The Engineering Staff of
TEXAS INSTRUMENTS INCORPORATED
Semiconductor Group

TM 990/301
MICROTERMINAL

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IMPORTANT NOTICE

TM 990/301 MICROTERMINAL

1. GENERAL

The Texas Instruments Microterminal offers all of the features of a minicomputer front panel at reduced cost. The Microterminal, intended primarily to support the Texas Instruments TM 990/100M and TM 990/180M microcomputers, allows the user to do the following:

- Read from ROM or read/write to RAM
- Enter/display Program Counter
- Execute user program in free running mode or in single instruction mode
- Halt user program execution
- Enter/display Status Register
- Enter/display Workspace Pointer (this term is unique to the Texas Instruments 9900 microprocessor)
- Enter/display CRU data (this term is unique to the Texas Instruments 9900 microprocessor)
- Convert hexadecimal quantity to signed decimal quantity
- Convert signed decimal quantity to hexadecimal quantity

2. SPECIFICATIONS

- Power Requirements
  +12V (±3%), 50 mA
  −12V (±3%), 50 mA
  +5V (±3%), 150 mA
- Operating Temperature: 0°C to 50°C (+32° to +122°F)
- Operating Humidity: 0 to 95 percent, non-condensing
- Shock: Withstand 2 foot vertical drop

3. INSTALLATION AND STARTUP

To install the Microterminal onto a TM 990/100M or TM 990/180M microcomputer, do the following:

- Attach jumpers to J13, J14, and J15 on the TM 990/100M or to J4, J5, and J6, on the TM 990/180M board to route voltages to the Microterminal. Set jumper J7 on the TM 990/100M or jumper J13 on the TM 990/180M to the EIA position.
- Attach the EIA cable from the Microterminal to connector P2. Signals between the Microterminal and the microcomputer are listed as in Table 1.
- To initialize the system, actuate the microcomputer RESET switch, then press the microterminal CLR key.

NOTE

If the user has installed the *optional* filter capacitor on the $\overline{\text{RESTART}}$ input, this capacitor must be removed for proper operation (e.g., if C5 is installed on the TM 990/100M or TM 990/180M microcomputer, this capacitor must be removed).

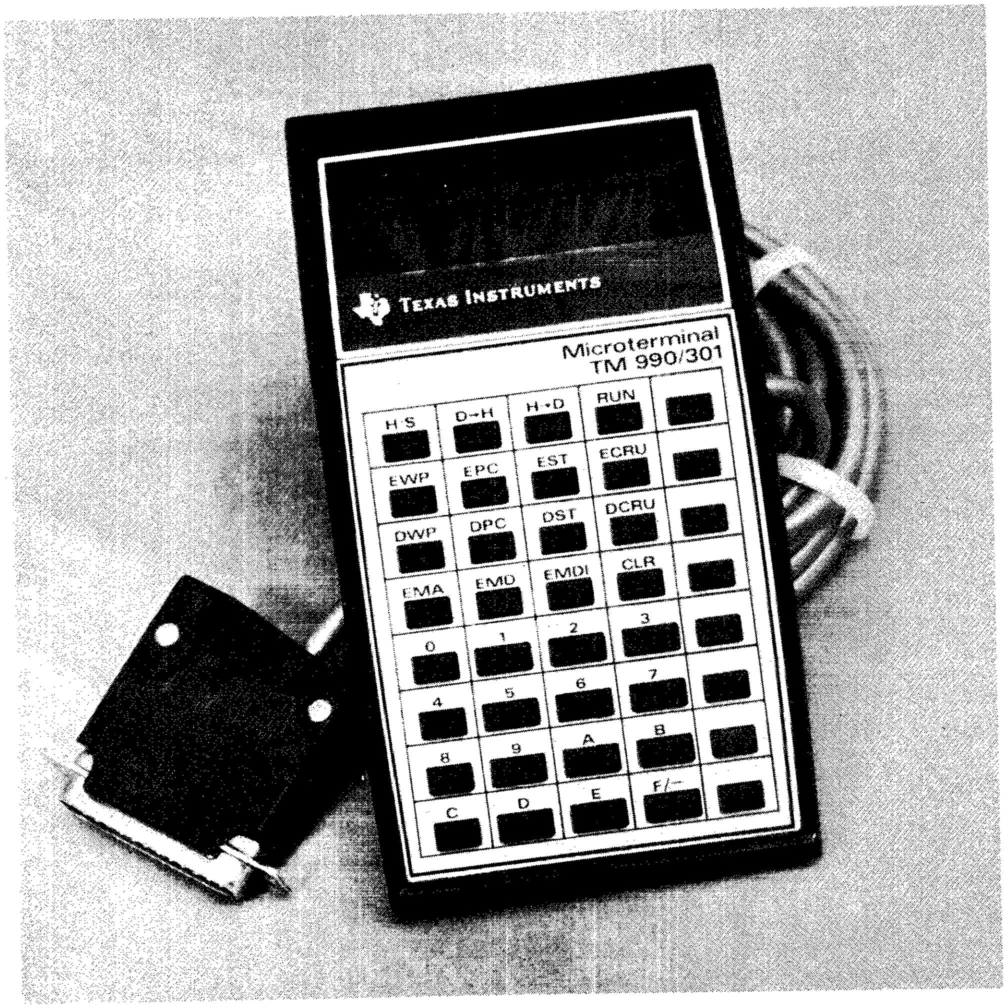


FIGURE 1. TM 990/301 MICROTERMINAL

TABLE 1. EIA CABLE SIGNALS

EIA Connector Pin	Interface Signal	At TM 990/100M/180M	
		P2 Pin	Signal
2	$\overline{\text{TERMINAL DATA OUT}}$	−2	RS232 RCV
3	$\overline{\text{TERMINAL DATA IN}}$	−3	RS232 XMT
7	GND	−7	GND
12	+12V	−12	+12V
13	−12V	−13	−12V
14	+ 5V	−14	+ 5V
16	$\overline{\text{HALT}}$	−16	$\overline{\text{RESTART}}$

CAUTION

Before attaching the Microterminal to a power source, verify voltage levels between ground and EIA connector pins 12, 13, and 14 at connector P2 on the board. Voltage should not exceed values in Table 1.

4. KEY DEFINITIONS

4.1 DATA KEYS

CLR Clear Key – Depressing this key blanks display, initializes and sends initialization message (ASCII code for A and ASCII code for Z) to host microcomputer.

0
1
:
:
F/–

Hexadecimal Data Keys – Data is entered with the most significant digit (MSD) first. Depressing any one of these keys shifts that value into the right-hand display digit. All digits already in the data display are left shifted. For all operations other than decimal to hexadecimal conversion, the fourth digit from the right is shifted off the end of the right-hand display field when a data key is depressed. For a decimal to hexadecimal conversion, the fifth display digit from the right, rather than the fourth, is shifted off the end of the data field.

4.2 INSTRUCTION EXECUTION

H/S Pressing this key while a program is running (run displayed) will halt program execution. The address of the next instruction will be displayed in the four left-hand display digits, and the contents of that address will be displayed in the four right-hand digits. Pressing this key while the program is halted, will execute a single instruction using the values in the Workspace Pointer (WP), Program Counter (PC), and Status Register (ST), and the displays will be updated to the next memory address and contents at that address.

RUN Pressing this key initiates program execution at the current values in the WP, PC; run is displayed in the three right-hand display digits.

4.3 ARITHMETIC

H→D The signed hexadecimal data contained in the four right-hand display digits is converted to signed decimal data. Note that the most significant bit of the fourth display digit from the right is the sign bit (1 = negative). The conversion limits are minus $32{,}768_{10}$ (8000_{16}) to plus $32{,}767$ ($7FFF_{16}$). Two H→D key depressions are required. The sequence is:

1. Depress H→D .
2. Enter data via four hex data key depressions.
3. Depress H→D . The results of the conversion are displayed in the five right-hand display digits.

D→H The decimal data contained in the five right-hand display digits is converted to hexadecimal. The conversion limits are the same as for hexadecimal to decimal conversion. If the decimal number is negative, press the F/– key first to begin with a negative sign. The sequence is:

1. Depress D→H .
2. Enter data via hex data key depressions.
3. Depress D→H . The results of the conversion are displayed in the four right-hand display digits. .

4.4 REGISTER ENTER/DISPLAY

EWP Pressing this key causes the value displayed in the four right-hand digits to be entered into the WP.

DWP Pressing this key causes the WP contents to be displayed in the four right-hand display digits.

EPC Pressing this key causes the value displayed in the four right-hand digits to be entered into the PC.

DPC Pressing this key causes the PC contents to be displayed in the four right-hand display digits.

EST Pressing this key causes the value displayed in the four right-hand digits to be entered into the ST.

DST Pressing this key causes the ST contents to be displayed in the four right-hand display digits.

4.5 CRU DISPLAY/ENTER

DCRU Pressing this key causes the data at the designated Communications Register Unit (CRU) addresses to be displayed. Designate from one to 16 CRU bits at a specified CRU address by using four hexadecimal digits. The first digit is the count of bits to be displayed. The next three digits are the CRU address (equal to bits 3 to 14 in register 12 for CRU addressing). When DCRU is depressed, the bit count and address are shifted to the left-hand display, and the right-hand display will contain the values at the selected CRU output addresses. The output value will be zero-filled on the left, depending upon bit count entered. If less than nine bits, the value will be contained in the left two hexadecimal digits. If nine or more, the value will be right justified in all four hexadecimal digits

ECRU Pressing this key enters a new data value at the CRU addresses and bit count shown in the left display after depressing DCRU . The new value is entered from the keyboard and displayed in the right-hand display. Pressing ECRU enters this value onto the CRU at the address shown in the left display.

CAUTION

Avoid setting new values at the TMS 9902 on the TM 990/100M/180M through the CRU (TMS 9902 is at CRU address 0040_{16}), as this device controls I/O functions.

4.6 MEMORY ENTER, DISPLAY, INCREMENT

EMA Pressing this key will cause (1) the memory address (MA) in the right-hand display to be shifted to the left-hand display and (2) the contents of that memory address to be displayed in the right-hand display.

EMD Pressing this key causes the value in the right-hand display to be entered into the memory address contained in the left-hand display. The contents of that location will then be displayed in the four right-hand display digits (entered then read back).

EMDI Pressing this key causes the same action as described for the EMD key; it also increments the memory address by two and displays the contents at that new address. The memory address is displayed on the left and the contents at that address is displayed on the right.

5. EXAMPLES

5.1 EXAMPLE 1, ENTER PROGRAM INTO MEMORY

Enter the following program starting at RAM location $FE00_{16}$. Set the workspace pointer to $FF00_{16}$ and the status register to 2000_{16}. Single step through the program and verify execution. Then execute the program in free run mode and verify execution. Then halt program execution.

NOTE

In the following examples, XXXX indicates memory contents at current value in Memory Address Register.

OPCODE	INSTRUCTIONS		
04C0	CLR	R0	CLEAR WORKSPACE REGISTER 0
0580	INC	R0	INCREMENT WORKSPACE REGISTER 0
0280	CI	R0, >00FF	CHECK FOR COUNT 255
00FF			
16FC	JNE	$–6	JUMP TO INC R0 IF NOT DONE
10FF	JMP	$–0	STAY HERE WHEN FINISHED

	KEY ENTRIES		DISPLAY	
Clear Display	Depress	CLR		
Enter PC Value	Depress	F/– E 0 0		FE00
Enter into PC	Depress	EPC		FE00
Display PC	Depress	DPC		FE00
Enter ST Value	Depress	2 0 0 0		2000
Enter into ST	Depress	EST		2000
Display ST	Depress	DST		2000
Enter WP Value	Depress	F/– F/– 0 0		FF00
Enter Into WP	Depress	EWP		FF00
Display WP	Depress	DWP		FF00
Enter MA Value	Depress	F/– E 0 0		FE00
Enter Into MA	Depress	EMA	FE00	xxxx
Enter CLR 0 Opcode	Depress	0 4 C 0	FE00	04C0
Enter data, increment MA	Depress	EMDI	FE02	xxxx
Enter INC 0 Opcode	Depress	0 5 8 0	FE02	0580
Enter Data, Increment MA	Depress	EMDI	FE04	xxxx
Enter CI Opcode	Depress	0 2 8 0	FE04	0280
Enter Data, Increment MA	Depress	EMDI	FE06	xxxx

		KEY ENTRIES	DISPLAY
ENTER CI Immediate Operand	Depress	0 0 F F	FE06 00FF
Enter Data, Increment MA	Depress	EMDI	FE08 xxxx
Enter JNE $-6 Opcode	Depress	1 6 F C	FE08 16FC
Enter Data, Increment MA	Depress	EMDI	FE0A xxxx
Enter JMP $-0 Opcode	Depress	1 0 F F	FE0A 10FF
Enter Data, Increment MA	Depress	EMDI	FE0C xxxx

The program has now been entered into RAM. Since the PC, ST and WP values have been previously set, the program can be executed in single step mode by depressing the H/S key.

		DISPLAY (AFTER)	EXECUTES INSTRUCTION
Depress	H/S	FE02 0580	CLR RO
Depress	H/S	FE04 0280	INC RO
Depress	H/S	FE08 16FC	CI RO,>00FF
Depress	H/S	FE02 0580	JNE $–6

This cycle will continue until R0 reaches the count of 255 at which point the program will continuously execute at location FE0A$_{16}$ because it is a jump to itself.

To verify this, depress:	DISPLAY
RUN	run

The program should now be "looping to self" at location FE0A$_{16}$. To verify this, depress:

H/S	FE0A 10FF

Now examine the memory location corresponding to Register 0.

Depress	F F 0 0	FE0A FF00
Depress	EMA	FF00 00FF

This illustrates that FF$_{16}$ did become the final contents of WP0. Note that, when the program was being entered into RAM, EMDI was used rather than EMD because of the rather desirable feature of automatic address incrementing. The advantage of using EMD is that the actual contents of the addressed memory location are displayed after key depression (echoed back after being entered).

5.2 EXAMPLE 2, HEXADECIMAL TO DECIMAL CONVERSIONS

Convert 8000_{16} to a decimal number

Depress	CLR		
Depress	H→D		
Depress	8 0 0 0		8000
Depress	H→D	−3	2768

Convert 0020_{16} to a decimal number

Depress	CLR		
Depress	H→D		
Depress	2 0		20
Depress	H→D		32

5.3 EXAMPLE 3, DECIMAL TO HEXADECIMAL CONVERSIONS

Convert 45_{10} to hex

Depress	CLR		
Depress	D→H		
Depress	4 5		45
Depress	D→H		2D

Convert -1024_{10} to hex

Depress	CLR		
Depress	D→H		
Depress	F/− 1 0 2 4	−	1024
Depress	D→H		FC00

5.4 EXAMPLE 4, ENTER VALUE ON CRU

Send a bit pattern to the CRU at CRU address (bits 3 to 14 of R12) 090_{16} with a bit count of 9 containing a value of 5 (000000101_2).

Depress	CLR		
Depress	9 0 9 0		9090
Depress	DCRU	9090	YYYY
Depress	0 0 0 5	9090	0005
Depress	ECRU		

The data will be entered into the onboard TMS 9901 of the TM 990/100/180M. To verify the data on the TMS 990, do the following:

Depress	CLR		
Depress	9 0 9 0		9090
Depress	DCRU	9090	0005

YYYY indicates value at the current CRU address. Note that a DCRU operation is always required to specify bit count/CRU address.

5.5 EXAMPLE 5. ENTER, VERIFY VALUE AT MEMORY ADDRESS

Enter 0040_{16} into location FE20 and verify that it got there.

Depress	CLR		
Depress	F E 2 0		FE20
Depress	EMA	FE20	xxxx
Depress	0 0 4 0	FE20	0040
Depress	EMD	FE20	0040

The contents of address FE20 are verified by an echo of data from memory to display following the pressing of EMD. If it is desired to view and enter data at address FE22, depress EMD.

6. DEVICE SERVICE ROUTINE CODING

6.1 INTRODUCTION

When used with the Texas Instruments TM 990/100M or TM 990/180M Microcomputers, the Microterminal requires no special user coding because the software device service routine required to accommodate the Microterminal is resident in *TIBUG*, the debug monitor used on these boards. If the user utilizes any other microcomputer in conjunction with the Microterminal, a device service routine must be coded by the user to accommodate the Microterminal.

6.2 HARDWARE OPERATION

The Microterminal interfaces to any microcomputer utilizing the signals indicated in Table 2. The block diagram is shown in Figure 2.

TABLE 2. MICROTERMINAL INTERFACE SIGNALS

Signal Name	Maximum Voltage	Level	Connector
+5V	6V	POWER	P1 – 14
+12V	+14V	POWER	P1 – 12
–12V	–14V	POWER	P1 – 13
GROUND	–	GROUND	P1 – 7
TERMINAL DATA IN	+14V	RS-232-C	P1 – 3
TERMINAL DATA OUT	+14V	RS-232-C	P1 – 2
HALT	+6V	OPEN COLLECTOR NPN	P1 – 16

The Microterminal receives +12V, –12V, +5V and ground from the host microcomputer. Great care must be taken not to exceed the maximum rated voltages; otherwise, permanent damage to the Microterminal might occur. TERMINAL DATA OUT is an RS-232-C, 110 baud output from the Microterminal. A serial bit stream will be output from the Microterminal utilizing TERMINAL DATA OUT for commands and data from the Microterminal. Refer to Figure 3 for the format of commands and data. It should be noted that commands utilize one RS-232-C character (one start bit, a five bit command, two "don't care" bits, a parity bit and three stop bits), but a 16-bit data word utilizes four RS-232-C characters because only four data bits are included in an RS-232-C Microterminal data character. The software significance of commands and data is defined in paragraph 6.3. It should be noted that the Microterminal sends two unique ASCII characters (an A and Z) over TERMINAL DATA OUT when the CLR key is depressed. TERMINAL DATA OUT utilizes standard RS-232-C voltage levels:

- 12.0 volts ⩾ Logic 1 > 6.0 volts
- –6.0 volts > Logic 0 ⩾ –12.0 volts

TERMINAL DATA IN is a RS-232-C, 110-baud input to the Microterminal. A serial bit stream of data is required from the host microcomputer to update LED displays in situations defined in paragraph 6.3. Figure 3 defines the format of a Microterminal input data character (one start bit, four data bits, three "don't care" bits, an even parity bit and two stop bits). As in the case of Microterminal output data, four data characters are required to form a 16-bit word. The voltage levels required on TERMINAL DATA IN are RS-232-C standard (the same levels defined for TERMINAL DATA OUT). The frequency of TERMINAL DATA IN, as with any terminal device must not vary more than 2 per cent from its proper rate (110 baud).

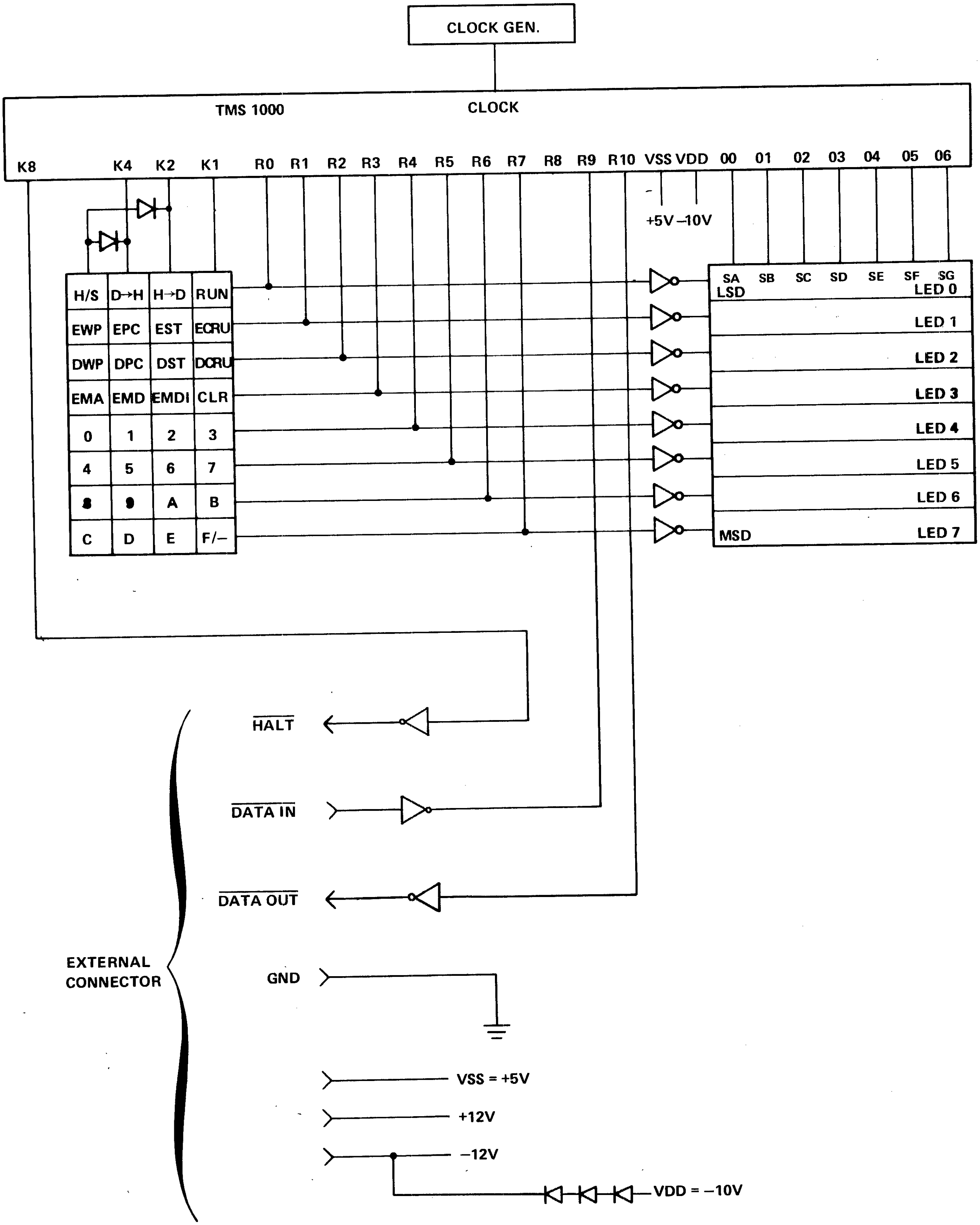
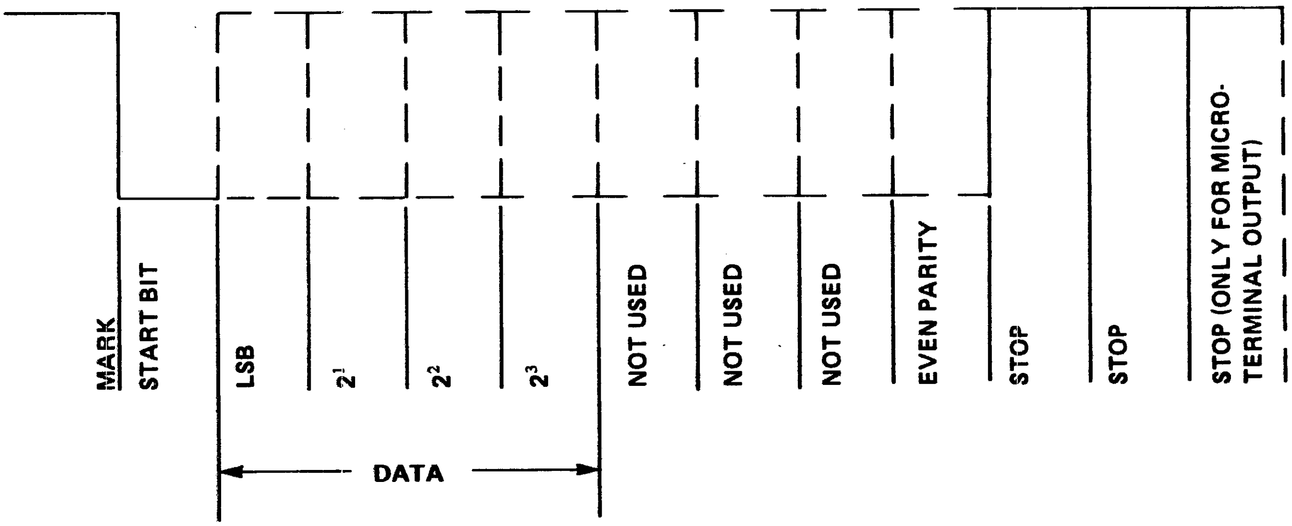
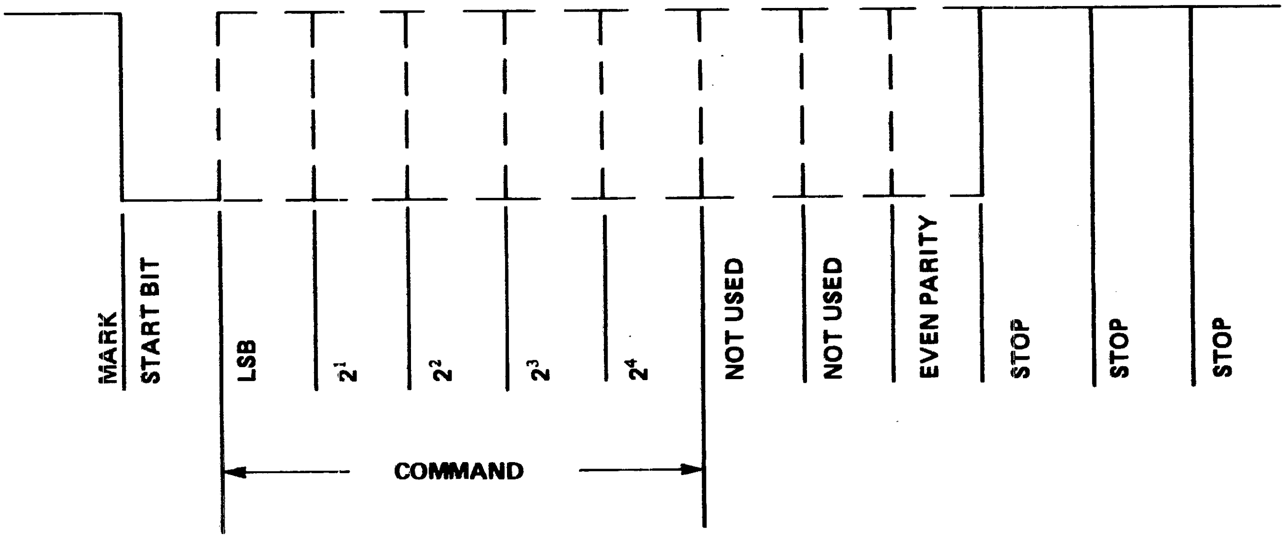


Figure 2. Microterminal Block Diagram



DATA CHARACTER

NOTE: DATA WORDS ARE SENT MSD FIRST, LSD LAST
MICROTERMINAL OUTPUT DATA WORDS CONTAIN 3 STOP BITS
990/100M OUTPUT DATA WORDS CONTAIN 2 STOP BITS



COMMAND CHARACTER

NOTE: THE INDICATED BIT POLARITY IS THAT OUTPUTTED OR SEEN BY THE SOFTWARE. THE INTERFACE BETWEEN THE MICROTERMINAL AND MICROCOMPUTER IS OF INVERSE POLARITY.

Figure 3. Character Format

HALT is the open collector output of a NPN transistor (pin 16 as shown in Table 1). This signal must be connected to a 1K resistor that is pulled up to 5 volts on the host microcomputer. HALT becomes active low for 30 μsec when the user depresses H/S on the Microterminal while a user program is being executed. HALT provides one source for LOAD, a nonmaskable interrupt, on the TM 990/100M Microcomputer. Since the purpose of the HALT signal is to halt program execution, the user will be required to provide an interrupt to the host microcomputer when HALT becomes active low. The logic levels for HALT are:

Logic 1 = +5V Supply Level

GROUND ⩽ Logic 0 < 0.8V

Since HALT is an NPN transistor output, great care must be taken not to short the signal to a voltage.

6.3 SOFTWARE OPERATION

The Microterminal is internally controlled by a TMS 1000 microprocessor which does the following:

- Scans the keyboard to detect and process key depressions
- Refreshes the 7-segment LED displays
- Outputs commands to the host microcomputer to specify the function that the microcomputer must perform
- Outputs any required data to the microcomputer
- Outputs two unique characters (ASCII A and ASCII Z) when CLR is depressed
- Lowers LOAD for 30 μsec to halt program execution
- Receives input data from the host microcomputer for display

Figure 4 is the TMS 1000 software flowchart. The host microcomputer must receive and decode commands, receive any required data coming after the command, output any required data to the Microterminal and interrupt program execution when HALT = 0.

The required communication between the Microterminal and host microcomputer is shown in Table 3. As an example of the communication sequence, consider the following case of the user desiring to utilize the EMA function (display contents and address of designated memory address):

1. The user enters a memory address using four hex (0 to F) key depressions. The TMS 1000 detects and displays these four hexadecimal entries.
2. The user depresses EMA. The TMS 1000 sends a command character (00_{16}) over the interface via TERMINAL DATA OUT to specify the EMA operation.
3. The host microcomputer receives and decodes the command character. The microcomputer must now prepare to receive four data characters and assemble them into a 16-bit memory address register specifying the address of the desired memory location. The command contains three stop bits with the start bit of the first data character coming after the third stop bit of the command character. The start bit of each data character comes after the third stop bit of the preceding data character.

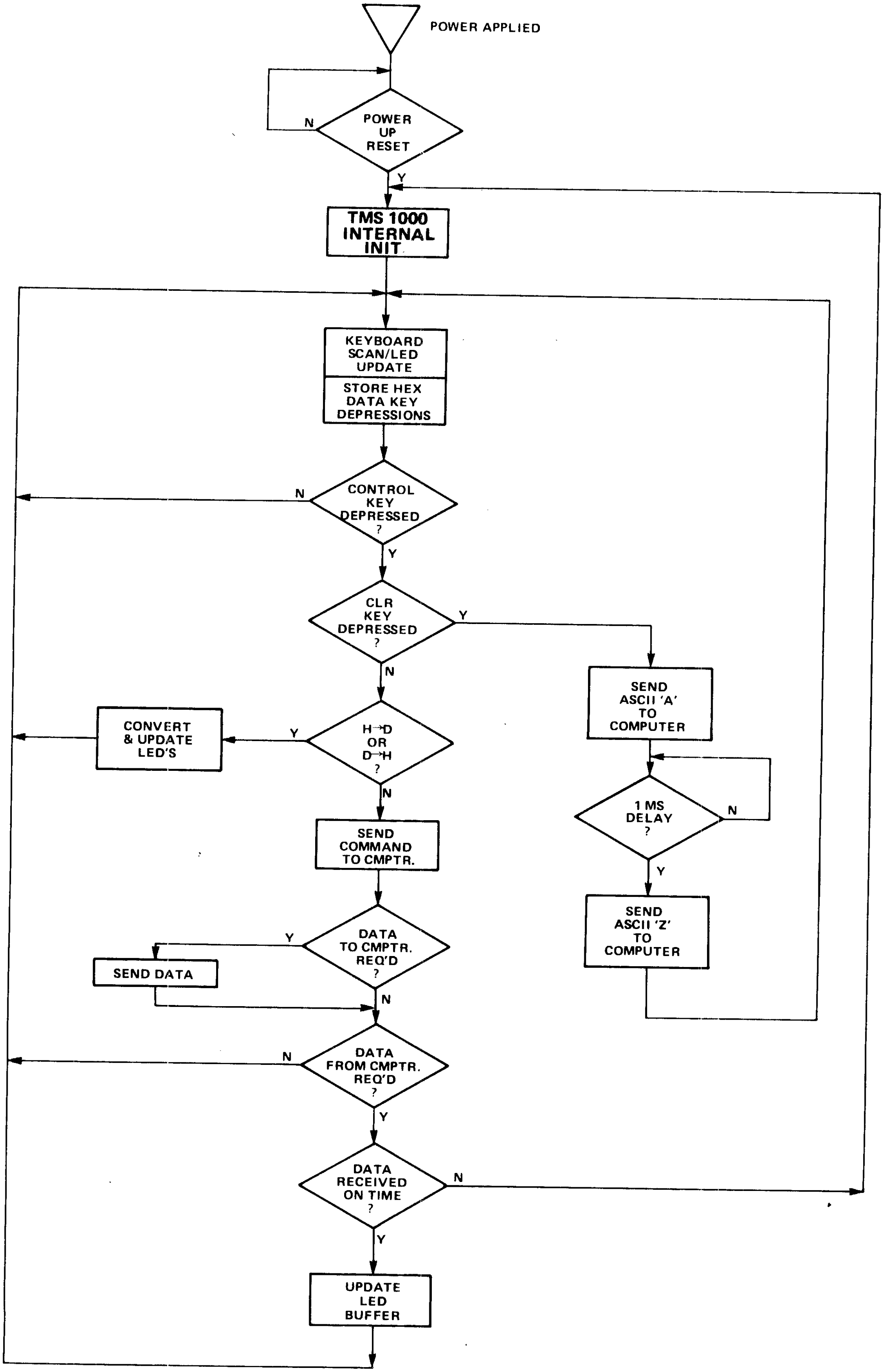


Figure 4. TMS 1000 Software Flowchart

TABLE 3. MICROTERMINAL CONTROL SEQUENCE

Key Depressed	Hexadecimal Code	Microterminal Sends	Microcomputer Sends In Response
EWP	06_{16}	Command (1 EIA Character) Data to Enter (4 EIA Characters)	— —
EST	04_{16}	Command (1 EIA Character) Data to Enter (4 EIA Characters)	— —
EPC	02_{16}	Command (1 EIA Character) Data to Enter (4 EIA Characters)	— —
DWP	$0C_{16}$	Command (1 EIA Character)	*Data to be displayed (4 EIA Characters)
DST	$0A_{16}$	Command (1 EIA Character)	*Data to be displayed (4 EIA Characters)
DPC	08_{16}	Command (1 EIA Character)	*Data to be displayed (4 EIA Characters)
EMA	00_{16}	Command (1 EIA Character) Address (4 EIA Characters)	*Data to be displayed (4 EIA Characters)
EMD	14_{16}	Command (1 EIA Character) Data to Enter (4 EIA Characters)	*Data to be displayed (4 EIA Characters)
EMDI	12_{16}	Command (1 EIA Character) Data to Enter (4 EIA Characters)	*Data to be displayed (4 EIA Characters)
DCRU	$0E_{16}$	Command (1 EIA Character) Bit Count/Address (4 EIA Characters)	*Data to be displayed (4 EIA Characters)
ECRU	10_{16}	Command (1 EIA Character) Data (4 EIA Characters)	— —
CLR		ASCII A (1 EIA Character) ASCII Z (1 EIA Character)	— —
RUN	16_{16}	Command (1 EIA Character)	—
H/S	(Unit in Run Mode)	$\overline{\text{HALT}}$ = 0 For 30 μsec	**PC to be displayed (4 EIA Characters) Data to be displayed (4 EIA Characters)
H/S	18_{16} (Unit not in Run Mode)	Command (1 EIA Character)	*PC to be displayed (4 EIA Characters) Data to be displayed (4 EIA Characters)

*First character must be received by the Microterminal within 5 milliseconds after the end of the third stop bit of the command word is sent by the Microterminal. Each succeeding character must be received by the Microterminal within 5 milliseconds after the end of the second stop bit of the preceding data character is received from the microcomputer.

**First EIA character must be received by the Microterminal between 6 to 10 milliseconds of $\overline{\text{HALT}}$ becoming active low. Each succeeding character must be received by the Microterminal within 6 to 10 milliseconds of center point of second stop bit of the preceding character.

4. The host microcomputer fetches the 16-bit data word from the memory location specified by the contents of the memory address register.

5. This data is output from the microcomputer via four data characters on the $\overline{\text{TERMINAL DATA IN}}$ signal. The start bit for the first data character must occur before five ms has elapsed after receiving the third stop bit of the last memory address character from the Microterminal. Each of the remaining three data characters from the microcomputer must present a start bit within 5 milliseconds after the second stop bit of the preceding microcomputer data character. Longer time delays will cause the Microterminal to detect a data transmission error and blank the display.

6. The Microterminal displays the receive data.

The following points must be noted by the user who wishes to code a device service routine for the Microterminal:

- When data characters follow a Microterminal command character, each start bit follows the third stop bit of the previous character.
- All required input data to the Microterminal must occur within the required time frame; otherwise, the Microterminal will detect a data transmission error and blank the display.
- Command and data characters are of the format shown in Figure 3. When the Microterminal outputs a command followed by data, each character has three stop bits followed by the start bit of the next character.
- A 16-bit data word requires four data characters of the form shown in Figure 3.
- The Microterminal will always output two characters in succession (an ASCII A and ASCII Z) when CLR is depressed. For the user that might have several different types of terminal devices, these two characters might serve as an ID for the Microterminal.
- $\overline{\text{HALT}}$ must be wired to an interrupt in order to halt program execution.

6.4 LISTING OF SAMPLE MICROTERMINAL DEVICE SERVICE ROUTINE

Enclosed is a listing of a stand-alone device service routine for the Microterminal utilizing the TM 990/100M Microcomputer as the host device. A stand-alone service routine rather than *TIBUG* is included to focus understanding on the Microterminal functions (i.e., *TIBUG* contains many functions besides the Microterminal routines). Refer to Figures 5 to 10 for detailed program flow of parts of the stand-alone device service routine. Table 4 explains DSR assembly language action in response to keys pressed on the Microterminal. Note the following points about the stand-alone device service routine

- Since this program is of a stand-alone nature, it is not necessary to use the A and Z character output by the Microterminal to identify itself when CLR is depressed. These two characters will be ignored because they will be recognized as invalid commands by the microcomputer command scanner.
- When the RESET pushbutton is depressed, the TM 990/100M will begin execution at the Program Counter location specified by the contents of memory location 0002_{16} with the workspace pointer specified by the contents of memory location 0000_{16}.

- LOAD is the entry point when the nonmaskable interrupt of the TMS 9900 is activated by the $\overline{\text{HALT}}$ signal (from the Microterminal) becoming low or the output from a TM 990/100M circuit activated two instructions after a LREX instruction (or two instructions are executed after the LREX instruction, then LOAD is entered). LOAD is used to halt program execution or for single instruction execution.

TABLE 4. DSR ACTION TO KEY COMMANDS

Microterminal Key Command	**DSR Action And Comment**			**Listing Source Line**
EPC	INPT	R14	XOP1, INPUT PC TO R14	079
	JMP	MTIN	TO COMMAND SCANNER	080
EST	INPT	R15	XOP1, INPUT ST TO R15	081
	JMP	MTIN	TO COMMAND SCANNER	082
EWP	INPT	R13	XOP1, INPUT UP TO R13	083
	JMP	MTIN	TO COMMAND SCANNER	084
DPC	OTPT	R14	XOP0, OUTPUT PC FROM R14	085
	JMP	MTIN	TO COMMAND SCANNER	086
DST	OTPT	R15	XOP0, OUTPUT ST FROM R15	087
	JMP	MTIN	TO COMMAND SCANNER	088
DWP	OTPT	R13	XOP0, OUTPUT WP FROM R13	089
	JMP	MTIN	TO COMMAND SCANNER	090
EMA	INPT	R8	XOP1, INPUT ADDR TO R8	091
	MOV	*R8, R9	DATA AT ADDR TO R9	098
	OTPT	R9	XOP0, OUTPUT (R9)	125
	JMP	MTIN	TO COMMAND SCANNER	126
EMD	INPT	R9	XOP1, INPUT DATA TO R9	093
	MOV	R9, *R8	TO MEMORY INDIRECT R8	094
	MOV	*R8, R9	TO R9 INDIRECT R8	098
	OTPT	R9	XOP0, OUTPUT (R9)	125
	JMP	MTIN	TO COMMAND SCANNER	126
EMDI	INPT	R9	XOP1, INPUT DATA TO R9	096
	MOV	R9, *R8+	TO MEMORY, INDIRECT R8, INCREMENT R8 TO NEXT ADDR.	097
	MOV	*R8, R9	(NEXT M.A.) TO R9	098
	OTPT	R9	XOP0, OUTPUT (R9)	125
	JMP	MTIN	TO COMMAND SCANNER	126
STEP (H/S)	SETO	@STEPFG	SET STEP FLAG	104
	CLR	@HALTFG	CLEAR HALT FLAG	105
	LREX		CAUSE LOAD INTERRUPT WHICH GOES TO STEP ROUTINE	106 195-202

TABLE 4. DSR ACTION TO KEY COMMANDS (Concluded)

Microterminal Key Command	DSR Action And Comment			Listing Source Line
DCRU	*DO LOAD ROUTINE			195-202
	INPT	R10	XOP1, GET BIT COUNT	108
	•		AND CRU ADDR	
	•			
	•			
	*MOVE CRU ADDR TO R12			110-112
	*EXECUTE MOVE (CRU) TO R9			113-116
	OTPT	R9	XOP0, OUTPUT (R9)	125
	JMP	MTIN	TO COMMAND SCANNER	126
ECRU	INPT	R9	XOP1, CRU DATA TO R9	118
	•			
	•			
	•			
	*EXECUTE MOVE (R9) TO CRU			119, 120
	JMP	MTIN	TO COMMAND SCANNER	121
RUN	RTWP		BRANCH *R14 WITH (R13) =	
			ADDR. OF WP AND (R15) = STATUS REG	077
HALT	SETO	R0	SET DELAY FLAG	122
(H/S)	OTPT	R14	XOP0, OUTPUT VALUE OF PC	123
	MOV	*R14, R9	MOVE DATA AT PC TO R9	124
	OTPT	R9	OUTPUT (R9)	125
	JMP	MTIN	TO COMMAND SCANNER	126

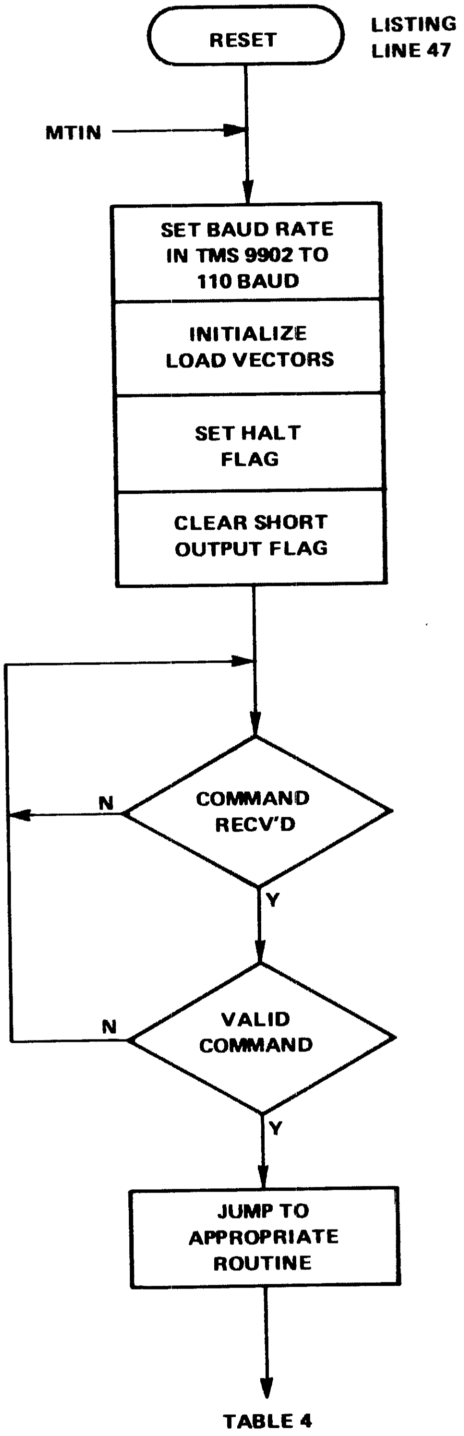


Figure 5. Microterminal Initialization and Command Scanner

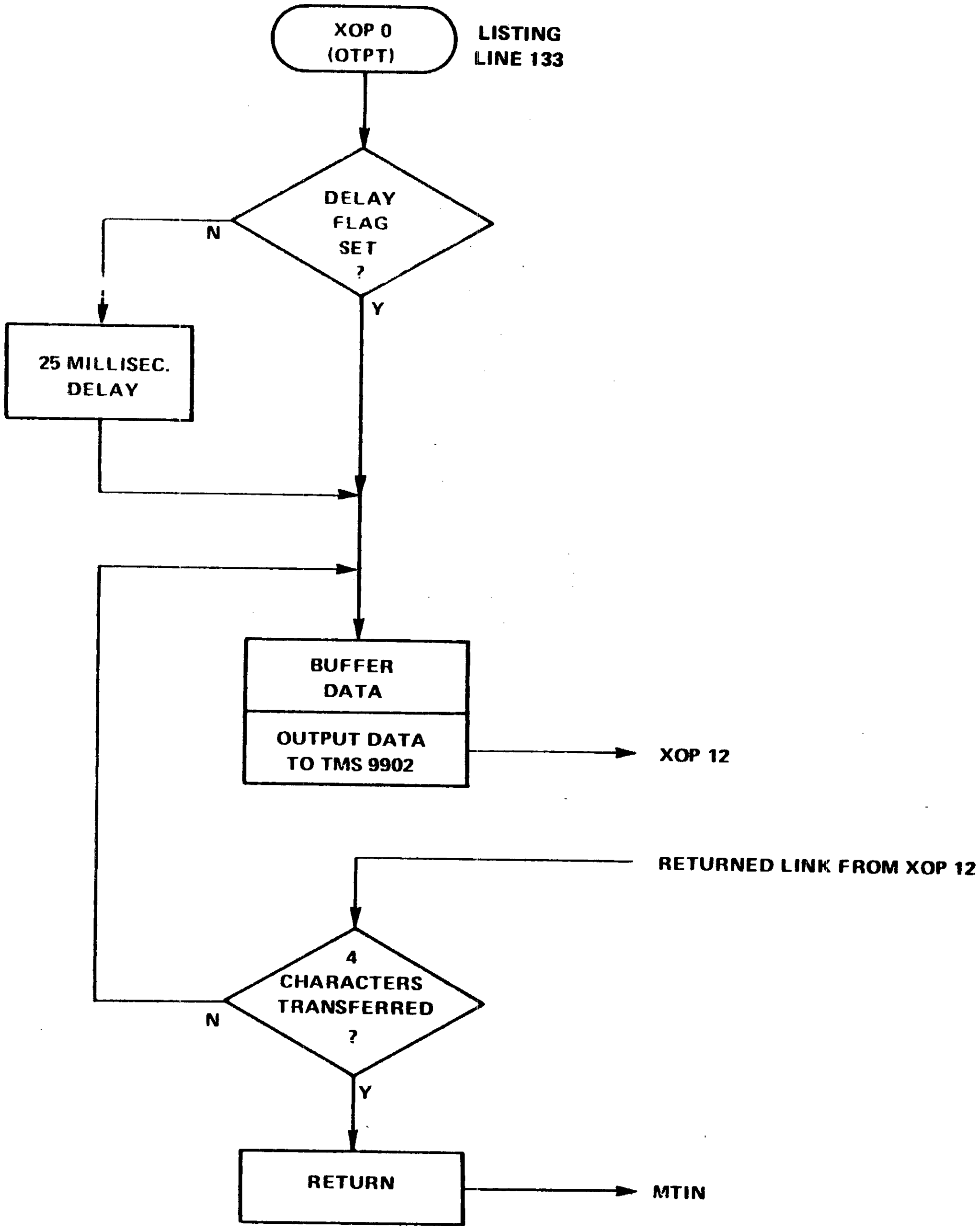


Figure 6. Output Data to Microterminal

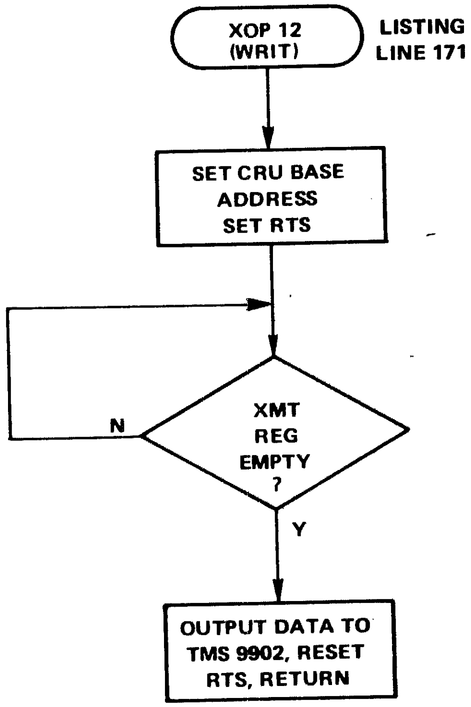


Figure 7. Output Data to TMS 9902 (to Microterminal)

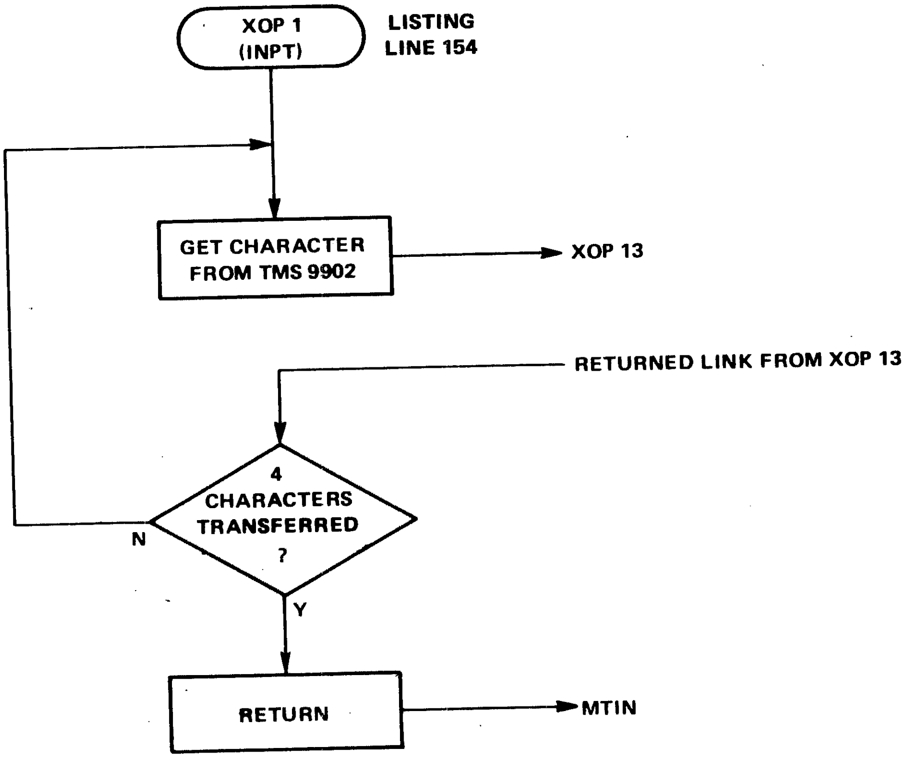


Figure 8. Input Data From Microterminal

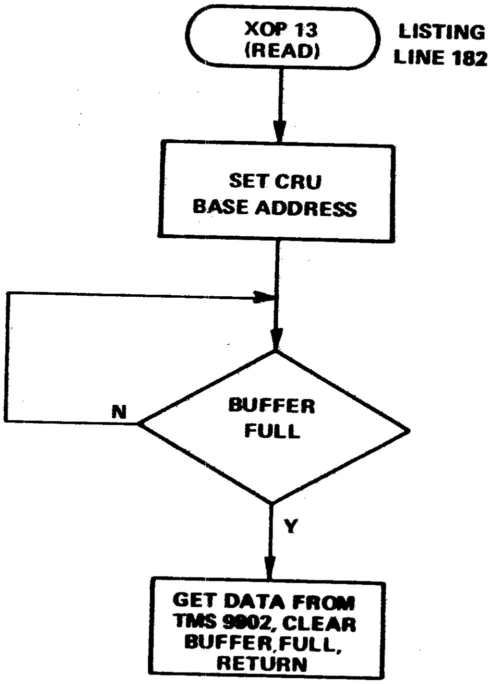


Figure 9. Get Data From TMS 9902 (from Microterminal)

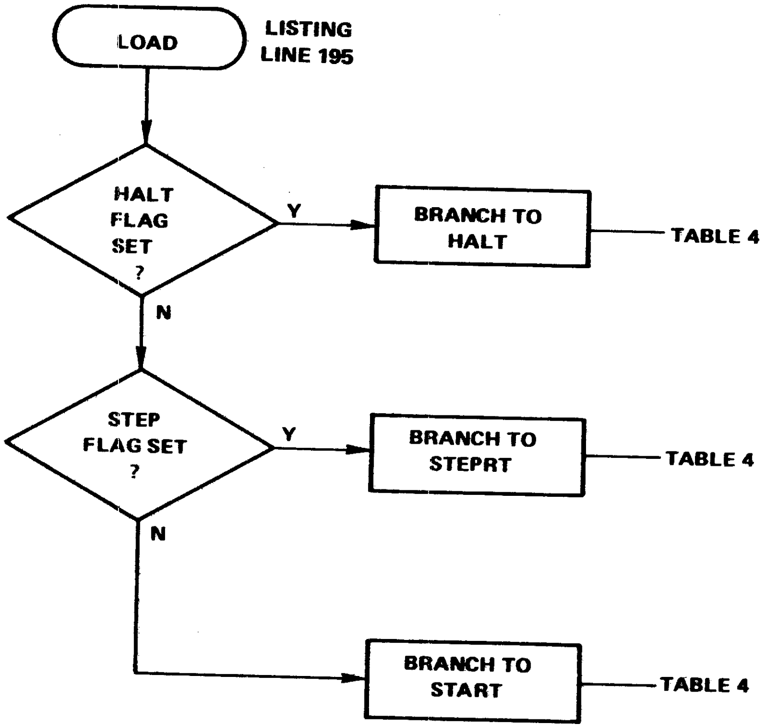


Figure 10. Load Signal Execution

```
0001                   *
0002                   ************************************************************
0003                   *  THIS IS A STAND ALONE DEVICE SERVICE ROUTINE FOR THE     *
0004                   *  TEXAS INSTRUMENTS TM990/30I MICROTERMINAL UTILIZING THE *
0005                   *  TEXAS INSTRUMENTS TM990/100M MICROCOMPUTER AS THE HOST  *
0006                   *  DEVICE.THE 990/100M UTILIZES MEMORY LOCATIONS 00 THRU   *
0007                   *  80(ALL NUMBERS ARE HEX)FOR INTERRUPT VECTORS AND XOP    *
0008                   *  VECTORS,MEMORY LOCATIONS 80 THRU 7FF FOR EXECUTABLE     *
0009                   *  CODE AND MEMORY LOCATIONS FE00 THRU FFFF FOR RAM STORAGE*
0010                   *  THE DATA INTERFACE BETWEEN THE MICROTERMINAL AND        *
0011                   *  TM990/100M IS RS232C SERIAL.A TMS9902 ACIA IS UTILIZED  *
0012                   *  ON THE TM990/100M AS THE UART DEVICE.                   *
0013                   ************************************************************
0014                           IDT     'MCTER'
0015           000B    LINK    EQU     R11
0016           000C    CRUBAS  EQU     R12
0017           FFB0    MREGS   EQU     >FFB0
0018           FFD4    XREGS   EQU     >FFD4
0019           FFC6    IREGS   EQU     >FFC6
0020           FFF8    STEPFG  EQU     >FFF8
0021           FFFA    HALTFG  EQU     >FFFA
0022                           DXOP    OTPT,0
0023                           DXOP    INPT,1
0024                           DXOP    READ,13
0025                           DXOP    WRIT,12
0026     0000  FFB0            DATA    MREGS,INIT  RESET VECTORS
         0002  ----
0027     0004  FFFF            DATA    >FFFF,>FFFF,>FFFF,>FFFF,>FFFF,>FFFF
         0006  FFFF
         0008  FFFF
         000A  FFFF
         000C  FFFF
         000E  FFFF
0028     0010  FFFF            DATA    >FFFF,>FFFF,>FFFF,>FFFF,>FFFF,>FFFF,>FFFF,>FFF
         0012  FFFF
         0014  FFFF
         0016  FFFF
         0018  FFFF
         001A  FFFF
         001C  FFFF
         001E  0FFF
0029     0020  FFFF            DATA    >FFFF,>FFFF,>FFFF,>FFFF,>FFFF,>FFFF,>FFFF,>FFF
         0022  FFFF
         0024  FFFF
         0026  FFFF
         0028  FFFF
         002A  FFFF
         002C  FFFF
         002E  0FFF
0030     0030  FFFF            DATA    >FFFF,>FFFF,>FFFF,>FFFF,>FFFF,>FFFF,>FFFF,>FFF
         0032  FFFF
         0034  FFFF
         0036  FFFF
         0038  FFFF
         003A  FFFF
```

```
      003C  FFFF
      003E  0FFF
0031  0040  FFD4         DATA   XREGS,OTPTEN  XOP0 VECTORS
      0042  ----
0032  0044  FFD4         DATA   XREGS,INPTEN  XOP1 VECTORS
      0046  ----
0033  0048  FFFF         DATA   >FFFF,>FFFF,>FFFF,>FFFF
      004A  FFFF
      004C  FFFF
      004E  FFFF
0034  0050  FFFF         DATA   >FFFF,>FFFF,>FFFF,>FFFF,>FFFF,>FFFF,>FFFF,>FFF
      0052  FFFF
      0054  FFFF
      0056  FFFF
      0058  FFFF
      005A  FFFF
      005C  FFFF
      005E  0FFF
0035  0060  FFFF         DATA   >FFFF,>FFFF,>FFFF,>FFFF,>FFFF,>FFFF,>FFFF,>FFF
      0062  FFFF
      0064  FFFF
      0066  FFFF
      0068  FFFF
      006A  FFFF
      006C  FFFF
      006E  0FFF
0036  0070  FFC6         DATA   IREGS,WENTRY
      0072  ----
0037  0074  FFC6         DATA   IREGS,RENTRY
      0076  ----
0038  0078  FFFF         DATA   >FFFF,>FFFF,>FFFF,>FFFF
      007A  FFFF
      007C  FFFF
      007E  FFFF
0039                *                                                           *
0040                *************************************************************
0041                *  MICROTERMINAL INITIALIZATION AND COMMAND SCANNER-THIS    *
0042                *  ROUTINE IS ENTERED AS A RESULT OF A RESET PUSHBUTTON     *
0043                *  DEPRESSION.THE BAUD RATE IS SET TO 110 BAUD,THE LOAD     *
0044                *  VECTORS ARE INITIALIZED AND A WAIT LOOP IS ENTERED       *
0045                *  AWAITING COMMAND INPUT FROM THE MICROTERMINAL.           *
0046                *************************************************************
0047  0080  020C  INIT   LI     CRUBAS,>80  LOAD CRU BASE REG
      0082  0080
      0002**0080'
0048  0084  1D1F         SBO    31          INITIALIZE UART
0049  0086  3220         LDCR   @CR,8
      0088  ----
0050  008A  1E0D         SBZ    13
0051  008C  3320         LDCR   @BR,12      SET BAUD RATE
      008E  ----
0052  0090  0202         LI     2,>FFFC     INITIALIZE LOAD VECTORS
      0092  FFFC
0053  0094  04C1         CLR    1
0054  0096  CCB1         MOV    *1+,*2+
```

```
0055  0098  0201          LI     1,LOAD
      009A  ----
0056  009C  C481          MOV    1,*2
0057  009E  2F42   MTIN   READ   2          GET MICROTERMINAL COMMAND
0058  00A0  04C0          CLR    0          CLEAR SHORT OUTPUT FLAG
0059  00A2  0720          SETO   @HALTFG    SET HALT FLAG
      00A4  FFFA
0060  00A6  06C2          SWPB   2          RIGHT JUSTIFY COMMAND
0061  00A8  0242          ANDI   2,>1E      STRIP OFF UNDEFINED BITS
      00AA  001E
0062  00AC  0282          CI     2,>18      CHECK FOR INVALID COMMAND
      00AE  0018
0063  00B0  15F6          JGT    MTIN       DISREGARD INVALID COMMAND
0064  00B2  0222          AI     2,JMTB     ADD COMMAND AND JUMP TABLE BIAS
      00B4  ----
0065  00B6  0452          B      *2         GO EXECUTE SPECIFIED FUNCTION
0066  00B8  10--   JMTB   JMP    EMA        JUMP TABLE
      00B4**00B8
0067  00BA  10--          JMP    EPC
0068  00BC  10--          JMP    EST
0069  00BE  10--          JMP    EWP
0070  00C0  10--          JMP    DPC
0071  00C2  10--          JMP    DST
0072  00C4  10--          JMP    DWP
0073  00C6  10--          JMP    DCRU
0074  00C8  10--          JMP    ECRU
0075  00CA  10--          JMP    EMDI
0076  00CC  10--          JMP    EMD
0077  00CE  0380          RTWP
0078  00D0  10--          JMP    STEP
0079  00D2  2C4E   EPC    INPT   14         GET PC
      00BA**100B
0080  00D4  10E4          JMP    MTIN       GO AWAIT NEXT COMMAND
0081  00D6  2C4F   EST    INPT   15         GET ST
      00BC**100C
0082  00D8  10E2          JMP    MTIN
0083  00DA  2C4D   EWP    INPT   13         GET WP
      00BE**100D
0084  00DC  10E0          JMP    MTIN
0085  00DE  2C0E   DPC    OTPT   14         OUTPUT PC
      00C0**100E
0086  00E0  10DE          JMP    MTIN
0087  00E2  2C0F   DST    OTPT   15         OUTPUT ST
      00C2**100F
0088  00E4  10DC          JMP    MTIN
0089  00E6  2C0D   DWP    OTPT   13         OUTPUT WP
      00C4**1010
0090  00E8  10DA          JMP    MTIN
0091  00EA  2C48   EMA    INPT   8          GET MEMORY ADDRESS REG
      00B8**1018
0092  00EC  10--          JMP    EMDI1      GO EXECUTE FUNCTION
0093  00EE  2C49   EMD    INPT   9          GET DATA
      00CC**1010
0094  00F0  C609          MOV    9,*8       STORE DATA IN MEMORY
0095  00F2  10--          JMP    EMDI1
```

```
0096  00F4  2C49  EMDI    INPT   9           GET DATA
      00CA**1014
0097  00F6  CE09          MOV    9,*8+       STORE DATA IN MEMORY AND AUTO INC
0098  00F8  C258  EMDI1   MOV    *8,9        GET DATA FROM MEMORY
      00EC**1005
      00F2**1002
0099  00FA  10--          JMP    HALT1
0100  00FC  2C0E  STEPRT  OTPT   14          OUTPUT PC
0101  00FE  C25E          MOV    *14,9       GET PC MEMORY DATA
0102  0100  0700          SETO   0           SET DELAY FLAG
0103  0102  10--          JMP    HALT1
0104  0104  0720  STEP    SETO   @STEPFG     SET STEP FLAG
      0106  FFF8
      00D0**1019
0105  0108  04E0          CLR    @HALTFG     CLEAR HALT FLAG
      010A  FFFA
0106  010C  03E0          LREX               FIRE LOAD INTERRUPT
0107  010E  0380          RTWP               EXECUTE USER CODE
0108  0110  2C4A  DCRU    INPT   10          GET BIT COUNT AND CRU ADDRESS
      00C6**1024
0109  0112  04C9          CLR    9           CLEAR DATA REG
0110  0114  C30A          MOV    10,12
0111  0116  024C          ANDI   12,>0FFF    SAVE CRU ADDRESS
      0118  0FFF
0112  011A  0A1C          SLA    12,1        PUT IN PROPER WORD POSITION
0113  011C  09CA          SRL    10,12       STRIP OUT ZEROES
0114  011E  0A6A          SLA    10,6
0115  0120  022A          AI     10,>3409    SET UP STCR OP CODE
      0122  3409
0116  0124  048A          X      10          EXECUTE STCR
0117  0126  10--          JMP    HALT1
0118  0128  2C49  ECRU    INPT   9           GET DATA
      00C8**102F
0119  012A  022A          AI     10,>FC00    SET UP LDCR OP CODE
      012C  FC00
0120  012E  048A          X      10          EXECUTE LDCR
0121  0130  10B6          JMP    MTIN
0122  0132  0700  HALT    SETO   0           SET DELAY FLAG
0123  0134  2C0E          OTPT   14          OUTPUT PC
0124  0136  C25E          MOV    *14,9       GET PC MEMORY DATA
0125  0138  2C09  HALT1   OTPT   9           OUTPUT DATA
      00FA**101E
      0102**101A
      0126**1008
0126  013A  10B1          JMP    MTIN
0127              *
0128              ************************************************************
0129              *  MICROTERMINAL OUTPUT-XOP R,0                            *
0130              *  CONVERTS 1 MICROTERMINAL 16 BIT OUTPUT WORD TO 4 EIA    *
0131              *  OUTPUT WORDS.                                           *
0132              ************************************************************
0133  013C  C01D  OTPTEN MOV    *13,0             CHECK DELAY FLAG
      0042**013C
0134  013E  16--          JNE    BDLY              BYPASS DELAY IF FLAG SET
0135  0140  0200          LI     0,>0F00           25 MS DELAY
```

```
      0142  0F00
0136  0144  0600  DLY    DEC    0
0137  0146  16FE         JNE    DLY
0138  0148  0200  BDLY   LI     0,4                 LOAD NUMBER OF TRANSFERS
      014A  0004
      013E**1604
0139  014C  C25B         MOV    *11,9               MOVE DATA TO REG9
0140  014E  C049  CNOT   MOV    9,1                 MOVE DATA TO REG1
0141  0150  09C1         SRL    1,12                SAVE MSD
0142  0152  0A81         SLA    1,8                 LEFT JUSTIFY
0143  0154  0221         AI     1,>3000             ADD CODE BIAS
      0156  3000
0144  0158  2F01         WRIT   1                   CALL TIBUG OUTPUT ROUTINE
0145  015A  0A49         SLA    9,4                 SHIFT IN NEW DIGIT
0146  015C  0600         DEC    0                   DECREMENT WORD COUNT
0147  015E  16F7         JNE    CNOT                GO BACK IF NOT FINISHED
0148  0160  0380         RTWP
0149              ************************************************************
0150              *  MICROTERMINAL INPUT-XOP R,1
0151              *  CONVERTS 1 MICROTERMINAL 16 BIT INPUT WORD TO 4 EIA INPUT
0152              *  WORDS.
0153              ************************************************************
0154  0162  0201  INPTEN LI     1,>0004             LOAD NUMBER OF TRANSFERS
      0164  0004
      0046**0162'
0155  0166  04DB         CLR    *11                 CLEAR DATA
0156  0168  C15B  CNIN   MOV    *11,5               MOVE DATA TO REG5
0157  016A  0A45         SLA    5,4                 SHIFT TO LEFT
0158  016C  C6C5         MOV    5,*11               PUT DATA IN MEMORY
0159  016E  2F43         READ   3                   GET EIA WORD
0160  0170  0A43         SLA    3,4                 LEFT JUSTIFY
0161  0172  09C3         SRL    3,12
0162  0174  E6C3         SOC    3,*11               SET ONES IN DATA WORD
0163  0176  0601         DEC    1                   DECREMENT WORD COUNT
0164  0178  16F7         JNE    CNIN                GO BACK IF NOT FINISHED
0165  017A  0380         RTWP
0166              ************************************************************
0167              *  WRITE CHARACTER-XOP R,12
0168              *  TRANSFER THE CHARACTER IN THE LEFT BYTE OF REGISTER R TO
0169              *  THE UART.
0170              ************************************************************
0171  017C  020C  WENTRY LI     CRUBAS,>0080        SET CRU BASE ADDRESS
      017E  0080
      0072**017C'
0172  0180  1D10         SBO    16                  SET RTS
0173  0182  1F16         TB     22                  CHECK XMT REG EMPTY
0174  0184  16FB         JNE    WENTRY              GO BACK IF NOT EMPTY
0175  0186  321B         LDCR   *11,8               OUTPUT DATA TO UART
0176  0188  1E10         SBZ    16                  RESET RTS
0177  018A  0380         RTWP
0178              ************************************************************
0179              *  READ CHARACTER-XOP R,13
0180              *  PUTS THE CHARACTER ASSEMBLED IN THE UART INTO REGISTER R.
0181              ************************************************************
0182  018C  020C  RENTRY LI     CRUBAS,>0080        SET CRU BASE ADDRESS
```

```
                                                                   PAGE 0006
      018E  0080
      0076**018C'
0183  0190  1F15          TB      21                 CHECK BUFFER FULL
0184  0192  16FC          JNE     RENTRY             GO BACK IF BUFFER NOT FULL
0185  0194  04DB          CLR     *11                CLEAR DATA
0186  0196  361B          STCR    *11,8              GET DATA FROM UART
0187  0198  1E12          SBZ     18                 CLEAR BUFFER FULL
0188  019A  0380          RTWP
0189                ******************************************************
0190                *  LOAD ROUTINE-THIS ROUTINE IS ENTERED IF A LREX INSTRUCTIO
0191                *  IS EXECUTED(THERE IS A TWO INSTRUCTION DELAY AFTER THE LR
0192                *  BEFORE THIS ROUTINE IS ENTERED)OR IF THE LOAD SIGNAL FROM
0193                *  THE MICROTERMINAL BECOMES ACTIVE LOW.
0194                ******************************************************
0195  019C  0201  LOAD    LI      1,HALTFG           CHECK HALT FLAG
      019E  FFFA
      009A**019C'
0196  01A0  C091          MOV     *1,2
0197  01A2  13--          JEQ     LOAD1              JUMP IF NOT SET
0198  01A4  0460          B       @HALT              GO EXECUTE HALT FUNCTION
      01A6  0132'
0199  01A8  0641  LOAD1   DECT    1                  CHECK STEP FLAG
      01A2**1302
0200  01AA  C091          MOV     *1,2
0201  01AC  13--          JEQ     LOAD2              JUMP IF NOT SET
0202  01AE  0460          B       @STEPRT            GO EXECUTE STEP FUNCTION
      01B0  00FC'
0203  01B2  0460  LOAD2   B       @INIT              REINITIALIZE FOR INVALID LOA
      01B4  0080'
      01AC**1302
0204  01B6  0638  BR      DATA    >0638           TMS9902 DATA RATE REG CONTENTS
      008E**01B6'
0205  01B8    62  CR      BYTE    >62             TMS9902 CONTROL REG CONTENTS
0206                      END     INIT
      0088**01B8'
```

NOTES

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