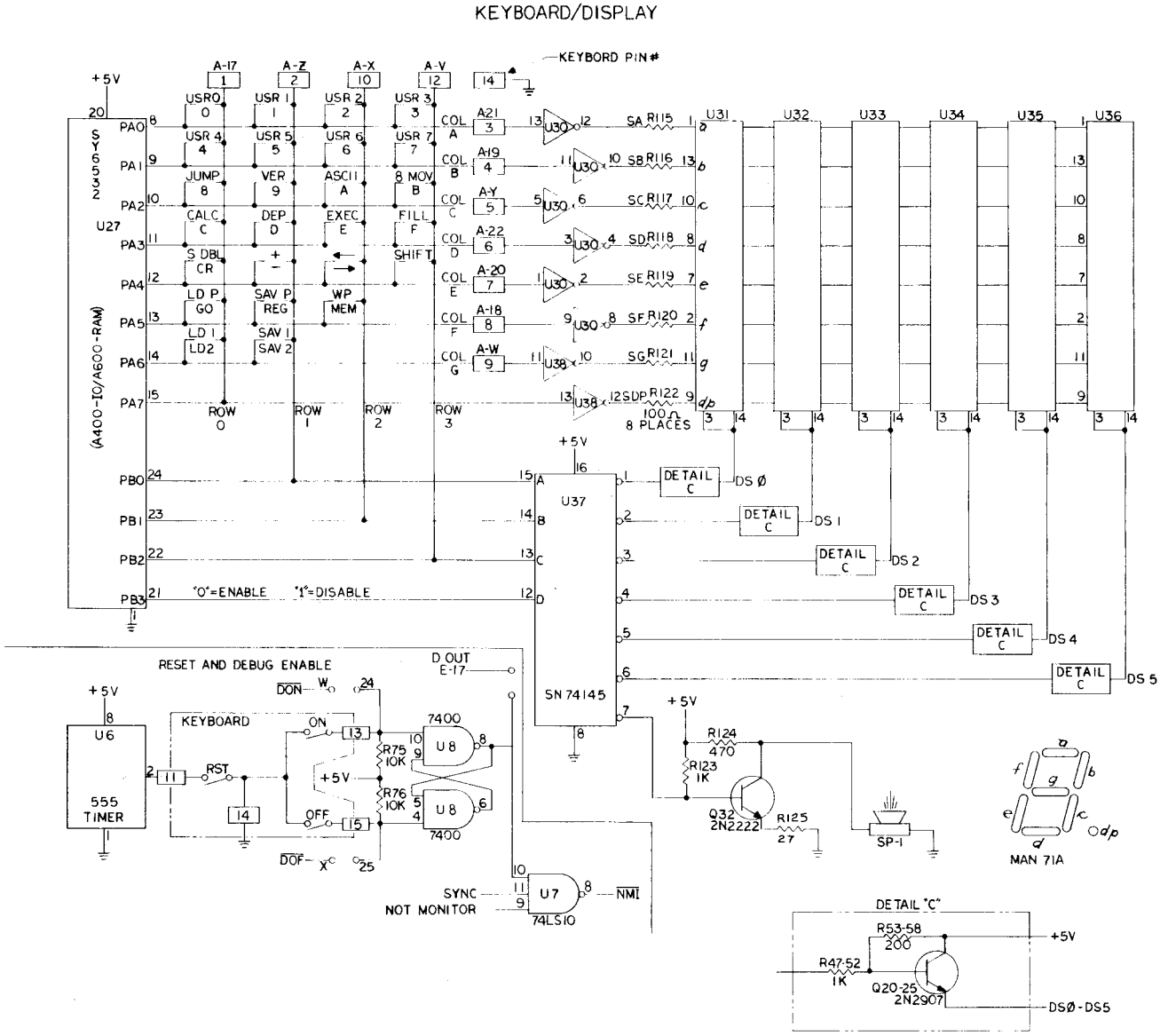


Figure 4-6. KEYBOARD/DISPLAY SCHEMATIC

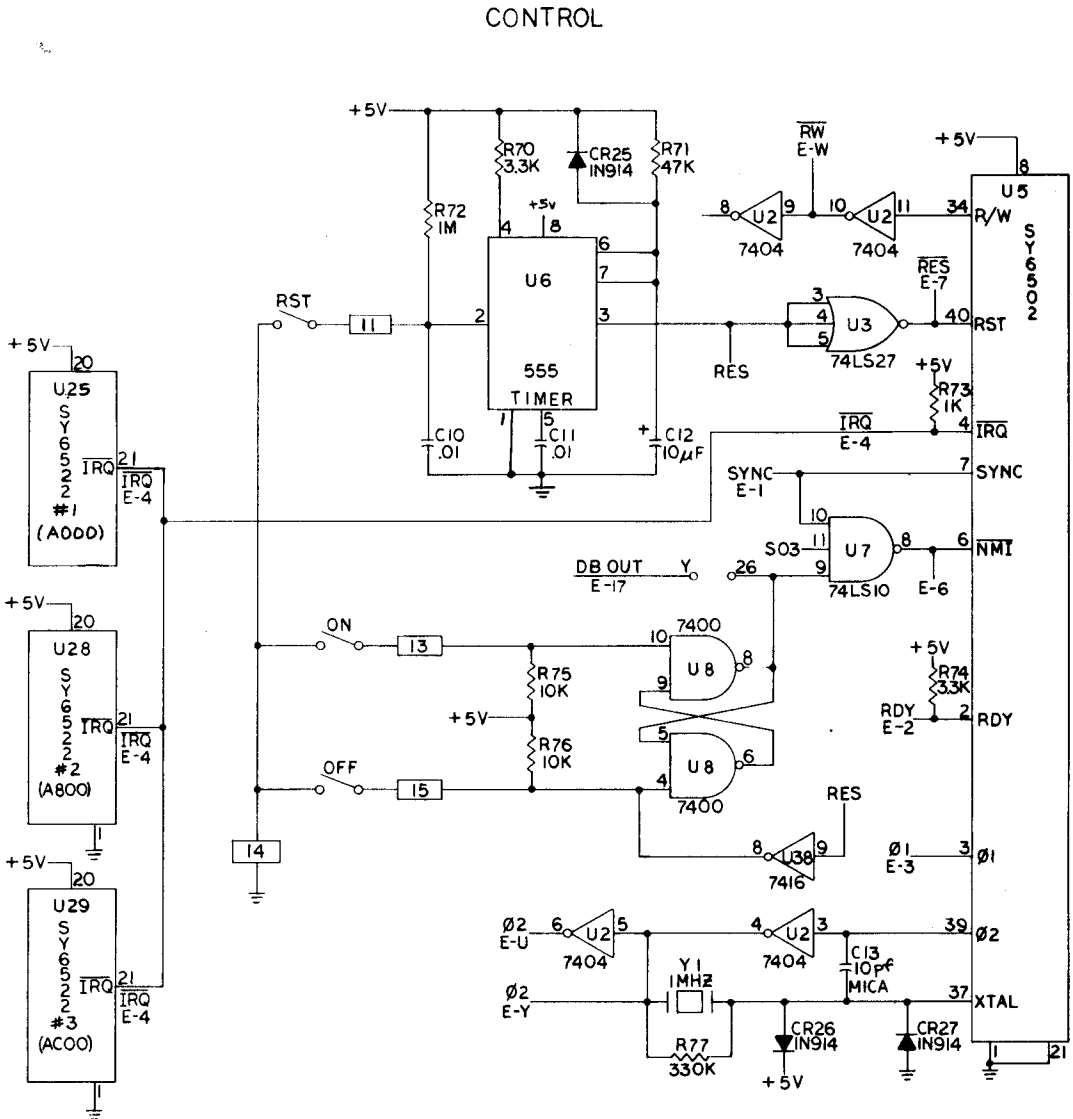


Figure 4-7. CONTROL SECTION SCHEMATIC

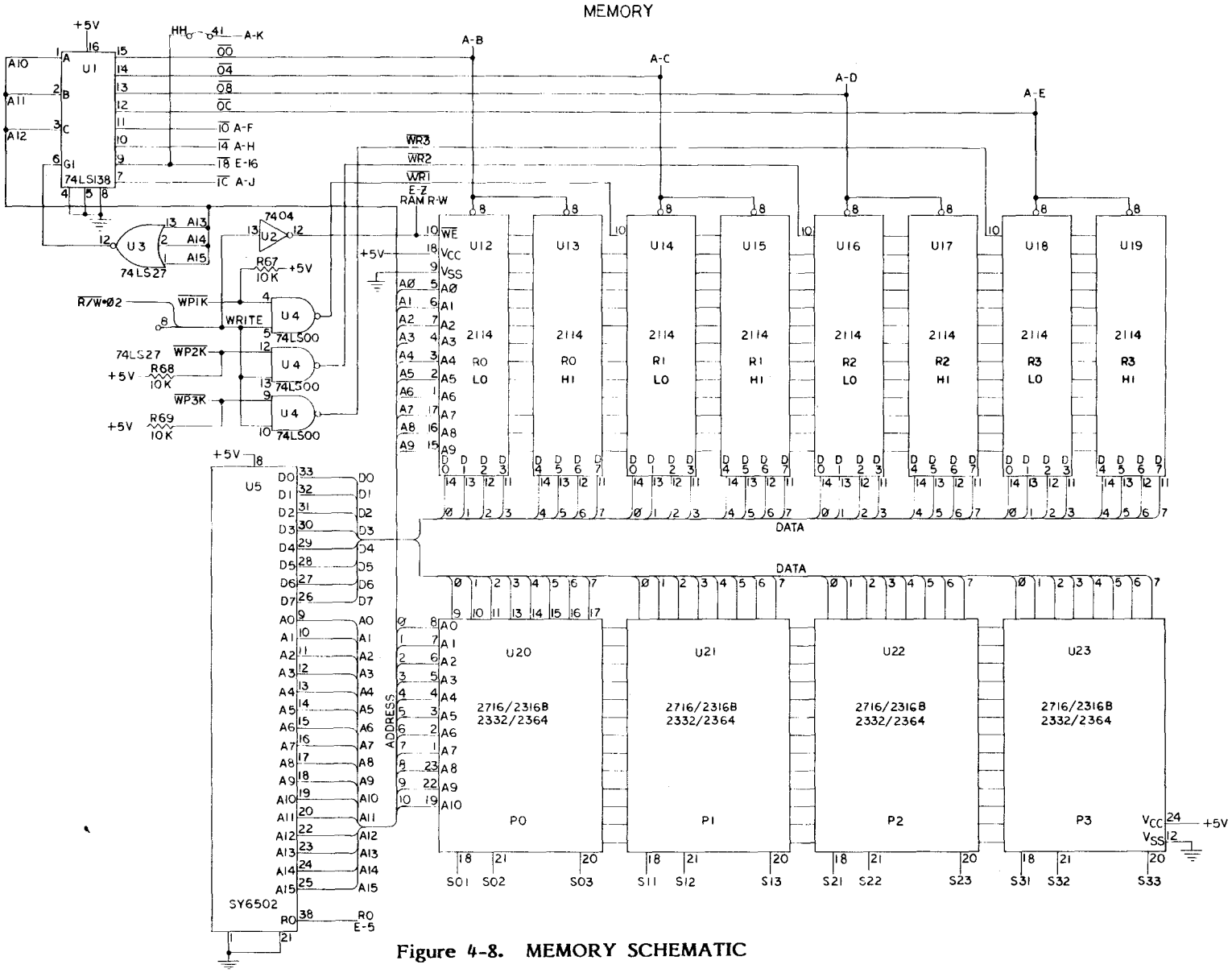


Figure 4-8. MEMORY SCHEMATIC

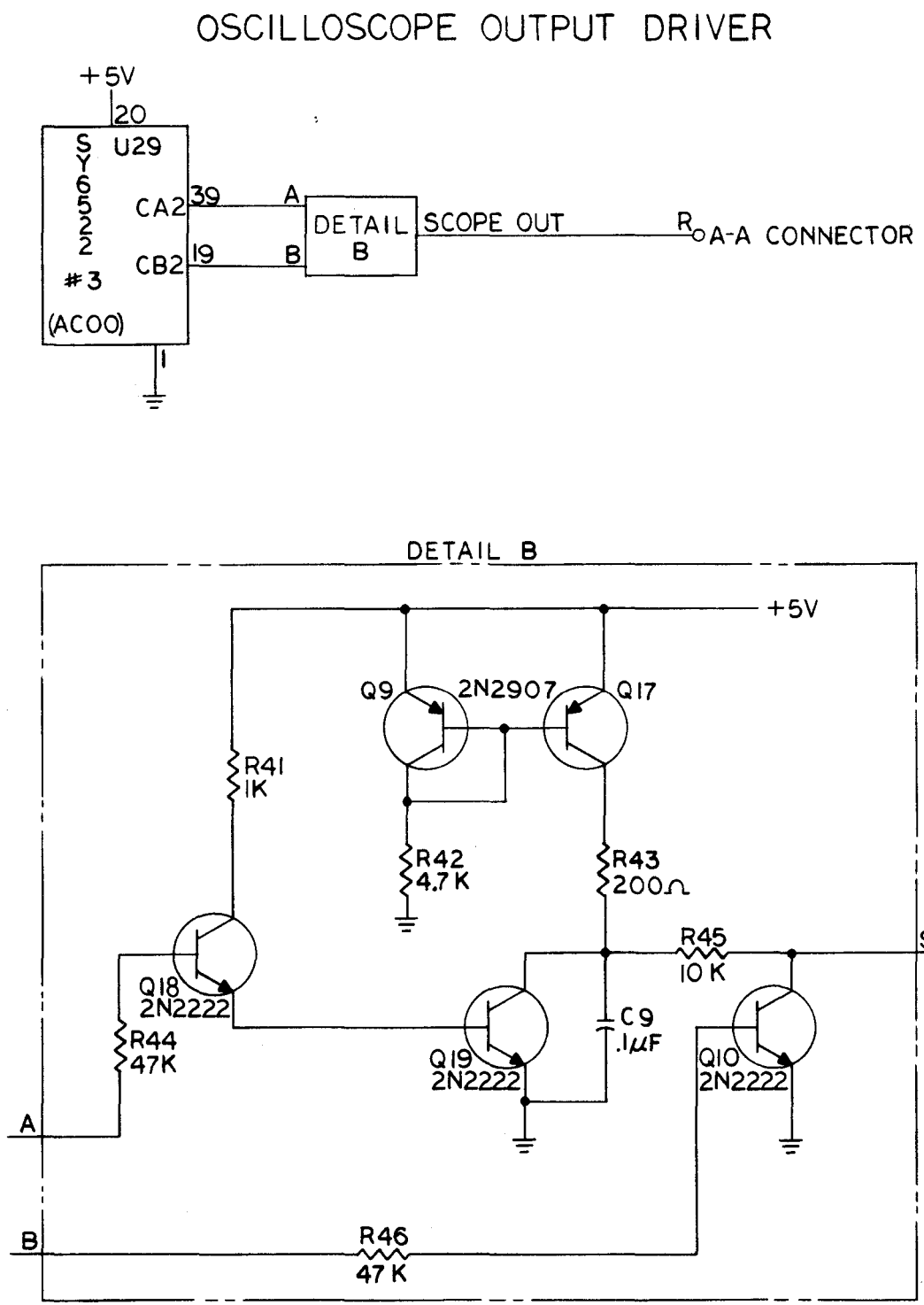


Figure 4-9. OSCILLOSCOPE OUTPUT DRIVER SCHEMATIC

4.2 MEMORY ALLOCATION

This section describes the standard memory allocation in your SYM-1 microcomputer system. It makes extensive use of the detailed Memory Map contained in Figure 4-10. Also described in this section is the technique by which ROM and RAM addressing and usage may be altered by using an array of on-board jumpers which allow you to modify and expand your SYM-1 memory. Expanding RAM memory using off-board components is taken up briefly in Section 4.2.3, although a detailed discussion of this is reserved for Chapter 8, "System Expansion".

4.2.1 Standard Memory Allocation

Figure 4-10 is a map of the standard memory allocation in your SYM-1 microcomputer. Provided with your system are 1K of on-board RAM, extending from location 0000 to 03FF in the Memory Map. Note that the top-most eight bytes (locations 00F8 to 00FF) in Page Zero of this 1K block are reserved for use by the system and should not be used by your programs. The remainder of Page Zero is largely similar to the rest of the RAM provided, but it also has some special significance for addressing which will become clearer in Section 4.3. Locations 0100-01FF in the 1K memory block furnished with your system are reserved for stack usage. Your programs may use this area, but you should use it for normal stack operations incidental to operating your programs. Locations 01FF-03FF are general-use RAM for your program and data storage.

In addition to the 1K of on-board RAM furnished with your system, sockets are provided for 3K of plug-in RAM, allowing you to have 4K of on-board RAM memory. These sockets occupy memory locations 0400-0FFF.

The SUPERMON monitor resides in ROM at memory locations 8000-8FFF. (As you know, the SY6502 CPU addresses all memory and I/O identically, so that it is immaterial whether a specific address location is occupied by RAM, ROM or I/O devices.) The next 4K block, from 9000-9FFF, is reserved for future expasion of SUPERMON, although you may use those locations if you wish to do so, provided you remember that if you should obtain an expanded SUPERMON system in the future these addresses may be used.

Extending from A000-AFFF are the I/O devices on your SYM-1 module. As we have previously said, each port on the SY6522/SY6532 devices in SYM-1 is an addressable location. Sheets 2-6 of Figure 4-10 provide you with a detailed Memory Map breakdown of how these devices are addressed. Note that within the SY6532 is a 128 byte segment (locations A600-A7FF). This is the RAM which is resident on the SY6532 used by SYM-1 as System RAM. Sheet 4 of Figure 4-10 describes each memory location within System RAM in detail; you will need this data if you wish to make use of the capability of the system for modifications to SUPERMON. These modifications may include creating your own commands (as described in Chapter 5) which may be entered as if they were Monitor commands. Other such modifications making use of System RAM locations are described in Chapter 9 of this manual.

Memory locations B000-FF80 may be used by your programs, provided of course you have expanded memory to fill those address locations (see Chapter 8). Note, however, that if you plan to obtain the Synertek Systems 8K BASIC module at some later date, that module will occupy locations C000-DFFF. You should plan your applications programs accordingly. Locations FF80-FFFF are reserved for special use by the system, and should not be used in any of your applications code.

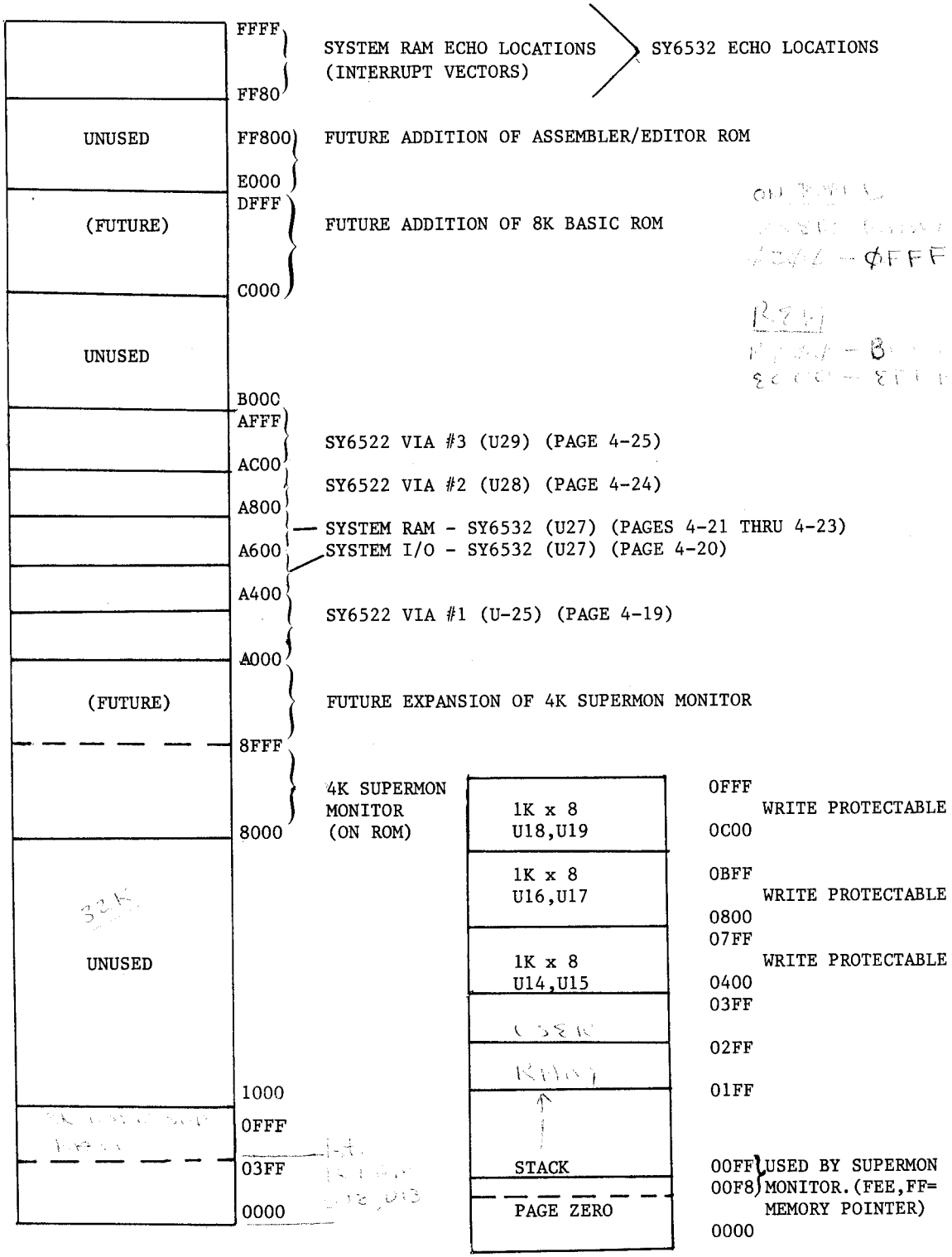


Figure 4-10. STANDARD MEMORY MAP, SYM-1

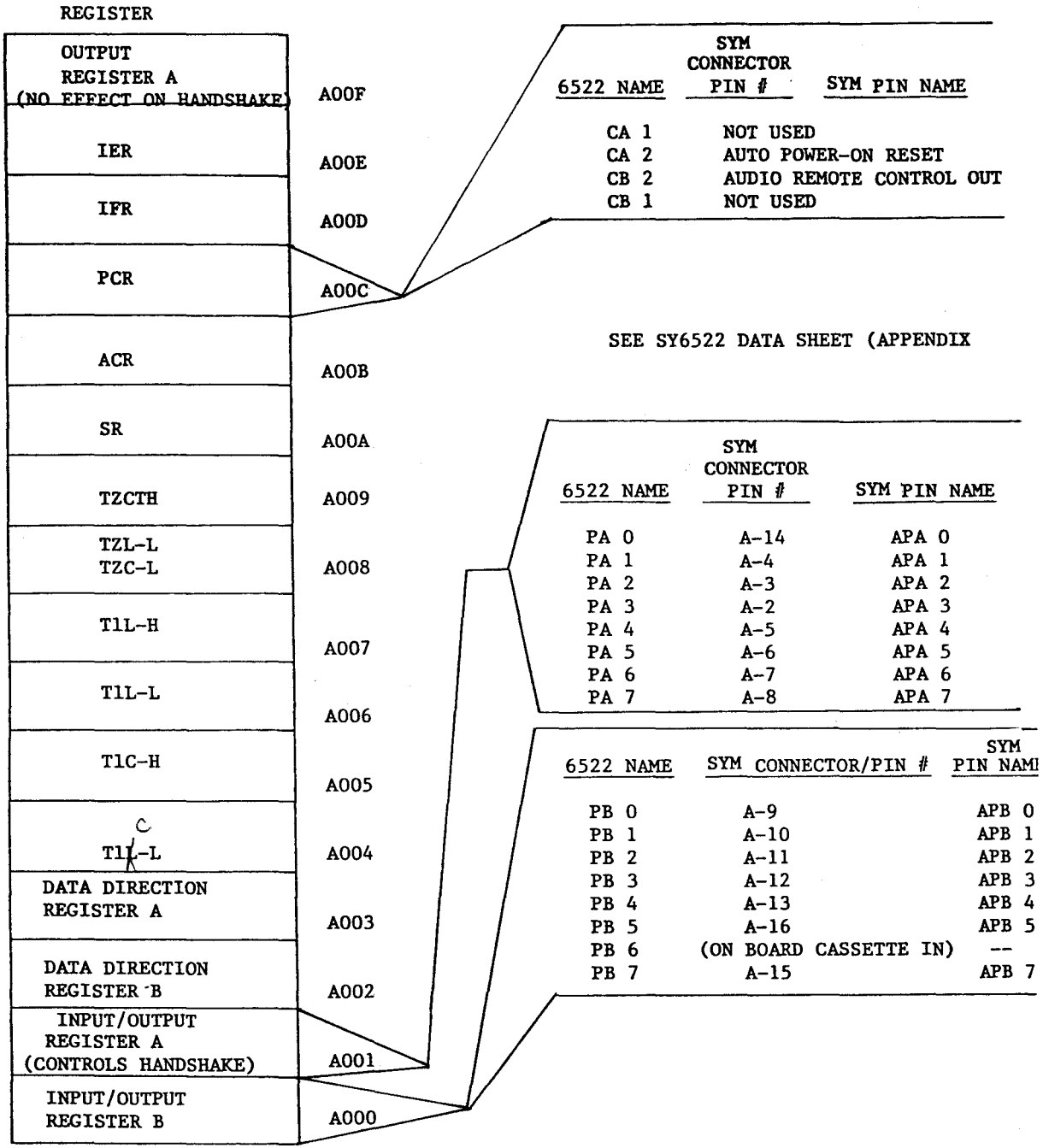


Figure 4-10 (Cont'd). MEMORY MAP FOR SY6522 VIA #1 (DEVICE U25)

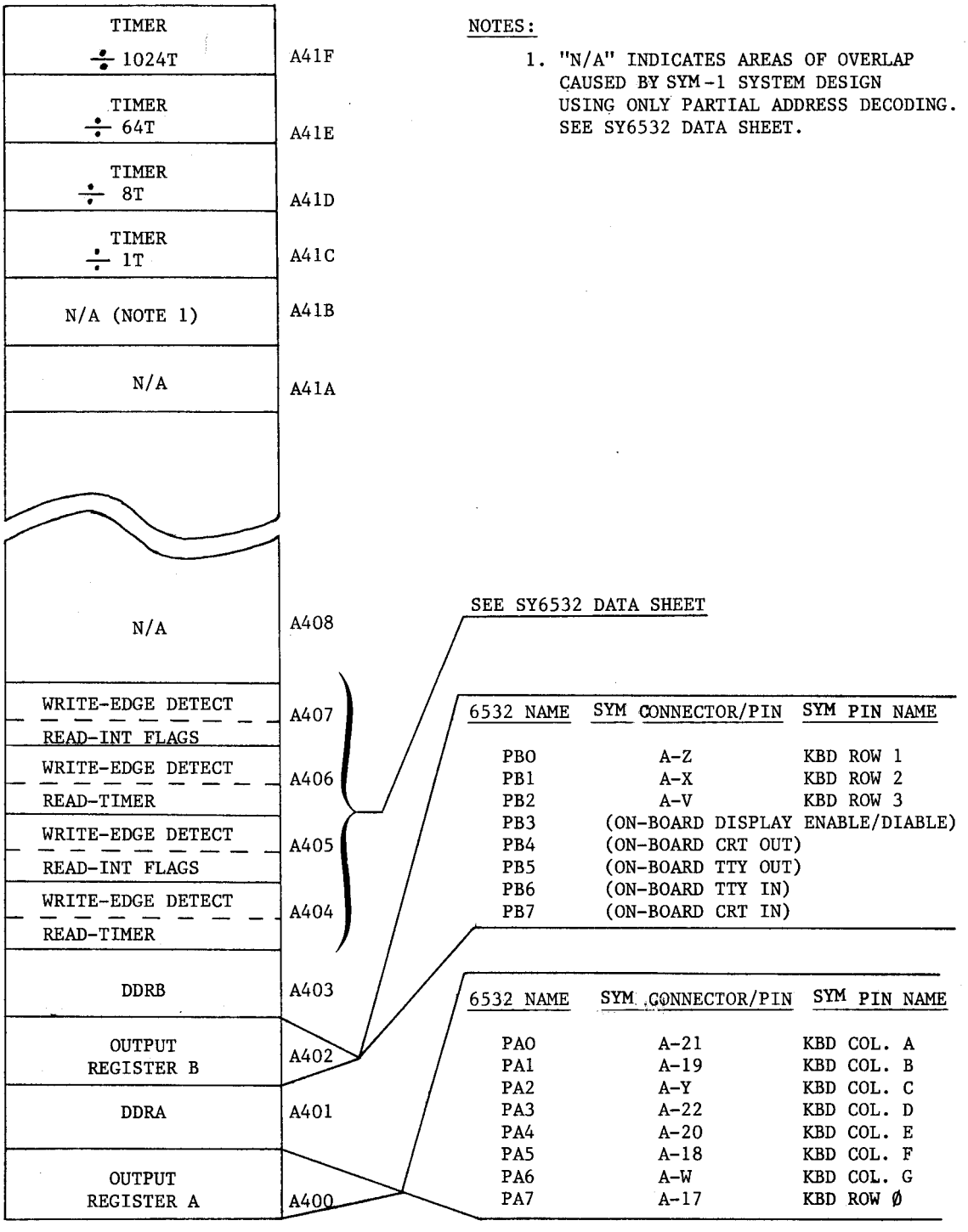


Figure 4-10 (Cont'd). MEMORY MAP FOR SY6532 (DEVICE U27)

SYMBOL	ADDRESS	DEFAULT VALUE	COMMENTS
IRQVEC	A67F	80	IRQ Vector
	A67E	0F	
RSTVEC	A67D	8B	RESET Vector
	A67C	4A	
NMIVEC	A67B	80	NMI Vector
	A67A	9B	
UIRQVC	A679	80	User IRQ Vector
	A678	29	
UBRKVC	A677	80	User Break Vector
	A676	4A	
TRCVEC	A675	80	Trace Vector
	A674	C0	
EXEVEC	A673	88	'Execute' Vector
	A672	7E	
SCNVEC	A671	89	Display Scan Vector
	A670	06	
	A66F	4C	
URCVEC	A66E	81	Unrecognized Command Vector
	A66D	D1	
	A66C	4C	
	A66B	00	Not Used
	A66A	00	
	A669	00	
INSVEC	A668	89	In Status Vector
	A667	6A	
	A666	4C	
OUTVEC	A665	89	Output Vector
	A664	00	
	A663	4C	
INVEC	A662	89	Input Vector
	A661	BE	
	A660	4C	
YR	A65F	00	User Registers
XR	A65E	00	
AR	A65D	00	
FR	A65C	00	
SR	A65B	FF	
PCHR	A65A	8B	
PCLR	A659	4A	
MAXRC	A658	10	Max. No. Bytes/Record, Paper Tape (Note 6)
LSTCOM	A657	00	Last Monitor Command
TV	A656	00	Trace Velocity (Note 5)
KSHFL	A655	00	Hex Keyboard Shift Flag
TOUTFL	A654	B0	In/Out Enable Flags (Note 4)

Figure 4-10. SYSTEM RAM MEMORY MAP, SY6532

SYMBOL	ADDRESS	DEFAULT VALUE	COMMENTS
TECHO	A653	80	Terminal Echo (Note 3)
ERCNT	A652	00	Error Count (Note 2)
SDBYT	A651	4C	Baud Rate (Note 1)
PADBIT	A650	01	Number of Padbits on Carriage Return
P1H	A64F	00	
P1L	A64E	00	
P2H	A64D	00	16-Bit Parameters
P2L	A64C	00	
P3H	A64B	00	
P3L	A64A	00	
PARNR	A649	00	No. of Parameters Entered
	A648	00	
	A647	00	Not Used
	A646	00	
RDIG	A645	3F	Right-most Digit
DISBUF	A644	86	
	A643	6E	
	A642	6D	Display Buffer
	A641	00	
	A640	00	
SCRF	A63F	00	
			Monitor Scratch Locations SCR0-SCRF
SCR0	A630	00	
JTABLE	A62F	D0	User Socket P3 (Jump Entry No. 7)
	A62E	00	
	A62D	C8	User Socket P2 (Jump Entry No. 6)
	A62C	00	
	A62B	03	0300 (Jump Entry 5)
	A62A	00	
	A629	02	0200 (Jump Entry 4)
	A628	00	
	A627	00	0000 (Jump Entry 3)
	A626	00	
	A625	8B	NEWDEV (Jump Entry 2) (Note 7)
	A624	64	
	A623	8B	TTY (Jump Entry 1)
	A622	A7	
	A621	C0	BASIC (Jump Entry 0)
	A620	00	
SCPBUF	A61F	--	
			Scope Buffer, No Defaults (32 locations)
	A600	--	

Figure 4-10. SYSTEM RAM MEMORY MAP, SY6532 (Continued)

NOTES - SYSTEM RAM

1. BAUD RATE -

BAUD	SDBYT
110	D5
300	4C
600	24
1200	10
2400	06
4800	01

2. ERCNT - Used by LD P, FILL, B MOV

   Count of bytes which failed to write correctly
   And invalid checksums up to $FF

3. TECHO - bit 7 - ECHO/NO ECHO

   bit 6 - OUTPUT/NO OUTPUT This bit is toggled everytime a control O (ASCII 0F) is encountered in the input stream.

4. TOUTFL - bit 7 = enable CRT IN
   bit 6 = enable TTY IN
   bit 5 = enable TTY OUT
   bit 4 = enable CRT OUT

5. TV - TRACE VELOCITY
   00 = SINGLE STEP

   non-zero - PRINT PROGRAM COUNTER AND ACCUMULATOR
   THEN PAUSE AND RESUME

   PAUSE DEPENDS ON TV
   (TRY TV = 09)

6. USER PC - DEFAULT = 8B4A = RESET

7. NEW DEV TO CHANGE BAUD RATE ON RS-232 INTERFACE.

Figure 4-10. SYSTEM RAM MEMORY MAP, SY6532 (Continued)

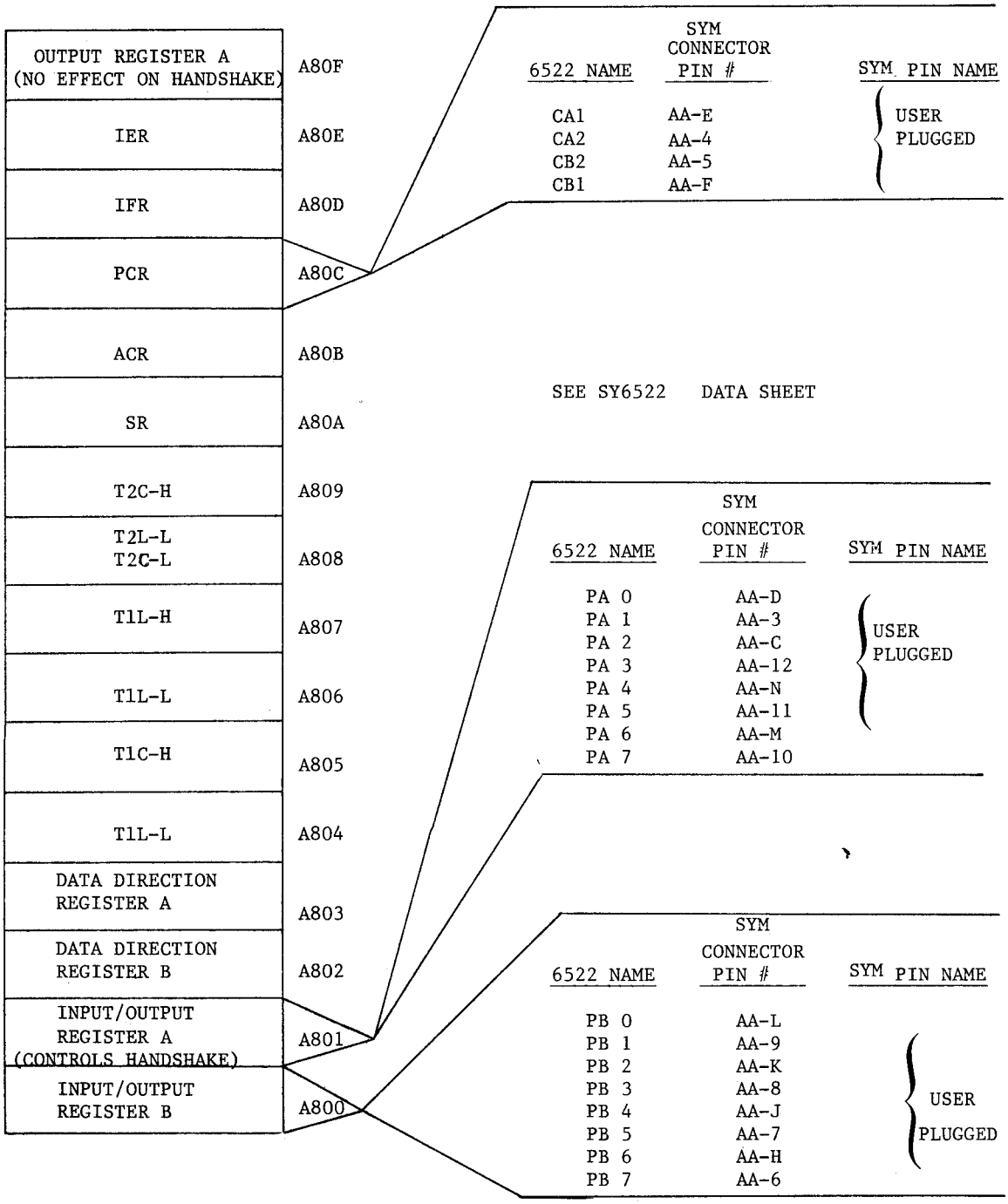


Figure 4-10. MEMORY MAP FOR SY6522 VIA #2 (DEVICE U28-USER SUPPLIED)
(Continued)

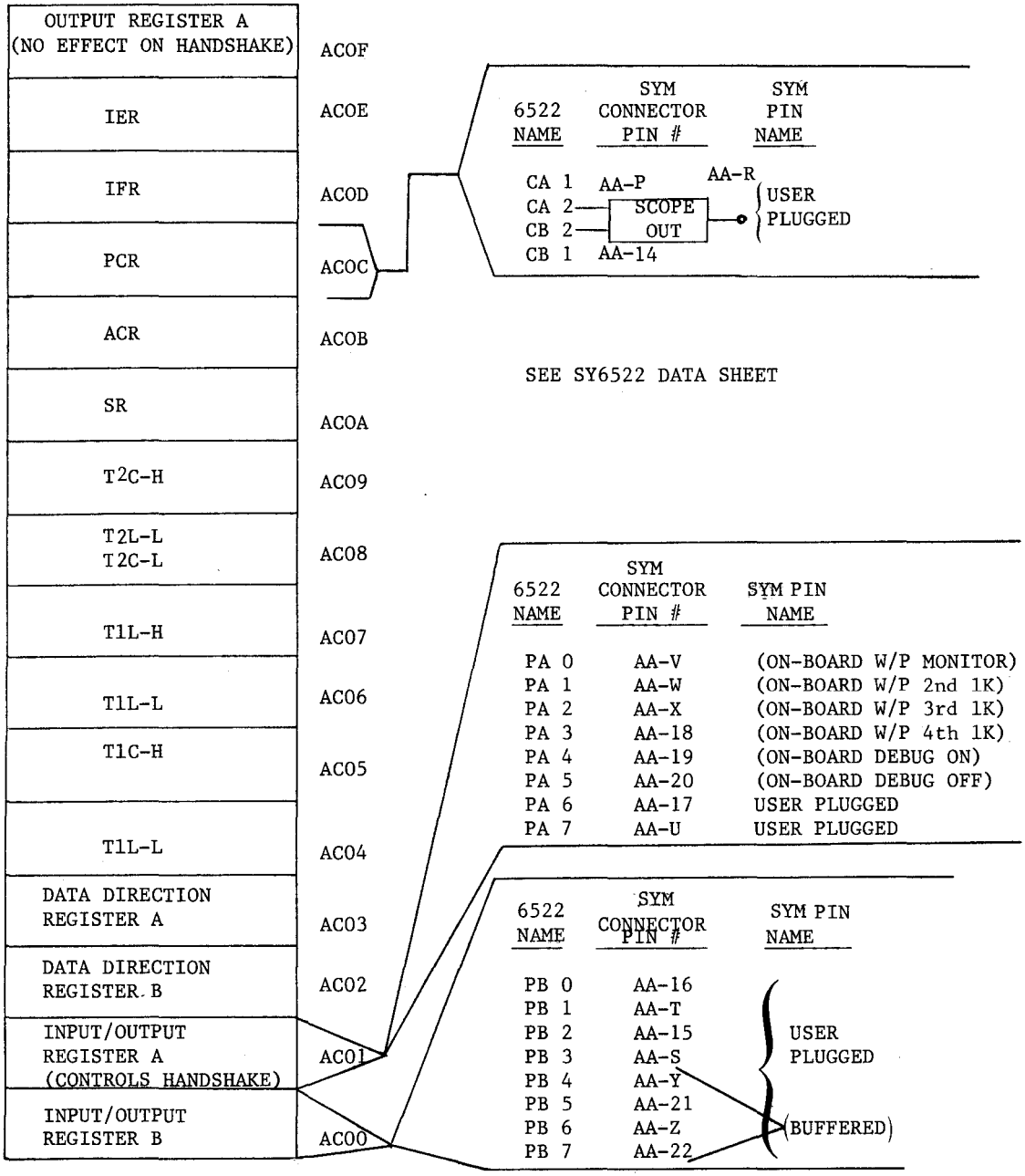


Figure 4-10. MEMORY MAP FOR SY6522 VIA #3 (DEVICE U29) (Continued)

4.2.2 Address Decoding Jumper Options

Four sockets (labeled P0-P3 on the board) for ROM PROM or EPROM are provided with your SYM-1. Each socket may contain any of four different types of Read-Only Memory devices, up to a total of 24K. The four acceptable devices are the SY2716, the SY2316B, the SY2332 and the SY2364. Each device is slightly different, but they are all read-only memories. They may appear in any combination on a SYM-1 microcomputer system, provided their total capacity does not exceed 24K. But since the devices have different memory capacities, it is necessary to alter normal addressing to accomodate the specific devices selected.

To serve this purpose, we have provided a set of jumpers, located just to the left of the center of the board and directly under the two 74LS145's. The schematic in Figure 4-11 illustrates each useful jumper combination and Table 4-3 outlines them in greater detail. (Note that Table 4-3 contains other jumpers available on the SYM-1, not all of which pertain to memory use.) The broken lines in Figure 4-11 indicate the jumpers installed at the factory. Note, for example, that the first PROM socket, labeled P0 (device U20) is associated with the address group beginning with 8000. If it were necessary to change this configuration, you would remove the connection from Pin 1 of the lower address decoder (74LS145) to jumper connection 7-J so that it becomes associated with a jumper combination which addresses the device you wish to address. Table 4-3a will assist you in configuring your selection of ROM correctly.

Near the bottom of the board below the speaker unit are four jumpers labeled JJ, KK, LL and MM. These enable Write Protection on the RAM in the four 1K blocks available on the board. Jumper 45-MM is factory-installed, enabling Write Protection on System RAM (the 128-byte block in the SY6532). As you add RAM later, or to Write Protect any of the on-board RAM aside from System RAM, you must connect the appropriate jumpers to enable the Write Protect function on the desired memory locations. RAM may be enabled for Write Protect in 1K blocks.

These jumpers offer you flexibility to adapt the SYM-1 board to your particular application. The jumpers will give you the ability to do the following:

- Use 2K, 4K, or 8K byte ROM or PROM in each 24 pin socket.
- Complete flexibility in selecting user PROM addressing.
- Ability to auto power-on to any of the ROM/PROM sockets.
- Write protect expansion RAM.

4.2.3 Off-Board Expandability

SYM-1 is expandable, on-board, up to 24K bytes of EPROM/ROM memory and 4K bytes of RAM, with 8K bytes of address space allocated to the on-board I/O devices. Further expansion of any combination of ROM, PROM, RAM or I/O can be implemented by using SYM's "E" (Expansion) connector to attach an auxiliary board containing the additional devices. Total expandability is limited only by the amount of addressing capability of the SY6502 CPU, i.e., 64K bytes.

Detailed instructions for implementing off-board expansion are contained in Chapter 8, "System Expansion."

4.2.4 I/O Buffers

Your SYM-1 board comes to you equipped with four specially configured I/O buffer circuits. (See Figure 4-5.) The circuit configuration and PC Board layout allow the user to configure these buffers in many ways.

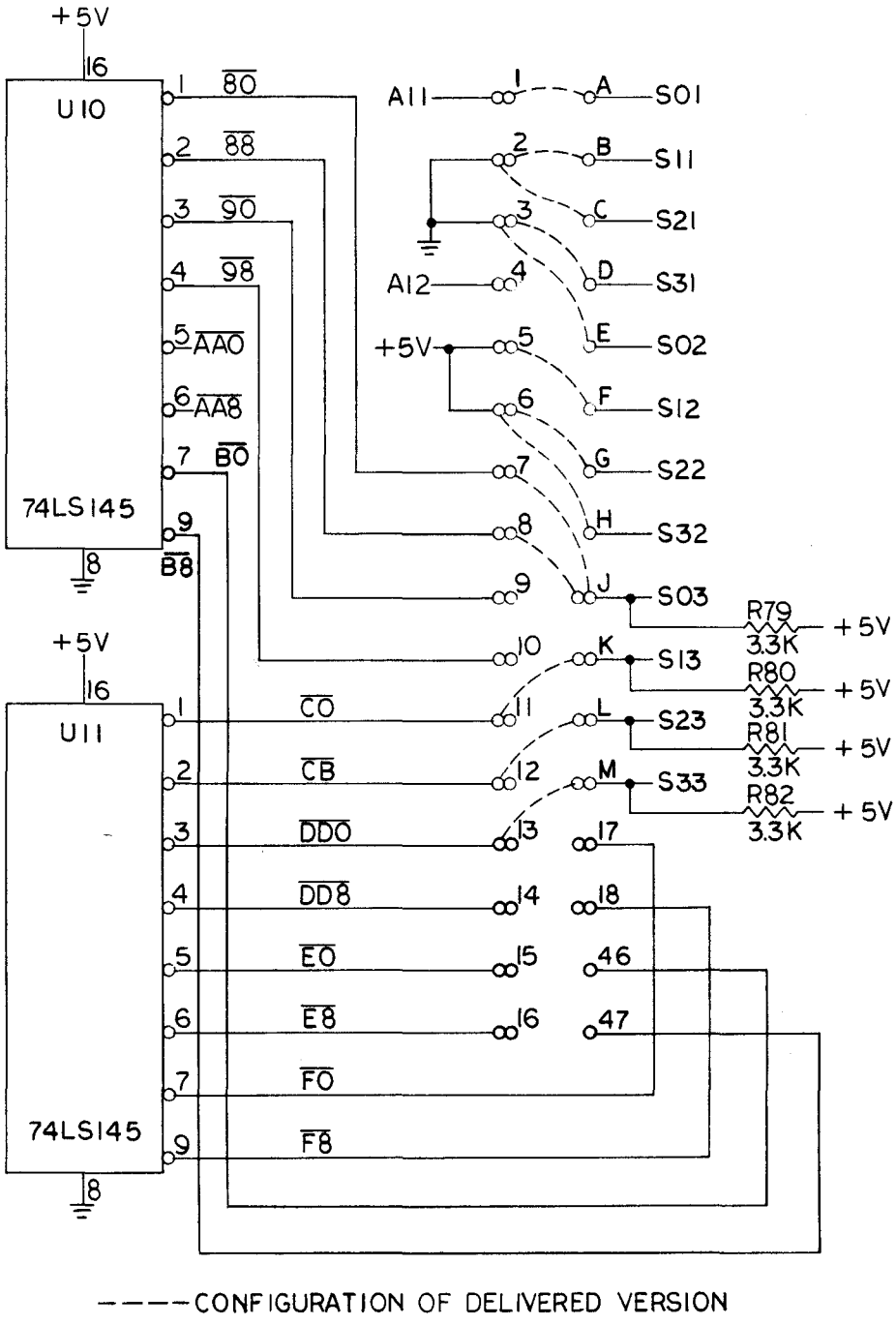


Figure 4-11. MEMORY ADDRESS DECODING JUMPER OPTIONS

Table 4-3. SYM-1 JUMPERS

JUMPER LETTER	POSITION NUMBER	DESCRIPTION
A,B,C,D E,F,G,H	1,2,3 4,5,6	PROM/ROM Device Select (See Table 4-3a)
J,K,L,M	7,8,9,10,11,12 13,14,15,16,17,18	ADDRESS SELECT (See Table 4-3b)
N	19 (1) 20	Auto Power-On to U20 (2) Disable Auto Power-On to U20
P	19 (1) 20	Auto Power-On to U21 (2) Disable Auto Power-On to U21
R	19 (1) 20	Auto Power-On to U22 (2) Disable Auto Power-On to U22
S	19 (1) 20	Auto Power-On to U23 (2) Disable Auto Power-On to U23
T U	21 22	Enables Monitor RAM at A0xx (3) Enables Monitor RAM at F8xx (3)
V	23	RCN-1 to connector A-N
W X	24 25	Enables Software Debug ON Enables Software Debug OFF
Y	26	DBOUT to connector E-17
BB CC	31 32	Connects TTY IN to PB6 @A402 Connects CRT IN to PB7 @A402
DD	33 34	To run TTY @ +5V and GND To run TTY @ +5V and -Vn (4)
EE	35 36	To run TTY @ +5V and -Vn (4) To run TTY @ +5V and GND
FF	37 38	To run TTY @ +5V and GND To run TTY @ +5V and -Vn (4)
GG	39 40	To run RS232 @+5V and GND To run RS232 @+5V and -Vn (5)
HH	41	Decode line $\overline{18}$ to connector A-K
JJ KK LL MM	42 43 44 45	Enable software write protect 3K block Enable software write protect 2K block Enable software write protect 1K block Enable software write protect monitor RAM

Table 4-3. SYM-1 JUMPERS (Continued)

NOTES

1 Only one socket (U20, U21, U22, U23) should be jumpered to position 19 at one time. The remaining three sockets should be jumpered to position 20.

2 See software consideration of auto power-on in Chapter 9.

3 One or both can be connected at the same time.

4 These positions require a recommended -9V to -15V supply applied to the power connector pin E. R107 should be adjusted (removed and replaced) for your proper current loop requirements.

Example: (for 60ma current loops and Vn = -10V)

a. Connect DD to 33
EE to 35
FF to 38

b. $R107 = \frac{Vn - 5V}{I} = \frac{(10 - 5)}{60\ ma} = 100$

R107 = 300Ω (as installed) for 20 ma current loop and Vn=-10V

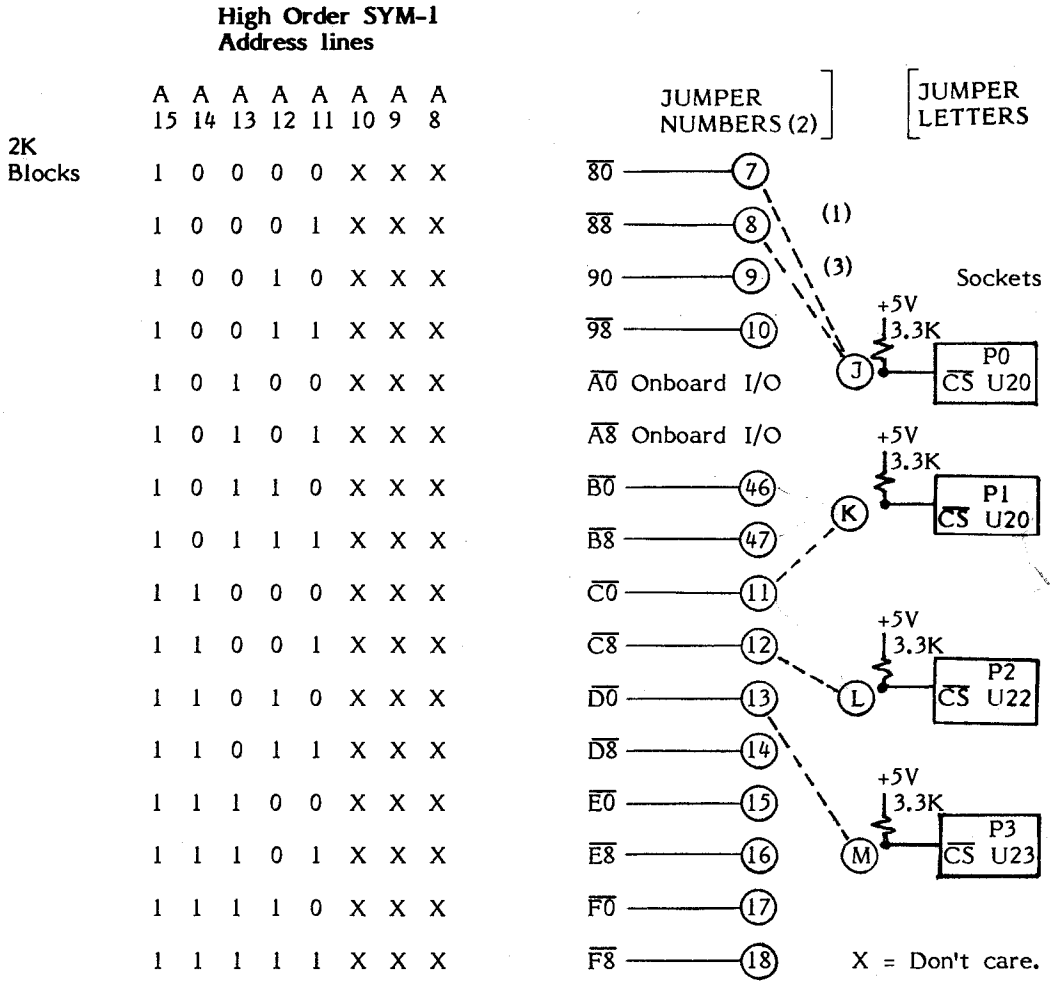
5 For RS232 devices using other than LM1489 or equivalent input receivers (i.e., probably terminals older than ten years) then GG should be strapped to 40 and a -9V to -15V supply applied to the power connector pin E.

Table 4-3a. SYM-1 PROM/ROM DEVICE SELECT

SOCKET LOCATION	SOCKET NAME	MEMORY DEVICE	JUMPER LETTER	POSITION NUMBER
U20	P0	2716	A E	2 or 3 5 or 6
U20	PO	2316	A E	2 or 3 2 or 3
U20	PO	2332	A E	1 2 or 3
U20	PO	2364	A E	1 4
U21	P1	2716	B F	2 or 3 5 or 6
U21	P1	2316	B F	2 or 3 2 or 3
U21	P1	2332	B F	1 2 or 3
U21	P1	2364	B F	1 4
U22	P2	2716	C G	2 or 3 5 or 6
U22	P2	2316	C G	2 or 3 5 or 6
U22	P2	2332	C G	1 2 or 3
U22	P2	2364	C G	1 4
U23	P3	2716	D H	2 or 3 5 or 6
U23	P3	2316	D H	2 or 3 2 or 3
U23	P3	2332	D H	1 2 or 3
U23	P3	2364	D H	1 4

NOTE: 2716 devices assumes Synertek, Intel or equivalent pin outs.

Table 4-3b. SYM-1 ADDRESS SELECT



NOTES:

(1) Broken lines indicate delivered version of jumpers.
(2) Each jumper number represents a 2K address space decode.
(3) Jumper numbers can be wire or'ed to increase the address space of the $\overline{CS}$ on any socket (i.e., decoder is open collector.)

The single-stage circuit consists of a transistor and "circuit positions" for the user to add resistors, capacitors and dioders in any of many positions. This flexibility allows inverting and noninverting stages, input-resistive or capacitive coupling and much more. The user should refer to the schematic and P.C. layout in Figure 4-5a in order to completely understand this circuit.

4.3 SOFTWARE DESCRIPTION

Software on your SYM-1 microcomputer must be discussed from two perspectives. First, the SYM SUPERMON Monitor software which handles keyboard display, interrupts and other requirements for system operation must be understood. We will discuss this subject in succeeding sections. The second aspect of software is the microprocessor assembly language with which you will write your applications programs. A brief introduction to the 6502 instruction set is included later in this chapter.

In this chapter, we discuss the SYM-1 command language syntax only briefly; Chapter 5 contains a detailed discussion of each of the instructions in the set. Chapter 6 will help you through the process of using these and the 6502 language in applications programming by describing three selected sample programs.

4.3.1 Monitor Description - General

Figure 9-1 illustrates the general system flow of the SYM-1 SUPERMON Monitor software. As you can tell, the main program is simple and straightforward. Its purpose is to direct processing to the appropriate I/O or command routine, and for this reason it is thought of as a "driver"--it "drives" or directs the software.

The means by which the Monitor handles the direction of software flow is one of the unique features of the SYM-1 system and is worth a brief explanation at this point. We will discuss the subject in greater detail in Chapters 5 and 8.

When the SUPERMON Monitor receives a one- or two-character command from the on-board keyboard, TTY or CRT terminal, it then accepts 0-3 parameters associated with the command. The string of command and parameters (if any) is terminated by a carriage return. It is noteworthy that each instruction which may be entered by use of a single key on the on-board keyboard may also be entered with a similar command from a terminal.

Upon receiving a command and up to three parameters, SUPERMON checks to determine whether the command and its associated number of parameters is a defined combination. If so, the command is executed. Otherwise, an error message is printed or displayed showing the ASCII representation of the command which was not recognized.

For example, a "GO" with one parameter causes the program to pass control to the program stored at the memory location indicated by the parameter. Thus, a "GO" followed by "0200" instructs the system to begin executing the instructions stored starting at memory location 0200. A "GO" with no parameters (i.e., "GO" followed by a Carriage Return) will cause program execution to resume at the address stored in the "pseudo Program Counter" (memory locations A659 and A65A).

However, a "GO" command with two or three parameters is not a defined command in SUPERMON, and will result in a display or message of "Er 47". The "47" is the ASCII representation for a "G" and is designed to help you define the instruction or command which was not recognized.

The monitor is designed so that you can extend the range of defined command-parameter combinations by "intercepting" the error routine before it executes and designing your own series of pointers to memory locations to be associated with specific commands. Thus, you might wish to define a "GET" routine which could be entered at the keyboard with a "GO" and two parameters. You will learn how to do this in Chapter 9.

4.3.2 Software Interfacing

The SYM-1 Monitor is structured to be device-independent. Special requirements for device handling are "outside" the Monitor's central control routines, which isolate them from the Monitor's standard functions. Also, as we have indicated, SYM-1 commands may be entered from any device. It is not necessary to use the on-board keyboard to do so. This means you need not concern yourself with the details of I/O; they are handled internally.

4.3.3 6502 Microprocessor Assembly Language Syntax

The SY6502 microprocessor used on your SYM-1 is an eight-bit CPU, which means that eight bits of data are transferred or operated upon at a time. It has a usable set of 56 instructions used with 13 addressing modes. Instructions are divided into three groups.

Group One instructions, of which there are eight, are those which have the greatest addressing flexibility and are therefore the most general-purpose. These include Add With Carry (ADC), the logical AND (AND), Compare (CMP), the logical Exclusive OR (EOR), Load A (LDA), logical OR with Accumulator (ORA), Subtract With Carry (SBC) and Store Accumulator (STA).

Group Two instructions include those which are used to read and write data or to modify the contents of registers and memory locations.

The remaining 39 instructions in the SY6502 instruction set are Group Three instructions which operate with the X and Y registers and control branching within the program. You'll learn more about these instructions in the next section. More detailed information can be found in the Synertek Programming Manual for the SY6500 family.

An assembly language instruction consists of the following possible parts:

Label - Optional. Used to allow branching to the line containing the label and for certain addressing situations.

Mnemonic - Required. The mnemonic is a three-character abbreviation which represents the instruction to be carried out. Thus the mnemonic to store the contents of the accumulator in a specific memory location is "STA" (STore Accumulator).

Operand(s) - Some may be required, or none may be allowed. This depends entirely upon the instruction itself and may be determined from the later discussion.

Comment - Optional. Separated from last operand (or from the command mnemonic where no operand is used) by at least one blank. These words are ignored by the assembler program but are included only to allow the programmer and others to understand the program.

The SY6502 allows 13 modes of addressing, which makes it one of the most flexible CPUs on the market. Table 4-4 describes these addressing modes briefly. Details may be found in the Synertek Programming Manual for the SY6500 family.

You will note that some of the addressing modes make use of Page Zero, a concept introduced briefly earlier in this chapter. Page Zero addressing modes are designed to reduce memory requirements and provide faster execution. When the SY6502 processor encounters an instruction using Page Zero addressing, it assumes the high-order byte of the address to be 00, which means you need not define that byte in your program. This technique is particularly useful in dealing with working registers and intermediate values. As the Memory Map (Figure 4-10, Sheet 1) shows, memory locations 0000-00FF make up Page Zero.

4.3.4 SY6502 Instruction Set

Table 4-5 provides you with a summary of the SY6502 instruction set. Each instruction is shown with its mnemonic, a brief description of the function(s) it carries out, and the corresponding "op code" for each of its valid addressing modes. The "op code" is the hexadecimal representation of the instruction and is what will appear when the instruction byte is displayed by SUPERMON.

When creating applications programs for your SYM-1, you will typically write them in the SY6502 assembly language mnemonic structure shown in Table 4-5, then perform a "hand assembly" to generate the "op codes" and operands. The process of hand assembling code is explained in greater detail in Section 6.2.2. You will be referring to this table--or to your SYM Reference Card--quite frequently during programming.

To understand some of the instructions, you should be aware of six "status register" flags which are set and reset by the results of program execution. Generally, these flags and their functions are:

N - Set to "1" by CPU when the result of the previous instruction is negative
Z - Set to "1" by CPU when the result of the previous instruction is zero
C - Set to "1" by CPU when the previous instruction results in an arithmetic "carry"
Set to "0" by CPU when the previous instruction results in "borrow" (subtract)
Also modified by shift, rotate and compare instructions.
I - When "1," IRQ to the CPU is held pending
D - When "1," CPU arithmetic is operates in decimal mode
V - Set to "1" by CPU when the result of the previous instruction causes an arithmetic overflow

The Synertek Programming Manual discusses this subject in greater detail.

Table 4-4. SUMMARY OF SY6502 CPU ADDRESSING MODES

SY6502 INSTRUCTION SET SUMMARY

Addressing Modes

Mode	Description	# Bytes	Example		
IMPLIED	The operation performed is implied by the instruction.	1*	TAX	AA	Code for transfer A to X
ACCUMULATOR	The operation is performed upon the A register.	1	ROL A	2A	Code for rotate left A
IMMEDIATE	The data accessed is in the second byte of the instruction.	2	LDA #3	A9 03	Code for load A immediate Constant to use
ZERO PAGE	The address within page zero of the data accessed is in the second byte of the instruction.	2	LDA Z	A5 75	Code for load A zero page Low part of address on page zero
ZERO PAGE INDEXED BY X	The second byte of the instruction plus the contents of the X register (without carry) is the address on page zero of the data accessed.	2	LDA Z,X	B5 75	Code for zero page indexed by X Base address on page zero
ZERO PAGE INDEXED BY Y	The second byte of the instruction plus the contents of the Y register (without carry) is the address on page zero of the data accessed.	2	LDX Z,Y	B6 75	Code for zero page indexed by Y Base address on page zero
ABSOLUTE	The address of the data accessed is in the second and third bytes of the instruction.	3	LDA L	AD 47 02	Code for load A absolute Low part of address High part of address

*Except BRK which is two bytes when not using SUPERMON or when in DEBUG mode.

Table 4-4. SUMMARY OF SY6502 CPU ADDRESSING MODES (Continued)

Mode	Description	# Bytes	Example		
INDEXED BY X	The address in the second and third bytes of the instruction, plus the contents of the X register is the address of the data accessed.	3	LDA L,X	BD 47 02	Code for load A indexed by X Low part of base address High part of base address
INDEXED BY Y	The address in the second and third bytes of the instruction, plus the contents of the Y register is the address of the data accessed.	3	LDA L,Y	B9 47 02	Code for load A indexed by Y Low part of base address High part of base address
INDIRECT PRE-INDEXED BY X	The second byte of the instruction plus the contents of the X register (without carry) is the address on page zero of the two-byte address of the data accessed.	2	LDA (Z,X)	A1 75	Code for load A, indirect pre-indexed by X Base address on page zero
INDIRECT POST-INDEXED BY Y	The contents of the page zero two-byte address specified by the second byte in the instruction, plus the contents of the Y register is the address of the data accessed.	2	LDA (Z),Y	B1 75	Code for load A, indirect post-indexed by Y Base address of page zero
RELATIVE BRANCH	The second byte of the instruction contains the offset (in bytes) to branch address.	2	BEQ LOC	F0 07	Code for branch if equal Seven bytes ahead
INDIRECT JUMP	The address in the second and third bytes of the instruction is the address of the address to which the jump is made.	3	JMP (LOC)	6C 47 02	Code for jump indirect Low part of indirect address High part of indirect address

Table 4-5. SY6502 CPU Instruction Set Summary

6502 INSTRUCTION SET SUMMARY

Instr	Description	Mode													Condition Codes						
		IMP	ACC	IMM	Z	Z,X	Z,Y	ABS	L,X	L,Y	(Z,X)	(Z),Y	REL	IND	N	Z	C	I	D	V	B
ADC	A + M + C → A, C Add memory to accumulator with carry			69	65	75		6D	7D	79	61	71			*	*	*	-	-	*	-
AND	A ∧ M → A "AND" memory with accumulator			29	25	35		2D	3D	39	21	31			*	*	-	-	-	-	-
ASL	C ← 7 6 5 4 3 2 1 0 ← 0 Shift left one bit (memory or accumulator		0A		06	16		0E	1E						*	*	*	-	-	-	-
BCC	Branch on C = 0 Branch on carry clear												90		-	-	-	-	-	-	-
BCS	Branch on C = 1 Branch on carry set												B0		-	-	-	-	-	-	-
BEQ	Branch on Z = 1 Branch on result zero												F0		-	-	-	-	-	-	-
BIT	A ∧ M, M_7 → N, M_6 → V Test bits in memory with accumulator				24			2C							M_7	*	-	-	-	M_6	-
BMI	Branch on N = 1 Branch on result minus												30		-	-	-	-	-	-	-
BNE	Branch on Z = 0 Branch on result not zero												D0		-	-	-	-	-	-	-
BPL	Branch on N = 0 Branch on result plus												10		-	-	-	-	-	-	-
BRK	Forced interrupt PC↓ P↓ Force break	00													-	-	-	1	-	-	1

Table 4-5. SY6502 CPU Instruction Set Summary (Continued)

6502 INSTRUCTION SET SUMMARY

Instr	Description	Mode													Condition Codes						
		IMP	ACC	IMM	Z	Z,X	Z,Y	ABS	L,X	L,Y	(Z,X)	(Z),Y	REL	IND	N	Z	C	I	D	V	B
BVC	Branch on V = 0 Branch on overflow clear												50		-	-	-	-	-	-	-
BVS	Branch on V = 1 Branch on overflow set												70		-	-	-	-	-	-	-
CLC	0 → C Clear carry flag	18													-	-	0	-	-	-	-
CLD	0 → D Clear decimal mode flag	D8													-	-	-	-	0	-	-
CLI	0 → I Clear interrupt disable flag	58													-	-	-	0	-	-	-
CLV	0 → V Clear overflow flag	B8													-	-	-	-	-	0	-
CMP	A - M Compare memory and accumulator			C9	C5	D5		CD	DD	D9	C1	D1			*	*	*	-	-	-	-
CPX	X - M Compare memory and index X			E0	E4			EC							*	*	*	-	-	-	-
CPY	Y - M Compare memory and index Y			C0	C4			CC							*	*	*	-	-	-	-
DEC	M - 1 → M Decrement memory by one				C6	D6		CE	DE						*	*	-	-	-	-	-
DEX	X - 1 → X Decrement index X by one	CA													*	*	-	-	-	-	-

Table 4-5. SY6502 CPU Instruction Set Summary (Continued)

6502 INSTRUCTION SET SUMMARY		Mode												Condition Codes						
Instr	Description	IMP	ACC	IMM	Z	Z,X	Z,Y	ABS	L,X	L,Y	(Z,X)	(Z),Y	REL	IND	N	Z	C	I	D	V	B
DEY	Y - 1 → Y Decrement index Y by one	88													*	*	-	-	-	-	-
EOR	A ⊻ M → A "Exclusive-Or" memory with accumulator			49	45	55		4D	5D	59	41	51			*	*	-	-	-	-	-
INC	M + 1 → M Increment memory by one				E6	F6		EE	FE						*	*	-	-	-	-	-
INX	X + 1 → X Increment Index X by one	E8													*	*	-	-	-	-	-
INY	Y + 1 → Y Increment index Y by one	C8													*	*	-	-	-	-	-
JMP	(PC + 1) → PCL (PC + 2) → PCH Jump to new location							4C						6C	-	-	-	-	-	-	-
JSR	PC + 2 ↓, (PC + 1) → PCL (PC + 2) → PCH Jump to new location saving return address							20							-	-	-	-	-	-	-
LDA	M → A Load accumulator with memory			A9	A5	B5		AD	BD	B9	A1	B1			*	*	-	-	-	-	-
LDX	M → X Load index X with memory			A2	A6		B6	AE		BE					*	*	-	-	-	-	-
LDY	M → Y Load index Y with memory			A0	A4	B4		AC	BC						*	*	-	-	-	-	-

Table 4-5. SY6502 CPU Instruction Set Summary (Continued)

6502 INSTRUCTION SET SUMMARY

Instr	Description	Mode													Condition Codes						
		IMP	ACC	IMM	Z	Z,X	Z,Y	ABS	L,X	L,Y	(Z,X)	(Z),Y	REL	IND	N	Z	C	I	D	V	B
LSR	0 → [7][6][5][4][3][2][1][0] → [C] Shift right one bit (memory or accumulator)		4A		46	56		4E	5E						0	*	*	-	-	-	-
NOP	No Operation	EA													-	-	-	-	-	-	-
ORA	A V M → A "OR" memory with accumulator			09	05	15		0D	1D	19	01	11			*	*	-	-	-	-	-
PHA	A ↓ Push accumulator on stack	48													-	-	-	-	-	-	-
PHP	P ↓ Push processor status on stack	08													-	-	-	-	-	-	1
PLA	A ↑ Pull accumulator from stack	68													*	*	-	-	-	-	-
PLP	P ↑ Pull processor status from stack	28													From Stack						
ROL	M or A [7][6][5][4][3][2][1][0] ← [C] Rotate one bit left (memory or accumulator)		2A		26	36		2E	3E						*	*	*	-	-	-	-
ROR	Rotate One Bit Right (Memory or Accumulator)		6A		66	76		6E	7E						*	*	*	-	-	-	-
RTI	P ↑ PC ↑ Return from interrupt	40													From Stack						
RTS	PC ↑, PC + 1 → PC Return from subroutine	60													-	-	-	-	-	-	-

Table 4-5. SY6502 CPU Instruction Set Summary (Continued)

6502 INSTRUCTION SET SUMMARY		Mode													Condition Codes						
Instr	Description	IMP	ACC	IMM	Z	Z,X	Z,Y	ABS	L,X	L,Y	(Z,X)	(Z),Y	REL	IND	N	Z	C	I	D	V	B
SBC	A - M - $\overline{C}$ → A Note: $\overline{C}$ = Borrow Subtract memory from accumulator with borrow			E9	E5	F5		ED	FD	F9	E1	F1			*	*	*	-	-	*	-
SEC	1 → C Set carry flag	38													-	-	1	-	-	-	-
SED	1 → D Set decimal mode flag	F8													-	-	-	-	1	-	-
SEI	1 → I Set interrupt disable flag	78													-	-	-	1	-	-	-
STA	A → M Store accumulator in memory				85	95		8D	9D	99	81	91			-	-	-	-	-	-	-
STX	X → M Store index X in memory				86		96	8E							-	-	-	-	-	-	-
STY	Y → M Store index Y in memory				84	94		8C							-	-	-	-	-	-	-
TAX	A → X Transfer accumulator to index X	AA													*	*	-	-	-	-	-
TAY	A → Y Transfer accumulator to index Y	A8													*	*	-	-	-	-	-
TSX	S → X Transfer stack pointer to index X	BA													*	*	-	-	-	-	-

Table 4-5. SY6502 CPU Instruction Set Summary (Continued)

6502 INSTRUCTION SET SUMMARY		Mode													Condition Codes						
Instr	Description	IMP	ACC	IMM	Z	Z,X	Z,Y	ABS	L,X	L,Y	(Z,X)	(Z),Y	REL	IND	N	Z	C	I	D	V	B
TXA	X → A Transfer index X to accumulator	8A													*	*	-	-	-	-	-
TXS	X → S Transfer index X to stack pointer	9A													-	-	-	-	-	-	-
TYA	Y → A Transfer index Y to accumulator	98													*	*	-	-	-	-	-

CHAPTER 5

OPERATING THE SYM

In this chapter you will learn how to operate your SYM-1. The keyboard functions are described, formation of monitor commands is discussed, and procedures for using an audio cassette, TTY or CRT are explained.

As you operate your SYM-1, you will be dealing with the system monitor, SUPERMON, which is a tool for entering, debugging and controlling your 6502 programs. The monitor also provides a wealth of software resources (notably subroutines and tables) which are available to your applications programs as they run on the SYM-1 system.

SUPERMON is a 4K-byte program which is stored on a single ROM chip located at addresses 8000-8FFF, as you learned in Chapter 4. It also uses locations 00F8-00FF for special purposes and special locations called "System RAM" located at addresses A600-A7FF. These usages were outlined in detail in Chapter 4 and in the Memory Map.

Operationally, SUPERMON gets commands, parameters and data from its input channels (the HEX Keyboard, HKB; a teletype, TTY; a CRT terminal or RAM memory and others) and, based on this input, performs internal manipulations and various outputs (to the on-board LED display, TTY or CRT terminal screen or other peripheral devices).

5.1 KEYBOARD LAYOUT

The SYM-1 keyboard (see Figure 5-1) consists of 28 color-coded dual-function keys. The characters and functions on the lower half of the keys are entered by pressing the keys directly. To enter the functions shown in the upper halves of the keys, press SHIFT before you press the key you wish to enter. Remove your finger from SHIFT before pressing the second key. Very little pressure is necessary to actuate a key, and except for DEBUG, you will hear an audible tone when the computer senses that a key has been pressed. RST will cause a beep after a short delay.

The functions included on the SYM-1 provide you with a formidable array of programming tools. You can examine and modify the contents of memory locations and CPU registers, deposit binary or ASCII data in memory, move blocks of data from one area of memory to another, search memory for a specific byte, and fill selected memory locations with a specified data byte. You can also store a double byte of data with a single command, display the two's complement of a number, or compute an address displacement.

The RST, DEBUG ON and DEBUG OFF keys do not transmit any characters to the monitor, but perform the functions indicated by their names directly using hardware logic.

5.2 SYM COMMAND SYNTAX

As we have indicated earlier, each SYM-1 command entered from the on-board keyboard or other device may have from 0-3 parameters associated with it. Each command, with its string of parameters, is terminated by a "**CR**" (on the HKB) or a carriage return on a terminal device.

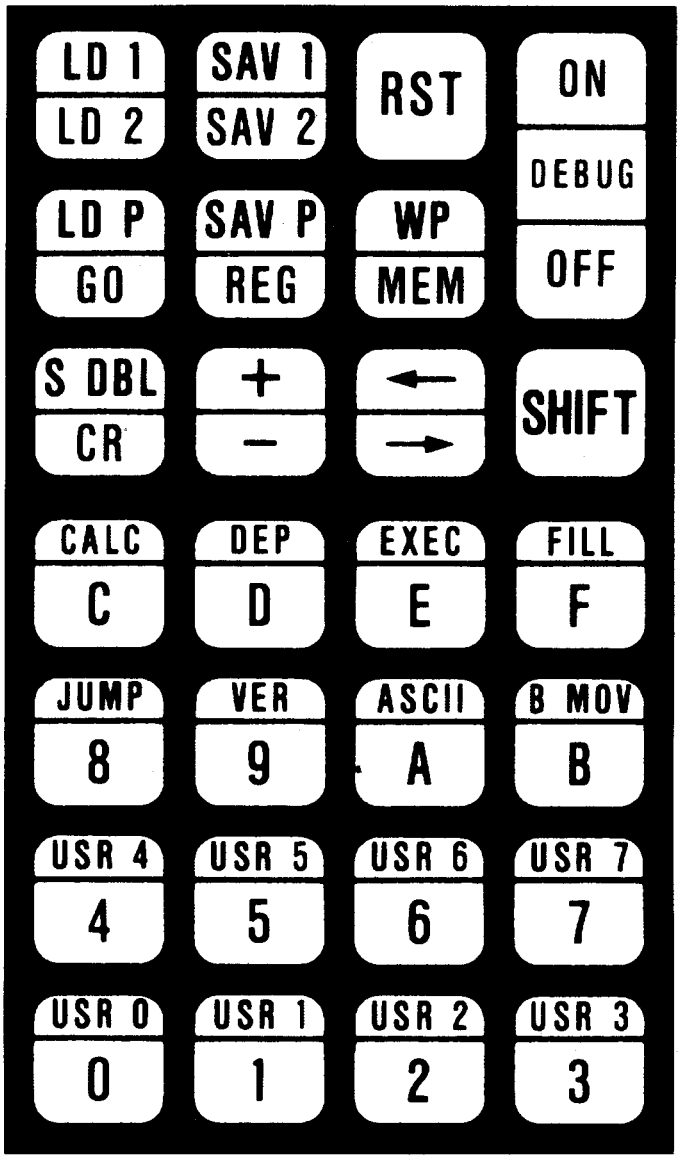


Figure 5-1. SYM-1 KEYBOARD

Table 5-1 summarizes the SYM-1 command set. The first column indicates the command, in both HKB and terminal format. The values (1), (2), and (3) refer to the values of the first, second, and third parameters entered. The term "old" is used to mean the memory location most recently referenced by any of the following commands: M, D, V, B, F, SD, S1, S2, SP, L1, L2, LP. All of these commands use locations 00FE and 00FF as an indirect pointer to memory; where a reference to "old" (or (OLD) in some cases) occurs, the former value remains in the memory pointer locations 00FE-00FF.

Note that in the second column of Table 5-1 we have provided you with the ASCII code for each instruction. Several of the commands do not have associated ASCII codes and use instead a computed "hash code." Hash codes are marked with an asterisk. You need not concern yourself with the means by which the hash code is determined, but you should note that SYM will display these values when the commands are entered with an incorrect syntax, i.e., if you make an error when entering these commands.

Table 5-2 provides you with a brief summary of the additional keys found on the on-board keyboard of the SYM-1. These are operational and special keys which do not generally have parameters associated with them, with the exception of the special user-function keys.

In the discussion of each monitor command which follows, the same basic format is followed. First, the appropriate segment of Table 5-1 is reproduced, for easy reference. Next, the command is described in some detail. Examples are used where they will make understanding the monitor command easier.

Because it is believed that most users of the SYM-1 will ultimately use a TTY to enter and obtain printouts of instruction strings, the remainder of Chapter 5 is designed to use the TTY keyboard function designations rather than those of the on-board keyboard. Remember, though, that both keyboards are functionally the same as far as SUPERMON is concerned. For this reason, we are also using a comma as a delimiter in the command string; the minus sign on the on-board keyboard (or, for that matter, on the TTY or CRT keyboard) may also be used for this purpose.

The examples provided were entered from a terminal device. When entering commands from the HKB, remember to use the (-) key instead of a comma to delimit parameters.

Table 5-1. SYM-1 COMMAND SUMMARY

Command	Code	Number of Associated Parameters			
HKB/TTY	ASCII	0	1	2	3
MEM M	4D	Memory Examine and modify, begin at (OLD)	Memory Examine and modify, begin at (1)	Memory Search for byte (1), in locations (OLD) - (2)	Memory Search for byte (1), in locations (2) - (3)
REG R	52	Examine and modify user registers PC, S,F,A,X,Y			
GO G	47	Restore all user registers and resume execution at PC	Restore user registers except PC = (1) S = FD, monitor return address is on stack		
VER V	56	Display 8 bytes with checksum beginning at (OLD)	Display 8 bytes with checksum beginning at (1)	Display (1)-(2), 8 bytes per line, with addresses and cumulative checksums	
DEP D	44	Deposit to memory, beginning at (OLD). CRLF/ address after 8 bytes, auto spacing	Deposit to memory, beginning at (1)		
CALC C	43		Calculate 0-(1) or two's complement of (1)	Calculate (1)-(2) or displacement	Calculate (1)+(2)-(3) or displacement with offset
BMOV B	42				Move all of (2) thru (3) to (1) thru (1)+(3)-(2)

* HASHED ASCII CODE

Table 5-1. SYM-1 COMMAND SUMMARY (Continued)

Command	Code	Number of Associated Parameters			
HKB/TTY	ASCII	0	1	2	3
JUMP J	4A		Restore user registers except PC= entry (1) of JUMP TABLE, S=FD, monitor return on stack		
SDBL SD	*10			Store high byte of (1) in (2) + 1 then lo byte of (1) in (2), good for changing vectors	
FILL F	46				Fill all of (2) - (3) with data byte (1)
WP W	57		Write protect user RAM according to lo 3 digits of (1)		
LD1 L1	*12	Load first KIM format record found into locations from which it was saved	Load KIM record with ID = (1) into locations from which it was saved	(1) must = FF load first KIM record found, but start at location (2)	
LD2 L2	*13	Load first hi speed record found into locations from which it was saved	load hi speed record with ID = (1)		(1) must = FF load first hi speed record found into (2) - (3)
LDP LP	*11	Load data in paper tape format. To signal end of file for tape without EOF record, type ;00 **CR** in on-line mode.			

* HASHED ASCII CODE

Table 5-1. SYM-1 Command Summary (Continued)

Command	Code	Number of Associated Parameters			
HKB/TTY	ASCII	0	1	2	3
SAVP SP	*1C			Save data from locations (1) - (2) in paper tape format. To create end of file record, unlock punch, switch to local mode, lock punch, type ;00 **CR**	
SAV1 S1	*1D				Save cassette tape locations (2) - (3) with ID = (1) KIM format
SAV2 S2	*1E				Save cassette tape locations (2) - (3) with ID = (1) hi speed format
EXEC E	45		Get monitor input from RAM, starting (1)	Get monitor input from RAM, starting (2) and store (1) for later use	Get monitor input from RAM, starting (3) and store (1) and (2) for later use.

* HASHED ASCII CODE

Table 5-2. OPERATIONAL AND SPECIAL KEY DEFINITION (ON-BOARD KEYBOARD ONLY)

Key	ASCII or *Hash Code	Description/Use
CR	OD	Carriage Return (terminates all command strings)
+	2B	Advance eight bytes
-	2D	Retreat eight bytes; also used to delimit parameters
→	3E	Advance one byte or register
←	3C	Retreat one byte
USRO	*14	All USR keys transmit the indicated Hash Code when entered as a command. The same hash codes can be sent from another terminal by entering UO (two characters, no spaces) through U7 as commands. These functions are not defined in SUPERMON and will cause the monitor to vector through the unrecognized command vector. See Chapter 9 for instructions on using this SUPERMON command feature to program your own special functions.
USR1	*15	
USR2	*16	
USR3	*17	
USR4	*18	
USR5	*19	
USR6	*1A	
USR7	*1B	
SHIFT	None	Next key entered is upper position of the selected key.
RST	None	System RESET. System RAM reinitialized to default values
DEBUG ON	None	Turn hardware Debug function "ON"
DEBUG OFF	None	Turn hardware Debug function "OFF"
ASCII	None	Next two keys entered (Hex) will be combined to form one ASCII character (e.g., SHIFT ASCII 4 D followed by a CR is the same as MEM followed by a carriage return).

* HASHED ASCII CODE

5.3 SYM-1 MONITOR COMMANDS

5.3.1 M (Display and/or Modify Memory)

Number of Associated Parameters			
0	1	2	3
Memory Examine and modify, begin at (OLD)	Memory Examine and modify, begin at (1)	Memory Search for for byte (1), in locations (OLD)-(2)	Memory Search for byte (1), in locations (2)-(3)

- The standard form for this command uses **one parameter** and is shown below.

M addr **CR**

SUPERMON will then display the address and the byte contained in the location "addr." The following options are then available:

1. Enter 2 Hex digits: bb is replaced and the next address and byte are displayed.

2. Enter single quote (from terminal) and any character: bb is replaced with the ASCII code for the entered character.

3. Enter → or ← (> or < from terminal): bb is left unchanged and addr+1 or addr-1, with its contents, is displayed.

4. Enter + or - : bb is left unchanged and addr+8 or addr-8 with its contents, is displayed.

5. Enter **CR** : Return to monitor command mode; bb unchanged.

- Another form of the display memory command uses **no parameter** as shown below:

M CR

This will cause SYM-1 to resume memory examine and modify at (OLD).

- The same memory (M) key may be used to search for a particular byte in memory, using **three parameters** in this form:

M bb,addr1,addr2 **CR**

This instructs the system to search for byte bb from addr1 to addr2. When an occurrence of bb is found, the location and contents are displayed, and all of the standard **M** options described above become available. In addition, a "G" entered following any halt will continue the search.

- Similarly, the **two parameter** sequence:

M bb,addr **CR**

will resume memory search for byte bb from (OLD) to addr.

The following examples demonstrate the various uses of memory display/modify commands. Characters entered by the user are underlined.

One Parameter

```
.M ↓                    Display memory location (OLD); return to Monitor
0215 BB ↓
.

.M A656↓                Display memory location A656
A656 00 0A              Put some data there; return to Monitor
A657 4D ↓
.

.M 200↓                 Display memory location 200
0200 20 'A              Replace data with ASCII code for A
0201 86 'B              Next location displayed; replace data with ASCII B
0202 8B 'C              Next location displayed; replace data with ASCII C
0203 20 ↓               Return to Monitor
.

.M 0200↓                Display memory location 200
0200 41 >               Display next location; data unchanged
0201 42 >               Display next location; data unchanged
0202 43 _               Use space bar for same purpose as arrow
0203 20 _
0204 AF ↓               Return to Monitor
.

.M 0300 ↓               Display memory location 300
0300 B4 <               Display previous location; data unchanged
02FF BB <
02FE 44 <
02FD BB ↓               Return to Monitor
.

.M 0200 ↓               Display memory location 200
0200 41 +               Advance 8 bytes and display memory
0208 F0 _               Space used to advance one location; data unchanged
0209 06 _
020A 20 =               Reverse 8 bytes and display memory
0202 43 ↓               Return to Monitor
.

.M 0200↓                Display memory location 200
0200 41 ↓               Return to Monitor
.M↓                     Display (OLD) which is still 200
0200 41 ↓               Return to Monitor
.
```

```
.M 6C,8000,8400↓                    Search for 6C in range 8000-8400
801F,6C,=
8017,29,↓
.V↓
8017 29 10 F0 07 68 AA 69 28,D2
 02D2
.M 6C,8400↓                         Continue search
801F,6C,_
8020,F6,_
8021,FF,G                           Continue search
8026,6C,_
8027,F8,_
8028,FF,↓                           Halt search
.
```

5.3.2 R (Display and/or Modify User Registers)

Number of Associated Parameters			
0	1	2	3
Examine and modify user registers PC,S,F,A,X,Y			

- The only pre-defined form of this command is with **no parameters**, i.e.:

R CR

As soon as the command is entered, the contents of the PC are displayed as follows:

P 8B4A,

Using a forward arrow (→ or >), you may examine the next register. Registers are displayed in the order PC, S, F, A, X, Y, with wrap-around (i.e., PC is displayed after Y). Each register except PC carries a Register Number on the display or TTY printout; S is R1, F is R2, A is R3, X is R4, and Y is R5 (see example below).

To modify the displayed register, enter two or four digits (four only in the case of the PC). The register will be automatically modified and the next will be displayed. A **CR** will cause control to return to the monitor for another command.

In the following example, we have modified the contents of the PC register to become 0200, and the A register to be set to 16. The other registers are not modified and at the conclusion of the complete register cycle and redisplay of PC, a **CR** is used to return to monitor command mode.

```
.R↓                          Display registers
P 8B4A,__                    PC; space is used to advance
R1  FF,__                    S
R2  00,__                    F
R3  00,__                    A
R4  00,__                    X
R5  00,__                    Y
P 8B4A,↓                     PC re-displayed; return to Monitor
.

.R↓
P 8B4A,0200
R1  FF,>
R2  00,_
R3  00,16                    Alter PC = 200, A = 16
R4  00,↓
.
```

5.3.3 G (GO)

Number of Associated Parameters			
0	1	2	3
Restore all user registers and resume execution at PC	Restore user registers except PC = (1) S = FD; monitor return address is pushed onto stack		

- The GO command may be used with **no parameters** to restore all user registers and begin execution at PC:

G CR

- With **one parameter**, the command will restore user registers except that PC is set to addr, S is set to FD and SUPERMON's return address is pushed onto the stack. Thus, if a subroutine return is executed, it will result in a return to monitor command mode (with the user's stack not saved). Its format is as follows:

G addr CR

5.3.4 V (VERIFY)

Number of Associated Parameters			
0	1	2	3
Display 8 bytes with checksum beginning at (OLD)	Display 8 bytes with checksum beginning at (1)	Display (1)-(2), 8 bytes per line, with addresses and cumulative checksums	

- With **one parameter**, this command will result in the display of 8 bytes beginning at addr, with checksum. The format is as follows:

V addr CR

In this example, bytes stored in locations 200-207 are displayed, along with their checksum:

```
.V 200↓
0200 41 42 43 20 AF 88 C9 0D,F3
 02F3
.
```

Note that on the on-board display, only the two-byte checksum will be visible.

The checksum is a 16-bit arithmetic sum of all of the data bytes displayed. The low byte is displayed on the data line, and the full checksum on the next. The address is not included in the checksum.

- With **no parameters**, the command will display 8 bytes beginning at (OLD).

V CR

```
.V↓
0200 41 42 43 20 AF 88 C9 0D,F3
 02F3
.
```

- With **two parameters**, the "V" command will display memory from addr1 through addr2. Eight bytes per line are displayed, with cumulative checksums. A single byte checksum is included on each data line, and a final two-byte checksum is printed on a new line.

V addr1,addr2 CR

```
.V 8000,8015↓
8000 4C 7C 8B 20 FF 80 20 4A,5C
8008 81 20 71 81 4C 03 80 08,C6
8010 48 8A 48 BA BD 04,5B
 085B
.
```

5.3.5 D (Deposit)

Number of Associated Parameters			
0	1	2	3
Deposit to memory, beginning at (OLD), CRLF/address after 8 bytes, auto spacing	Deposit to memory, beginning at (1)		

- This command is used for entering data to memory from a terminal. With **one parameter**, this command instructs the system to output a **CR** and line feed and print addr. As each two-digit byte is entered, a space is output. If you enter a space (instead of a two-digit byte), you will cause two more spaces to be output, and that memory location will remain unchanged.

D addr CR

```
.D 200↓
0200 A9 3A 85 46 20 13 08 20
0208 EE 08 85 44 84 45 C6 46
0210 D0 F2 60 ↓
.
```

- As with other commands, the "D" with **no parameters** will deposit beginning at (OLD).

D CR

Notice that V and D line up, so that a line displayed with V may be altered with D, as shown below:

```
.V 200↓                                  Verify contents of 0200-0207
0200 A9 3A 85 46 20 13 08 20,09
 0209                                    Checksum
.D↓                                      Deposit memory from 0200; space to advance
0200 _  0D _  45 _  80 03 ↓
.V 200↓                                  Re-verify contents of 0200-0207
0200 A9 0D 85 45 20 80 03 20,43
 0243                                    New checksum
.
```

5.3.6 C (Calculate)

Number of Associated Parameters			
0	1	2	3
	Calculate 0-(1), the two's complement of (1)	Calculate (1)-(2) or displacement	Calculate (1)+(2)-(3) or displacement with offset

This command is used to do Hexadecimal arithmetic. It is very useful in programming to compute branch operands required for SY6502 instructions.

- With **one parameter**, it calculates 0 minus addr (i.e., the two's complement).

C addr **CR**

- With **two parameters**, the "C" command will calculate addr1 minus addr2 (i.e., displacement).

C addr1, addr2 **CR**

- With **three parameters**, the "C" command will calculate addr1 plus addr2 minus addr3 (i.e., displacement with offset).

C addr1,addr2,addr3 **CR**

5.3.7 B (Block Move in Memory)

Number of Associated Parameters			
0	1	2	3
			Move all of (2) thru (3) to (1) thru (1)+(3)-(2)

- This command is only defined for **three parameters** and is demonstrated by the following examples:

```
.B 200,300,320↓
.
```

Move 300 thru 320 to 200 thru 220.

```
.B 200,220,250↓
.
```

Move 220 thru 250 to 200 thru 230. No data is lost, even though the regions overlap.

```
.B 220,200,230↓
.
```

Move 230 thru 200 to 250 thru 220. (Note that this move occurs in the opposite direction. No data is lost.)

5.3.8 J (JUMP)

Number of Associated Parameters			
0	1	2	3
	Restore user registers except PC=entry (1) of JUMP TABLE, S=FD, monitor return pushed on stack		

- This command is only defined for **one parameter.**

J n CR

The parameter, n, must be in the range 0-7. All user registers are restored, except PC is taken from the JUMP TABLE in System RAM, and S=FD. The monitor return address is pushed onto the stack.

(Because the monitor return is on the stack, a JUMP to a subroutine is allowable.)

Note also that certain useful default addresses are inserted in the JUMP TABLE at Reset. (See Memory Map.)

5.3.9 SD (Store Double Byte)

Number of Associated Parameters			
0	1	2	3
		Store high byte of (1) in (2)+1 then low byte of (1) in (2). Good for changing vectors	

- This command is defined only for **two parameters** and is most useful for changing vectors.

SD addr1,addr2 **CR**

The example below was used to enter the address of the Hex keyboard input routine into INVEC, in correct order (low byte-high byte). Note that this vector could not have been altered with M, because after one byte had been altered, the vector would have pointed to an invalid address.

```
.SD 89BE,A661↓
.
```

5.3.10 F (Fill)

Number of Associated Parameters			
0	1	2	3
			Fill all of (2)-(3) with data byte (1)

- Defined only for **three parameters,** this command will fill the defined region of memory (addr1-addr2) with a specified byte (bb).

F bb,addr1,addr2 **CR**

For example:

```
.F EA,200,300↵
.
```

Fill the region 200 thru 300 with the byte EA, which is a NOP instruction.

5.3.11 W (Write Protect)

Number of Associated Parameters			
0	1	2	3
	Write protect user RAM according to 3 digits of (1)		

- This command is defined for only **one parameter.** To unprotect all of user RAM, the command is:

W 0 CR

Its general form is:

W $d_1d_2d_3$ CR

Where each of d_1, d_2, d_3 are the digits 0 (unprotect) or 1 (protect).

d_1 = 400-7FF 1K above first K of RAM
d_2 = 800-BFF 2K above first K of RAM
d_3 = C00-FFF 3K above first K of RAM

For example

```
*W 101↵
*
```

1 protect 400-7FF
0 unprotect 800-BFF
1 protect C00-FFF

Note that write protect applies to extended user RAM on-board, and also that it requires a jumper insertion (see Chapter 4).

5.3.12 E (Execute)

Number of Associated Parameters			
0	1	2	3
	Get monitor input from RAM, starting at (1)	Get monitor input from RAM, starting at (2) and store (1) for later use at A64C	Get monitor input from RAM, starting at (3) and store (1) and (2) for later user at A64E and A64C

- The standard form of the execute command uses **one parameter**.

E addr CR

SUPERMON adjusts its INPUT vectors to receive its input from RAM, beginning at addr. It is assumed that the user has entered a string of ASCII codes into RAM locations beginning at addr, terminated by a byte containing 00. When 00 is encountered, input vectors will be restored. The easiest way to enter these codes is to use the M command with the single-quote option (Section 5.3.1).

When E is used with **two** or **three parameters**, the additional parameters will be stored in system RAM at A64C and A64E. It is the user's responsibility to interpret them. (Note that the E command is vectored; see Chapter 9.)

```
.D 300↓
0300 'C 'F 'F 'F 'E ', 00 ↓
.
```

The sequence at 300 is part of a commonly used Calculate routine.

```
.E 300↓
.C FFFE,200,280↓
 FF7E
.
```

Notice that part of this C command came from RAM, and part was entered at the terminal.

5.4 CASSETTE AND PAPER TAPE COMMANDS

The SYM-1 handles cassette I/O in two formats, KIM-compatible format (8 bytes/sec), and SYM high-speed format (185 bytes/sec).

The S1 and L1 commands refer to KIM format, while the S2 and L2 commands refer to SYM high-speed format.

With each Save command you specify a two-digit ID, as well as starting and ending addresses. The ID, the addresses, and the contents of all memory locations from starting to ending address, inclusive, will be written to tape. Each Save command will create one **RECORD.**

You should be careful to assign unique ID's to different records on the same tape, and to label the tape with the ID's and addresses of all the records it contains.

While SYM is searching for a record or trying to synchronize to the tape, an "S" will be lit in the left-most digit of the display on the on-board keyboard. If the "S" does not turn off, SYM is unable to locate or to read the requested record.

5.4.1 S1, S2 (Save Cassette Tape)

Number of Associated Parameters			
0	1	2	3
(S1)			Save cassette tape, locations (2) - (3) with ID = (1) in KIM format
(S2)			Save cassette tape, locations (2) - (3) with ID = (1) in High Speed format

- These commands are discussed together, as their syntax is identical. Recall that S1 refers to KIM format while S2 refers to SYM high-speed format.

Both are defined only for **three parameters.**

S2 bb,addr$_s$,addr$_e$ **CR**

The first parameter is a 2-digit ID, which may be any value other than 00 or FF. It is followed by the starting address and the ending address. In the example below, all memory locations from 0200 thru 0280, inclusive are written to tape, and given the ID 05.

```
.S1 5,200,280
.
```

5.4.2 L2 (Load High-Speed Format Record)

Number of Associated Parameters			
0	1	2	3
Load first Hi Speed record found into locations from which it was saved	Load Hi Speed record with ID = (1)		(1) must = FF. Load first Hi Speed record found into (2) - (3)

- The standard form of this command uses **one parameter**, as follows:

L2 bb **CR**

The parameter bb is the ID of the record to be loaded. When found, the record will be loaded into memory, using the addresses saved in the record itself.

If the record bb is not the first high-speed record on the tape, the "S" light will go out as VIM reads through, but ignores, the preceding records. After each unselected record is read, the "S" will re-display.

- With **no parameters** (or a single parameter of zero), the instruction will load the first high-speed format record found, without regard to its ID, using the addresses saved in the record itself.

L2 CR

or

L2 0 CR

- The L2 command exists in a third form, using **three parameters**, as follows:

L2 FF,addr1,addr2, **CR**

This usage will load a record into a **different** area of memory from where it was saved. The first parameter **must** be FF, followed by the requested starting and ending address. It is your responsibility to supply addr1 and addr2 such that their difference is the same as the difference of the addresses used to save the record.

5.4.3 L1 (Load KIM Format Record From Tape)

Number of Associated Parameters			
0	1	2	3
Load first KIM format record found into locations from which it was saved	Load Kim record with ID = (1) into locations from which it was saved	(1) must = FF. Load first KIM record found, but start at location (2)	

- The L1 command, used with **zero or** with **one parameter**, is identical in syntax to the L2 command (see Section 5.4.2, above).
- With **two parameters**, the L1 command is used to load into a **different region of the memory than that with which the record was saved.**

L1 FF,addr **CR**

The first parameter **must** be FF, followed by the requested starting address. No ending address is necessary, as the load operation will halt when the end of the record is found.

5.4.4 SP (Save Paper Tape)

Number of Associated Parameters			
0	1	2	3
		Save data from locations (1) - (2) in paper tape format. To create end of file record, unlock punch, switch to local mode, lock punch, type ;00 **CR**	

- Defined only for **two parameters**, this command will output data from RAM in paper tape format (see Appendix D).

SP addr1,addr2 **CR**

For example:

```
.SP 200.215↓
;10020034AB743E44BB44BB44BB44BB44BB44BB44BB079A
;060210AC1BF49ED4BE03FD
.
```

5.4.5 LP (Load Paper Tape)

Number of Associated Parameters			
0	1	2	3
Load data in paper tape in format. To signal end of file for tape without EOF record, type ;00 **CR** in on-line mode			

- This command is defined for **no parameters** only. It will load memory with data in paper tape format (see Appendix D).

LP CR

5.5 USER-DEFINED FUNCTIONS

You may, as we have previously pointed out, write programs to be called from the on-board keyboard. You may do this by using any combination of command and number of parameters which is not already defined (e.g., B MOV with only two parameters) or by using any or all of the eight keys along the bottom two rows of the on-board keyboard (those labeled "USR 0" through "USR 7"). The exact means of implementing these special functions is discussed in detail in Chapter 9.

5.6 ERROR CODES

The SYM-1 microcomputer system handles error codes in an interactive way, with codes being designed to be determined by the context in which the error occurs. No table of error conditions and their meanings is therefore provided with this manual, since these are context dependent.

However, you should be aware of the general method by which errors are handled by your SYM-1 system.

When your SUPERMON encounters an error of some type, it displays a 2-digit representation of the byte which was being processed when the error was detected. For example, if you attempt to carry out a CALC command with no parameters (and you haven't defined such a routine yourself as explained in Chapter 9), the system will display a "43." which is the ASCII representation for the "C" which represents the CALC function.

Similarly, if you attempt to use an ID of 00 or FF with either SAV1 or SAV2, the system will display the ID used in error.

After the "er" message is printed, a new prompt (decimal point) is displayed, and SUPERMON waits for a new command. Note that you do not need to RESET when an error condition occurs, since that results in System RAM being cleared and necessitates a re-start of your routine. It is also worth noting that when you carry out an EXEC command at the on-board keyboard the system does not halt when an error occurs; rather, it continues in the same fashion as if new commands were coming directly from the keyboard. The error condition therefore flashes too rapidly on the LED display for you to see it. Command sequences to be executed by EXEC should be pretested prior to such use.

Some fixed error codes do exist in the monitor. Four such codes are used in audio cassette operations and are defined in Table 5-3. Additionally, if in carrying out LD P, FILL or B MOV commands you either attempt to store data in a non-existent or WRITE-protected memory location or if during execution of one of these commands a memory error occurs, the LED display will show the number of locations read incorrectly. This number will always stop at "FF" if it exceeds that number, so that the display will have some intelligible meaning.

Table 5-3. ERROR CODES IN AUDIO CASSETTE OPERATIONS

Code Displayed	Meaning
2F	Last-character error. The last character in a tape record should be a 2F. If that is not the case, the system displays the error code shown.
CC	Checksum error. Usually indicates data transfer problems. Re-position the tape and try again.
FF	In KIM-1 format loading, this error code means a non-Hexadecimal character has been encountered. This almost always means a synchronization error. Restart the procedure.
	In High-Speed format loading, a framing (i.e., synchronization) error is the cause. Restart the procedure.

The following examples provide some representative errors to enable you to become familiar with how they are reported on SYM-1 using a TTY or CRT.

```
.W 111↵
.F EA,300,400↵
ER 01
.
```

Memory location 400 write protected, therefore it could not be modified. One byte only in error.

```
.S2 200,280↵
ER 1E
.
```

S2 is not defined for two parameters. The hash code for S2 is 1E.

```
.C A,230,500,
ER 2C
.
```

Three parameters only permitted.

```
.C 200,2X
ER 58
```

X is not a valid Hex digit.

```
.S2 FF,200,280↵
ER FF
.
```

ID may not be FF or 00.

```
.L2 AA,200,280↵
ER AA
.
```

ID must be FF.

```
.M 6000↵
6000,60,F5?
6001,60,↵
.
```

No RAM at 6000, therefore it cannot be modified.

```
.D 8000↵
8000 AA? DD? ↵
.
```

ROM at 8000, therefore it cannot be modified

```
.D 200,280↵
ER 44
.
```

Deposit not defined for 2 parameters. D = ASCII 44.

```
.F EA,5000,6000↵
ER FF
.
```

No RAM at locations 5000-6000, therefore no modification was possible. The number of bytes which were not correctly changed is greater than or equal to 255 (decimal).

CHAPTER 6

PROGRAMMING THE SYM-1

Creating a program on the SYM-1 involves several steps. First, the input to the program and its desired output must be carefully defined. The flow of program logic is usually worked out graphically in the form of a flowchart. Next, the symbols on the flowchart are converted to assembly language instructions. These instructions are in turn translated into machine language, which is entered into memory and executed. If (as usual) the program does not run correctly the first time, you must debug it to uncover the errors in the program. This chapter illustrates the steps involved in creating a program to add two 16-bit binary numbers, and provides two other programming problems with suggested solutions. All three programs are designed to communicate basic programming principles and techniques and to demonstrate a programmer's approach to simple problems.

6.1 HARDWARE

All the sample programs listed here can be loaded and run on the basic SYM-1 with the minimum RAM. The only I/O devices required are the on-board keyboard and display.

If a printing or display terminal is available, by all means use it instead of the Hex keyboard provided. Both types are more comfortable for most users and allow much more data to be displayed at once.

Connect the terminal cable to the appropriate connector on the left edge of the card as described in Chapter 3. Verify that the switches on the terminal are set for full-duplex operation and no parity. The duplexing mode switch will usually be labelled HALF/FULL or H/F; the parity switch will be labelled EVEN/ODD/NO. If your terminal has a CRT, wait for it to warm up. To log on to a terminal, enter a "Q" immediately after reset.

6.2 DOUBLE-PRECISION ADDITION

Since the eight bits of the accumulator can represent positive values only in the range 0-255 (00-FF Hex), 255 is the largest sum that can be obtained by simply loading one 8-bit number into the accumulator and adding another. But by utilizing the Carry Flag, which is set to "1" whenever the result of an addition exceeds 255, multiple-byte numbers may be added and the results stored in memory. A 16-bit sum can represent values greater than 65,000 (up to FFFF Hex). Adding 16-bit rather than 8-bit numbers is called "double-precision" addition, using 24-bit numbers yields triple precision, etc.

6.2.1 Defining Program Flow

Flowcharting is an orderly way of representing a procedure. Much easier to follow than a list of instructions, a flowchart facilitates debugging and also serves as a handy reference when using a program written weeks or months earlier. Some common flowcharting symbols are shown in Figure 6-1. below.

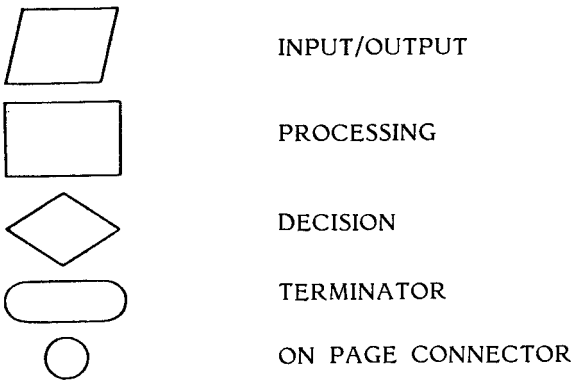


Figure 6-1. COMMON FLOWCHARTING SYMBOLS

The object of our program is to add two 16-bit numbers, each stored in two bytes of RAM, and obtain a 16-bit result. The sequence of operations the processor must perform is shown in the flowchart in Figure 6-2.

To accomplish double-precision addition, first clear the Decimal Mode and the Carry Flags. (The addition is in binary, so the system must not be expecting decimal numbers. The Carry Flag is used in the program and must start at zero.) Load the low byte of the first 16-bit number into the accumulator and add the low order byte of the second number using an Add With Carry (ADC) command. The contents of the accumulator are the low order byte of the result. The Carry Flag is set if the low-byte sum was greater than FF (Hex).

You now store the accumulator contents in memory, load the high order byte of the first number into the accumulator, and add the high order byte of the second number. The ADC command automatically adds the carry bit if it is set. After the second addition, the contents of the accumulator are the high order byte of the result. The example below shows the addition of 384 and 128.

```
      0000  0001  1000  0000     384  (0180 Hex)
      0000  0000  1000  0000     128  (0080 Hex)

      Add low order bytes:  (clear carry)

            1000  0000
            1000  0000
Carry = 1   0000  0000

      Add high order bytes:  (carry = 1)

            0000  0001
            0000  0000
                     1  CARRY
Carry = 0   0000  0010

   Result = 0000 0010  0000  0000 = 512  (0200 Hex)
```

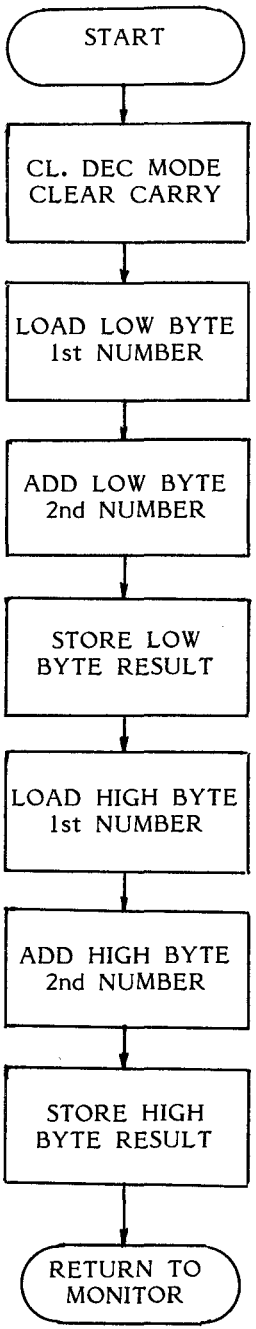


Figure 6-2. DOUBLE-PRECISION ADDITION FLOWCHART

6.2.2 Coding and "Hand Assembly"

Once you have flowcharted a program, you may "code" it onto a form like the one shown in Figure 6-3. SY6502 Microprocessor Assembly Language is described in Sections 4.3.3 and 4.3.4. Additional information is available in the Synertek "Programming Manual" for the 6500 family. Figure 6-4 shows the coding for our example.

The first step involves finding the SY6502 commands that correspond to the operations specified in the flowchart. A summary of the commands and their mnemonic codes is given in Table 4-7. Arbitrary labels were assigned to represent the addresses of the monitor, the two addends and the sum and entered in the operand field. As written, the assembly language program does not specify where in memory the program and data will be stored.

To store and execute the program, you must "assemble" it by translating the mnemonics into hexadecimal command codes and assign the program to a set of addresses in user RAM. Performing this procedure with pencil and paper, rather than with a special assembler program, is "hand assembly".

The SUPERMON monitor begins at Hex location 8000, and the addends and the sum have been arbitrarily assigned to locations 0301 through 0306. You should note that the high and low order bytes of a 16-bit number need not be stored in contiguous locations, although they are in this example.

The program will be stored beginning in location 0200, another arbitrary choice. Data and programs may be stored anywhere in user RAM. Columns B1, B2, and B3 represent the three possible bytes in any 6502 instruction. B1 always contains the Hexadecimal operation code. B2 and B3 represent the operand(s). Looking at the coding form, you can see that the CLD and CLC instructions each occupy one byte and that the LDA instruction occupies three bytes. On your instruction set summary card, you'll see that the LDA mnemonic represents several different operation codes depending on the addressing mode chosen. AD indicates absolute addressing and specifies a three-byte command. When all the operation codes and operands have been translated into pairs of Hex digits, the program is ready to be entered into memory and executed.

6.2.3 Entering and Executing the Program

The procedure for entering the double precision addition program is shown below.

YOU KEY IN	DISPLAY SHOWS	EXPLANATION
(RST)		
(CR)	SY1.0..	
(MEM) 200 (CR)	0200.**.	Enter memory display and modify mode
D8	0201.**.	Store D8 in location 0200, advance to next location
18	0202.**.	Store 18 in location 0201, advance to next location
AD	0203.**.	.
02	0204.**.	.
03	0205.**.	.
6D	0206.**.	.
	.	
	.	
	.	
80	0217.**.	
(CR)	217.**..	Exit memory display and modify mode

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PROGRAM_____

PROGRAMMER_____

DATE_____

ADDR	INSTRUCTIONS B1	B2	B3	LABEL	MNEMONIC	OPERAND	COMMENTS

Figure 6-3. SAMPLE CODING FORM

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PROGRAM_____

PROGRAMMER_____

DATE_____

DUAL-PRECISION ADD ROUTINE

ADDR	INSTRUCTIONS B1	B2	B3	LABEL	MNEMONIC	OPERAND	COMMENTS
200	DB				CLD		CLEAR DECIMAL MODE FLAG (MODE = 0)
201	18				CLC		CLEAR CARRY FLAG (CARRY=0)
202	AD	02	03		LDA	L1	LOAD LOW ORDER BYTE, FIRST NUMBER
205	6D	04	03		ADC	L2	ADD WITH CARRY, LOW ORDER BYTE, SECOND NUMBER
208	8D	06	03		STA	L3	STORE LOW ORDER BYTE, RESULT
20B	AD	01	03		LDA	H1	LOAD HIGH ORDER BYTE, FIRST NUMBER
20E	6D	03	03		ADC	H2	ADD WITH CARRY HIGH ORDER BYTE, SECOND NUMBER
211	8D	05	03		STA	H3	STORE HIGH ORDER BYTE, RESULT
214	4C	00	80		JMP	START	BRANCH TO MONITOR
301				H1	=	$301	HIGH ORDER BYTE OF FIRST NUMBER
302				L1	=	$302	LOW ORDER BYTE OF FIRST NUMBER
303				H2	=	$303	HIGH ORDER BYTE OF SECOND NUMBER
304				L2	=	$304	LOW ORDER BYTE OF SECOND NUMBER
305				H3	=	$305	HIGH ORDER BYTE OF RESULT
306				L3	=	$306	LOW ORDER BYTE OF RESULT
8000				START	=	$8000	MONITOR

Figure 6-4. DUAL-PRECISION ADD ROUTINE

The program is now entered. Examine each location to make sure that all values are correct. Then store the addend values in locations 0301-0304 as shown below. We'll use the numbers that were used in the example in Section 6.2.1, 0180 (Hex) and 0080 (Hex).

YOU KEY IN	DISPLAY SHOWS	EXPLANATION
(MEM) 301 (CR)	0301.**.	
01	0302.**.	Enter high order byte, first addend
80	0303.**.	Enter low order byte, first addend
00	0304.**.	Enter high order byte, second addend
80	0305.**.	Enter low order byte, second addend
(CR)	305.**..	

To execute the program, enter the command shown below.

YOU KEY IN	DISPLAY SHOWS	EXPLANATION
(GO) 200 (CR)	g 200.	Execute program starting at location 0200.

Now use MEM to examine locations 0305 and 0306. Verify that they are high and low order bytes of the result, 02 and 00. If you find other data at these locations, you will be pleased to know that the next section of this chapter tells you how to debug the program.

6.2.4 Debugging Methods

The first step in debugging is to make sure that the program and data have been entered correctly. Use the MEM command to examine the program starting address, and use the right-pointing arrow key to advance one location at a time and verify that the contents of each are correct. If you have a terminal, you can generate a listing by entering an SP command without turning on the tape punch or by using the VER command. Also examine the locations that contain the initial data.

If the program and data are correct, but the program still does not execute properly, you may want to use the SYM-1 DEBUG function. If DEBUG is ON when the execute (GO) command is entered, the program will execute the first instruction, then return control to the monitor. The address on the display will be the address of the first byte of the next instruction. If you again press GO (CR) to execute (do not specify an address this time), the computer will execute the next instruction, then halt as before. The program may be executed one step at a time in this manner.

By entering a non-zero Trace Velocity (at location A656), execution will automatically resume after a pause during which the Accumulator is displayed. Depress any key to halt automatic resumption.

After certain instructions, you will want to examine the contents of memory locations or registers. Use the MEM or REG commands, then resume operation by entering another GO command.

To examine the Carry Flag after the low order addition, for example, use the REG command as shown below.

YOU KEY IN	DISPLAY SHOWS	EXPLANATION
(ON)	unimportant	Turn DEBUG function ON
(GO) 200 (CR)	0201.2 .	Execute D8 instruction
(GO) (CR)	0202.2 .	Execute 18 instruction
(GO) (CR)	0205.2 .	Execute AD instruction
(GO) (CR)	0208.2 .	Execute 6D instruction, low order add with carry
(REG) (CR)	P 0208.	Program Counter
	r1 Fd.	Stack pointer
	r2 63.	Status register
(CR)	2 63.	End register examination
(GO) (CR)	020B.2 .	Execute 8D instruction
	.	
	.	

The Carry Flag is the lowest (rightmost) bit of the Status Register. To determine whether the flag was set, convert the Hex digits 63 to binary. The result of this conversion is 0110 0011, and since the low bit is "1", this confirms that the sum of the two low order bytes was greater than 255 (FF Hex).

You may turn the DEBUG switch OFF after any instruction. When you next press GO, the program will finish executing.

Since reading from or writing to any I/O port is the same as reading from or writing to a memory location, the DEBUG feature may also be used to debug I/O operations. When the port address is examined with a MEM command, the two Hex digits that represent data indicate the status of each line of the port. For example, if the value C2 is displayed, pin status is as follows:

PIN	7	6	5	4	3	2	1	0
STATUS	1	1	0	0	0	0	1	0

0 = Low
1 = High

For more advanced debugging techniques, including how to write and use your own trace routines, see Sections 9.5 and 9.6.

You now know how to code, enter, and debug programs on the SYM-1. Let's go look at two more examples that illustrate useful programming concepts.

6.3 CONDITIONAL TESTING

Most useful computer programs don't go in straight lines -- they don't simply execute a series of instructions in consecutive memory locations. They do perform different operations for different data by testing data words and jumping to different locations depending on the results of the test. Typical tests answer the following kinds of questions:

1. Is a selected bit of a specified data word a 1 or a 0?
2. Is a specified data word set to a selected ASCII character or numeric value?

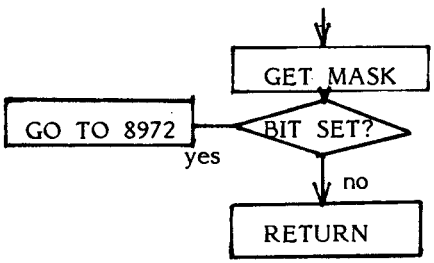
The sample program discussed below will answer question "1". It can be patched easily to answer question "2". You can use the principles you learn in the first two examples to make many more complicated tests.

Bit Testing

This sample program looks at the word in Hex location 31 and tests bit 3. If bit 3 is set to one, it jumps to location 8972; if bit 3 is zero, it returns to the executive. Location 8972 is a monitor subroutine that makes the SYM-1 go "beep".

The only problem involved is in isolating bit 3. The simplest way is to use a mask — a word in memory with bit 3 set and none other. If we logically AND the mask with the sample word, the resultant value will be zero if bit 3 was zero and non-zero otherwise. The BIT test performs the AND and tests the value without altering the state of the accumulator.

Here is the flow chart. The code is in Figure 6-5. The mask (F7 Hex) is in location 30, the test value in location 31.



Hint

If you wish to test bit 0 or bit 7 of a byte, you need not use a mask. Simply use a shift operation to place the selected bit in the CARRY status bit and use a BCC or BCS to test CARRY. This saves one or more program locations. Note that it alters the accumulator - you may have to shift it back for later processing.

Character, Value, or Magnitude Testing

To test whether a byte is exactly equal to an ASCII character or a value, use the Compare command or first set a mask location exactly equal to the character or value. Then use the EOR command to find the exclusive OR of the two values and test the result for zero. It will be zero if and only if the values were identical. Note that this destroys the test value -- keep another copy of it if you must use it again.

To test whether a byte is greater, equal to, or less than a given value, use the Compare command or set a mask to the test values and subtract it from the test value. The test value will be destroyed. Test the result to see whether it is positive, negative, or zero (this takes two sequential tests) and skip accordingly. Try writing a program that makes a series of magnitude tests to determine whether a given byte is an ASCII control character (0-1F Hex), punctuation mark, number, or letter. The values of the ASCII character set are listed on the summary instruction card.

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BIT 3 TEST ROUTINE

ADDR	INSTRUCTIONS B1	B2	B3	LABEL	MNEMONIC	OPERAND	COMMENTS
30	8			MASK			BIT 3 MASK
31	X			TEST			(USE DIFFERENT VALUES)
200	A9	30			LDA	MASK	GET MASK
202	24	31			BIT	TEST	COMPARE AND SET ZERO BIT
204	F0	03			BEQ	HOME	NO BIT, RETURN
206	4C	72	89		JMP	BEEP	BEEP ANNUNCIATOR
209	60			HOME	RTS		RETURN

Figure 6-5. BIT 3 TEST ROUTINE

6.4 MULTIPLICATION

The sample program described here multiplies two one-byte unsigned integers and stores the results in two bytes. Note that in any base of two or more, the product of two numbers may be as long as the sum of the lengths of the numbers. In decimal, 99 X 99= 9801; in Hex FF X FF= FE01.

Since many programs will involve multiplication, it is not good practice to write a multiplication routine every time the need comes up. The sample is set up as a subroutine to allow it to be used by many programs. Serious programmers will usually wind up with libraries of subroutines specialized for their applications.

How to Multiply

Multiplication is normally introduced to students as a form of sequential addition. Humans can in fact multiply 22 (decimal) by 13 by performing an addition:

22 + 22 + 22 . . . . 22 = 286

This technique is of course foolish -- it involves a lot of work and a high probability of error. It would be easy to write a program that would multiply this way (try it) but it would be a terrible waste of time.

How then to multiply? We could use a table. Humans use memorized tables that work up to about 10 X 10:

7 X 8 = 56

Humans cannot, however, remember well enough to know that:

22 X 13 = 286

Computers, of course, can "remember" an arbitrarily large table. But the table for the problem at hand would have FFFF entries, which is far too many for practicality.

Humans solve the problem by breaking the multiplication down into smaller steps. We multiply one factor, one digit at a time, by each digit of the other factor in turn. Then we shift some of the partial products to the left and add:

```
    22
X   13
   ---
    66
   22
  ----
   286
```

We would multiply the binary equivalents of the numbers the same way:

```
   10110
    1101
  -------
   10110
      0
  10110
 10110
-------
100011110
```

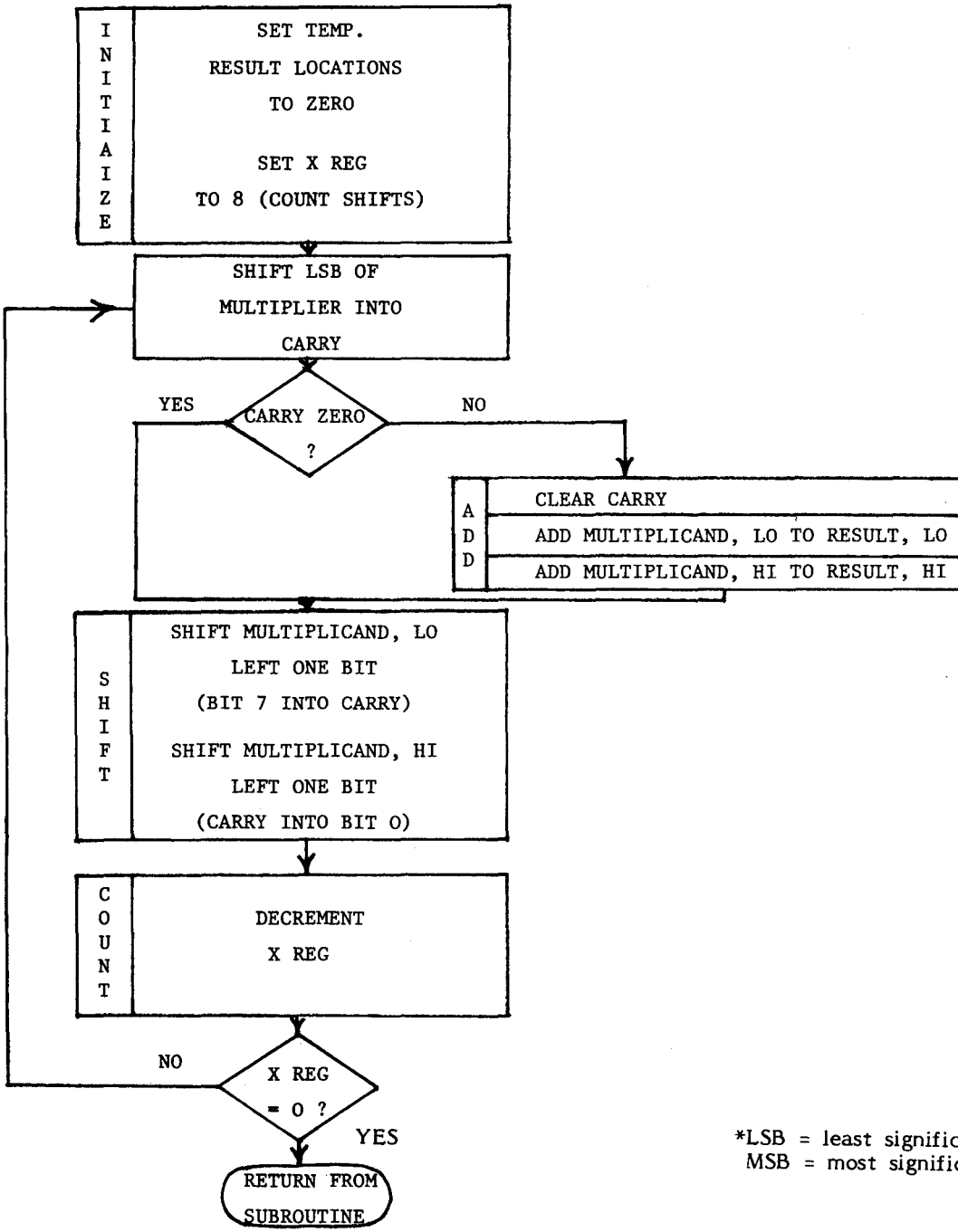


Figure 6-6. GENERAL MULTIPLICATION FLOWCHART

A little figuring will verify that the result is correct. Note that the "tables" for multiplying binary numbers by a single digit are very simple -- a number times one is itself; a number times zero is zero. We can multiply, then, by using a series of additions and shifts, as shown in the flow chart below. The first factor is eight bits long; the second is extended to two bytes (the high-order byte is zero), and the result goes into two bytes set initially to zero. The flowchart in Figure 6-6 is general and not suitable for direct coding.

This procedure could be coded quite easily. Each bit test on the first factor could be made with a different mask as shown in the previous example. Note, however, that the same basic set of instructions is repeated eight times, wasting memory space. A more efficient routine would loop over the same code eight times.

The more efficient routine could also use eight masks, but there's a simpler way. Simply shift the factor to the left once per addition. The bit to be tested will wind up in the CARRY indicator, and we can simply test that. Figure 6-7 is a more formal flowchart of the multiply routine as it is coded that it includes the coding details. The coding chart is shown in Figure 6-8.

Testing

The listing below shows one way to key in the program. The code occupies the RAM space from 200 to 222 Hex. The factor come from locations 21 and 22; the product goes to locations 23 and 24.

Note that the original factors are destroyed by the routine. If it is necessary to preserve them for other subroutines, simply copy them into unused memory locations and perform the multiplication on the copies.

Division

Try to write a parallel routine for performing integer division that divides a two-byte quotient and a two-byte remainder. You may wish to test the remainder and, if its MSB is one, round the result by incrementing the quotient.

Arithmetic

The examples given so far show some basic integer arithmetic techniques. They may be expanded easily for double-precision operation. (Multiply two bytes by two bytes for a four-bit product. Use double-precision addition and fifteen shifts instead of seven.)

MULTIPLIER = P

MULTIPLICAND = Q

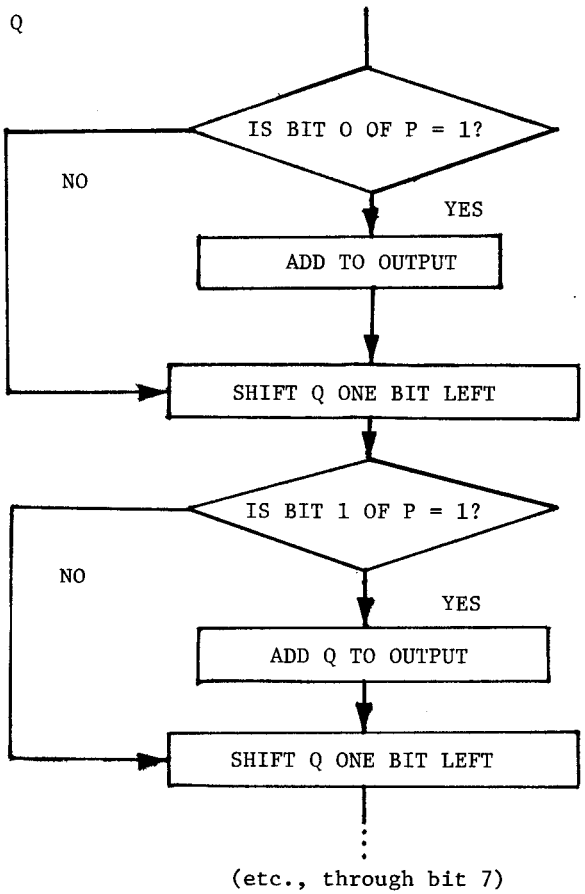


Figure 6-7. DETAILED MULTIPLICATION FLOWCHART

SYNERTEK SYSTEMS CORPORATION

PROGRAM _____

PROGRAMMER _____

DATE _____

SINGLE - PRECISION MULTIPLY ROUTINE

ADDR	INSTRUCTIONS B1	B2	B3	LABEL	MNEMONIC	OPERAND	COMMENTS
200	A9	00		MULT1	LDA	#0	ZERO ACCUMULATOR
202	85	20			STA	INHI (20)	SET TEMPORARY STORAGE LOCATION (20) TO ZERO
204	85	23			STA	OUTLO (23)	" LOW BYTE RESULT " (23) " "
206	85	24			STA	OUTHI (24)	" HIGH " " " (24) " "
208	A2	08			LDX	#8	SET X TO 8 TO COUNT SHIFTS
20A	46	22		MORE	LSR	IN2 (22)	SHIFT FACTOR RIGHT
20C	90	0D			BCC	ZERBIT (+D)	IF CARRY = 0 SKIP ADDITION, GO TO ZERBIT
20E	18				CLC		CLEAR CARRY
20F	A5	23			LDA	OUTLO	GET LOW BYTE ASSEMBLED SO FAR
211	65	21			ADC	IN1	ADD CURRENT TERM
213	85	23			STA	OUTLO	SAVE UPDATED LOW BYTE
215	A5	24			LDA	OUT HI	GET HIGH BYTE ASSEMBLED SO FAR
217	65	20			ADC	TEMPHI	ADD CURRENT TERM
219	85	24			STA	OUT HI	SAVE UPDATED HI BYTE
21B	06	21		ZERBIT	ASL	IN1	SHIFT LEFT FOR NEXT ADDITION
21D	26	20			ROL	INHI	SHIFT HIGH BYTE LEFT (ENTER CARRY)
21F	CA				DEX		DECREMENT INDEX REGISTER (COUNT ADDS)
220	D0	E8			BNE	MORE	IF X > 0, GO BACK AND DO NEXT ADD
222	60				RTS		DONE; GO BACK TO CALLING ROUTINE

Figure 6-8. SINGLE-PRECISION MULTIPLY ROUTINE

CHAPTER 7

OSCILLOSCOPE OUTPUT FEATURE

7.1 INTRODUCTION

Your SYM-1 module is hardware-equipped to allow you to use an ordinary oscilloscope as a display device. In this section, we will describe the hardware and connections between the system and the oscilloscope and also provide a listing of a software driver for this output. This listing is just one way of handling the oscilloscope output; you may wish to modify it or develop your own.

7.2 OPERATION OF OSCILLOSCOPE OUTPUT

The circuitry shown in the detail on the schematic (Figure 4-9) enables the SYM to output alphanumeric characters to an oscilloscope. The circuitry is adapted from a published schematic and was included on the SYM to help relieve the bottleneck found on most single-board computers, i.e., the 7 segment displays. Many things can be done with the scope-out circuit, like displaying alphanumeric characters, bar graphs, and game displays. The alphanumeric output is usually organized as 16 or 32 characters, each character being a 5-by-7 dot matrix. The characters could be English, Greek or Cuneiform, or could even be stick-men, cars, dog houses, or laser guns.

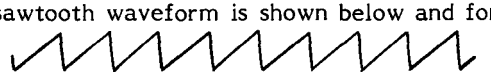
The "video" signal from the collector of Q10, is 3V peak-to-peak with a cycle time of about 50 ms (using the suggested software driver included in section 7.3). The sync pulse which begins the line should synchronize all triggered sweep scopes and most recurrent sweep scopes. In the driver which follows, sync could be brought out on a separate pin by replacing the code from SYNC to CHAR with a routine that would output a pulse on PB4 or some other output line.

7.2.1 Connection Procedures

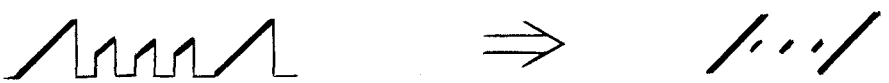
Connect the oscilloscope vertical input to pin R on connector AA ("scope out") and connect scope ground to pin 1 of connector AA (SYM ground). Start the software and adjust the scope for the stable 32-character display. If the sync pulse was output on PB4, connect the scope's trigger to pin 4 of connector AA.

7.2.2 Circuit Operation

The operation of the circuit is simple. Basically, the circuit is a sawtooth waveform generator whose output is sometimes the sawtooth and sometimes ground. The sawtooth is generated by the current source, Q9-Q17-R42-R43, charging C9. When C9 gets up to about 3V the discharge path, Q19-Q18-R41-R44, shorts it back to ground due to a pulse sent out by CA-2. The sawtooth waveform is shown below and forms the columns of the display.



By pulling the sawtooth to ground with Q10 any columns or portions thereof can be "removed" from the display. The result of this can be seen below:



The sawtooth is pulled to ground by bringing CB-2 high.

Because Q10 in the "ON" state will cause loading of C9 (thru R45) and C9 will charge a little more slowly, the time for a "dark" column should be slightly longer than for a "light" column.

If more than 8 vertical dots are desired, the charging rate of C9 must be slowed by lowering the charging current. R42 controls the charging current and can be increased up to about 10K before the loading effects of R45 get completely out of hand.

7.3 USING OUR SOFTWARE

The program listing in Table 7-1 is one way of handling oscilloscope output. After entering the program and character table and attaching an oscilloscope to the scope output, enter the following commands:

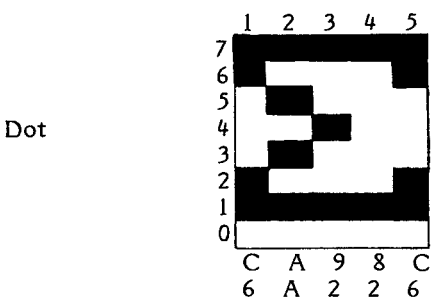
	Comments
.SD 500, A670(CR)	Change SCANVEC. (DISPLAY GOES BLANK)
.SD 58C, A664(CR)	Change OUTVEC.
.SD 560, A661(CR)	Change INVEC.

Now enter any stream of characters from the HKB to fill SCPBUF.

Put the scope input on AC couple and the trigger on DC couple. Adjust the time base, attenuation, and trigger until the display becomes readable. If your screen is very small, you may wish to change the number of characters per line by adjusting the value at location $0506.

Example: Creating translation table for scope driver.

Character: $\sum$ (Greek capital letter sigma)



Each byte corresponds to a single column, with each bit corresponding to a single dot.

sigma = $C6, $AA, $92, $82, $C6

Bit Ø is always Ø to raise the character off of the Ground line.

Table 7-1. OSCILLOSCOPE OUTPUT DRIVER SOFTWARE LISTING

```
LINE # LOC      CODE        LINE

0002  0000                ; SCOPE LINE DRIVER 05/01/78
0003  0000                ; USES CHARACTER SET IN TABLE SYMBLS
0004  0000                ; 5 BYTES PER CHAR
0005  0000                ; ENTRY 'LINE' IS ANALOGOUS TO 'SCAND'
0006  0000                ; BELOW ROUTINES HKEY AND HDOUT INTERFACE TO HEX KB
0007  0000                ; CHAR SET PROVIDED IS FOR HEX KB
0008  0000                ; AND RELATED TO ASCII TABLE IN MONITOR ROM
0009  0000                ; THIS DRIVER CAN ACCESS A MAX OF 51 CHARS
0010  0000                TXTSHV =$8A06
0011  0000                SCNVEC =$A66F
0012  0000                GETKEY =$88AF
0013  0000                KEYQ   =$8923
0014  0000                SAVER  =$8188
0015  0000                BEEPP3 =$8975
0016  0000                ASCIM1 =$8BEE
0017  0000                RESALL =$81C4
0018  0000                PCR3   =$AC0C          ;CA2,CB2 = SCOPE
0019  0000                TXTCTR =$03FE
0020  0000                COLCTR =$03FF
0021  0000                TEXT   =$A600          ;SCOPE BUFFER IN SYS RAM
0022  0000                SYMBLS =$0400          ;CHARACTER TABLE
0023  0000                       *=$500
0024  0500  A9 EE         LINE   LDA #$EE        ;DISCHARGE CAP
0025  0502  8D 0C AC             STA PCR3
0026  0505  A9 21                LDA #32+1      ;# CHARS PER LINE
0027  0507  8D FE 03             STA TXTCTR
0028  050A  A9 CC         SYNC   LDA #$CC        ;CHARGE CAP FOR SYNC
0029  050C  8D 0C AC             STA PCR3
0030  050F  A2 EA         LDLY   LDX #$EA        ;LONG DELAY !
0031  0511  CA                    DEX
0032  0512  D0 FC                BNE LDLY+1
0033  0514  CE FE 03     CHAR   DEC TXTCTR      ;LOOP HERE FOR CHAR
0034  0517  AE FE 03             LDX TXTCTR
0035  051A  D0 03                BNE POIMFG
0036  051C  4C 23 89     EXIT   JMP KEYQ        ;SCAN KB AND RETURN
0037  051F                ;
0038  051F  BD FF A5     POIMFG LDA TEXT-1,X    ;POINTER MANUFACTURER
0039  0522  0A                    ASL A          ;PTR X 4 + PTR
0040  0523  0A                    ASL A
0041  0524  18                    CLC
0042  0525  7D FF A5             ADC TEXT-1,X   ;MULT'PY BY 5
0043  0528  AA                    TAX
0044  0529  A9 06                LDA #6
0045  052B  8D FF 03             STA COLCTR
0046  052E  A9 EE         COLUMN LDA #$EE        ;LOOP HERE FOR COL'S
0047  0530  8D 0C AC             STA PCR3       ;DISCHARGE CAP
0048  0533  CE FF 03             DEC COLCTR
0049  0536  30 DC                BMI CHAR       ;BRANCH IF DONE W/6 COL'S
0050  0538  D0 02                BNE COLUP
0051  053A  A2 00                LDX #0         ;INTER CHAR SPACE
0052  053C  A9 EC         COLUP  LDA #$EC        ;START RAMP UP ...
0053  053E  8D 0C AC             STA PCR3       ;... BUT HOLD DOT DOWN
0054  0541  E8                    INX            ;NEXT COL
0055  0542  8A                    TXA            ;SAVE X
0056  0543  48                    PHA
```

Table 7-1. OSCILLOSCOPE OUTPUT DRIVER SOFTWARE LISTING (Continued)

```
LINE #  LOC   CODE        LINE

0057  0544  BD FF 03      LDA SYMBLS-1,X  ;GET COL
0058  0547  A0 08         LDY #8          ;COUNT DOTS
0059  0549  88         DOT DEY
0060  054A  30 0F         BMI CLEAN
0061  054C  4A            LSR A           ;NEXT DOT IN CARRY
0062  054D  B0 04         BCS LIGHT       ;C SET = LIGHT, C CLEAR = DAR
0063  054F  A2 EC      DARK LDX #$EC      ;PULL OUTPUT LOW
0064  0551  D0 02         BNE *+4
0065  0553  A2 CC      LIGHT LDX #$CC     ;OUTPUT FOLLWS RAMP UP
0066  0555  8E 0C AC      STX PCR3
0067  0558  4C 49 05      JMP DOT
0068  055B  68         CLEAN PLA          ;RESTORE X
0069  055C  AA            TAX
0070  055D  4C 2E 05      JMP COLUMN
0071  0560               ;
0072  0560               ;
0073  0560  20 AF 88   HKEY  JSR GETKEY   ;GET KEY + ECHO TO SCOPE
0074  0563  20 88 81   SCPDSP JSR SAVER   ;FILL SCPBUF FROM ASCII IN A
0075  0566  29 7F         AND #$7F
0076  0568  C9 07         CMP #$07        ;BELL?
0077  056A  D0 03         BNE NBELL
0078  056C  4C 75 89      JMP BEEPP3
0079  056F            ; SEARCH ASCII TABLE IN MONITOR ROM
0080  056F  A2 36      NBELL LDX #$36
0081  0571  DD EE 8B    OUD2  CMP ASCIM1,X
0082  0574  F0 06         BEQ GOTX
0083  0576  CA            DEX
0084  0577  D0 F8         BNE OUD2
0085  0579  4C C4 81      JMP RESALL      ;NOT IN TABLE
0086  057C  CA         GOTX  DEX
0087  057D  8A            TXA
0088  057E  C9 0B         CMP #$0B        ;TABLE NOT CONTINUOUS
0089  0580  90 03         BCC GOOD
0090  0582  38            SEC
0091  0583  E9 05         SBC #5          ;ADJUST DISCONTINUITY
0092  0585  CA         GOOD  DEX
0093  0586  20 06 8A      JSR TXTSHV      ;SHOVE SCPBUF DOWN
0094  0589  4C C4 81      JMP RESALL
0095  058C  20 63 05   HDOUT  JSR SCPDSP  ;CHAR TO SCPBUF AND SINGLE SC
0096  058F  4C 6F A6      JMP SCNVEC
0097  0592               .END
```

Table 7-1. OSCILLOSCOPE OUTPUT DRIVER SOFTWARE LISTING (Continued)

```
;
; 8X5 MATRIX CHAR SET FOR SCOPE LINE DRIVER
; CONTAINS ALL HEX KB CHARS
; FIRST BYTE OF TABLE MUST BE 00
; EACH CHAR : FIRST BYTE = LEFTMOST COLUMN,
;             MSB = TOP DOT, LSB = 0, BIT 1 = BOTTOM DOT
;
*=$400 ;PAGE 4 ALLOCATED TO CHARACTER SET
.BYT $00,$7C,$92,$A2,$7C ;ZERO
.BYT $00,$42,$FE,$02,$00 ;ONE
.BYT $4E,$92,$92,$92,$62 ;TWO
.BYT $44,$82,$92,$92,$6C ;THREE
.BYT $18,$28,$48,$FE,$08 ;FOUR
.BYT $E4,$A2,$A2,$A2,$9C ;FIVE
.BYT $3C,$52,$92,$92,$0C ;SIX
.BYT $86,$88,$90,$A0,$C0 ;SEVEN
.BYT $6C,$92,$92,$92,$6C ;EIGHT
.BYT $60,$92,$92,$94,$78 ;NINE
.BYT $3E,$50,$90,$50,$3E ;A
.BYT $00,$1E,$86,$4A,$32 ;C/R
.BYT $10,$10,$10,$10,$10 ;DASH
.BYT $82,$44,$28,$10,$00 ;RIGHT ARROW
.BYT $FE,$FE,$FE,$FE,$FE ;SH
.BYT $7C,$82,$82,$8A,$4E ;G
.BYT $FE,$90,$98,$94,$62 ;R
.BYT $FE,$40,$30,$40,$FE ;M
.BYT $FE,$02,$02,$02,$02 ;L2
.BYT $44,$A2,$92,$8A,$44 ;S2
.BYT $80,$80,$80,$80,$80 ;U0
.BYT $02,$02,$02,$02,$02 ;U1
.BYT $82,$82,$82,$82,$82 ;U2
.BYT $FE,$00,$00,$00,$00 ;U3
.BYT $FE,$00,$00,$00,$FE ;U4
.BYT $1E,$12,$12,$12,$1E ;U5
.BYT $F0,$90,$90,$90,$F0 ;U6
.BYT $80,$80,$80,$80,$F0 ;U7
.BYT $04,$02,$02,$02,$FC ;J
.BYT $E0,$18,$06,$18,$E0 ;V
.BYT $FF,$FF,$FF,$FF,$FF ;ASCII
.BYT $FE,$92,$92,$92,$6C ;B
.BYT $7C,$82,$82,$82,$44 ;C
.BYT $FE,$82,$82,$82,$7C ;D
.BYT $FE,$92,$92,$82,$82 ;E
.BYT $FE,$90,$90,$80,$80 ;F
.BYT $44,$A2,$92,$8A,$44 ;SD
.BYT $10,$10,$7C,$10,$10 ;+
.BYT $00,$10,$28,$44,$82 ;<
.BYT $00,$00,$00,$00,$00 ;SH
.BYT $FE,$02,$02,$02,$02 ;LP
.BYT $44,$A2,$92,$8A,$44 ;SP
.BYT $FE,$04,$08,$04,$FE ;W
.BYT $FE,$02,$02,$02,$02 ;L1
.BYT $44,$A2,$92,$8A,$44 ;S1
.BYT $00,$06,$06,$00,$00 ;DECIMAL
.BYT $00,$00,$00,$00,$00 ;BLANK
.BYT $40,$80,$8A,$90,$60 ;QUESTION
.BYT $FE,$90,$90,$90,$60 ;P
.END
```

CHAPTER 8

SYSTEM EXPANSION

This chapter discusses the means by which you can expand your SYM-1 microcomputer system by adding memory and peripheral devices to its basic configuration. By now, you realize that data access, whether from RAM, PROM or ROM is a function of addressing interface devices (i.e., 6522's and 6532). Hardware has been built into your SYM-1 module to allow large-scale expansion of the system. A thorough understanding of the SYM-1 System Memory Map (Figure 4-10) will aid considerably in understanding how to expand your system.

8.1 MEMORY EXPANSION

Your SYM-1 module comes equipped with 1K of on-board RAM. It also contains all address decoding logic required to support an additional 3K on-board with no changes by you. In other words, to add 3K of on-board RAM, all you need to do is purchase additional SY2114 devices and plug them into the sockets provided on your board. Your PC board is marked for easy identification of 1K memory blocks. RO equals the lower 1K block and R3 equals the upper 1K block. LO means low order data lines (D0-D3) and HI means high order data lines (D4-D7).

You will recall that the lowest 8K memory locations are defined by an address decoder included on your SYM-1 module (a 74LS138). The eight outputs of this decoder ($\overline{00}$-$\overline{1C}$) each define a 1K block of addresses in the lowest 8K of the Memory Map. Four of the outputs ($\overline{00}$, $\overline{04}$, $\overline{08}$, $\overline{0C}$) are used to select the on-board static RAM. The remaining four outputs ($\overline{10}$, $\overline{14}$, $\overline{18}$, $\overline{1C}$) are used to interface to the Application Connector (Connector "A"), where you can use them to add another 4K of off-board memory. Again, no external decoding logic is required. By this simple means, you can convert your SYM-1 module into an 8K device quickly. Figure 8-1 shows you how to interface these decode lines at the connector for your SYM-1 system.

To go beyond this 8K size, conceivably up to the maximum 65K addressability limit of the SYM CPU, you could build or buy an additional memory board with on-board decoding logic. In this case, you will use the Expansion Connector (Connector "E") in a manner shown schematically in Figure 8-2. Note that the three high-order address bits (AB13-AB15) not used in the earlier expansion are brought to this connector as shown. These are then used with a decoder to create outputs $\overline{M0}$ through $\overline{M7}$, which in turn are used to select and de-select additional decoders (line receivers). You need add only as many decoders (one for each 8K block of memory) as you need for the expansion you require.

Incidentally, the line receivers shown in Figure 8-2 are provided for electrical reasons. There are loading limitations on the address bus lines of the 6502 CPU, which require the insertion of these receivers. (For your information, each 6502 address line is capable of driving one standard TTL load and 130pf of capacity.)

You should make a careful study of the loading limitations of the required SYM-1 lines before deciding on memory expansion size and devices. It is likely you will want to use additional buffer circuits to attain "cleaner" operation of your expanded memory in conjunction with your SYM-1 system.

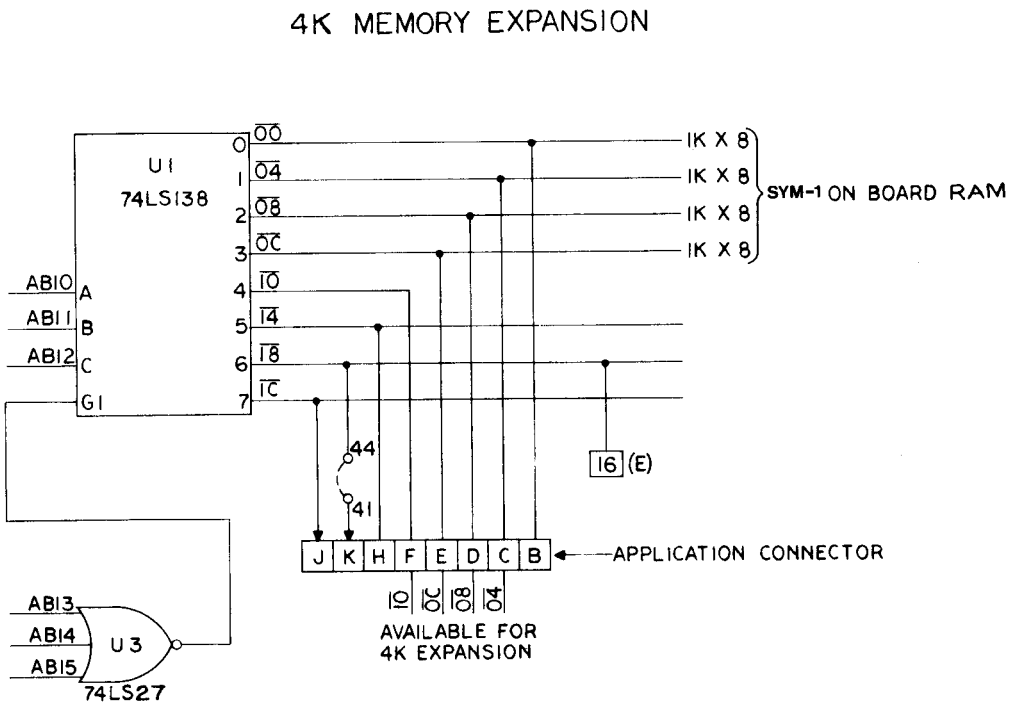


Figure 8-1. 4K MEMORY EXPANSION

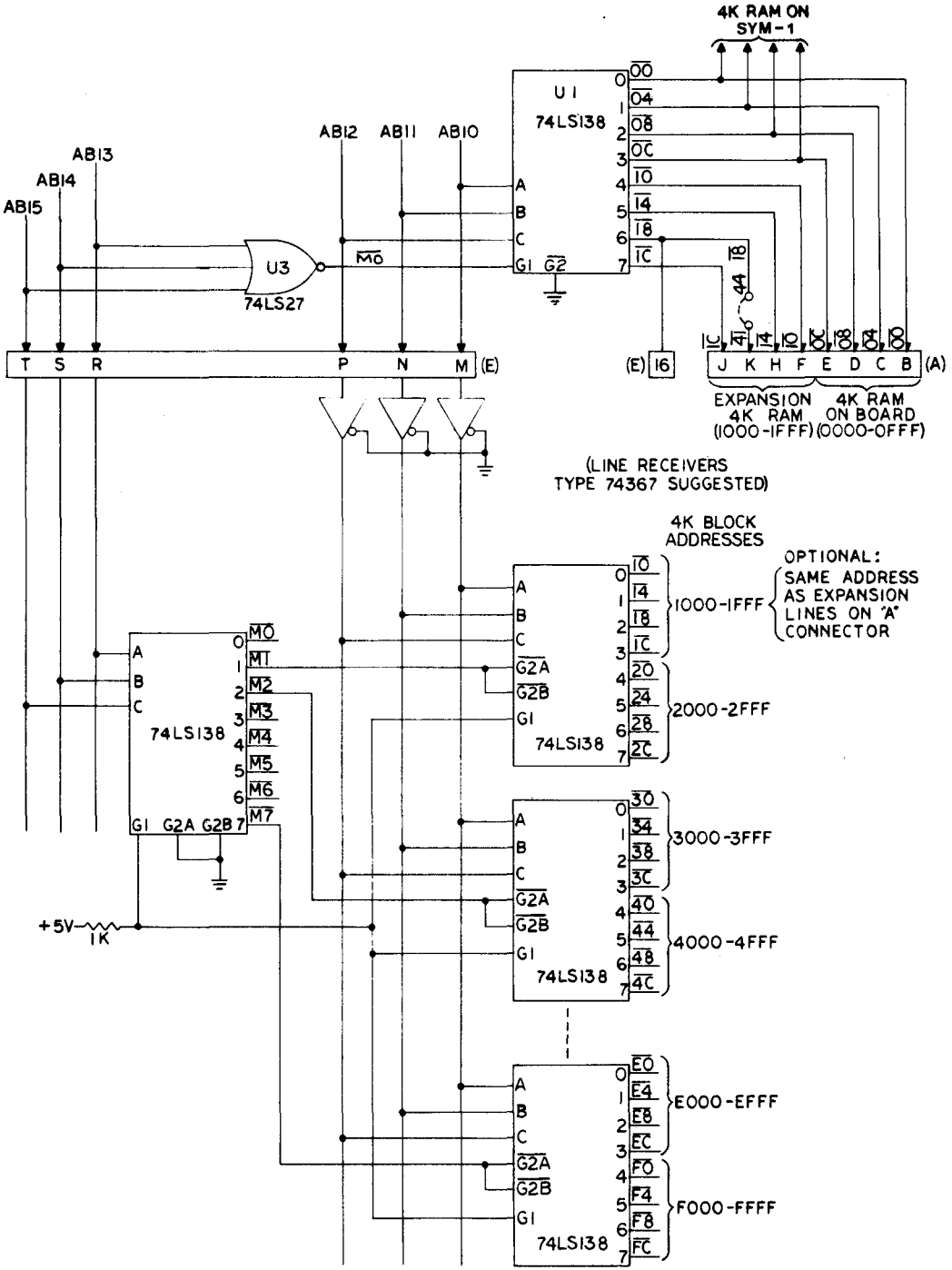


Figure 8-2. MEMORY - I/O EXPANSION TO 65K

8.2 PERIPHERAL EXPANSION

As you already know, the SYM-1 microcomputer system includes 51 I/O lines. This means, theoretically, that you could drive as many as 51 peripheral lines (plus 4 control lines) with your SYM-1.

Using either Application Connector ("A" or "AA"), you can add most commercially available printers or other devices requiring parallel interfaces, although you will have to create your own software driver for the printer. Since the provision of that driver is, to some extent, dependent upon the printer you purchase, we do not attempt to discuss the implementation of the software in this manual.

You can expand your SYM-1 system's peripheral I/O capability easily and quickly merely by installing an additional SY6522 in the socket provided for that device. This will give you 16 additional on-board data lines with no requirement for additional work (beyond the software driver) on your part. To go beyond that level, you must use the Expansion Port (Connector "E") described earlier.

Again, we emphasize that the proper understanding and use of the Memory Map in Figure 4-10 will allow you to use your imagination in expanding the I/O capability of your SYM-1 system. Its flexibility is extremely broad and the fact that all I/O and memory are handled as an addressing function allows you expandability to the full capability of the 6502 CPU itself.

CHAPTER 9

ADVANCED MONITOR AND PROGRAMMING TECHNIQUES

This chapter contains information which you will find useful as you explore the more sophisticated capabilities of your versatile SYM-1 microcomputer system. As we have pointed out many times, the SYM-1 is the most flexible and expandable monitor of its kind. The SUPERMON monitor uses transfer vectors and other techniques to allow you to modify its operation, and these are provided in detail in this chapter. In addition, the extended use of debug and trace facilities, which are invaluable tools as your programming skill advances, are explained. The use of the Hex keyboard provided on your SYM-1 for configurations using a printer (or other serial device) without a keyboard is also described. And last, an example and discussion of extending SUPERMON's command repertoire.

9.1 MONITOR FLOW

SUPERMON is the 4K byte monitor program supplied with your SYM-1. It resides in locations 8000-8FFF on a single ROM chip. It shares the stack with user programs and uses locations 00F8-00FF in Page Zero. In addition, it uses locations A600-A67F (RAM on the 6532), which are referred to as 'System RAM'. Since these locations are dedicated to monitor functions SUPERMON write protects them before transferring control to user programs.

The flowcharts in Figures 9-1 through 9-5 will demonstrate the major structure of SUPERMON. You will notice that GETCOM (and its entry, PARM), DISPAT, and ERMSG are subroutines, and therefore available for your programs' use. Note that a JSR to ACCESS to remove write protection from System RAM is necessary before using most monitor routines. Also, notice that the unrecognized command flow (error) is vectored. Thus, you can extend the monitor with your own software.

9.2 MONITOR CALLS

SUPERMON contains many subroutines and entry points which you will want to use in order to save memory and code and avoid duplication of effort. Table 9-1 is a summary of calls and their addresses.

The three calls which you will most commonly use are:

```
JSR   ACCESS    (address 8B86) (must be called before using LED display)
JSR   INCHR     (address 8A1B)
JSR   OUTCHR    (address 8A47)
```

ACCESS is used to unwrite-protect system RAM. In performing the input/output, these routines save all registers and use INVEC and OUTVEC, so all you need be concerned with when using them are the ASCII characters passed as arguments in the accumulator.

9.3 MONITOR CALLS, ENTRIES AND TABLES

Table 9-1, which occupies the next several pages of this Chapter, provides you with a comprehensive list of important subroutine symbolic names, addresses, registers and functions of SUPERMON monitor calls, entry points and tables. With this data, you can more easily utilize SUPERMON to perform a wide variety of tasks. All (except those marked with an asterisk) are callable by JSR.

Table 9-1. MONITOR CALLS, ENTRIES AND TABLES

NAME	ADDRESS	REGISTERS ALTERED	FUNCTION (S)
*MONITR	8000		Cold entry to monitor. Stack, D flag initialized, System RAM unprotected.
*WARM	8003		Warm entry to monitor
USRENT	8035		User pseudo-interrupt entry - saves all registers when entered with JSR. Displays PC and code 3. Passes control to monitor.
SAVINT	8064	ALL	Saves registers when called after interrupt. Returns by RTS.
DBOFF	80D3	A,F	Simulates depressing debug off key.
DBON	80E4	A,F	Simulates depressing debug on key.
DBNEW	80F6	A,F	Release debug mode to key control.
GETCOM	80FF	A,F	Get command and 0-3 parameters. No error: A=0D (carriage return) Error: A contains erroneous entry.
DISPAT	814A	A,F	Dispatch to execute blocks. Dispatch to URCVEC if error. At return, if error: Carry set, A contains byte in error.
ERMSG	8171	F	If Carry set, print (CR)ER NN, where NN is contents of A.
SAVER	8188	None	Save all registers on stack. At return, stack looks like: F A X Y (See paragraph 9.9)
*RESXAF	81B8	restored	Jumped to after SAVER, restore registers from stack except A,F unchanged, perform RTS.
*RESXF	81BE	restored	Jumped to after SAVER, restore registers from stack except F unchanged, perform RTS.
*RESALL	81C4	restored	Jumped to after SAVER, restore all registers from stack, perform RTS.
INBYTE	81D9	A,F	Get 2 ASCII Hex digits from INCHR and pack to byte in A. If Carry set, V clear, first digit non-Hex. If Carry set, V set, second digit nonHex. N and Z reflect compare with carriage return if Carry set.

*Do not enter by JSR.

Table 9-1. MONITOR CALLS, ENTRIES AND TABLES (Continued)

NAME	ADDRESS	REGISTERS	FUNCTION (S)
PSHOVE	8208	X,F	Shove Parms down 16 bits; Move: P2 to P1 P3 to P2 zeros to P3
PARM	8220	A,F	Get 0 to 3 parameters. Return on (CR) or error. A contains last character entered. Flags reflect compare with (CR).
ASCN1B	8275	A,F	Convert ASCII character in A to 4 bits in LO nibble of A. Carry set if non-Hex.
OUTPC	82EE	A,X,F	Print user PC. At return, A=PCL, X=PCH.
OUTXAH	82F4	F	Print X,A (4 Hex digits)
OUTBYT	82FA	F	Print A (2 Hex digits)
NIBASC	8309	A,F	Convert LO nibble of A to ASCII Hex in A.
COMMA	833A	F	Print comma.
CRLF	834D	F	Print **(CR) (LF).**
DELAY	835A	F	Delay according to TV. (Relation is approximately logarithmic, base=2). Result of INSTAT returned in Carry.
INSTAT	8386	F	If key down, wait for release. Carry set if key down. (Vectored thru INSVEC)
GETKEY	88AF	A,F	Get key from Hex keyboard (more than one if SHIFT or ASCII key used) return with ASCII or HASH code in A. Scans display while waiting (vectored through SCNVEC).
HDOUT	8900	A,X,Y,F	ASCII character from A to Hex display, scan display once, return with Z=1 if key down.
KEYQ	8923	A,F	Determine if key down on Hex keyboard. If down, then [redacted]. Z = 0 AND N = 1.
KYSTAT	896A	A,F	Determine if key down. If down, then Carry set.
BEEP	8972	None	BEEP on-board beeper.
HKEY	89BE	A,F	Get key from Hex keyboard and echo in DISBUF. ASCII returned in A. Scans display while waiting (vectored thru SCNVEC)

*Do not enter by JSR

Table 9-1. MONITOR CALLS, ENTRIES AND TABLES (Continued)

NAME	ADDRESS	REGISTERS	FUNCTION (S)
OUTDSP	89C1	None	Convert ASCII in A to segment code, put in DISBUF.
TEXT	8A06	F	Shove scope buffer down, push A onto SCPBUF.
INCHR	8A1B	A,F	Get character (vectored thru INVEC). Drop parity, convert to upper case. If character CTL O (0F), toggle Bit 6 of TECHO and get another.
NBASOC	8A44	A,F	Convert low nibble of A to ASCII, output (vectored thru OUTVEC).
OUTCHR	8A47	None	Output ASCII from A (vectored thru OUTVEC). Output inhibited by Bit 6 of TECHO.
INTCHR	8A58	A,F	Get character from serial ports. Echo inhibited by Bit 7 of TECHO. Baud rate determined by SDBYT. Input, echo masked with TOUTFL.
TSTAT	8B3C	A,F	See if break key down on terminal. If down, then Carry set.
*RESET	8B4A	All	Initialize all registers, disable POR, stop tape, initialize system RAM to default values, determine input on keyboard or terminal, determine baud rate, cold monitor entry.
*NEWDEV	8B64		Determine baud rate, cold monitor entry.
ACCESS	8B86	None	Un-write protect System RAM.
NACCESS	8B9C	None	Write protect System RAM.
*TTY	8BA7	A,X,F	Set vectors, TOUTFL, and SDBYT for TTY.
*DFTBLK	8FA0	Table	Default block - entirely copied into System RAM (A620 - A67F) at reset.
*ASCII	8BEF	Table	Table of ASCII codes and HASH codes.
*SEGS	8C29	Table	Table of segment codes corresponding to ASCII codes (above).

*Do not enter by JSR

SPACE 8342 NONE PRINTS SPACE.

MAIN MONITOR FLOW

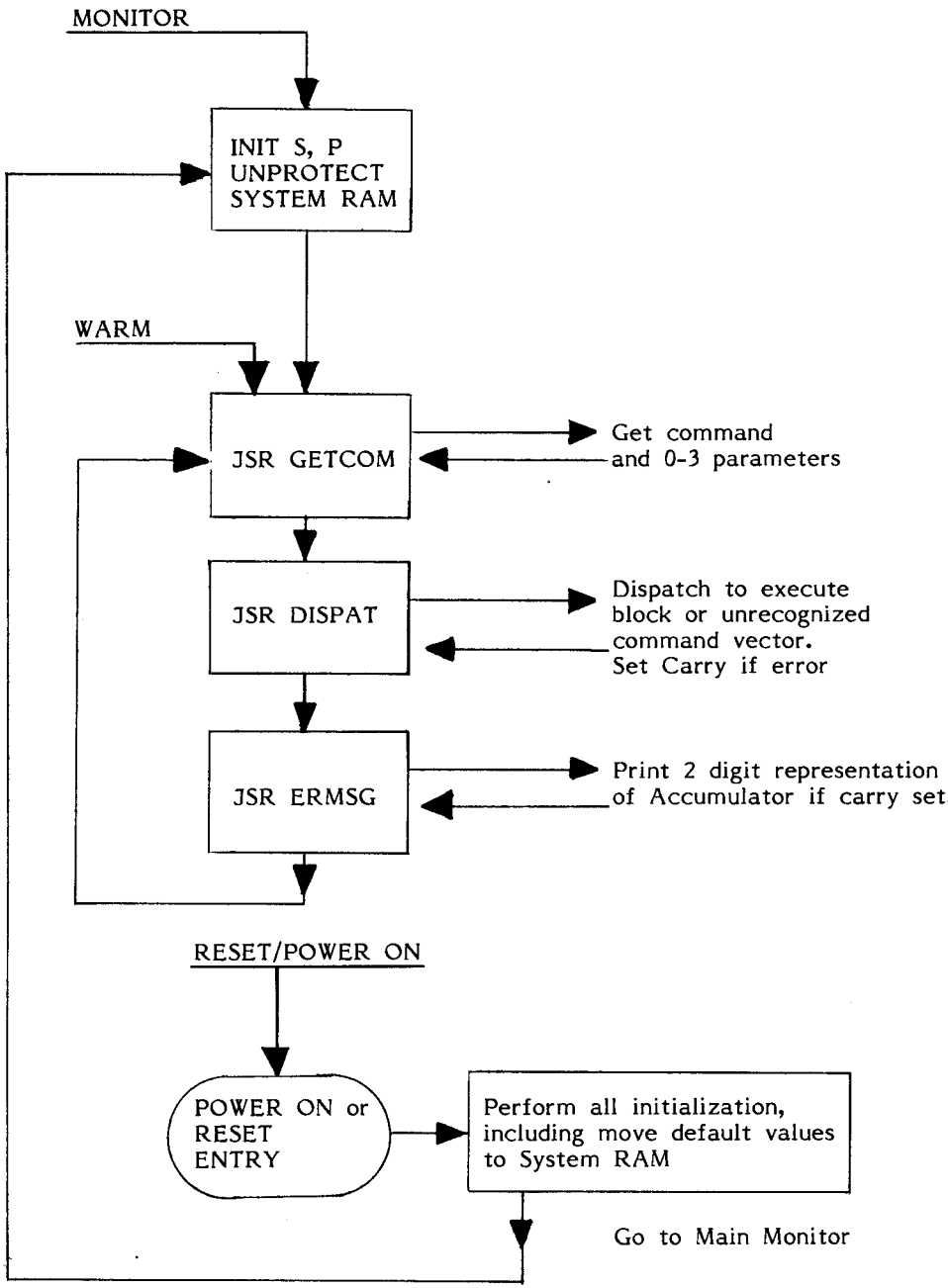


Figure 9-1. MAIN MONITOR FLOW

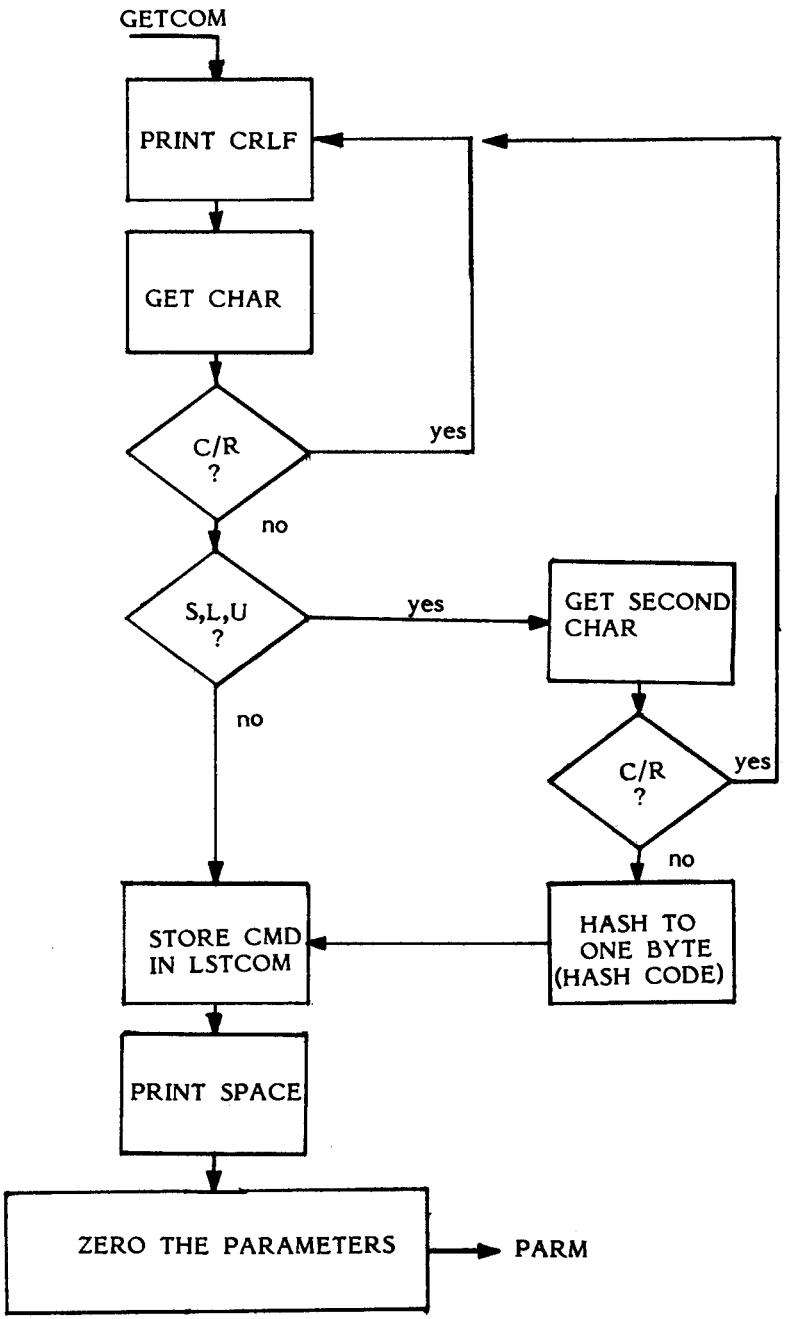


Figure 9-2. GETCOM FLOWCHART

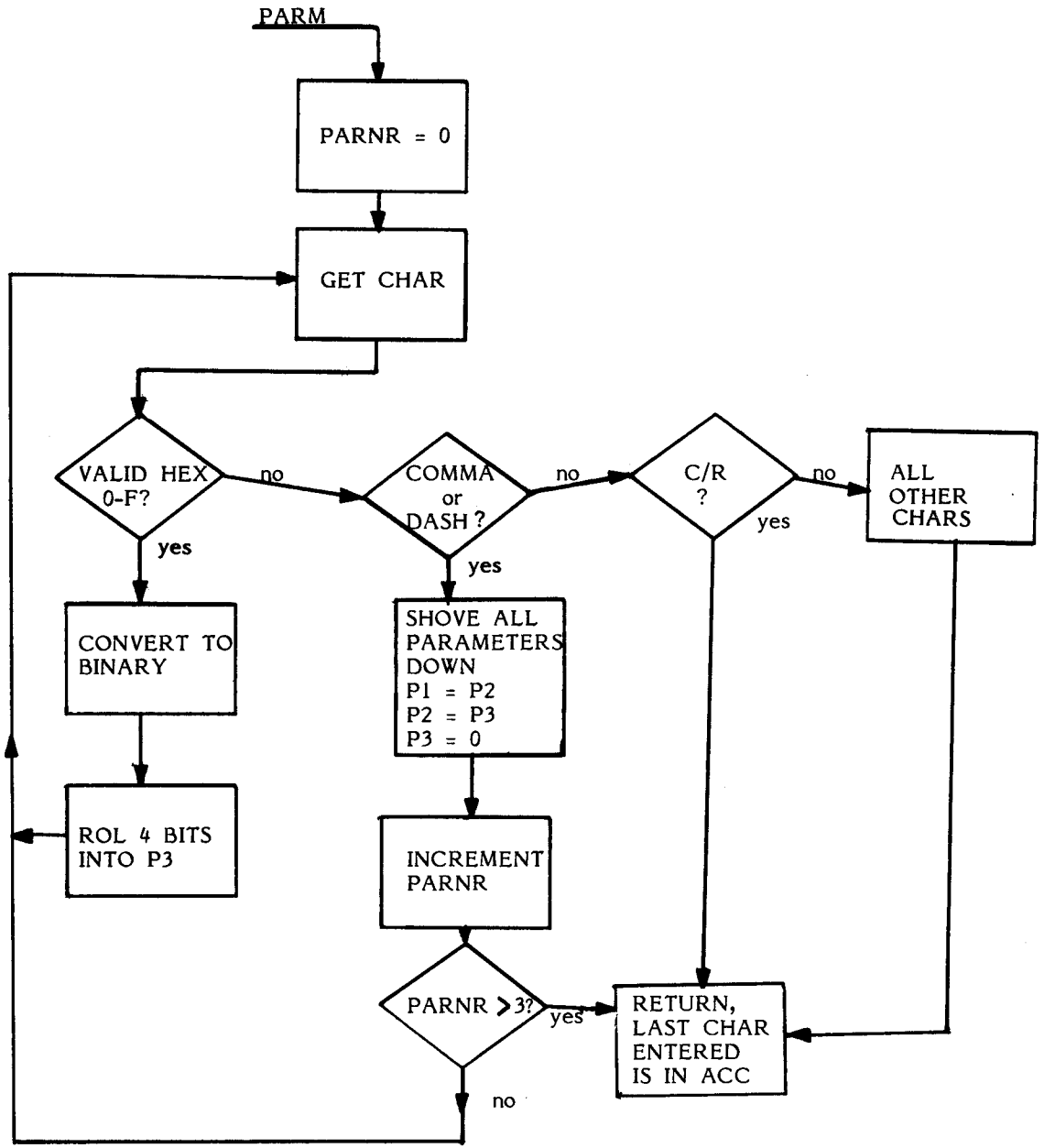


Figure 9-3. PARM FLOWCHART

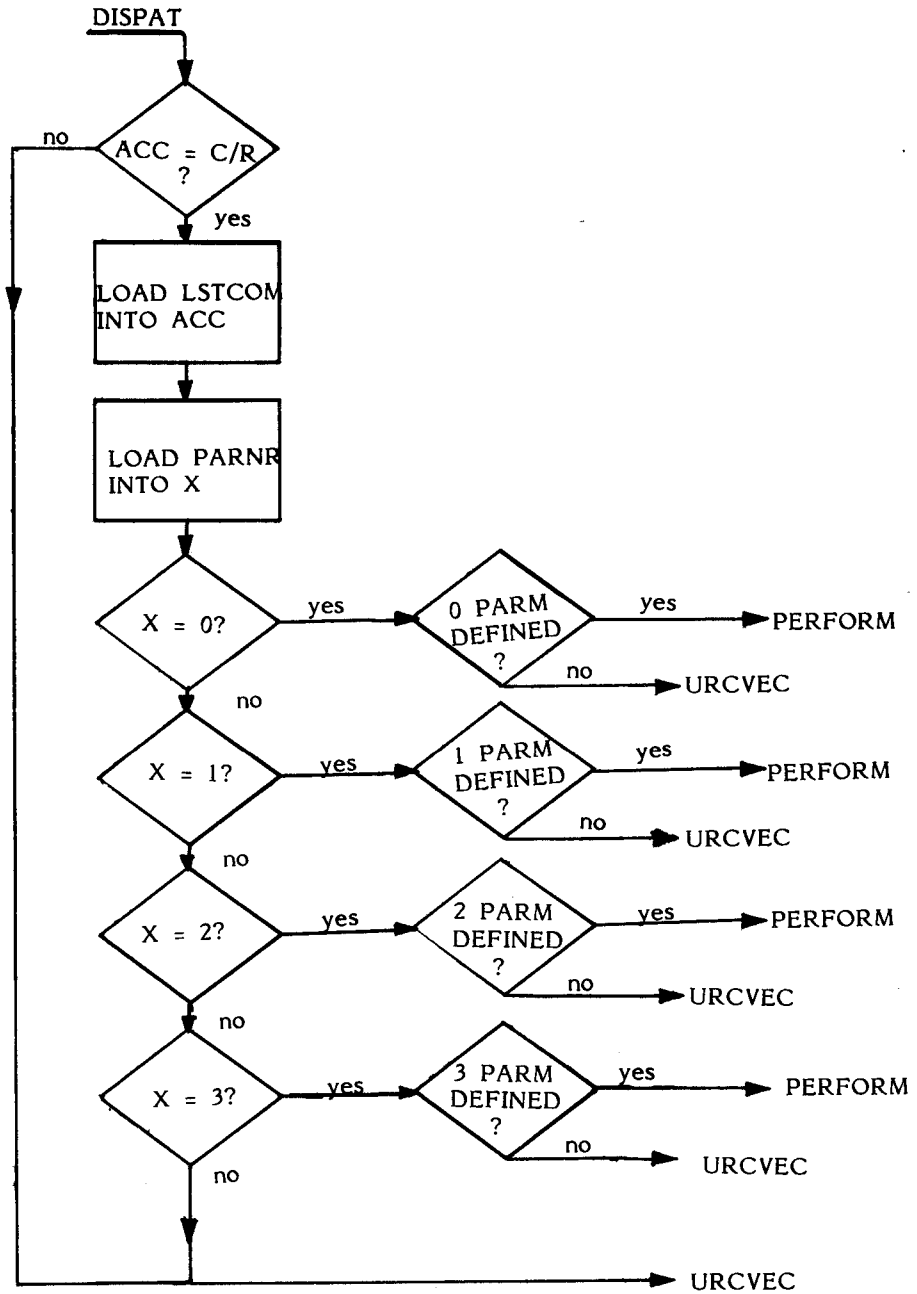


Figure 9-4. DISPAT FLOWCHART

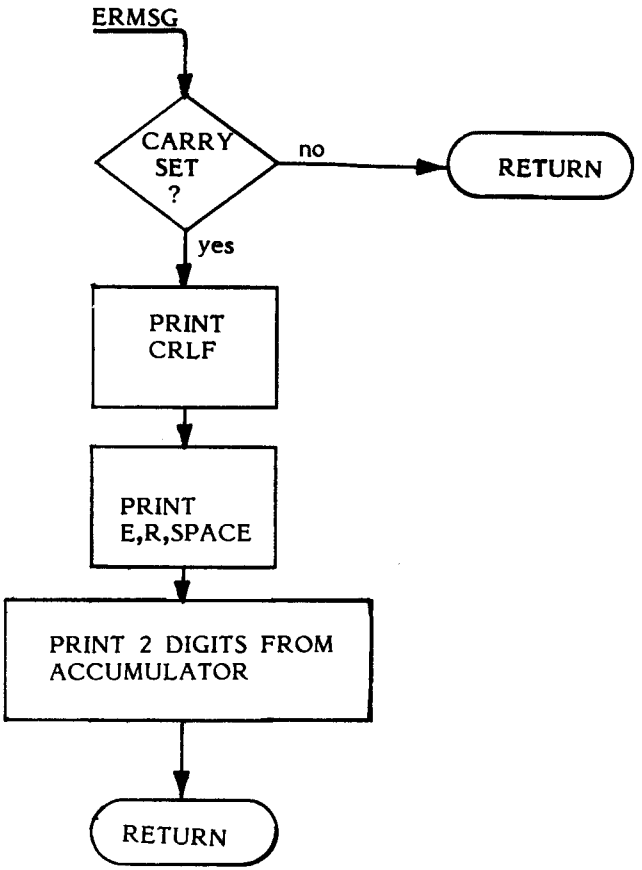


Figure 9-5. ERMSG FLOWCHART

9.4 VECTORS AND INTERRUPTS

A concept which is very important in understanding the SY6502 and SUPERMON is that of a transfer vector. A transfer vector consists of two or three locations at a fixed address in memory. These locations contain an address, or a Hex 4C **(JMP)** and an address. The address is in low-order, high-order byte order.

As an example, consider the function of outputting a character. In some cases, the character is to go to the display, in others to a terminal device. The action required in each case is radically different. It would be inefficient, in code and in time, to make the decision before outputting each character. The solution is a transfer vector. Whenever SUPERMON must output a character, it performs a JSR to OUTCHR. OUTCHR saves all registers, then performs a JSR to OUTVEC (at A663, in System RAM). If you are working at the Hex keyboard OUTVEC will contain a JMP HDOUT. HDOUT is the subroutine which will enter a character, in segment code, into the display buffer. If you are using a TTY or CRT, OUTVEC will contain a JMP TOUT. TOUT is the subroutine which sends a character, one bit at a time, to the serial I/O ports. When HDOUT or TOUT performs an RTS, control passes back to OUTCHR. OUTCHR restores the registers and performs an RTS, returning control to the caller.

Notice that the calling routine need not worry where the output is going. It is all taken care of by OUTCHR and OUTVEC.

When a vector is to be referenced by a JMP Indirect, only two bytes are required. Two-byte vectors are normally used only for interrupts.

An **INTERRUPT** is a method of transferring program control, or interrupting, the processor during execution. There are three interrupts defined on the SY6502:

NMI	--	non-maskable interrupt
RST	--	reset/power-on
IRQ	--	interrupt request

When one of these interrupts occurs, the processor pushes the PC register and the Flags register onto the stack, and gets a new PC from the **INTERRUPT VECTOR.** The interrupt vectors are located at the following addresses:

FFFA,FFFB	--	NMI
FFFC,FFFD	--	RESET
FFFE,FFFF	--	IRQ

These locations must contain the addresses of programs which will determine the cause of the interrupt, and respond appropriately.

In the SYM-1, System RAM (A600-A67F) is duplicated at FF80-FFFF (it is "echoed" there). On Reset, SUPERMON points these vectors to its own interrupt-handling routines. When an interrupt occurs, SUPERMON displays the address where the interrupt occurred with one of the following codes indicating the cause of the interrupt:

0	=	BRK instruction
1	=	IRQ
2	=	NMI
3	=	USER ENTRY (caused by JSR to USRENT at 8035)

Because all registers are saved, a **(G) (CR)** will cause execution to resume at the point of interruption. The user can intercept interrupt handling by inserting pointers to user interrupt routines in TRCVEC, UBRKVC, NMIVEC, or IRQVEC. See Section 9.7.2 for a discussion of the User Entry pseudo-interrupt. Table 9-2 describes all vectors used by the Monitor.

Table 9-2. SUPERMON VECTORS

NAME	LOCATION	FUNCTION
INVEC	A660-A662	Points to input driver.
OUTVEC	A663-A665	Points to output driver.
INSVEC	A666-A668	Points to routine which determines whether or not a key is down.
URCVEC	A66C-A66E	Unrecognized command. All unrecognized commands and parameter entry errors vectored here. Points to a sequence of: SEC - Set Carry RTS - Return
SCNVEC	A66F-A671	Points to routine which performs one scan of display from DISBUF.
EXEVEC	A672-A673	Points to RIN - get ASCII from RAM subroutine. The Execute (E) command temporarily replaces INVEC with EXEVEC, saving INVEC in SCRA, SCRB. The Hi byte of EXEVEC must be different from the Hi byte of INVEC.
TRCVEC	A674-A675	May be used to point to user trace routine after TRCOFF (See Section 9.6).
UBRKVC	A676-A677	May be used to point to user BRK routine after IRQVEC.
UIRQVC	A678-A679	May be used to point to user NON-BRK IRQ routine after IRQVEC.
NMIVEC	A67A-A67B	Points to routine which saves registers, determines whether or not to trace, based on TV.
IRQVEC	A67E-A67F	Points to routine which saves registers, determines whether or not BRK has occurred, and continues thru UBRKVC or UIRQVC.

9.5 DEBUG ON and TRACE

When the DEBUG ON key on your SYM-1 is depressed, DEBUG mode is enabled. In DEBUG mode, an NMI interrupt occurs every time an instruction is fetched from an address that is not within the monitor. SUPERMON's response is to save the registers and display the PC, with code 2 (for NMI). With each **(G) (CR)**, one instruction of the user program will be executed. This is called Single-Stepping.

In order to TRACE, alter the Trace Velocity (TV, at A656) to a non-zero value. (09 is a good value.) If you now enter **(G) (CR)**, SUPERMON will display the PC and the contents of the accumulator, pause, and resume execution. Addresses and accumulator contents will flash by one at a time. To stop the flow, depress any key (Hex keyboard) or the BREAK key (terminal). Execution will halt. A **(G) (CR)** will resume execution. The length of the delay is related to TV (not linearly; try different values) and, of course, the baud rate, if you are working from a terminal.

9.6 USER TRACE ROUTINES

As the complexity of your programs increases, you may wish to implement other types of trace routines. To demonstrate how this is done, an example of a user trace routine is provided in Figure 9-6. It prints the op code of the instruction about to be executed, instead of the accumulator contents.

But first of all, we don't want to be interrupted during trace mode by responding to an interrupt (a problem called recursion). SUPERMON will handle this by turning DEBUG OFF, then back ON. However, to implement this program control of DEBUG, you must add jumpers W24 and X25 to your SYM-1 board (see Chapter 4).

Now that you have added the jumpers, we are ready to enter the program UTRC and change vectors.

First, enter the program UTRC as given in Figure 9-6. Then change NMIVEC to point to TRCOFF, which will save registers, turn DEBUG OFF, and vector thru TRCVEC:

SD 80C0,A67A **(CR)**

Now, point TRCVEC to UTRC.

SD 0380,A674 **(CR)**

Enter a non-zero value in TV, depress DEBUG ON, and you're ready to trace.

NOTE: BRK instructions with DEBUG ON will operate as two-byte instructions and should be programmed as 00,EA (BRK,NOP).

Also, the first instruction after leaving SUPERMON will not be traced.

```
LINE # LOC      CODE        LINE

0002  0000                ; UTRC - USER TRACE ROUTINE -
0003  0000                ; PRINT NEXT OP CODE INSTEAD OF ACCUMULATOR
0004  0000                ;
0005  0000                OPPCOM =$8337          ;PRINT PC, PRINT COMMA
0006  0000                PCLR   =$A659
0007  0000                PCHR   =$A65A
0008  0000                OBCRLF =$834A          ;PRINT BYTE FROM ACC, PRINT CRLF
0009  0000                DELAY  =$835A          ;DELAY BASED ON TV
0010  0000                WARM   =$8003          ;WARM MONITOR ENTRY
0011  0000                TRACON =$80CD          ;TURN TRACE ON, RESUME EXECUTION
0012  0000                TV     =$A656          ;TRACE VELOCITY
0013  0000                ;
0014  0000                       *=$380          ;PUT IN HI RAM (ENTIRELY RELOCATE/
0015  0380  20 37 83     UTRC   JSR OPPCOM      ;PRINT PC,-COMMA
0016  0383  AD 59 A6            LDA PCLR        ;USE PC AS PTR TO OP CODE
0017  0386  85 F0               STA $F0
0018  0388  AD 5A A6            LDA PCHR
0019  038B  85 F1               STA $F1
0020  038D  A0 00               LDY #0
0021  038F  B1 F0               LDA ($F0),Y     ;PICK UP OP CODE
0022  0391  20 4A 83            JSR OBCRLF      ;OUTPUT OP CODE, CRLF
0023  0394  AE 56 A6            LDX TV          ;GET TRACE VELOCITY
0024  0397  F0 05               BEQ NOGO        ;NOGO IF ZERO
0025  0399  20 5A 83            JSR DELAY       ;DELAY ACCORDING TO TV
0026  039C  90 03               BCC GO          ;CARRY SET IF KEY DOWN
0027  039E  4C 03 80     NOGO   JMP WARM        ;HALT
0028  03A1  4C CD 80     GO     JMP TRACON      ;CONTINUE
0029  03A4                       .END
```

Figure 9-6. LISTING OF SAMPLE USER TRACE ROUTINE

USER TRACE EXAMPLE

```
.V 200,20A (CR)
  0200 A9 00 A9 11 A9 22 A9 33,0A
  0208  4C 00 02,58
0358
.SD 80C0,A67A (CR)          Vector modification
.SD 380,A674 (CR)           Vector modification
.G 200 (CR)                 Single-Step (Remember
0202,A9                     to set DEBUG ON before
                            each (G) (CR)
 G (CR)
0204,A9

.M A656(CR)
A656,00,09(CR)              Trace Velocity = 9
A657,4D (CR)
.G 200 (CR)
0202,A9
0204,A9
0206,A9
0208,4C                     Continuous trace of op codes
0200,A9
0202,A9
0204,A9
0206,A9
0208,4C
0200,A9
0202,A9
```

9.7 MIXED I/O CONFIGURATIONS

The Reset routine that is activated when power is turned on or RST is pressed establishes the terminal I/O configuration by loading a specified value into a location in System RAM, TOUTFL (A654). The high-order four bits of TOUTFL define which terminal devices may be used for input and output. A "1" signifies that a device is enabled, a "0" that it is disabled. The meaning of each bit and the values assigned at system reset are shown below. The routine referenced by entry (1) in the JUMP table will enable the TTY for input. For other configurations, load the appropriate value into TOUTFL.

TOUTFL bit:	7	6	5	4
default value:	1	0	1	1
meaning:	CRT INPUT	TTY INPUT	TTY OUTPUT	CRT OUTPUT

Bits 6 and 7 of another location in System RAM, TECHO (A653), are used to inhibit serial output (bit 6) and to control echo to a terminal (bit 7). Bit 6 may be toggled by entering "(CONTROL) O" (0F Hex) on the terminal keyboard or in software. The possible values for TECHO are shown below.

TECHO	80	echo output	(default value)
	C0	echo no output	
	40	no echo no output	
	00	no echo output	

With this information, you can alter the SUPERMON standard I/O configurations to suit your special needs. A common use would be routing your output to a terminal while using the Hex keyboard as an input device. Two possible ways of doing this will be discussed.

First, by merely altering SDBYT and OUTVEC, your input and echo will use the on-board keyboard and display, while Monitor and program output will go to the serial device. Choose the proper baud rate value for your device from the following table and put it in SDBYT (at A651) with the "M" command. Then enter the address of TOUT into OUTVEC from the hex keyboard as follows:

.SD 8AA0,A664 **(CR)**

Terminal Baud Rate	Value Placed in SDBYT
110	D5
300	4C
600	24
1200	10
2400	06
4800	01

Second, if you wish your input to be echoed on the terminal device, a small program must be entered. First, complete the sequence discussed above. Then, enter the following program:

```
UIN   JSR  GETKEY    20  AF  88
      BIT  TECHO     2C  53  A6
      BPL  UOUT      10  03
      JMP  OUTCHR    4C  47  8A
UOUT  RTS            60
```

Enter the program called "UIN" above at any user RAM location. Then use the "SD" command to put the address of UIN into INVEC (at A661) as follows:

.SD (UIN),A661 **(CR) (ENTER AT HKB)**

where (UIN) is the address of the program UIN.

9.8 USER MONITOR EXTENSIONS

Having read the section on Monitor flow, you will have noticed that unrecognized commands and parameter entries are vectored through URCVEC (A66C-A66E), which normally points to a SEC, RTS sequence at 81D1. By pointing URCVEC to a user-supplied routine in RAM or PROM, SUPERMON can easily be extended. The following example will illustrate the basic principle; many more sophisticated extensions are left to your imagination.

9.8.1 Monitor Extension Example

This example will define U0 with two parameters as a logical AND. The parameters and the result are in Hexadecimal.

```
LOGAND   CMP  LSTCOM     ;CMD loaded?
         BEQ  OK
BAD      SEC              ;set for error print
         RTS
OK       CMP #$14  ;USR0
         BNE  BAD         ;branch to next
                          ;command if defined
         CPX  #2          ;two parms
         BNE  BAD
DOAND    LDA  P2H
         AND  P3H         ;here's the 'and' hi
         TAX
         LDA  P2L
         AND  P3L         ;'and' lo
         JSR  CRLF        ;get new line
         JSR  SPACE
         JMP  OUTXAH      ;PRINT X and A
        .END
```

To attach LOGAND to the monitor, it must be assembled (probably by hand), entered into memory, and URCVEC altered to contain a JMP to LOGAND. Notice that more than one command could have been added, by pointing BAD to the next possible command, instead of a RTS.

9.8.2 SUPERMON As Extension to User Routines

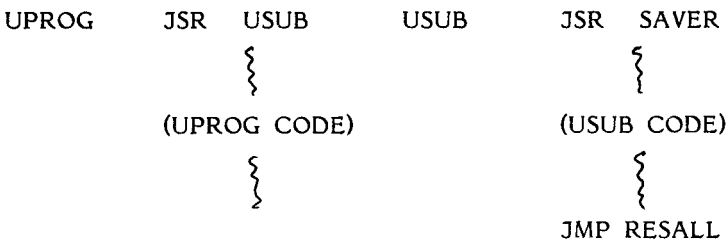
Because SUPERMON contains a user entry, it can easily be appended to your software. An example of the utility of this feature is a user trace routine, which could have an 'M' command, which would direct it to make SUPERMON available to the user. Here's what the code would look like.

```
UTRACE
. . .                                   Trace code

          JSR INCHR
          CMP #'M
          BNE ELSE
          JSR USRENT
          JMP UTRACE
          . . .

ELSE                                    Code executed if character
                                        input is not 'M.'
```

In this example, the user will type an 'M' to get into monitor, and a **(G) (CR)** to return to the calling portion of UTRACE. Note that the user PC and S registers should not be modified while in monitor if a return to UTRACE is intended.

9.9 USE OF SAVER AND RES ROUTINES

SAVER and the RES routines are designed to be used with subroutines. Their usage is as follows:



In this example, UPROG calls USUB. USUB calls SAVER, performs its function, and then jumps to RESALL. RESALL restores all registers and returns to UPROG. If RESXF or RESXAF were used instead of RESALL, UPROG would receive the F, or F and A registers as left by USUB.

APPENDIX A

IMMEDIATE ACTION

Your SYM-1 microcomputer has been thoroughly tested at the factory and carefully packed to prevent damage in shipping. It should provide you with years of trouble-free operation. If your unit does not respond properly when you attempt to apply power, enter commands from the keyboard, or attach peripheral devices to the system, do not immediately assume that it is defective. Re-read the appropriate sections of this manual and verify that all connections have been properly wired and all procedures properly executed.

If you finally conclude that your SYM-1 is defective, you should return it for repair to an authorized service representative. Specific instructions for obtaining a service authorization number and shipping your unit are contained with warranty information on the card entitled "LIMITED WARRANTY AND SERVICE PLAN" that is included with system reference material.

APPENDIX B

PARTS LIST

MATERIALS AND ACCESSORIES

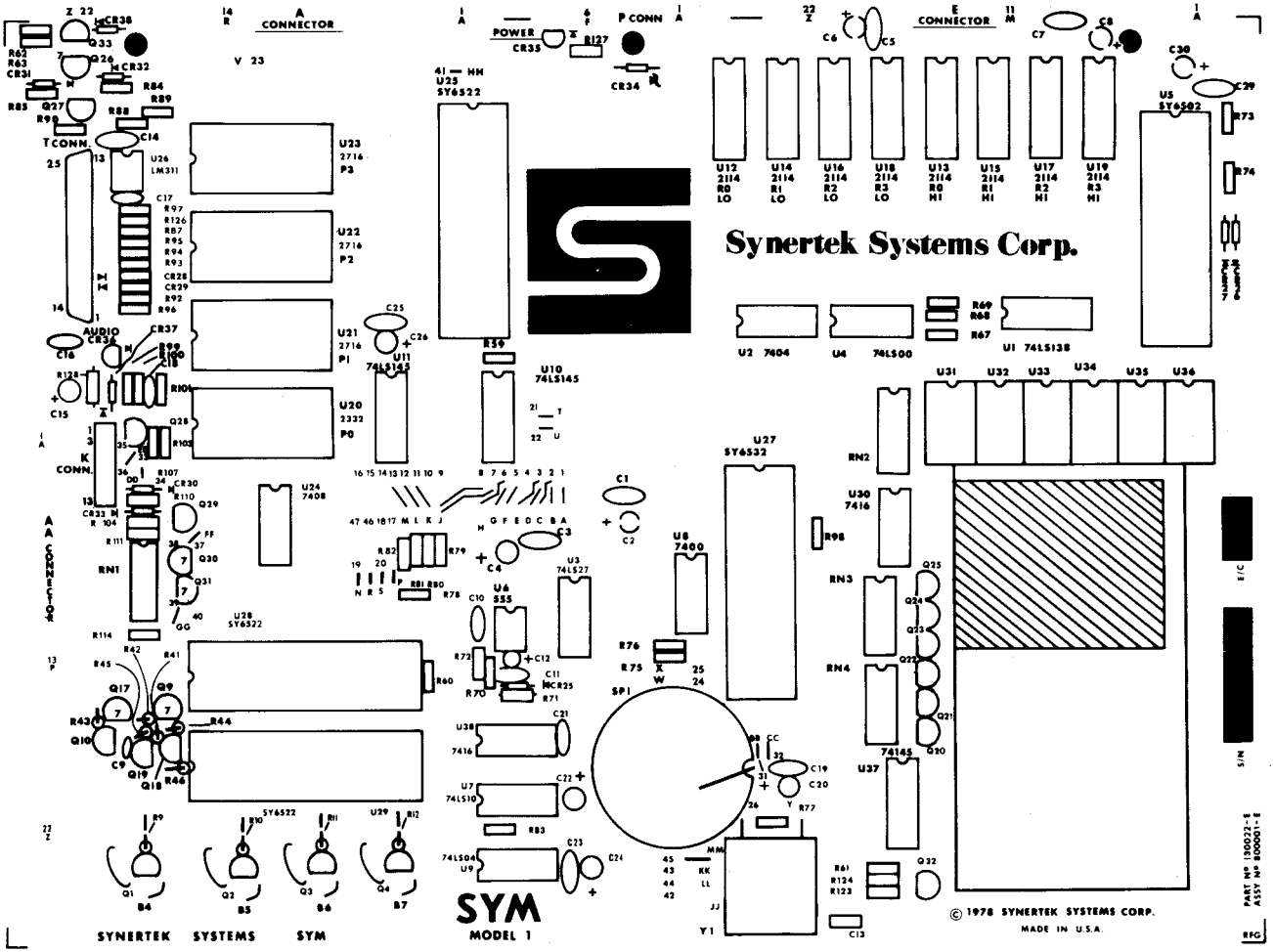
QTY.	DESCRIPTION	MANUFACTURER/PART NUMBER
1	CONNECTOR, DUAL 22/44	Microplastic 15622DPIS
1	CONNECTOR, DUAL 6/12	Teka TP3-061-E04
6	RUBBER FEET	3M SJ5018
1	SYNERTEK SOFTWARE MANUAL	
1	SYM-1 WARRANTY/USER CLUB REFERENCE CARD	
1	SYM REFERENCE MANUAL	
1	SYM-1 PC BOARD ASSEMBLY	

SYM-1 PC BOARD COMPONENTS

QTY.	DESCRIPTION	MFR. NO.	REFERENCE DESIGNATION
1	CPU	SYP6502	U5
2	VIA	SYP6522	U25,U29
1	RAM-I/O	SYP6532	U27
2	4K BIT RAM	SYP2114	U12, U13
1	32K BIT ROM	SYP2332	U20
1	NAND GATE	7400	U8
1	HEX INVERTER	7404	U2
1	AND GATE	7408	U24
2	HEX INVERTER-O.C.	7416	U30, U38
1	NAND GATE	74LS00	U4
1	HEX INVERTER	74LS04	U9
1	TRIPLE NOR GATE	74LS27	U3
1	TIMER	555	U6

QTY.	DESCRIPTION	MFR. NO.	REFERENCE DESIGNATION
1	DECODER	74LS138	U1
1	TRIPLE 3 INPUT NAND	74LS10	U7
1	DECODER	74145	U37
2	DECODER	74LS145	U10, U11
1	COMPARATOR	311	U26
1	RES-100 ohm, ¼W, 5%	RF14J100B	R128
3	RES-200 ohm, ¼W, 5%	RF14J200B	R43, 111, 114
1	RES-300 ohm, ¼W, 5%	RF14J300B	R107
4	RES-470 ohm, ¼W, 5%	RF14J470B	R84, 88, 124, 127
14	RES-1K, ¼W, 5%	RF14J1KB	R9-12, 41, 61-63, 73, 78, 85, 92, 101, 113, 123
1	RES-1M, ¼W, 5%	RF14J1MB	R72
1	RES-2.2K, ¼W, 5%	RJ14J2.2KB	R103
14	RES-3.3K, ¼W, 5%	RF14J3.3KB	R59, 60, 70, 74, 79-82, 87, 94, 95, 97, 98, 126
1	RES-4.7K, ¼W, 5%	RF14J4.7KB	R42
10	RES-10K, ¼W, 5%	RF14J10KB	R45, 67-69, 75, 76, 83, 89, 93, 104
3	RES-47K, ¼W, 5%	RF14J47KB	R44, 46,71
1	RES-330K, ¼W, 5%	RF14J330KB	R77
2	RES-27K, ¼W, 5%	RF14J27KC	R90, 96
2	RES-150 ohm, ¼W, 5%	RF14J150B	R99, 110
1	RES-6.8K, ¼W, 5%	RF14J6.8KB	R100
1	CAP-10pf	DM15100J	C13
13	CAP - .01 mfd, 100V	DB203YZ1032	C1, 3, 5, 7, 10, 11, 16, 17, 19, 23, 25, 29
10	CAP - 10 mfd, 25V	T368B106K025PS	C2, 4, 6, 8, 12, 20, 22, 24, 26, 30

QTY.	DESCRIPTION	MFR. NO.	REFERENCE DESIGNATION
3	CAP - .1 mfd, 50V	3429-050E-104M	C9, 18
2	CAP - .47 mfd	C330C474M5V5EA	C15
1	CAP - .0047 mfd	UR2025100X7R472K	C14
12	NPN TRANSISTOR	2N2222A	Q1-4, 10, 18, 19, 2729, 32, 33
11	PNP TRANSISTOR	2N2907A	Q9, 17, 20-26, 30, 31
11	DIODE, G.P.	1N914	CR25-33, 37, 38
1	DIODE, ZENER	1N4735	CR34
4	SOCKET - 24-PIN DIP	TIC8424-02	SK20-23
5	SOCKET - 40-PIN DIP	TIC8440-02	SK5, 25, 27-29
8	SOCKET - 18-PIN DIP	TIC8418-02	SK12-19
1	DUAL HEADER	AP929665-01-07	"K" Connector
1	KEYBOARD		KB1
1	PC BOARD		PC1
6	7-SEGMENT DISPLAY, 0.3"	MAN 71A	U31-36
2	LED	RL4850	CR35,36
1	SPEAKER	70057	SP1
1	CRYSTAL	CY1A	Y1
	TAPE - 1½" x 2" STRIP		
1	RES. PACK - 100 ohm	898-3-R100	RN2
1	RES. PACK - 3.3K ohm	899-3-R3.3K	RN1
2	RES. PACK - 1K ohm	899-3-RIK	RN3, RN4
1	RED FILTER		


Synertek Systems Corp.
SYM
MODEL 1
SYNERTEK SYSTEMS SYM
A CONNECTOR
P CONN
E CONNECTOR
POWER
T CONN.
K CONN.
AUDIO
U23 2716 P3
U22 2716 P2
U21 2716 P1
U20 2332 P0
U26 LM311
U11 74LS145
U10 74LS145
U25 SY6522
U28 SY6522
U24 7408
U3 74LS27
U6 555
U8 7400
U27 SY6532
U2 7404
U4 74LS00
U1 74LS138
U5 SY6502
U12 2114 R0 LO
U14 2114 R1 LO
U16 2114 R2 LO
U18 2114 R3 LO
U13 2114 R0 HI
U15 2114 R1 HI
U17 2114 R2 HI
U19 2114 R3 HI
U30 7416
U37 74145
U38 7416
U7 74LS10
U9 74LS04
RN1
RN2
RN3
RN4
SPI
Y1
SS-C-800001-E
PART Nº 130022-E
ASSY Nº 800001-E
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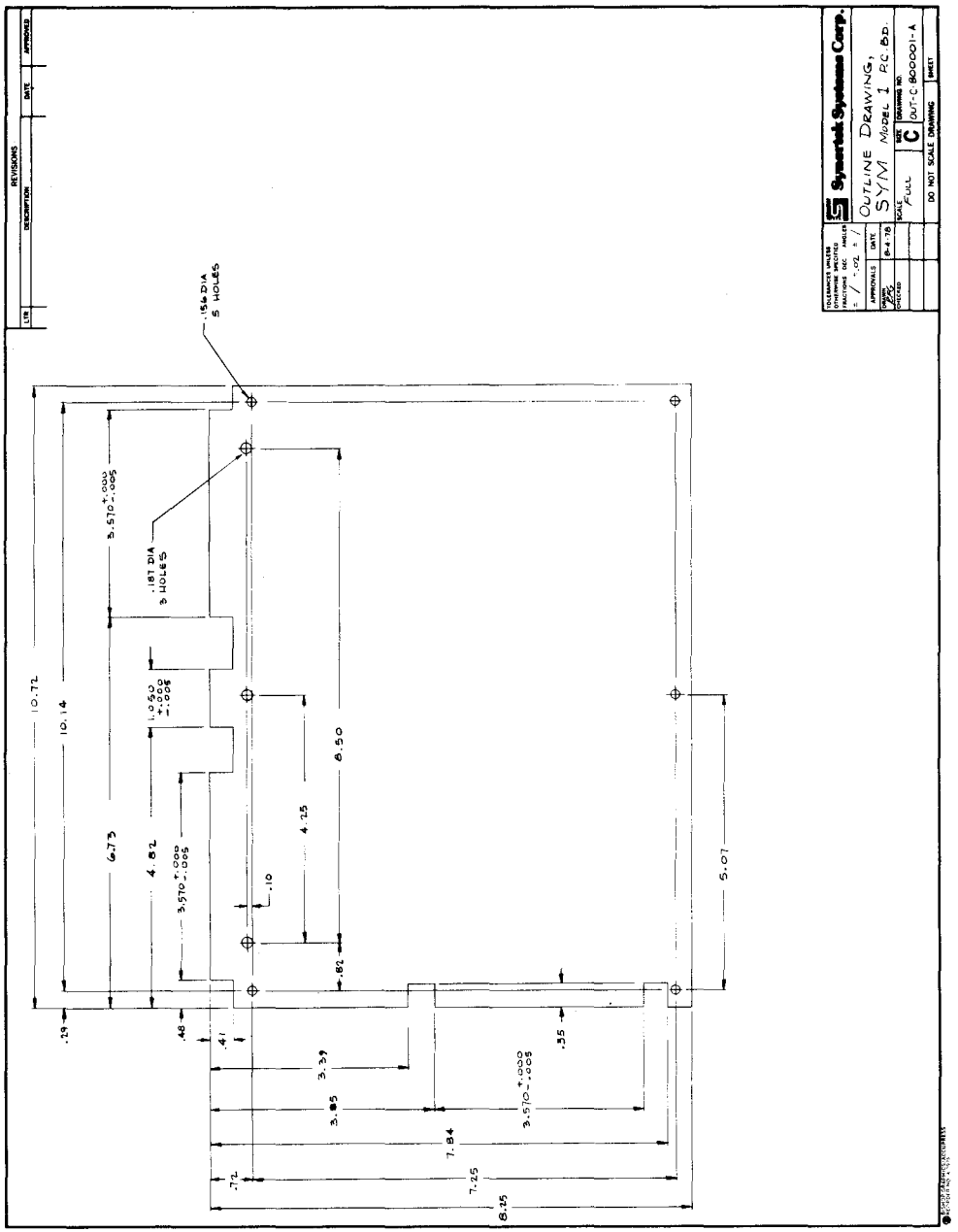


OUTLINE DRAWING

B–5

APPENDIX C

AUDIO TAPE FORMATS

HIGH-SPEED FORMAT -- High speed data transfer takes place at 185 bytes per second. Every byte consists of a start bit (0), followed by eight data bits. The least significant bit is transmitted first. A "1" bit is represented by 1 cycle of 3000 Hz, while a "0" bit is represented by ½ cycles of 1500 Hz. Physical record format is shown below.

8 sec. "mark"	256 SYN chars.	*	ID	SAL	SAH	EAL +1	EAH +1	DATA	/	CKL	CKH	EOT	EOT

8 sec. "mark" - Allows the tape to advance beyond the leader and creates an inter-record gap.

SYN (16 Hex) - ASCII synch characters that allow the SYM-1 to synchronize with the data stream.

* (2A Hex) - ASCII character that indicates the start of a valid record.

ID - Single byte that uniquely identifies the record.

SAL - Low order byte of the Starting Address from which data was taken from memory.

SAH - High order byte of the Starting Address from which data was taken from memory.

EAL +1 - Low order byte of the address following the Ending Address from which data was taken from memory.

EAH +1 - High order byte of the address following the Ending Address from which data was taken from memory.

DATA - Data bytes.

/ (2F Hex) - ASCII character that indicates the end of the data position of a record.

CKL - Low order byte of a computed checksum.

CKH - High order byte of a computed checksum.

EOT (04 Hex) - ASCII characters that indicate the end of the tape record.

KIM FORMAT -- Data transfer in KIM format takes place at approximately 8 bytes per second. A "1" bit is represented by 9 cycles of 3600 Hz followed by 18 cycles of 2400 Hz, while a "0" bit is represented by 18 cycles of 3600 Hz followed by 6 cycles of 2400 Hz. Each 8-bit byte from memory is represented by two ASCII characters. The byte is separated into two half-bytes, then each half-byte is converted into an ASCII character that represents a Hex digit. The least significant bit is transmitted first. The KIM physical record format is shown below.

128 SYN chars.	*	ID	SAL	SAH	DATA	/	CKL	CKH	EOT	EOT

The sync characters, the ASCII characters "*" (2A Hex) and "/" (2F Hex) as well as ID, SAL, SAH, CKL, CKH and EOT serve the same functions as in HIGH-SPEED format. Sync characters, *, / and EOT are represented by single ASCII characters, while the remaining record items require two ASCII characters. Note that EAL and EAH are not used in the KIM format.

APPENDIX D

PAPER TAPE FORMAT

When data from memory is stored on paper tape, each 8-bit byte is separated into two half-bytes, then each half-byte is converted into an ASCII character that represents a Hex digit (O-F). Consequently, two ASCII characters are used to represent one byte of data. In the paper tape record format shown below, each N, A, D, and X represents one ASCII character.

; N_1N_0 $A_3A_2A_1A_0$ $(D_1D_0)_1$ $(D_1D_0)_2$ . . . $(D_1D_0)_n$ $X_3X_2X_1X_0$

;	- Start of record mark
N_1N_0	- Number of data bytes in (Hex) contained in the record
$A_3A_2A_1A_0$	- Starting address from which data was taken
(D_1D_0)-$(D_1D_0)_n$	- Data
$X_3X_2X_1X_0$	- 16-bit checksum of all preceding bytes in the record including N_1N_0 and $A_3A_2A_1A_0$, but excluding the start of record mark.

A single record will normally contain a maximum of 16 (10 Hex) data bytes. This is the system default value that is stored in system RAM at power-up or reset in location MAXRC (A658). You can substitute your own value by storing different number in MAXRC. To place an end of file after the last data record saved, place the TTY in local mode punch on, and enter ;00 followed by **(CR).**

APPENDIX E

SYM COMPATABILITY WITH KIM PRODUCTS

If you are a SYM-1 user who has peripheral devices which you have previously used with the KIM system or software which has been run on a KIM module, you'll find SYM to be generally upward compatible with your hardware and software. The following two sections describe the levels of compatability between the two systems to allow you to undertake any necessary modifications.

E.1 HARDWARE COMPATABILITY

Table E-1 describes the upward compatability between SYM and KIM at the Expansion (E) connector, while Table E-2 describes the compatability on the Applications (A) connector.

I/O port addresses differ between the two systems; you should consult the Memory Map in Figure 4-10 for details.

Power Supply inputs are provided on a separate connector with SYM-1, which means that if you have been using your power supply with a KIM device it will be necessary to rewire its connections to use the special connector on the SYM-1 board.

E.2 SOFTWARE COMPATABILITY

Table E-3 lists important user-available addresses and routines in the KIM-1 monitor program and their counterparts in SYM-1's SUPERMON. Many of the routines do not perform identically in the two systems, however, and you should check their operation in Table 9-1 before using them.

Table E-1. EXPANSION CONNECTOR (E) COMPATABILITY

SYM DESCRIPTION	SYM NAME	PIN #	KIM NAME	KIM DESCRIPTION
Jumper (Y,26) Selectable: OFF - Open Pin ON - Debug On/Off Output (U8-8)	DBOUT	17	SSTOUT	From (SYNC • NOT MONITOR) U26-6
Power On Reset Signal Output: "0" After power on "1" When reset by software	$\overline{POR}$	18		No equivalent

Table E-2. APPLICATION CONNECTOR (A) COMPATABILITY

SYM DESCRIPTION	SYM NAME	PIN #	KIM NAME	KIM DESCRIPTION
Jumper (V,23) Selectable: OFF - Open Pin ON - Remote Audio Control Out	AUD.RC	N	+12V	+12V Not required on SYM
Jumper (HH,41) Selectable: OFF Open Pin ON $\overline{\text{ICXX}}$ Decode Out		K	DECODE Enable	Enable 8K Decoder

Table E-3. SYM-KIM SOFTWARE COMPATABILITY

SYM		KIM		FUNCTION
Label	Address(es)	Label	Address(es)	
PCLR	A659	PCL	00EF	Program Counter - low
PCHR	A65A	PCH	00F0	Program Counter - high
FR	A65C	PREG	00F1	Status Register
SR	A65B	SPUSER	00F2	Stack Pointer
AR	A65D	ACC	00F3	Accumulator
YR	A65F	YREG	00F4	Y - Register
XR	A65E	XREG	00F5	X - Register
SCR6	A636	CHKHI	00F6	Checksum - low
SCR7	A637	CHKSUM	00F7	Checksum - high
P2L	A64C	SAL	17F5	Start Addr Low - audio/paper tape
P2H	A64D	SAH	17H6	Start Addr High - audio/paper tape
P3L	A64A	EAL	17F7	End Addr+1 Low - audio/paper tape
P3H	A64B	EAH	17F8	End Addr+1 High - audio/paper tape
P1L	A64E	ID	17F9	ID Byte audio Tape
NMIVEC	A67A-B FFFA-B	NMIV	17FA-B FFFA-B	NMI Vector
RSTVEC	FFFC-D	RSTV	17FC-D FFFC-D	Reset Vector
IRQVEC	A67E-F FFFE-F	IRQV	17FE-F FFFE-F	IRQ Vector
DUMPT	8E87	DUMPT	1800	Dump memory to audio tape
LOADT	8C78	LOADT	1873	Load memory from audio tape
CHKT	8E78	CHKT	194C	Compute checksum for audio tape
OUTBTC	8F4A	OUTBTC	195E	Output one KIM byte
HEXOUT	8F52	HEXOUT	196F	Convert LSD of A to ASCII AND write to audio tape

Table E-3. SYM-KIM SOFTWARE COMPATABILITY (Continued)

SYM		KIM		FUNCTION
Label	Address(es)	Label	Address(es)	
OUTCHT	8F5D	OUTCHT	197A	Write one ASCII character to audio tape
RDBYT	8E2C	RDBYT	19F3	Read one byte from audio tape
PACKT	8E3E	PACKT	1A00	Pack ASCII to nibble
RDCHT	8E61	RDCHT	1A24	Read one character from audio tape
RDBITK	8E0F	RDBIT	1A41	Read one bit from tape
SVNMI	809B	SAVE	1C00	Monitor NMI entry
RESET	8B4A	RST	1C22	Monitor RESET entry
OUTPC	82EE	PCCMD	1CDC	Display PC
INCHR	8A1B	READ	1C6A	Get character
LP2B+7	841E	LOAD	1CE7	Load paper tape
SP2B+4	869C	DUMP	1D42	Save paper tape
OUTS2	8319	PRTPNT	1E1E	Print pointer
OUTBYT	82FA	PRTBYT	1E3B	Print 1 byte as 2 ASCII character
INCHR	8A1B	GETCH	1E5A	Get character
DLYF	8AE6	DELAY	1ED4	Delay 1 bit time
DLYH	8AE9	DEHALF	1EEB	Delay ½ bit time
INSTAT	8386	AK	1EFE	Determine if key is down
OUTDSP	89C1	SCAND	1F19	Output to LED display
SCAND	8906	SCANDS	1F1F	Scan LED display
INCCMP	82B2	INCPT	1F63	Increment pointer
GETKEY	88AF	GETKEY	1F6A	Get key
CHKSAD	82DD	CHK	1F91	Compute checksum
INBYTE	81D9	GETBYT	1F9D	Get 2 Hex characters and pack

APPENDIX F

CREATING AND USING A SYNC TAPE

To read serial data from tape, the SYM-1 makes use of synchronizing (sync) characters that are part of every tape record. For a complete description of audio tape record formats, refer to Appendix C.

When the SYM-1 searches for a record, an "S" is displayed until the sync characters are recognized and data transfer begins. However, if the volume and tone controls on the recorder are not set correctly, the sync characters will not be recognized, the "S" on the display will not go out, and the record will not be loaded into memory.

Before attempting to save and load data for the first time, or whenever the control levels have been changed since the recorder was last used, you should perform a load operation using a tape containing only sync characters. By adjusting the volume and tone controls until the displayed "S" goes out, you can set the control levels properly for actual data.

You may want to generate two sync tapes, one for HIGH-SPEED format, the other for KIM format, just once, and save them for future use.

To generate a sync tape, enter the sync character generation program for one of the formats into RAM starting in location 0200 (Hex). The assembly language code and the machine language code for both formats are shown below. Read the pairs of Hex digits from left to right and top to bottom. For example, the code for HIGH-SPEED format should be entered in the following sequence: A0 80 20 B6 8D A9 . . . .

Next, insert a tape into the cassette unit. If the unit is equipped with remote control, place it in Record mode. Set the volume and tone controls to mid-range, then enter the command to execute the program:

(GO) 200 (CR)

If you are operating the cassette controls manually, place the unit in Record mode after entering the command, but before entering (CR). Remote controlled units will advance the tape automatically. Let the tape run for several minutes, then press RST to end the program. For manual operation, also press STOP on the tape unit.

To set the volume and tone controls for loading data into memory, rewind the tape to the beginning (you may need to pull out the Remote jack or keep your finger on RST), then place the unit in Play mode if it is equipped with remote control. Next, enter the load command for the appropriate format ((LD 1) for KIM, (LD 2) for HIGH-SPEED, followed by a carriage return (CR)).

If you have a manually operated unit, place it in Play mode after entering the command. While the tape advances, adjust the volume and tone controls until the "S" on the display goes out and remains out, then press RST and stop the tape.

You can now remove the sync tape and proceed to save and load actual programs and data.

SYNERTEK SYSTEMS CORPORATION

PROGRAM SYNC TAPE

PROGRAMMER SYNERTEK SYSTEMS

DATE 5-78

ADDR	INSTRUCTIONS B1	B2	B3	LABEL	MNEMONIC	OPERAND	COMMENTS
						MODE = $80	HIGH-SPEED; USE $00 FOR KIM
						OUTCHT = $8F5D	
						OUTBTH = $8F17	
						TAPOUT = $A402	
						START = $8DB6	
						* = $200	
0200	A0	80			LDY	#MODE	IN KIM, A0 00
0202	20	B6	8D		JSR	START	IN KIM, 20 B6 8D
0205	A9	07			LDA	#7	IN KIM, A9 07
0207	8D	02	A4		STA	TAPOUT	IN KIM, 8D 02 A4
020A	A9	16		SYNMOR	LDA	#$16	IN KIM, A9 16
020C	20	17	8F		JSR	OUTBTH	HIGH-SPEED; USE JSR OUTCHT (20 5D 8F) KIM
020F	4C	0A	02		JMP	SYNMOR	IN KIM, 4C 0A 02

Adjusting Your Recorder

The audio signal appears on the T and A connectors in two forms: Aud Out (HI) and Aud Out (LO). The only difference between these signals is their magnitude. For most recorders, the best arrangement is to run Aud Out (LO) into the MIC input of the recorder. Some recorders also have an AUX input, which bypasses the MIC pre-amp, and may work better if Aud Out (HI) is wired into AUX.

Read Appendix F, and follow the procedure for creating a "SYNC" tape. Rewind the tape and enter the LD command appropriate to the SYNC tape you created. Adjust the tone and volume controls, observing the S on the display. Leave the controls in the middle of the range where the S remains off. (If there are two ranges of volume which cause the S to turn off, the higher range should be used. If a sharp tap causes the S to relight and remain lit, you are in the wrong range.)

If your recorder has an automatic-recording-level defeat switch, it will probably work better in the engaged position.

Now write a short record to tape and read it back to verify correct operation. (Do not use the memory form $F8 to $FF, or the stack area ((page 1)), as these are used by the cassette software.)

Recommended Tape Equipment

Most moderate quality tape recorders should produce satisfactory results. (A tone control is recommended.) The following models have been used successfully at Synertek Systems:

Sanyo M2533A	GE IC #3-5002B
Sony TC-205	Superscope C-190
Sony TC-62	Realistic Ctr-40

Almost any tape will suffice, so long as it winds smoothly (does not produce a jittery tape motion). A very short tape will be more convenient. The following tapes have been used successfully at Synertek Systems:

TDK
AMPEX
MALLORY
REALISTIC

APPENDIX G

MONITOR ADDENDA

1. While tracing or single stepping, SUPERMON uses G01ENT ($83FA) to return to the user program. G01ENT write protects System RAM. If you must trace a program that needs access to System RAM, use a user trace routine and go to G01ENT +3, or remove jumper MM-45 (enables System RAM protect).

2. The DEBUG-ON switch bounces, therefore it should not be used to interrupt user programs while using a user trace routine or while OUTVEC points to a user routine. (This will cause recursive interrupts.)

3. The audio cassette software will not read or write location $FFFF. Use $A67F ($A600 thru $A67F is echoed at $FF80 thru $FFFF).

APPENDIX H

SUPPLEMENTARY INFORMATION

Changing Automatic Log-On

After power is applied to the SYM, SUPERMON waits for the keyboard or the device connected to PB7 on the 6532 (normally the RS232 device) to become active. PB6 (the current loop device) is ignored because a disconnected current loop always looks active.

If you expect always to log-on a current-loop device, the following jumper change will eliminate the necessity of entering (SHIFT) (JUMP) (1):

Change CC-32 and BB-31
to CC-31 and BB-32

Now the log-on for your current loop device is simply a "Q", entered at the device. (Note that you cannot now log-on automatically to the keyboard unless the current loop device is connected, and powered-up.)

Using On-Board LED Display

Because of the extensive use of transfer vectors in SUPERMON, the same monitor calls can be used to activate the LED display as for terminal devices. The major difference is that you must call ACCESS (address 8B86) before outputting the first character in order to remove write-protection from the display buffer (DISBUF, address A640 thru A645).

If the SYM-1 was logged-on to from the HKB, each call to OUTCHR (address 8A47) will examine the ASCII character in the Accumulator, look up its segment code, shift everything in the display buffer of segment codes left one digit, place the new code in the rightmost digit, and scan the display once.

If the SYM-1 was logged-on to the HKB, each call to INCHR (address 8A1B) will scan the display from the codes in DISBUF continuously until a key is depressed (2 keys in the case of SHIFT keys, 4 in the case of SHIFT ASCII keys). The key will be fully debounced, the beeper beeped, the ASCII or HASHED ASCII code taken from a table, and passed back to the caller in the Accumulator. The Flags will reflect a compare with carriage-return.

Other useful routines are:

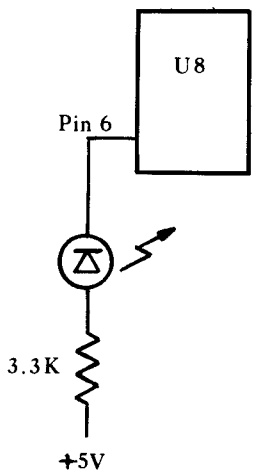
GETKEY (88AF)	Same as description of INCHR above, but disregard log-on and no compare performed.
OUTDSP (89C1)	Same as description of OUTCHR above, but disregard log-on.
KEYQ (8923)	Test for key depressed on HKB. On return, Z Flag = 1 if key down.
SCAND (8906)	Scan display once from segment codes in DISBUF. On return, Flags reflect call to KEYQ.

INSTAT If logged-on to HKB, check for key down (else check for BREAK key). On return, carry set if key down (or BREAK key). Leading edge of key debounced.

See also chapter 9 for discussion of monitor calls.

Adding DEBUG Indicator

While using trace routines which turn DEBUG on and off, it is often desirable to have an external indication of the DEBUG state. The addition of an LED and a resistor as follows will achieve this.



U8 is a 14 pin package located above the beeper.

The LED will remain on while DEBUG is on.

APPENDIX I

SY6502 DATA SHEET

Synertek®

3050 Coronado Drive, Santa Clara, CA. 95051
(408) 984-8900 TWX 910-338-0135

SY6500

SY6500 MICROPROCESSORS

The SY6500 Microprocessor Family Concept ----

The SY6500 Series Microprocessors represent the first totally software compatible microprocessor family. This family of products includes a range of software compatible microprocessors which provide a selection of addressable memory range, interrupt input options and on-chip clock osscillators and drivers. All of the microprocessors in the SY6500 group are software compatible within the group and are bus compatible with the M6800 product offering.

The family includes five microprocessors with on-board clock oscillators and drivers and four microprocessors driven by external clocks. The on-chip clock versions are aimed at high performance, low cost applications where single phase inputs, crystal or RC inputs provide the time base. The external clock versions are geared for the multi processor system applications where maximum timing control is mandatory. All versions of the microprocessors are available in 1 MHz and 2 MHz ("A" suffix on product numbers) maximum operating frequencies.

Features of the SY6500 Family

- Single five volt supply
- N channel, silicon gate, depletion load technology
- Eight bit parallel processing
- 56 Instructions
- Decimal and binary arithmetic
- Thirteen addressing modes
- True indexing capability
- Programmable stack pointer
- Variable length stack
- Interrupt capability
- Non-maskable interrupt
- Use with any type or speed memory
- Bi-directional Data Bus
- Instruction decoding and control
- Addressable memory range of up to 65K bytes
- "Ready" input
- Direct memory access capability
- Bus compatible with MC6800
- Choice of external or on-board clocks
- 1MHz and 2MHz operation
- On-the-chip clock options
  - * External single clock input
  - * RC time base input
  - * Crystal time base input
- 40 and 28 pin package versions
- Pipeline architecture

Members of the Family

Microprocessors with On-Board Clock Oscillator

- SY6502
- SY6503
- SY6504
- SY6505
- SY6506

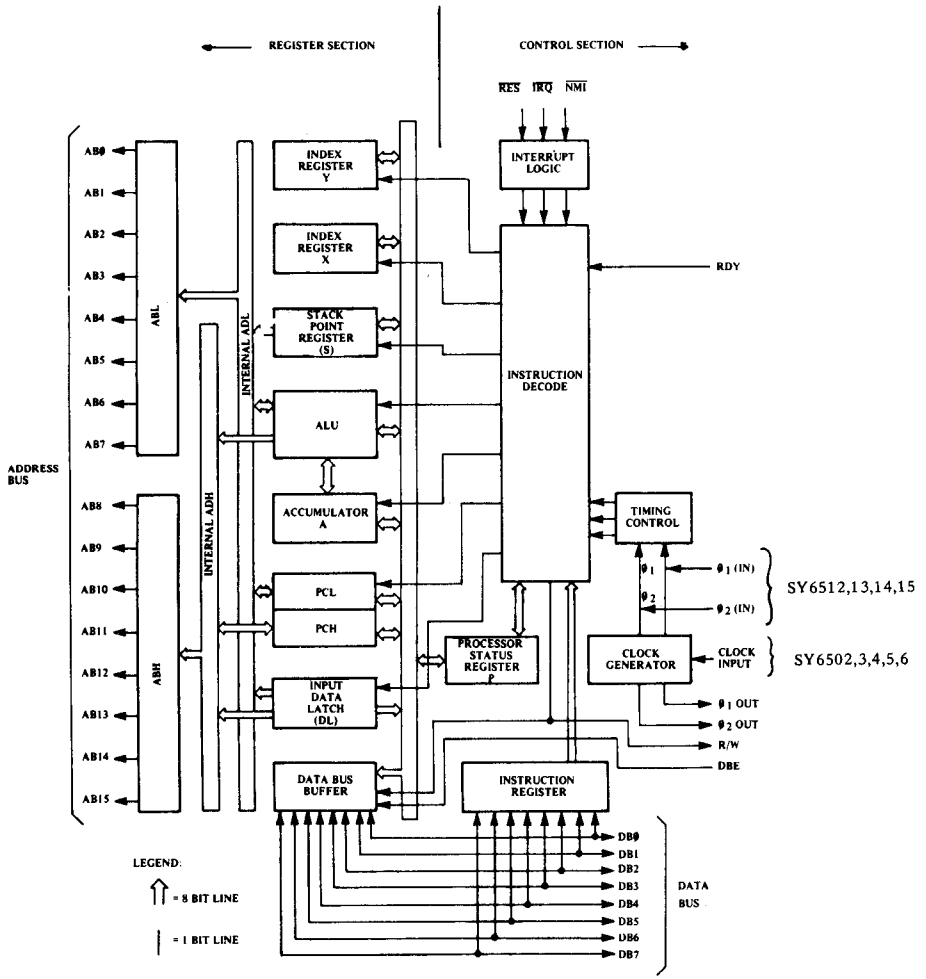
Microprocessors with External Two Phase Clock Input

- SY6512
- SY6513
- SY6514
- SY6515

Comments on the Data Sheet

The data sheet is constructed to review first the basic "Common Characteristics" - those features which are common to the general family of microprocessors. Subsequent to a review of the family characteristics will be sections devoted to each member of the group with specific features of each.

COMMON CHARACTERISTICS



Note: 1. Clock Generator is not included on SY6512,13,14,15

2. Addressing Capability and control options vary with each of the SY6500 Products.

SY6500 Internal Architecture

COMMON CHARACTERISTICS

MAXIMUM RATINGS

RATING	SYMBOL	VALUE	UNIT
SUPPLY VOLTAGE	Vcc	-0.3 to +7.0	Vdc
INPUT VOLTAGE	Vin	-0.3 to +7.0	Vdc
OPERATING TEMPERATURE	T_A	0 to +70	°C
STORAGE TEMPERATURE	T_{STG}	-55 to +150	°C

This device contains input protection against damage due to high static voltages or electric fields; however, precautions should be taken to avoid application of voltages higher than the maximum rating.

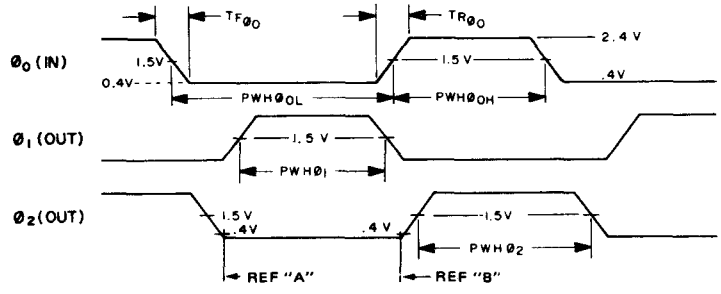
ELECTRICAL CHARACTERISTICS (Vcc = 5.0V ± 5%, Vss = 0, T_A = 25° C)

ϕ_1, ϕ_2 applies to SY6512, 13, 14, 15, $\phi_{o\ (in)}$ applies to SY6502, 03, 04, 05 and 06

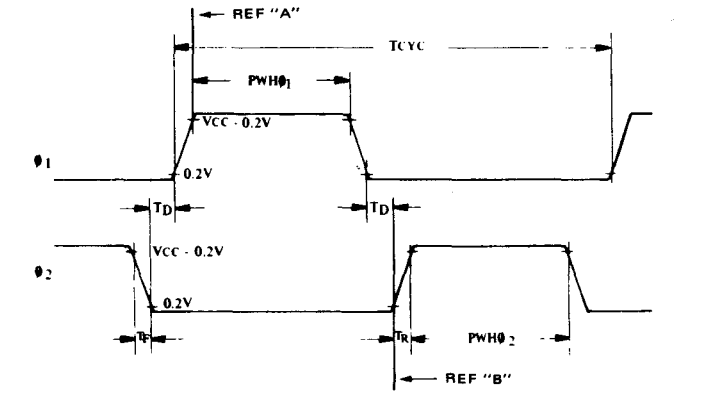
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT
Input High Voltage	V_{IH}				Vdc
Logic, $\phi_{o(in)}$		Vss + 2.4	-	Vcc	
ϕ_1, ϕ_2		Vcc - 0.2	-	Vcc + 0.25	
Input Low Voltage	V_{IL}				Vdc
Logic, $\phi_{o(in)}$		Vss - 0.3	-	Vss + 0.4	
ϕ_1, ϕ_2		Vss - 0.3	-	Vss + 0.2	
Input High Threshold Voltage	V_{IHT}				
$\overline{RES}$, $\overline{NMI}$, RDY, $\overline{IRQ}$, Data, S.O.		Vss + 2.0	-	-	Vdc
Input Low Threshold Voltage	V_{ILT}				
$\overline{RES}$, $\overline{NMI}$, RDY, $\overline{IRQ}$, Data, S.O.		-	-	Vss + 0.8	Vdc
Input Leakage Current (V_{in} = 0 to 5.25V, Vcc = 0)	I_{in}				
Logic (Excl. RDY, S.O.)		-	-	2.5	μA
ϕ_1, ϕ_2		-	-	100	μA
$\phi_{o(in)}$		-	-	10.0	μA
Three-State (Off State) Input Current (V_{in} = 0.4 to 2.4V, Vcc = 5.25V)	I_{TSI}				μA
Data Lines		-	-	10	
Output High Voltage (I_{LOAD} = -100μAdc, Vcc = 4.75V)	V_{OH}				
SYNC, Data, A0-A15, R/W		Vss + 2.4	-	-	Vdc
Output Low Voltage (I_{LOAD} = 1.6mAdc, Vcc = 4.75V)	V_{OL}				
SYNC, Data, A0-A15, R/W		-	-	Vss + 0.4	Vdc
Power Dissipation	P_D	-	.25	.70	W
Capacitance (V_{in} = 0, T_A = 25°C, f = 1MHz)	C				pF
Logic	C_{in}	-	-	10	
Data		-	-	15	
A0-A15, R/W, SYNC	C_{out}	-	-	12	
$\phi_{o(in)}$	$C_{\phi_{o(in)}}$	-	-	15	
ϕ_1	C_{ϕ_1}	-	30	50	
ϕ_2	C_{ϕ_2}	-	50	80	

Note: $\overline{IRQ}$ and $\overline{NMI}$ require 3K pull-up resistors.

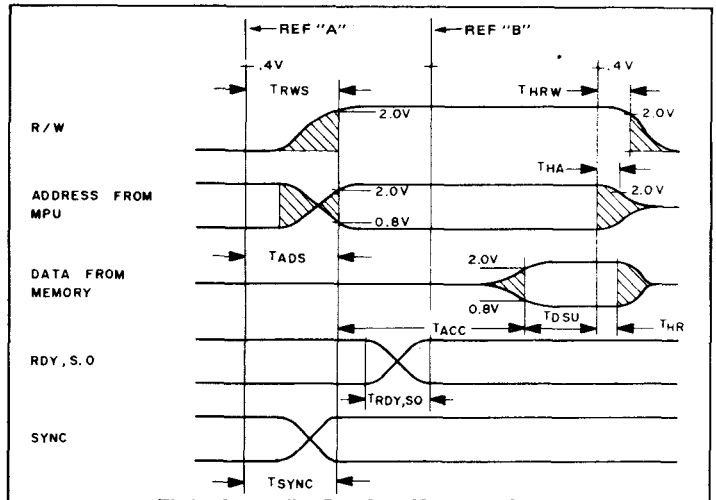
COMMON CHARACTERISTICS



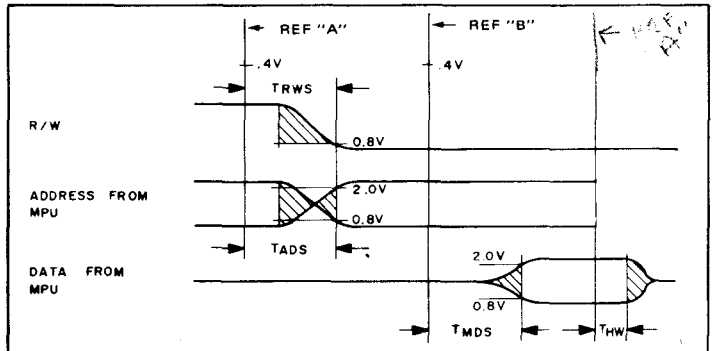
CLOCK TIMING – SY6502, 03, 04, 05, 06



CLOCK TIMING – SY6512, 13, 14, 15



Timing for Reading Data from Memory or Peripherals



Timing for Writing Data to Memory or Peripherals

Note: "REF." means Reference Points on clocks.

1 MHz TIMING

CLOCK TIMING – SY6512, 13, 14, 15

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT
Cycle Time	T_{CYC}	1000	---	---	nsec
Clock Pulse Width Ø1 (Measured at Vcc - 0.2v) Ø2	PWH Ø1 PWH Ø2	430 470	---	---	nsec
Fall Time (Measured from 0.2v to Vcc - 0.2v)	T_F	---	---	25	nsec
Delay Time between Clocks (Measured at 0.2v)	T_D	0	---	---	nsec

CLOCK TIMING – SY6502, 03, 04, 05, 06

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNITS
Cycle Time	T_{CYC}	1000	--	--	ns
$\phi_{o(IN)}$ Pulse Width (measured at 1.5V)	$PWH\phi_o$	460	--	520	ns
$\phi_{o(IN)}$ Rise, Fall Time	$TR\phi_o$, $TF\phi_o$	--	--	10	ns
Delay Time Between Clocks (measured at 1.5V)	T_D	5	--	--	ns
$\phi_{1(OUT)}$ Pulse Width (measured at 1.5V)	$PWH\phi_1$	$PWH\phi_{oL}$-20	--	$PWH\phi_{oL}$	ns
$\phi_{2(OUT)}$ Pulse Width (measured at 1.5V)	$PWH\phi_2$	$PWH\phi_{oH}$-40	--	$PWH\phi_{oH}$-10	ns
$\phi_{1(OUT)}$, $\phi_{2(OUT)}$ Rise, Fall Time (measured .8V to 2.0 V) (Load = 30pf + 1 TTL)	T_R, T_F	--	--	25	ns

READ/WRITE TIMING

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNITS
Read/Write Setup Time from SY6500	T_{RWS}	--	100	300	ns
Address Setup Time from SY6500	T_{ADS}	--	100	300	ns
Memory Read Access Time	T_{ACC}	--	--	575	ns
Data Stability Time Period	T_{DSU}	100	--	--	ns
Data Hold Time - Read	T_{HR}	10	--	--	ns
Data Hold Time - Write	T_{HW}	30	60	--	ns
Data Setup Time from SY6500	T_{MDS}	--	150	200	ns
RDY, S.O. Setup Time	T_{RDY}	100	--	--	ns
SYNC Setup Time from SY6500	T_{SYNC}	--	--	350	ns
Address Hold Time	T_{HA}	30	60	--	ns
R/W Hold Time	T_{HRW}	30	60	--	ns

2 MHz TIMING

CLOCK TIMING – SY6512,13,14,15,16

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT
Cycle Time	T_{CYC}	500	---	---	nsec
Clock Pulse Width Ø1 (Measured at Vcc - 0.2v) Ø2	PWH Ø1 PWH Ø2	215 235	---	---	nsec
Fall Time (Measured from 0.2v to Vcc - 0.2v)	T_F	---	---	12	nsec
Delay Time between Clocks (Measured at 0.2v)	T_D	0	---	---	nsec

CLOCK TIMING – SY6502, 03, 04, 05, 06

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNITS
Cycle Time	T_{CYC}	500	--	--	ns
$\phi_{o(IN)}$ Pulse Width (measured at 1.5V)	$PWH\phi_o$	240	--	260	ns
$\phi_{o(IN)}$ Rise, Fall Time	$TR\phi_o$, $TF\phi_o$	--	--	10	ns
Delay Time Between Clocks (measured at 1.5V)	T_D	5	--	--	ns
$\phi_{1(OUT)}$ Pulse Width (measured at 1.5V)	$PWH\phi_1$	$PWH\phi_{oL}$-20	--	$PWH\phi_{oL}$	ns
$\phi_{2(OUT)}$ Pulse Width (measured at 1.5V)	$PWH\phi_2$	$PWH\phi_{oH}$-40	--	$PWH\phi_{oH}$-10	ns
$\phi_{1(OUT)}$, $\phi_{2(OUT)}$ Rise, Fall Time (measured .8V to 2.0 V) (Load = 30pf + 1 TTL)	T_R, T_F	--	--	25	ns

READ/WRITE TIMING

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNITS
Read/Write Setup Time from SY6500 A	T_{RWS}	--	100	150	ns
Address Setup Time from SY6500 A	T_{ADS}	--	100	150	ns
Memory Read Access Time	T_{ACC}	--	--	300	ns
Data Stability Time Period	T_{DSU}	50	--	--	ns
Data Hold Time - Read	T_{HR}	10	--	--	ns
Data Hold Time - Write	T_{HW}	30	60	--	ns
Data Setup Time from SY6500 A	T_{MDS}	--	75	100	ns
RDY, S.O. Setup Time	T_{RDY}	50	--	--	ns
SYNC Setup Time from SY6500 A	T_{SYNC}	--	--	175	ns
Address Hold Time	T_{HA}	30	60	--	ns
R/W Hold Time	T_{HRW}	30	60	--	ns

COMMON CHARACTERISTICS

Clocks (ϕ_1, ϕ_2)

The SY651X requires a two phase non-overlapping clock that runs at the Vcc voltage level.

The SY650X clocks are supplied with an internal clock generator. The frequency of these clocks is externally controlled. Details of this feature are discussed in the SY6502 portion of this data sheet.

Address Bus (A_0-A_{15}) (See sections on each micro for respective address lines on those devices.)

These outputs are TTL compatible, capable of driving one standard TTL load and 130pf.

Data Bus (D_0-D_7)

Eight pins are used for the data bus. This is a bi-directional bus, transferring data to and from the device and peripherals. The outputs are tri-state buffers capable of driving one standard TTL load and 130pf.

Data Bus Enable (DBE)

This TTL compatible input allows external control of the tri-state data output buffers and will enable the microprocessor bus driver when in the high state. In normal operation DBE would be driven by the phase two (ϕ_2) clock, thus allowing data output from microprocessor only during ϕ_2. During the read cycle, the data bus drivers are internally disabled, becoming essentially an open circuit. To disable data bus drivers externally, DBE should be held low.

Ready (RDY)

This input signal allows the user to single cycle the microprocessor on all cycles except write cycles. A negative transition to the low state during or coincident with phase one (ϕ_1) will halt the microprocessor with the output address lines reflecting the current address being fetched. This condition will remain through a subsequent phase two (ϕ_2) in which the Ready signal is low. This feature allows microprocessor interfacing with low speed PROMS as well as fast (max. 2 cycle) Direct Memory Access (DMA). If Ready is low during a write cycle, it is ignored until the following read operation.

Interrupt Request ($\overline{IRQ}$)

This TTL level input requests that an interrupt sequence begin within the microprocessor. The microprocessor will complete the current instruction being executed before recognizing the request. At that time, the interrupt mask bit in the Status Code Register will be examined. If the interrupt mask flag is not set, the microprocessor will begin an interrupt sequence. The Program Counter and Processor Status Register are stored in the stack. The microprocessor will then set the interrupt mask flag high so that no further interrupts may occur. At the end of this cycle, the program counter low will be loaded from address FFFE, and program counter high from location FFFF, therefore transferring program control to the memory vector located at these addresses. The RDY signal must be in the high state for any interrupt to be recognized. A 3KΩ external resistor should be used for proper wire-OR operation.

Non-Maskable Interrupt ($\overline{NMI}$)

A negative going edge on this input requests that a non-maskable interrupt sequence be generated within the microprocessor.

$\overline{NMI}$ is an unconditional interrupt. Following completion of the current instruction, the sequence of operations defined for $\overline{IRQ}$ will be performed, regardless of the state interrupt mask flag. The vector address loaded into the program counter, low and high, are locations FFFA and FFFB respectively, thereby transferring program control to the memory vector located at these addresses. The instructions loaded at these locations cause the microprocessor to branch to a non-maskable interrupt routine in memory.

$\overline{NMI}$ also requires an external 3KΩ register to Vcc for proper wire-OR operations.

Inputs $\overline{IRQ}$ and $\overline{NMI}$ are hardware interrupts lines that are sampled during ϕ_2 (phase 2) and will begin the appropriate interrupt routine on the ϕ_1 (phase 1) following the completion of the current instruction.

Set Overflow Flag (S.O.)

A NEGATIVE going edge on this input sets the overflow bit in the Status Code Register. This signal is sampled on the trailing edge of ϕ_1.

SYNC

This output line is provided to identify those cycles in which the microprocessor is doing an OP CODE fetch. The SYNC line goes high during ϕ_1 of an OP CODE fetch and stays high for the remainder of that cycle. If the RDY line is pulled low during the ϕ_1 clock pulse in which SYNC went high, the processor will stop in its current state and will remain in the state until the RDY line goes high. In this manner, the SYNC signal can be used to control RDY to cause single instruction execution.

Reset

This input is used to reset or start the microprocessor from a power down condition. During the time that this line is held low, writing to or from the microprocessor is inhibited. When a positive edge is detected on the input, the microprocessor will immediately begin the reset sequence.

After a system initialization time of six clock cycles, the mask interrupt flag will be set and the microprocessor will load the program counter from the memory vector locations FFFC and FFFD. This is the start location for program control.

After Vcc reaches 4.75 volts in a power up routine, reset must be held low for at least two clock cycles. At this time the R/W and (SYNC) signal will become valid.

When the reset signal goes high following these two clock cycles, the microprocessor will proceed with the normal reset procedure detailed above.

COMMON CHARACTERISTICS

INSTRUCTION SET – ALPHABETIC SEQUENCE

ADC	Add Memory to Accumulator with Carry
AND	"AND" Memory with Accumulator
ASL	Shift left One Bit (Memory or Accumulator)
BCC	Branch on Carry Clear
BCS	Branch on Carry Set
BEQ	Branch on Result Zero
BIT	Test Bits in Memory with Accumulator
BMI	Branch on Result Minus
BNE	Branch on Result not Zero
BPL	Branch on Result Plus
BRK	Force Break
BVC	Branch on Overflow Clear
BVS	Branch on Overflow Set
CLC	Clear Carry Flag
CLD	Clear Decimal Mode
CLI	Clear Interrupt Disable Bit
CLV	Clear Overflow Flag
CMP	Compare Memory and Accumulator
CPX	Compare Memory and Index X
CPY	Compare Memory and Index Y
DEC	Decrement Memory by One
DEX	Decrement Index X by One
DEY	Decrement Index Y by One
EOR	"Exclusive-or" Memory with Accumulator
INC	Increment Memory by One
INX	Increment Index X by One
INY	Increment Index Y by One
JMP	Jump to New Location
JSR	Jump to New Location Saving Return Address
LDA	Load Accumulator with Memory
LDX	Load Index X with Memory
LDY	Load Index Y with Memory
LSR	Shift One Bit Right (Memory or Accumulator)
NOP	No Operation
ORA	"OR Memory with Accumulator
PHA	Push Accumulator on Stack
PHP	Push Processor Status on Stack
PLA	Pull Accumulator from Stack
PLP	Pull Processor Status from Stack
ROL	Rotate One Bit Left (Memory or Accumulator)
ROR	Rotate One Bit Right (Memory or Accumulator)
RTI	Return from Interrupt
RTS	Return from Subroutine
SBC	Subtract Memory from Accumulator with Borrow
SEC	Set Carry Flag
SED	Set Decimal Mode
SEI	Set Interrupt Disable Status
STA	Store Accumulator in Memory
STX	Store Index X in Memory
STY	Store Index Y in Memory
TAX	Transfer Accumulator to Index X
TAY	Transfer Accumulator to Index Y
TSX	Transfer Stack Pointer to Index X
TXA	Transfer Index X to Accumulator
TXS	Transfer Index X to Stack Pointer
TYA	Transfer Index Y to Accumulator

ADDRESSING MODES

ACCUMULATOR ADDRESSING - This form of addressing is represented with a one byte instruction, implying an operation on the accumulator.

IMMEDIATE ADDRESSING - In immediate addressing, the operand is contained in the second byte of the instruction, with no further memory addressing required.

ABSOLUTE ADDRESSING - In absolute addressing, the second byte of the instruction specifies the eight low order bits of the effective address while the third byte specifies the eight high order bits. Thus, the absolute addressing mode allows access to the entire 65K bytes of addressable memory.

ZERO PAGE ADDRESSING - The zero page instructions allow for shorter code and execution times by only fetching the second byte of the instruction and assuming a zero high address byte. Careful use of the zero page can result in significant increase in code efficiency.

INDEXED ZERO PAGE ADDRESSING - (X, Y indexing) - This form of addressing is used in conjunction with the index register and is referred to as "Zero Page, X" or "Zero Page, Y". The effective address is calculated by adding the second byte to the contents of the index register. Since this is a form of "Zero Page" addressing, the content of the second byte references a location in page zero. Additionally due to the "Zero Page" addressing nature of this mode, no carry is added to the high order 8 bits of memory and crossing of page boundaries does not occur.

INDEXED ABSOLUTE ADDRESSING - (X, Y indexing) - This form of addressing is used in conjunction with X and Y index register and is referred to as "Absolute, X", and "Absolute, Y". The effective address is formed by adding the contents of X or Y to the address contained in the second and third bytes of the instruction. This mode allows the index register to contain the index or count value and the instruction to contain the base address. This type of indexing allows any location referencing and the index to modify multiple fields resulting in reduced coding and execution time.

IMPLIED ADDRESSING - In the implied addressing mode, the address containing the operand is implicitly stated in the operation code of the instruction.

RELATIVE ADDRESSING - Relative addressing is used only with branch instructions and establishes a destination for the conditional branch.

The second byte of the instruction becomes the operand which is an "Offset" added to the contents of the lower eight bits of the program counter when the counter is set at the next instruction. The range of the offset is -128 to +127 bytes from the next instruction.

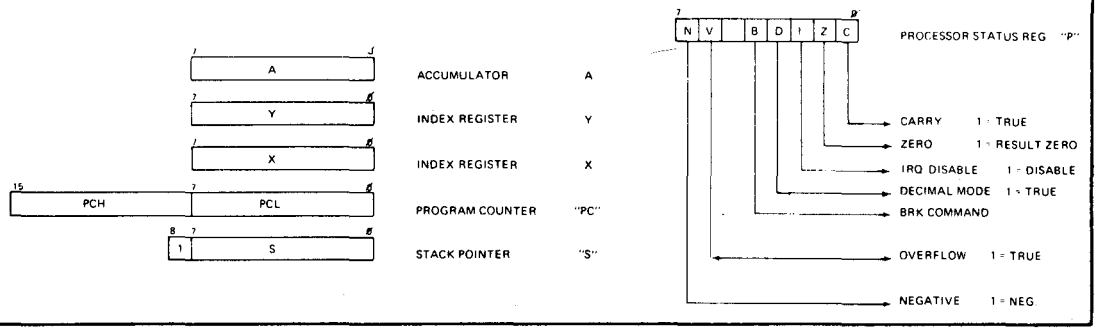
INDEXED INDIRECT ADDRESSING - In indexed indirect addressing (referred to as (Indirect,X)), the second byte of the instruction is added to the contents of the X index register, discarding the carry. The result of this addition points to a memory location on page zero whose contents is the low order eight bits of the effective address. The next memory location in page zero contains the high order eight bits of the effective address. Both memory locations specifying the high and low order bytes of the effective address must be in page zero.

INDIRECT INDEXED ADDRESSING - In indirect indexed addressing (referred to as (Indirect),Y), the second byte of the instruction points to a memory location in page zero. The contents of this memory location is added to the contents of the Y index register, the result being the low order eight bits of the effective address. The carry from this addition is added to the contents of the next page zero memory location, the result being the high order eight bits of the effective address.

ABSOLUTE INDIRECT - The second byte of the instruction contains the low order eight bits of a memory location. The high order eight bits of that memory location is contained in the third byte of the instruction. The contents of the fully specified memory location is the low order byte of the effective address. The next memory location contains the high order byte of the effective address which is loaded into the sixteen bits of the program counter.

COMMON CHARACTERISTICS

PROGRAMMING MODEL



INSTRUCTION SET – OP CODES, Execution Time, Memory Requirements

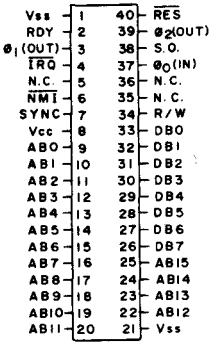
INSTRUCTIONS		IMMEDIATE			ABSOLUTE			ZERO PAGE			ACCUM.			IMPLIED			(IND,X)			(IND),Y			Z,PAGE,X			ABS,X			ABS,Y			RELATIVE			INDIRECT			Z,PAGE,Y			CONDITION CODES					
MNEMONIC	OPERATION	OP	N	#	OP	N	#	OP	N	#	OP	N	#	OP	N	#	OP	N	#	OP	N	#	OP	N	#	OP	N	#	OP	N	#	OP	N	#	OP	N	#	OP	N	#	N	Z	C	I	D	V
ADC	A+M+C → A (4) (1)	69	2	2	6D	4	3	65	3	2							61	6	2	71	5	2	75	4	2	7D	4	3	79	4	3											✓	✓	✓	-	-	✓
AND	A∧M → A (1)	29	2	2	2D	4	3	25	3	2							21	6	2	31	5	2	35	4	2	3D	4	3	39	4	3											✓	✓	-	-	-	-
ASL	C ← 7 ← 0 ← 0				0E	6	3	06	5	2	0A	2	1										16	6	2	1E	7	3													✓	✓	✓	-	-	-
BCC	BRANCH ON C = 0 (2)																															90	2	2							-	-	-	-	-	-
BCS	BRANCH ON C = 1 (2)																															B0	2	2							-	-	-	-	-	-
BEQ	BRANCH ON Z = 1 (2)																															F0	2	2							-	-	-	-	-	-
BIT	A∧M				2C	4	3	24	3	2																														M7	✓	-	-	-	M6
BMI	BRANCH ON N = 1 (2)																															30	2	2							-	-	-	-	-	-
BNE	BRANCH ON Z = 0 (2)																															D0	2	2							-	-	-	-	-	-
BPL	BRANCH ON N = 0 (2)																															10	2	2							-	-	-	-	-	-
BRK	(See Fig. 11)													00	7	1																									-	-	-	1	-	-
BVC	BRANCH ON V = 0 (2)																															50	2	2							-	-	-	-	-	-
BVS	BRANCH ON V = 1 (2)																															70	2	2							-	-	-	-	-	-
CLC	0 → C													18	2	1																									-	-	0	-	-	-
CLD	0 → D													D8	2	1																									-	-	-	-	0	-
CLI	0 → I													58	2	1																									-	-	-	0	-	-
CLV	0 → V													B8	2	1																									-	-	-	-	-	0
CMP	A - M (1)	C9	2	2	CD	4	3	C5	3	2							C1	6	2	D1	5	2	D5	4	2	DD	4	3	D9	4	3											✓	✓	✓	-	-	-
CPX	X - M	E0	2	2	EC	4	3	E4	3	2																															✓	✓	✓	-	-	-
CPY	Y - M	C0	2	2	CC	4	3	C4	3	2																															✓	✓	✓	-	-	-
DEC	M - 1 → M				CE	6	3	C6	5	2													D6	6	2	DE	7	3													✓	✓	-	-	-	-
DEX	X - 1 → X													CA	2	1																									✓	✓	-	-	-	-
DEY	Y - 1 → Y													88	2	1																									✓	✓	-	-	-	-
EOR	A ⊻ M → A (1)	49	2	2	4D	4	3	45	3	2							41	6	2	51	5	2	55	4	2	5D	4	3	59	4	3											✓	✓	-	-	-	-
INC	M + 1 → M				EE	6	3	E6	5	2													F6	6	2	FE	7	3													✓	✓	-	-	-	-
INX	X + 1 → X													E8	2	1																									✓	✓	-	-	-	-
INY	Y + 1 → Y													C8	2	1																									✓	✓	-	-	-	-
JMP	JUMP TO NEW LOC				4C	3	3																													6C	5	3				-	-	-	-	-	-
JSR	(See Fig. 2) JUMP SUB				20	6	3																																		-	-	-	-	-	-
LDA	M → A (1)	A9	2	2	AD	4	3	A5	3	2							A1	6	2	B1	5	2	B5	4	2	BD	4	3	B9	4	3											✓	✓	-	-	-	-

MNEMONIC	OPERATION	IMMEDIATE			ABSOLUTE			ZERO PAGE			ACCUM.			IMPLIED			(IND,X)			(IND),Y			Z,PAGE,X			ABS,X			ABS,Y			RELATIVE			INDIRECT			Z,PAGE,Y			CONDITION CODES					
		OP	N	#	OP	N	#	OP	N	#	OP	N	#	OP	N	#	OP	N	#	OP	N	#	OP	N	#	OP	N	#	OP	N	#	OP	N	#	OP	N	#	OP	N	#	N	Z	C	I	D	V
LDX	M → X (1)	A2	2	2	AE	4	3	A6	3	2																			BE	4	3											✓	✓	-	-	-	-
LDY	M → Y (1)	A0	2	2	AC	4	3	A4	3	2													B4	4	2	BC	4	3													✓	✓	-	-	-	-
LSR	0 → 7 → 0 → C				4E	6	3	46	5	2	4A	2	1										56	6	2	5E	7	3													0	✓	✓	-	-	-
NOP	NO OPERATION													EA	2	1																									-	-	-	-	-	-
ORA	A∨M → A (1)	09	2	2	0D	4	3	05	3	2							01	6	2	11	5	2	15	4	2	1D	4	3	19	4	3											✓	✓	-	-	-	-
PHA	A → M(S), S - 1 → S													48	3	1																									-	-	-	-	-	-
PHP	P → M(S), S - 1 → S													08	3	1																									-	-	-	-	-	-
PLA	S + 1 → S, M(S) → A													68	4	1																									✓	✓	-	-	-	-
PLP	S + 1 → S, M(S) → P													28	4	1																									(RESTORED)					
ROL	C ← 7 ← 0 ← C				2E	6	3	26	5	2	2A	2	1										36	6	2	3E	7	3													✓	✓	✓	-	-	-
ROR	C → 7 → 0 → C				6E	6	3	66	5	2	6A	2	1										76	6	2	7E	7	3													✓	✓	✓	-	-	-
RTI	(See Fig. 3) RTRN INT													40	6	1																									(RESTORED)					
RTS	(See Fig. 2) RTRN SUB													60	6	1																									-	-	-	-	-	-
SBC	A - M - C → A (1) (3)	E9	2	2	ED	4	3	E5	3	2							E1	6	2	F1	5	2	F5	4	2	FD	4	3	F9	4	3											✓	✓	(3)	-	-	✓
SEC	1 → C													38	2	1																									-	-	1	-	-	-
SED	1 → D													F8	2	1																									-	-	-	-	1	-
SEI	1 → I													78	2	1																									-	-	-	1	-	-
STA	A → M				8D	4	3	85	3	2							81	6	2	91	6	2	95	4	2	9D	5	3	99	5	3											-	-	-	-	-	-
STX	X → M				8E	4	3	86	3	2																														96	4	2	-	-	-	-	-	-
STY	Y → M				8C	4	3	84	3	2													94	4	2																	-	-	-	-	-	-
TAX	A → X													AA	2	1																									✓	✓	-	-	-	-
TAY	A → Y													A8	2	1																									✓	✓	-	-	-	-
TSX	S → X													BA	2	1																									✓	✓	-	-	-	-
TXA	X → A													8A	2	1																									✓	✓	-	-	-	-
TXS	X → S													9A	2	1																									-	-	-	-	-	-
TYA	Y → A													98	2	1																									✓	✓	-	-	-	-

(1) ADD 1 TO 'N' IF PAGE BOUNDRY IS CROSSED
(2) ADD 1 TO 'N' IF BRANCH OCCURS TO SAME PAGE
ADD 2 TO 'N' IF BRANCH OCCURS TO DIFFERENT PAGE.
(3) CARRY NOT BORROW
(4) IF IN DECIMAL MODE Z FLAG IS INVALID
ACCUMULATOR MUST BE CHECKED FOR ZERO RESULT

X = INDEX X
Y = INDEX Y
A = ACCUMULATOR
M = MEMORY PER EFFECTIVE ADDRESS
Mn = MEMORY PER STACK POINTER
+ = ADD
∧ = AND
- = SUBTRACT
∨ = INCLUSIVE OR
⊻ = EXCLUSIVE OR
→ = REPLACE
✓ = MODIFIED
- = NOT MODIFIED
Mn = MEMORY BIT n
N = NO CYCLES
# = NO BYTES

SY6502 – 40 Pin Package

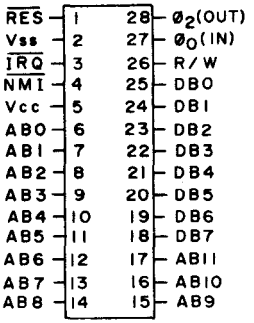


SY6502

* 65K Addressable Bytes of Memory
* $\overline{IRQ}$ Interrupt * $\overline{NMI}$ Interrupt
* On-the-chip Clock
  - ✓ TTL Level Single Phase Input
  - ✓ RC Time Base Input
  - ✓ Crystal Time Base Input
* SYNC Signal
  (can be used for single instruction execution)
* RDY Signal
  (can be used for single cycle execution)
* Two Phase Output Clock for Timing of Support Chips

Features of SY6502

SY6503 – 28 Pin Package

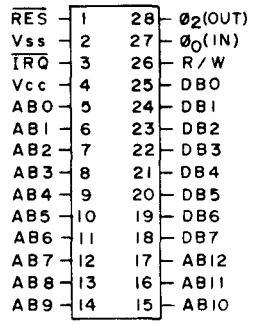


SY6503

* 4K Addressable Bytes of Memory (AB00-AB11)
* On-the-chip Clock
* $\overline{IRQ}$ Interrupt
* $\overline{NMI}$ Interrupt
* 8 Bit Bi-Directional Data Bus

Features of SY6503

SY6504 – 28 Pin Package

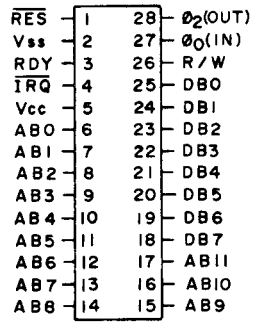


SY6504

* 8K Addressable Bytes of Memory (AB00-AB12)
* On-the-chip Clock
* $\overline{IRQ}$ Interrupt
* 8 Bit Bi-Directional Data Bus

Features of SY6504

SY6505 – 28 Pin Package

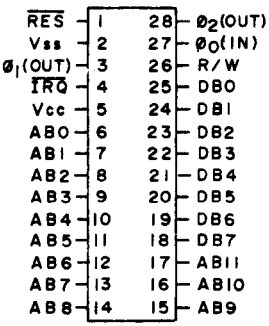


SY6505

* 4K Addressable Bytes of Memory (AB00-AB11)
* On-the-chip Clock
* $\overline{IRQ}$ Interrupt
* RDY Signal
* 8 Bit Bi-Directional Data Bus

Features of SY6505

SY6506 – 28 Pin Package

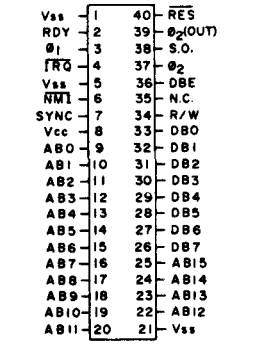


SY6506

* 4K Addressable Bytes of Memory (AB00-AB11)
* On-the-chip Clock
* $\overline{IRQ}$ Interrupt
* Two phases off
* 8 Bit Bi-Directional Data Bus

Features of SY6506

SY6512 – 40 Pin Package

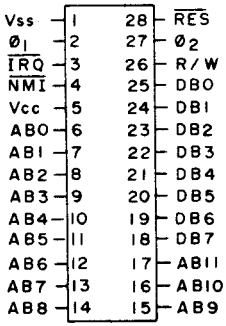


SY6512

* 65K Addressable Bytes of Memory
* $\overline{IRQ}$ Interrupt
* $\overline{NMI}$ Interrupt
* RDY Signal
* 8 Bit Bi-Directional Data Bus
* SYNC Signal
* Two phase input
* Data Bus Enable

Features of SY6512

SY6513 – 28 Pin Package

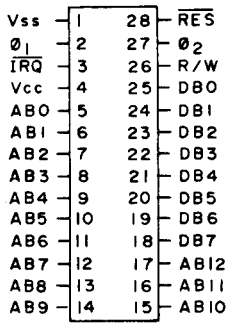


SY6513

* 4K Addressable Bytes of Memory (AB00-AB11)
* Two phase clock input
* $\overline{IRQ}$ Interrupt
* $\overline{NMI}$ Interrupt
* 8 Bit Bi-Directional Data Bus

Features of SY6513

SY6514 – 28 Pin Package

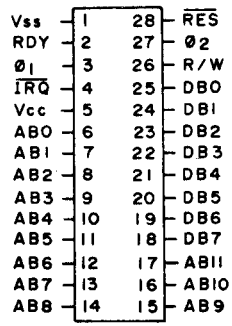


SY6514

* 8K Addressable Bytes of Memory (AB00-AB12)
* Two phase clock input
* $\overline{IRQ}$ Interrupt
* 8 Bit Bi-Directional Data Bus

Features of SY6514

SY6515 – 28 Pin Package



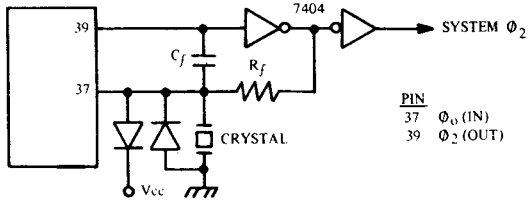
SY6515

* 4K Addressable Bytes of Memory (AB00-AB11)
* Two phase clock input
* $\overline{IRQ}$ Interrupt
* 8 Bit Bi-Directional Data Bus

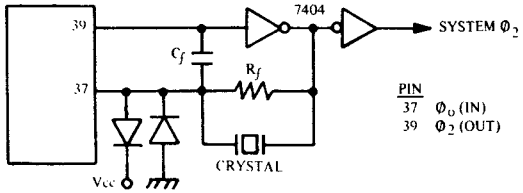
Features of SY6515

TIME BASE GENERATION OF INPUT CLOCK

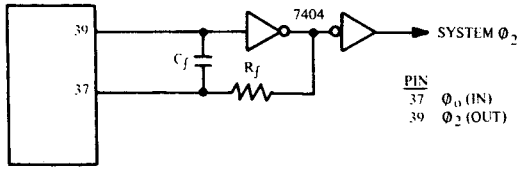
SY6502



SY6502 Parallel Mode Crystal Controlled Oscillator

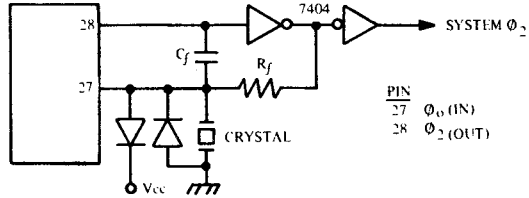


SY6502 Series Mode Crystal Controlled Oscillator

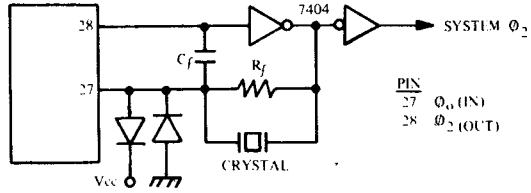


SY6502 Time Base Generator – RC Network

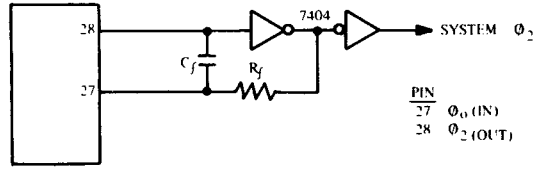
SY6503, SY6504, SY6505, SY6506



SY6503,4,5,6 Parallel Mode Crystal Controlled Oscillator



SY6503,4,5,6 Series Mode Crystal Controlled Oscillator



SY6503,4,5,6 Time Base Generation RC Network

APPENDIX J

SY6522 DATA SHEET

Synertek®

3050 Coronado Drive, Santa Clara, CA. 95051
(408) 984-8900 TWX 910-338-0135

SY6522

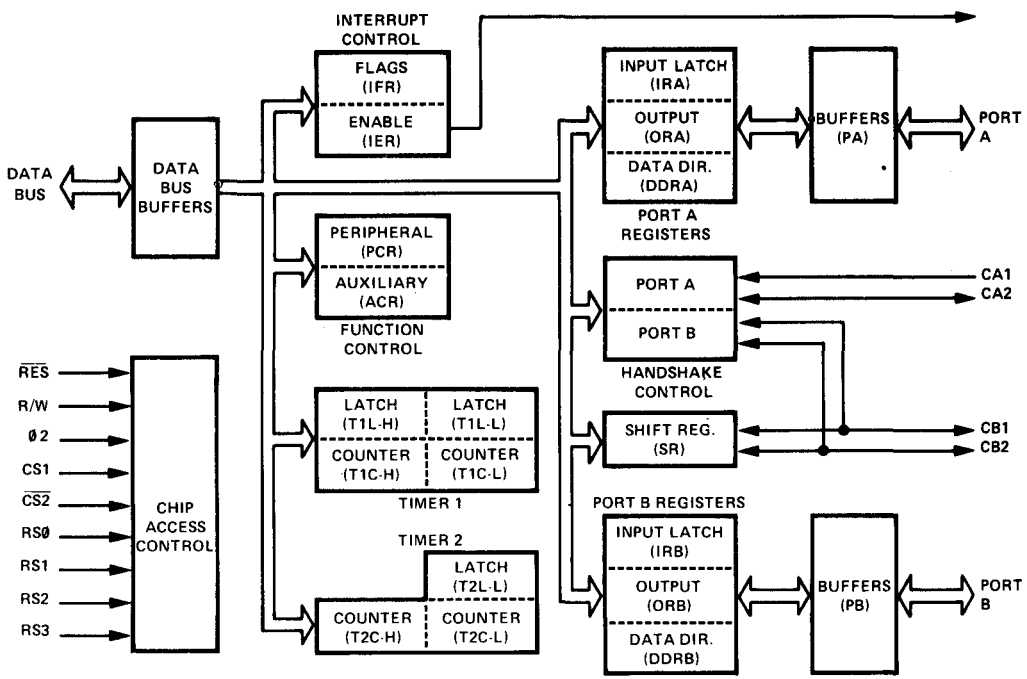
SY6522 (VERSATILE INTERFACE ADAPTER)

The SY6522 Versatile Interface Adapter (VIA) provides all of the capability of the SY6520. In addition, this device contains a pair of very powerful interval timers, a serial-to-parallel/parallel-to-serial shift register and input data latching on the peripheral ports. Expanded handshaking capability allows control of bi-directional data transfers between VIA's in multiple processor systems.

Control of peripheral devices is handled primarily through two 8-bit bi-directional ports. Each of these lines can be programmed to act as either an input or an output. Also, several peripheral I/O lines can be controlled directly from the interval timers for generating programmable frequency square waves and for counting externally generated pulses. To facilitate control of the many powerful features of this chip, the internal registers have been organized into an interrupt flag register, an interrupt enable register and a pair of function control registers.

- Very powerful expansion of basic SY6520 capability.
- N channel, depletion load technology, single +5V Supply.
- Completely static and TTL compatible.
- CMOS compatible peripheral control lines.
- Expanded "handshake" capability allows very positive control of data transfers between processor and peripheral devices.

Figure 1. SY6522 BLOCK DIAGRAM



MAXIMUM RATINGS

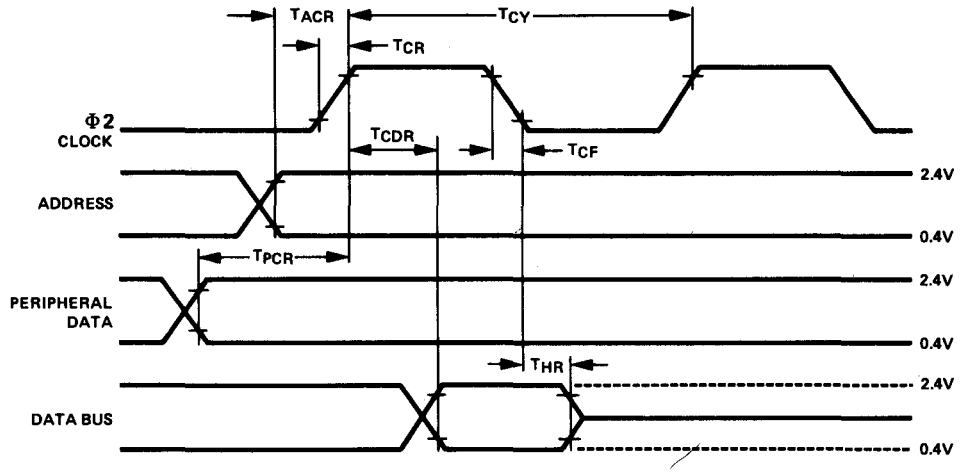
	Symbol	Value	Unit
Supply Voltage	Vcc	-0.3 to +7.0	Vdc
Input Voltage	Vin	-0.3 to +7.0	Vdc
Operating Temperature Range	T_A	0 to +70	°C
Storage Temperature Range	T_{stg}	-55 to +150	°C

This device contains circuitry to protect the inputs against damage due to high static voltages. However, it is advised that normal precautions be taken to avoid application of any voltage higher than maximum rated voltages.

Electrical Characteristics (V_{CC} = 5.0V ±5%, V_{SS} = 0, T_A = 0°C to 70°C unless otherwise noted)

CHARACTERISTIC	SYMBOL	MIN	TYP	MAX	UNIT
Input high voltage (normal operation)	V_{IH}	+2.4	–	Vcc	Vdc
Input Low Voltage (normal operation)	V_{IL}	-0.3	–	+0.4	Vdc
Input Leakage current - V_{IN} = 0 to 5 Vdc R/W, $\overline{RES}$, RS0, RS1, RS2, RS3, CS1, $\overline{CS2}$, CA1, Φ2	I_{IN}	–	±1.0	±2.5	μAdc
Off-state input current - V_{IN} = .4 to 2.4 V Vcc = Max, D0 to D7	I_{TSI}	–	±2.0	±10	μAdc
Input high current - V_{IH} = 2.4 V PA0 - PA7, CA2, PB0 - PB7, CB1, CB2	I_{IH}	-100	-250	–	μAdc
Input low current - V_{IL} = 0.4 Vdc PA0 - PA7, CA2, PB0 - PB7, CB1, CB2	I_{IL}	–	-1.0	-1.6	mAdc
Output high voltage Vcc = min, I_{load} = -100 μAdc PA0 - PA7, CA2, PB0 -PB7, CB1, CB2	V_{OH}	2.4	–	–	Vdc
Output low voltage Vcc = min, I_{load} = 1.6 mAdc	V_{OL}	–	–	+0.4	Vdc
Output high current (sourcing) V_{OH} = 2.4 V V_{OH} = 1.5 V, PB0 - PB7, CB1, CB2	I_{OH}	 -100 -3.0	 -1000 -5.0	 – –	 μAdc mAdc
Output low current (sinking) V_{OL} = 0.4 Vdc	I_{OL}	1.6	–	–	mAdc
Output leakage current (off state) $\overline{IRQ}$	I_{off}	–	1.0	10	μAdc
Input capacitance - T_A = 25°C, f = 1 Mhz R/W, $\overline{RES}$, RS0, RS1, RS2, RS3, CS1, $\overline{CS2}$ DO - D7, PA0 - PA7, CA1, CA2, PB0 - PB7, CB1, CB2 Φ2 input	C_{in}	 – –	 – –	 7.0 10	 pF pF
		–	–	20	pF
Output capacitance - T_A = 25°C, f = 1 Mhz	C_{out}	–	–	10	pF
Power dissipation	P_d	–	–	1000	MW

Figure 2. READ TIMING CHARACTERISTICS



DYNAMIC CHARACTERISTICS

Read Timing Characteristics (Figure 2, loading 130 pF and one TTL load)

Characteristic	Symbol	Min	Typ	Max	Unit
Cycle time	T_{CY}	1	–	50	μs
Delay time, address valid to clock positive transition	T_{ACR}	180	–	–	nS
Delay time, clock positive transition to data valid on bus	T_{CDR}	–	–	395	nS
Peripheral data setup time	T_{PCR}	300	–	–	nS
Data bus hold time	T_{HR}	10	–	–	nS
Rise and fall time for clock input	T_{CR} T_{CF}	–	–	25	nS

Write Timing Characteristics (Figure 3)

Characteristic	Symbol	Min	Typ	Max	Unit
Cycle Time	T_{CY}	1	–	50	μS
Enable pulse width	T_C	0.47	–	25	μS
Delay time, address valid to clock positive transition	T_{ACW}	180	–	–	nS
Delay time, data valid to clock negative transition	T_{DCW}	300	–	–	nS
Delay time, read/write negative transition to clock positive transition	T_{WCW}	180	–	–	nS
Data bus hold time	T_{HW}	10	–	–	nS
Delay time, Enable negative transition to peripheral data valid	T_{CPW}	–	–	1.0	μS
Delay time, clock negative transition to peripheral data valid CMOS (Vcc - 30%)	T_{CMOS}	–	–	2.0	μS

Figure 3. WRITE TIMING CHARACTERISTICS

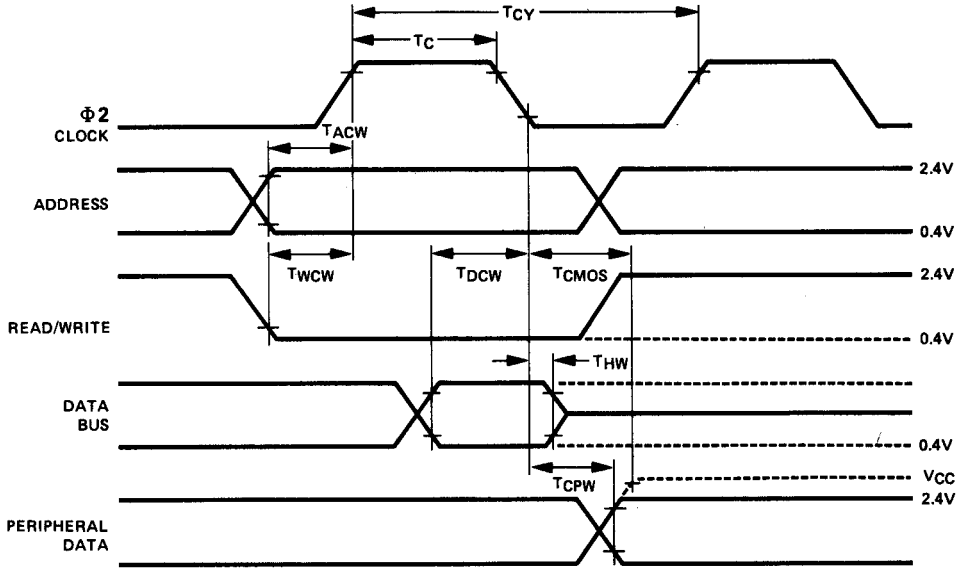
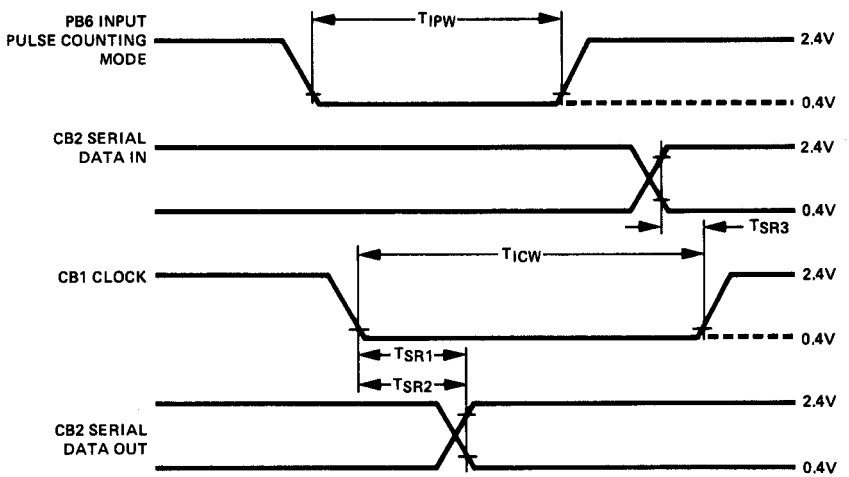


Figure 4. I/O TIMING CHARACTERISTICS



PERIPHERAL INTERFACE CHARACTERISTICS

Characteristic	Symbol	Min	Typ	Max	Unit
Rise and fall time for CA1, CB1, CA2, and CB2 input signals.	T_{RF}	–	–	1.0	μS
Delay time, clock negative transition to CA2 negative transition (read handshake or pulse mode).	T_{CA2}	–	–	1.0	μS
Delay time, clock negative transition to CA2 positive transition (pulse mode).	T_{RS1}	–	–	1.0	μS
Delay time, CA1 active transition to CA2 positive transition (handshake mode).	T_{RS2}	–	–	2.0	μS
Delay time, clock positive transition to CA2 or CB2 negative transition (write handshake).	T_{WHS}	–	–	1.0	μS
Delay time, peripheral data valid to CB2 negative transition.	T_{DC}	0	–	1.5	μS
Delay time, clock positive transition to CA2 or CB2 positive transition (pulse mode).	T_{RS3}	–	–	1.0	μS
Delay time, CB1 active transition to CA2 or CB2 positive transition (handshake mode).	T_{RS4}	–	–	2.0	μS
Delay time, peripheral data valid to CA1 or CB1 active transition (input latching).	T_{IL}	300	–	–	nS
Delay time, CB1 negative transition to CB2 data valid (internal SR clock, shift out).	T_{SR1}	–	–	300	nS
Delay time, negative transition of CB1 input clock to CB2 data valid (external clock, shift out).	T_{SR2}	–	–	300	nS
Delay time, CB2 data valid to positive transition of CB1 clock (shift in, internal or external clock)	T_{SR3}	–	–	300	nS
Pulse Width - PB6 Input Pulse	T_{IPW}	2	–	–	μS
Pulse Width - CB1 Input Clock	T_{ICW}	2	–	–	μS
Pulse Spacing - PB6 Input Pulse	I_{IPS}	2	–	–	μS
Pulse Spacing - CB1 Input Pulse	I_{ICS}	2	–	–	μS

PROCESSOR INTERFACE

This section contains a description of the buses and control lines which are used to interface the SY6522 to the system processor. Electrical parameters associated with this interface are specified elsewhere in this document.

1. Phase Two Clock (Φ2)

Data transfers between the SY6522 and the system processor take place only while the Phase Two Clock is high. In addition, Φ2 acts as the time base for the various timers, shift registers, etc. on the chip.

2. Chip Select Lines (CS1, $\overline{CS2}$)

The two chip select inputs are normally connected to processor address lines either directly or through decoding. The selected SY6522 register will be accessed when CS1 is high and $\overline{CS2}$ is low.

3. Register Select Lines (RS0, RS1, RS2, RS3)

The four Register select lines are normally connected to the processor address bus lines to allow the processor to select the internal SY6522 register which is to be accessed. The sixteen possible combinations access the registers as follows:

RS3	RS2	RS1	RS0	REGISTER	REMARKS
L	L	L	L	ORB, IRB	
L	L	L	H	ORA, IRA	Controls Handshake
L	L	H	L	DDRB	
L	L	H	H	DDRA	
L	H	L	L	T1L-L	Write Latch Read Counter
L	H	L	H	T1C-H	Trigger T1L-L/ T1C-L Transfer
L	H	H	L	T1L-L	
L	H	H	H	T1L-H	
H	L	L	L	T2L-L T2C-L	Write Latch Read Counter
H	L	L	H	T2C-H	Triggers T2L-L/ T2C-L Transfer
H	L	H	L	SR	
H	L	H	H	ACR	
H	H	L	L	PCR	
H	H	L	H	IFR	
H	H	H	L	IER	
H	H	H	H	ORA	No Effect on Handshake

NOTE: L ≤ 0.4V
H ≥ 2.4V

4. Read/Write Line (R/W)

The direction of the data transfers between the SY6522 and the system processor is controlled by the R/W line. If R/W is low, data will be transferred out of the processor into the selected SY6522 register (write operation). If R/W is high and the chip is selected, data will be transferred out of the SY6522 (read operation).

5. Data Bus (DB0 - DB7)

The 8 bi-directional data bus lines are used to transfer data between the SY6522 and the system processor. The internal drivers will remain in the high-impedance state except when the chip is selected (CS1=HI, $\overline{CS2}$=LO), Read/Write is high and the Phase Two Clock is high. At this time, the contents of the selected register are placed on the data bus. When the chip is selected, with Read/Write low and Φ2 = 1, the data on the data bus will be transferred into the selected SY6522 register.

6. Reset ($\overline{RES}$)

The reset input clears all internal registers to logic 0 (except T1, T2 and SR). This places all peripheral interface lines in the input state, disables the timers, shift register, etc. and disables interrupting from the chip.

7. Interrupt Request ($\overline{IRQ}$)

The Interrupt Request output goes low whenever an internal interrupt flag is set and the corresponding interrupt enable bit is a logic 1. This output is "open-drain" to allow the interrupt request signal to be "wire-or'ed" with other equivalent signals in the system.

PERIPHERAL INTERFACE

This section contains a brief description of the buses and control lines which are used to drive peripheral devices under control of the internal SY6522 registers.

1. Peripheral A Port (PA0 - PA7)

The Peripheral A port consists of 8 lines which can be individually programmed to act as an input or an output under control of a Data Direction Register. The polarity of output pins is controlled by an Output Register and input data can be latched into an internal register under control of the CA1 line. All of these modes of operation are controlled by the system processor through the internal control registers. These lines represent one standard TTL load in the input mode and will drive one standard TTL load in the output mode.

2. Peripheral A Control Lines (CA1, CA2)

The two peripheral A control lines act as interrupt inputs or as handshake outputs. Each line controls an internal interrupt flag with a corresponding interrupt enable bit. In addition, CA1 controls the latching of data on Peripheral A Port Input lines. The various modes of operation are controlled by the system processor through the internal control registers. CA1 is a high-impedance input only while CA2 represents one standard TTL load in the input mode. CA2 will drive one standard TTL load in the output mode.

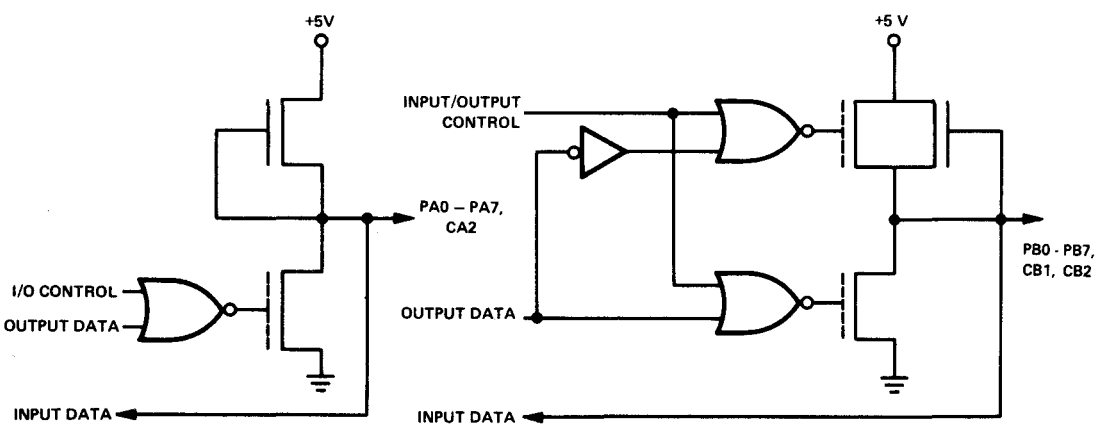
3. Peripheral B Port (PB0 - PB7)

The Peripheral B Port consists of 8 bi-directional lines which are controlled by an output register and a data direction register in much the same manner as the PA port. In addition, the polarity of the PB7 output signal can be controlled by one of the interval timers while the second timer can be programmed to count pulses on the PB6 pin. These lines represent one standard TTL load in the input mode and will drive one standard TTL load in the output mode. In addition, they are capable of sourcing 3.0 ma at 1.5 VDC in the output mode to allow the outputs to directly drive Darlington transistor switches.

4. Peripheral B Control Lines (CB1, CB2)

The Peripheral B control lines act as interrupt inputs or as handshake outputs. As with CA1 and CA2, each line controls an interrupt flag with a corresponding interrupt enable bit. In addition, these lines act as a serial port under control of the Shift Register. These lines represent one standard TTL load in the input mode and will drive one standard TTL load in the output mode. In addition, they are capable of sourcing 3.0 ma at 1.5 VDC in the output mode to allow the outputs to directly drive Darlington transistor switches.

Figure 5. PERIPHERAL DATA OUTPUT BUFFERS



SY6522 OPERATION

This section contains a discussion of the various blocks of logic shown in Figure 1. In addition, the internal operation of the SY6522 is described in detail.

A. Data Bus Buffers (DB), Peripheral A Buffers (PA), Peripheral B Buffers (PB)

The characteristics of the buffers which provide the required voltage and current drive capability were discussed in the previous section. Electrical paramenters for these buffers are specified elsewhere in this document.

B. Chip Access Control

The Chip Access Control contains the necessary logic to detect the chip select condition and to decode the Register Select inputs to allow accessing the desired internal registers. In addition, the R/W and Φ2 signals are utilized to control the direction and timing of data transfers. When writing into the SY6522, data is first latched into a data input register during Φ2. Data is then transferred into the desired internal register during Φ2 · Chip Select. This allows the peripheral I/O lines to change states cleanly. When the processor reads the SY6522, data is transferred from the desired internal register directly onto the Data Bus during Φ2.

C. Port A Registers, Port B Registers

Three registers are used in accessing each of the 8-bit peripheral ports. Each port has a Data Direction Register (DDRA, DDRB) for specifying whether the peripheral pins are to act as inputs or outputs. A 0 in a bit of the Data Direction Register causes the corresponding peripheral pin to act as an input. A 1 causes the pin to act as an output.

Each peripheral pin is also controlled by a bit in the Output Register (ORA, ORB) and an Input Register (IRA, IRB). When the pin is programmed to act as an output, the voltage on the pin is controlled by the corresponding bit of the Output Register. A 1 in the Output Register causes the pin to go high, and a 0 causes the pin to go low. Data can be written into Output Register bits corresponding to pins which are programmed to act as inputs; however, the pin will be unaffected.

Reading a peripheral port causes the contents of the Input Register (IRA, IRB) to be transferrred onto the Data Bus. With input latching disabled, IRA will always reflect the data on the PA pins. With input latching enabled, IRA will reflect the contents of the Port A prior to setting the CA1 Interrupt Flag (IFR1) by an active transition on CA1.

The IRB register operates in a similar manner. However, for output pins, the corresponding IRB bit will reflect the contents of the Output Register bit instead of the actual pin. This allows proper data to be read into the processor if the output pin is not allowed to go to full voltage. With input latching enabled on Port B, setting CB1 interrupt flag will cause the IRB to latch this combination of input data and ORB data until the interrupt flag is cleared.

D. Handshake Control

The SY6522 allows very positive control of data transfers between the system processor and peripheral devices through the operation of "handshake" lines. Port A lines (CA1, CA2) handshake data on both a read and a write operation while the Port B lines (CB1, CB2) handshake on a write operation only.

Read Handshake

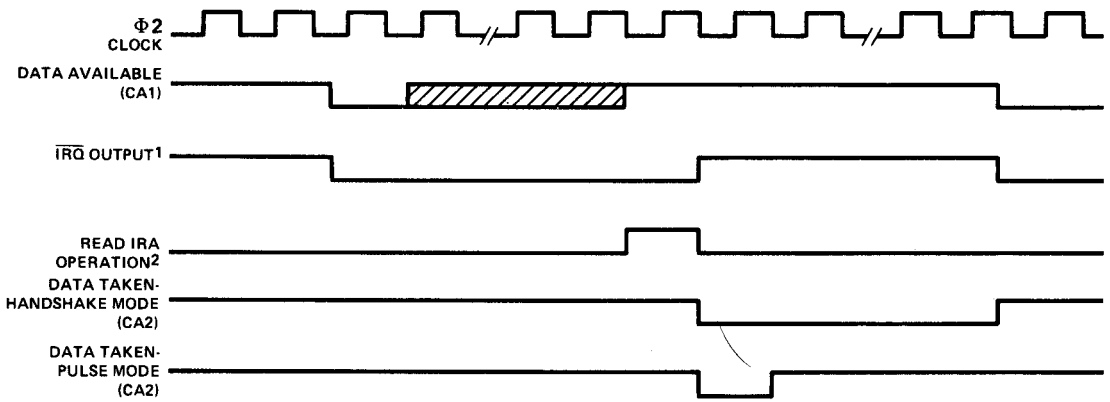
Positive control of data transfers from peripheral devices into the system processor can be accomplished very effectively using "Read" handshaking. In this case, the peripheral device must generate "Data Ready" to signal the processor that valid data is present on the peripheral port. This signal normally interrupts the processor, which then reads the data, causing generation of a "Data Taken" signal. The peripheral device responds by making new data available. This process continues until the data transfer is complete.

In the SY6522, automatic "Read" handshaking is possible on the Peripheral A port only. The CA1 interrupt input pin accepts the "Data Ready" signal and CA2 generates the "Data Taken" signal. The Data Ready signal will set an internal flag which may interrupt the processor or which can be polled under software control. The Data Taken signal can either be a pulse or a level which is set low by the system processor and is cleared by the Data Ready signal. These options are shown in Figure 6which illustrates the normal Read Handshaking sequence.

Write Handshake

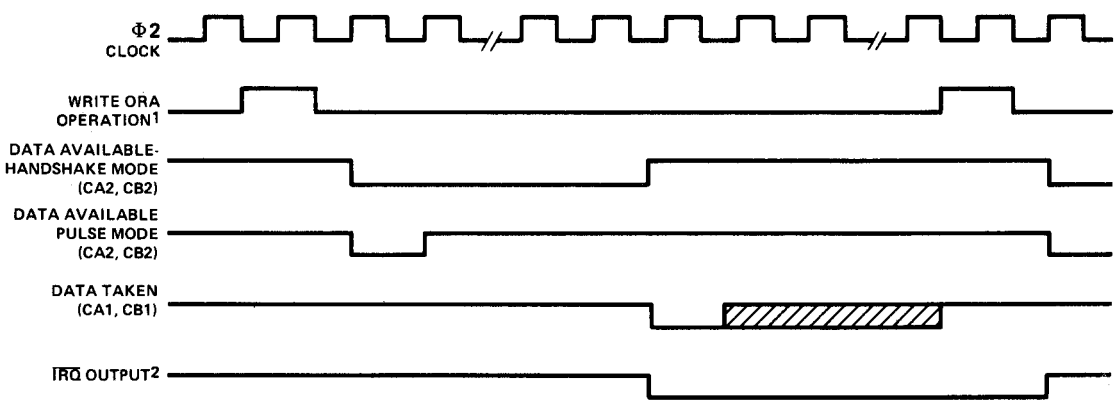
The sequence of operations which allows handshaking data from the system processor to a peripheral device is very similar to that described in Section A for Read Handshaking. However, for "Write" handshaking, the processor must generate the "Data Ready" signal (through the SY6522) and the peripheral device must respond with the "Data Taken" signal. This can be accomplished on both the PA port and the PB port on the SY6522. CA2 or CB2 acts as a Data Ready Output in either the DC level of pulse mode and CA1 or CB1 accepts the "Data Taken" signal from the peripheral device, setting the interrupt flag and clearing the "Data Ready" output. This sequence is shown in Figure 7.

Figure 6. READ HANDSHAKE TIMING SEQUENCE



NOTES:
1. Signals "data available" to the system processor.
2. R/W = 1, $\overline{CS2}$ = 0, CS1 = 1, RS2 = 0, RS3 = 0, RS0 = 1.

Figure 7. WRITE HANDSHAKE TIMING SEQUENCE



NOTES:
1. R/W = 0, $\overline{CS2}$ = 0, CS1 = 1, RS3 = 0, RS2 = 0, RS1 = 0, RS0 = 1.
2. Signals "data taken" to the system processor.

E. Timer 1

Interval Timer T1 consists of two 8-bit latches and a 16-bit counter. The latches are used to store data which is to be loaded into the counter. After loading, the counter decrements at system clock rate, i.e., under control of the clock applied to the Phase Two input pin. Upon reaching zero, an interrupt flag will be set, and $\overline{IRQ}$ will go low. The timer will then disable any further interrupts, or will automatically transfer the contents of the latches into the counter and will continue to decrement. In addition, the timer can be instructed to invert the output signal on a peripheral pin each time it "times-out". Each of these modes is dicussed separately below.

Writing the Timer 1 Registers

The operations which take place when writing to each of the four T1 addresses are as follows:

RS3	RS2	RS1	RS0	Operation (R/W =L)
L	H	L	L	Write into low order latch.
				Write into high order latch.
L	H	L	H	Write into high order counter. Transfer low order latch into low order counter. Reset T1 interrupt flag.
L	H	H	L	Write into low order latch.
L	H	H	H	Write into high order latch. Reset T1 interrupt flag.

Note that the processor does not write directly into the low order counter (T1C-L). Instead, this half of the counter is loaded automatically from the low order latch when the processor writes into the high order counter. In fact, it may not be necessary to write to the low order counter in some applications since the timing operation is triggered by writing to the high order counter.

The second set of addresses allows the processor to write into the latch register without affecting the count-down in progress. This is discussed in detail below.

Reading the Timer 1 Registers

For reading the Timer 1 registers, the four addresses relate directly to the four registers as follows.

RS3	RS2	RS1	RS0	Operation (R/W = H)
L	H	L	L	Read T1 low order counter. Reset T1 interrupt flag.
L	H	L	H	Read T1 high order counter.
L	H	H	L	Read T1 low order latch.
L	H	H	H	Read T1 high order latch.

Timer 1 Operating Modes

Two bits are provided in the Auxiliary Control Register to allow selection of the T1 operating modes. These bits and the four possible modes are as follows:

ACR7 Output Enable	ACR6 "Free-Run" Enable	Mode
0	0	Generate a single time-out interrupt each time T1 is loaded. PB7 disabled.
0	1	Generate continuous interrupts. PB7 disabled.
1	0	Generate a single interrupt and an output pulse on PB7 for each T1 load operation.
1	1	Generate continuous interrupts and a square wave output on PB7.

TIMER 1 ONE-SHOT MODE

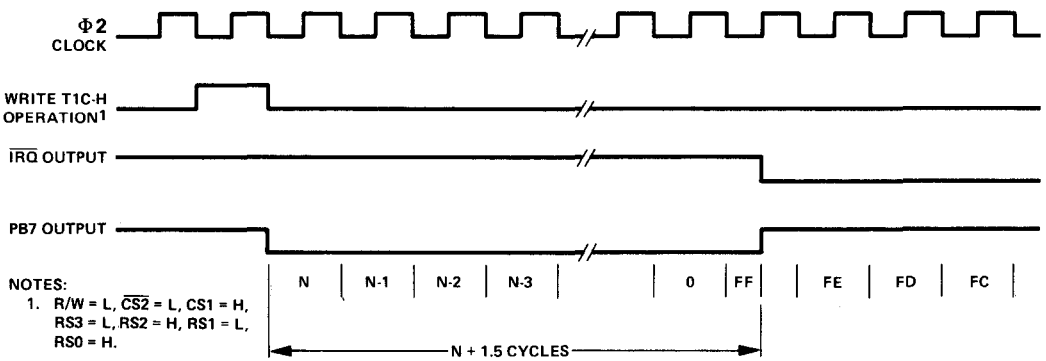
The interval timer one-shot mode allows generation of a single interrupt for each timer load operation. As with any interval timer, the delay between the "write T1C-H" operation and generation of the processor interrupt is a direct function of the data loaded into the timing counter. In addition to generating a single interrupt, Timer 1 can be programmed to produce a single negative pulse on the PB7 peripheral pin. With the output enabled (ACR7=1) a "write T1C-H" operation will cause PB7 to go low. PB7 will return high when Timer 1 times out. The result is a single programmable width pulse.

> **NOTE**
>
> PB7 will act as an output if DDRB7 = 1 or if ACR7 = 1. However, if both DDRB7 and ACR7 are logic 1, PB7 will be controlled from Timer 1 and ORB7 will have no effect on the pin.

In the one-shot mode, writing into the high order latch has no effect on the operation of Timer 1. However, it will be necessary to assure that the low order latch contains the proper data before initiating the count-down with a "write T1C-H" operation.When the processor writes into the high order counter, the T1 interrupt flag will be cleared, the contents of the low order latch will be transferred into the low order counter, and the timer will begin to decrement at system clock rate. If the PB7 output is enabled, this signal will go low on the phase two following the write operation. When the counter reaches zero, the T1 interrupt flag will be set, the $\overline{IRQ}$ pin will go low (interrupt enabled), and the signal on PB7 will go high. At this time the counter will continue to decrement at system clock rate. This allows the system processor to read the contents of the counter to determine the time since interrupt. However, the T1 interrupt flag cannot be set again unless it has been cleared as described elsewhere in this specification.

Timing for the SY6522 interval timer one-shot modes is shown in figure 8.

Figure 8. INTERVAL TIMER "ONE-SHOT" MODE TIMING SEQUENCE



NOTES:
1. R/W = L, $\overline{CS2}$ = L, CS1 = H, RS3 = L, RS2 = H, RS1 = L, RS0 = H.

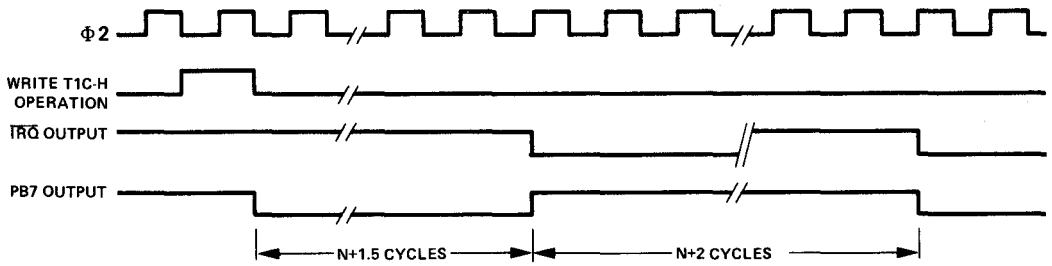
TIMER 1 FREE-RUNNING MODE

The most important advantage associated with the latches in T1 is the ability to produce a continuous series of evenly spaced interrupts and the ability to produce a square wave on PB7 whose frequency is not affected by variations in the processor interrupt response time. This is accomplished in the "free-running" mode.

In the free-running mode (ACR6 = 1), the interrupt flag is set and the signal on PB7 is inverted each time the counter reaches zero. However, instead of continuing to decrement from zero after a time-out, the timer automatically transfers the contents of the latch into the counter (16 bits) and continues to decrement from there. The interrupt flag can be cleared by writing T1C-H, by reading T1C-L, or by writing directly into the flag as described below. However, it is not necessary to rewrite the timer to enable setting the interrupt flag on the next time-out.

All interval timers in the SY6500 family devices are "re-triggerable". Rewriting the counter will always re-initialize the time-out period. In fact, the time-out can be prevented completely if the processor continues to rewrite the timer before it reaches zero. Timer 1 will operate in this manner if the processor writes into the high order counter (T1C-H). However, by loading the latches only, the processor can access the timer during each down-counting operation without affecting the time-out in process. Instead, the data loaded into the latches will determine the length of the next time-out period. This capability is particularly valuable in the free-running mode with the output enabled. In this mode, the signal on PB7 is inverted and the interrupt flag is set with each time-out. By responding to the interrupts with new data for the latches, the processor can determine the period of the next half cycle during each half cycle of the output signal on PB7. In this manner, very complex waveforms can be generated. Timing for the free-running mode is shown in Figure 9.

Figure 9. TIMER 1 "FREE-RUNNING" MODE



F. Timer 2

Timer 2 operates as an interval timer (in the "one-shot" mode only), or as a counter for counting negative pulses on the PB6 peripheral pin. A single control bit is provided in the Auxiliary Control Register to select between these two modes. This timer is comprised of a "write-only" low-order latch (T2L-L), a "read-only" low-order counter and a read/write high order counter. The counter registers act as a 16-bit counter which decrements at Φ2 rate.

Timer 2 addressing can be summarized as follows:

RS3	RS2	RS1	RS0	R/W = 0	R/W = 1
H	L	L	L	Write T2L-L	Read T2C-L Clear Interrupt flag
H	L	L	H	Write T2C-H Transfer T2L-L to T2C-L Clear Interrupt flag	Read T2C-H

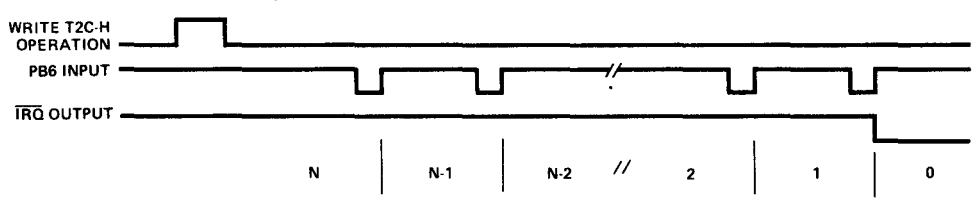
Timer 2 Interval Timer Mode

As an interval timer, T2 operates in the "one-shot" mode similar to Timer 1. In this mode, T2 provides a single interrupt for each "write T2C-H" operation. After timing out, the counter will continue to decrement. However, setting of the interrupt flag will be disabled after initial time-out so that it will not be set by the counter continuing to decrement through zero. The processor must rewrite T2C-H to enable setting of the interrupt flag. The interrupt flag is cleared by reading T2C-L or by writing T2C-H. Timing for this operation is shown in Figure 8.

Timer 2 Pulse Counting Mode

In the pulse counting mode, T2 serves primarily to count a predetermined number of negative-going pulses on PB6. This is accomplished by first loading a number into T2. Writing into T2C-H clears the interrupt flag and allows the counter to decrement each time a pulse is applied to PB6. The interrupt flag will be set when T2 reaches zero. At this time the counter will continue to decrement with each pulse on PB6. However, it is necessary to rewrite T2C-H to allow the interrupt flag to set on subsequent down-counting operations. Timing for this mode is shown in Figure 10. The pulse must be low on the leading edge of Φ2.

Figure 10. TIMER 2 PULSE COUNTING MODE



G. Shift Register

The Shift Register (SR) performs serial data transfers into and out of the CB2 pin under control of an internal modulo-8 counter. Shift pulses can be applied to the CB1 pin from an external source or, with the proper mode selection, shift pulses generated internally will appear on the CB1 pin for controlling external devices.

The control bits which select the various shift register operating modes are located in the Auxiliary Control Register. These bits can be set and cleared by the system processor to select one of the operating modes discussed in the following paragraphs.

Shift Register Input Modes

Bit 4 of the Auxiliary Control Register selects the input or output modes. There are three input modes and four output modes, differing primarily in the source of the pulses which control the shifting operation. With ACR4 = 0 the input modes are selected by ACR3 and ACR2 as follows:

ACR4	ACR3	ACR2	Mode
0	0	0	Shift Register Disabled
0	0	1	Shift in under control of Timer 2
0	1	0	Shift in at System Clock Rate.
0	1	1	Shift in under control of external input pulses

Mode 000 - Shift Register Disabled

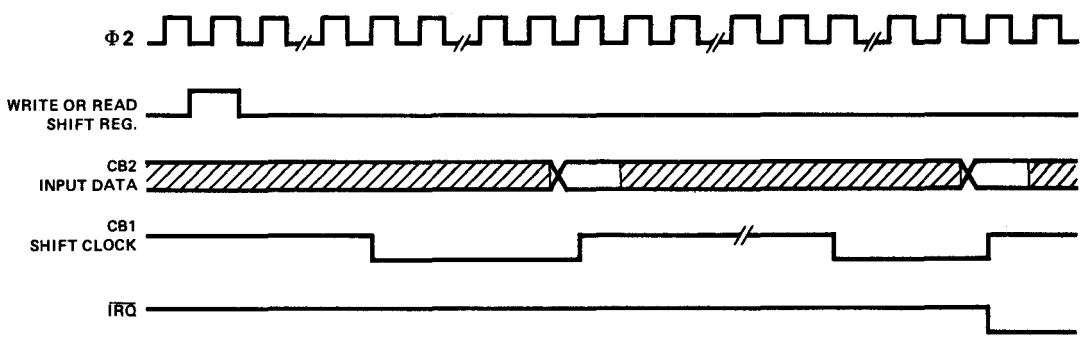
The 000 mode is used to disable the Shift Register. In this mode the microprocessor can write or read the SR, but the shifting operation is disabled and operation of CB1 and CB2 is controlled by the appropriate bits in the Peripheral Control Register (PCR). In this mode the SR Interrupt Flag is disabled (held to a logic 0).

Mode 001 - Shift in Under Control of Timer 2

In this mode the shifting rate is controlled by the low order 8 bits of T2. Shift pulses are generated on the CB1 pin to control shifting in external devices. The time between transitions of this output clock is a function of the system clock period and the contents of the low order T2 latch.

The shifting operation is triggered by writing or reading the shift register. Data is shifted first into the low order bit of SR and is then shifted into the next higher order bit or the shift register on the trailing edge of each clock pulse. As shown in Figure 11, the input data should change before the leading edge of the clock pulse. This data is loaded into the shift register during the system clock cycle following the trailing edge of the clock pulse. After 8 clock pulses, the shift register interrupt flag will be set and IRQ will go low.

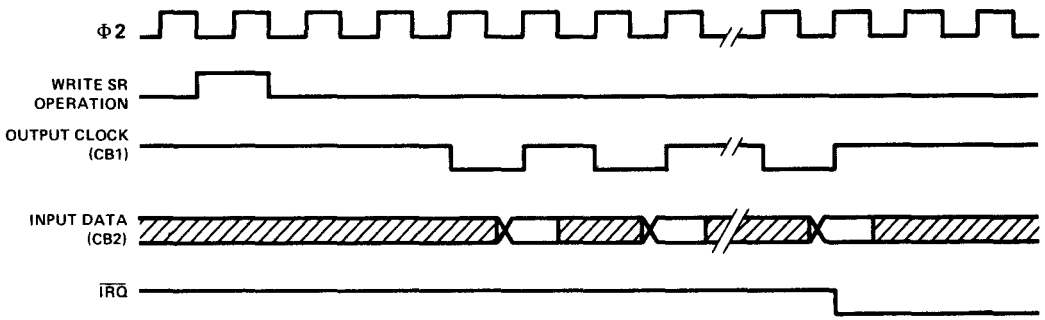
Figure 11. SHIFTING IN UNDER CONTROL OF T2



Mode 010 - Shift in at System Clock Rate

In this mode the shift rate is a direct function of the system clock frequency. CB1 becomes an output which generates shift pulses for controlling external devices. Timer 2 operates as an independent interval timer and has no effect on SR. The shifting operation is triggered by reading or writing the Shift Register. Data is shifted first into bit 0 and is then shifted into the next higher order bit of the shift register on the trailing edge of each clock pulse. After 8 clock pulses, the shift register interrupt flag will be set, and the output clock pulses on CB1 will stop.

Figure 12. TIMING SEQUENCE FOR SHIFTING IN AT SYSTEM CLOCK RATE

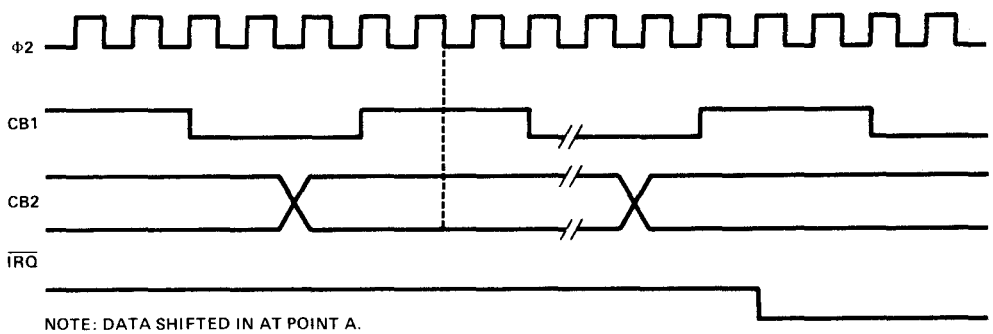


Mode 011 - Shift in Under Control of External Clock

In this mode CB1 becomes an input. This allows an external device to load the shift register at its own pace. The shift register counter will interrupt the processor each time 8 bits have been shifted in. However, the shift register counter does not stop the shifting operation; it acts simply as a pulse counter. Reading or writing the Shift Register resets the Interrupt flag and initializes the SR counter to count another 8 pulses.

Note that the data is shifted during the first system clock cycle following the leading edge of the CB1 shift pulse. For this reason, data must be held stable during the first full cycle following CB1 going high. Timing for this operation is shown in Figure 13.

Figure 13. TIMING SEQUENCE FOR SHIFTING IN UNDER CONTROL OF EXTERNAL CLOCK



NOTE: DATA SHIFTED IN AT POINT A.

Shift Register Output Modes

The four Shift Register Output Modes are selected by setting the Input/Output Control Bit (ACR4) to a logic 1 and then selecting the specific output mode with ACR3 and ACR2. In each of these modes the Shift Register shifts data out of bit 7 to the CB2 pin. At the same time the contents of bit 7 are shifted back into bit 0. As in the input modes, CB1 is used either as an output to provide shifting pulses out or as an input to allow shifting from an external pulse. The four modes are as follows:

ACR4	ACR3	ACR2	Mode
1	0	0	Shift out - Free-running mode. Shift rate controlled by T2.
1	0	1	Shift out - Shift rate controlled by T2. Shift pulses generated on CB1.
1	1	0	Shift out at system clock rate.
1	1	1	Shift out under control of an external pulse.

Mode 100 Free-Running Output

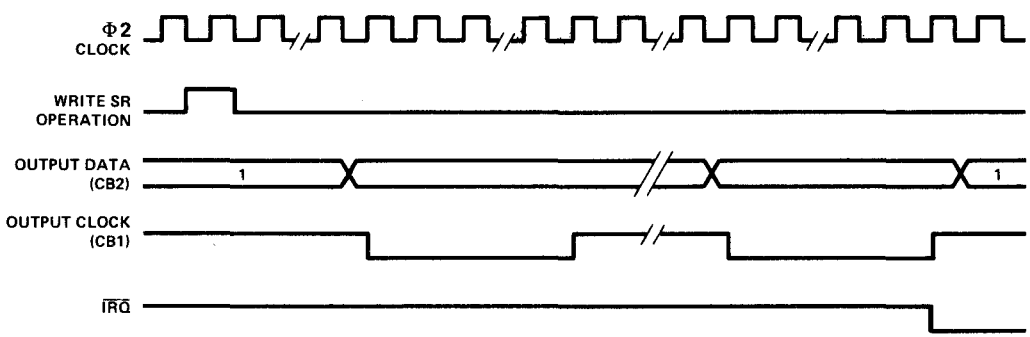
This mode is very similar to mode 101 in which the shifting rate is set by T2. However, in mode 100 the SR Counter does not stop the shifting operation. Since the Shift Register bit 7 (SR7) is recirculated back into bit 0, the 8 bits loaded into the shift register will be clocked onto CB2 repetitively. In this mode the shift register counter is disabled.

Mode 101 - Shift out Under Control of T2

In this mode the shift rate is controlled by T2 (as in the previous mode). However, with each read or write of the shift register the SR Counter is reset and 8 bits are shifted onto CB2. At the same time, 8 shift pulses are generated on CB1 to control shifting in External devices. After the 8 shift pulses, the shifting is disabled, the SR Interrupt Flag is set and CB2 goes to a state determined by the CB2 Control bit (PC5) in the Peripheral Control Register.

The CB2 Control bits (PC7, PC6, and PC5) must be used to set CB2 to a manual output selecting either a high or low polarity. If the shift register is reloaded before the last time-out, the shifting will continue. This sequence is illustrated in Figure 14.

Figure 14. SHIFTING OUT UNDER CONTROL OF T2

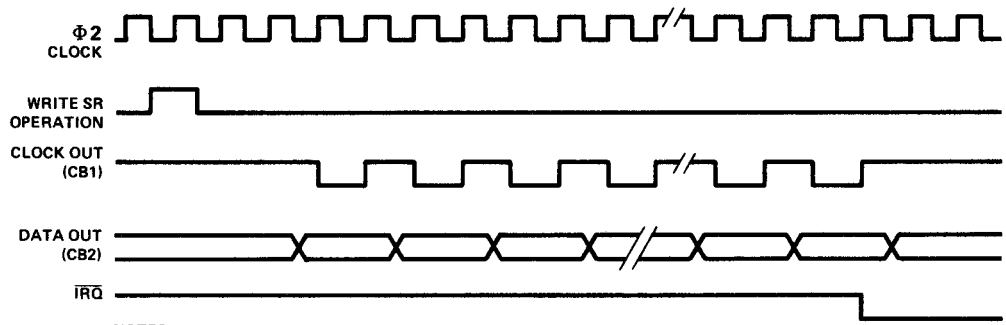


NOTES:
1. DATA OUT DETERMINED BY CB2 CONTROL IN PCR.

Mode 110 - Shifting out at System Clock Rate

In this mode the shift register operation is similar to that shown in Figure 11. However, the shifting rate is a function of the system clock on the chip enable pin (Φ2) and is independent of T2. Timer 2 resumes its normal function as an independent interval timer. Figure 15 illustrates the timing sequence for mode 110.

Figure 15. SHIFTING OUT UNDER CONTROL OF SYSTEM CLOCK

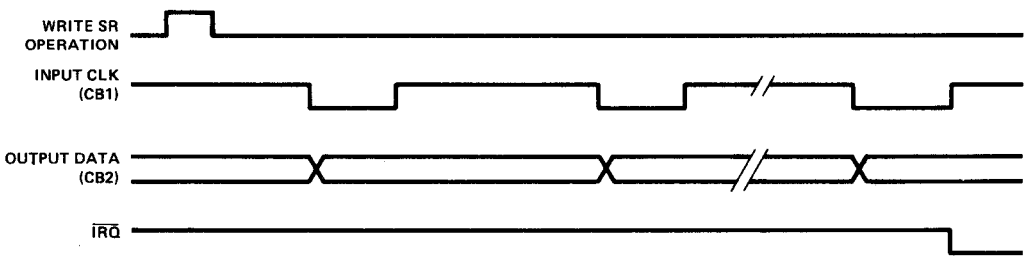


NOTES:
1. Data out determined by CB2 control in PCR.

Mode 111 - Shift out under Control of an External Pulse

In this mode, shifting is controlled by pulses applied to the CB1 pin by an external device. The SR counter sets the SR Interrupt flag each time it counts 8 pulses but it does not disable the shifting function. Each time the microprocessor writes or reads the shift register, the SR Interrupt flag is reset and the SR counter is initialized to begin counting the next 8 shift pulses on pin CB1. After 8 shift pulses, the interrupt flag is set. The microprocessor can then load the shift register with the next byte of data.

Figure 16. SHIFTING OUT UNDER CONTROL OF EXTERNAL CLOCK



H. Interrupt Control

Controlling interrupts within the SY6522 involves three principal operations. These are flagging the interrupts, enabling interrupts and signalling to the processor that an active interrupt exists within the chip. Interrupt flags are set by interrupting conditions which exist within the chip or on inputs to the chip. These flags normally remain set until the interrupt has been serviced. To determine the source of an interrupt, the microprocessor must examine these flags in order from highest to lowest priority. This is accomplished by reading the flag register into the processor accumulator, shifting this register either right or left and then using conditional branch instructions to detect an active interrupt.

Associated with each interrupt flag is an interrupt enable bit. This bit can be set or cleared by the processor to enable interrupting the processor from the corresponding interrupt flag. If an interrupt flag is set to a logic 1 by an interrupting condition, and the corresponding interrupt enable bit is set to a 1, the Interrupt Request Output ($\overline{IRQ}$) will go low. $\overline{IRQ}$ is an "open-collector" output which can be "wire-or'ed" with other devices in the system to interrupt the processor.

In the SY6522, all the interrupt flags are contained in one register. In addition, bit 7 of this register will be read as a logic 1 when an interrupt exists within the chip. This allows very convenient polling of several devices within a system to locate the source of an interrupt.

REGISTER NAME	REGISTER BIT							
	7	6	5	4	3	2	1	0
Interrupt Flag Register (IFR)	IRQ	T1	T2	CB1	CB2	SR	CA1	CA2
Interrupt Enable Register (IER)	Set/ clear control	T1	T2	CB1	CB2	SR	CA1	CA2

Interrupt Flag Register

The IFR is a read/bit-clear register. When the proper chip select and register signals are applied to the chip, the contents of this register are placed on the data bus. Bit 7 indicates the status of the $\overline{IRQ}$ output. This bit corresponds to the logic function: IRQ = IFR6 x IER6 + IFR5 x IER5 + IFR4 x IER4 + IFR3 x IER3 + IFR2 x IER2 + IFR1 x IER1 + IFR0 x IER0. Note: X = logic AND, + = Logic OR.

Bits six through zero are latches which are set and cleared as follows:

Bit #	Set by	Cleared By
0	Active transition of the signal on the CA2 pin.	Reading or writing the A port Output Register (ORA) using address 0001.
1	Active transition of the signal on the CA1 pin.	Reading or writing the A Port Output Register (ORA) using address 0001.
2	Completion of eight shifts.	Reading or writing the Shift Register.
3	Active transition of the signal on the CB2 pin.	Reading or writing the B Port Output Register.
4	Active transition of the signal on the CB1 pin.	Reading or writing the B Port Output Register.
5	Time-out of Timer 2.	Reading T2 low order counter. Writing T2 high order counter.
6	Time-out of Timer 1.	Reading T1 low order counter. Writing T1 high order counter.

The IFR bit 7 is not a flag. Therefore, this bit is not directly cleared by writing a logic 1 into it. It can only be cleared by clearing all the flags in the register or by disabling all the active interrupts as discussed in the next section.

Interrupt Enable Register (IER)

For each interrupt flag in IFR, there is a corresponding bit in the Interrupt Enable Register. The system processor can set or clear selected bits in this register to facilitate controlling individual interrupts without affecting others. This is accomplished by writing to address 1110 (IER address). If bit 7 of the data placed on the system data bus during this write operation is a 0, each 1 in bits 6 through 0 clears the corresponding bit in the Interrupt Enable Register. For each zero in bits 6 through 0, the corresponding bit is unaffected.

Setting selected bits in the Interrupt Enable Register is accomplished by writing to the same address with bit 7 in the data word set to a logic 1. In this case, each 1 in bits 6 through 0 will set the corresponding bit. For each zero, the corresponding bit will be unaffected. This individual control of the setting and clearing operations allows very convenient control of the interrupts during system operation.

In addition to setting and clearing IER bits, the processor can read the contents of this register by placing the proper address on the register select and chip select inputs with the R/W line high. Bit 7 will be read as a logic 0.

I. Function Control

Control of the various functions and operating modes within the SY6522 is accomplished primarily through two registers, the Peripheral Control Register (PCR) and the Auxiliary Control Register (ACR). The PCR is used primarily to select the operating mode for the four peripheral control pins. The Auxiliary Control Register selects the operating mode for the interval timers (T1, T2), and the serial port (SR).

Peripheral Control Register

The Peripheral Control Register is organized as follows:

Bit #	7 6 5	4	3 2 1	0
Function	CB2 Control	CB1 Control	CA2 Control	CA1 Control

Each of these functions is discussed in detail below.

1. CA1 Control

Bit 0 of the Peripheral Control Register selects the active transition of the input signal applied to the CA1 interrupt input pin. If this bit is a logic 0, the CA1 interrupt flag will be set by a negative transition (high to low) of the signal on the CA1 pin. If PCR0 is a logic 1, the CA1 interrupt flag will be set by a positive transition (low to high) of this signal.

2. CA2 Control

The CA2 pin can be programmed to act as an interrupt input or as a peripheral control output. As an input, CA2 operates in two modes, differing primarily in the methods available for resetting the interrupt flag. Each of these two input modes can operate with either a positive or a negative active transition as described above for CA1.

In the output mode, the CA2 pin combines the operations performed on the CA2 and CB2 pins of the SY6522. This added flexibility allows processor to perform a normal "write" handshaking in a system which uses CB1 and CB2 for the serial operations described above. The CA2 operating modes are selected as follows:

PCR3	PCR2	PCR1	Mode
0	0	0	Input mode–Set CA2 interrupt flag (IFR0) on a negative transition of the input signal. Clear IFR0 on a read or write of the Peripheral A Output Register.
0	0	1	Independent interrupt input mode–Set IFR0 on a negative transition of the CA2 input signal. Reading or writing ORA does not clear the CA2 Interrupt flag.
0	1	0	Input mode–Set CA2 interrupt flag on a positive transition of the CA2 input signal. Clear IFR0 with a read or write of the Peripheral A Output Register.
0	1	1	Independent Interrupt input mode–Set IFR0 on a positive transition of the CA2 input signal. Reading or writing ORA does not clear the CA2 interrupt flag.
1	0	0	Handshake output mode–Set CA2 output low on a read or write of the Peripheral A Output Register. Reset CA2 high with an active transition on CA1.
1	0	1	Pulse Output mode–CA2 goes low for one cycle following a read or write of the Peripheral A Output Register.
1	1	0	Manual output mode–The CA2 output is held low in this mode.
1	1	1	Manual output mode–The CA2 output is held high in this mode.

In the independent input mode, writing or reading the ORA register has no effect on the CA2 interrupt flag. This flag must be cleared by writing a logic 1 into the appropriate IFR bit. This mode allows the processor to handle interrupts which are independent of any operations taking place on the peripheral I/O ports.

The handshake and pulse output modes have been described previously. Note that the timing of the output signal varies slightly depending on whether the operation is initiated by a read or a write.

3. CB1 Control

Control of the active transition of the CB1 input signal operates in exactly the same manner as that described above for CA1. If PCR4 is a logic 0 the CB1 interrupt flag (IFR4) will be set by a negative transition of the CB1 input signal and cleared by a read or write of the ORB register. If PCR4 is a logic 1, IFR4 will be set by a positive transition of CB1.

If the Shift Register function has been enabled, CB1 will act as an input or output for the shift register clock signals. In this mode the CB1 interrupt flag will still respond to the selected transition of the signal on the CB1 pin.

4. CB2 Control

With the serial port disabled, operation of the CB2 pin is a function of the three high order bits of the PCR. The CB2 modes are very similar to those decribed previously for CA2. These modes are selected as follows:

PCR7	PCR6	PCR5	Mode
0	0	0	Interrupt input mode–Set CB2 interrupt flag (IFR3) on a negative transition of the CB2 input signal. Clear IFR3 on a read or write of the Peripheral B Output Register.
0	0	1	Independent interrupt input mode–Set IFR3 on a negative transition of the CB2 input signal. Reading or writing ORB does not clear the interrupt flag.
0	1	0	Input mode–Set CB2 interrupt flag on a positive transition of the CB2 input signal. Clear the CB2 interrupt flag on a read or write of ORB.
0	1	1	Independent input mode–Set IFR3 on a positive transition of the CB2 input signal. Reading or writing ORB does not clear the CB2 interrupt flag.
1	0	0	Handshake output mode–Set CB2 low on a write ORB operation. Reset CB2 high with an active transition of the CB1 input signal.
1	0	1	Pulse output mode–Set CB2 low for one cycle following a write ORB operation.
1	1	0	Manual output mode–The CB2 output is held low in this mode.
1	1	1	Manual output mode–The CB2 output is held high in this mode.

AUXIALIARY CONTROL REGISTER

Many of the functions in the Auxiliary Control Register have been discussed previously. However, a summary of this register is presented here as a convenient reference for the SY6522 user. The Auxiliary Control Register is organized as follows:

Bit #	7 6	5	4 3 2	1	0
Function	T1 Control	T2 Control	Shift Register Control	PB Latch Enable	PA Latch Enable

1. PA Latch Enable

The SY6522 provides input latching on both the PA and PB ports. In this mode, the data present on the peripheral A input pins will be latched within the chip when the CA1 interrupt flag is set. Reading the PA port will result in these latches being transferred into the processor. As long as the CA1 interrupt flag is set, the data on the peripheral pins can change without affecting the data in the latches. This input latching can be used with any of the CA2 input or output modes.

It is important to note that on the PA port, the processor always reads the data on the peripheral pins (as reflected in the latches). For output pins, the processor still reads the latches. This may or may not reflect the data currently in the ORA. Proper system operation requires careful planning on the part of the system designer if input latching is combined with output pins on the peripheral ports.

Input latching is enabled by setting bit 0 in the Auxiliary Control Register to a logic 1. As long as this bit is a 0, the latches will directly reflect the data on the pins.

2. PB Latch Enable

Input latching on the PB port is controlled in the same manner as that described for the PA port. However, with the peripheral B port the input latch will store either the voltage on the pin or the contents of the Output Register (ORB) depending on whether the pin is programmed to act as an input or an output. As with the PA port, the processor always reads the input latches.

3 Shift Register Control

The Shift Register operating mode is selected as follows:

ACR4	ACR3	ACR2	Mode
0	0	0	Shift Register Disabled.
0	0	1	Shift in under control of Timer 2.
0	1	0	Shift in under control of system clock.
0	1	1	Shift in under control of external clock pulses.
1	0	0	Free-running output at rate determined by Timer 2.
1	0	1	Shift out under control of Timer 2.
1	1	0	Shift out under control of the system clock.
1	1	1	Shift out under control of external clock pulses.

4. T2 Control

Timer 2 operates in two modes. If ACR5 = 0, T2 acts as an interval timer in the one-shot mode. If ACR5 = 1, Timer 2 acts to count a predetermined number of pulses on pin PB6.

5. T1 Control

Timer 1 operates in the one-shot or free-running mode with the PB7 output control enabled or disabled. These modes are selected as follows:

ACR7	ACR6	Mode
0	0	One-shot mode–Output to PB7 disabled
0	1	Free-running mode–Output to PB7 disabled.
1	0	One-shot mode–Output to PB7 enabled.
1	1	Free-running mode–Output to PB7 enabled.

APPLICATION OF THE SY6522

The SY6522 represents a significant advance in general-purpose microprocessor I/O. Unfortunately, its many powerful features, coupled with a set of very flexible operating modes, cause this device to appear to be very complex at first glance. However, a detailed analysis will show that the VIA is organized to allow convenient control of these powerful features. This section seeks to assist the system designer in his understanding of the SY6522 by illustrating how the device can be used in microprocessor-based systems.

A. Control of the SY6522 Interrupts

Organization of the SY6522 interrupt flags into a single register greatly facilitates the servicing of interrupts from this device. Since there is only one $\overline{IRQ}$ output for the seven possible sources of interrupt within the chip, the processor must examine these flags to determine the cause of an interrupt. This is best accomplished by first transferring the contents of the flag register into the accumulator. At this time it may be necessary to mask off these flags which have been disabled in the Interrupt Enable Register. This is particularly important for the edge detecting inputs where the flags may be set whether or not the interrupting function has been enabled. Masking off these flags can be accomplished by performing an AND operation between the IER and the accumulator or by performing an "AND IMMEDIATE". The second byte of this AND # instruction should specify those flags which correspond to interrupt functions which are to be serviced.

If the N flag is set after these operations, an active interrupt exists within the chips. This interrupt can be detected with a series of shift and branch instructions.

Clearing interrupt flags is accomplished very conveniently by writing a logic 1 directly into the appropriate bit of the Interrupt Flag Register. This can be combined with an interrupt enable or disable operation as follows:

```
LDA #@10010000  ; initialize accumulator
STA IFR         ; clear interrupt flag
STA IER         ; set interrupt enable flag
```

or:

```
LDA #@00001000  ; initialize accumulator
STA IFR         ; clear interrupt flag
STA IER         ; disable interrupt
```

Another very useful technique for clearing interrupt flags is to simply transfer the contents of the flag register back into this register as follows:

```
LDA IFR         ; transfer IFR to accumulator
STA IFR         ; clear flags corresponding to active interrupts
```

After completion of this operation the accumulator will still contain the interrupt flag information. Most important, writing into the flag register clears only those flags which are already set. This eliminates the possibility of inadvertently clearing a flag while it is being set.

B. Use of Timer 1

Timer 1 represents one of the most powerful features of the SY6522. The ability to generate very evenly spaced interrupts and the ability to control the voltage on PB7 makes this timer particularly valuable in various timing, data detection and waveform generation applications.

Time-of-Day Clock Applications

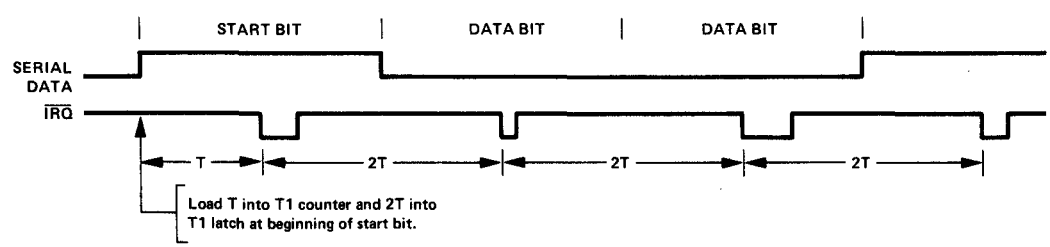
An important feature of many systems is the time-of-day clock. In microprocessor-based systems the time of day is usually maintained in memory and is updated in an interrupt service routine. A regular processor interrupt will then assure that this time of day will always be available when it is needed in the main program.

Generating very regular interrupts using previously available timers presented difficulties because of the need to re-load the timer for each interrupt. Unfortunately, the time between the interrupts will fluctuate due to variations in the interrupt response time. This problem is eliminated in the Timer 1 "free-running" mode. The accuracy of these "free-running" interrupts is only a function of the system clock and is not affected by interrupt response time.

Asynchronous Data Detection

The extraction of clock and data information from serial asynchronous ASCII signals or from any single channel data recording device relies on the ability to establish accurate strobes. As discussed previously, the period of these strobes can be seriously affected by the interrupt response time using conventional timers. However, T1 again allows generation of very accurate interrupts. The processor responds to these interrupts by strobing the input data. The ability to reload the T1 latches without affecting the count-down in progress is very useful in this application. This allows the strobe time to be doubled or halved during data detection. This sequence of operation is as follows:

Figure 17. DETECTING ASYNCHRONOUS DATA USING TIMER 1



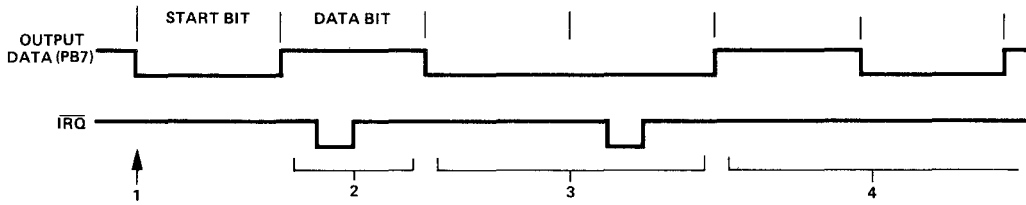
Waveform Generation with Timer 1

In addition to generating processor interrupts, Timer 1 can be used to control the output voltage on peripheral pin PB7 (output mode). In this mode a single negative pulse can be generated on PB7 (one-shot mode) or, in the free-running mode, a continuous waveform can be generated. In this latter mode the voltage on PB7 will be inverted each time T1 times out.

A single solenoid can be triggered very conveniently in the one-shot mode if the PB7 signal is used to control the solenoid directly. With this configuration the solenoid can be triggered by simply writing to T1C-H.

Generating very complex waveforms can be a simple problem if T1 is used to control PB7 in the free-running mode. During any count-down process the latches can be loaded to determine the length of the next count-down period. Figure 18 shows this timing sequence for generating ASCII serial data.

Figure 18. ASCII SERIAL DATA GENERATION USING T1

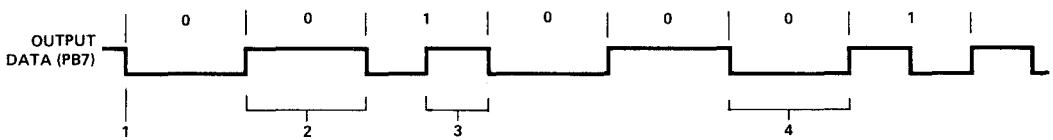


1. Load T into T1 counter and latch. Load T into T2 to trigger T1 latch reload.
2. Load 2T into T1 latch during this bit time. Load 2T into T2, as before.
3. Load T into T1 latch anytime during this period. Load NT into T2. N = number of 1's or 0's which follow.
4. A series of 1's and 0's will be generated until the T1 latch is again changed. Note that the use of T2 to control reloading the T1 latch eliminates the need to interrupt on each transition.

An application where this mode of operation is also very powerful is in the generation of bi-phase encoded data for tape or disk storage. This encoding technique and the sequence of operations which would take place are illustrated in Figure 19.

These applications represent only a tiny portion of the potential T1 applications. Some other possibilities are pulse width modulation waveforms, sound generation for video games, A/D techniques requiring very accurate pulse widths, and waveform synthesis in electronic games.

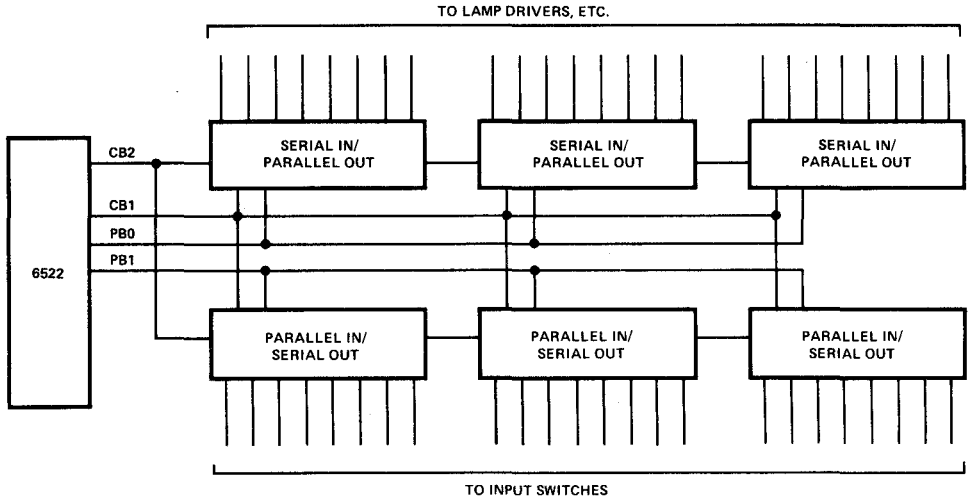
Figure 19. GENERATING BI-PHASE ENCODED DATA



1. Load T1 counter and latch.
2. Shift T1 latch one bit to the right during this period.
3. Shift T1 latch left during this period.
4. Shift T1 latch right during this period.

Note that T1 must be accessed only when the output data changes. A string of 1's or 0's can be generated without processor intervention.

Figure 22. EXPANDING SYSTEM I/O USING SHIFT REGISTER



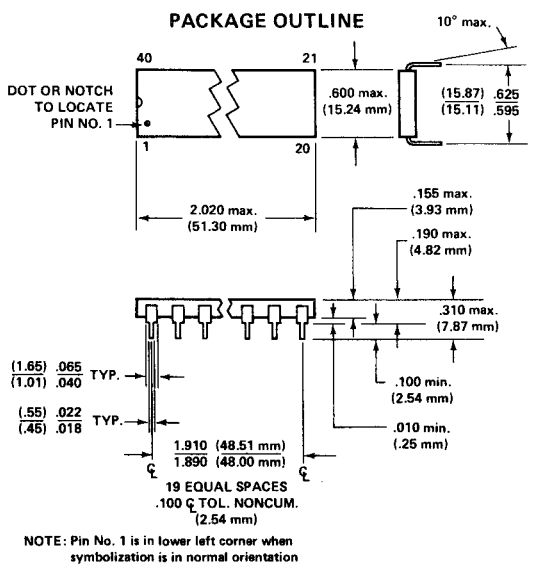
Clock Generation Using the Shift Register

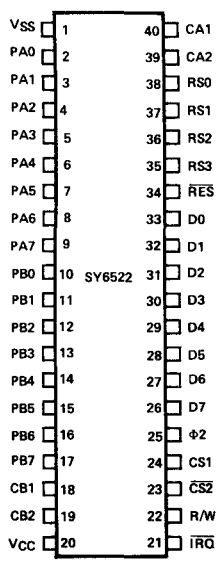
In all output modes the data shifted out of bit 7 will also be shifted into bit 0. For this reason the Shift Register need not be re-loaded if the same data is to be shifted out each time. A Shift Register read operation can be used to trigger the shifting operation.

This capability is very useful for generating peripheral clocks in the continuous output mode. This mode allows an 8-bit pattern to be shifted out continuously. This is illustrated in Figure 23. Note that in this mode the shifting operation is controlled by Timer 2. A single bit time can therefore be up to 256 clock cycles in length.

Figure 23. CLOCK GENERATION USING SR FREE-RUNNING MODE

NOTES:
1. Shift Register loaded with 1110 0000_2 initially. 2. T determined by Timer 2.

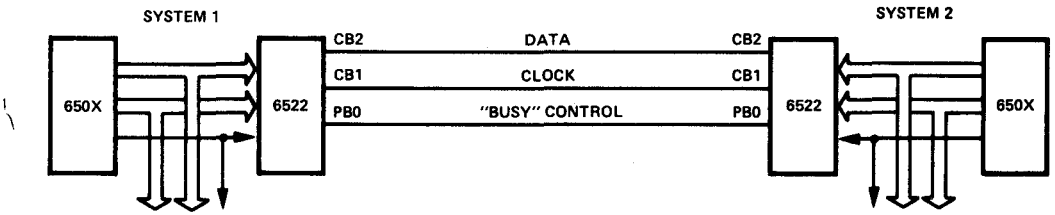




Using the SY6522 Shift Register

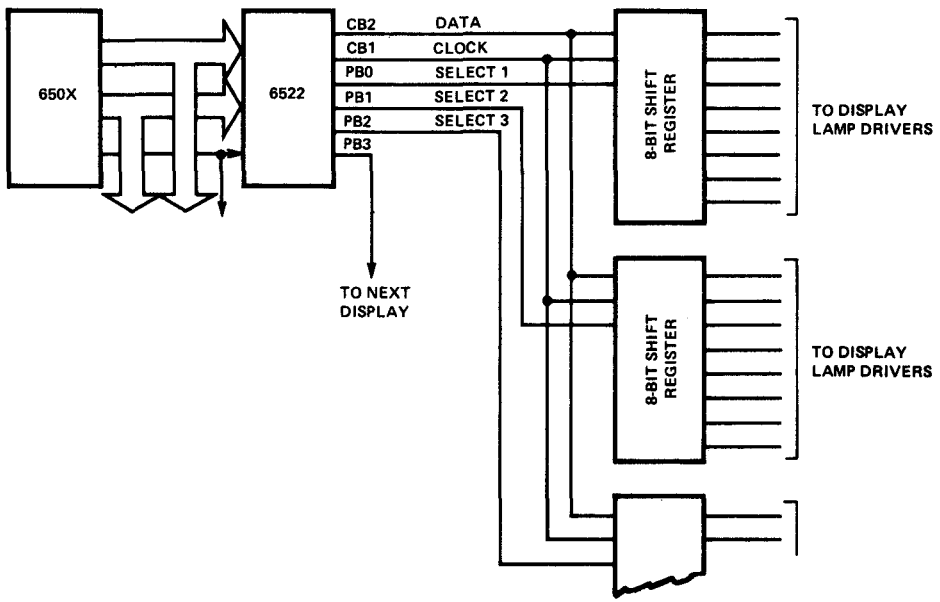
The Shift Register in the SY6522 is designed primarily as a synchronous serial communications port for distributed systems. These systems can be either single-processor with distributed peripheral controllers or distributed processor systems. The most important characteristic of the Shift Register in these applications is its ability to transfer information at relatively slow data rates to allow the use of R-C noise suppression techniques. This transfer can be accomplished while the processor is servicing other aspects of the system. An example of a simple 2-processor distributed system is shown in Figure 20. Use of the SY6522 Shift Register allows effective communication between the two systems without the use of relatively complex asynchronous communications techniques.

Figure 20. USING SHIFT REGISTER FOR INTER-SYSTEM COMMUNICATION



In a system with distributed peripherals, the Shift Register can be used to transfer data to the peripheral interface devices. This is illustrated in Figure 21 for a system with a number of distributed status displays. These displays are serviced by stand-alone controllers which actuate the lamps in the status displays with simple drivers. The data and clock lines are wired in parallel to each unit. In addition, a single SY6522 peripheral port allows selection of the display to be loaded. These select lines can be eliminated if all displays are to contain the same information. With the system shown, the status display can be updated at any time by simply selecting the desired display and then writing to the Shift Register.

Figure 21. USING THE SHIFT REGISTER FOR SERVICING REMOTE STATUS DISPLAYS



Remote input devices can be serviced in much the same manner by shifting data into the Shift Register under control of a peripheral port output as shown in Figure 21. Each set of input switches can be polled by first selecting the set to be polled and then triggering the shifting operation with a Shift Register read operation. A shift register interrupt can be used to cause the processor to read the resulting input information after shifting is complete.

The techniques described above can be utilized to expand I/O capability in a microprocessor based system. In a system with many status lamps or many input switches, simple TTL shift registers will provide the necessary I/O in a very cost effective manner. This is illustrated in Figure 22.

APPENDIX K

SY6532 DATA SHEET

Synertek®

3050 Coronado Drive, Santa Clara, CA. 95051
(408) 984-8900 TWX 910-338-0135

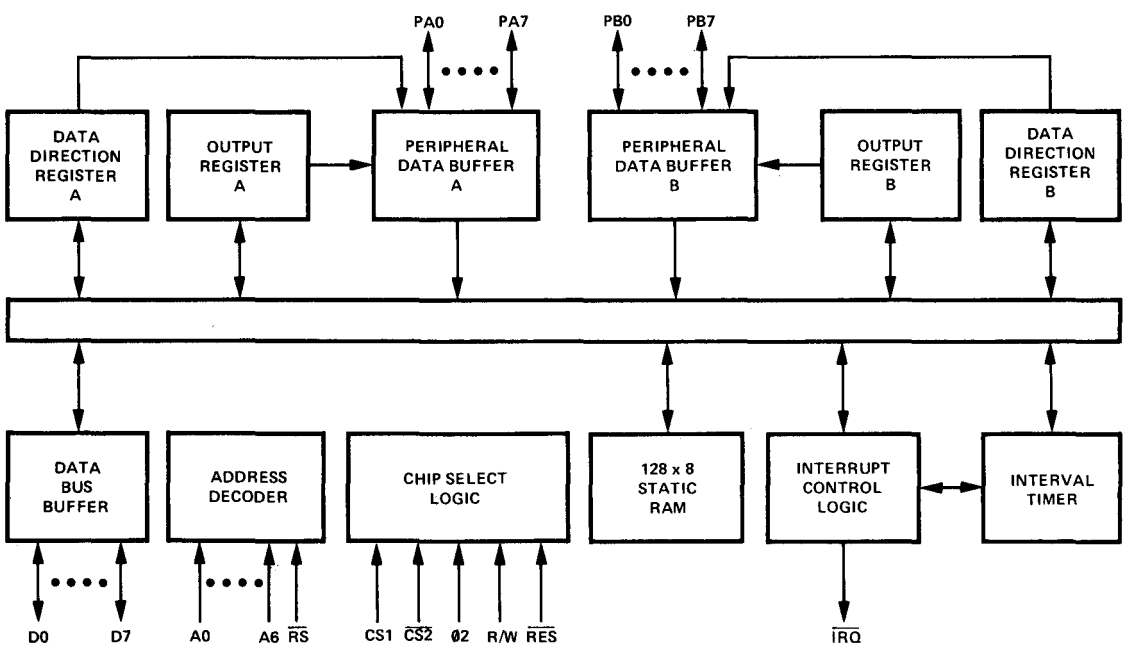
SY6532

SY6532 (RAM, I/O, TIMER ARRAY)

The SY6532 is designed to operate in conjuction with the SY6500 Microprocessor Family. It is comprised of a 128 x 8 static RAM, two software controlled 8 bit bi-directional data ports allowing direct interfacing between the microprocessor unit and peripheral devices, a software programmable interval timer with interrupt capable of timing in various intervals from 1 to 262,144 clock periods, and a programmable edge-detect interrupt circuit.

- 8 bit bi-directional Data Bus for direct communication with the microprocessor
- Programmable edge-sensitive interrupt
- 128 x 8 static RAM
- Two 8 bit bi-directional data ports for interface to peripherals
- Two programmable I/O Peripheral Data Direction Registers
- Programmable Interval Timer
- Programmable Interval Timer Interrupt
- TTL & CMOS compatible peripheral lines
- Peripheral pins with Direct Transistor Drive Capability
- High Impedance Three-State Data Pins

Figure 1. 6532 BLOCK DIAGRAM



MAXIMUM RATINGS

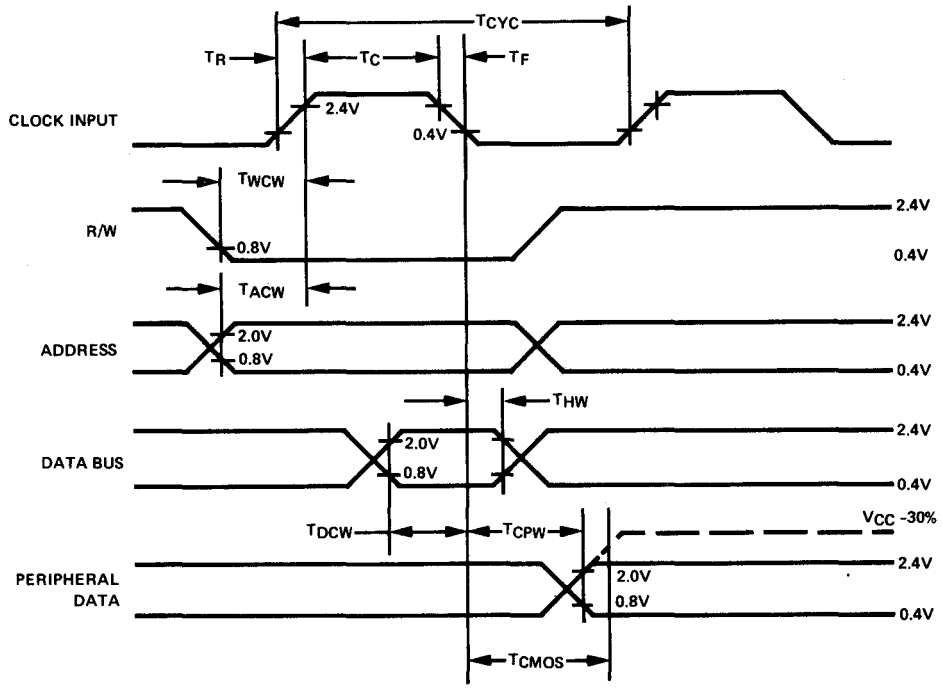
RATING	SYMBOL	VOLTAGE	UNIT
Supply Voltage	V_{CC}	-.3 to +7.0	V
Input/Output Voltage	V_{IN}	-.3 to +7.0	V
Operating Temperature Range	T_{OP}	0 to 70	°C
Storage Temperature Range	T_{STG}	-55 to +150	°C

ELECTRICAL CHARATERISTICS (V_{CC} = 5.0V ±5%, V_{SS} = 0V, T_A = 25° C)

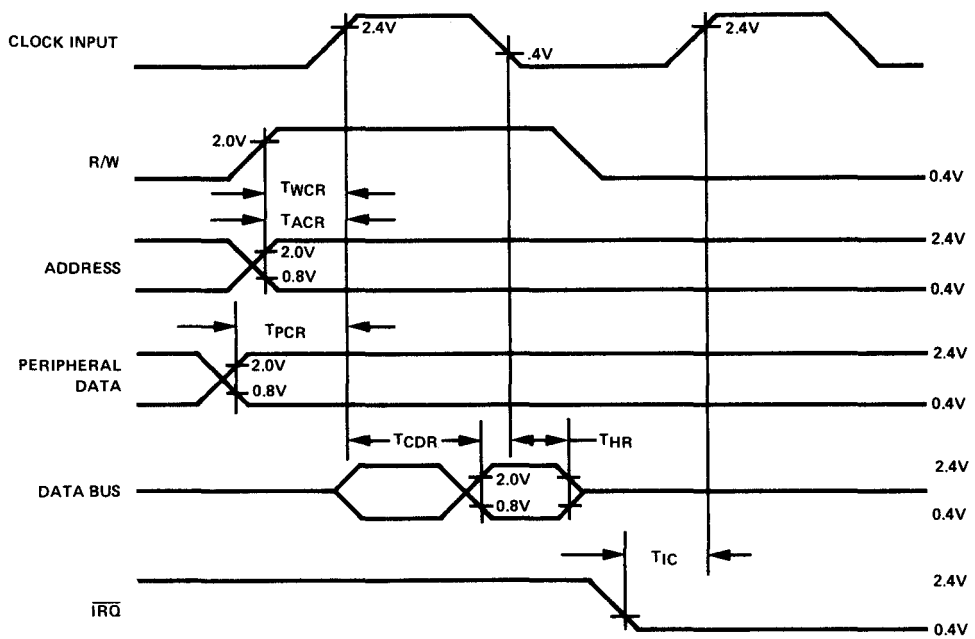
CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT
Input High Voltage	V_{IH}	V_{SS} + 2.4		V_{CC}	V
Input Low Voltage	V_{IL}	V_{SS} - .3		V_{SS} + .4	V
Input Leakage Current; V_{IN} = V_{SS} + 5V AØ-A6, $\overline{RS}$, R/W, $\overline{RES}$, Ø2, CS1, $\overline{CS2}$	I_{IN}		1.0	2.5	μA
Input Leakage Current for High Impedance State (Three State); V_{IN} = .4V to 2.4V; DØ-D7	I_{TSI}		±1.0	±10.0	μA
Input High Current; V_{IN} = 2.4V PAØ-PA7, PBØ-PB7	I_{IH}	-100.	-300.		μA
Input Low Current; V_{IN} = .4V PAØ-PA7, PBØ-PB7	I_{IL}		-1.0	-1.6	MA
Output High Voltage V_{CC} = MIN, $I_{LOAD} \leq$ -100μA (PAØ-PA7, PBØ-PB7, DØ-D7) $I_{LOAD} \leq$ 3 MA (PBØ-PB7)	V_{OH}	 V_{SS} + 2.4 V_{SS} + 1.5			V
Output Low Voltage V_{CC} = MIN, $I_{LOAD} \leq$ 1.6MA	V_{OL}			V_{SS} + .4	V
Output High Current (Sourcing); $V_{OH} \geq$ 2.4V (PAØ-PA7, PBØ-PB7, DØ-D7) $\geq$ 1.5V Available for direct transistor drive (PBØ-PB7)	I_{OH}	 -100 3.0	 -1000 5.0		 μA MA
Output Low Current (Sinking); $V_{OL} \leq$ .4V	I_{OL}	1.6			MA
Clock Input Capacitance	C_{Clk}			30	pf
Input Capacitance	C_{IN}			10	pf
Output Capacitance	C_{OUT}			10	pf
Power Dissipation	I_{CC}		100	125	mA

All inputs contain protection circuitry to prevent damage due to high static charges. Care should be exercised to prevent unnecessary application of voltage outside the specification range.

WRITE TIMING CHARACTERISTICS



READ TIMING CHARACTERISTICS



WRITE TIMING CHARACTERISTICS

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT
Clock Period	T_{CYC}	1			μS
Rise & Fall Times	TR, TF			25	NS
Clock Pulse Width	TC	470			NS
R/W valid before positive transition of clock	TWCW	180			NS
Address valid before positive transition of clock	TACW	180			NS
Data Bus valid before negative transition of clock	TDCW	300			NS
Data Bus Hold Time	THW	10			NS
Peripheral data valid after negative transition of clock	TCPW			1	μS
Peripheral data valid after negative transition of clock driving CMOS (Level = V_{CC} = 30%)	TCMOS			2	μS

READ TIMING CHARACTERISTICS

CHARACTERISTIC	SYMBOL	MIN.	TYP.	MAX.	UNIT
R/W valid after positive transition of clock	TWCR	180			NS
Address valid before positive transition of clock	TACR	180			NS
Peripheral data valid before positive transition of clock	TPCR	300			NS
Data Bus valid after positive transition of clock	TCDR			395	NS
Data Bus Hold Time	THR	10			NS
$\overline{IRQ}$ (Interval Timer Interrupt) valid before positive transition of clock	TIC	200			NS

Loading = 30 pf + 1 TTL load for PAØ-PA7, PBØ-PB7
= 130 pf + 1 TTL load for DØ-D7

INTERFACE SIGNAL DESCRIPTION

Reset ($\overline{RES}$)

During system initialization a Logic "0" on the $\overline{RES}$ input will cause a zeroing of all four I/O registers. This in turn will cause all I/O buses to act as inputs thus protecting external components from possible damage and erroneous data while the system is being configured under software control. The Data Bus Buffers are put into an OFF-STATE during Reset. Interrupt capability is disabled with the $\overline{RES}$ signal. The $\overline{RES}$ signal must be held low for at least one clock period when reset is required.

Input Clock

The input clock is a system Phase Two clock which can be either a low level clock ($V_{IL} < 0.4$, $V_{IH} > 2.4$) or high level clock ($V_{IL} < 0.2$, $V_{IH} = Vcc \begin{smallmatrix}+.3\\-.2\end{smallmatrix}$).

Read/Write (R/W)

The R/W signal is supplied by the microprocessor array and is used to control the transfer of data to and from the microprocessor array and the SY6532. A high on the R/W pin allows the processor to read (with proper addressing) the data supplied by the SY6532. A low on the R/W pin allows a write (with proper addressing) to the SY6532.

Interrupt Request ($\overline{IRQ}$)

The $\overline{IRQ}$ pin is an interrupt pin from the interrupt control logic. It will be normally high with a low indicating an interrupt from the SY6532. $\overline{IRQ}$ is an open-drain output, permitting several units to be wire-or'ed to the common $\overline{IRQ}$ microprocessor input pin. The $\overline{IRQ}$ pin may be activated by a transition on PA7 or timeout of the interval timer.

Data Bus (D0-D7)

The SY6532 has eight bi-directional data pins (D0-D7). These pins connect to the system's data lines and allow transfer of data to and from the microprocessor array. The output buffers remain in the off state except when a Read operation occurs.

Peripheral Data Ports

The SY6532 has 16 pins available for peripheral I/O operations. Each pin is individually programmable to act as either an input or an output. The 16 pins are divided into two 8-bit ports, PA0-PA7 and PB0-PB7. PA7 may also function as an interrupt input pin. This feature is described in another section. The pins are set up as an input by writing a "0" into the corresponding bit of the data direction register. A "1" into the data direction register will cause its corresponding bit to be an output. When in the input mode, the peripheral output buffers are in the "1" state and a pull-up device acts as less than one TTL load to the peripheral data lines. On a Read operation, the microprocessor unit reads the peripheral pin. When the peripheral device gets information from the SY6532 it receives data stored in the data register. The microprocessor will read correct information if the peripheral lines are greater than 2.4 volts for a "1" and less than 0.4 volts for a "0" as the peripheral pins are all TTL compatible. Pins PB0-PB7 are also capable of sourcing 3 ma at 1.5 v thus making them capable of direct transistor drive.

Address Lines (A0-A6)

There are 7 address pins. In addition to these, there is the $\overline{RS}$ pin. The above pins, A0-A6 and $\overline{RS}$, are always used as addressing pins. There are 2 additional pins which are used as CHIP SELECTS. They are pins CS1 and $\overline{CS2}$.

INTERNAL ORGANIZATION

A block diagram of the internal architecture is shown in Figure 1. The SY6532 is divided into four basic sections: RAM, I/O, Timer, and Interrupt Control. The RAM interfaces directly with the microprocessor through the system data bus and address lines. The I/O section consists of two 8-bit halves. Each half contains a Data Direction Register (DDR) and an I/O register.

RAM 128 Bytes (1024 Bits)

A 128 x 8 static RAM is contained on the SY6532. It is addressed by A0-A6 (Byte Select), $\overline{RS}$, CS1, and $\overline{CS2}$.

Internal Peripheral Registers

There are four 8-bit internal registers: two data direction registers and two output registers. The two data direction registers (A side and B side) control the direction of data into and out of the peripheral I/O pins. A logic zero in a bit of the data direction register (DDRA and DDRB) causes the corresponding pin of the I/O port to act as an input. A logic one causes the corresponding pin to act as an output. The voltage on any pin programmed as an output is determined by the corresponding bit in the output register (ORA and ORB).

Data is read directly from the PA pins during a peripheral read operation. Thus, for a PA pin programmed as an output, the data transferred into the processor will be the same as the data in the ORA only if the voltage on the pin is allowed to be $\geqslant$ 2.4 volts for a logic one and $\leqslant$ 0.4 volts for a zero. If the loading on the pin does not allow this, then the data resulting from the read operation may not match the contents of ORA.

The output buffers for the PB pins are somewhat different from the PA buffers. The PB buffers are push-pull devices which are capable of sourcing 3ma at 1.5 volts. This allows for these pins to directly drive transistor circuits. To assure that the processor will read the proper data when performing a peripheral read operation, logic is provided in the peripheral B port to permit the processor to read the contents of ORB, instead of the PB pins as is the case for the PA port.

Interval Timer

The timer section of the SY6532 contains three basic parts: preliminary divide down register, programmable 8-bit register and interrupt logic. These are illustrated in Figure 2.

The interval timer can be programmed to count up to 256 time intervals. Each time interval can be either 1T, 8T, 64T or 1024T increments, where T is the system clock period. When a full count is reached, and interrupt flag is set to a logic "1." After the interrupt flag is set the internal clock begins counting down to a maximum of -255T. Thus, after the interrupt flag is set, a Read of the timer will tell how long since the flag was set up to a maximum of 255T.

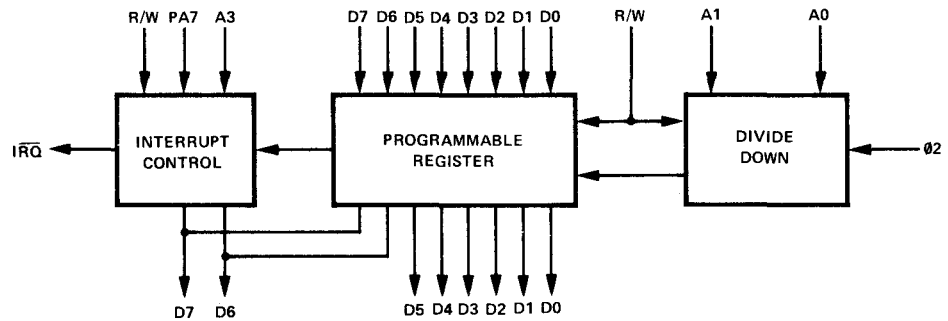
The 8-bit system Data Bus is used to transfer data to and from the Interval Timer. If a count of 52 time intervals were to be counted, the pattern 0 0 1 1 0 1 0 0 would be put on the Data Bus and written into the Interval Time register.

At the same time that data is being written to the Interval Timer, the counting intervals of 1, 8, 64, 1024T are decoded from address lines A0 and A1. During a Read or Write operation address line A3 controls the interrupt capability of $\overline{IRQ}$, i.e., $A_3 = 1$ enables $\overline{IRQ}$, $A_3 = 0$ disables $\overline{IRQ}$. In either case, when timeout occurs, bit 7 of the Interrupt Flag Register is set. This flag is cleared when the Timer register is either read from or written to by the processor. If $\overline{IRQ}$ is enabled by A3 and an interrupt occurs $\overline{IRQ}$ will go low. When the timer is read prior to the interrupt flag being set, the number of time intervals remaining will be read, i.e., 51, 50, 49, etc.

When the timer has counted down to 0 0 0 0 0 0 0 0 on the next count time an interrupt will occur and the counter will read 1 1 1 1 1 1 1 1. After interrupt, the timer register decrements at a divide by "1" rate of the system clock. If after interrupt, the timer is read and a value of 1 1 1 0 0 1 0 0 is read, the time since interrupt is 28T. The value read is in two's complement.

Value read	= 1 1 1 0 0 1 0 0
Complement	= 0 0 0 1 1 0 1 1
Add 1	= 0 0 0 1 1 1 0 0 = 28.

Figure 2. BASIC ELEMENTS OF INTERVAL TIMER

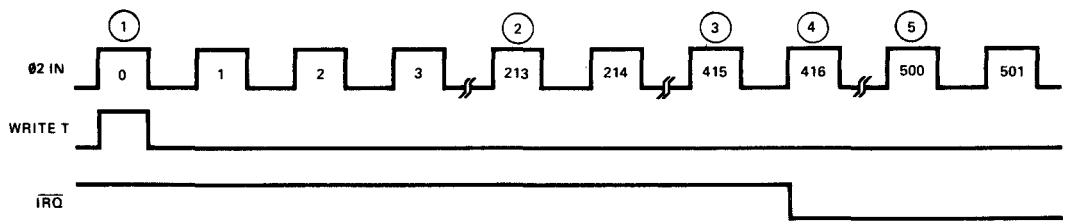


Thus, to arrive at the total elapsed time, merely do a two's complement add to the original time written into the timer. Again, assume time written as 0 0 1 1 0 1 0 0 (=52). With a divide by 8, total time to interrupt is (52 x 8) + 1 = 417T. Total elapsed time would be 416T + 28T = 444T, assuming the value read after interrupt was 1 1 1 0 0 1 0 0.

After interrupt, whenever the timer is written or read the interrupt is reset. However, the reading of the timer at the same time the interrupt occurs will not reset the interrupt flag.

Figure 3 illustrates an example of interrupt.

Figure 3. TIMER INTERRUPT TIMING



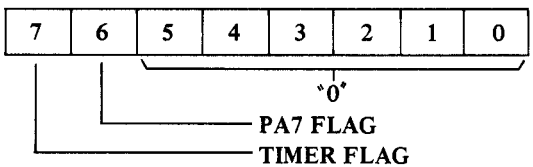
1. Data written into interval timers is $0\,0\,1\,1\,0\,1\,0\,0 = 52_{10}$
2. Data in Interval timer is $0\,0\,0\,1\,1\,0\,0\,1 = 25_{10}$
   $52 - \frac{213}{8} - 1 = 52\text{-}26\text{-}1 = 25$
3. Data in Interval timer is $0\,0\,0\,0\,0\,0\,0\,0 = 0_{10}$
   $52 - \frac{415}{8} - 1 = 52\text{-}51\text{-}1 = 0$
4. Interrupt has occurred at Ø2 pulse #416
   Data in Interval timer = 1 1 1 1 1 1 1 1
5. Data in Interval timer is 1 0 1 0 1 1 0 0
   two's complement is $0\,1\,0\,1\,0\,1\,0\,0 = 84_{10}$
   $84 + (52 \times 8) = 500_{10}$

When reading the timer after an interrupt, A3 should be low so as to disable the $\overline{IRQ}$ pin. This is done so as to avoid future interrupts until after another Write operation.

Interrupt Flag Register

The Interrupt Flag Register consists of two bits: the timer interrupt flag and the PA7 interrupt flag. When a read operation is performed on the Interrupt Flag Register, the bits are transferred to the processor on the data bus, as the diagram below, indicates.

Figure 4. INTERRUPT FLAG REGISTER



The PA7 flag is cleared when the Interrupt Flag Register is read. The timer flag is cleared when the timer register is either written or read.

ADDRESSING

Addressing of the SY6532 is accomplished by the 7 addressing pins, the $\overline{RS}$ pin and the two chip select pins CS1 and $\overline{CS2}$. To address the RAM, CS1 must be high with $\overline{CS2}$ and $\overline{RS}$ low. To address the I/O and Interval timer CS1 and $\overline{RS}$ must be high with $\overline{CS2}$ low. As can be seen to access the chip CS1 is high and $\overline{CS2}$ is low. To distinguish between RAM or I/O Timer the $\overline{RS}$ pin is used. When this pin is low the RAM is addressed, when high the I/O Interval timer section is addressed. To distinguish between timer and I/O address line A2 is utilized. When A2 is high the interval timer is accessed. When A2 is low the I/O section is addressed. Table 1 illustrates the chip addressing.

Edge Sense Interrupt

In addition to its use as a peripheral I/O line, the PA7 pin can function as an edge sensitive input. In this mode, an active transition on PA7 will set the internal interrupt flag (bit 6 of the Interrupt Flag Register). When this occurs, and providing the PA7 interrupt is enabled, the $\overline{IRQ}$ output will go low.

Control of the PA7 edge detecting logic is accomplished by performing a write operation to one of four addresses. The data lines for this operation are "don't care" and the addresses to be used are found in Figure 4.

The setting of the internal Interrupt flag by an active transition on PA7 is always enabled, no matter whether PA7 is set up as an input or an output.

The $\overline{RES}$ signal disables the PA7 interrupt and sets the active transition to the negative edge-detect state. During the reset operation, the interrupt flag may be set by a negative transition. It may, therefore, be necessary to clear the flag before its normal use as an edge detecting input is enabled. This can be achieved by reading the Interrupt Flag Register, as defined by Figure 4 immediately after reset.

I/O Register - Timer Addressing

Table 1 illustrates the address decoding for the internal elements and timer programming. Address line A2 distinguishes I/O registers from the timer. When A2 is low and $\overline{RS}$ is high, the I/O registers are addressed. Once the I/O registers are addressed, address lines A1 and A0 decode the desired register.

When the timer is selected A1 and A0 decode the "divide-by" matrix. This decoding is defined in Table 1. In addition, Address A3 is used to enable the interrupt flag to $\overline{IRQ}$.

Table 1 ADDRESSING DECODE

OPERATION	$\overline{RS}$	R/W	A4	A3	A2	A1	A0
Write RAM	0	0	–	–	–	–	–
Read RAM	0	1	–	–	–	–	–
Write DDRA	1	0	–	–	0	0	1
Read DDRA	1	1	–	–	0	0	1
Write DDRB	1	0	–	–	0	1	1
Read DDRB	1	1	–	–	0	1	1
Write Output Reg A	1	0	–	–	0	0	0
Read Output Reg A	1	1	–	–	0	0	0
Write Output Reg B	1	0	–	–	0	1	0
Read Output Reg B	1	1	–	–	0	1	0
Write Timer							
÷ 1T	1	0	1	(a)	1	0	0
÷ 8T	1	0	1	(a)	1	0	1
÷ 64T	1	0	1	(a)	1	1	0
÷ 1024T	1	0	1	(a)	1	1	1
Read Timer	1	1	–	(a)	1	–	0
Read Interrupt Flag	1	1	–	–	1	–	1
Write Edge Detect Control	1	0	0	–	1	(b)	(c)

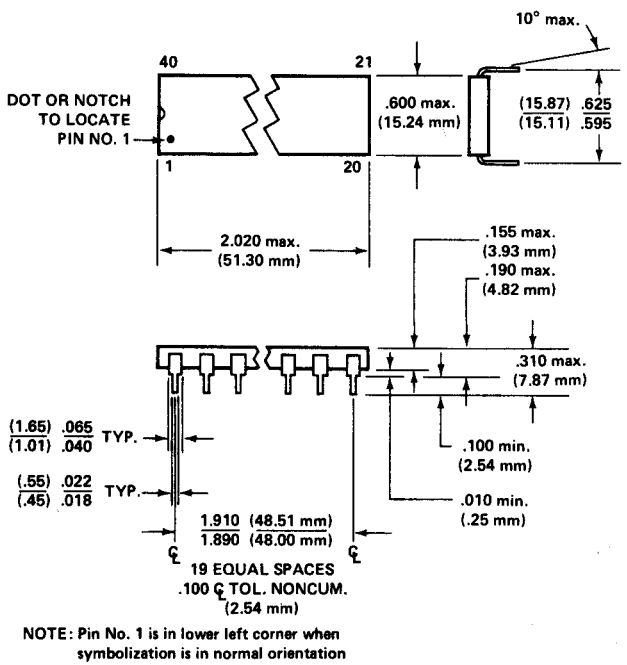
NOTES: – = Don't Care, "1" = High level (≥2.4V), "0" = Low level (≤0.4V)

(a) A3 = 0 to disable interrupt from timer to $\overline{IRQ}$
A3 = 1 to enable interrupt from timer to $\overline{IRQ}$

(b) A1 = 0 to disable interrupt from PA7 to $\overline{IRQ}$
A1 = 1 to enable interrupt from PA7 to $\overline{IRQ}$

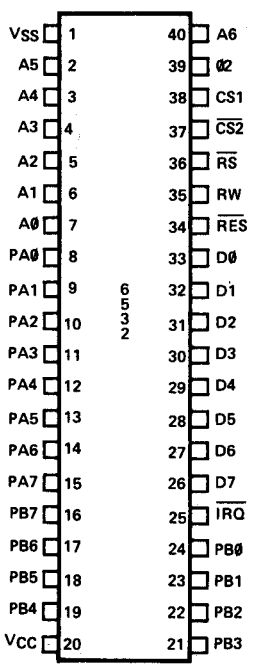
(c) A0 = 0 for negative edge-detect
A0 = 1 for positive edge-detect

PACKAGE OUTLINE



NOTE: Pin No. 1 is in lower left corner when symbolization is in normal orientation

PIN DESIGNATION



APPENDIX L

SY2114 RAM DATA SHEET

1024x4 Static Random Access Memory

SY2114

MEMORY PRODUCTS

Synertek®

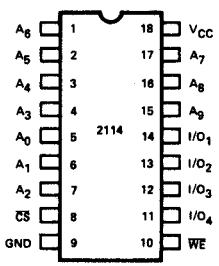
- 300 ns Maximum Access
- Low Operating Power Dissipation 0.1 mW/Bit
- No Clocks or Strobes Required
- Identical Cycle and Access Times
- Single +5V Supply
- Totally TTL Compatible: All Inputs, Outputs, and Power Supply
- Common Data I/O
- 400 mv Noise Immunity
- High Density 18 Pin Package

The SY2114 is a 4096-Bit static Random Access Memory organized 1024 words by 4-bits and is fabricated using Synertek's N-channel Silicon-Gate MOS technology. It is designed using fully DC stable (static) circuitry in both the memory array and the decoding and therefore requires no clock or refreshing to operate. Address setup times are not required and the data is read out nondestructively with the same polarity as the input data. Common Input/Output pins are provided to simplify design of the bus oriented systems, and can drive 2 TTL loads.

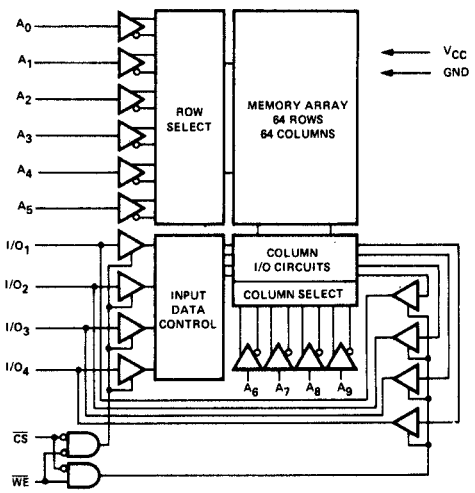
The SY2114 is designed for memory applications where high performance, low cost, large bit storage, and simple interfacing are important design objectives. It is totally TTL compatible in all respects: inputs, outputs, and the single +5V supply. A separate Chip Select ($\overline{CS}$) input allows easy selection of an individual device when outputs are or-tied.

The SY2114 is packaged in an 18-pin DIP for the highest possible density and is fabricated with N-channel, Ion Implanted, Silicon-Gate technology – a technology providing excellent performance characteristics as well as protection against contamination allowing the use of low cost packaging techniques.

PIN CONFIGURATION



BLOCK DIAGRAM



ORDERING INFORMATION

Order Number	Package Type	Access Time	Supply Current (Max)	Temperature Range
SYC2114	Ceramic	450nsec	100mamp	0°C to 70°C
SYP2114	Molded	450nsec	100mamp	0°C to 70°C
SYC2114-3	Ceramic	300nsec	100mamp	0°C to 70°C
SYP2114-3	Molded	300nsec	100mamp	0°C to 70°C
SYC2114L	Ceramic	450nsec	70mamp	0°C to 70°C
SYP2114L	Molded	450nsec	70mamp	0°C to 70°C
SYC2114L-3	Ceramic	300nsec	70mamp	0°C to 70°C
SYP2114L-3	Molded	300nsec	70mamp	0°C to 70°C

ABSOLUTE MAXIMUM RATINGS

Temperature Under Bias	−10°C to 80°C
Storage Temperature	−65°C to 150°C
Voltage on Any Pin with Respect to Ground	−0.5V to +7V
Power Dissipation	1.0W

COMMENT

Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied.

D.C. CHARACTERISTICS $T_A = 0°C$ to $+70°C$, $V_{CC} = 5V \pm 5\%$ (Unless Otherwise Specified)

Symbol	Parameter	2114-3, 2114 Min	2114-3, 2114 Max	2114L, 2114L-3 Min	2114L, 2114L-3 Max	Unit	Conditions
I_{LI}	Input Load Current (All input pins)		10		10	μA	V_{IN} = 0 to 5.25V
I_{LO}	I/O Leakage Current		10		10	μA	$\overline{CS}$ = 2.0V, $V_{I/O}$ = 0.4V to V_{CC}
I_{CC1}	Power Supply Current		95		65	mA	V_{CC} = 5.25V, $I_{I/O}$ = 0 mA, $T_A = 25°C$
I_{CC2}	Power Supply Current		100		70	mA	V_{CC} = 5.25V, $I_{I/O}$ = 0 mA, $T_A = 0°C$
V_{IL}	Input Low Voltage	-0.5	0.8	-0.5	0.8	V	
V_{IH}	Input High Voltage	2.0	V_{CC}	2.0	V_{CC}	V	
V_{OL}	Output Low Voltage		0.4		0.4	V	I_{OL} = 3.2 mA
V_{OH}	Output High Voltage	2.4	V_{CC}	2.4	V_{CC}	V	I_{OH} = -1.0 mA

CAPACITANCE $T_A = 25°C$, f = 1.0 MHz

Symbol	Test	Typ	Max	Units
$C_{I/O}$	Input/Output Capacitance		5	pF
C_{IN}	Input Capacitance		5	pF

NOTE: This parameter is periodically sampled and not 100% tested.

A.C. CHARACTERISTICS $T_A = 0°C$ to $70°C$, $V_{CC} = 5V \pm 5\%$ (Unless Otherwise Specified)

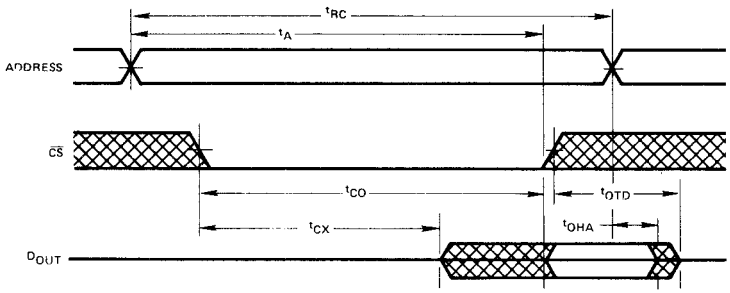
SYMBOL	PARAMETER	2114-3,2114L-3 MIN	2114-3,2114L-3 MAX	2114, 2114L MIN	2114, 2114L MAX	UNIT
READ CYCLE						
t_{RC}	Read Cycle Time	300		450		nsec
t_A	Access Time		300		450	nsec
t_{CO}	Chip Select to Output Valid		100		120	nsec
t_{CX}	Chip Select to Output Enabled	20		20		nsec
t_{OTD}	Chip Deselect to Output Off	0	80	0	100	nsec
t_{OHA}	Output Hold From Address Change	50		50		nsec
WRITE CYCLE						
t_{WC}	Write Cycle Time	300		450		nsec
t_{AW}	Address to Write Setup Time	0		0		nsec
t_W	Write Pulse Width	150		200		nsec
t_{WR}	Write Release Time	0		0		nsec
t_{OTW}	Write to Output Off	0	80	0	100	nsec
t_{DW}	Data to Write Overlap	150		200		nsec
t_{DH}	Data Hold	0		0		nsec

A.C. Test Conditions

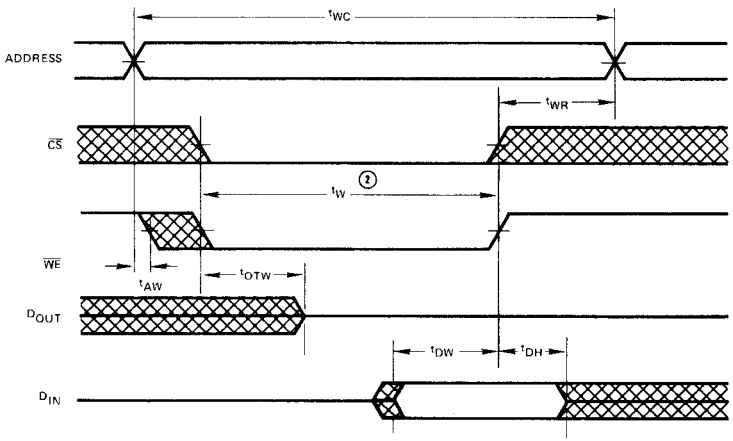
Input Pulse Levels . . . . . 0.8V to 2.0V
Input Rise and Fall Time . . . . . 10 n sec
Timing Measurement Levels: Input 1.5V
Output . . . . . 0.8 and 2.0V
Output Load . . . . . 1TTL Gate and 100pF

TIMING DIAGRAMS

Read Cycle ①



Write Cycle



NOTES:

① $\overline{WE}$ is high for a Read Cycle

② t_W is measured from the latter of $\overline{CS}$ or $\overline{WE}$ going low to the earlier of $\overline{CS}$ or $\overline{WE}$ going high.

DATA STORAGE

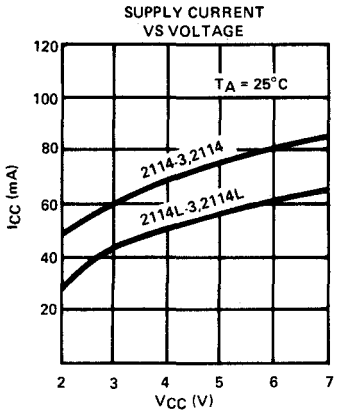
When $\overline{WE}$ is high, the data input buffers are inhibited to prevent erroneous data from being written into the array. As long as $\overline{WE}$ remains high, the data stored cannot be affected by the Address, Chip Select, or Data I/O logic levels or timing transitions.

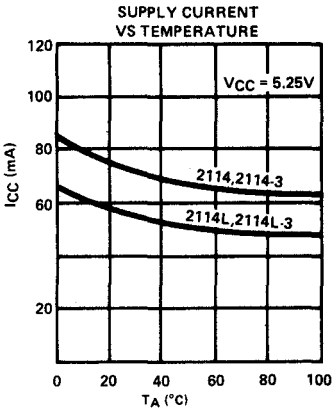
Data storage also cannot be affected by $\overline{WE}$, Addresses, or the I/O ports as long as $\overline{CS}$ is high. Either $\overline{CS}$ or $\overline{WE}$ or both can prevent extraneous writing due to signal transitions.

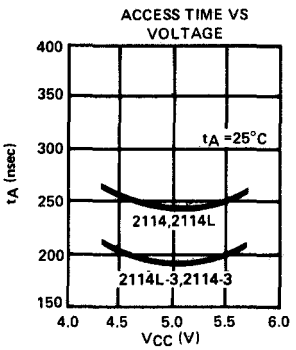
Data within the array can only be changed during Write time – defined as the overlap of $\overline{CS}$ low and $\overline{WE}$ low. The addresses must be properly established during the entire Write time plus t_{WR}.

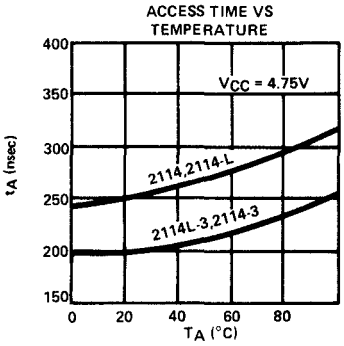
Internal delays are such that address decoding propagates ahead of data inputs and therefore no address setup time is required. If the Write time precedes the addresses, the data in previously addressed locations, or some other location, may be changed. Addresses must remain stable for the entire Write cycle but the Data Inputs may change. The data which is stable for t_{DW} at the end of the Write time will be written into the addressed location.

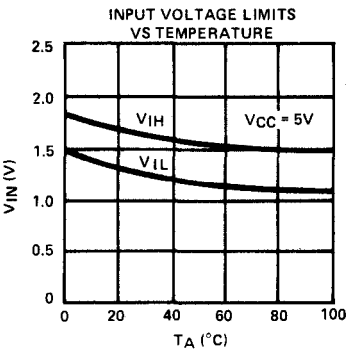
TYPICAL CHARACTERISTICS

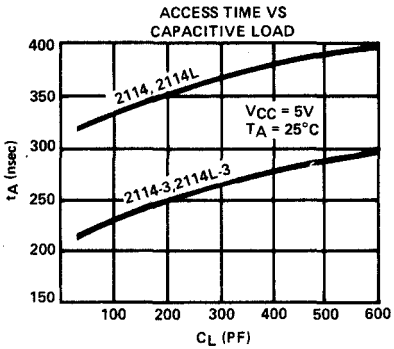






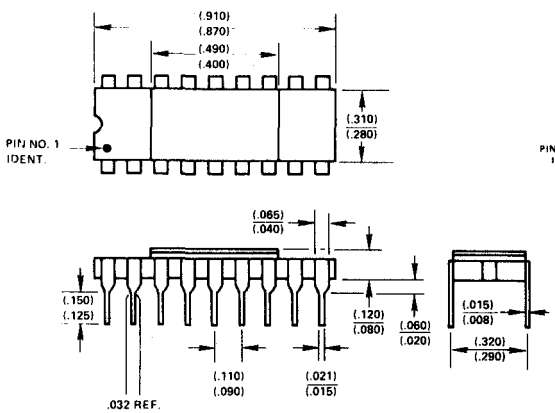




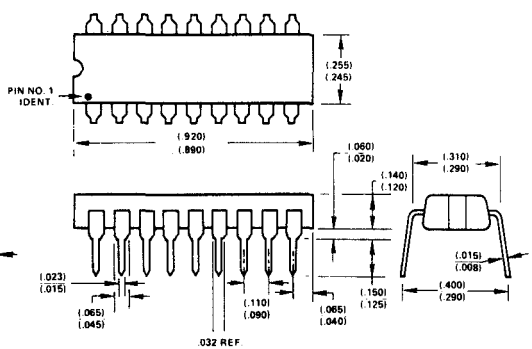


PACKAGE DIAGRAM

CERAMIC PACKAGE



MOLDED PACKAGE



SUPERMON Monitor Listing

```
LINE #  LOC     CODE        LINE

0002   0000                ;
0003   0000                ;*****
0004   0000                ;***** COPYRIGHT 1978 SYNERTEK SYSTEMS CORPORATION
0005   0000                ;*****
0006   0000                        *=$A600          ;SYS RAM (ECHOED AT TOP OF MEM)
0007   A600                SCPBUF  *=*+$20          ;SCOPE BUFFER LAST 32 CHRS
0008   A620                RAM     =*               ;DEFAULT BLK FILLS STARTING HERE
0009   A620                JTABLE  *=*+$10          ; 8JUMPS - ABS ADDR, LO HI ORDER
0010   A630                SCR0    *=*+1            ;RAM SCRATCH LOCS 0-F
0011   A631                SCR1    *=*+1
0012   A632                SCR2    *=*+1
0013   A633                SCR3    *=*+1
0014   A634                SCR4    *=*+1
0015   A635                SCR5    *=*+1
0016   A636                SCR6    *=*+1
0017   A637                SCR7    *=*+1
0018   A638                SCR8    *=*+1
0019   A639                SCR9    *=*+1
0020   A63A                SCRA    *=*+1
0021   A63B                SCRB    *=*+1
0022   A63C                SCRC    *=*+1
0023   A63D                SCRD    *=*+1
0024   A63E                RC      =SCRD
0025   A63E                SCRE    *=*+1
0026   A63F                SCRF    *=*+1
0027   A640                DISBUF  *=*+5            ;DISPLAY BUFFER
0028   A645                RDIG    *=*+1            ;RIGHT MOST DIGIT OF DISPLAY
0029   A646                        *=*+3            ;NOT USED
0030   A649                PARNR   *=*+1            ;NUMBER OF PARMS RECEIVED
0031   A64A                ;
0032   A64A                ; 3 16 BIT PARMS, LO HI ORDER
0033   A64A                ; PASSED TO EXECUTE BLOCKS
0034   A64A                ;
0035   A64A                P3L     *=*+1
0036   A64B                P3H     *=*+1
0037   A64C                P2L     *=*+1
0038   A64D                P2H     *=*+1
0039   A64E                P1L     *=*+1
0040   A64F                P1H     *=*+1
0041   A650                PADBIT  *=*+1            ;PAD BITS FOR CARRIAGE RETURN
0042   A651                SDBYT   *=*+1            ;SPEED BYTE FOR TERMINAL I/O
0043   A652                ERCNT   *=*+1            ; ERROR COUNT  (MAX $FF)
0044   A653                ; BIT 7 = ECHO /NO ECHO, BIT 6 = CTL O TOGGLE SW
0045   A653                TECHO   *=*+1            ;TERMINAL ECHO FLAG
0046   A654                ; BIT7 =CRT IN, 6 =TTY IN, 5 = TTY OUT, 4 = CRT OUT
0047   A654                TOUTFL  *=*+1            ;OUTPUT FLAGS
0048   A655                KSHFL   *=*+1            ;KEYBOARD SHIFT FLAG
0049   A656                TV      *=*+1            ;TRACE VELOCITY (O=SINGLE STEP)
0050   A657                LSTCOM  *=*+1            ;STORE LAST MONITOR COMMAND
0051   A658                MAXRC   *=*+1            ;MAX REC LENGTH FOR MEM DUMP
0052   A659                ;
0053   A659                ; USER REG'S FOLLOW
0054   A659                ;
0055   A659                PCLR    *=*+1            ;PROG CTR
0056   A65A                PCHR    *=*+1
```

```
LINE #  LOC      CODE        LINE

0057   A65B                SR      *=*+1           ;STACK
0058   A65C                FR      *=*+1           ;FLAGS
0059   A65D                AR      *=*+1           ;AREG
0060   A65E                XR      *=*+1           ;XREG
0061   A65F                YR      *=*+1           ;YREG
0062   A660                ;
0063   A660                ; I/O VECTORS FOLLOW
0064   A660                ;
0065   A660                INVEC   *=*+3           ;IN CHAR
0066   A663                OUTVEC  *=*+3           ;OUT CHAR
0067   A666                INSVEC  *=*+3           ;IN STATUS
0068   A669                        *=*+3           ;NOT USED
0069   A66C                URCVEC  *=*+3           ;UNRECOGNIZED CMD/ERROR VECTOR
0070   A66F                SCNVEC  *=*+3           ;SCAN ON-BOARD DISPLAY
0071   A672                ;
0072   A672                ; TRACE, INTERRUPT VECTORS
0073   A672                ;
0074   A672                EXEVEC  *=*+2           ; EXEC CMD ALTERNATE INVEC
0075   A674                TRCVEC  *=*+2           ;TRACE
0076   A676                UBRKVC  *=*+2           ;USER BRK AFTER MONITOR
0077   A678                UBRKV   =UBRKVC
0078   A678                UIRQVC  *=*+2           ;USER NON-BRK IRQ AFTER MONITOR
0079   A67A                UIRQV   =UIRQVC
0080   A67A                NMIVEC  *=*+2           ;NMI
0081   A67C                RSTVEC  *=*+2           ;RESET
0082   A67E                IRQVEC  *=*+2           ;IRQ
0083   A680                ;
0084   A680                ;
0085   A680                                        ;I/O REG DEFINITIONS
0086   A680                PADA    =$A400          ;KEYBOARD/DISPLAY
0087   A680                PBDA    =$A402          ;DATA DIRECTION FOR SAME
0088   A680                OR3A=$AC01              ;WP, DBON, DBOFF
0089   A680                DDR3A=OR3A+2            ;DATA DIRECTION FOR SAME
0090   A680                OR1B=$A000
0091   A680                DDR1B=$A002
0092   A680                PCR1    =$A00C          ; POR/TAPE REMOTE
0093   A680                ;
0094   A680                ; MONITOR MAINLINE
0095   A680                ;
0096   A680                        *=$8000
0097   8000  4C 7C 8B     MONITR  JMP MONENT      ;INIT S, CLD, GET ACCESS
0098   8003  20 FF 80      WARM    JSR GETCOM      ;GET COMMAND + PARMS  (0-3)
0099   8006  20 4A 81              JSR DISPAT      ;DISPATCH CMD,PARMS TO EXEC BLKS
0100   8009  20 71 81              JSR ERMSG       ;DISP ER MSG IF CARRY SET
0101   800C  4C 03 80              JMP WARM        ;AND CONTINUE
0102   800F                ;
0103   800F                ; TRACE AND INTERRUPT ROUTINES
0104   800F                ;
0105   800F  08            IRQBRK  PHP             ;IRQ OR BRK ?
0106   8010  48                    PHA
0107   8011  8A                    TXA
0108   8012  48                    PHA
0109   8013  BA                    TSX
0110   8014  BD 04 01              LDA $104,X      ;PICK UP FLAGS
0111   8017  29 10                 AND #$10
```

```
LINE # LOC      CODE        LINE

0112  8019  F0 07             BEQ DETIRQ
0113  801B  68          DETBRK PLA              ;BRK
0114  801C  AA                 TAX
0115  801D  68                 PLA
0116  801E  28                 PLP
0117  801F  6C F6 FF           JMP ($FFF6)
0118  8022  68          DETIRQ PLA              ;IRQ (NON BRK)
0119  8023  AA                 TAX
0120  8024  68                 PLA
0121  8025  28                 PLP
0122  8026  6C F8 FF           JMP ($FFF8)
0123  8029  20 86 8B    SVIRQ  JSR ACCESS       ;SAVE REGS AND DISPLAY CODE
0124  802C  38                 SEC
0125  802D  20 64 80           JSR SAVINT
0126  8030  A9 31               LDA #'1
0127  8032  4C 53 80           JMP IDISP
0128  8035  08          USRENT PHP              ;USER ENTRY
0129  8036  20 86 8B           JSR ACCESS
0130  8039  38                 SEC
0131  803A  20 64 80           JSR SAVINT
0132  803D  EE 59 A6           INC PCLR
0133  8040  D0 03              BNE *+5
0134  8042  EE 5A A6           INC PCHR
0135  8045  A9 33               LDA #'3
0136  8047  4C 53 80           JMP IDISP
0137  804A  20 86 8B    SVBRK  JSR ACCESS
0138  804D  18                 CLC
0139  804E  20 64 80           JSR SAVINT
0140  8051  A9 30               LDA #'0
0141  8053              ; INTRPT CODES      ;0 = BRK
0142  8053              ;                   1 = IRQ
0143  8053              ;                   2 = NMI
0144  8053              ;                   3 = USER ENTRY
0145  8053  48          IDISP  PHA              ;OUT PC, INTRPT CODE (FROM A)
0146  8054  20 D3 80           JSR DBOFF       ;STOP NMI'S
0147  8057  20 4D 83           JSR CRLF
0148  805A  20 37 83           JSR OPCCOM
0149  805D  68                 PLA
0150  805E  20 47 8A           JSR OUTCHR
0151  8061  4C 03 80           JMP WARM
0152  8064  8D 5D A6    SAVINT STA AR           ;SAVE USER REGS AFTER INTRPT
0153  8067  8E 5E A6           STX XR
0154  806A  8C 5F A6           STY YR
0155  806D  BA                 TSX
0156  806E  D8                 CLD
0157  806F  BD 04 01           LDA $104,X
0158  8072  69 FF              ADC #$FF
0159  8074  8D 59 A6           STA PCLR
0160  8077  BD 05 01           LDA $105,X
0161  807A  69 FF              ADC #$FF
0162  807C  8D 5A A6           STA PCHR
0163  807F  BD 03 01           LDA $103,X
0164  8082  8D 5C A6           STA FR
0165  8085  BD 02 01           LDA $102,X
0166  8088  9D 05 01           STA $105,X
```

```
LINE #  LOC    CODE        LINE

0167   808B  BD 01 01          LDA $101,X
0168   808E  9D 04 01          STA $104,X
0169   8091  E8               INX
0170   8092  E8               INX
0171   8093  E8               INX
0172   8094  9A               TXS
0173   8095  E8               INX
0174   8096  E8               INX
0175   8097  8E 5B A6          STX SR
0176   809A  60               RTS
0177   809B  20 86 8B   SVNMI  JSR ACCESS       ;TRACE IF TV NE 0
0178   809E  38               SEC
0179   809F  20 64 80          JSR SAVINT
0180   80A2  20 D3 80          JSR DBOFF        ;STOP NMI'S
0181   80A5  AD 56 A6          LDA TV
0182   80A8  D0 05             BNE TVNZ
0183   80AA  A9 32             LDA #'2
0184   80AC  4C 53 80          JMP IDISP
0185   80AF  20 37 83   TVNZ   JSR OPCCOM       ;TRACE WITH DELAY
0186   80B2  AD 5D A6          LDA AR
0187   80B5  20 4A 83          JSR OBCRLF       ;DISPLAY ACC
0188   80B8  20 5A 83          JSR DELAY
0189   80BB  90 10             BCC TRACON       ;STOP IF KEY ENTERED
0190   80BD  4C 03 80          JMP WARM
0191   80C0  20 86 8B   TRCOFF JSR ACCESS       ;DISABLE NMIS
0192   80C3  38               SEC
0193   80C4  20 64 80          JSR SAVINT
0194   80C7  20 D3 80          JSR DBOFF
0195   80CA  6C 74 A6          JMP (TRCVEC) AND GO TO SPECIAL TRACE
0196   80CD  20 E4 80   TRACON JSR DBON         ;ENABLE NMI'S
0197   80D0  4C FA 83          JMP GO1ENT       ;AND RESUME
0198   80D3  AD 01 AC   DBOFF  LDA OR3A         ;PULSE DEBUG OFF
0199   80D6  29 DF             AND #$DF
0200   80D8  09 10             ORA #$10
0201   80DA  8D 01 AC          STA OR3A
0202   80DD  AD 03 AC          LDA DDR3A
0203   80E0  09 30             ORA #$30
0204   80E2  D0 0F             BNE DBNEW-3      ;RELEASE FLIP FLOP SO KEY WORKS
0205   80E4  AD 01 AC   DBON   LDA OR3A         ;PULSE DEBUG ON
0206   80E7  29 EF             AND #$EF
0207   80E9  09 20             ORA #$20
0208   80EB  8D 01 AC          STA OR3A
0209   80EE  AD 03 AC          LDA DDR3A
0210   80F1  09 30             ORA #$30
0211   80F3  8D 03 AC          STA DDR3A
0212   80F6  AD 03 AC   DBNEW  LDA DDR3A        ;RELEASE FLIP FLOP
0213   80F9  29 CF             AND #$CF
0214   80FB  8D 03 AC          STA DDR3A
0215   80FE  60                RTS
0216   80FF                  ;
0217   80FF                  ; GETCOM - GET COMMAND AND 0-3 PARMS
0218   80FF                  ;
0219   80FF  20 4D 83   GETCOM JSR CRLF
0220   8102  A9 2E             LDA #'.          ;PROMPT
0221   8104  20 47 8A          JSR OUTCHR
```

```
LINE #  LOC    CODE        LINE

0222  8107  20 1B 8A  GETC1  JSR INCHR
0223  810A  F0 F3            BEQ GETCOM       ;CARRIAGE RETURN?
0224  810C  C9 7F            CMP #$7F         ;DELETE?
0225  810E  F0 F7            BEQ GETC1
0226  8110  C9 00            CMP #0           ;NULL?
0227  8112  F0 F3            BEQ GETC1
0228  8114                  ; L,S,U NEED TO BE HASHED 2 BYTES TO ONE
0229  8114  C9 53            CMP #'S
0230  8116  F0 1B            BEQ HASHUS
0231  8118  C9 55            CMP #'U
0232  811A  F0 17            BEQ HASHUS
0233  811C  C9 4C            CMP #'L
0234  811E  F0 0F            BEQ HASHL
0235  8120  8D 57 A6  STOCOM STA LSTCOM
0236  8123  20 42 83         JSR SPACE
0237  8126  20 08 82         JSR PSHOVE       ;ZERO PARMS
0238  8129  20 08 82         JSR PSHOVE
0239  812C  4C 20 82         JMP PARM        ;AND GO GET PARMS
0240  812F  A9 01      HASHL  LDA #$01         ;HASH LOAD CMDS TO ONE BYTE
0241  8131  10 02            BPL HASHUS+2
0242  8133  0A        HASHUS ASL A            ;HASH 'USER' CMDS TO ONE BYTE A
0243  8134  0A               ASL A            ;U0 = $14 THRU U7 =$1B
0244  8135  8D 57 A6         STA LSTCOM
0245  8138  20 1B 8A         JSR INCHR        ;GET SECOND
0246  813B  F0 C2            BEQ GETCOM       ;CARRIAGE RETURN?
0247  813D  18               CLC
0248  813E  6D 57 A6         ADC LSTCOM
0249  8141  29 0F            AND #$0F
0250  8143  09 10            ORA #$10
0251  8145  10 D9            BPL STOCOM
0252  8147  20 1B 8A         JSR INCHR
0253  814A                  ;
0254  814A                  ;DISPATCH TO EXEC BLK 0PARM, 1PARM, 2PARM, OR 3PARM
0255  814A                  ;
0256  814A  C9 0D      DISPAT CMP #$0D         ;C/R IF OK ELSE URCVEC
0257  814C  D0 20            BNE HIPN
0258  814E  AD 57 A6         LDA LSTCOM
0259  8151  AE 49 A6         LDX PARNR
0260  8154  D0 03            BNE M12
0261  8156  4C 95 83         JMP BZPARM       ;0 PARM BLOCK
0262  8159  E0 01      M12    CPX #$01
0263  815B  D0 03            BNE M13
0264  815D  4C DA 84         JMP B1PARM       ;1PARM BLOCK
0265  8160  E0 02      M13    CPX #$02
0266  8162  D0 03            BNE M14
0267  8164  4C 19 86         JMP B2PARM      ;2 PARM BLOCK
0268  8167  E0 03      M14    CPX #$03
0269  8169  D0 03            BNE HIPN
0270  816B  4C 14 87         JMP B3PARM      ;3 PARM BLOCK
0271  816E  6C 6D A6  HIPN   JMP (URCVEC+1)  ;ELSE UNREC COMMAND VECTOR
0272  8171                  ;
0273  8171                  ; ERMSG - PRINT ACC IN HEX IF CARRY SET
0274  8171                  ;
0275  8171  90 44      ERMSG  BCC M15
0276  8173  48               PHA
```

```
LINE #  LOC    CODE        LINE

0277  8174  20 40 83           JSR CRLF
0278  8177  A9 45              LDA #'E
0279  8179  20 47 8A           JSR OUTCHR
0280  817C  A9 52              LDA #'R
0281  817E  20 47 8A           JSR OUTCHR
0282  8181  20 42 83           JSR SPACE
0283  8184  68                 PLA
0284  8185  4C FA 82           JMP OUTBYT
0285  8188                 ;
0286  8188                 ; SAVER - SAVE ALL REG'S + FLAGS ON STACK
0287  8188                 ; RETURN WITH F,A,X,Y UNCHANGED
0288  8188                 ; STACK HAS          FLAGS,A,X,Y PUSHED
0289  8188  08            SAVER  PHP              ;
0290  8189  48                   PHA             ;
0291  818A  48                   PHA             ;
0292  818B  48                   PHA
0293  818C  08                   PHP
0294  818D  48                   PHA
0295  818E  8A                   TXA
0296  818F  48                   PHA
0297  8190  BA                   TSX
0298  8191  BD 09 01             LDA $0109,X
0299  8194  9D 05 01             STA $0105,X
0300  8197  BD 07 01             LDA $0107,X
0301  819A  9D 09 01             STA $0109,X
0302  819D  BD 01 01             LDA $0101,X
0303  81A0  9D 07 01             STA $0107,X
0304  81A3  BD 08 01             LDA $0108,X
0305  81A6  9D 04 01             STA $0104,X
0306  81A9  BD 06 01             LDA $0106,X
0307  81AC  9D 08 01             STA $0108,X
0308  81AF  98                   TYA
0309  81B0  9D 06 01             STA $0106,X
0310  81B3  68                   PLA
0311  81B4  AA                   TAX
0312  81B5  68                   PLA
0313  81B6  28                   PLP
0314  81B7  60            M15    RTS
0315  81B8                 ; RESTORE EXCEPT A,F
0316  81B8  08            RESXAF PHP
0317  81B9  BA                   TSX
0318  81BA  9D 04 01             STA $0104,X
0319  81BD  28                   PLP
0320  81BE                 ; RESTORE EXCEPT F
0321  81BE  08            RESXF  PHP
0322  81BF  68                   PLA
0323  81C0  BA                   TSX
0324  81C1  9D 04 01             STA $0104,X
0325  81C4                 ; RESTORE ALL 100%
0326  81C4  68            RESALL PLA
0327  81C5  A8                   TAY
0328  81C6  68                   PLA
0329  81C7  AA                   TAX
0330  81C8  68                   PLA
0331  81C9  28                   PLP
```

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LINE # LOC      CODE        LINE

0332  81CA  60                    RTS
0333  81CB                  ;
0334  81CB                  ; MONITOR UTILITIES
0335  81CB                  ;
0336  81CB  C9 20        ADVCK   CMP #$20          ;SPACE?
0337  81CD  F0 02                BEQ M1
0338  81CF  C9 3E                CMP #'>         ;FWD ARROW?
0339  81D1  38           M1      SEC
0340  81D2  60                    RTS
0341  81D3  20 FA 82     OBCMIN  JSR OUTBYT        ;OUT BYTE, OUT COMMA, IN BYTE
0342  81D6  20 3A 83     COMINB  JSR COMMA         ;OUT COMMA, IN BYTE
0343  81D9  20 1B 8A     INBYTE  JSR INCHR
0344  81DC  20 75 82             JSR ASCNIB
0345  81DF  B0 14                BCS OUT4
0346  81E1  0A                    ASL A
0347  81E2  0A                    ASL A
0348  81E3  0A                    ASL A
0349  81E4  0A                    ASL A
0350  81E5  8D 33 A6             STA SCR3
0351  81E8  20 1B 8A             JSR INCHR
0352  81EB  20 75 82             JSR ASCNIB
0353  81EE  B0 11                BCS OUT2
0354  81F0  0D 33 A6             ORA SCR3
0355  81F3  18           GOOD    CLC
0356  81F4  60                    RTS
0357  81F5  C9 27        OUT4    CMP #$27          ;SINGLE TIC ?
0358  81F7  D0 05                BNE OUT1
0359  81F9  20 1B 8A             JSR INCHR
0360  81FC  D0 F5                BNE GOOD          ;CARRIAGE RETURN?
0361  81FE  B8           OUT1    CLV
0362  81FF  50 03                BVC CRCHK
0363  8201  2C 04 82     OUT2    BIT CRCHK
0364  8204  C9 0D        CRCHK   CMP #$0D          ;CHECK FOR C/R
0365  8206  38                    SEC
0366  8207  60                    RTS
0367  8208  A2 10        PSHOVE  LDX #$10          ;PUSH PARMS DOWN
0368  820A  0E 4A A6     PRM10   ASL P3L
0369  820D  2E 4B A6             ROL P3H
0370  8210  2E 4C A6             ROL P2L
0371  8213  2E 4D A6             ROL P2H
0372  8216  2E 4E A6             ROL P1L
0373  8219  2E 4F A6             ROL P1H
0374  821C  CA                    DEX
0375  821D  D0 EB                BNE PRM10
0376  821F  60                    RTS
0377  8220  20 88 81     PARM    JSR SAVER         ;GET PARMS - RETURN ON C/R OR ERR
0378  8223  A9 00                LDA #0
0379  8225  8D 49 A6             STA PARNR
0380  8228  8D 33 A6             STA SCR3
0381  822B  20 08 82     PM1     JSR PSHOVE
0382  822E  20 1B 8A     PARFIL  JSR INCHR
0383  8231  C9 2C                CMP #',           ;VALID DELIMITERS - ,
0384  8233  F0 04                BEQ M21
0385  8235  C9 2D                CMP #'-
0386  8237  D0 11                BNE M22
```

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LINE # LOC      CODE        LINE

0387  8239  A2 FF        M21     LDX #$FF
0388  823B  8E 33 A6              STX SCR3
0389  823E  EE 49 A6              INC PARNR
0390  8241  AE 49 A6              LDX PARNR
0391  8244  E0 03                 CPX #$03
0392  8246  D0 E3                 BNE PM1
0393  8248  F0 1D                 BEQ M24
0394  824A  20 75 82     M22     JSR ASCNIB
0395  824D  B0 18                 BCS M24
0396  824F  A2 04                 LDX #4
0397  8251  0E 4A A6     M23     ASL P3L
0398  8254  2E 4B A6              ROL P3H
0399  8257  CA                    DEX
0400  8258  D0 F7                 BNE M23
0401  825A  0D 4A A6              ORA P3L
0402  825D  8D 4A A6              STA P3L
0403  8260  A9 FF                 LDA #$FF
0404  8262  8D 33 A6              STA SCR3
0405  8265  D0 C7                 BNE PARFIL
0406  8267  2C 33 A6     M24     BIT SCR3
0407  826A  F0 03                 BEQ M25
0408  826C  EE 49 A6              INC PARNR
0409  826F  C9 0D        M25     CMP #$0D
0410  8271  18                    CLC
0411  8272  4C B8 81              JMP RESXAF
0412  8275  C9 0D        ASCNIB  CMP #$0D        ;C/R?
0413  8277  F0 19                 BEQ M29
0414  8279  C9 30                 CMP #'0
0415  827B  90 0C                 BCC M26
0416  827D  C9 47                 CMP #'G
0417  827F  B0 08                 BCS M26
0418  8281  C9 41                 CMP #'A
0419  8283  B0 08                 BCS M27
0420  8285  C9 3A                 CMP #':
0421  8287  90 06                 BCC M28
0422  8289  C9 30        M26     CMP #'0
0423  828B  38                    SEC             ;CARRY SET - NON HEX
0424  828C  60                    RTS
0425  828D  E9 37        M27     SBC #$37
0426  828F  29 0F        M28     AND #$0F
0427  8291  18                    CLC
0428  8292  60          M29     RTS
0429  8293  EE 4A A6     INCP3   INC P3L         ;INCREMENT P3 (16 BITS)
0430  8296  D0 03                 BNE *+5
0431  8298  EE 4B A6              INC P3H
0432  829B  60                    RTS
0433  829C  AE 4D A6     P2SCR   LDX P2H         ;MOVE P2 TO FE,FF
0434  829F  86 FF                 STX $FF
0435  82A1  AE 4C A6              LDX P2L
0436  82A4  86 FE                 STX $FE
0437  82A6  60                    RTS
0438  82A7  AE 4B A6     P3SCR   LDX P3H         ;MOVE P3 TO FE,FF
0439  82AA  86 FF                 STX $FF
0440  82AC  AE 4A A6              LDX P3L
0441  82AF  86 FE                 STX $FE
```

```
LINE # LOC     CODE        LINE

0442  82B1  60                    RTS
0443  82B2  E6 FE        INCCMP  INC $FE          ;INCREM FE,FF, COMPARE TO P3
0444  82B4  D0 14                BNE COMPAR
0445  82B6  E6 FF                INC $FF
0446  82B8  D0 10        WRAP    BNE COMPAR       ;TEST FOR WRAP AROUND
0447  82BA  2C BD 82              BIT EXWRAP
0448  82BD  60           EXWRAP  RTS
0449  82BE  A5 FE        DECCMP  LDA $FE          ;DECREM FE,FF AND COMPARE TO P3
0450  82C0  D0 06                BNE M32
0451  82C2  A5 FF                LDA $FF
0452  82C4  F0 F2                BEQ WRAP
0453  82C6  C6 FF                DEC $FF
0454  82C8  C6 FE        M32     DEC $FE
0455  82CA  20 88 81     COMPAR  JSR SAVER        ;COMPARE FE,FF TO P3
0456  82CD  A5 FF                LDA $FF
0457  82CF  CD 4B A6              CMP P3H
0458  82D2  D0 05                BNE EXITCP
0459  82D4  A5 FE                LDA $FE
0460  82D6  CD 4A A6              CMP P3L
0461  82D9  B8           EXITCP  CLV
0462  82DA  4C BE 81              JMP RESXF
0463  82DD  08           CHKSAD  PHP              ;16 BIT CKSUM IN SCR6,7
0464  82DE  48                    PHA
0465  82DF  18                    CLC
0466  82E0  6D 36 A6              ADC SCR6
0467  82E3  8D 36 A6              STA SCR6
0468  82E6  90 03                 BCC M33
0469  82E8  EE 37 A6              INC SCR7
0470  82EB  68           M33     PLA
0471  82EC  28                    PLP
0472  82ED  60                    RTS
0473  82EE  AD 59 A6     OUTPC   LDA PCLR         ;OUTPUT PC
0474  82F1  AE 5A A6              LDX PCHR
0475  82F4  48           OUTXAH  PHA
0476  82F5  8A                    TXA
0477  82F6  20 FA 82              JSR OUTBYT
0478  82F9  68                    PLA
0479  82FA  48           OUTBYT  PHA              ;OUTPUT 2 HEX DIGS FROM A
0480  82FB  48                    PHA
0481  82FC  4A                    LSR A
0482  82FD  4A                    LSR A
0483  82FE  4A                    LSR A
0484  82FF  4A                    LSR A
0485  8300  20 44 8A              JSR NBASOC
0486  8303  68                    PLA
0487  8304  20 44 8A              JSR NBASOC
0488  8307  68                    PLA
0489  8308  60                    RTS
0490  8309  29 0F        NIBASC  AND #$0F         ;NIBBLE IN A TO ASCII IN A
0491  830B  C9 0A                CMP #$0A
0492  830D  B0 04                BCS NIBALF
0493  830F  69 30                ADC #$30
0494  8311  90 02                BCC EXITNB
0495  8313  69 36        NIBALF  ADC #$36
0496  8315  60           EXITNB  RTS
```

```
LINE #  LOC    CODE        LINE

0497   8316  20 4D 83    CRLFSZ JSR CRLF          ;PRINT CRLF, FF, FE
0498   8319  A6 FF       OUTSZ  LDX $FF
0499   831B  A5 FE              LDA $FE
0500   831D  4C F4 82           JMP OUTXAH
0501   8320  A9 3F       OUTQM  LDA #'?
0502   8322  4C 47 8A           JMP OUTCHR
0503   8325  20 3A 83    OCMCK  JSR COMMA         ;OUT COMMA, CKSUM LO
0504   8328  AD 36 A6           LDA SCR6
0505   832B  4C FA 82           JMP OUTBYT
0506   832E  A9 00       ZERCK  LDA #0            ;INIT CHECKSUM
0507   8330  8D 36 A6           STA SCR6
0508   8333  8D 37 A6           STA SCR7
0509   8336  60                 RTS
0510   8337  20 EE 82    OPCCOM JSR OUTPC         ;PC OUT, COMMA OUT
0511   833A  48          COMMA  PHA               ;COMMA OUT
0512   833B  A9 2C              LDA #',
0513   833D  D0 06              BNE SPCP3
0514   833F  20 42 83    SPC2   JSR SPACE         ;2 SPACES OUT
0515   8342  48          SPACE  PHA               ;1 SPACE OUT
0516   8343  A9 20              LDA #$20
0517   8345  20 47 8A    SPCP3  JSR OUTCHR
0518   8348  68                 PLA
0519   8349  60                 RTS
0520   834A  20 FA 82    OBCRLF JSR OUTBYT        ;BYTE OUT, CRLF OUT
0521   834D  48          CRLF   PHA
0522   834E  A9 0D              LDA #$0D
0523   8350  20 47 8A           JSR OUTCHR
0524   8353  A9 0A              LDA #$0A        ;LINE FEED
0525   8355  20 47 8A           JSR OUTCHR
0526   8358  68                 PLA
0527   8359  60                 RTS
0528   835A  AE 56 A6    DELAY  LDX TV            ;DELAY DEPENDS ON TV
0529   835D  20 88 81    DL1    JSR SAVER
0530   8360  A9 FF              LDA #$FF
0531   8362  8D 39 A6           STA SCR9
0532   8365  8D 38 A6           STA SCR8
0533   8368  0E 38 A6    DLY1   ASL SCR8
0534   836B  2E 39 A6           ROL SCR9
0535   836E  CA                 DEX
0536   836F  D0 F7              BNE DLY1
0537   8371  20 03 89    DLY2   JSR IJSCNV       ;SCAN DISPLAY
0538   8374  20 86 83           JSR INSTAT       ;SEE IF KEY DOWN
0539   8377  B0 0A              BCS DLYO
0540   8379  EE 38 A6           INC SCR8
0541   837C  D0 03              BNE *+5
0542   837E  EE 39 A6           INC SCR9
0543   8381  D0 EE              BNE DLY2
0544   8383  4C BE 81    DLYO   JMP RESXF
0545   8386                     ; INSTAT - SEE IF KEY DOWN, RESULT IN CARRY
0546   8386                     ; KYSTAT, TSTAT RETURN IMMEDIATELY W/STATUS
0547   8386                     ; INSTAT WAITS FOR RELEASE
0548   8386  20 92 83    INSTAT JSR INJISV
0549   8389  90 06              BCC INST2
0550   838B  20 92 83    INST1  JSR INJISV
0551   838E  B0 FB              BCS INST1
```

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LINE # LOC      CODE        LINE

0552  8390  38              SEC
0553  8391  60          INST2  RTS
0554  8392  6C 67 A6     INJISV JMP (INSVEC+1)
0555  8395              ;
0556  8395              ;
0557  8395              ; *** EXECUTE BLOCKS BEGIN HERE
0558  8395              ;
0559  8395              BZPARM=*
0560  8395              ; ZERO PARM COMMANDS
0561  8395              ;
0562  8395  C9 52        REGZ   CMP #'R          ;DISP REGISTERS
0563  8397  D0 5A              BNE GOZ         ;PC,S,F,A,X,Y
0564  8399  20 4D 83     RGBACK JSR CRLF
0565  839C  A9 50              LDA #'P
0566  839E  20 47 8A           JSR OUTCHR
0567  83A1  20 42 83           JSR SPACE
0568  83A4  20 EE 82           JSR OUTPC
0569  83A7  20 D6 81           JSR COMINB
0570  83AA  B0 13              BCS NH3
0571  83AC  8D 34 A6           STA SCR4
0572  83AF  20 D9 81           JSR INBYTE
0573  83B2  B0 0B              BCS NH3
0574  83B4  8D 59 A6           STA PCLR
0575  83B7  AD 34 A6           LDA SCR4
0576  83BA  8D 5A A6           STA PCHR
0577  83BD  90 09              BCC M34
0578  83BF  D0 02        NH3    BNE NOTCR
0579  83C1  18           EXITRG CLC
0580  83C2  60           EXRGP1 RTS
0581  83C3  20 CB 81     NOTCR  JSR ADVCK
0582  83C6  D0 FA              BNE EXRGP1
0583  83C8  A0 00        M34    LDY #0
0584  83CA  C8           M35    INY
0585  83CB  C0 06              CPY #6
0586  83CD  F0 CA              BEQ RGBACK
0587  83CF  20 4D 83           JSR CRLF
0588  83D2  A9 52        NXTRG  LDA #'R
0589  83D4  20 47 8A           JSR OUTCHR
0590  83D7  98                 TYA
0591  83D8  20 44 8A           JSR NBASOC
0592  83DB  20 3F 83           JSR SPC2
0593  83DE  B9 5A A6           LDA PCHR,Y
0594  83E1  20 D3 81           JSR OBCMIN
0595  83E4  B0 05              BCS M36
0596  83E6  99 5A A6           STA PCHR,Y
0597  83E9  90 DF              BCC M35
0598  83EB  F0 D4        M36    BEQ EXITRG
0599  83ED  20 CB 81           JSR ADVCK
0600  83F0  F0 D8              BEQ M35
0601  83F2  60                 RTS
0602  83F3  C9 47        GOZ    CMP #$47
0603  83F5  D0 20              BNE LPZB
0604  83F7  20 4D 83     GO2    JSR CRLF
0605  83FA  20 9C 8B     GO1ENT JSR NACCES       ;WRITE PROT MONITR RAM
0606  83FD  AE 5B A6           LDX SR            ;RESTORE REGS
```

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LINE # LOC      CODE        LINE

0607  8400  9A              TXS
0608  8401  AD 5A A6        LDA PCHR
0609  8404  48              PHA
0610  8405  AD 59 A6        LDA PCLR
0611  8408  48        NR10  PHA
0612  8409  AD 5C A6        LDA FR
0613  840C  48              PHA
0614  840D  AC 5F A6        LDY YR
0615  8410  AE 5E A6        LDX XR
0616  8413  AD 5D A6        LDA AR
0617  8416  40              RTI
0618  8417  C9 11     LPZB  CMP #$11        ;LOAD PAPER TAPE
0619  8419  F0 03           BEQ *+5
0620  841B  4C A7 84        JMP DEPZ
0621  841E  20 88 81        JSR SAVER
0622  8421  20 4D 83        JSR CRLF
0623  8424  A9 00           LDA #0
0624  8426  8D 52 A6        STA ERCNT
0625  8429  20 2E 83  LPZ    JSR ZERCK
0626  842C  20 1B 8A  LP1    JSR INCHR
0627  842F  C9 3B           CMP #$3B
0628  8431  D0 F9           BNE LP1
0629  8433  20 A1 84        JSR LDBYTE
0630  8436  B0 56           BCS TAPERR
0631  8438  D0 09           BNE NUREC
0632  843A  AD 52 A6        LDA ERCNT       ;ERRORS ?
0633  843D  F0 01           BEQ *+3
0634  843F  38        EXITLP SEC
0635  8440  4C BE 81        JMP RESXF
0636  8443  8D 3D A6  NUREC  STA RC
0637  8446  20 A1 84        JSR LDBYTE
0638  8449  B0 43           BCS TAPERR
0639  844B  85 FF           STA $FF
0640  844D  20 A1 84        JSR LDBYTE
0641  8450  B0 D7           BCS LPZ
0642  8452  85 FE           STA $FE
0643  8454  20 A1 84  MORED  JSR LDBYTE
0644  8457  B0 35           BCS TAPERR
0645  8459  A0 00           LDY #0
0646  845B  91 FE           STA ($FE),Y
0647  845D  D1 FE           CMP ($FE),Y
0648  845F  F0 0C           BEQ LPGD
0649  8461  AD 52 A6        LDA ERCNT
0650  8464  29 0F           AND #$0F
0651  8466  C9 0F           CMP #$0F
0652  8468  F0 03           BEQ *+5
0653  846A  EE 52 A6        INC ERCNT
0654  846D  20 B2 82  LPGD   JSR INCCMP
0655  8470  CE 3D A6        DEC RC
0656  8473  D0 DF           BNE MORED
0657  8475  20 D9 81        JSR INBYTE
0658  8478  B0 14           BCS TAPERR
0659  847A  CD 37 A6        CMP SCR7
0660  847D  D0 0C           BNE BADDY
0661  847F  20 D9 81        JSR INBYTE
```

```
LINE # LOC      CODE        LINE

0662  8482  B0 0A           BCS TAPERR
0663  8484  CD 36 A6        CMP SCR6
0664  8487  F0 A0           BEQ LPZ
0665  8489  D0 03           BNE TAPERR      ;(ALWAYS)
0666  848B  20 D9 81  BADDY  JSR INBYTE
0667  848E  AD 52 A6  TAPERR LDA ERCNT
0668  8491  29 F0           AND #$F0
0669  8493  C9 F0           CMP #$F0
0670  8495  F0 92           BEQ LPZ
0671  8497  AD 52 A6        LDA ERCNT
0672  849A  69 10           ADC #$10
0673  849C  8D 52 A6        STA ERCNT
0674  849F  D0 88           BNE LPZ
0675  84A1  20 D9 81  LDBYTE JSR INBYTE
0676  84A4  4C DD 82        JMP CHKSAD
0677  84A7  C9 44     DEPZ   CMP #'D         ;DEPOSIT, 0 PARM - USE (OLD)
0678  84A9  D0 03           BNE MEMZ
0679  84AB  4C E1 84        JMP NEWLN
0680  84AE  C9 4D     MEMZ   CMP #'M         ;MEM, 0 PARM - USE (OLD)
0681  84B0  D0 03           BNE VERZ
0682  84B2  4C 17 85        JMP NEWLOC
0683  84B5  C9 56     VERZ   CMP #'V         ;VERIFY, 0 PARM - USE (OLD)
0684  84B7  D0 0D           BNE L1ZB        ; ... DO 8 BYTES (LIKE VER 1 PARM
0685  84B9  A5 FE           LDA $FE
0686  84BB  8D 4A A6        STA P3L
0687  84BE  A5 FF           LDA $FF
0688  84C0  8D 4B A6        STA P3H
0689  84C3  4C 9A 85        JMP VER1+4
0690  84C6  C9 12     L1ZB   CMP #$12        ;LOAD KIM, ZERO PARM
0691  84C8  D0 05           BNE L2ZB
0692  84CA  A0 00           LDY #0          ;MODE = KIM
0693  84CC  4C 78 8C  L1J    JMP LENTRY      ;GO TO CASSETTE ROUTINE
0694  84CF  C9 13     L2ZB   CMP #$13        ;LOAD HS, ZERO PARM
0695  84D1  D0 04           BNE EZPARM
0696  84D3  A0 80           LDY #$80        ;MODE = HS
0697  84D5  D0 F5           BNE L1J         ;(ALWAYS)
0698  84D7  6C 6D A6  EZPARM JMP (URCVEC+1) ; ... ELSE UNREC CMD
0699  84DA           B1PARM=*
0700  84DA           ;
0701  84DA           ; 1 PARAMETER COMMAND EXEC BLOCKS
0702  84DA           ;
0703  84DA  C9 44     DEP1   CMP #'D         ;DEPOSIT, 1 PARM
0704  84DC  D0 32           BNE MEM1
0705  84DE  20 A7 82        JSR P3SCR
0706  84E1  20 16 83  NEWLN  JSR CRLFSZ
0707  84E4  A0 00           LDY #0
0708  84E6  A2 08           LDX #$8
0709  84E8  20 42 83  DEPBYT JSR SPACE
0710  84EB  20 D9 81        JSR INBYTE
0711  84EE  B0 11           BCS NH41
0712  84F0  91 FE           STA ($FE),Y
0713  84F2  D1 FE           CMP ($FE),Y     ;VERIFY
0714  84F4  F0 03           BEQ DEPN
0715  84F6  20 20 83        JSR OUTQM       ;TYPE ? IF NG
0716  84F9  20 B2 82  DEPN   JSR INCCMP
```

```
LINE #  LOC    CODE        LINE

0717  84FC  CA            DEX
0718  84FD  D0 E9         BNE DEPBYT
0719  84FF  F0 E0         BEQ NEWLN
0720  8501  F0 0B    NH41 BEQ DEPEC
0721  8503  C9 20         CMP #$20        ;SPACE = FWD
0722  8505  D0 4C         BNE DEPES
0723  8507  70 F0         BVS DEPN
0724  8509  20 42 83      JSR SPACE
0725  850C  10 EB         BPL DEPN
0726  850E  18      DEPEC CLC
0727  850F  60            RTS
0728  8510  C9 4D    MEM1 CMP #'M         ;MEMORY, 1 PARM
0729  8512  D0 65         BNE G01
0730  8514  20 A7 82      JSR P3SCR
0731  8517  20 16 83 NEWLOC JSR CRLFSZ
0732  851A  20 3A 83      JSR COMMA
0733  851D  A0 00         LDY #0
0734  851F  B1 FE         LDA ($FE),Y
0735  8521  20 D3 81      JSR OBCMIN
0736  8524  B0 11         BCS NH42
0737  8526  A0 00         LDY #0
0738  8528  91 FE         STA ($FE),Y
0739  852A  D1 FE         CMP ($FE),Y     ;VERIFY MEM
0740  852C  F0 03         BEQ NXTLOC
0741  852E  20 20 83      JSR OUTQM       ;TYPE ? AND CONTINUE
0742  8531  20 B2 82 NXTLOC JSR INCCMP
0743  8534  18            CLC
0744  8535  90 E0         BCC NEWLOC
0745  8537  F0 3E    NH42 BEQ EXITM1
0746  8539  50 04         BVC *+6
0747  853B  C9 3C         CMP #'<
0748  853D  F0 D8         BEQ NEWLOC
0749  853F  C9 20         CMP #$20       ;SPACE ?
0750  8541  F0 EE         BEQ NXTLOC
0751  8543  C9 3E         CMP #'>
0752  8545  F0 EA         BEQ NXTLOC
0753  8547  C9 2B         CMP #'+
0754  8549  F0 10         BEQ LOCP8
0755  854B  C9 3C         CMP #'<
0756  854D  F0 06         BEQ PRVLOC
0757  854F  C9 2D         CMP #'-
0758  8551  F0 16         BEQ LOCM8
0759  8553  38      DEPES SEC
0760  8554  60            RTS
0761  8555  20 BE 82 PRVLOC JSR DECCMP      ;BACK ONE BYT
0762  8558  18            CLC
0763  8559  90 BC         BCC NEWLOC
0764  855B  A5 FE    LOCP8 LDA $FE          ;GO FWD 8 BYTES
0765  855D  18            CLC
0766  855E  69 08         ADC #$08
0767  8560  85 FE         STA $FE
0768  8562  90 02         BCC M42
0769  8564  E6 FF         INC $FF
0770  8566  18      M42   CLC
0771  8567  90 AE         BCC NEWLOC
```

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LINE # LOC      CODE        LINE

0772  8569  A5 FE        LOCM8  LDA $FE          ; GO BACKWD 8 BYTES
0773  856B  38                  SEC
0774  856C  E9 08               SBC #$08
0775  856E  85 FE               STA $FE
0776  8570  B0 02               BCS M43
0777  8572  C6 FF               DEC $FF
0778  8574  18           M43    CLC
0779  8575  90 A0               BCC NEWLOC
0780  8577  18           EXITM1 CLC
0781  8578  60                  RTS
0782  8579  C9 47         G01    CMP #'G          ; GO, 1 PARM (RTRN ADDR ON STK)
0783  857B  D0 19               BNE VER1         ...  PARM IS ADDR TO GO TO
0784  857D  20 4D 83            JSR CRLF
0785  8580  20 9C 8B            JSR NACCES       ;WRITE PROT MONITR RAM
0786  8583  A2 FF               LDX #$FF         ;PUSH RETURN ADDR
0787  8585  9A                  TXS
0788  8586  A9 7F               LDA #$7F
0789  8588  48                  PHA
0790  8589  A9 FF               LDA #$FF
0791  858B  48                  PHA
0792  858C  AD 4B A6            LDA P3H
0793  858F  48                  PHA
0794  8590  AD 4A A6            LDA P3L
0795  8593  4C 08 84            JMP NR10
0796  8596  C9 56         VER1   CMP #'V          ;VERIFY, 1 PARM (8 BYTES, CKSUM)
0797  8598  D0 1A               BNE JUMP1
0798  859A  AD 4A A6            LDA P3L
0799  859D  8D 4C A6            STA P2L
0800  85A0  18                  CLC
0801  85A1  69 07               ADC #$07
0802  85A3  8D 4A A6            STA P3L
0803  85A6  AD 4B A6            LDA P3H
0804  85A9  8D 4D A6            STA P2H
0805  85AC  69 00               ADC #0
0806  85AE  8D 4B A6            STA P3H
0807  85B1  4C 40 86            JMP VER2+4
0808  85B4  C9 4A         JUMP1  CMP #'J          ;JUMP (JUMP TABLE IN SYS RAM)
0809  85B6  D0 1F               BNE L11B
0810  85B8  AD 4A A6            LDA P3L
0811  85BB  C9 08               CMP #$8          ; 0-7 ONLY VALID
0812  85BD  B0 26               BCS JUM2
0813  85BF  20 9C 8B            JSR NACCES       ;WRITE PROT SYS RAM
0814  85C2  0A                  ASL A
0815  85C3  A8                  TAY
0816  85C4  A2 FF               LDX #$FF         ;INIT STK PTR
0817  85C6  9A                  TXS
0818  85C7  A9 7F               LDA #$7F         ;PUSH COLD RETURN
0819  85C9  48                  PHA
0820  85CA  A9 FF               LDA #$FF
0821  85CC  48                  PHA
0822  85CD  B9 21 A6            LDA JTABLE+1,Y   ;GET ADDR FROM TABLE
0823  85D0  48                  PHA              ;PUSH ON STACK
0824  85D1  B9 20 A6            LDA JTABLE,Y
0825  85D4  4C 08 84            JMP NR10         ;LOAD UP USER REG'S AND RTI
0826  85D7  C9 12         L11B   CMP #$12         ;LOAD KIM FMT, 1 PARM
```

```
LINE #  LOC    CODE        LINE

0827   85D9  D0 14           BNE L21B
0828   85DB  A0 00           LDY #0          ;MODE = KIM
0829   85DD  AD 4A A6  L11C   LDA P3L
0830   85E0  C9 FF           CMP #$FF        ; ID MUST NOT BE FF
0831   85E2  D0 02           BNE *+4
0832   85E4  38              SEC
0833   85E5  60        JUM2   RTS
0834   85E6  20 08 82         JSR PSHOVE      ;FIX PARM POSITION
0835   85E9  20 08 82  L11D   JSR PSHOVE
0836   85EC  4C 78 8C         JMP LENTRY
0837   85EF  C9 13     L21B   CMP #$13        ;LOAD TAPE, HS FMT, 1 PARM
0838   85F1  D0 04           BNE WPR1B
0839   85F3  A0 80           LDY #$80        ;MODE = HS
0840   85F5  D0 E6           BNE L11C
0841   85F7  C9 57     WPR1B  CMP #'W         ;WRITE PROT USER RAM
0842   85F9  D0 1B           BNE E1PARM
0843   85FB  AD 4A A6         LDA P3L         ; FIRST DIG IS 1K ABOVE 0,
0844   85FE  29 11           AND #$11        ; SECOND IS 2K ABOVE 0
0845   8600  C9 08           CMP #8          ; THIRD IS 3K ABOVE 0.
0846   8602  2A              ROL A
0847   8603  4E 4B A6         LSR P3H
0848   8606  2A              ROL A
0849   8607  0A              ASL A
0850   8608  29 0F           AND #$0F
0851   860A  49 0F           EOR #$0F        ;0 IS PROTECT
0852   860C  8D 01 AC         STA DR3A
0853   860F  A9 0F           LDA #$0F
0854   8611  8D 03 AC         STA DDR3A
0855   8614  18              CLC
0856   8615  60              RTS
0857   8616  4C 27 88  E1PARM JMP CALC3
0858   8619           B2PARM=*
0859   8619           ;
0860   8619           ; 2 PARAMETER EXEC BLOCKS
0861   8619           ;
0862   8619  C9 10     STD2   CMP #$10        ;STORE DOUBLE BYTE
0863   861B  D0 12           BNE MEM2
0864   861D  20 A7 82         JSR P3SCR
0865   8620  AD 4D A6         LDA P2H
0866   8623  A0 01           LDY #1
0867   8625  91 FE           STA ($FE),Y
0868   8627  88              DEY
0869   8628  AD 4C A6         LDA P2L
0870   862B  91 FE           STA ($FE),Y
0871   862D  18              CLC
0872   862E  60              RTS
0873   862F  C9 4D     MEM2   CMP #'M         ;CONTINUE MEM SEARCH W/OLD PTR
0874   8631  D0 09           BNE VER2
0875   8633  AD 4C A6         LDA P2L
0876   8636  8D 4E A6         STA P1L
0877   8639  4C 08 88         JMP MEM3C
0878   863C  C9 56     VER2   CMP #'V         ;VERIFY MEM W/CHKSUMS , 2 PARM
0879   863E  D0 48           BNE L12B
0880   8640  20 9C 82         JSR P2SCR
0881   8643  20 2E 83         JSR ZERCK
```

```
LINE #  LOC    CODE        LINE

0882  8646  20 16 83    VADDR  JSR CRLFSZ
0883  8649  A2 08              LDX #8
0884  864B  20 42 83    V2     JSR SPACE
0885  864E  A0 00              LDY #0
0886  8650  B1 FE              LDA ($FE),Y
0887  8652  20 DD 82           JSR CHKSAD
0888  8655  20 FA 82           JSR OUTBYT
0889  8658  20 B2 82           JSR INCCMP
0890  865B  70 10              BVS V1
0891  865D  F0 02              BEQ *+4
0892  865F  B0 0C              BCS V1
0893  8661  CA                 DEX
0894  8662  D0 E7              BNE V2
0895  8664  20 25 83    VOCK   JSR OCMCK
0896  8667  20 86 83           JSR INSTAT
0897  866A  90 DA              BCC VADDR
0898  866C  60                 RTS
0899  866D  20 BE 82    V1     JSR DECCMP
0900  8670  E0 08              CPX #8
0901  8672  F0 03              BEQ *+5
0902  8674  E8                 INX
0903  8675  10 F6              BPL V1
0904  8677  20 25 83           JSR OCMCK
0905  867A  20 4D 83           JSR CRLF
0906  867D  20 42 83           JSR SPACE
0907  8680  AE 37 A6           LDX SCR7
0908  8683  20 F4 82           JSR OUTXAH
0909  8686  18                 CLC
0910  8687  60                 RTS
0911  8688  C9 12       L12B   CMP #$12          ;LOAD KIM FMT TAPE, 2 PARMS
0912  868A  D0 0C              BNE SP2B
0913  868C  AD 4C A6    L12C   LDA P2L
0914  868F  C9 FF              CMP #$FF          ;ID MUST BE FF
0915  8691  D0 F4              BNE L12B-1        ;ERR
0916  8693  A0 00              LDY #0            ;MODE = HS
0917  8695  4C E9 85           JMP L11D
0918  8698  C9 1C       SP2B   CMP #$1C          ;SAVE PAPER TAPE, 2 PARMS
0919  869A  D0 75              BNE E2PARM
0920  869C  18                 CLC
0921  869D  20 88 81           JSR SAVER
0922  86A0  20 9C 82           JSR P2SCR
0923  86A3  20 FA 86    SP2C   JSR DIFFZ
0924  86A6  B0 03              BCS SP2D
0925  86A8  4C C4 81    SPEXIT JMP RESALL
0926  86AB  20 4D 83    SP2D   JSR CRLF
0927  86AE  CD 58 A6           CMP MAXRC
0928  86B1  90 05              BCC SP2E
0929  86B3  AD 58 A6           LDA MAXRC
0930  86B6  B0 02              BCS SP2F
0931  86B8  69 01       SP2E   ADC #1
0932  86BA  8D 3D A6    SP2F   STA RC
0933  86BD  A9 3B              LDA #$3B
0934  86BF  20 47 8A           JSR OUTCHR
0935  86C2  AD 3D A6           LDA RC
0936  86C5  20 F4 86           JSR SVBYTE
```

```
LINE # LOC      CODE        LINE

0937  86C8  A5 FF           LDA $FF
0938  86CA  20 F4 86        JSR SVBYTE
0939  86CD  A5 FE           LDA $FE
0940  86CF  20 F4 86        JSR SVBYTE
0941  86D2  A0 00     MORED2 LDY #$00
0942  86D4  B1 FE           LDA ($FE),Y
0943  86D6  20 F4 86        JSR SVBYTE
0944  86D9  20 86 83        JSR INSTAT      ;STOP IF KEY DEPRESSED
0945  86DC  B0 CA           BCS SPEXIT
0946  86DE  20 B2 82        JSR INCCMP
0947  86E1  70 C5           BVS SPEXIT
0948  86E3  CE 3D A6        DEC RC
0949  86E6  D0 EA           BNE MORED2
0950  86E8  AE 37 A6        LDX SCR7
0951  86EB  AD 36 A6        LDA SCR6
0952  86EE  20 F4 82        JSR OUTXAH
0953  86F1  18              CLC
0954  86F2  90 AF           BCC SP2C
0955  86F4  20 DD 82  SVBYTE JSR CHKSAD
0956  86F7  4C FA 82        JMP OUTBYT
0957  86FA  20 2E 83  DIFFZ  JSR ZERCK
0958  86FD  AD 4A A6  DIFFL  LDA P3L
0959  8700  38              SEC
0960  8701  E5 FE           SBC $FE
0961  8703  48              PHA
0962  8704  AD 4B A6        LDA P3H
0963  8707  E5 FF           SBC $FF
0964  8709  F0 04           BEQ DIFF1
0965  870B  68              PLA
0966  870C  A9 FF           LDA #$FF
0967  870E  60              RTS
0968  870F  68        DIFF1 PLA
0969  8710  60        DIFFL2 RTS
0970  8711  4C 27 88  E2PARM JMP CALC3       ;MAY BE CALC OR EXEC
0971  8714           B3PARM=*
0972  8714           ;
0973  8714           ; 3 PARAMETER COMMAND EXECUTE BLOCKS
0974  8714           ;
0975  8714  C9 46     FILL3  CMP #'F          ;FILL MEM
0976  8716  D0 21           BNE BLK3
0977  8718  20 9C 82        JSR P2SCR
0978  871B  A9 00           LDA #0
0979  871D  8D 52 A6        STA ERCNT       ;ZERO ERROR COUNT
0980  8720  AD 4E A6        LDA P1L
0981  8723  A0 00     F1    LDY #0
0982  8725  91 FE           STA ($FE),Y
0983  8727  D1 FE           CMP ($FE),Y     ;VERIFY
0984  8729  F0 03           BEQ F3
0985  872B  20 C1 87        JSR BRTT        ;INC ERCNT (UP TO FF)
0986  872E  20 B2 82  F3     JSR INCCMP
0987  8731  70 7C           BVS B1
0988  8733  F0 EE           BEQ F1
0989  8735  90 EC           BCC F1
0990  8737  B0 76     F2    BCS B1          ;(ALWAYS)
0991  8739  C9 42     BLK3  CMP #'B         ;BLOCK MOVE (OVERLAP OK)
```

```
LINE #  LOC     CODE        LINE

0992   873B  F0 03          BEQ *+5
0993   873D  4C CD 87        JMP S13B
0994   8740  A9 00          LDA #0
0995   8742  8D 52 A6        STA ERCNT
0996   8745  20 9C 82        JSR P2SCR
0997   8748  AD 4E A6        LDA P1L
0998   874B  85 FC           STA $FC
0999   874D  AD 4F A6        LDA P1H
1000   8750  85 FD           STA $FD
1001   8752  C5 FF           CMP $FF          ;WHICH DIRECTION TO MOVE?
1002   8754  D0 06           BNE *+8
1003   8756  A5 FC           LDA $FC
1004   8758  C5 FE           CMP $FE
1005   875A  F0 53           BEQ B1           ;16 BITS EQUAL THEN FINISHED
1006   875C  B0 14           BCS B2           ;MOVE DEC'NG
1007   875E  20 B7 87     BLP   JSR BMOVE     ;MOVE INC'NG
1008   8761  E6 FC           INC $FC
1009   8763  D0 02           BNE *+4
1010   8765  E6 FD           INC $FD
1011   8767  20 B2 82        JSR INCCMP
1012   876A  70 43           BVS B1
1013   876C  F0 F0           BEQ BLP
1014   876E  90 EE           BCC BLP
1015   8770  B0 3D           BCS B1
1016   8772  A5 FC        B2    LDA $FC        ;CALC VALS FOR MOVE DEC'NG
1017   8774  18              CLC
1018   8775  6D 4A A6        ADC P3L
1019   8778  85 FC           STA $FC
1020   877A  A5 FD           LDA $FD
1021   877C  6D 4B A6        ADC P3H
1022   877F  85 FD           STA $FD
1023   8781  38              SEC
1024   8782  A5 FC           LDA $FC
1025   8784  E5 FE           SBC $FE
1026   8786  85 FC           STA $FC
1027   8788  A5 FD           LDA $FD
1028   878A  E5 FF           SBC $FF
1029   878C  85 FD           STA $FD
1030   878E  20 A7 82        JSR P3SCR
1031   8791  AD 4C A6        LDA P2L
1032   8794  8D 4A A6        STA P3L
1033   8797  AD 4D A6        LDA P2H
1034   879A  8D 4B A6        STA P3H
1035   879D  20 B7 87     BLP1  JSR BMOVE     ;MOVE DEC'NG
1036   87A0  A5 FC           LDA $FC
1037   87A2  D0 02           BNE *+4
1038   87A4  C6 FD           DEC $FD
1039   87A6  C6 FC           DEC $FC
1040   87A8  20 BE 82        JSR DECCMP
1041   87AB  70 02           BVS B1
1042   87AD  B0 EE           BCS BLP1
1043   87AF  AD 52 A6     B1    LDA ERCNT      ;FINISHED, TEST ERCNT
1044   87B2  38              SEC
1045   87B3  D0 01           BNE *+3
1046   87B5  18              CLC
```

```
LINE # LOC      CODE        LINE

1047  87B6  60              RTS
1048  87B7  A0 00     BMOVE  LDY #0          ;MOVE 1 BYT + VER
1049  87B9  B1 FE           LDA ($FE),Y
1050  87BB  91 FC           STA ($FC),Y
1051  87BD  D1 FC           CMP ($FC),Y
1052  87BF  F0 0B           BEQ BRT
1053  87C1  AC 52 A6  BRTT   LDY ERCNT       ;INC ERCNT, DONT PASS FF
1054  87C4  C0 FF           CPY #$FF
1055  87C6  F0 04           BEQ *+6
1056  87C8  C8              INY
1057  87C9  8C 52 A6        STY ERCNT
1058  87CC  60        BRT    RTS
1059  87CD  C9 1D     S13B   CMP #$1D         ;SAVE KIM FMT TAPE, 3 PARMS
1060  87CF  D0 15           BNE S23B
1061  87D1  A0 00           LDY #$0          ;MODE = KIM
1062  87D3  AD 4E A6  S13C   LDA P1L
1063  87D6  D0 02           BNE *+4          ;ID MUST NOT = 0
1064  87D8  38              SEC
1065  87D9  60              RTS
1066  87DA  C9 FF           CMP #$FF         ;ID MUST NOT = FF
1067  87DC  D0 02           BNE *+4
1068  87DE  38        S1NG   SEC
1069  87DF  60              RTS
1070  87E0  20 93 82        JSR INCP3        ;USE END ADDR + 1
1071  87E3  4C 87 8E        JMP SENTRY
1072  87E6  C9 1E     S23B   CMP #$1E         ;SAVE HS FMT TAPE, 3 PARMS
1073  87E8  D0 04           BNE L23P
1074  87EA  A0 80           LDY #$80         ;MODE = HS
1075  87EC  D0 E5           BNE S13C         ;(ALWAYS)
1076  87EE  C9 13     L23P   CMP #$13         ;LOAD HS, 3 PARMS
1077  87F0  D0 0F           BNE MEM3
1078  87F2  AD 4E A6        LDA P1L
1079  87F5  C9 FF           CMP #$FF         ;ID MUST BE FF
1080  87F7  D0 E5           BNE S1NG         ;ERR RETURN
1081  87F9  20 93 82        JSR INCP3        ;USE END ADDR + 1
1082  87FC  A0 80           LDY #$80         ;MODE = HS
1083  87FE  4C 78 8C        JMP LENTRY
1084  8801  C9 4D     MEM3   CMP #'M          ;MEM 3 SEARCH - BYTE
1085  8803  D0 22           BNE CALC3
1086  8805  20 9C 82        JSR P2SCR
1087  8808  AD 4E A6  MEM3C  LDA P1L
1088  880B  A0 00           LDY #0
1089  880D  D1 FE           CMP ($FE),Y
1090  880F  F0 0B           BEQ MEM3E        ;FOUND SEARCH BYTE?
1091  8811  20 B2 82  MEM3D  JSR INCCMP       ;NO, INC BUFFER ADDR
1092  8814  70 04           BVS MEM3EX       ;WRAP AROUND?
1093  8816  F0 F0           BEQ MEM3C
1094  8818  90 EE           BCC MEM3C
1095  881A  18        MEM3EX CLC
1096  881B  60              RTS              ;SEARCHED TO BOUND
1097  881C  20 17 85  MEM3E  JSR NEWLOC       ;FOUND SEARCH BYTE
1098  881F  90 05           BCC MEM3F
1099  8821  C9 47           CMP #'G          ;ENTERED G?
1100  8823  F0 EC           BEQ MEM3D
1101  8825  38              SEC
```

```
LINE # LOC      CODE        LINE

1102  8826  60            MEM3F  RTS
1103  8827  C9 43         CALC3  CMP #'C CLACULATE, 1, 2 OR 3 PARMS
1104  8829  D0 26                BNE EXE3          ;RESULT = P1+P2-P3
1105  882B  20 4D 83       C1     JSR CRLF
1106  882E  20 42 83              JSR SPACE
1107  8831  18                    CLC
1108  8832  AD 4E A6              LDA P1L
1109  8835  6D 4C A6              ADC P2L
1110  8838  A8                    TAY
1111  8839  AD 4F A6              LDA P1H
1112  883C  6D 4D A6              ADC P2H
1113  883F  AA                    TAX
1114  8840  38                    SEC
1115  8841  98                    TYA
1116  8842  ED 4A A6              SBC P3L
1117  8845  A8                    TAY
1118  8846  8A                    TXA
1119  8847  ED 4B A6              SBC P3H
1120  884A  AA                    TAX
1121  884B  98                    TYA
1122  884C  20 F4 82              JSR OUTXAH
1123  884F  18                    CLC
1124  8850  60                    RTS
1125  8851  C9 45         EXE3   CMP #'E           ;EXECUTE FROM RAM, 1-3 PARMS
1126  8853  D0 57                BNE E3PARM
1127  8855                ; SEE IF VECTOR ALREADY MOVED
1128  8855  AD 62 A6              LDA INVEC+2       ;INVEC MOVED TO SCRA, SCRB
1129  8858                ; HI BYTE OF EXEVEC MUST BE DIFFERENT FROM INVEC
1130  8858  CD 73 A6              CMP EXEVEC+1      ;$FA, $FB USED AS RAM PTR
1131  885B  F0 15                 BEQ PTRIN
1132  885D  8D 3B A6              STA SCRA+1        ;SAVE INVEC IN SCRA,B
1133  8860  AD 61 A6              LDA INVEC+1
1134  8863  8D 3A A6              STA SCRA
1135  8866  AD 72 A6              LDA EXEVEC        ;PUT ADDR OF RIN IN INVEC
1136  8869  8D 61 A6              STA INVEC+1
1137  886C  AD 73 A6              LDA EXEVEC+1
1138  886F  8D 62 A6              STA INVEC+2
1139  8872  AD 4B A6       PTRIN  LDA P3H           ;INIT RAM PTR IN $FA, $FB
1140  8875  85 FB                 STA $FB
1141  8877  AD 4A A6              LDA P3L
1142  887A  85 FA                 STA $FA
1143  887C  18                    CLC
1144  887D  60                    RTS
1145  887E  20 88 81       RIN    JSR SAVER         ;GET INPUT FROM RAM
1146  8881  A0 00                 LDY #$0           ;RAM PTR IN $FA, $FB
1147  8883  B1 FA                 LDA ($FA),Y
1148  8885  F0 12                 BEQ RESTIV        ;IF 00 BYTE, RESTORE INVEC
1149  8887  E6 FA                 INC $FA
1150  8889  D0 02                 BNE *+4
1151  888B  E6 FB                 INC $FB
1152  888D  2C 53 A6              BIT TECHO         ;ECHO CHARS IN ?
1153  8890  10 03                 BPL *+5
1154  8892  20 47 8A              JSR OUTCHR
1155  8895  18                    CLC
1156  8896  4C B8 81              JMP RESXAF
```

```
LINE # LOC      CODE        LINE

1157  8899  AD 3A A6    RESTIV LDA SCRA         ;RESTORE INVEC
1158  889C  8D 61 A6           STA INVEC+1
1159  889F  AD 3B A6           LDA SCRA+1
1160  88A2  8D 62 A6           STA INVEC+2
1161  88A5  18                 CLC
1162  88A6  20 1B 8A           JSR INCHR
1163  88A9  4C B8 81           JMP RESXAF
1164  88AC  6C 6D A6    E3PARM JMP (URCVEC+1)  ;... ELSE UNREC CMD
1165  88AF               ; ***
1166  88AF               ; *** HEX KEYBOARD I/O
1167  88AF               ; ***
1168  88AF  20 88 81    GETKEY JSR SAVER        ;FIND KEY
1169  88B2  20 CF 88           JSR GK
1170  88B5  C9 FE              CMP #$FE
1171  88B7  D0 13              BNE EXITGK
1172  88B9  20 CF 88           JSR GK
1173  88BC  8A                 TXA
1174  88BD  0A                 ASL A
1175  88BE  0A                 ASL A
1176  88BF  0A                 ASL A
1177  88C0  0A                 ASL A
1178  88C1  8D 3E A6           STA SCRE
1179  88C4  20 CF 88           JSR GK
1180  88C7  8A                 TXA
1181  88C8  18                 CLC
1182  88C9  6D 3E A6           ADC SCRE
1183  88CC  4C B8 81    EXITGK JMP RESXAF
1184  88CF  A9 00       GK     LDA #0
1185  88D1  8D 55 A6           STA KSHFL
1186  88D4  20 03 89    GK1    JSR IJSCNV       ;SCAN KB
1187  88D7  F0 FB              BEQ GK1
1188  88D9  20 2C 89           JSR LRNKEY      ;WHAT KEY IS IT?
1189  88DC  F0 F6              BEQ GK1
1190  88DE  48                 PHA
1191  88DF  8A                 TXA
1192  88E0  48                 PHA
1193  88E1  20 72 89           JSR BEEP
1194  88E4  20 23 89    GK2    JSR KEYQ
1195  88E7  D0 FB              BNE GK2         ;Z=0 IF KEY DOWN
1196  88E9  20 9B 89           JSR NOBEEP      ;DELAY (DEBOUNCE) W/O BEEP
1197  88EC  20 23 89           JSR KEYQ
1198  88EF  D0 F3              BNE GK2
1199  88F1  68                 PLA
1200  88F2  AA                 TAX
1201  88F3  68                 PLA
1202  88F4  C9 FF              CMP #$FF        ;IF SHIFT, SET FLAG + GET NEXT KEY
1203  88F6  D0 07              BNE EXITG
1204  88F8  A9 19              LDA #$19
1205  88FA  8D 55 A6           STA KSHFL
1206  88FD  D0 D5              BNE GK1
1207  88FF  60          EXITG  RTS
1208  8900  20 C1 89    HDOUT  JSR OUTDSP       ;CHAR OUT, SCAN KB
1209  8903  6C 70 A6    IJSCNV JMP (SCNVEC+1)
1210  8906  A9 09       SCAND  LDA #$9          ;SCAN DISPLAY FROM DISBUF
1211  8908  20 A5 89           JSR CONFIG
```

```
LINE # LOC      CODE        LINE

1212  890B  A2 05           LDX #5
1213  890D  A0 00     SC1   LDY #0
1214  890F  BD 40 A6        LDA DISBUF,X
1215  8912  8C 00 A4        STY PADA
1216  8915  8E 02 A4        STX PBDA
1217  8918  8D 00 A4        STA PADA
1218  891B  A0 10           LDY #$10
1219  891D  88        SC2   DEY
1220  891E  D0 FD           BNE SC2
1221  8920  CA              DEX
1222  8921  10 EA           BPL SC1
1223  8923  20 A3 89  KEYQ  JSR KSCONF      ; KEY DOWN ? (YES THEN Z=0)
1224  8926  AD 00 A4        LDA PADA
1225  8929  49 7F           EOR #$7F
1226  892B  60              RTS
1227  892C  29 3F     LRNKEY AND #$3F       ;DETERMINE WHAT KEY IS DOWN
1228  892E  8D 3F A6        STA SCRF
1229  8931  A9 05           LDA #$05
1230  8933  20 A5 89        JSR CONFIG
1231  8936  AD 02 A4        LDA PBDA
1232  8939  29 07           AND #$07
1233  893B  49 07           EOR #$07
1234  893D  D0 05           BNE LK1
1235  893F  2C 00 A4        BIT PADA
1236  8942  30 1A           BMI NOKEY
1237  8944  C9 04     LK1   CMP #$04
1238  8946  90 02           BCC LK2
1239  8948  A9 03           LDA #$03
1240  894A  0A        LK2   ASL A
1241  894B  0A              ASL A
1242  894C  0A              ASL A
1243  894D  0A              ASL A
1244  894E  0A              ASL A
1245  894F  0A              ASL A
1246  8950  18              CLC
1247  8951  6D 3F A6        ADC SCRF
1248  8954  A2 19           LDX #$19
1249  8956  DD D6 8B  LK3   CMP SYM,X
1250  8959  F0 05           BEQ FOUND
1251  895B  CA              DEX
1252  895C  10 F8           BPL LK3
1253  895E  E8        NOKEY INX
1254  895F  60              RTS
1255  8960  8A        FOUND TXA
1256  8961  18              CLC
1257  8962  6D 55 A6        ADC KSHFL
1258  8965  AA              TAX
1259  8966  BD EF 8B        LDA ASCII,X
1260  8969  60              RTS
1261  896A  20 23 89  KYSTAT JSR KEYQ       ;KEY DOWN? RETURN IN CARRY
1262  896D  18              CLC
1263  896E  F0 01           BEQ *+3
1264  8970  38              SEC
1265  8971  60              RTS
1266  8972  20 88 81  BEEP  JSR SAVER       ;DELAY (BOUNCE) W/BEEP
```

```
LINE # LOC      CODE        LINE

1267  8975  A9 0D        BEEPP3 LDA #$0D
1268  8977  20 A5 89     BEEPP5 JSR CONFIG
1269  897A  A2 40               LDX #$40        ;DURATION CONSTANT
1270  897C  A9 08        BE1    LDA #8
1271  897E  8D 02 A4            STA PBDA
1272  8981  20 95 89            JSR BE2
1273  8984  A9 06               LDA #6
1274  8986  8D 02 A4            STA PBDA
1275  8989  20 95 89            JSR BE2
1276  898C  CA                  DEX
1277  898D  D0 ED               BNE BE1
1278  898F  20 A3 89            JSR KSCONF
1279  8992  4C C4 81            JMP RESALL
1280  8995  A0 28        BE2    LDY #$28
1281  8997  88          BE3    DEY
1282  8998  D0 FD               BNE BE3
1283  899A  60                  RTS
1284  899B  20 88 81     NOBEEP JSR SAVER         ;DELAY W/O BEEP
1285  899E  A9 01               LDA #$01
1286  89A0  4C 77 89            JMP BEEPP5
1287  89A3  A9 01        KSCONF LDA #$1           ;CONFIGURE FOR KEYBOARD
1288  89A5  20 88 81     CONFIG JSR SAVER         ;CONFIGURE I/O FROM TABLE VAL
1289  89A8  A0 01               LDY #$01
1290  89AA  AA                  TAX
1291  89AB  BD C8 8B     CON1   LDA VALSP2,X
1292  89AE  99 02 A4            STA PBDA,Y
1293  89B1  BD C6 8B            LDA VALS,X
1294  89B4  99 00 A4            STA PADA,Y
1295  89B7  CA                  DEX
1296  89B8  88                  DEY
1297  89B9  10 F0               BPL CON1
1298  89BB  4C C4 81            JMP RESALL
1299  89BE  20 AF 88     HKEY   JSR GETKEY        ;GET KEY FROM KB AND ECHO ON KB
1300  89C1  20 88 81     OUTDSP JSR SAVER         ;DISPLAY OUT
1301  89C4  29 7F               AND #$7F
1302  89C6  C9 07               CMP #$07
1303  89C8  D0 03               BNE NBELL
1304  89CA  4C 75 89            JMP BEEPP3
1305  89CD  20 06 8A     NBELL  JSR TEXT          ;PUSH INTO SCOPE BUFFER
1306  89D0  C9 2C               CMP #$2C        ;SINGLE QUOTE?
1307  89D2  D0 0A               BNE OUD1
1308  89D4  AD 45 A6            LDA RDIG
1309  89D7  09 80               ORA #$80
1310  89D9  8D 45 A6            STA RDIG
1311  89DC  D0 25               BNE EXITOD
1312  89DE  A2 3A        OUD1   LDX #$3A
1313  89E0  DD EE 8B     OUD2   CMP ASCIM1,X
1314  89E3  F0 05               BEQ GETSGS
1315  89E5  CA                  DEX
1316  89E6  D0 F8               BNE OUD2
1317  89E8  F0 19               BEQ EXITOD
1318  89EA  BD 28 8C     GETSGS LDA SEGSM1,X     ;GET CORR SEG CODE FROM TABLE
1319  89ED  C9 F0               CMP #$F0
1320  89EF  F0 12               BEQ EXITOD
1321  89F1  A2 00               LDX #0
```

```
LINE # LOC      CODE        LINE

1322  89F3  48              PHA
1323  89F4  BD 41 A6  OUD3  LDA DISBUF+1,X  ;SHOVE DOWN DISPLAY BUFFER
1324  89F7  9D 40 A6        STA DISBUF,X
1325  89FA  E8              INX
1326  89FB  E0 05           CPX #5
1327  89FD  D0 F5           BNE OUD3
1328  89FF  68              PLA
1329  8A00  8D 45 A6        STA RDIG
1330  8A03  4C C4 81  EXITOD JMP RESALL
1331  8A06  48        TEXT  PHA             ;UPDATE SCOPE BUFFER
1332  8A07  8A              TXA
1333  8A08  48              PHA
1334  8A09  A2 1E           LDX #$1E
1335  8A0B  BD 00 A6  TXTMOV LDA SCPBUF,X
1336  8A0E  9D 01 A6        STA SCPBUF+1,X
1337  8A11  CA              DEX
1338  8A12  10 F7           BPL TXTMOV
1339  8A14  68              PLA
1340  8A15  AA              TAX
1341  8A16  68              PLA
1342  8A17  8D 00 A6        STA SCPBUF
1343  8A1A  60              RTS
1344  8A1B            ;
1345  8A1B            ;***
1346  8A1B            ;*** TERMINAL I/O
1347  8A1B            ;***
1348  8A1B  20 88 81  INCHR  JSR SAVER       ;INPUT CHAR
1349  8A1E  20 41 8A        JSR INJINV
1350  8A21  29 7F           AND #$7F
1351  8A23  C9 61           CMP #$61
1352  8A25  90 06           BCC INRT1
1353  8A27  C9 7B           CMP #$7B
1354  8A29  B0 02           BCS INRT1
1355  8A2B  29 DF           AND #$DF
1356  8A2D  C9 0F     INRT1 CMP #$0F        ;CTL O ?
1357  8A2F  D0 0B           BNE INRT2
1358  8A31  AD 53 A6        LDA TECHO
1359  8A34  49 40           EOR #$40        ;TOGGLE CTL O BIT
1360  8A36  8D 53 A6        STA TECHO
1361  8A39  18              CLC
1362  8A3A  90 E2           BCC INCHR+3     ;GO GET ANOTHER CHAR
1363  8A3C  C9 0D     INRT2 CMP #$0D        ;CARRIAGE RETURN?
1364  8A3E  4C B8 81        JMP RESXAF
1365  8A41  6C 61 A6  INJINV JMP (INVEC+1)
1366  8A44  20 09 83  NBASOC JSR NIBASC
1367  8A47  20 88 81  OUTCHR JSR SAVER
1368  8A4A  2C 53 A6        BIT TECHO       ;LOOK AT CTL O FLAG
1369  8A4D  70 03           BVS *+5
1370  8A4F  20 55 8A        JSR INJOUV
1371  8A52  4C C4 81        JMP RESALL
1372  8A55  6C 64 A6  INJOUV JMP (OUTVEC+1)
1373  8A58  20 88 81  INTCHR JSR SAVER       ;IN TERMINAL CHAR
1374  8A5B  A9 00           LDA #0
1375  8A5D  85 F9           STA $F9
1376  8A5F  AD 02 A4  LOOK  LDA PBDA        ;FIND LEADING EDGE
```

```
LINE #  LOC     CODE        LINE

1377   8A62  2D 54 A6            AND TOUTFL
1378   8A65  38                  SEC
1379   8A66  E9 40               SBC #$40
1380   8A68  90 F5               BCC LOOK
1381   8A6A  20 E9 8A     TIN     JSR DLYH          ;TERMINAL BIT
1382   8A6D  AD 02 A4             LDA PBDA
1383   8A70  2D 54 A6             AND TOUTFL
1384   8A73  38                   SEC
1385   8A74  E9 40                SBC #$40          ;OR BITS 6,7 (TTY,CRT)
1386   8A76  2C 53 A6             BIT TECHO         ;ECHO BIT?
1387   8A79  10 06                BPL DMY1
1388   8A7B  20 D4 8A             JSR OUT
1389   8A7E  4C 87 8A             JMP SAVE
1390   8A81  A0 07        DMY1    LDY #7
1391   8A83  88           TLP1    DEY
1392   8A84  D0 FD                BNE TLP1
1393   8A86  EA                   NOP
1394   8A87  66 F9        SAVE    ROR $F9
1395   8A89  20 E9 8A             JSR DLYH
1396   8A8C  48                   PHA               ;TIMING
1397   8A8D  B5 00                LDA 0,X
1398   8A8F  68                   PLA
1399   8A90  90 D8                BCC TIN
1400   8A92  20 E9 8A             JSR DLYH
1401   8A95  18                   CLC
1402   8A96  20 D4 8A             JSR OUT
1403   8A99  A5 F9                LDA $F9
1404   8A9B  49 FF                EOR #$FF
1405   8A9D  4C B8 81             JMP RESXAF
1406   8AA0  85 F9        TOUT    STA $F9           ;TERMINAL CHR OUT
1407   8AA2  20 88 81             JSR SAVER
1408   8AA5  20 E9 8A             JSR DLYH
1409   8AA8  A9 30                LDA #$30
1410   8AAA  8D 03 A4             STA PBDA+1
1411   8AAD  A5 F9                LDA $F9
1412   8AAF  A2 0B                LDX #$0B
1413   8AB1  49 FF                EOR #$FF
1414   8AB3  38                   SEC
1415   8AB4  20 D4 8A     OUTC    JSR OUT
1416   8AB7  20 E6 8A             JSR DLYF
1417   8ABA  A0 06                LDY #$06
1418   8ABC  88           PHAKE   DEY
1419   8ABD  D0 FD                BNE PHAKE
1420   8ABF  EA                   NOP
1421   8AC0  4A                   LSR A
1422   8AC1  CA                   DEX
1423   8AC2  D0 F0                BNE OUTC
1424   8AC4  A5 F9                LDA $F9
1425   8AC6  C9 0D                CMP #$0D
1426   8AC8  F0 04                BEQ GOPAD
1427   8ACA  C9 0A                CMP #$0A
1428   8ACC  D0 03                BNE LEAVE
1429   8ACE  20 32 8B     GOPAD   JSR PAD
1430   8AD1  4C C4 81     LEAVE   JMP RESALL
1431   8AD4  48           OUT     PHA               ;TERMINAL BIT OUT
```

```
LINE # LOC      CODE        LINE

1432  8AD5  AD 02 A4          LDA PBDA
1433  8AD8  29 0F             AND #$0F
1434  8ADA  90 02             BCC OUTONE
1435  8ADC  09 30             ORA #$30
1436  8ADE  2D 54 A6  OUTONE  AND TOUTFL      ;MASK OUTPUT
1437  8AE1  8D 02 A4          STA PBDA
1438  8AE4  68                PLA
1439  8AE5  60                RTS
1440  8AE6                    ;
1441  8AE6  20 E9 8A  DLYF    JSR DLYH        ;DELAY FULL
1442  8AE9  08        DLYH    PHP             ;DELAY HALF
1443  8AEA  48                PHA
1444  8AEB  8A                TXA
1445  8AEC  48                PHA
1446  8AED  98                TYA
1447  8AEE  AE 51 A6          LDX SDBYT
1448  8AF1  A0 03     DLYX    LDY #3
1449  8AF3  88        DLYY    DEY
1450  8AF4  D0 FD             BNE DLYY
1451  8AF6  CA                DEX
1452  8AF7  D0 F8             BNE DLYX
1453  8AF9  A8                TAY
1454  8AFA  68                PLA
1455  8AFB  AA                TAX
1456  8AFC  68                PLA
1457  8AFD  28                PLP
1458  8AFE  60                RTS
1459  8AFF  A9 00     BAUD    LDA #0          ;DETERMINE BAUD RATE ON PB7
1460  8B01  A8                TAY
1461  8B02  AD 02 A4  SEEK    LDA PBDA
1462  8B05  0A                ASL A
1463  8B06  B0 FA             BCS SEEK
1464  8B08  20 27 8B  CLEAR   JSR INK
1465  8B0B  90 FB             BCC CLEAR
1466  8B0D  20 27 8B  SET     JSR INK
1467  8B10  B0 FB             BCS SET
1468  8B12  8C 51 A6          STY SDBYT
1469  8B15  BD 63 8C  DEAF    LDA DECPTS,X
1470  8B18  CD 51 A6          CMP SDBYT
1471  8B1B  B0 07             BCS AGAIN
1472  8B1D  BD 69 8C          LDA STDVAL,X    ;LOAD CLOSEST STD VALUE
1473  8B20  8D 51 A6          STA SDBYT
1474  8B23  60                RTS
1475  8B24  E8        AGAIN   INX
1476  8B25  10 EE             BPL DEAF
1477  8B27  C8        INK     INY
1478  8B28  A2 1C             LDX #$1C
1479  8B2A  CA        INK1    DEX
1480  8B2B  D0 FD             BNE INK1
1481  8B2D  AD 02 A4          LDA PBDA
1482  8B30  0A                ASL A
1483  8B31  60                RTS
1484  8B32  AE 50 A6  PAD     LDX PADBIT      ;PAD CARRIAGE RETURN
1485  8B35  20 E6 8A  PAD1    JSR DLYF
1486  8B38  CA                DEX
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LINE # LOC      CODE        LINE

1487  8B39  D0 FA            BNE PAD1
1488  8B3B  60               RTS
1489  8B3C  20 A3 89    TSTAT JSR KSCONF       ;SEE IF BREAK KEY DOWN
1490  8B3F  2C 02 A4         BIT PBDA
1491  8B42  18               CLC
1492  8B43  10 01            BPL *+3
1493  8B45  38               SEC
1494  8B46  60               RTS
1495  8B47  20 0F 87         JSR DIFF1
1496  8B4A              ; ***
1497  8B4A              ; *** RESET - TURN OFF POR, INIT SYS RAM, ENTER MONITOR
1498  8B4A              ; ***
1499  8B4A              ;
1500  8B4A  A2 FF       RESET LDX #$FF
1501  8B4C  9A               TXS              ;INIT STACK PTR
1502  8B4D  A9 CC       POR   LDA #$CC
1503  8B4F  8D 0C A0         STA PCR1         ;DISABLE POR, TAPE OFF
1504  8B52  A9 04            LDA #4
1505  8B54  48               PHA
1506  8B55  28               PLP              ;INIT F, DISABLE IRQ DURING DFTXFR
1507  8B56  20 86 8B         JSR ACCESS       ;UN WRITE PROT SYS RAM
1508  8B59  A2 5F       DFTXFR LDX #$5F       ;INIT SYS RAM (EXCPT SCPBUF)
1509  8B5B  BD A0 8F         LDA DFTBLK,X
1510  8B5E  9D 20 A6         STA RAM,X
1511  8B61  CA               DEX
1512  8B62  10 F7            BPL DFTXFR+2
1513  8B64  A9 07       NEWDEV LDA #7         ;CHANGE DEVC/BAUD RATE
1514  8B66  20 47 8A         JSR OUTCHR       ;BEEP
1515  8B69  20 A3 89    SWITCH JSR KSCONF     ;KEYBOARD OR TERMINAL?
1516  8B6C  20 26 89    SWLP  JSR KEYQ+3
1517  8B6F  D0 0B            BNE MONENT
1518  8B71  2C 02 A4         BIT PBDA
1519  8B74  10 F6            BPL SWLP
1520  8B76  20 B7 8B         JSR VECSW        ;SWITCH VECTORS
1521  8B79  20 FF 8A         JSR BAUD
1522  8B7C  A2 FF       MONENT LDX #$FF       ;MONITOR ENTRY
1523  8B7E  9A               TXS
1524  8B7F  D8               CLD
1525  8B80  20 86 8B         JSR ACCESS       ;UNWRITE PROT MONITOR RAM
1526  8B83  4C 03 80         JMP WARM
1527  8B86  20 88 81    ACCESS JSR SAVER      ;UN WRITE PROT SYS RAM
1528  8B89  AD 01 AC         LDA OR3A
1529  8B8C  09 01            ORA #1
1530  8B8E  8D 01 AC    ACC1  STA OR3A
1531  8B91  AD 03 AC         LDA DDR3A
1532  8B94  09 01            ORA #1
1533  8B96  8D 03 AC         STA DDR3A
1534  8B99  4C C4 81         JMP RESALL
1535  8B9C  20 88 81    NACCES JSR SAVER      ;WRITE PROT SYS RAM
1536  8B9F  AD 01 AC         LDA OR3A
1537  8BA2  29 FE            AND #$FE
1538  8BA4  18               CLC
1539  8BA5  90 E7            BCC ACC1
1540  8BA7  20 86 8B    TTY   JSR ACCESS       ;UN WRITE PROT RAM
1541  8BAA  A9 D5            LDA #$D5         ;110 BAUD
```

```
LINE #  LOC     CODE        LINE

1542  8BAC  8D 51 A6            STA SDBYT
1543  8BAF  AD 54 A6            LDA TOUTFL
1544  8BB2  09 40               ORA #$40
1545  8BB4  8D 54 A6            STA TOUTFL
1546  8BB7  20 86 8B     VECSW  JSR ACCESS       ;UN WRITE PROT RAM
1547  8BBA  A2 08               LDX #$8
1548  8BBC  BD 6F 8C     SWLP2  LDA TRMTBL,X
1549  8BBF  9D 60 A6            STA INVEC,X
1550  8BC2  CA                  DEX
1551  8BC3  10 F7               BPL SWLP2
1552  8BC5  60                  RTS
1553  8BC6                ;
1554  8BC6                ;***
1555  8BC6                ;*** TABLES (I/O CONFIGURATIONS, KEY CODES, ASCII CODES)
1556  8BC6                ;***
1557  8BC6  00            VALS   .BYT $00,$80,$08,$37 ;KB SENSE, A=1
1557  8BC7  80
1557  8BC8  08
1557  8BC9  37
1558  8BCA  00                   .BYT $00,$7F,$00,$30 ;KB LRN, A=5
1558  8BCB  7F
1558  8BCC  00
1558  8BCD  30
1559  8BCE  00                   .BYT $00,$FF,$00,$3F ;SCAN DSP, A=9
1559  8BCF  FF
1559  8BD0  00
1559  8BD1  3F
1560  8BD2  00                   .BYT $00,$00,$07,$3F ;BEEP, A=D
1560  8BD3  00
1560  8BD4  07
1560  8BD5  3F
1561  8BD6                VALSP2 =VALS+2
1562  8BD6                SYM    =*                   ;KEY CODES RETURNED BY LRNKEY
1563  8BD6                TABLE=*
1564  8BD6  01                   .BYT $01             ;0/U0
1565  8BD7  41                   .BYT $41             ;1/U1
1566  8BD8  81                   .BYT $81             ;2/U2
1567  8BD9  C1                   .BYT $C1             ;3/U3
1568  8BDA  02                   .BYT $02             ;4/U4
1569  8BDB  42                   .BYT $42             ;5/U5
1570  8BDC  82                   .BYT $82             ;6/U6
1571  8BDD  C2                   .BYT $C2             ;7/U7
1572  8BDE  04                   .BYT $04             ;8/JMP
1573  8BDF  44                   .BYT $44             ;9/VER
1574  8BE0  84                   .BYT $84             ;A/ASCII
1575  8BE1  C4                   .BYT $C4             ;B/BLK MOV
1576  8BE2  08                   .BYT $08             ;C/CALC
1577  8BE3  48                   .BYT $48             ;D/DEP
1578  8BE4  88                   .BYT $88             ;E/EXEC
1579  8BE5  C8                   .BYT $C8             ;F/FILL
1580  8BE6  10                   .BYT $10             ;CR/SD
1581  8BE7  50                   .BYT $50             ;-/+
1582  8BE8  90                   .BYT $90             ;>/<
1583  8BE9  D0                   .BYT $D0             ;SHIFT
1584  8BEA  20                   .BYT $20             ;GO/LP
```

```
LINE # LOC      CODE        LINE

1585  8BEB  60                      .BYT $60        ;REG/SP
1586  8BEC  A0                      .BYT $A0        ;MEM/WP
1587  8BED  00                      .BYT $00        ;L2/L1
1588  8BEE  40                      .BYT $40        ;S2/S1
1589  8BEF                  ASCIM1  =*-1
1590  8BEF                  ASCII   =*              ;ASCII CODES AND HASH CODES
1591  8BEF  30                      .BYT $30        ;ZERO
1592  8BF0  31                      .BYT $31        ;ONE
1593  8BF1  32                      .BYT $32        ;TWO
1594  8BF2  33                      .BYT $33        ;THREE
1595  8BF3  34                      .BYT $34        ;FOUR
1596  8BF4  35                      .BYT $35        ;FIVE
1597  8BF5  36                      .BYT $36        ;SIX
1598  8BF6  37                      .BYT $37        ;SEVEN
1599  8BF7  38                      .BYT $38        ;EIGHT
1600  8BF8  39                      .BYT $39        ;NINE
1601  8BF9  41                      .BYT $41        ;A
1602  8BFA  42                      .BYT $42        ;B
1603  8BFB  43                      .BYT $43        ;C
1604  8BFC  44                      .BYT $44        ;D
1605  8BFD  45                      .BYT $45        ;E
1606  8BFE  46                      .BYT $46        ;F
1607  8BFF  0D                      .BYT $0D        ;CR
1608  8C00  2D                      .BYT $2D        ;DASH
1609  8C01  3E                      .BYT $3E        ;>
1610  8C02  FF                      .BYT $FF        ;SHIFT
1611  8C03  47                      .BYT $47        ;G
1612  8C04  52                      .BYT $52        ;R
1613  8C05  4D                      .BYT $4D        ;M
1614  8C06  13                      .BYT $13        ;L2
1615  8C07  1E                      .BYT $1E        ;S2
1616  8C08                  ; KB UPPER CASE
1617  8C08  14                      .BYT $14        ;U0
1618  8C09  15                      .BYT $15        ;U1
1619  8C0A  16                      .BYT $16        ;U2
1620  8C0B  17                      .BYT $17        ;U3
1621  8C0C  18                      .BYT $18        ;U4
1622  8C0D  19                      .BYT $19        ;U5
1623  8C0E  1A                      .BYT $1A        ;U6
1624  8C0F  1B                      .BYT $1B        ;U7
1625  8C10  4A                      .BYT $4A        ;J
1626  8C11  56                      .BYT $56        ;V
1627  8C12  FE                      .BYT $FE        ;ASCII
1628  8C13  42                      .BYT $42        ;B
1629  8C14  43                      .BYT $43        ;C
1630  8C15  44                      .BYT $44        ;D
1631  8C16  45                      .BYT $45        ;E
1632  8C17  46                      .BYT $46        ;F
1633  8C18  10                      .BYT $10        ;SD
1634  8C19  2B                      .BYT $2B        ;+
1635  8C1A  3C                      .BYT $3C        ;<
1636  8C1B  00                      .BYT $00        ;SHIFT
1637  8C1C  11                      .BYT $11        ;LP
1638  8C1D  1C                      .BYT $1C        ;SP
1639  8C1E  57                      .BYT $57        ;W
```

```
LINE # LOC      CODE        LINE

1640   8C1F   12                    .BYT $12          ;L1
1641   8C20   1D                    .BYT $1D          ;S1
1642   8C21   2E                    .BYT $2E          ;.
1643   8C22   20                    .BYT $20          ;BLANK
1644   8C23   3F                    .BYT $3F          ;?
1645   8C24   50                    .BYT $50          ;P
1646   8C25   07                    .BYT $07          ;BELL
1647   8C26   63                    .BYT $63          ;SMALL C
1648   8C27   2F                    .BYT $2F          ;/
1649   8C28   2A                    .BYT $2A          ;*
1650   8C29                 ; SEGMENT CODES FOR ON-BOARD DISPLAY
1651   8C29                 SEGSM1 =*-1
1652   8C29   3F                    .BYT $3F          ;ZERO
1653   8C2A   06                    .BYT $06          ;ONE
1654   8C2B   5B                    .BYT $5B          ;TWO
1655   8C2C   4F                    .BYT $4F          ;THREE
1656   8C2D   66                    .BYT $66          ;FOUR
1657   8C2E   6D                    .BYT $6D          ;FIVE
1658   8C2F   7D                    .BYT $7D          ;SIX
1659   8C30   07                    .BYT $07          ;SEVEN
1660   8C31   7F                    .BYT $7F          ;EIGHT
1661   8C32   67                    .BYT $67          ;NINE
1662   8C33   77                    .BYT $77          ;A
1663   8C34   7C                    .BYT $7C          ;B
1664   8C35   39                    .BYT $39          ;C
1665   8C36   5E                    .BYT $5E          ;D
1666   8C37   79                    .BYT $79          ;E
1667   8C38   71                    .BYT $71          ;F
1668   8C39   F0                    .BYT $F0          ;CR
1669   8C3A   40                    .BYT $40          ;DASH
1670   8C3B   70                    .BYT $70          ;>
1671   8C3C   00                    .BYT $00          ;SHIFT
1672   8C3D   6F                    .BYT $6F          ;G
1673   8C3E   50                    .BYT $50          ;R
1674   8C3F   54                    .BYT $54          ;M
1675   8C40   38                    .BYT $38          ;L2
1676   8C41   6D                    .BYT $6D          ;S2
1677   8C42   01                    .BYT $01          ;U0
1678   8C43   08                    .BYT $08          ;U1
1679   8C44   09                    .BYT $09          ;U2
1680   8C45   30                    .BYT $30          ;U3
1681   8C46   36                    .BYT $36          ;U4
1682   8C47   5C                    .BYT $5C          ;U5
1683   8C48   63                    .BYT $63          ;U6
1684   8C49   03                    .BYT $03          ;U7
1685   8C4A   1E                    .BYT $1E          ;J
1686   8C4B   72                    .BYT $72          ;V
1687   8C4C   77                    .BYT $77          ;A
1688   8C4D   7C                    .BYT $7C          ;B
1689   8C4E   39                    .BYT $39          ;C
1690   8C4F   5E                    .BYT $5E          ;D
1691   8C50   79                    .BYT $79          ;E
1692   8C51   71                    .BYT $71          ;F
1693   8C52   6D                    .BYT $6D          ;SD
1694   8C53   76                    .BYT $76          ;+
```

```
LINE # LOC     CODE        LINE

1695  8C54  46                    .BYT $46          ;<
1696  8C55  00                    .BYT $00          ;SHIFT
1697  8C56  38                    .BYT $38          ;LF
1698  8C57  6D                    .BYT $6D          ;SP
1699  8C58  1C                    .BYT $1C          ;W
1700  8C59  38                    .BYT $38          ;L1
1701  8C5A  6D                    .BYT $6D          ;S1
1702  8C5B  80                    .BYT $80          ;.
1703  8C5C  00                    .BYT $00          ;SPACE
1704  8C5D  53                    .BYT $53          ;?
1705  8C5E  73                    .BYT $73          ;P
1706  8C5F  49                    .BYT $49          ;BELL
1707  8C60  5C                    .BYT $5C          ;SMALL C
1708  8C61  52                    .BYT $52          ;/
1709  8C62  63                    .BYT $63          ;
1710  8C63  97              DECPTS .BYT $97,$3D,$1F,$10,$08,$00 ; TO DETERMINE BAUD
1710  8C64  3D
1710  8C65  1F
1710  8C66  10
1710  8C67  08
1710  8C68  00
1711  8C69  D5 4C           STDVAL .DBY $D54C,$2410,$0601    ;STD VALS FOR BAUD RATES
1711  8C6B  24 10
1711  8C6D  06 01
1712  8C6F                 ; 110,300,600,1200,2400,4800 BAUD
1713  8C6F  4C 58 8A       TRMTBL JMP INTCHR         ;ALTERNATE VCTRS FOR TIO
1714  8C72  4C A0 8A              JMP TOUT
1715  8C75  4C 3C 8B              JMP TSTAT
1716  8C78                 LENTRY =*                 ;LINK TO AUDIO CASSETTE
1717  8C78                 SENTRY =*+$20F
1718  8C78                 ;***
1719  8C78                 ;*** DEFAULT TABLE
1720  8C78                 ;***
1721  8C78                       *=$8FA0
1722  8FA0                 DFTBLK=*
1723  8FA0  00 C0                .WORD $C000       ;BASIC  *** JUMP TABLE
1724  8FA2  A7 8B                .WORD TTY
1725  8FA4  64 8B                .WORD NEWDEV
1726  8FA6  00 00                .WORD $0000       ;PAGE ZERO
1727  8FA8  00 02                .WORD $0200
1728  8FAA  00 03                .WORD $0300
1729  8FAC  00 C8                .WORD $C800
1730  8FAE  00 D0                .WORD $D000
1731  8FB0  00 00                .DBY $0000,$0000,$0000,$0000  ;SCR0 - SCR7
1731  8FB2  00 00
1731  8FB4  00 00
1731  8FB6  00 00
1732  8FB8  00 00                .DBY $0000,$0000,$0000,$0000 ;SCR8 - SCRF
1732  8FBA  00 00
1732  8FBC  00 00
1732  8FBE  00 00
1733  8FC0  00                   .BYT $00,$00,$6D,$6E,$86,$3F ;DISP BUFFER (SY1,0)
1733  8FC1  00
1733  8FC2  6D
1733  8FC3  6E
```

```
LINE # LOC      CODE        LINE

1733  8FC4  86
1733  8FC5  3F
1734  8FC6  00                    .BYT $00,$00,$00 ;NOT USED
1734  8FC7  00
1734  8FC8  00
1735  8FC9  00                    .BYT $00         ;PARNR
1736  8FCA  00 00                 .DBYT $0000,$0000,$0000 ;PARMS
1736  8FCC  00 00
1736  8FCE  00 00
1737  8FD0  01                    .BYT $01         ;PADBIT
1738  8FD1  4C                    .BYT $4C         ;SDBYT
1739  8FD2  00                    .BYT $00         ;ERCNT
1740  8FD3  80                    .BYT $80         ;TECHO
1741  8FD4  B0                    .BYT $B0         ;TOUTFL
1742  8FD5  00                    .BYT $00         ;KSHFL
1743  8FD6  00                    .BYT $00         ;TV
1744  8FD7  00                    .BYT $00         ;LSTCOM
1745  8FD8  10                    .BYT $10         ;MAXRC
1746  8FD9  4A 8B                 .WORD RESET      ;USER REG'S
1747  8FDB  FF                    .BYT $FF         ;STACK
1748  8FDC  00                    .BYT $00         ;FLAGS
1749  8FDD  00                    .BYT $00         ;A
1750  8FDE  00                    .BYT $00         ;X
1751  8FDF  00                    .BYT $00         ;Y
1752  8FE0                  ; VECTORS
1753  8FE0  4C BE 89              JMP HKEY         ;INVEC
1754  8FE3  4C 00 89              JMP HDOUT        ;OUTVEC
1755  8FE6  4C 6A 89              JMP KYSTAT       ;INSVEC
1756  8FE9  00                    .BYT $00,$00,$00 ;NOT USED
1756  8FEA  00
1756  8FEB  00
1757  8FEC  4C D1 81              JMP M1           ;UNRECOGNIZED CHAR (ERR RTN)
1758  8FEF  4C 06 89              JMP SCAND        ;SCNVEC
1759  8FF2  7E 88                 .WORD RIN        ;IN PTR FOR EXEC FROM RAM
1760  8FF4  C0 80                 .WORD TRCOFF     ;USER TRACE VECTOR
1761  8FF6  4A 80                 .WORD SVBRK      ;BRK
1762  8FF8  29 80                 .WORD SVIRQ      ;USER IRQ
1763  8FFA  9B 80                 .WORD SVNMI      ;NMI
1764  8FFC  4A 8B                 .WORD RESET      ;RESET
1765  8FFE  0F 80                 .WORD IRQBRK     ;IRQ
1766  9000                        .END


ERRORS = 0000 <0000>
```

SYMBOL	VALUE	LINE DEFINED	CROSS-REFERENCES
ACCESS	8B86	1527	123 129 137 177 191 1507 1525 1540 1546
ACC1	8B8E	1530	1539
ADVCK	81CB	336	581 599
AGAIN	8B24	1475	1471
AR	A65D	59	152 186 616
ASCII	8BEF	1590	1259
ASCIM1	8BEE	1589	1313
ASCNIB	8275	412	344 352 394
BADDY	848B	666	660
BAUD	8AFF	1459	1521
BEEP	8972	1266	1193
BEEPP3	8975	1267	1304
BEEPP5	8977	1268	1286
BE1	897C	1270	1277
BE2	8995	1280	1272 1275
BE3	8997	1281	1282
BLK3	8739	991	976
BLP	875E	1007	1013 1014
BLP1	879D	1035	1042
BMOVE	87B7	1048	1007 1035
BRT	87CC	1058	1052
BRTT	87C1	1053	985
BZPARM	8395	559	261
B1	87AF	1043	987 990 1005 1012 1015 1041
B1PARM	84DA	699	264
B2	8772	1016	1006
B2PARM	8619	858	267
B3PARM	8714	971	270
CALC3	8827	1103	857 970 1085
CHKSAD	82DD	463	676 887 955
CLEAR	8B08	1464	1465
COMINB	81D6	342	569
COMMA	833A	511	342 503 732
COMPAR	82CA	455	444 446
CONFIG	89A5	1288	1211 1230 1268
CON1	89AB	1291	1297
CRCHK	8204	364	362 363
CRLF	834D	521	147 219 277 497 564 587 604 622 784 905 926 1105
CRLFSZ	8316	497	706 731 882
C1	882B	1105	****
DBNEW	80F6	212	204
DBOFF	80D3	198	146 180 194
DBON	80E4	205	196
DDR1B	A002	91	****
DDR3A	AC03	89	202 209 211 212 214 854 1531 1533
DEAF	8B15	1469	1476
DECCMP	82BE	449	761 899 1040
DECPTS	8C63	1710	1469
DELAY	835A	528	188
DEPBYT	84E8	709	718
DEPEC	850E	726	720
DEPES	8553	759	722
DEPN	84F9	716	714 723 725

```
SYMBOL   VALUE  LINE DEFINED        CROSS-REFERENCES

DEPZ     84A7         677   620
DEP1     84DA         703   ****
DETBRK   801B         113   ****
DETIRQ   8022         118   112
DFTBLK   8FA0        1722  1509
DFTXFR   8B59        1508  1512
DIFFL    86FD         958   ****
DIFFL2   8710         969   ****
DIFFZ    86FA         957   923
DIFF1    870F         968   964  1495
DISBUF   A640          27  1214  1323  1324
DISPAT   814A         256    99
DLYF     8AE6        1441  1416  1485
DLYH     8AE9        1442  1381  1395  1400  1408  1441
DLYO     8383         544   539
DLYX     8AF1        1448  1452
DLYY     8AF3        1449  1450
DLY1     8368         533   536
DLY2     8371         537   543
DL1      835D         529   ****
DMY1     8A81        1390  1387
ERCNT    A652          43   624   632   649   653   667   671   673   979   995  1043
                             1053  1057
ERMSG    8171         275   100
EXEVEC   A672          74  1130  1135  1137
EXE3     8851        1125  1104
EXITCP   82D9         461   458
EXITG    88FF        1207  1203
EXITGK   88CC        1183  1171
EXITLP   843F         634   ****
EXITM1   8577         780   745
EXITNB   8315         496   494
EXITOD   8A03        1330  1311  1317  1320
EXITRG   83C1         579   598
EXRGP1   83C2         580   582
EXWRAP   82BD         448   447
EZPARM   84D7         698   695
E1PARM   8616         857   842
E2PARM   8711         970   919
E3PARM   88AC        1164  1126
FILL3    8714         975   ****
FOUND    8960        1255  1250
FR       A65C          58   164   612
F1       8723         981   988   989
F2       8737         990   ****
F3       872E         986   984
GETCOM   80FF         219    98   223   246
GETC1    8107         222   225   227
GETKEY   88AF        1168  1299
GETSGS   89EA        1318  1314
GK       88CF        1184  1169  1172  1179
GK1      88D4        1186  1187  1189  1206
GK2      88E4        1194  1195  1198
GOOD     81F3         355   360
GOPAD    8ACE        1429  1426
GO2      83F7         604   ****
GOZ      83F3         602   563
```

SYMBOL	VALUE	LINE DEFINED	CROSS-REFERENCES
G01	8579	782	729
G01ENT	83FA	605	197
HASHL	812F	240	234
HASHUS	8133	242	230 232 241
HDOUT	8900	1208	1754
HIPN	816E	271	257 269
HKEY	89BE	1299	1753
IDISP	8053	145	127 136 184
IJSCNV	8903	1209	537 1186
INBYTE	81D9	343	572 657 661 666 675 710
INCCMP	82B2	443	654 716 742 889 946 986 1011 1091
INCHR	8A1B	1348	222 245 252 343 351 359 382 626 1162 1362
INCP3	8293	429	1070 1081
INJINV	8A41	1365	1349
INJISV	8392	554	548 550
INJOUV	8A55	1372	1370
INK	8B27	1477	1464 1466
INK1	8B2A	1479	1480
INRT1	8A2D	1356	1352 1354
INRT2	8A3C	1363	1357
INSTAT	8386	548	538 896 944
INST1	838B	550	551
INST2	8391	553	549
INSVEC	A666	67	554
INTCHR	8A58	1373	1713
INVEC	A660	65	1128 1133 1136 1138 1158 1160 1365 1549
IRQBRK	800F	105	1765
IRQVEC	A67E	82	****
JTABLE	A620	9	822 824
JUMP1	85B4	808	797
JUM2	85E5	833	812
KEYQ	8923	1223	1194 1197 1261 1516
KSCONF	89A3	1287	1223 1278 1489 1515
KSHFL	A655	48	1185 1205 1257
KYSTAT	896A	1261	1755
LDBYTE	84A1	675	629 637 640 643
LEAVE	8AD1	1430	1428
LENTRY	8C78	1716	693 836 1083
LK1	8944	1237	1234
LK2	894A	1240	1238
LK3	8956	1249	1252
LOCM8	8569	772	758
LOCP8	855B	764	754
LOOK	8A5F	1376	1380
LPGD	846D	654	648
LPZ	8429	625	641 664 670 674
LPZB	8417	618	603
LP1	842C	626	628
LRNKEY	892C	1227	1188
LSTCOM	A657	50	235 244 248 258
L1J	84CC	693	697
L1ZB	84C6	690	684
L11B	85D7	826	809
L11C	85DD	829	840
L11D	85E9	835	917
L12B	8688	911	879 915
L12C	868C	913	****

SYMBOL	VALUE	LINE DEFINED		CROSS-REFERENCES					
L2ZB	84CF	694	691						
L21B	85EF	837	827						
L23P	87EE	1076	1073						
MAXRC	A658	51	927	929					
MEMZ	84AE	680	678						
MEM1	8510	728	704						
MEM2	862F	873	863						
MEM3	8801	1084	1077						
MEM3C	8808	1087	877	1093	1094				
MEM3D	8811	1091	1100						
MEM3E	881C	1097	1090						
MEM3EX	881A	1095	1092						
MEM3F	8826	1102	1098						
MONENT	8B7C	1522	97	1517					
MONITR	8000	97	****						
MORED	8454	643	656						
MORED2	86D2	941	949						
M1	81D1	339	337	1757					
M12	8159	262	260						
M13	8160	265	263						
M14	8167	268	266						
M15	81B7	314	275						
M21	8239	387	384						
M22	824A	394	386						
M23	8251	397	400						
M24	8267	406	393	395					
M25	826F	409	407						
M26	8289	422	415	417					
M27	828D	425	419						
M28	828F	426	421						
M29	8292	428	413						
M32	82C8	454	450						
M33	82EB	470	468						
M34	83C8	583	577						
M35	83CA	584	597	600					
M36	83EB	598	595						
M42	8566	770	768						
M43	8574	778	776						
NACCES	8B9C	1535	605	785	813				
NBASOC	8A44	1366	485	487	591				
NBELL	89CD	1305	1303						
NEWDEV	8B64	1513	1725						
NEWLN	84E1	706	679	719					
NEWLOC	8517	731	682	744	748	763	771	779	1097
NH3	83BF	578	570	573					
NH41	8501	720	711						
NH42	8537	745	736						
NIBALF	8313	495	492						
NIBASC	8309	490	1366						
NMIVEC	A67A	80	****						
NOBEEP	899B	1284	1196						
NOKEY	895E	1253	1236						
NOTCR	83C3	581	578						
NR10	8408	611	795	825					
NUREC	8443	636	631						
NXTLOC	8531	742	740	750	752				
NXTRG	83D2	588	****						

SYMBOL	VALUE	LINE DEFINED	CROSS-REFERENCES
OBCMIN	81D3	341	594 735
OBCRLF	834A	520	187
OCMCK	8325	503	895 904
OPCCOM	8337	510	148 185
OR1B	A000	90	****
OR3A	AC01	88	89 198 201 205 208 852 1528 1530 1536
OUD1	89DE	1312	1307
OUD2	89E0	1313	1316
OUD3	89F4	1323	1327
OUT	8AD4	1431	1388 1402 1415
OUTBYT	82FA	479	284 341 477 505 520 888 956
OUTC	8AB4	1415	1423
OUTCHR	8A47	1367	150 221 279 281 502 517 523 525 566 589 934 1154 1514
OUTDSP	89C1	1300	1208
OUTONE	8ADE	1436	1434
OUTPC	82EE	473	510 568
OUTQM	8320	501	715 741
OUTSZ	8319	498	****
OUTVEC	A663	66	1372
OUTXAH	82F4	475	500 908 952 1122
OUT1	81FE	361	358
OUT2	8201	363	353
OUT4	81F5	357	345
PAD	8B32	1484	1429
PADA	A400	86	1215 1217 1224 1235 1294
PADBIT	A650	41	1484
PAD1	8B35	1485	1487
PARFIL	822E	382	405
PARM	8220	377	239
PARNR	A649	30	259 379 389 390 408
PBDA	A402	87	1216 1231 1271 1274 1292 1376 1382 1410 1432 1437 1461 1481 1490 1518
PCHR	A65A	56	134 162 474 576 593 596 608
PCLR	A659	55	132 159 473 574 610
PCR1	A00C	92	1503
PHAKE	8ABC	1418	1419
PM1	822B	381	392
POR	8B4D	1502	****
PRM10	820A	368	375
PRVLOC	8555	761	756
PSHOVE	8208	367	237 238 381 834 835
PTRIN	8872	1139	1131
P1H	A64F	40	373 999 1111
P1L	A64E	39	372 876 980 997 1062 1078 1087 1108
P2H	A64D	38	371 433 804 865 1033 1112
P2L	A64C	37	370 435 799 869 875 913 1031 1109
P2SCR	829C	433	880 922 977 996 1086
P3H	A64B	36	369 398 431 438 457 688 792 803 806 847 962 1021 1034 1119 1139
P3L	A64A	35	368 397 401 402 429 440 460 686 794 798 802 810 829 843 958 1018 1032 1116 1141
P3SCR	82A7	438	705 730 864 1030
RAM	A620	8	1510
RC	A63D	24	636 655 932 935 948
RDIG	A645	28	1308 1310 1329
REGZ	8395	562	****

SYMBOL	VALUE	LINE DEFINED	CROSS-REFERENCES
RESALL	81C4	326	925 1279 1298 1330 1371 1430 1534
RESET	8B4A	1500	1746 1764
RESTIV	8899	1157	1148
RESXAF	81B8	316	411 1156 1163 1183 1364 1405
RESXF	81BE	321	462 544 635
RGBACK	8399	564	586
RIN	887E	1145	1759
RSTVEC	A67C	81	****
SAVE	8A87	1394	1389
SAVER	8188	289	377 455 529 621 921 1145 1168 1266 1284 1288
			1300 1348 1367 1373 1407 1527 1535
SAVINT	8064	152	125 131 139 179 193
SCAND	8906	1210	1758
SCNVEC	A66F	70	1209
SCPBUF	A600	7	1335 1336 1342
SCRA	A63A	20	1132 1134 1157 1159
SCRB	A63B	21	****
SCRC	A63C	22	****
SCRD	A63D	23	24
SCRE	A63E	25	1178 1182
SCRF	A63F	26	1228 1247
SCR0	A630	10	****
SCR1	A631	11	****
SCR2	A632	12	****
SCR3	A633	13	350 354 380 388 404 406
SCR4	A634	14	571 575
SCR5	A635	15	****
SCR6	A636	16	466 467 504 507 663 951
SCR7	A637	17	469 508 659 907 950
SCR8	A638	18	532 533 540
SCR9	A639	19	531 534 542
SC1	890D	1213	1222
SC2	891D	1219	1220
SDBYT	A651	42	1447 1468 1470 1473 1542
SEEK	8B02	1461	1463
SEGSM1	8C28	1651	1318
SENTRY	8E87	1717	1071
SET	8B0D	1466	1467
SPACE	8342	515	236 282 514 567 709 724 884 906 1106
SPCP3	8345	517	513
SPC2	833F	514	592
SPEXIT	86A8	925	945 947
SP2B	8698	918	912
SP2C	86A3	923	954
SP2D	86AB	926	924
SP2E	86B8	931	928
SP2F	86BA	932	930
SR	A65B	57	175 606
STDVAL	8C69	1711	1472
STD2	8619	862	****
STOCOM	8120	235	251
SVBRK	804A	137	1761
SVBYTE	86F4	955	936 938 940 943
SVIRQ	8029	123	1762
SVNMI	809B	177	1763
SWITCH	8B69	1515	****
SWLP	8B6C	1516	1519

SYMBOL	VALUE	LINE DEFINED	CROSS-REFERENCES
SWLP2	8BBC	1548	1551
SYM	8BD6	1562	1249
S1NG	87DE	1068	1080
S13B	87CD	1059	993
S13C	87D3	1062	1075
S23B	87E6	1072	1060
TABLE	8BD6	1563	****
TAPERR	848E	667	630 638 644 658 662 665
TECHO	A653	45	1152 1358 1360 1368 1386
TEXT	8A06	1331	1305
TIN	8A6A	1381	1399
TLP1	8A83	1391	1392
TOUT	8AA0	1406	1714
TOUTFL	A654	47	1377 1383 1436 1543 1545
TRACON	80CD	196	189
TRCOFF	80C0	191	1760
TRCVEC	A674	75	195
TRMTBL	8C6F	1713	1548
TSTAT	8B3C	1489	1715
TTY	8BA7	1540	1724
TV	A656	49	181 528
TVNZ	80AF	185	182
TXTMOV	8A0B	1335	1338
UBRKV	A676	77	****
UBRKVC	A676	76	77
UIRQV	A678	79	****
UIRQVC	A678	78	79
URCVEC	A66C	69	271 698 1164
USRENT	8035	128	****
VADDR	8646	882	897
VALS	8BC6	1557	1293 1561
VALSP2	8BC8	1561	1291
VECSW	8BB7	1546	1520
VERZ	84B5	683	681
VER1	8596	796	689 783
VER2	863C	878	807 874
VOCK	8664	895	****
V1	866D	899	890 892 903
V2	864B	884	894
WARM	8003	98	101 151 190 1526
WPR1B	85F7	841	838
WRAP	82B8	446	452
XR	A65E	60	153 615
YR	A65F	61	154 614
ZERCK	832E	506	625 881 957

```
LINE # LOC      CODE        LINE

0002  0000                ; AUDIO CASSETTE INTERFACE
0003  0000                ;******
0004  0000                ;****** COPYRIGHT 1978 SYNERTEK SYSTEMS CORPORATION
0005  0000                ;******
0006  0000                ;
0007  0000                ;VARIABLES
0008  0000                ;
0009  0000                OLD     =$F9              ;REMEMBER PREV INPUT LEVEL IN LOA
0010  0000                CHAR    =$FC              ;CHAR ASSY AND DISASSY
0011  0000                MODE    =$FD              ;BIT7=1 IS HS, 0 IS KIM
0012  0000                ;                 ... BIT6=1 IS HS REC W/WRONG ID BEING READ
0013  0000                ;           ... OR NOT YET IN SYNC (NO FRAME ERR)
0014  0000                BUFADL  =$FE              ;RUNNING BUFFER ADR
0015  0000                BUFADH  =$FF
0016  0000                CHKL    =$A636            ;SCR 6
0017  0000                CHKH    =$A637            ;SCR 7
0018  0000                TEMP1   =$A638            ;SCR 8
0019  0000                TEMP2   =$A639            ;SCR 9
0020  0000                ; PARAMETER AREA
0021  0000                        *=$A64A
0022  A64A                P3L     *=*+1             ;END ADDR +1 (LO)
0023  A64B                P3H     *=*+1             ; (HI)
0024  A64C                P2L     *=*+1             ;START ADDR ; (LO)
0025  A64D                P2H     *=*+1             ; (HI)
0026  A64E                P1L     *=*+1             ; ID
0027  A64F                ; CONSTANTS
0028  A64F                ;
0029  A64F                EOT     = $04
0030  A64F                SYN     = $16
0031  A64F                TM1500  =71               ;DELAY CONSTANT FOR OUTBTH
0032  A64F                C1500   =$1F              ;CLOCK LO LATCH FOR 1500 BAUD
0033  A64F                CKIM    =$AE              ;CLOCK LO LATCH FOR KIM
0034  A64F                TPBIT   =%1000            ;BIT 3 IS ENABLE/DISABLE TO DECOD
0035  A64F                ;
0036  A64F                ;EQUATES
0037  A64F                ;
0038  A64F                P2SCR   =$829C            ;MOVE P2 TO $FF,$FE IN PAGE ZERO
0039  A64F                ZERCK   =$832E            ;ZERO OUT CHECK SUM
0040  A64F                CONFIG  =$89A5
0041  A64F                ;
0042  A64F                ID      = P1L
0043  A64F                SAH     = P2H
0044  A64F                SAL     = P2L
0045  A64F                EAH     = P3H
0046  A64F                EAL     = P3L
0047  A64F                ;
0048  A64F                FRAME   =$FF              ;ERROR MSG # FOR FRAMING ERROR
0049  A64F                CHECK   =$CC              ;ERROR # FOR CHECKSUM ERROR
0050  A64F                LSTCHR  =$2F              ;LAST CHAR NOT '/'
0051  A64F                NONHEX  =$FF              ;NON HEX CHAR IN KIM REC
0052  A64F                ;
0053  A64F                ; I/O - TAPE ON/OFF IS CB2 ON VIA 1 (A000)
0054  A64F                ;       TAPE IN IS PB6 ON VIA 1 (A000)
0055  A64F                ;       TAPE OUT IS CODE 7 TO DISPLAY DECODER, THRU 6532
0056  A64F                ;            PB0-PB3 (A400)
```

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LINE # LOC      CODE        LINE

0057  A64F                  ;
0058  A64F                  VIAACR =$A00B
0059  A64F                  VIAPCR =$A00C           ;CONTROL CB2 TAPE ON/OFF, FOR
0060  A64F                  TPOUT  =$A402
0061  A64F                  TAPOUT =TPOUT
0062  A64F                  DDROUT =$A403
0063  A64F                  TAPIN  =$A000
0064  A64F                  DDRIN  =$A002
0065  A64F                  CLOKHI =$A005
0066  A64F                  CLOKLO =$A004
0067  A64F                  LATCHL =$A004
0068  A64F                  DDRDIG =$A401
0069  A64F                  DIG    =$A400
0070  A64F                  ; LOADT ENTER W/ ADDR IN PARM 2, MODE IN ACC
0071  A64F                  ;
0072  A64F                        *=$8C78
0073  8C78  20 B6 8D        LOADT  JSR START        ;INITIALIZE
0074  8C7B  AD 02 A0              LDA DDRIN
0075  8C7E  29 BF                 AND #$BF          ;BIT 6 = 0, INPUT IS PB6
0076  8C80  8D 02 A0              STA DDRIN
0077  8C83  A9 00                 LDA #0
0078  8C85  8D 0B A0              STA VIAACR
0079  8C88  A9 AE                 LDA #CKIM         ; SET UP CLOCK FOR GETTR (KIM)
0080  8C8A  24 FD                 BIT MODE
0081  8C8C  10 02                 BPL LOADT1        ;KIM - GO AHEAD
0082  8C8E  A9 1F                 LDA #C1500        ;HS - CHANGE GETTR VALUE
0083  8C90  8D 04 A0        LOADT1 STA LATCHL       ;STORE GETTR VAL IN LO LATCH
0084  8C93  20 82 8D        LOADT2 JSR SYNC         ;GET IN SYNC
0085  8C96  20 DE 8D        LOADT4 JSR RDCHTX
0086  8C99  C9 2A                 CMP #'*           ;START OF DATA?
0087  8C9B  F0 06                 BEQ LOAD11
0088  8C9D  C9 16                 CMP #SYN          ;NO - SYN?
0089  8C9F  D0 F2                 BNE LOADT2        ;IF NOT, RESTART SYNC SEARCH
0090  8CA1  F0 F3                 BEQ LOADT4        ;IF YES, KEEP LOOKING FOR *
0091  8CA3                  ;
0092  8CA3  A5 FD           LOAD11 LDA MODE
0093  8CA5  29 BF                 AND #$BF          ;CLEAR 'NOT IN SYNC' BIT
0094  8CA7  85 FD                 STA MODE
0095  8CA9  20 28 8E              JSR RDBYTX        ;READ ID BYTE ON TAPE
0096  8CAC  CD 4E A6              CMP ID            ;COMPARE WITH REQUESTED ID
0097  8CAF  F0 35                 BEQ LOADT5        ;LOAD IF EQUAL
0098  8CB1  AD 4E A6              LDA ID            ;COMPARE WITH 0
0099  8CB4  C9 00                 CMP #0
0100  8CB6  F0 2E                 BEQ LOADT5        ;IF 0, LOAD ANYWAY
0101  8CB8  C9 FF                 CMP #$FF          ;COMPARE WITH FF
0102  8CBA  F0 07                 BEQ LOADT6        ;IF FF, USE REQUEST SA TO LOAD
0103  8CBC                  ;
0104  8CBC  24 FD                 BIT MODE          ;UNWANTED RECORD, KIM OR HS?
0105  8CBE  30 22                 BMI HWRONG
0106  8CC0  4C 93 8C              JMP LOADT2        ;IF KIM, RESTART SEARCH
0107  8CC3                  ;
0108  8CC3                  ; SA (&EA IF USED) COME FROM REQUEST, DISCARD TAPE VALUE
0109  8CC3                  ;   (BUFAD ALREADY SET TO SA BY 'START')
0110  8CC3                  ;
0111  8CC3  20 28 8E        LOADT6 JSR RDBYTX       ;GET SAL FROM TAPE
```

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LINE # LOC      CODE        LINE

0112  8CC6  20 78 8E            JSR CHKT          ;INCLUDE IN CHECKSUM BUT IGNORE
0113  8CC9                     ;
0114  8CC9  20 28 8E            JSR RDBYTX        ;GET SAH FROM TAPE
0115  8CCC  20 78 8E            JSR CHKT          ;INCLUDE IN CHECKSUM
0116  8CCF                     ;
0117  8CCF  24 FD               BIT MODE          ;HS OR KIM?
0118  8CD1  10 63               BPL LOADT7        ;IF KIM, START READING DATA
0119  8CD3  20 E2 8D            JSR RDBYTH        ;HS. GET EAH, EAL FROM ...
0120  8CD6  20 78 8E            JSR CHKT          ; ... TAPE, INCLUDE IN CHECKSUM
0121  8CD9  20 E2 8D            JSR RDBYTH        ; ... BUT IGNORE
0122  8CDC  20 78 8E            JSR CHKT
0123  8CDF  4C 0C 8D            JMP LT7H          ;START READING HS DATA
0124  8CE2                     ;
0125  8CE2                     ; SA (& EA IF USED) COME FROM TAPE. SA REPLACES BUFAD
0126  8CE2                     ;
0127  8CE2  A9 C0            HWRONG LDA #$C0       ;READ THRU TO GET TO NEXT REC
0128  8CE4  85 FD               STA MODE          ;BUT DON'T CHECK CKSUM, NO FRAME I
0129  8CE6                     ;
0130  8CE6  20 28 8E         LOADT5 JSR RDBYTX     ;GET SAL FROM TAPE
0131  8CE9  20 78 8E            JSR CHKT
0132  8CEC  85 FE               STA BUFADL        ;PUT IN BUF START L
0133  8CEE  20 28 8E            JSR RDBYTX        ;SAME FOR SAH
0134  8CF1  20 78 8E            JSR CHKT
0135  8CF4  85 FF               STA BUFADH
0136  8CF6                     ;(SAL - H STILL HAVE REQUEST VALUE)
0137  8CF6  24 FD               BIT MODE          ;HS OR KIM?
0138  8CF8  10 3C               BPL LOADT7        ;IF KIM, START READING RECORD
0139  8CFA  20 E2 8D            JSR RDBYTH        ;HS. GET & SAVE EAL,EAH
0140  8CFD  20 78 8E            JSR CHKT
0141  8D00  8D 4A A6            STA EAL
0142  8D03  20 E2 8D            JSR RDBYTH
0143  8D06  20 78 8E            JSR CHKT
0144  8D09  8D 4B A6            STA EAH
0145  8D0C                     ;
0146  8D0C                     ; READ HS DATA
0147  8D0C                     ;
0148  8D0C  20 E2 8D         LT7H   JSR RDBYTH     ;GET NEXT BYTE
0149  8D0F  A6 FE               LDX BUFADL        ;CHECK FOR END OF DATA + 1
0150  8D11  EC 4A A6            CPX EAL
0151  8D14  D0 07               BNE LT7HA
0152  8D16  A6 FF               LDX BUFADH
0153  8D18  EC 4B A6            CPX EAH
0154  8D1B  F0 13               BEQ LT7HB
0155  8D1D  20 78 8E         LT7HA  JSR CHKT       ;NOT END. UPDATE CHECKSUM
0156  8D20  24 FD               BIT MODE          ;WRONG RECORD?
0157  8D22  70 04               BVS LT7HC         ;IF SO, DONT STORE BYTE
0158  8D24  A0 00               LDY #0            ;STORE BYTE
0159  8D26  91 FE               STA (BUFADL),Y
0160  8D28  E6 FE         LT7HC  INC BUFADL       ;BUMP BUFFER ADDR
0161  8D2A  D0 E0               BNE LT7H
0162  8D2C  E6 FF               INC BUFADH        ;CARRY
0163  8D2E  D0 DC               BNE LT7H          ;ALWAYS
0164  8D30                     ;
0165  8D30  C9 2F         LT7HB  CMP #'/          ;EA, MUST BE "/"
0166  8D32  D0 31               BNE LCERR         ;LAST CHAR NOT '/'
```

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LINE # LOC      CODE        LINE

0167  8D34  F0 19           BEQ LOADT8        ;(ALWAYS BRANCH)
0168  8D36                 ;
0169  8D36                 ; READ KIM DATA
0170  8D36                 ;
0171  8D36  20 2C 8E     LOADT7 JSR RDBYT
0172  8D39  B0 2E           BCS NHERR         ;NONHEX CHAR?
0173  8D3B  C9 2F           CMP #'/           ;LAST ?
0174  8D3D  F0 10           BEQ LOADT8
0175  8D3F  20 78 8E        JSR CHKT          ;UPDATE CHECKSUM (PACKED BYTE)
0176  8D42  A0 00           LDY #0            ;STORE BYTE
0177  8D44  91 FE           STA (BUFADL),Y
0178  8D46  E6 FE           INC BUFADL        ;BUMP BUFFER ADR
0179  8D48  D0 EC           BNE LOADT7        ;CARRY?
0180  8D4A  E6 FF           INC BUFADH
0181  8D4C  4C 36 8D        JMP LOADT7
0182  8D4F                 ;
0183  8D4F                 ; TEST CHECKSUM & FINISH
0184  8D4F                 ;
0185  8D4F                 LOADT8 =*
0186  8D4F  20 28 8E     LT8A   JSR RDBYTX       ;CHECK SUM
0187  8D52  CD 36 A6           CMP CHKL
0188  8D55  D0 16           BNE CKERR
0189  8D57  20 28 8E        JSR RDBYTX
0190  8D5A  CD 37 A6        CMP CHKH
0191  8D5D  D0 0E           BNE CKERR         ;CHECK SUM ERROR
0192  8D5F  F0 11           BEQ OKEXIT        ;(ALWAYS)
0193  8D61                 ;
0194  8D61  A9 FF        FRERR  LDA #FRAME      ;FRAMING ERROR
0195  8D63  D0 0A           BNE NGEXIT        ;(ALWAYS)
0196  8D65  A9 2F        LCERR  LDA #LSTCHR     ;LAST CHAR IS NOT '/'
0197  8D67  D0 06           BNE NGEXIT        ;(ALWAYS)
0198  8D69                 ;
0199  8D69  A9 FF        NHERR  LDA #NONHEX     ;KIM ONLY, NON HEX CHAR READ
0200  8D6B  D0 02           BNE NGEXIT        ;(ALWAYS)
0201  8D6D                 ;
0202  8D6D  A9 CC        CKERR  LDA #CHECK      ;CHECKSUM ERROR
0203  8D6F                 ;
0204  8D6F  38           NGEXIT SEC            ;ERROR INDICATOR TO MONITOR IS CAI
0205  8D70  B0 01           BCS EXIT          ;(ALWAYS)
0206  8D72                 ;
0207  8D72  18           OKEXIT CLC            ;NO ERROR
0208  8D73                 ;
0209  8D73  24 FD        EXIT   BIT MODE
0210  8D75  50 05           BVC EX10          ;READING WRONG REC?
0211  8D77  A0 80           LDY #$80
0212  8D79  4C 78 8C        JMP LOADT         ;RESTART SEARCH
0213  8D7C  A2 CC        EX10   LDX #$CC
0214  8D7E  8E 0C A0        STX VIAPCR        ;STOP TAPE
0215  8D81  60              RTS
0216  8D82  A9 6D        SYNC   LDA #$6D
0217  8D84  8D 00 A4        STA DIG           ;TURN ON OUT OF SYNC INDICATOR
0218  8D87  A5 FD           LDA MODE          ;TURN ON OUT OF SYNC MODE
0219  8D89  09 40           ORA #$40          ;BIT6
0220  8D8B  85 FD           STA MODE
0221  8D8D  20 A8 8D     SYNC5  JSR SYNBIT     ; SYNC TO TAPE
```

```
LINE #  LOC    CODE        LINE

0222   8D90  66 FC              ROR CHAR
0223   8D92  A5 FC              LDA CHAR
0224   8D94  C9 16              CMP #SYN
0225   8D96  D0 F5              BNE SYNC5
0226   8D98  A2 0A        SYNC10 LDX #10          ;NOW MAKE SURE CAN GET 10 SYNS
0227   8D9A  20 DE 8D           JSR RDCHTX
0228   8D9D  C9 16              CMP #SYN
0229   8D9F  D0 EC              BNE SYNC5
0230   8DA1  CA                 DEX
0231   8DA2  D0 F6              BNE SYNC10+2
0232   8DA4  8E 00 A4           STX DIG           ;TURN OFF DISPLAY
0233   8DA7  60                 RTS
0234   8DA8                ;SYNBIT - GET BIT IN SYN SEARCH. IF HS, ENTER WITH
0235   8DA8                ;  TIMER STARTED BY PREV BIT. BIT RETURNED IN CARRY.
0236   8DA8                ;
0237   8DA8  24 FD         SYNBIT BIT MODE           ;KIM OR HS?
0238   8DAA  10 63              BPL RDBITK           ;KIM
0239   8DAC  20 C9 8D      SYB10  JSR GETTR          ;HS
0240   8DAF  B0 01              BCS SYBONE           ;IF SHORT, GET NEXT TRANS
0241   8DB1  60                 RTS                  ;BIT IS ZERO
0242   8DB2  20 C9 8D      SYBONE JSR GETTR
0243   8DB5  60                 RTS
0244   8DB6                ;
0245   8DB6  84 FD         START  STY MODE           ;MODE PARM PASSED IN ACC
0246   8DB8  A9 09              LDA #9
0247   8DBA  20 A5 89           JSR CONFIG           ;PARTIAL I/O CONFIGURATION
0248   8DBD  20 2E 83           JSR ZERCK            ;ZERO THE CHECK SUM
0249   8DC0  20 9C 82           JSR P2SCR            ;MOVE SA TO FE,FF IN PAGE ZERO
0250   8DC3  A9 EC              LDA #$EC
0251   8DC5  8D 0C A0           STA VIAPCR           ;TAPE ON
0252   8DC8  60                 RTS
0253   8DC9                ;
0254   8DC9                ; GETTR - GET TRANSITION TIME FROM 16 BIT CLOCK
0255   8DC9                ; DESTROYS A,Y
0256   8DC9                ; LO LATCH OF CLOCK MUST BE PRELOADED ACCORDING TO MODE
0257   8DC9                ; SO THAT LSB OF HI BYTE OF CTR =BIT (HS)
0258   8DC9                ;       OR LSB OF HI BYTE IS 1/0 HF/LF  (KIM)
0259   8DC9                ; LSB OF HI CLOCK BYTE RETURNED IN CARRY
0260   8DC9                ;
0261   8DC9  A0 FF         GETTR  LDY #$FF
0262   8DCB  AD 00 A0           LDA TAPIN
0263   8DCE  29 40              AND #$40
0264   8DD0  C5 F9              CMP OLD
0265   8DD2  F0 F7              BEQ GETTR+2
0266   8DD4  85 F9              STA OLD
0267   8DD6  AD 05 A0           LDA CLOKHI
0268   8DD9  8C 05 A0           STY CLOKHI           ;RESTART CLOCK
0269   8DDC  4A                 LSR A                ;GET LSB INTO CARRY
0270   8DDD  60                 RTS
0271   8DDE                ;
0272   8DDE  24 FD         RDCHTX BIT MODE
0273   8DE0  10 7F              BPL RDCHT            ;KIM
0274   8DE2                ;
0275   8DE2                ; RDBYTH - READ HS BYTE
0276   8DE2                ; Y DESTROYED, BYTE RETURNED IN CHAR AND A
```

```
LINE # LOC      CODE        LINE

0277  8DE2                  ; TIME FROM ONE CALL TO NEXT MUST BE LESS THAN
0278  8DE2                  ;     START BIT TIME (TIMER STILL RUNNING)
0279  8DE2                  ;
0280  8DE2  8E 38 A6        RDBYTH STX TEMP1        ;SAVE X
0281  8DE5  A2 08                 LDX #8
0282  8DE7  20 C9 8D             JSR GETTR          ;GET START BIT TIME
0283  8DEA  2A                   ROL A              ;RESTORE CLOCK HI BYTE
0284  8DEB  C9 FD               CMP #$FD           ;START BIT MAY BE LONGER THAN FC
0285  8DED  B0 15               BCS RDBH90         ;IF NOT ZERO , FRAMING ERR
0286  8DEF  20 C9 8D        RDBH10 JSR GETTR        ;GET BIT IN CARRY
0287  8DF2  90 05               BCC RDASSY
0288  8DF4  20 C9 8D           JSR GETTR          ;BIT IS ONE, WAIT HALF CYC
0289  8DF7  90 0B               BCC RDBH90         ;IF PHASE WRONG, FRAMING ERR
0290  8DF9  66 FC        RDASSY ROR CHAR
0291  8DFB  CA                   DEX
0292  8DFC  D0 F1               BNE RDBH10
0293  8DFE  A5 FC               LDA CHAR           ;GET IN ACC
0294  8E00  AE 38 A6           LDX TEMP1          ;RESTORE X
0295  8E03  60                   RTS
0296  8E04  24 FD        RDBH90 BIT MODE           ;NO ERR IF NOT IN SYNC
0297  8E06  70 F8               BVS RDBH90-4       ;OR READING WRONG REC
0298  8E08  68                   PLA                ;FIX STACK
0299  8E09  68                   PLA
0300  8E0A  A9 FF               LDA #FRAME         ;GET ERROR INDICATOR ÍN ACC
0301  8E0C  4C 6F 8D           JMP NGEXIT
0302  8E0F                  ;
0303  8E0F                  ; RDBITK - READ KIM BIT - X,Y,A DESTROYED, BIT RETURNED
0304  8E0F                  ; (INVERTED)
0305  8E0F                  ;
0306  8E0F  A2 02        RDBITK LDX #2
0307  8E11  20 C9 8D           JSR GETTR          ;RESYNC
0308  8E14  20 C9 8D      WAITLO JSR GETTR
0309  8E17  90 FB               BCC WAITLO         ;WAIT FOR HF
0310  8E19  CA                   DEX
0311  8E1A  D0 F8               BNE WAITLO         ;GET 2 HALF CYCS TO BE SURE
0312  8E1C                  ;
0313  8E1C  E8              HFCNT  INX              ;COUNT HF CYCS WITH X
0314  8E1D  20 C9 8D           JSR GETTR
0315  8E20  B0 FA               BCS HFCNT
0316  8E22  E0 1B               CPX #27            ;ONE=18 CYCS, ZERO =36 CYCS
0317  8E24  B0 37               BCS RDRTN-1        ;INVERT CARRY
0318  8E26  90 37               BCC PACKT3
0319  8E28                  ;
0320  8E28  24 FD        RDBYTX BIT MODE
0321  8E2A  30 B6               BMI RDBYTH         ;HS
0322  8E2C                  ;READ KIM BYTE, RETURN IN CHAR AND A
0323  8E2C                  ;
0324  8E2C  20 61 8E        RDBYT  JSR RDCHT
0325  8E2F  C9 2F               CMP #'/            ;READ ONE CHAR IF LAST
0326  8E31  F0 2A               BEQ RDRTN-1        ;CLEAR CARRY AND RETURN
0327  8E33  20 3E 8E           JSR PACKT
0328  8E36  B0 26               BCS RDRTN          ;NON HEX CHAR?
0329  8E38  AA                   TAX                ;SAVE MSD
0330  8E39  20 61 8E           JSR RDCHT
0331  8E3C  86 FC               STX CHAR           ;MOVE MSD TO CHAR
```

```
LINE # LOC      CODE        LINE

0332  8E3E                ; AND FALL INTO PACKT AGAIN
0333  8E3E                ;
0334  8E3E                ;PACKT - ASCII HEX TO 4 BITS
0335  8E3E                ;INPUT IN A, OUTPUT IN CHAR AND A, CARRY SET = NON HEX
0336  8E3E                ;
0337  8E3E  C9 30        PACKT   CMP #$30          ;LT "0"?
0338  8E40  90 1D                BCC PACKT3
0339  8E42  C9 47                CMP #$47          ;GT "F" ?
0340  8E44  B0 19                BCS PACKT3
0341  8E46  C9 40                CMP #$40          ;A-F?
0342  8E48  F0 15                BEQ PACKT3        ;40 NOT VALID
0343  8E4A  90 03                BCC PACKT1
0344  8E4C  18                   CLC
0345  8E4D  69 09                ADC #9
0346  8E4F  2A              PACKT1 ROL A             ;GET LSD INTO LEFT NIBBLE
0347  8E50  2A                   ROL A
0348  8E51  2A                   ROL A
0349  8E52  2A                   ROL A
0350  8E53  A0 04                LDY #4
0351  8E55  2A              PACKT2 ROL A             ;ROTATE 1 BIT AT A TIME INTO CHAR
0352  8E56  26 FC                ROL CHAR
0353  8E58  88                   DEY
0354  8E59  D0 FA                BNE PACKT2
0355  8E5B  A5 FC                LDA CHAR          ;GET INTO ACCUM ALSO
0356  8E5D  18                   CLC               ;OK
0357  8E5E  60              RDRTN  RTS
0358  8E5F  38              PACKT3 SEC               ;NOT HEX
0359  8E60  60                   RTS
0360  8E61                ;
0361  8E61                ; RDCHT - READ KIM CHAR
0362  8E61                ; PRESERVES X, RETURNS CHAR IN CHAR (W/PARITY)
0363  8E61                ; AND A (W/O PARITY)
0364  8E61                ;
0365  8E61  8E 38 A6      RDCHT   STX TEMP1         ;SAVE X
0366  8E64  A9 FF                LDA #$FF          ;USE A TO COUNT BITS (BY SHIFTING
0367  8E66  48              KBITS  PHA               ;SAVE COUNTER
0368  8E67  20 0F 8E             JSR RDBITK
0369  8E6A  66 FC                ROR CHAR
0370  8E6C  68                   PLA
0371  8E6D  0A                   ASL A
0372  8E6E  D0 F6                BNE KBITS         ;DO 8 BITS
0373  8E70  A5 FC                LDA CHAR
0374  8E72  2A                   ROL A
0375  8E73  4A                   LSR A             ;DROP PARITY
0376  8E74  AE 38 A6             LDX TEMP1         ;RESTORE X
0377  8E77  60                   RTS
0378  8E78                ;
0379  8E78                ; CHKT - UPDATE CHECK SUM FROM BYTE IN A
0380  8E78                ; DESTROYS Y
0381  8E78                ;
0382  8E78  A8              CHKT    TAY               ;SAVE ACCUM
0383  8E79  18                   CLC
0384  8E7A  6D 36 A6             ADC CHKL
0385  8E7D  8D 36 A6             STA CHKL
0386  8E80  90 03                BCC CHKT10
```

```
LINE #  LOC    CODE        LINE

0387  8E82  EE 37 A6          INC CHKH        ;BUMP HI BYTE
0388  8E85  98          CHKT10 TYA             ;RESTORE A
0389  8E86  60                 RTS
0390  8E87  20 B6 8D    DUMPT  JSR START       ;INIT VIA & CKSUM, SA TO BUFAD & S
0391  8E8A  A9 07               LDA #7          ;CODE FOR TAPE OUT
0392  8E8C  8D 02 A4            STA TAPOUT      ;BIT 3 USED FOR HI/LO
0393  8E8F  A0 80               LDY #$80
0394  8E91  24 FD               BIT MODE
0395  8E93  10 13               BPL DUMPT1      ;KIM - DO 128 SYNS
0396  8E95                ;HS - WRITE 8 SEC STEADY MARK
0397  8E95  EE 02 A4            INC TAPOUT      ;DISABLE OUTPUT
0398  8E98  A2 08               LDX #$8         ;8 TIMES ...
0399  8E9A  A0 15         MARK8A LDY #21         ;... 1SEC
0400  8E9C  20 5D 8F      MARK8B JSR OUTCHT      ;BENIGN PAUSE
0401  8E9F  88                 DEY
0402  8EA0  D0 FA               BNE MARK8B
0403  8EA2  CA                  DEX
0404  8EA3  D0 F5               BNE MARK8A
0405  8EA5  CE 02 A4            DEC TAPOUT      ;RESTORE OUTPUT
0406  8EA8                ; AND DO 256 SYNS
0407  8EA8  A9 16         DUMPT1 LDA #SYN
0408  8EAA  20 13 8F            JSR OUTCTX      ;WRITE SYN
0409  8EAD  88                 DEY
0410  8EAE  D0 F8               BNE DUMPT1
0411  8EB0                ;
0412  8EB0  A9 2A               LDA #'*         ;WRITE START
0413  8EB2  20 13 8F            JSR OUTCTX
0414  8EB5                ;
0415  8EB5  AD 4E A6            LDA ID          ;WRITE ID
0416  8EB8  20 46 8F            JSR OUTBTX
0417  8EBB                ;
0418  8EBB  AD 4C A6            LDA SAL         ;WRITE SA
0419  8EBE  20 43 8F            JSR OUTBCX
0420  8EC1  AD 4D A6            LDA SAH
0421  8EC4  20 43 8F            JSR OUTBCX
0422  8EC7                ;
0423  8EC7                ;
0424  8EC7  24 FD               BIT MODE        ;KIM OR HS?
0425  8EC9  10 0C               BPL DUMPT2
0426  8ECB                ;
0427  8ECB  AD 4A A6            LDA EAL         ;HS. WRITE EA
0428  8ECE  20 43 8F            JSR OUTBCX
0429  8ED1  AD 4B A6            LDA EAH
0430  8ED4  20 43 8F            JSR OUTBCX
0431  8ED7                ;
0432  8ED7  A5 FE         DUMPT2 LDA BUFADL      ;CHECK FOR LAST BYTE
0433  8ED9  CD 4A A6            CMP EAL
0434  8EDC  D0 25               BNE DUMPT4
0435  8EDE  A5 FF               LDA BUFADH
0436  8EE0  CD 4B A6            CMP EAH
0437  8EE3  D0 1E               BNE DUMPT4
0438  8EE5                ;
0439  8EE5  A9 2F               LDA #'/         ;LAST. WRITE "/"
0440  8EE7  20 13 8F            JSR OUTCTX
0441  8EEA  AD 36 A6            LDA CHKL        ;WRITE CHECK SUM
```

```
LINE #  LOC    CODE        LINE

0442  8EED  20 46 8F            JSR OUTBTX
0443  8EF0  AD 37 A6            LDA CHKH
0444  8EF3  20 46 8F            JSR OUTBTX
0445  8EF6                     ;
0446  8EF6  A9 04               LDA #EOT          ;WRITE TWO EOT'S
0447  8EF8  20 46 8F            JSR OUTBTX
0448  8EFB  A9 04               LDA #EOT
0449  8EFD  20 46 8F            JSR OUTBTX
0450  8F00                     ;
0451  8F00                     DT3E    = * (SET "OK" MARK)
0452  8F00  4C 72 8D            JMP OKEXIT
0453  8F03                     ;
0454  8F03  A0 00               DUMPT4 LDY #0           ;GET BYTE
0455  8F05  B1 FE                     LDA (BUFADL),Y
0456  8F07  20 43 8F            JSR OUTBCX        ;WRITE IT W/CHK SUM
0457  8F0A  E6 FE               INC BUFADL        ;BUMP BUFFER ADDR
0458  8F0C  D0 C9               BNE DUMPT2
0459  8F0E  E6 FF               INC BUFADH        ;CARRY
0460  8F10  4C D7 8E            JMP DUMPT2
0461  8F13  24 FD               OUTCTX BIT MODE         ;HS OR KIM?
0462  8F15  10 46                     BPL OUTCHT        ;KIM
0463  8F17                     ;
0464  8F17                     ;  OUTBTH - NO CLOCK
0465  8F17                     ; A,X DESTROYED
0466  8F17                     ; MUST RESIDE ON ONE PAGE - TIMING CRITICAL
0467  8F17  A2 09               OUTBTH LDX #9           ;8 BITS + START BIT
0468  8F19  8C 39 A6                  STY TEMP2
0469  8F1C  85 FC                     STA CHAR
0470  8F1E  AD 02 A4                  LDA TAPOUT        ;GET PREV LEVEL
0471  8F21  46 FC               GETBIT LSR CHAR
0472  8F23  49 08                     EOR #TPBIT
0473  8F25  8D 02 A4                  STA TAPOUT        ;INVERT LEVEL
0474  8F28                     ; *** HERE STARTS FIRST 416 USEC PERIOD
0475  8F28  A0 47                     LDY #TM1500
0476  8F2A  88                  A416   DEY               ;TIME FOR THIS LOOP IS 5Y-1
0477  8F2B  D0 FD                     BNE A416
0478  8F2D  90 11                     BCC NOFLIP        ;NOFLIP IF BIT ZERO
0479  8F2F  49 08                     EOR #TPBIT        ;BIT IS ONE - INVERT OUTPUT
0480  8F31  8D 02 A4                  STA TAPOUT
0481  8F34                     ; *** END OF FIRST 416 USEC PERIOD
0482  8F34  A0 46               B416   LDY #TM1500-1
0483  8F36  88                  B416B  DEY               ;LENGTH OF LOOP IS 5Y-1
0484  8F37  D0 FD                     BNE B416B
0485  8F39  CA                        DEX
0486  8F3A  D0 E5                     BNE GETBIT        ;GET NEXT BIT (LAST IS 0 START BI
0487  8F3C  AC 39 A6                  LDY TEMP2         ; (BY 9 BIT LSR)
0488  8F3F  60                        RTS
0489  8F40  EA                  NOFLIP NOP               ;TIMING
0490  8F41  90 F1                     BCC B416          ;(ALWAYS)
0491  8F43                     ;
0492  8F43  20 78 8E            OUTBCX JSR CHKT
0493  8F46  24 FD               OUTBTX BIT MODE
0494  8F48  30 CD                     BMI OUTBTH        ;HS
0495  8F4A                     ;
0496  8F4A                     ;OUTBTC - OUTPUT ONE KIM BYTE
```

```
LINE # LOC      CODE        LINE

0497  8F4A                  ;
0498  8F4A                  OUTBTC =*
0499  8F4A  A8              OUTBT  TAY              ;SAVE DATA BYTE
0500  8F4B  4A                     LSR A
0501  8F4C  4A                     LSR A
0502  8F4D  4A                     LSR A
0503  8F4E  4A                     LSR A
0504  8F4F  20 52 8F               JSR HEXOUT       ;MORE SIG DIGIT
0505  8F52              ; FALL INTO HEXOUT
0506  8F52              ;
0507  8F52              ;CONVERT LSD OF A TO ASCII
0508  8F52              ;
0509  8F52  29 0F        HEXOUT AND #$0F
0510  8F54  C9 0A               CMP #$0A
0511  8F56  18                   CLC
0512  8F57  30 02               BMI HEX1
0513  8F59  69 07               ADC #$07
0514  8F5B  69 30        HEX1   ADC #$30
0515  8F5D              ;
0516  8F5D              ; OUTCHT - OUTPUT ASCII CHAR (KIM)
0517  8F5D              ; CLOCK NOT USED
0518  8F5D              ; X,Y PRESERVED
0519  8F5D              ; MUST RESIDE ON ONE PAGE - TIMING CRITICAL
0520  8F5D              ;
0521  8F5D  8E 38 A6     OUTCHT STX TEMP1        ;PRESERVE X
0522  8F60  8C 39 A6            STY TEMP2        ;DITTO Y
0523  8F63  85 FC               STA CHAR
0524  8F65  A9 FF               LDA #$FF         ;USE FF W/SHIFTS TO COUNT BITS
0525  8F67  48        KIMBIT PHA                 ;SAVE BIT CTR
0526  8F68  AD 02 A4            LDA TPOUT        ;GET CURRENT OUTPUT LEVEL
0527  8F6B  46 FC               LSR CHAR         ;GET DATA BIT IN CARRY
0528  8F6D  A2 12               LDX #18          ;ASSUME 'ONE'
0529  8F6F  B0 02               BCS HF
0530  8F71  A2 24               LDX #36          ;BIT IS ZERO
0531  8F73  A0 19        HF     LDY #25
0532  8F75  49 08               EOR #TPBIT       ;INVERT OUTPUT
0533  8F77  8D 02 A4            STA TPOUT
0534  8F7A  88        HFP1   DEY                 ;PAUSE FOR 138 USEC
0535  8F7B  D0 FD               BNE HFP1
0536  8F7D  CA                  DEX              ;COUNT HALF CYCS OF HF
0537  8F7E  D0 F3               BNE HF
0538  8F80  A2 18        LF     LDX #24          ;ASSUME BIT IS ONE
0539  8F82  B0 02               BCS LF20
0540  8F84  A2 0C               LDX #12          ;BIT IS ZERO
0541  8F86  A0 27        LF20   LDY #39
0542  8F88  49 08               EOR #TPBIT      ;INVERT OUTPUT
0543  8F8A  8D 02 A4            STA TPOUT
0544  8F8D  88        LFP1   DEY                 ;PAUSE FOR 208 USEC
0545  8F8E  D0 FD               BNE LFP1
0546  8F90  CA                  DEX              ;COUNT HALF CYCS
0547  8F91  D0 F3               BNE LF20
0548  8F93  68                  PLA              ;RESTORE BIT CTR
0549  8F94  0A                  ASL A            ;DECREMENT IT
0550  8F95  D0 D0               BNE KIMBIT       ;FF SHIFTED 8X = 00
0551  8F97  AE 38 A6            LDX TEMP1
```

```
LINE # LOC      CODE        LINE

0552  8F9A  AC 39 A6            LDY TEMP2
0553  8F9D  98                  TYA                 ;RESTORE DATA BYTE
0554  8F9E  60                  RTS
0555  8F9F                  ;
0556  8F9F                  .END

ERRORS = 0000 <0000>
```

SYMBOL	VALUE	LINE DEFINED	CROSS-REFERENCES									
A208	8F2A	476	477									
BUFADH	00FF	15	135	152	162	180	435	459				
BUFADL	00FE	14	132	149	159	160	177	178	432	455	457	
B208	8F34	482	490									
B208B	8F36	483	484									
CHAR	00FC	10	222	223	290	293	331	352	355	369	373	469
			471	523	527							
CHECK	00CC	49	202									
CHKH	A637	17	190	387	443							
CHKL	A636	16	187	384	385	441						
CHKT	8E78	382	112	115	120	122	131	134	140	143	155	175
			492									
CHKT10	8E85	388	386									
CKERR	8D6D	202	188	191								
CKIM	00AE	33	79									
CLOKHI	A005	65	267	268								
CLOKLO	A004	66	****									
CONFIG	89A5	40	247									
C1500	001F	32	82									
DDRDIG	A401	68	****									
DDRIN	A002	64	74	76								
DDROUT	A403	62	****									
DIG	A400	69	217	232								
DT3E	8F00	451	****									
DUMPT	8E87	390	****									
DUMPT1	8EA8	407	395	410								
DUMPT2	8ED7	432	425	458	460							
DUMPT4	8F03	454	434	437								
EAH	A64B	45	144	153	429	436						
EAL	A64A	46	141	150	427	433						
EOT	0004	29	446	448								
EXIT	8D73	209	205									
EX10	8D7C	213	210									
FRAME	00FF	48	194	300								
FRERR	8D61	194	****									
GETBIT	8F21	471	486									
GETTR	8DC9	261	239	242	265	282	286	288	307	308	314	
HEXOUT	8F52	509	504									
HEX1	8F5B	514	512									
HF	8F73	531	529	537								
HFCNT	8E1C	313	315									
HFP1	8F7A	534	535									
HWRONG	8CE2	127	105									
ID	A64E	42	96	98	415							
KBITS	8E66	367	372									
KIMBIT	8F67	525	550									
LATCHL	A004	67	83									
LCERR	8D65	196	166									
LF	8F80	538	****									
LFP1	8F8D	544	545									
LF20	8F86	541	539	547								
LOADT	8C78	73	212									
LOADT1	8C90	83	81									
LOADT2	8C93	84	89	106								

SYMBOL	VALUE	LINE DEFINED	CROSS-REFERENCES									
LOADT4	8C96	85	90									
LOADT5	8CE6	130	97	100								
LOADT6	8CC3	111	102									
LOADT7	8D36	171	118	138	179	181						
LOADT8	8D4F	185	167	174								
LOAD11	8CA3	92	87									
LSTCHR	002F	50	196									

SYMBOL	VALUE	LINE DEFINED	CROSS-REFERENCES
LT7H	8D0C	148	123 161 163
LT7HA	8D10	155	151
LT7HB	8D30	165	154
LT7HC	8D28	160	157
LT8A	8D4F	****	
MARK8A	8E9A	399	404
MARK8B	8E9C	400	402
MODE	00FD	11	80 92 94 104 117 128 137 156 209 218 220 237 245 272 296 320 394 424 461 493
NGEXIT	8D6F	204	195 197 200 301
NHERR	8D69	199	172
NOFLIP	8F40	489	478
NONHEX	00FF	51	199
OKEXIT	8D72	207	192 452
OLD	00F9	9	264 266
OUTBCX	8F43	492	419 421 428 430 456
OUTBT	8F4A	499	****
OUTBTC	8F4A	498	****
OUTBTH	8F17	467	494
OUTBTX	8F46	493	416 442 444 447 449
OUTCHT	8F5D	521	400 462
OUTCTX	8F13	461	408 413 440
PACKT	8E3E	337	327
PACKT1	8E4F	346	343
PACKT2	8E55	351	354
PACKT3	8E5F	358	318 338 340 342
P1L	A64E	26	42
P2H	A64D	25	43
P2L	A64C	24	44
P2SCR	829C	38	249
P3H	A64B	23	45
P3L	A64A	22	46
RDASSY	8DF9	290	287
RDBH10	8DEF	286	292
RDBH90	8E04	296	285 289 297
RDBITK	8E0F	306	238 368
RDBYT	8E2C	324	171
RDBYTH	8DE2	280	119 121 139 142 148 321
RDBYTX	8E28	320	95 111 114 130 133 186 189
RDCHT	8E61	365	273 324 330
RDCHTX	8DDE	272	85 227
RDRTN	8E5E	357	317 326 328
SAH	A64D	43	420
SAL	A64C	44	418
START	8DB6	245	73 390
SYBONE	8DB2	242	240
SYB10	8DAC	239	****
SYN	0016	30	88 224 228 407
SYNBIT	8DA8	237	221
SYNC	8D82	216	84
SYNC10	8D98	226	231
SYNC5	8D8D	221	225 229
TAPIN	A000	63	262
TAPOUT	A402	61	392 397 405 470 473 480
TEMP1	A638	18	280 294 365 376 521 551
TEMP2	A639	19	468 487 522 552
TM1500	0047	31	475 482
TPBIT	0008	34	472 479 532 542
TPOUT	A402	60	61 526 533 543
VIAACR	A00B	58	78
VIAPCR	A00C	59	214 251
WAITLO	8E14	308	309 311
ZERCK	832E	39	248

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