SYM-1 REFERENCE MANUAL

SSC Pub MAN-A-260006-C

First Printing: May, 1978
Second Printing: August, 1978
Third Printing: June, 1979

Synertek Systems Corporation

P.O. BOX 552 SANTA CLARA, CALIFORNIA 95052 TEL. (408) 988-5689 TWX: 910-338-0135

SYM-1 REFERENCE MANUAL

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

* 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.

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, 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.

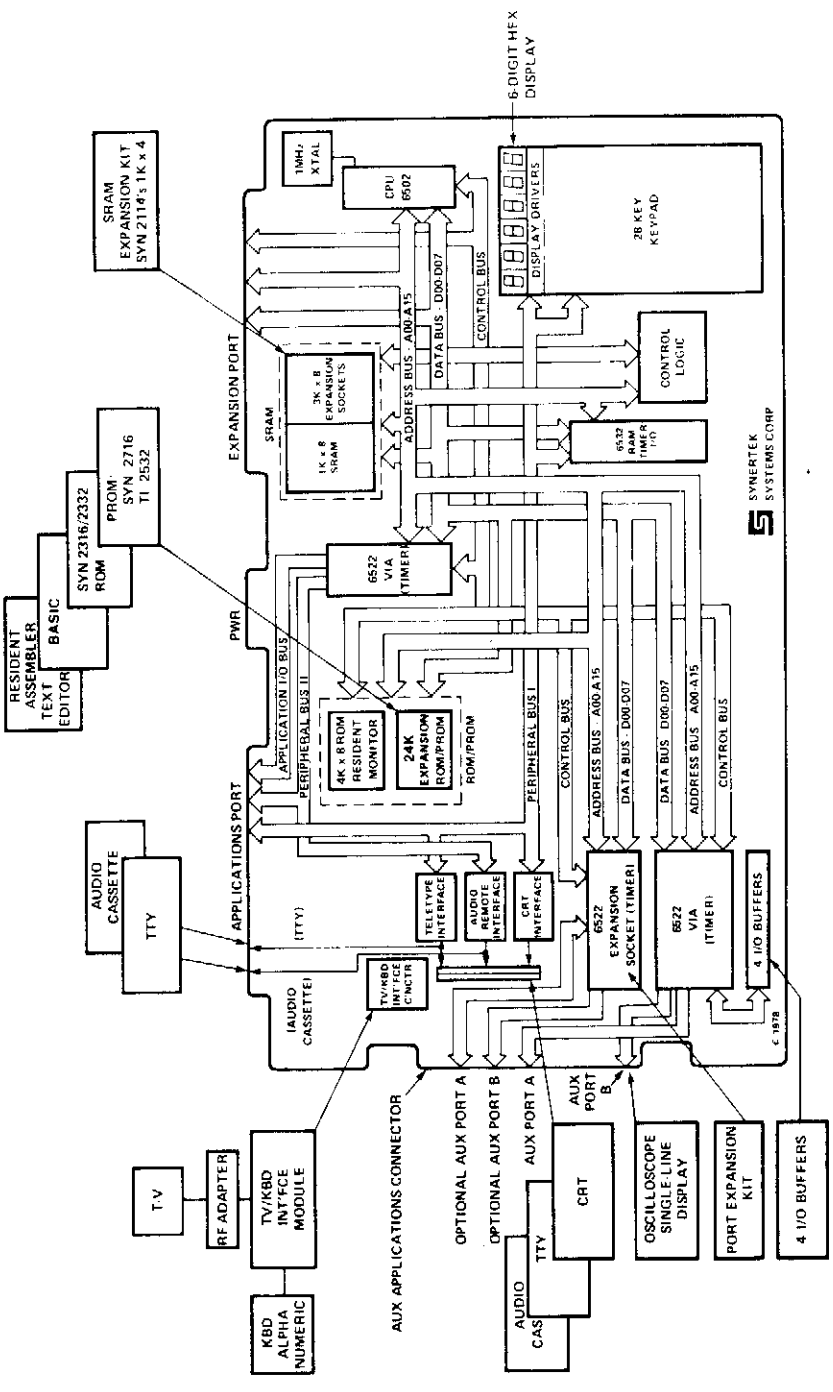
3.2 CAUTION ON MOS PARTS

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.



3–1. FUNCTIONAL BLOCK DIAGRAM

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 "SY1.1 . .". 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
```

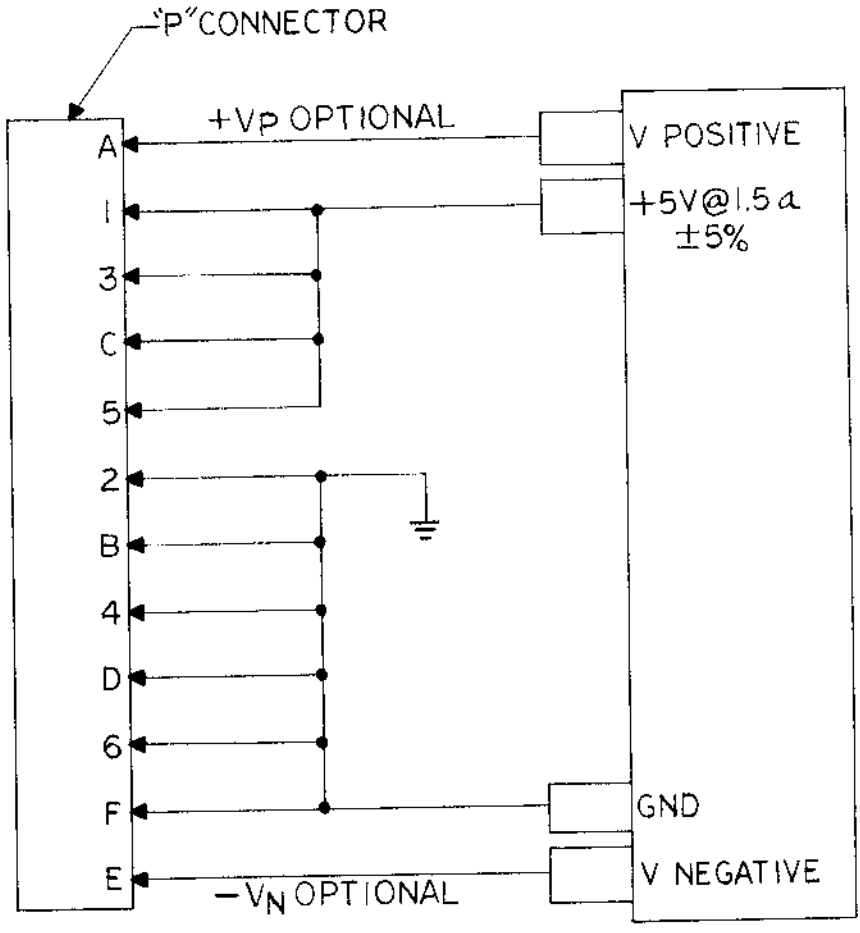


Figure 3-2. POWER SUPPLY CONNECTIONS

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)	SY1.1..	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.

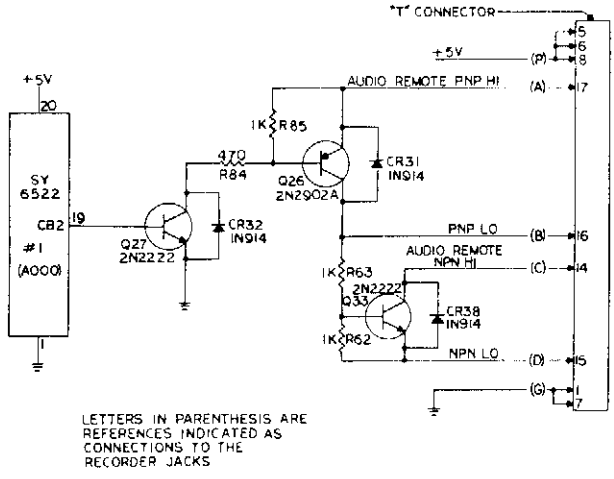
Since SYM-1 audio cassette operation involves high data transfer rates (185 bytes per second for HIGH-SPEED format), you should use a good quality recorder to ensure reliable performance. The unit should be equipped with an earphone jack for output, a microphone for input, a remote jack for remote control 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

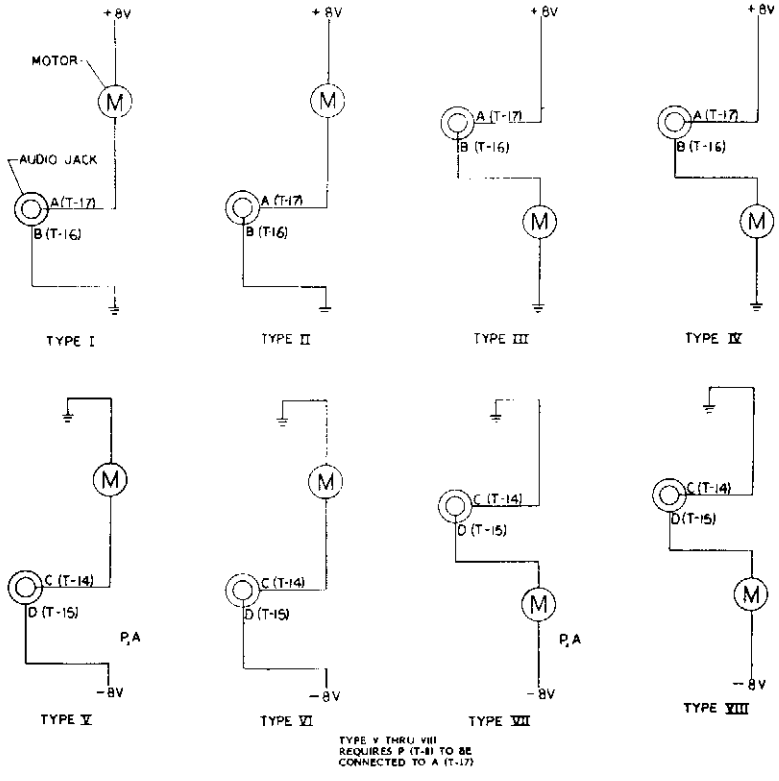


Figure 3-3. REMOTE CONTROL TYPES AND CONNECTIONS

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)

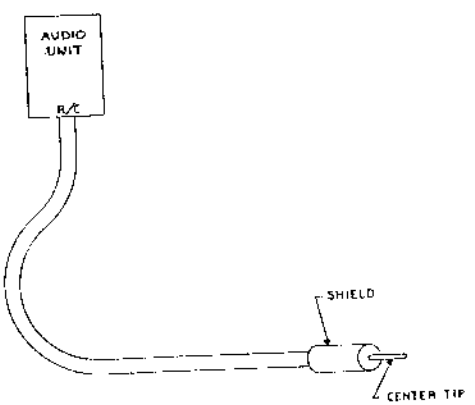


Figure 3-4. REMOTE CONTROL PLUG UNIT

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. Depress "PLAY" control on the cassette recorder before pressing (CR).

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 cassette ID will be displayed on the left digit (see Appendix M).

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)	SY1.1 . .	Log-on to keyboard
(SHIFT) (JUMP) ((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.

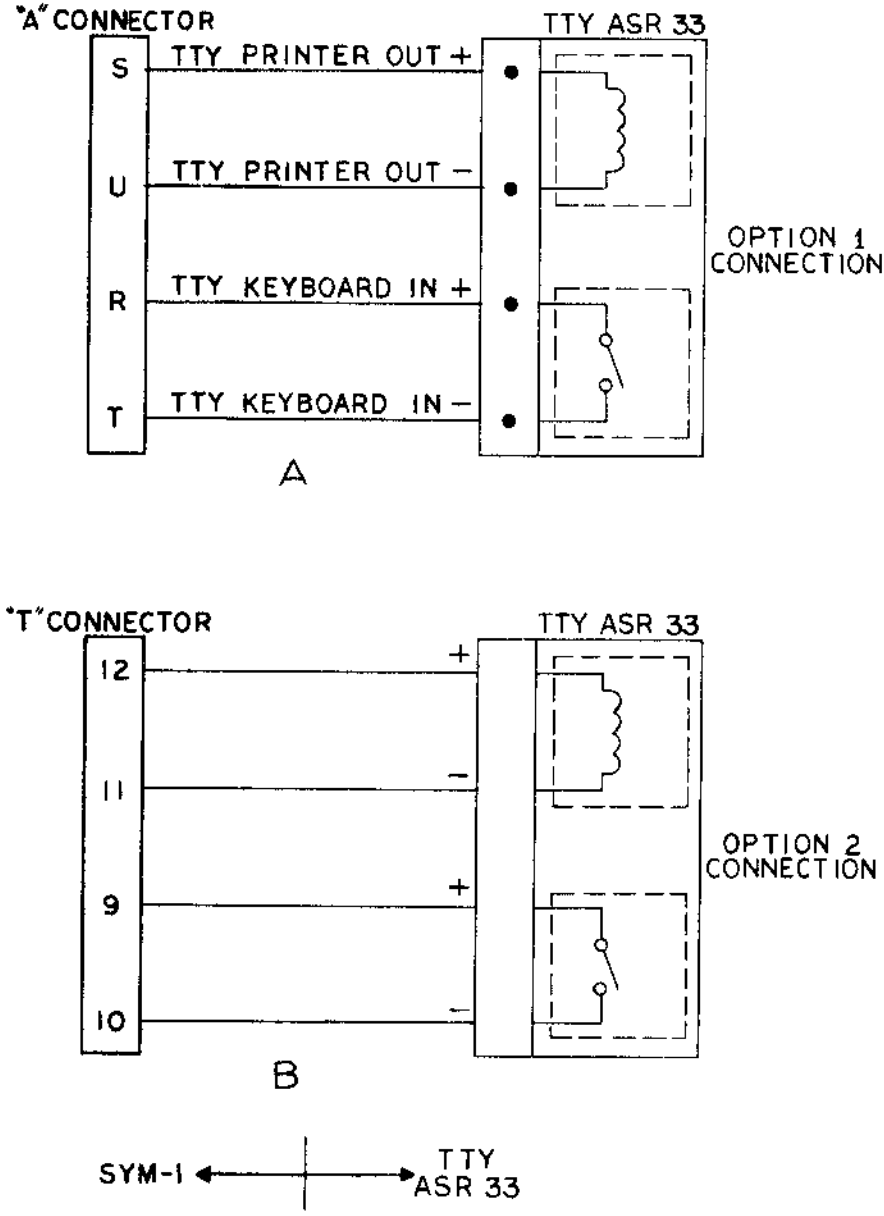


Figure 3-5. TTY I/O CONNECTIONS

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 shown 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, such as Synertek Systems' Keyboard Terminal Module, 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.

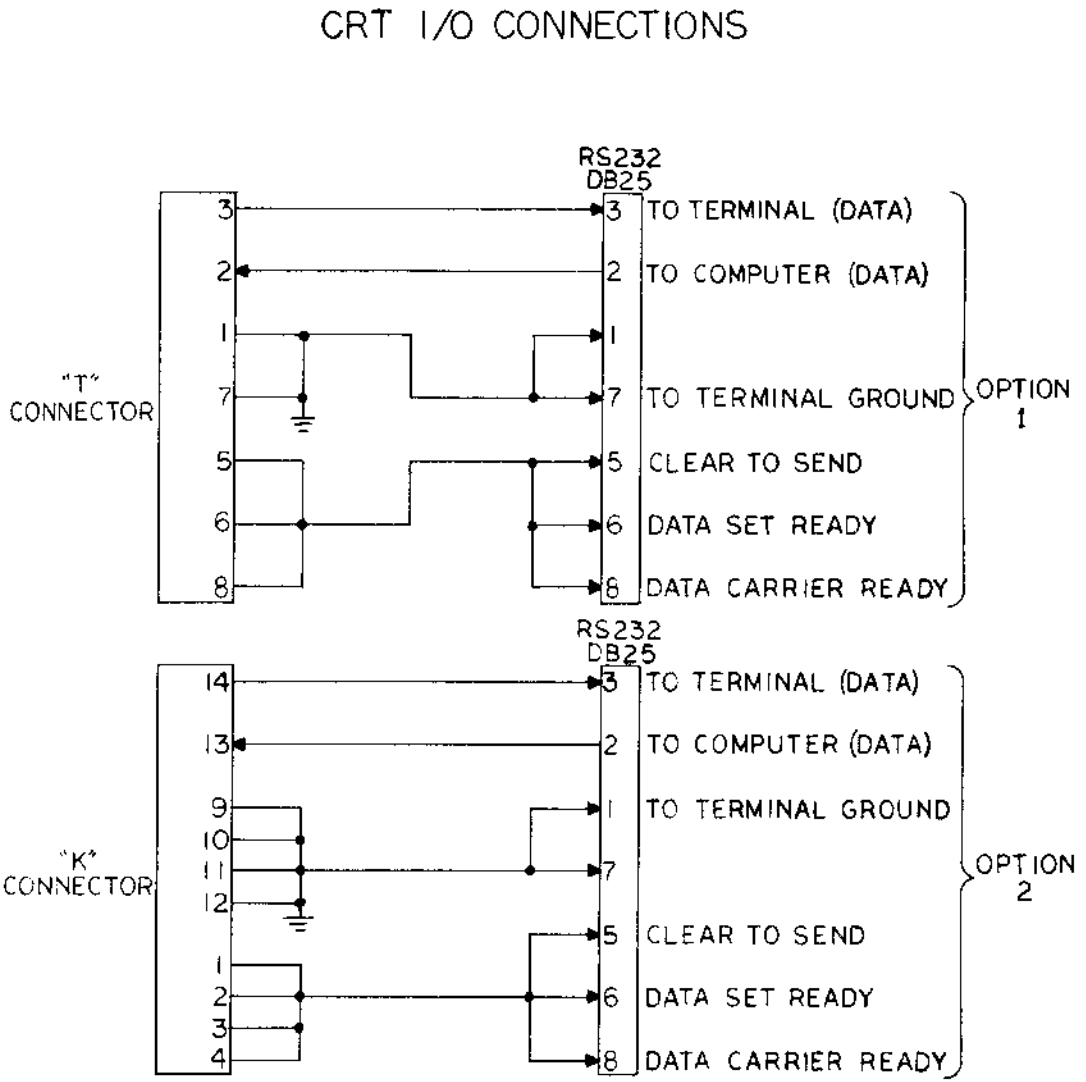


Figure 3-6. CRT I/O CONNECTIONS