M68HC16Z1EVB/D
Rev. 1

April 1998

M68HC16Z1EVB

USER'S MANUAL

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CHAPTER 1
GENERAL INFORMATION

1.1 INTRODUCTION

This manual provides general information, hardware preparation, installation instructions, operating instructions, functional description, and support information for the M68HC16Z1EVB Evaluation Board (EVB). Appendix A contains EVB downloading S-record information.

The EVB consists of the M68HC16Z1EVB printed circuit board (PCB) plus development software.

1.2 FEATURES

EVB features include:

- An economical means of evaluating target systems incorporating MC68HC16Z1 HCMOS microcontroller unit (MCU) devices.
- Background-mode operation, for detailed operation from a personal computer (PC) platform without an on-board monitor.
- Integrated assembly/editing/emulation environment for easy development.
- As many as seven software breakpoints.
- Memory map of your target system.
- RS-232C terminal input/output (I/O) port.
- Logic analyzer pod connectors.

1.3 SPECIFICATIONS

Table 1-1 lists EVB specifications.

Table 1-1. EVB Specifications

Characteristic	Specifications
Internal Clock	16.78 MHz bus operation (32 kHz crystal controlled, with on-chip phase lock loop)
External Clock	25—50 kHz
Pseudo ROM maximum memory	EPROM: 32 K bytes x 16 (word mode)(1) 32 K bytes x 8 (byte mode) RAM: 32 K bytes x 16 (word mode)(1) 32 K bytes x 8 (byte mode)
Data RAM maximum memory	64 K bytes: 32 K bytes x 16 (word mode)(1) 32 K bytes x 8 (byte mode)
MCU I/O ports	HCMOS compatible
Monitor interface	Centronics parallel compatible
Optional development interface	RS-232C compatible
Temperature Operating Storage	 *+25° C* *-40° to +85° C*
Relative humidity	0 to 90% (non-condensing)
Power requirements	*+5 Vdc @ 1.0 A (max)*
Dimensions	9.5 *x* 6.6 *in. (24*1 x 190 m*m)*
(1) See paragraph 2.3.2 for an explanation of word and byte modes.	

1.4 GENERAL DESCRIPTION

The EVB is an economical tool for designing, debugging, and evaluating MC68HC16Z1 MCU operation. The factory ships the EVB with a resident MC68HC16Z1 MCU device. By providing the essential MCU timing and I/O circuitry, the EVB simplifies user evaluation of prototype hardware/software products. The EVB requires a user-supplied power supply and host computer.

For communication with the EVB, the user needs a personal computer (PC), with a Centronics-type parallel port. The *P&E* software included with the EVB uses the parallel port for communications. The EVB also has an RS-232 serial port for user access to the on-chip serial communication interface (SCI) (although this port is not used with the EVB16 development system software).

The EVB operates in background mode: a *backdoor* method of talking to the CPU core.

There are two methods of generating MCU code:

1. Using the EVB one-line assembler/disassembler.
2. Downloading assembled code from an external source to user program RAM (pseudo ROM) via EVB16 (that is, through the background mode port).

The EVB includes jumper-selectable options such as clock source selection, ROM or RAM selection, and memory size selection. The EVB offers various operating configurations for the optional data converters. A switch lets the user reset EVB circuitry.

1.5 EQUIPMENT REQUIRED

The external requirements for EVB operation are a +5 Vdc power supply and a host computer. The computer must run under MS-DOS, PC-DOS, or Dr-DOS, and must have a Centronics-compatible interface port and cable assembly.

For optional analog/digital(A/D) data conversion, the user also must supply a Burr-Brown PCM56P device (for EVB location U12) and -8 Vdc to -15 Vdc power.

1.6 CUSTOMER SUPPORT

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CHAPTER 2
HARDWARE PREPARATION AND INSTALLATION

2.1 INTRODUCTION

This chapter provides unpacking instructions, hardware preparation information, and installation instructions for the EVB.

2.2 UNPACKING INSTRUCTIONS

NOTE

Should the product arrive damaged, save all packing material, and contact the carrier's agent.

Unpack the EVB from its shipping carton. Refer to the packing list and verify that all items are present. Save packing material for storing and shipping the EVB.

2.3 HARDWARE PREPARATION

The user should inspect and prepare the EVB before use. This portion of text explains how to do this, as well as how to configure the EVB for the system operation the user needs.

The EVB has been factory-tested; it is shipped with factory-installed jumpers. Figure 2-1 shows the locations of jumper headers and connectors.

Connectors P1 through P7 are the logic analyzer connectors. Connector P8 is for system power and connector P9 is the PC printer port. Connector P10 is the optional RS-232 interface connector, for user code development. Connector P11 is an additional power connector for the PCM56P power supply, -8 Vdc to -15 Vdc. Refer to Chapter 6 for connector pin assignments.

Switch SW1 is the reset switch.

Jumper headers J1 through J4 configure the EVB for RAM devices or either of two types of EPROM devices at locations 02 and U4. Jumper header J5 configures the correct address or control signals to the pins of the memory device at location U4. Jumper header J6 gives +5-volt power to logic analyzer connectors P1 and P2. Jumper header J7 selects a signal that prevents memory access faults. Jumper header J8 gives +5-volt power to logic analyzer connectors P5 and P6. Jumper header J9 connects the RXD signal of the HC16 device to location U8. Jumper header J10 connects the TXD signal of the HC16 device to location U8.

Jumper headers J11, J12, and J14 determine whether the EVB uses the on-board crystal clock source or an external clock source. (Jumper header J13 is for factory use.) And jumper headers J15 through J17 connect OSPI signals to an optional D/A conversion device at location U12.

Locations U1 through U4 are the EVB memory array. Sockets at these locations accommodate a variety of memory devices. EVB circuitry lets the user configure two memory devices as either byte-addressable or word addressable. This lets the user evaluate an HC16 device with an 8-bit RAM/EPPOM system. Paragraph 2.3.2 explains memory configuration.

NOTE

Many of the EVB jumper headers have cut-trace shorts for their factory configuration. For the alternate functionality of such a jumper header, carefully cut the trace on the bottom of the board. To restore the original functionality after a trace has been cut, insert a fabricated jumper the jumper header.

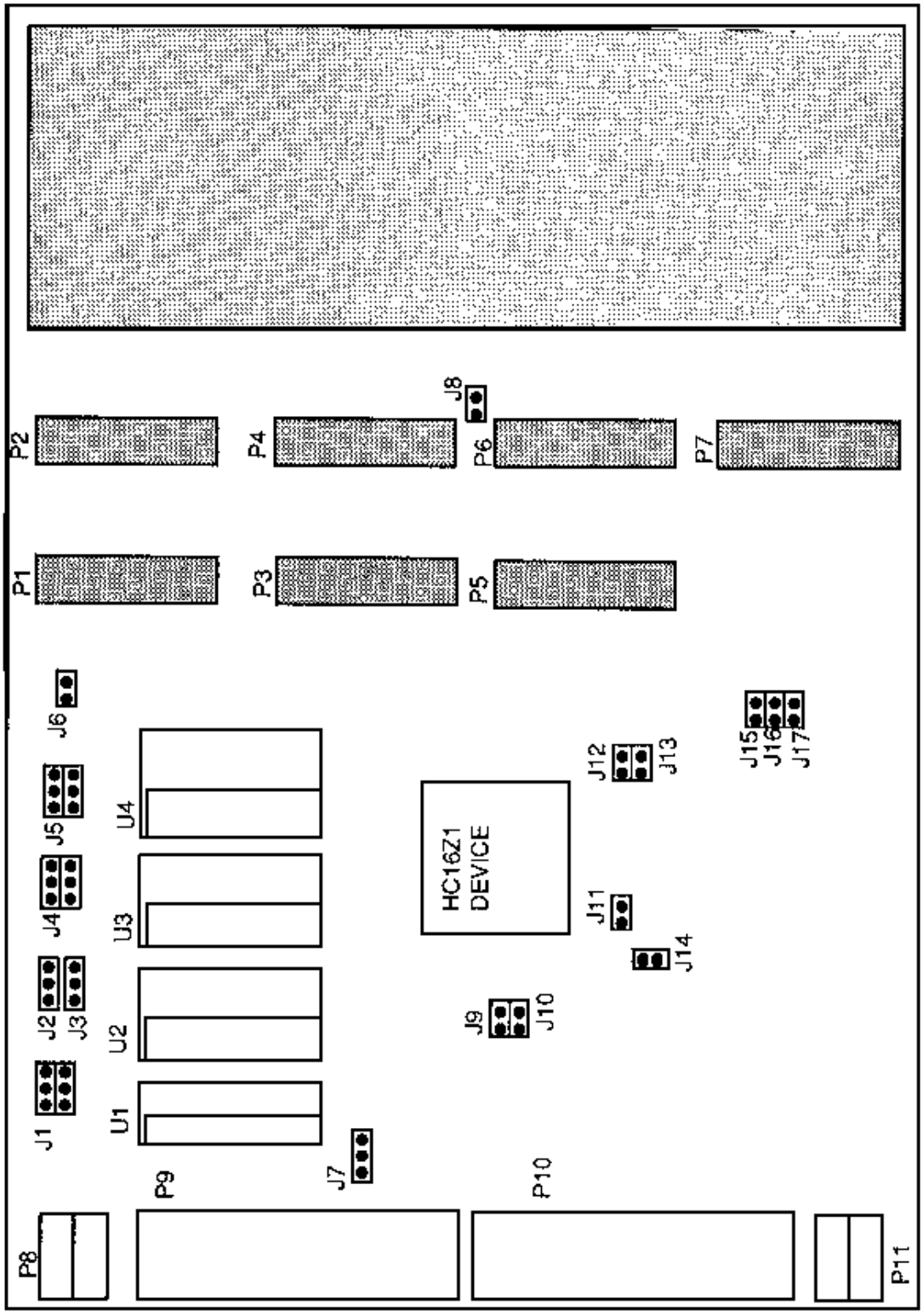


Figure 2-1. Jumper Header and Connector Location Diagram

2.3.1 RAM/EPROM Select Headers (J1—J4)

The top of Figure 2-2 shows the factory configuration of jumper headers J1 through J4. The fabricated jumpers between pins 1 and 2 and pins 4 and 5, of headers J1 and J4 configure the EVB for RAM devices at locations U2 and U4. If headers J1 and J4 are configured in this way, the jumper configuration of headers J2 and J3 does not matter (That is, fabricated jumpers may be absent from or in any position of headers J2 and J3.)

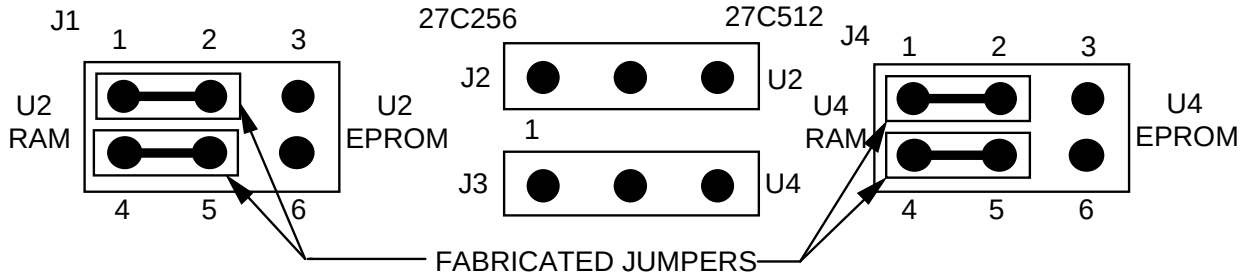
To use type 27C256 EPROM devices at locations U2 and U4 (instead of RAMs), reposition the fabricated jumpers of headers J1 and J4 between pins 2 and 3, and between pins 5 and 6. Additionally, install fabricated jumpers between pins 1 and 2 of both jumper header J2 and jumper header J3. The middle of Figure 2-2 shows this configuration.

To use type 27C512 EPROM devices at locations U2 and U4 (instead of either RAMs or 27C256 EPROMs), reposition the fabricated jumpers of headers J1 and J4 between pins 2 and 3, and between pins 5 and 6. Additionally, install fabricated jumpers between pins 2 and 3 of both jumper header J2 and jumper header J3. The bottom of Figure 2-2 shows this configuration.

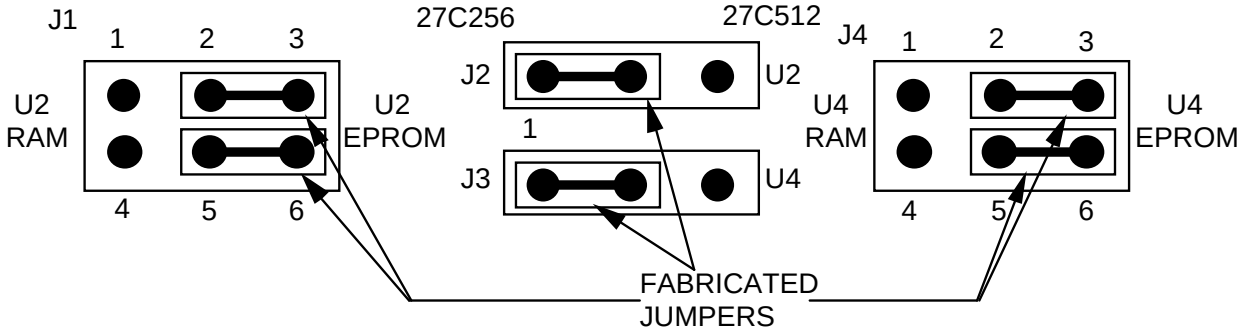
NOTES

The factory-supplied RAMS at locations U2 and U4 are for use only as pseudo ROM. Place variable storage and stack areas in internal RAM or in RAMs at locations U1 and U3.

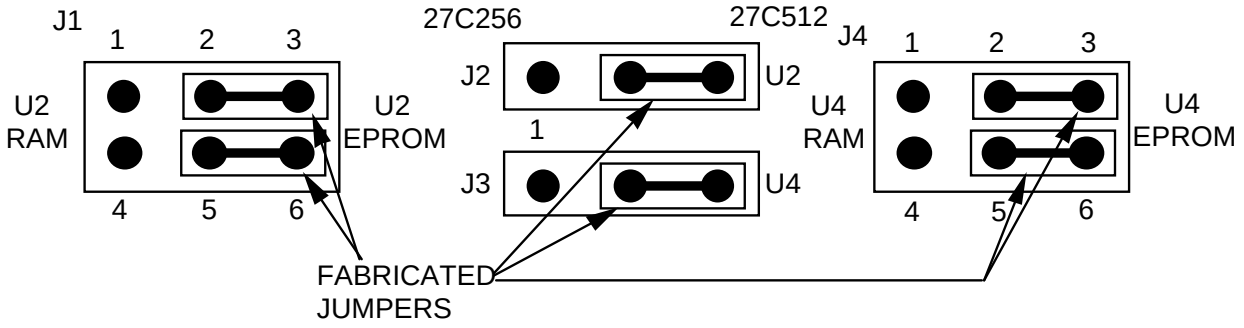
Make sure that the devices at locations U2 and U4 are identical: both RAM, both type 27C256 EPROMs, or both type 27C512 EPROMs.



CONFIGURATION FOR RAMS (FACTORY CONFIGURATION)



CONFIGURATION FOR 27C256 EPROMS



CONFIGURATION FOR 27C512 EPROMS

Figure 2-2. RAM/EPROM Select Header Configurations

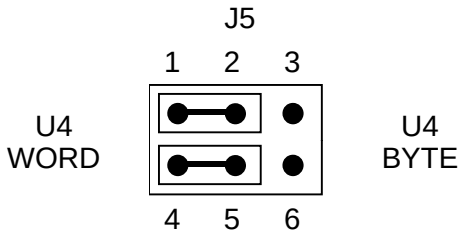
2.3.2 Memory Devices (U1-U4) and Byte/Word Select Header (J5)

Board locations U1 through U4 are the EVB memory array. Locations U1 and U3 are for RAM devices, and locations U2 and U4 are for either RAM or EPROM devices (as paragraph 2.3.1 explains). The sockets of all four devices accept memory devices of two widths: either 0.300 mil or 0.600 mil DIP devices.

The U1 and U2 sockets have three rows of holes. To use a narrow device at U1 or U2 insert the device into the left two rows of socket holes To use a wide device at U1 or 02, insert the device into the outer two rows of holes.

In addition to accommodating either narrow or wide devices, the U3 and U4 sockets permit memory configuration as either byte or word addressable. To handle this byte mode or word mode, these sockets have six rows of holes. To configure a narrow memory device at location U3 or U4 for byte mode, insert the device into rows 1 and 3 (the A position). To configure a narrow memory device at location U3 or U4 for word mode, insert the device into rows 2 and 4 (the B position). A wide device follows the same pattern: socket-hole rows 1 and 5 (byte mode, A position) or rows 2 and 6 (word mode, B position). Printing on the EVB guides device placement.

Jumper header J5 must be configured correctly for the memory device at location U4. Header J5 selects the top address lines of the U4 memory device. Fabricated jumpers between pins 1 and 2, and 4 and 5, as the drawing below shows, is correct for a U4 memory device in word-mode position.



If the U4 device is in the byte-mode position reposition the U5 jumpers to pins 2 and 3, and 5 and 6.

Note that jumper headers J3 and J4 also affect address and control signals for the device at location U4. Header J3 selects the signal on pin 1 of the memory only if header J4 is configured for EPROM. Header J4 selects the signal for pins l and 27 of the memory.

As an example, consider a 27C512 EPROM, 64K x 8, installed at location U4. This device requires 16 address lines. If the device is in the byte-mode position, the U4 socket directly provides lines A0 through A13. Jumper header J5, set to byte, passes line A14 to header J4 and line A15 to header J3. Header J3, set to 27C512, passes line A15 to header J4. Header J4 set to EPROM, passes lines A14 and A15 to the memory device. This completes the 16 address lines (A0—A15) that the device needs.

If the 27C512 EFROM device is in the word-mode position, the U4 socket directly provides address lines Al through A14. Jumper header J5, set to word, passes line A15 to header J4 and line Al6 to header J3. Header J3, set to 27C512, passes line A16 to header J4. Header J4, set to EPROM, passes lines A15 and A16 to the memory device. This completes the 16 address lines (A1—A16) that the device needs.

Tables 2-1 and 2-2 list pin signals and data bus sizes, respectively, for different configurations of the EVB memory array.

NOTES

Although the EVB provides proper byte- or word-mode signals to memory devices, the EVB does not select the data port size. The default data-port size at power-up is 16 bits for the CSBOOT pseudo-ROM control signal. At device reset, an internal pull-up of the data-0 (D0) signal again sets the data port size to 16 bits To select an 8-bit data-port size, the user must pull the D0 signal low at device reset.

The data HAM. at locations U1 and U3, uses chip selects. The user can program these chip selects for proper data bus sizing.

Table 2-1. Memory Device Pin Signals

Device and Configuration	Data Signals	Available Address Signals	Chip Select	Write Enable
Pseudo ROM U2 U4-A (byte) U4-B (word)	 D0–D7 D8–D15 D8–D15	 A1–A16 A0–A15 A1–A16	 CSBOOT CSBOOT CSBOOT	 R/W* R/W* R/W*
DATA RAM U1 U3-A (byte) U3-B (word)	 D0–D7 D8–D15 D8–D15	 A1–A16 A0–A15 A1–A16	 CS2* CS2* CS2*	 CS1* CS0* CS0*

Table 2-2. Memory Device Pin Signals

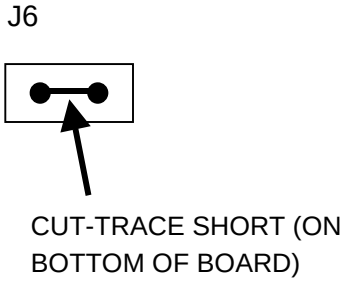
Device and Configuration	Word — 16 Bits		Byte — 8 Bits	
	Word Memory Access	Byte Memory Access	Word Memory Access	Byte Memory Access
Pseudo ROM U2 U4-A (byte) U4-B (word)	 Read, write N/A Read, write	 Read(1) N/A Read(1)	 N/A Read, write N/A	 N/A Read, write N/A
DATA RAM U1 U3-A (byte) U3-B (word)	 Read, write N/A Read, write	 Read, write(2) N/A Read, write(2)	 N/A Read, write N/A	 N/A Read, write N/A

(1) For a byte write, the HC16 places the data byte on both halves of the data bus This writes a word into the pseudo RQM memories, possibly causing an unexpected error.

(2) To accomplish this, program the chip selects before accessing memory.

2.3.3 P1, P2 +5-Volt Select Header (J6)

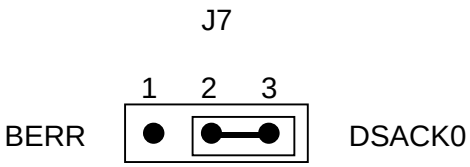
The cut-trace short of jumper header *36.* below, gives +5-volt power to pins 1 of logic analyzer connectors P1 and P2.



If you do not want this functionality, carefully cut the J6 trace, on the bottom of the board. Subsequently, to restore the power to pins 1 of P1 and P2, insert a fabricated jumper in header J6.

2.3.4 Memory Access Fault Prevention Header (J7)

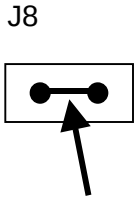
The factory configuration of jumper header J7 is shown below. The fabricated jumper installed between pins 2 and 3 ensures correct MCU operation at power-up by asserting the DSACK0 signal. (This asserted signal puts the MCU into background mode, should RAM reset vectors point to unimplemented memory.)



Repositioning the fabricated jumper to pins 1 and 2 asserts the BERR signal. (For future revisions of the HC16Z1, this will be an alternative way to ensure correct operation by putting the MCU into background mode.)

2.3.5 P5, P6 +5-Volt Select Header (J8)

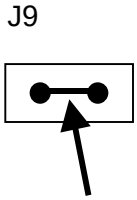
The cut-trace short of jumper header J8, below, gives +5-volt power to pins 1 of logic analyzer connectors P5 and P6.



If you do not want this functionality carefully cut the J8 trace on the bottom of the board. Subsequently, to restore the power to pins 1 of P5 and P6, insert a fabricated jumper in header J8

2.3.6 RXD Connect Header (J9)

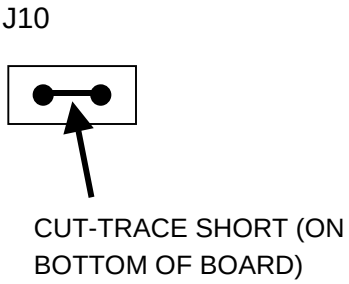
The cut-trace snort of jumper header J9, below, connects the RXD signal of the HC16 device to the RS-232 driver device at location U8.



To disconnect the RXD signal from the U8 device, carefully cut the J9 trace, on the bottom of the board. Subsequently, to reconnect the RXD signal, insert a fabricated jumper in header J9.

2.3.7 TXD Connect Header (J10)

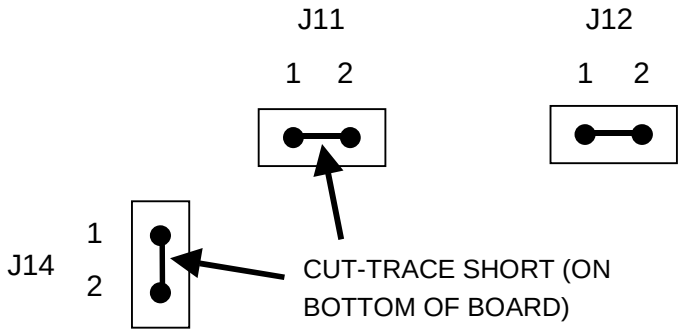
The cut-trace short of jumper header J10, below, connects the TXD signal of the HC16 device to the RS-232 driver device at board location U8.



To disconnect the TXD signal from the U8 device, carefully cut the J10 trace, on the bottom of the board. Subsequently, to reconnect the TXD signal, insert a fabricated jumper in header J10.

2.3.8 Clock Select Headers (J11, J12, J14)

The cut-trace shorts of jumper headers J11 and J14, and no fabricated jumper in jumper header J12, select the on-board crystal clock source. (This 32 kHz crystal provides for 16.78 MHz bus operation.)

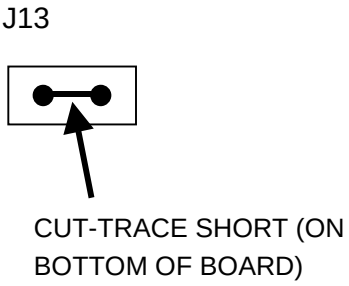


To use an external clock source instead, carefully cut the J11 and J14 traces, on the bottom of the board, and insert a fabricated jumper in header J12. Apply the external clock signal to pin 1 of header J11. The frequency of the external cock signal can be from 25 to 50 kHz.

Subsequently, to reinstate the on-board crystal clock source, remove the external clock signal from header J11, remove the fabricated jumper from header J12, and insert fabricated jumpers in headers J11 and J14.

2.3.9 Factory Test Header (J13)

If a jumper header is at board location J13, it is for factory use, there may be no jumper header at all. Do not use a fabricated jumper or make any other connections at board location J13.

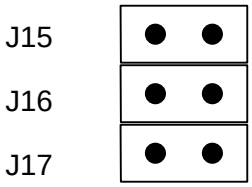


CAUTION

Do not change the factory configuration of board location J13. In particular, do not apply external power to pin 1 of location J13; doing so could cause damage to the external power supply.

2.3.10 D/A Select Headers (J15—J17)

The factory configuration of jumper headers J15 through J17 is no fabricated jumpers, as shown below. This is correct when there is no D/A data conversion.



For optional D/A data conversion via a user-supplied PCM56P device in EVB location U12, install fabricated jumpers in headers J15, J16, and J17. (These jumpers connect the SCK PCS/SS*, and MOSI lines, respectively.)

If a PCM56P device is installed at location U12, removing the jumpers from headers J15 through J17 removes the PCM56P device from the EVB circuitry.

2.4 INSTALLATION INSTRUCTIONS

The EVB is designed for table-top operation. A user-supplied power supply and host computer are required. The computer must have a Centronics-compatible parallel port, and must run MS-DOS.

The following paragraphs explain EVB connections.

2.4.1 Power Supply—EVB Connection (P8)

The EVB requires a +5 Vdc @ 1.0 Amp power supply for basic operation. Use connector P8 to connect this system power to the EVB. Contact 1 is GND; black lever. Contact 2 is VDD (+5 Vdc); red lever. Use 20 or 22 AWG wire for power connections. For each wire, trim back the insulation 1/4 in. (.635 cm), lift the appropriate lever of P8 to release tension on the contacts, then insert the bare wire into P8 and close the lever.

CAUTION

Do not use wire larger than 20 AWG in connector P8. Such wire could damage the connector.

NOTE

(D/A conversion, via an optional Burr-Brown PCM56P device, requires a user-supplied connector at location P11. This connector location accommodates user-supplied power of -7 Vdc or less.)

2.4.2 Computer—PC Printer Port Connection (P9)

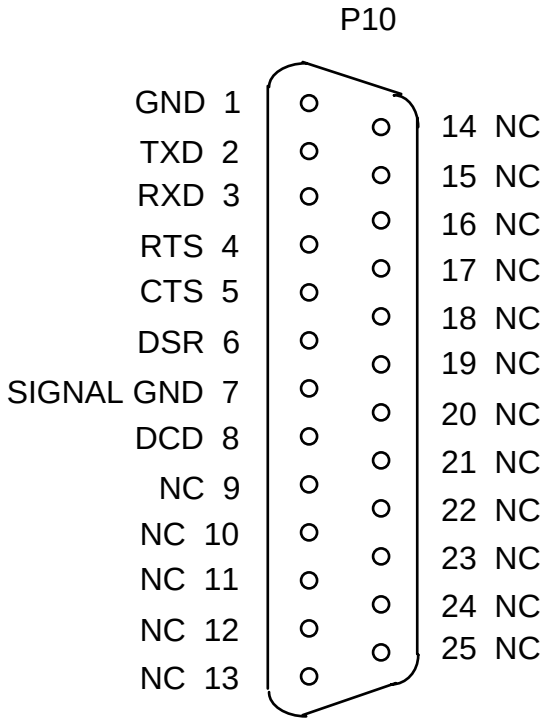
Connect the EVB to the host computer via a user-supplied 25-conductor cable assembly. One end of the cable assembly needs a female DB25 connector; this end of the cable connects to the EVB PC printer port (connector P9). The other end of the cable assembly needs a male DB25 connector; this end of the cable connects to the Centronics-compatible port of the computer. For connector pin assignments and signal descriptions of connector P9, refer to Chapter 6.

2.4.3 Computer—User Interface Port Connection (P10)

Connection of an RS-232C compatible terminal or host computer to the EVB requires a user-supplied 25-conductor cable assembly. One end of the cable assembly needs a male DB25 connector; this end of the cable connects to the EVB user interface port (connector P10), shown below. The other end of the cable assembly needs the appropriate connector for the RS-232C compatible port of the terminal or host computer. For connector pin assignments and signal descriptions of connector P10, refer to Chapter 6.

NOTE

This cable is not essential for proper operation of the EVB. Use this cable and connector P10 only if RS-232C communication with the on-chip SCI port is required.

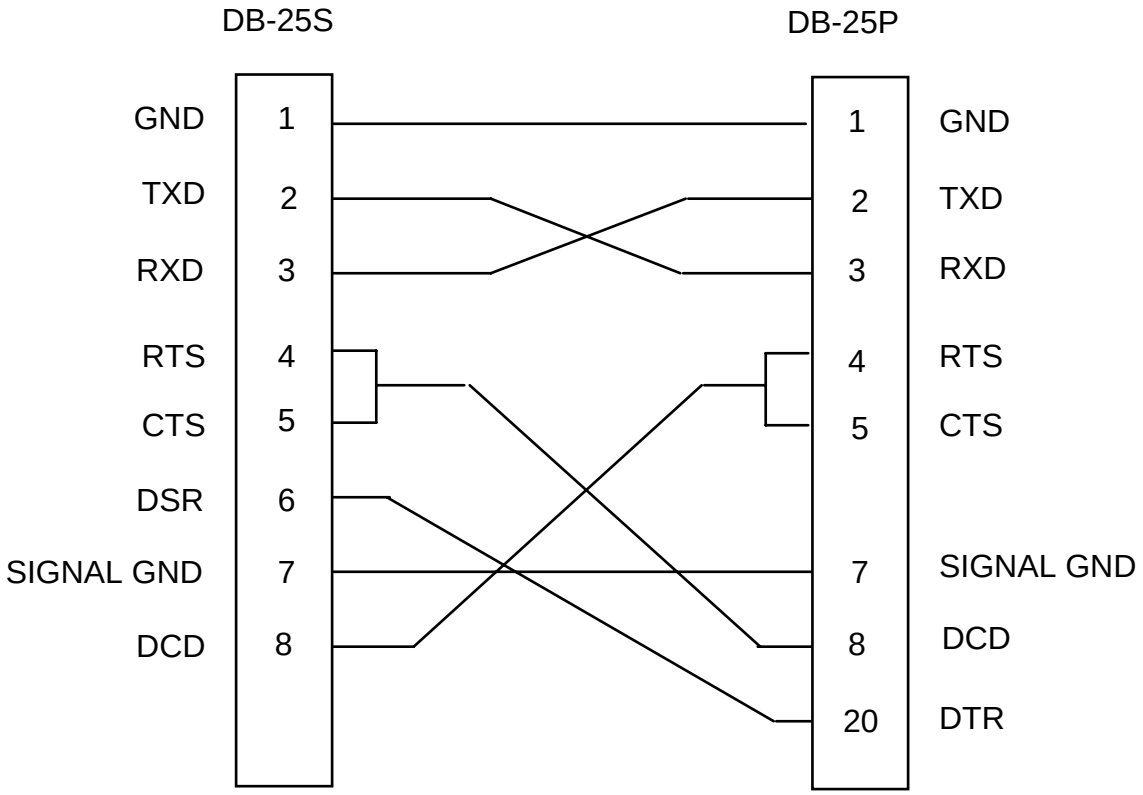


EVB User Interface Port (Connector P10)

The EVB is wired as data communication equipment (DCE) whereas a terminal and most serial modem ports on host computers are wired as data terminal equipment (DTE). This lets a straight-through cable be used for most setups.

If a different type of cable is used for RS-232C connection between the EVB and a host computer, a null modem adapter (shown below) may be required to match the cable to the EVB terminal port connector.

A null modem adapter reverses the roles of various data and control signals to make a DTE device appear as a DCE device, or vice versa.



Connector P10 Null Modem Adapter

2.4.4 Logic Analyzer—EVB Connections (P1—P7)

Use logic analyzer connectors P1 through P7 to connect the EVB to the circuit being evaluated. For signal descriptions, refer to chapter 6.

The EVB area of extra holes next to connectors P1 through P7 gives the user space for 10-pin Berg-type strips. To use such strips, install them on the *bottom* of the board, and solder the pins on the top. Wire-wrap from the bottom of the EVB to the user wire-wrap area. Be sure to put standoffs in the corner mounting holes to protect the wire-wrapping on the bottom of the EVB.

P1

+5V	1	●	●	2	SPARE
DSACK1	3	●	●	4	A15
A14	5	●	●	6	A13
A12	7	●	●	8	A11
A10	9	●	●	10	A9
A8	11	●	●	12	A7
A6	13	●	●	14	A5
A4	15	●	●	16	A3
A2	17	●	●	18	A1
A0	19	●	●	20	GND

P2

+5V	1	●	●	2	SPARE
AS	3	●	●	4	D15
D14	5	●	●	6	D13
D12	7	●	●	8	D11
D10	9	●	●	10	D9
D8	11	●	●	12	D7
D6	13	●	●	14	D5
D4	15	●	●	16	D3
D2	17	●	●	18	D1
D0	19	●	●	20	GND

P3

SPARE	1	●	●	2	SPARE
DSACK0	3	●	●	4	AVEC
HALT	5	●	●	6	AS
DS	7	●	●	8	BR/CS0
BG/CS1	9	●	●	10	CSBOOT
CLKOUT	11	●	●	12	A23/CS10
A22/CS9	13	●	●	14	A21/CS8
A20/CS7	15	●	●	16	A19/CS6
A18	17	●	●	18	A17
A16	19	●	●	20	GND

P4

SPARE	1	●	●	2	SPARE
SPARE	3	●	●	4	SPARE
TSTME/TSC	5	●	●	6	RESET
RXD	7	●	●	8	PCLK
PWMB	9	●	●	10	PWMA
PAI	11	●	●	12	IC4/OC5
OC4	13	●	●	14	OC3
OC2	15	●	●	16	OC1
IC3	17	●	●	18	IC2
IC1	19	●	●	20	GND

P5

+5V	1	2	SPARE
CLKOUT	3	4	BERR
BKPT/DSCLK	5	6	FREEZE
IPIPE0 LATCHED	7	8	IPIPE1 LATCHED
IPIPE0/DSO	9	10	IPIPE1/DSI
DSACK1	11	12	DSACK0
FC2/CS2	13	14	FC1/CS4
FC0/CS3	15	16	SIZ1
SIZ0	17	18	R/W
BGACK/CS2	19	20	GND

P6

+5V	1	2	SPARE
DS	3	4	MODCK
IRQ1	5	6	IRQ2
IRQ3	7	8	IRQ4
IRQ5	9	10	IRQ6
IRQ7	11	12	TXD
PCS0/SS	13	14	PCS1
PCS2	15	16	PCS3
SCK	17	18	MISO
MOSI	19	20	GND

P7

SPARE	1	2	SPARE
VRHP	3	4	VRLP
AD6	5	6	AD7
AD4	7	8	AD5
AD2	9	10	AD3
AD0	11	12	AD1
AN+	13	14	AN-
DAC2OUT	15	16	DAC1OUT
SPARE	17	18	SPARE
AGND	19	20	AGND

CHAPTER 3
EVB16 OPERATING PROCEDURE

3.1 INTRODUCTION

This chapter explains how to start and use EVB16. The explanations of this chapter cover startup, general use, the main screen, debug commands, source code debugging, and the trace buffer.

3.1.1 Typeface and Parameter Conventions

This chapter uses four different typefaces:

1. **Chapter heads, chapter subheads, and EVB16 commands appear in this bold typeface. Heads and subheads start at the far left margin; commands are indented about half an inch.**
2. `Examples are in this typeface.`
3. Text and explanations are in this normal typeface.
4. *Special comments are in this italic typeface.*

Also, note these conventions for parameters and keyboard entries:

- **add** indicates any valid, hexadecimal address or label.
- **file** indicates a file name.
- **IP** is the instruction pointer, which points to the next instruction to be executed.
- **n** indicates any hexadecimal number, 0—0FFFFF.
- **PC** is the program counter, which points to the next instruction to be fetched. (The PC value equals the IP value plus 6.)
- **[ ]** indicate an optional parameter.
- **<CR>** indicates the ENTER, RETURN, or carriage-return key of your keyboard.

3.1.2 EVB16 Numerical Formats

Unless otherwise specified, all numbers in EVB16 are hexadecimal: all numerical values EVB16 displays have base 16. Furthermore, EVB16 presumes that any numbers you enter also are base-16 numbers.

However, EVB16 does accommodate decimal, octal, and binary numbers, as long as the numbers have a proper prefix or suffix, per Table 3-1.

Table 3-1. EVB16 Number Symbols

Symbol	Meaning
$	Optional prefix for hexadecimal numbers, as *$0FF*
!	Required prefix for decimal numbers, as *!255* (which equals $0FF)
@	Required prefix for octal numbers, as *@377* (which equals $0FF and !255)
%	Required prefix for binary numbers, as *%11111111* (which equals $0FF, !255, and @377)
H	Optional hexadecimal-number suffix; an alternative to the $ prefix (*0FFH* = $0FF)
T	Decimal-number suffix; an alternative to the ! prefix (255T = !255)
O	Octal-number suffix; an alternative to the @ prefix (377O = @377)
Q	Binary-number suffix; an alternative to the % prefix (11111111Q = %11111111)

3.2 STARTUP

Before running EVB16 software, make sure that the EVB board is connected and powered up. To start EVB16 operation, enter the startup command at the DOS prompt:

```
EVB16 [<lptn>] [<path>] [bw]
```

<lptn> *Specifies the parallel port connected to the EVB. Possible values are lpt1, lpt2, and lpt3; lpt1 is the default. (The values lpt1, lpt2, and lpt3 also are valid commands from within EVB16.)*

<*path*> *Specifies the full path to a directory that contains the code for source-level debugging.*

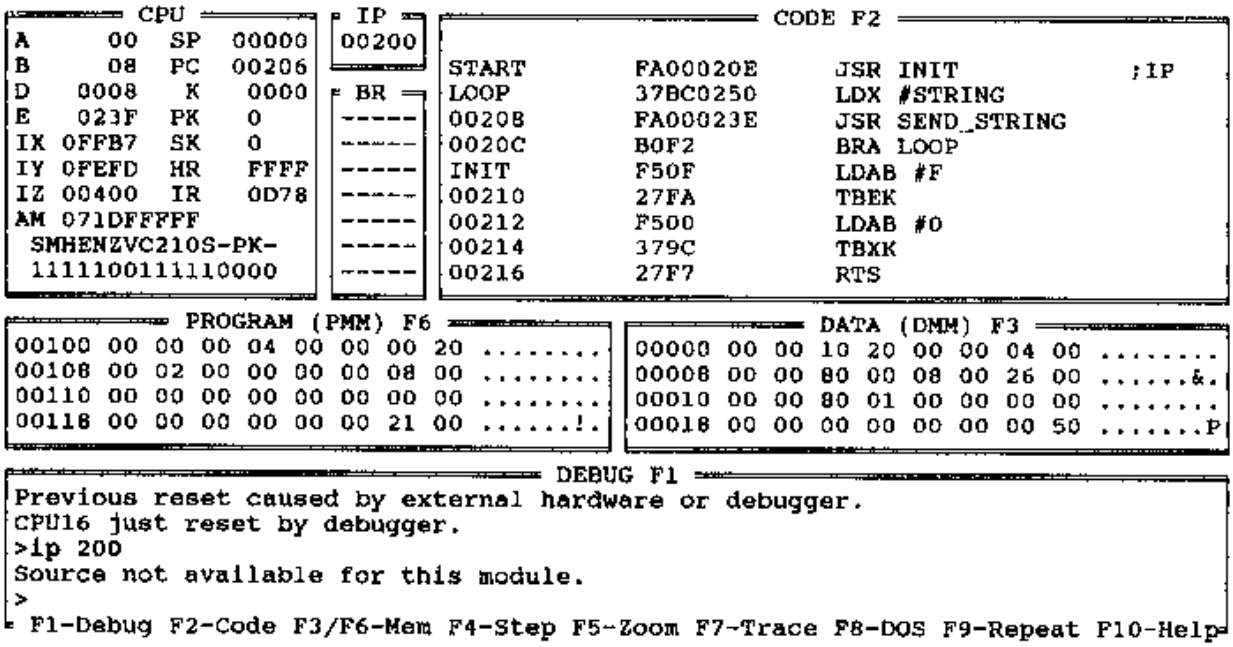
bw *Specifies black-and-white mode (often appropriate for using a lap-top computer).*

`EVB16 lpt2 path` *Starts program via lpt2 and points the way to the code to be debugged.*

`EVB16 bw` *Starts program, specifies black-and-whitemode.*

3.3 MAIN SCREEN

Figure 3-1 shows the main screen, which consists of seven windows: the CPU window, the instruction pointer (IP) window, the breakpoint (BR) window, the code window, the program (F6) memory window, the data (F3) memory window, and the debug (F1) window.



3.3.1 CPU Window

The CPU window, at the upper left of the main screen, shows the status of CPU resources. Use the debug window to change any register value in the CPU window: enter the resource, a space, and the new value. To change the value of the AM register, you must specify the high-order 20 bits (AMH) or the low-order 16 bits (AML). You may change individual bits in the condition code register by specifying the bit and entering the value (0 or 1).

3.3.2 Instruction Pointer (IP) Window

The IP window, at the top center of the main screen, shows the value of the instruction pointer, which the EVB16 software uses to designate the instruction to be executed next. Note that the IP value always is six bytes less than the program counter (PC) value. Use the debug window to change the IP value: enter IP, a space, and the new value .

NOTE

The IP is not a CPU resource, because it does not exist in the part.

3.3.3 Breakpoint (BR) Window

The BR window, below the IP window, lists the addresses of active breakpoints. As many as seven breakpoints may be active at once; their addresses are not in any particular order in the BR window. Use the debug window to add a breakpoint: enter BR, a space, and the new address value. To remove a breakpoint, make the same entry, but enter an address value from the BR window. To remove all breakpoints, enter NOBR in the debug window.

Using the GOTIL or STEPTIL command creates a temporary breakpoint not indicated in the BR window.

3.3.4 Code Window

The code window displays code in one of three ways. If no map file has been loaded, the code window displays disassembled code. If a full map file has been loaded, there are two possibilities: the code window either displays source code, or it displays disassembled code with labels defined in the map file. When appropriate, this window also shows the IP and PC values, as well as addresses of active breakpoints. The EVB16 software also uses the code window to display the trace buffer.

Paragraph 3.6 explains source-code debugging via the code window.

3.3.5 Memory Windows

The F6 and F3 memory windows, at the center of the main screen, display memory contents. The F6 window accesses program memory. The F3 window accesses data memory.

Values in these windows are hexadecimal and, when appropriate, in seven-bit ASCII symbols. A period appears in lieu of an unprintable ASCII character.

3.3.6 Debug Window

The debug window, at the bottom of the main screen, accepts most of your commands. The prompt symbol is the > character.

3.3.7 Window Function Keys

To move between windows, and to carry out certain other actions, use special function (F) keys of the keyboard. Table 3-2 lists the functions of these keys.

Table 3-2. EVB16 Special Function Keys

F Key	Function
F1	Go to the debug window
F2	Go to the code window. In this window, you may scroll or see future code.
F3	Go to the F3 memory window. In this window, you may scroll through data memory.
F4	Do a single-step trace. (This key has the same role as the ST command.)
F5	Shrink or enlarge the code window (if it displays source code).
F6	Go to the F6 memory window. In this window, you may scroll through code memory.
F7	Go to the code window as a trace window. In this format of the code window, you may scroll through the trace buffer.
F8	Shell to DOS.
F9	Repeat the last command.
F10	Activate the help window.

3.4 GENERAL USE

Do most of your debugging from the debug window. You may enter all debug commands in this window. Typically, the first command a user enters is one of the load commands. If you have created an object (.S19) file as well as a map (.MAP) file via the MASM16 assembler shell, enter the LOADALL command:

```
>LOADALL      Brings your code and symbols into EVB16.
Filename:
```

In response to the filename prompt, enter the name of the file. Next, if you have loaded appropriate reset vectors for the code, enter a reset command; this resets the hardware and initializes the IP and PC correctly.

```
>RESET        Resets the hardware.
```

The code window shows your code, either via disassembly or via your actual source. At this point, you may start debugging. To have the F3 or F6 memory windows display code starting at a useful address, enter the SHOWF3 (or SHOWF6) command:

```
>SHOWF3 myarray
```

*Sets location **myarray** as the start of the F3 window display.*

Now you may begin debugging and testing your code, by setting breakpoints or single-stepping. For example, to single-step, enter this command:

```
>ST 50        Single-step through $50 instructions.
```

3.5 DEBUG WINDOW COMMANDS

Table 3-3 lists EVB16 debug commands. Explanations of the individual commands follow the table.

Table 3-3. Debug Window Commands

Syntax	Meaning
ASM [add]	Assemble into pseudo ROM
BF add add n	Block fill memory with data
BR add	Set or remove breakpoint
BW	Change display to black-and-white mode
CLEARMAP	Remove source-level debug information
CODE add	Show disassembled code in code window
DMM[.X] add [n]	Assign data to RAM
EVAL n [op] [n]	Evaluate expression
EXIT	Exit the program
FILL add add n	Block fill memory with data
G [add] [add]	Go (execute program)
GO [add] [add]	Go (execute program)
GOTIL add	Go from IP to add
GOTILROM add	Single-step fast to add
HELP	Display help system
LOAD	Load S-records
LOADALL	Load S-records and debug file
LOADMAP	Load MASM debug file
LPT[x]	Specify printer port
MDF3 add	Set F3 window memory display
MDF6 add	Set F6 window memory display
NOBR	Remove all breakpoints

Table 3-3. Debug Window Commands (continued)

Syntax	Meaning
PMM[.X] add [n]	Modify memory in program space
QUIT	Exit the program
RESET	Do a hardware reset
SHOWF3 add	Set F3 window memory display
SHOWF6 add	Set F6 window memory display
SIGNLATCH n	Set sign latch to n
SOURCE	Toggle code display
SOURCEPATH	Search for code in another directory
ST [n]	Do single-step trace
STEP [n]	Do single-step trace
STEPFOR	Do single-step trace until breakpoint
STEPTIL add	Do single-step until add
SYMBOL chars val	Add symbol to loaded map file
T [n]	Do single-step trace
TRACE [add] [add]	Execute trace
VERIFY	Compare file to memory
WATCHDOG	Disable watchdog timer
WHEREIS symbol	Show symbol value

ASM [add] **Assemble into pseudo ROM**

add Starting address or label for assembly.

This command invokes the one-line assembler, starting at the specified address. If this command does not include an address, assembly starts at the address used by the previous ASM command.

This assembler assembles user code, including labels, provided that the labels are in a previously loaded map file. If no map file is loaded, labels may not be used. The ASM command does not define labels. Your entry must start with an opcode.

During assembly, EVB shows the instruction at the current location in the debug window. To modify this instruction, type in a new one. To end the assembly session, type a period (.) at the prompt. To advance to the next location without changing the present location, enter a carriage return.

You may press the F10 (help) key to see the format of assembly-language instructions.

```
>ASM 10500          Start assembly at location $10500.
10500 274c nop >    Shows disassembly, prompts for input.
```

BF add add n **Block fill memory with data**

add *First parameter: fill operation lower limit; second parameter: fill operation upper limit.*

n *Fill pattern.*

This command repeats a specific byte value throughout a specified user memory range. An invalid address leads to an error message. You may use this command at the beginning of a debug session to initialize an area of memory or an array.

```
>BF C000 C030 FF     Assign value $FF to each byte, $C000—$C030.
>BF C000 C000 0      Assign value 0 to location $C000.
```

BR add **Set or remove breakpoint**

add *Address or label of breakpoint to be set or removed.*

This command sets or removes the specified address in the breakpoint address table (shown in the BR window). Seven breakpoints may be active at any time. Program execution halts at any instruction whose address is in the breakpoint address table. The order of breakpoints in the BR window has no effect on their operation.

For a temporary, additional breakpoint in RAM or pseudo ROM, use the GOTIL or STEPTIL command. For such a breakpoint in ROM, use the GOTILROM command.

`>BR 200` *Set breakpoint at address $200.*

`>BR start1` *Set breakpoint at label **start1**.*

BW **Change display to black-and-white mode**

This command puts the display in black-and-white mode. Use this command if the default color display is hard to read, for example, if you use a lap-top computer. You also may use this command at the command line that starts the program. This action may be taken only once, following a hardware reset. There is no command to return to color mode.

`>BW` *Put display in black-and-white mode.*

CLEARMAP **Remove source-level debug information**

This command clears the previously loaded map file from EVB16 software. This eliminates symbols and eliminates source code debugging. The code window defaults to simple disassembly.

`>CLEARMAP` *Delete the current map information.*

CODE add **Show disassembled code in code window**

add *Starting address or label for disassembled code.*

This command is an alternative to scrolling in the code window. After execution of any instruction, the code window reverts to showing IP and PC values.

`>CODE 10300` *Show code starting at address $10300.*

`>CODE sub1` *Show code starting at label **sub1**.*

DMM[.X] add [n] ... [n] **Assign data to RAM**

.X RAM units: .B = bytes, .W = words, and .L = long words.

add RAM address or label to receive data value.

n Data to be entered.

This command writes the specified data into RAM at the specified address. Consecutive data values (separated by spaces) go into consecutive memory units defined by the .X parameter. (The default memory unit is the byte.)

If the command line does not specify data, the software prompts for data, one memory unit at a time. Such prompts include the memory location and current value. To change the value, enter the new value. To advance to the next location without changing the present location, press <CR>. To exit this command, enter a period or other nonsense value.

`>DMM 100 1 2 3 4` *Put values 1—4 into locations $100—$103.*

`>DMM[.B] 200` *Start interactive memory modification, in bytes.*

`200 = 41 >` *Shows current value, prompts for new one.*

EVAL n [op] [n] **Evaluate expression**

n First parameter: Expression or first term to be evaluated; third parameter: second term to be evaluated.

op Operator.

This command evaluates an arithmetic expression, giving the result in hexadecimal, decimal, octal, and binary values. The expression can contain the operators for addition, subtraction, multiplication, and division (+, –, *, and /). Single spaces must separate parameter values.

```
>EVAL 102T + 54      Evaluate !102 plus $54.
00BAH 186T 000272O 0000000010111010Q      Answer in four bases.
```

EXIT **Exit the program**

This command exits the program, returning to DOS.

```
>EXIT          Return to DOS.
```

FILL add add n **Block fill memory with data**

This command is an alternative form of the BF command.

G [add] [add] **Go (execute program)**

add First parameter: execution starting address or label; second parameter: breakpoint address or label.

This command starts and stops processor execution of instructions according to the specified address parameters:

- If the command has two parameter values, the system sets a new breakpoint at the second address or label, then executes code from the first address or label. Execution continues until it arrives at a breakpoint (which could be the one just set) or until the user presses a key.
- If the command has one parameter value, the system executes code from that address or label until it arrives at an existing breakpoint, or until the user presses a key.
- If the command has no parameter values, the system executes code from the IP value until it arrives at an existing breakpoint, or until the user presses a key.

The processor runs at full execution speed during a GO command.

NOTE

To terminate program execution started via the G command, press the F1 key.

`>G start time1`	*Start code execution at label **start**; break at label **time1**.*
`>G 1050`	*Start code execution at address $1050.*
`>G start`	*Start code execution at label **start**.*
`>G`	*Start code execution at IP value.*

GO [add] [add] **Go (execute program)**

This command is an alternative form of the G command.

GOTIL add **Go from IP to add**

add *Address or label of temporary breakpoint.*

This command inserts a temporary breakpoint at the specified address and starts execution of code at the IP value. Code execution stops when it reaches the temporary breakpoint (or an existing breakpoint). This command works only with program code in RAM or pseudo ROM. (To debug code in ROM, use the GOTILROM command.)

The processor runs at full execution speed during a GOTIL command.

`>GOTIL sub1` *Execute code from IP value to label **sub1**.*

`>GOTIL 1055` *Execute code from IP to address $1055.*

GOTILROM add **Single-step fast to add**

add ROM address or label of temporary breakpoint.

This command starts rapid single-stepping through code, beginning at the IP value. Single-stepping stops at the specified breakpoint address or label. This command is the fastest way to reach a breakpoint in ROM. The processor does not run at full execution speed during a GOTILROM command.

`>GOTILROM sub1` *Single-step through code from IP value to label **sub1**.*

`>GOTILROM 1055` *Execute code from IP to address $1055.*

HELP **Display help system**

This command, an alternative to F10, activates the help system. (The files EVB16.HLP and EVB16.EXE must reside in the same directory for this command to work.) The help system works via temporary pop-up windows. Once these windows are activated, use these keys to:

arrow keys	move within a menu
ENTER	go to a chosen menu
ESC	go to a previous menu or exit
PgDn	go back one menu page
PgUp	go forward one menu page

`>HELP` *Activate the help system.*

LOAD **Load S-records**

This command loads object code into the EVB16. When you enter the LOAD command, the system prompts for a file name. Enter the name of the file that contains the object code. If the file is not in the current directory, enter the entire DOS path. If you do not specify a file extension, the system assumes the extension **.S19**. Note that this command only loads a file; it does not do a reset, nor does it affect any CPU resources.

`>LOAD` *Load object code into the EVB16.*

LOADALL **Load S-records and debug file**

This command loads an object file and a debug map file at the same time. When you enter the LOADALL command, the system prompts for a file name. If the files are not in the current directory, enter the entire DOS path. The system assumes the file extensions **.S19** and **.MAP**. Note that this command only loads the files; it does not do a reset, nor does it affect any CPU resources. (MASM16 creates map files during assembly, as Chapter 4 explains.)

`>LOADALL` *Load object code and map file.*

LOADMAP **Load MASM debug file**

This command loads a debug map file into the EVB16. When you enter the LOADMAP command, the system prompts for a file name. Enter the name of the file that contains the map file. If the file is not in the current directory, enter the entire DOS path. If you do not specify a file extension, the system assumes the extension **.MAP**. (MASM16 creates map files during assembly, as Chapter 4 explains.)

```
>LOADMAP      Load map file into the EVB16.
```

LPT[x] **Specify printer port**

x Number of printer port: 1, 2, or 3 (1 is the default).

This command specifies the DOS printer port to use.

```
>LPT2         Use printer port LPT2.
```

MDF3 add **Set F3 window memory display**

add Starting address or label for code in the window

This command resets the display of the F3 screen window to show code starting at the specified address.

```
>MDF3 200          Start F3 window display with address $200.
>MDF3 myarray      Start F3 window display at label myarray.
```

MDF6 add **Set F6 window memory display**

add Starting address or label for code in the window

This command resets the display of the F6 screen window to show code starting at the specified address.

```
>MDF6 8000         Start F6 window display with address $8000.
>MDF6 table        Start F6 window display at label table.
```

NOBR **Remove all breakpoints**

This command removes all the addresses from the breakpoint address table (shown in the BR window).

```
>NOBR          Remove all breakpoints.
```

PMM[.X] add [n] ... [n] **Modify memory in program space**

.X Program space units: .B = bytes, .W = words, and .L = long words.

add Program space address or label to receive data value.

n Data to be entered.

This command writes the specified data into program space at the specified address. Consecutive data values (separated by spaces) go into consecutive units defined by the .X parameter. (The default unit is the byte.)

If the command line does not specify data, the software prompts for data one unit at a time. Such prompts include the memory location and current value. To change the value, enter the new value. To advance to the next location without changing the present location, press <CR>. To exit this command, enter a period or other nonsense value.

```
>PMM 100 1 2 3 4    Put values 1—4 into locations $100—$103.
>PMM 200            Start interactive memory modification.
200 = 41 >          Shows current value, prompts for new one.
```

QUIT **Exit the program**

This command is an alternative form of the EXIT command.

RESET **Do a hardware reset**

This command does an EVB hardware reset to the reset vector address in the 68HC16 device.

```
>RESET         Reset hardware.
```

SHOWF3 add **Set F3 window memory display**

This command is an alternative form of the MDF3 command.

SHOWF6 add **Set F6 window memory display**

This command is an alternative form of the MDF6 command.

SIGNLATCH n **Set sign latch to n**

n New value (0 or 1) for sign latch.

This command gives the specified value to the sign latch CPU resource.

```
>SIGNLATCH 1
```
Set sign latch value to 1.

SOURCE **Toggle code display**

This command toggles the display in the debug window between source code and disassembled code. A valid map file must be loaded for this command to work.

```
>SOURCE
```
Toggle debug window display to source code (or to disassembled code).

SOURCEPATH **Search for code in another directory**

This command starts a search for source code not in the current directory. The system prompts for the DOS path.

```
>SOURCEPATH
```
Search for code in another directory.

ST [n] **Do single-step trace**

n The number of steps to trace.

This command starts single-step tracing from the IP value for **n** number of steps. The default **n** value is 1. The processor does not run at full execution speed during an ST command.

```
>ST 10
```
Trace through 16 single steps.

```
>ST
```
Trace through 1 single step.

STEP [n] **Do single-step trace**

This command is an alternative form of the ST command.

STEPFOR **Do single-step trace until breakpoint**

This command begins continuous single-step tracing from the IP value. This single-stepping continues until it arrives at a breakpoint, until there is an error condition, or until the user presses a key. The processor does not run at full execution speed during a STEPFOR command.

```
>STEPFOR
```
Single-step trace from IP until breakpoint.

STEPTIL add **Do single-step until add**

add The trace stopping address or label.

This command starts single-step tracing from the IP value to the specified address or label. To stop such tracing, press any key.

```
>STEPTIL sub1
```
*Single-step trace from IP to label **sub1**.*

SYMBOL chars val **Add symbol to loaded map file**

chars ASCII characters of the new symbol label.

val The new symbol value.

This command adds the specified label to the symbol table, giving it the specified value. The symbol table contains as many as 30 user-defined labels.

`>SYMBOL start 200` *Defines the label **start** = $200.*

T [n] **Do single-step trace**

This command is an alternative form of the ST command.

TRACE [add] [add] **Execute trace**

add First parameter: execution starting address or label; second parameter: breakpoint address or label.

This command starts and stops tracing according to the specified add parameters:

- If the command has two parameter values, the system sets a new breakpoint at the second address or label, then traces code from the first address or label. Tracing continues until it arrives at a breakpoint (which could be the one just set) or until the user presses a key.
- If the command has one parameter value, the system traces code from that address or label until it arrives at an existing breakpoint, or until the user presses a key.
- If the command has no parameter values, the system traces code from the IP value until it arrives at an existing breakpoint, or until the user presses a key.

This command fills the trace buffer, so does not execute in real time.

`>TRACE 200 1050`	*Start code trace at address $200; break at address $1050.*
`>TRACE 1050`	*Start code trace at address $1050.*
`>TRACE start`	*Start code trace at label **start**.*
`>TRACE`	*Start code trace at IP value.*

VERIFY **Compare file to memory**

This command compares contents of a file with contents of EBV16 memory. When you enter the VERIFY command, the system prompts for a file name. If the file is not in the current directory, enter the entire DOS path. The compare action ends when the system finds a difference between contents, or at the end of the file.

```
>VERIFY          Verify contents of file and memory.
```

WATCHDOG **Disable watchdog timer**

This command disables the watchdog timer. This action may be taken only once, following a hardware reset. (A reset enables the watchdog timer.)

```
>WATCHDOG        Disable watchdog timer.
```

WHEREIS symbol **Show symbol value**

symbol Label or address.

This command echoes a specified label and displays its address. Alternatively, this command echoes a specified address and displays the label at that address.

```
>WHEREIS start   Show address of label start.
start = 200      System echoes label and shows address.

>WHEREIS 200     Show label at address $200.
start = 200      System echoes address and shows label.
```

3.6 SOURCE-LEVEL DEBUGGING

Loading a map file into the EVB via the LOADALL or LOADMAP command enables source-level debugging. If the IP points to a code location, the code that appears in the code window is your actual source code. (If no map file is loaded, or if the IP points outside source code, the code window shows disassembled code.)

MASM16 creates map files during assembly, as Chapter 4 explains.

The code window does not permit editing, but does let you set and remove breakpoints. The PC and IP values are highlighted in the code window. To maneuver within the code window, use the keys or key combinations of Table 3-4. (Hold down the ALT key to see a list of code-window commands at the bottom of the screen. When you release the ALT key, the bottom line reverts to its normal display.)

Note that you may set breakpoints in any module. (In this context, *module* means your main MASM16 source code or any include file.)

Even if the module in the code window has no breakpoints, the breakpoints remain active in other modules. If a break occurs in another such module, the module at breakpoint replaces the current module in the display.

NOTES

When appropriate, source-code debugging automatically reverts to symbolic disassembly. Typically, this is because the code displayed is not in the map file. Code in pseudo ROM from another source is an example.

If you use ASM, PMM, or another command to modify code memory, the code window does not reflect your changes in source mode. The code window does show your changes in disassembly mode.

Table 3-4. Code Window Commands

Keys(1)	Meaning
Alt—B	Sets a breakpoint at the highlighted line or removes a breakpoint from the highlighted line (like the BR command)
Alt—F	Prompts for and finds a search string
Alt—G	Executes code until the highlighted line (like GOTIL command, but the highlighted line functions as the cursor)
Alt—I	Sets the IP to the location of the highlighted line
Alt—L	Finds the next occurrence after Alt—F
Alt—M	Lists available source-code modules (press the carriage return or ESC to select one)
arrow keys	Scroll through code window or maneuver cursor in code window
<CR>	Selects a source-code module (from list displayed via the Alt—M keys)
<ESC>	Cancels a request for a source-file module
(1) Hold down the ALT key to see a list of code-window commands at the bottom of the screen. When you release the ALT key, the bottom line reverts to its normal display.	

3.7 TRACE BUFFER

The trace buffer is a software function of EVB16. There is no hardware trace capability in the board.

To turn on the trace function, enter the trace command:

>TRACE *Enable tracing.*

During tracing, the processor actually single-steps. All screen refreshes are disabled, so tracing happens as rapidly as possible. The only information requested from the CPU between steps is the PC value. This information is stored in a circular, 1024K buffer in EVB16.

To view the trace, press the **F7** key. The code-window display changes, to show a disassembly of the addresses in the trace buffer. Use the arrow keys to scroll through the buffer.

NOTES

The trace buffer shows disassembled code, not source code, using labels whenever possible.

Tracing through self-modifying code does not work properly, as the trace shows disassembly of the *current* memory contents.

CHAPTER 4
MASM16 OPERATING PROCEDURE

4.1 INTRODUCTION

This chapter covers MASM16, the user-interface shell to the EVB macro assembler. The assembler translates assembly-language source statements into object code. The assembler also assigns storage locations to instructions and data, and verifies programs' syntactical correctness.

For complete details of the assembler, see the separate user's manual, *ToolWare™ M68HC16 Macro Assembler User's Manual for MS-DOS, M68HCASM/D2.*

In this chapter, **<CR>** indicates the ENTER, RETURN, or carriage-return key of your keyboard.

4.1.1 System Requirements

Your system must run under MS-DOS or PC-DOS on an IBM PC, XT, AT, or compatible computer, and must have at least *640* K bytes of system memory. To print from within MASM16, use the standard DOS printer port.

4.1.2 System Overview

MASM16 is an integrated environment for writing, editing, assembling, and debugging source code. Write source-code statements in assembly language, a symbolic language of:

- Instruction, directive, and register mnemonics
- User-defined memory labels and macros
- Numbers (binary, octal, decimal, or hexadecimal notation)
- Special-purpose characters

MASM16 lets you convert the source code into three kinds of output files:

- *Object files* — machine language for the target processor. An object file has the same name as the source file, but with the file extension .S19.
- *Listing files* — copies of input text with machine-code, addresses, and other such annotations.
- *Map files* — files used by simulators, user interfaces, and other such software. Starting assembly via the MASM16 shell always creates a map file.

To control MASM16 functionality, you press hotkeys, make selections from various menus, and enter assembler directives.

When assembly begins, MASM16 in DOS memory swaps itself into EMS memory or to disk as a temporary file. This makes the most RAM possible available for assembling your program. In addition to creating object, listing, and map files, assembly includes creating files MASM16.ERR, which holds errors and warnings, and MASM16.CMD, which holds the DOS string that invokes the assembler.

At the end of successful assembly, MASM16 swaps itself back to DOS memory and deletes the temporary files.

NOTE

If no EMS or disk memory is available, you cannot shell to either the assembler or the EVB16 debugger. To use either, you must leave MASM16, then invoke the assembler or the debugger from the DOS prompt.

4.1.3 Getting Started

For the environment to work properly, four files must reside in your working directory or on your DOS path:

- **MASM16.EXE** — the main file; the number 16 corresponds with the M68HC16 cross assembler type.
- **MASM16.HLP** — the on-screen help file; needed only if you plan to use the built-in help system.
- **MASM.EXE** — the M68HC16 assembler.
- **HEX.EXE** — the S-record generator (creates .S19 files to be loaded into the EVB16 debugger).

To start the MASM16 environment, bringing up the editing screen, type the command line:

```
>MASM16 <filename>
```

where <filename> is an optional file name to be loaded into the editor immediately. Note that the editor gives all file names the default extension .ASM. If you do not enter a file name, the editor starts with the blank file NONAME.ASM; when you later save this file, the editor prompts for a name change.

The top line of the editing screen is the prompt line. The prompt line displays commands being executed and asks for user responses. Immediately below the prompt line are status indications for the file being edited: file name, cursor position, and mode indications. (Paragraph 4.6.1 explains these status indications.)

The first control level for MASM16 functions are the hotkeys (explained in paragraph 4.2). Hotkey labels are at the bottom of the editing screen. The first time you start MASM16, default control options apply; these defaults are appropriate for a tutorial test assembly program. To set defaults for an actual program, follow the guidance of paragraph 4.4.

4.2 HOTKEYS

Hotkey labels appear at the bottom of the editing screen, the first screen that appears when you activate MASM16. Table 4-1 explains the functions of these keys.

Table 4-1. MASM16 Hotkeys

Key	Name	Description
F1	Help	Brings up the help system.
F2	Save	Saves the file currently in the editor, makes a backup file, and returns the cursor to its position before you pressed this key.
F3	Load	Loads a new file. If you have changed the current file, prompts you to save the file, then asks for the name of the file to be loaded.
F4	Assemble	Assembles the file currently in the editor; any options chosen from the menu system will be in effect. (This hotkey function is the same as the **Assemble** submenu selection. Only one window may be open during assembly.)
Shift F4(1)	——	Invokes the EVB16 debugger.
F5	Exit	Ends the editing–assembling session. You may save any changes to the current file before returning to DOS. If more than one window is open, this key closes the current window.
F7	Error	Positions the cursor at the line containing the next error the assembler found in the current file.
Shift F7(1)	-----	Positions the cursor at the line containing the previous error the assembler found in the current file.
F9	DOS shell	Puts you into DOS. (Typing EXIT at the DOS prompt returns you to MASM16.)
F10	Menu	Brings up the menu system on the bottom line of the screen.
(1) Hold down the Shift key and press the F4 or F7 key. (The screen does not show these hotkey combinations.)		

4.3 MENU SYSTEM

To activate the menu system, press the F10 hotkey; selections appear at the bottom of the screen. To choose a menu item, highlight it via the cursor keys, then press <CR>. Alternatively, type the highlighted letter of the item (for example, E in Edit).

Choosing a menu item that has a submenu brings up the submenu. Choose a submenu item in the same way you choose a menu item. Press <CR> to toggle between two selection values. For selections that require a string or other keyboard entry, be sure to press <CR> at the end of the entry.

To go back to a previous menu or return to the editor, press the ESC key one or more times.

Note that you must exit the menu system before entering any input text.

Table 4-2. MASM16 Menus

Menu	Submenu	Choice
Edit	(none)	Leaves the menu system, returning you to the editor.
File	**L**oad	Loads a new file. If you have changed the current file, prompts you to save the file, then asks for the name of the file to be loaded. (Same as hotkey F3.)
	Save	Saves the file currently in the editor, makes a backup file, and returns the cursor to its position before you selected Save. (Same as hotkey F2.)
	Debug	Invokes EVB16. (Same as hotkey Shift:F4.)

Table 4-2. MASM16 Menus (continued)

Menu	Submenu	Choice
File (continued)	**F**iles	Shows the directory listing of all files that fit a specific pattern. (The user enters the pattern at the prompt, or accepts the default pattern of the prompt by pressing <CR>. The original default pattern is *.asm, which specifies all files of the current directory that have the extension .ASM.) To load a file from the listing, position the cursor on the filename and press <CR>.
	Quit	Exits MASM16 or the current window. (Same as hotkey F5.)
Assemble	**A**ssemble	Assembles the file currently in the editor; any options chosen from the menu system will be in effect. (Same as hotkey F4. Only one window may be open during assembly.)
	Object	Toggles between ON and OFF, indicating whether to create an object (.S19) file during assembly. (Creating an object file increases assembly time.)
	Listing	Toggles between ON and OFF, indicating whether to create a listing (.LST) file during assembly. (Creating a listing file increases assembly time.)
	X reference	Toggles between ON and OFF, indicating whether to create a cross-reference list of variables used.
	Symbols	Toggles between ON and OFF, indicating whether to create a symbol table.
	Header list	Toggles between ON and OFF, indicating whether to put a header on the listing file.
	Direct page	Toggles between ON and OFF, indicating whether to allow direct page addressing.
	Base default	Toggles between 10 and 16, indicating the default number base.

Table 4-2. MASM16 Menus (continued)

Menu	Submenu	Choice
Options	**C**hip	Specifies the target chip.
	Listing file	Specifies the path and name of the listing file.
	Object file	Specifies the path and name of the object file.
	Error limit	Limits to **n** the number of errors before assembly stops, where **n** is 1...999.
	Header	Specifies contents for a listing-file header.
	Path to MASM	Specifies the DOS directory that contains the MASM assembler and the HEX.EXE file.
	Debugger cmd	Specifies the command string to run the debugger. The string must include the path and must end with the printer port the debugger uses. Example: *EVB16 1*
	Save options	Saves selections of the **Assemble** and **Options** menus.
Help	(none)	Brings up the help menu. (Same as hotkey F1.)

4.4 SETTING OPTIONS

Assembly control options govern which output files the assembler creates, as well as the appearance of such files.

To set options, press the F10 hotkey to bring up the menu system. Then, select choices from the **Assemble** and **Options** menus. To make current option values apply to subsequent files, as well as a file assembled immediately, select Save options, from the **Options** menu.

From the **Assemble** menu, select values for these options:

- **O**bject — Set the ON value to create a .S19 object file.(You must enter a path and object file name, via the Object file option.) To assemble without creating an object file (for example, to error-check the file), set the OFF value.
- **L**isting — Set the ON value to create a listing file. (You must enter a path and listing file name, via the Listing file option.) To assemble without creating a listing file, set the OFF value.
- **X** reference — Set the ON value to create a cross-reference list of variables uses. To assemble without creating this list, set the OFF value.
- **S**ymbols — Set the ON value to create a symbol table. To assemble without creating this table, set the OFF value.
- **H**eader list — Set the ON value to print a header on the listing file. (You must set the Listing option to ON; you must specify header contents, via the Header option.) To assemble without putting a header on any listing file, set the OFF value.
- **D**irect page — Set the ON value for direct page-addressing mode. To assemble without this mode, set the OFF value.
- **B**ase default — Set the 16 value for hexadecimal default number base. Set the 10 value for decimal default number base.

From the **Options** menu, select values for these options:

- **L**isting file — Specify the path and name of the listing file if the Listing option is set to ON.
- **O**bject file — Specify the path and name of the object file if the Object option is set to ON.
- **E**rror limit — Enter the maximum number of errors, 1...999, the assembler will detect before it halts assembly.
- **H**eader — Specify header contents if the Listing and Header list options are set to ON.
- **P**ath to MASM — Specify the name of the DOS directory that contains files MASM.EXE and HEX.EXE.
- **D**ebugger cmd — Specify the path, filename, and parameters of the debugger (such as, "EVB16").
- **S**ave options — Select this option to save the current values, that is, to make them apply to subsequent files as well as to a file assembled immediately.

The file MASM16.CON is the storage location for option values you save, so it should be in the current directory when you execute MASM16. If this file is not in that same directory, MASM16 defaults to standard values.

4.5 HELP

To bring up the MASM16 help system, press the F1 key from within the editor or press the H key from the menu system.

The initial help window shows a list of topics. Use the arrow keys to highlight a topic, then press <CR>; the help information appears. For example, select INSTRUCTION SET to see the full list of factory opcode mnemonics.

A **PgDn** indicator at the bottom of the window means that there are two or more pages of help information on the topic. Use the page-down and page-up keys to scroll through the information.

Press the ESC key one or more times to step out of the help system.

4.6 EDITOR

The editor lets you type in text via the keyboard. New text starts at the cursor position. The editor includes several block commands, for moving and copying text; several delete commands, for correcting mistakes; and find and find-and-replace commands, for changing text. In many cases you can undo your last several commands via the restore line command.

Paragraphs 4.6.1 through 4.6.8 explain the various editor commands.

4.6.1 The Editing Screen

The top line of the editing screen is a prompt line. This line displays messages, instructions, and responses to prompts. When you enter a two-key command, the editor echoes the first key at the left edge of the prompt line.

Below the prompt line is the edit window. The top line of the edit window is a status line. Table 4-3 lists status-line information.

Table 4-3. Edit Window Status Line Information

Item	Role or Description
FILENAME.EXT	Name and extension of the file being edited. (You may specify full path names to the editor, but this item shows only name and extension.)
Line n	File line-number position of the cursor.
Col n	File column-number position of the cursor.
Byte n	Byte-number position of the cursor, relative to the first character in the file.
Insert	Indicates that the editor is in insert mode (as opposed to overwrite mode).
Indent	Indicates that the editor is in auto-indent mode.
Tab	Indicates that the editor is using fixed tab stops.
Save	Indicates that the file has been modified since it last was saved.

4.6.2 Prompt Editor

Most editor user-response prompts include default responses. To accept a default response, press <CR>. To enter a specific response on the prompt line, use the prompt editor. *The prompt editor has the same commands as the full assembler editor, plus:*

- Accept entry – <CR> or <CTRL>M
- Abort – ESC
- Insert control character – <CTRL>P

4.6.3 Tabs

The editor has two kinds of tabs:

- **Smart tabs** — The default tabs, these tabs echo the appearance of the preceding line. The first character of any non-space sequence acts as a tab stop for the next line. The smart-tab mode usually is the easiest tab mode for entering source code.
- **Fixed tabs** — The stops for fixed tabs are column 9 and every 8th successive column.

To change from one tab type to the other, enter the <CTRL>QT command. For either smart or fixed tabs, the editor automatically translates tabs to spaces. When a file is read into the editor, all tabs are expanded to the default settings.

4.6.4 Window Commands

As many as five windows may be open at any time. But during assembly, only one window may be open and this window must contain the file to be assembled.

Use the ALT key to access window commands. When you hold down the ALT key, the help line at the bottom of the display shows the command options. Table 4-4 explains the window commands.

Table 4-4. Editor Window Commands

Command	Keys	Description
Next window	ALT-F1	Makes the next text window the current editing window.
Previous window	ALT-F2	Makes the previous text window the current editing window.
Add window	ALT-F3	Opens another text window and prompts for a file to edit. If you do not specify a file, the editor creates the file NONAME.ASM, which you may save later as a named file. If 5 windows already are open, an error message appears. If the active window is too small to divide in half (to make room for the new window), an error message appears.
Resize window	ALT-F4	Lets you change the size of the current window via the up- and down-arrow keys. To return to the editor, press <CR>.
Close window	ALT-X	If two or more windows are open, closes the current window. If one window is open, closes the window and leaves MASM16.

4.6.5 Cursor Commands

There are two ways to move the screen cursor: via the cursor control keys or via control characters. Table 4-5 explains the cursor commands.

Table 4-5. Editor Cursor Commands

Command	Keys	Description
Beginning of file	<CTRL>PgUp or <CTRL>QR	Moves the cursor to the first character of the file.
Beginning of line	Home or <CTRL>QS	Moves the cursor to column 1 of the current line.
Bottom of block	<CTRL>QK	Moves the cursor to the block-end marker set via the <CTRL>KK command. This command works even if there is no block-begin marker or if the block is hidden.
Bottom of screen	<CTRL>End or <CTRL>QX	Moves the cursor to the last line on the screen.
Character left	Left arrow or <CTRL>S	Moves the cursor one character to the left.
Character right	Right arrow or <CTRL>D	Moves the cursor one character to the right.
End of file	<CTRL>PgDn or <CTRL>QC	Moves the cursor just beyond the end of the file.
End of line	End or <CTRL>QD	Moves the cursor to the end of the current line and removes trailing blanks.

Table 4-5. Editor Cursor Commands (continued)

Command	Keys	Description
Go to column	<CTRL>JC	Prompts for a column number (1—120), then moves the cursor to that column. Precede the value with + or -, to offset the target column number from the current column.
Go to line	<CTRL>JL	Prompts for a line number (1—32,767), then moves the cursor to that line. Precede the value with + or -, to offset the target line number from the current line.
Jump to marker 0 .. 9	<CTRL>Q0 .. <CTRL>Q9	Moves the cursor to one of nine previously set invisible markers.
Line down	Down arrow or <CTRL>X	Moves the cursor down one line; may scroll the screen.
Line up	Up arrow or <CTRL>E	Moves the cursor up one line; may scroll the screen.
Page down	PgDn or <CTRL>C	Moves the cursor down one page, with a single line of overlap.
Page up	PgUp or <CTRL>R	Moves the cursor up one page, with a single line of overlap.
Previous cursor position	<CTRL>QP	Moves the cursor to its previous position; very useful after a save, find, or find-and-replace.
Scroll down	<CTRL>Z	Scrolls the screen down one line. The cursor does not change lines until it hits the top of the screen.

Table 4-5. Editor Cursor Commands (continued)

Command	Keys	Description
Scroll up	<CTRL>W	Scrolls the screen up one line. The cursor does not change lines until it hits the bottom of the screen.
Set marker 0 .. 9	<CTRL>K0 .. <CTRL>K9	Sets one of nine invisible markers at the current cursor position.
Top of block	<CTRL>QB	Moves the cursor to the block-begin marker set via the <CTRL>KB command. This command works even if there is no block-end marker or if the block is hidden.
Top of screen	<CTRL>Home or <CTRL>QE	Moves the cursor to the top line on the screen.
Word left	<CTRL>Left arrow or <CTRL>E	Moves the cursor to the beginning of the word to the left; may move across a line break.
Word right	<CTRL>Right arrow or <CTRL>F	Moves the cursor to the beginning of the word to the right; may move across a line break.

4.6.6 Insert and Delete Commands

Table 4-6 explains the commands for inserting and deleting characters, words, and lines.

Table 4-6. Editor Insert and Delete Commands

Command	Keys	Description
Delete character left	Backspace or <CTRL>H	Moves the cursor left one position, deleting the character at that position. Following characters of the line also move left one position. If the cursor starts in column 1, this command joins the line to the preceding one.
Delete current character	Del or <CTRL>G	Deletes the character at the cursor position. Following characters of the line move left one position. (This command does not cross line breaks.)
Delete line	<CTRL>Y	Deletes the line containing the cursor. Following lines move up one, and the cursor moves to column 1 of the next line. (A line deleted via this command cannot be restored.)
Delete to end of line	<CTRL>QY	Deletes all characters from the cursor position to the end of the line.
Delete word	<CTRL>T	Deletes the word to the right of the cursor. This command works across line breaks, and can be used to remove line breaks.
Insert control character	<CTRL>P	Lets you insert editor control characters in the text. For example, <CTRL>P followed by <CTRL>G inserts <CTRL>G (the bell character). The editor displays control characters as upper-case, highlighted letters. (The assembler does not accept control characters.)

Table 4-6. Editor Insert and Delete Commands (continued)

Command	Keys	Description
Insert line	<CTRL>N	Inserts a line break at the cursor position. The cursor remains at that position.
New line	Return, Enter or <CTRL>M	In insert mode, inserts a line break at the cursor position. In autoindent mode, the cursor moves to the next line, either to the column of the first non-blank character in the current line. or to column 1. In overwrite mode, the cursor moves to column 1 of the next line without inserting a new line.
Tab	Tab or <CTRL>I	In insert mode, moves the cursor and following text right to the next tab stop. In overwrite mode, moves only the cursor right to the next tab stop. The extent of movement depends on the kind of tabs (fixed or smart) in use.

4.6.7 Block Commands

A block is any defined, contiguous stream of text, from a single character, to many lines — even an entire file. To define a block, put a block-begin marker at the first character and a block-end marker after the last. Once you define a block in this way, you can move it, copy it, delete it, or write it to a file.

The editor highlights defined blocks, but you may change this display via the hide-block command. Block commands work only with non-hidden, fully defined blocks. Table 4-7 explains the block commands.

Table 4-7. Editor Block Commands

Command	Keys	Description
Begin block	<CTRL>KB	Sets the invisible block-begin marker, so you can return the cursor to the position at any time via the <CTRL>QB command. If a block-end marker already is set, this command also highlights the block.
Copy block	<CTRL>KC	Copies a marked and displayed block, placing the copy at the cursor position. Markers move to the copied block; the original block is not affected.
Delete block	<CTRL>KY	Deletes a marked and displayed block. The undo last deletion (<CTRL>QU) command usually can restore portions of a block accidentally deleted, but there is no command to restore a deleted block completely.
End block	<CTRL>KK or F8	Sets the invisible block-end marker, so you can return the cursor to the position at any time via the <CTRL>QK command. If a block-begin marker already is set, this command also highlights the block.
Hide block	<CTRL>KH	Turns highlighting on or off, for a displayed block, without affecting the markers.

Table 4-7. Editor Block Commands (continued)

Command	Keys	Description
Mark single word	<CTRL>KT	Marks as a block the word that contains the cursor or the word to the left of the cursor. (This single command puts block-begin and block-end markers around the word.)
Move block	<CTRL>KV	Moves a marked and displayed block to the cursor position. Markers remain with the block.
Print block	<CTRL>KP	Prints the selected block. To cancel this command, press the ESC key.
Read block from file	<CTRL>KR	Reads an entire file into the text stream at the current cursor position, marking the file as a block. The editor prompts for a filename; if you already have used this command, the prompt includes the previous filename. Press <CR> to accept the previous filename, change the previous filename via the backspace key, or enter a new name. The filename may include a drive or path identifiers. To cancel this command, press the ESC key.
Write block to file	<CTRL>KW	Copies a marked and displayed block to a file, without changing the block or its markers. The editor prompts for a filename; do not use the .BAK extension, which is reserved for editor backup files. If the filename exists, another prompt asks whether to overwrite the file. If you respond no (N), you can enter a new filename, change the displayed filename via the backspace key, or cancel the command via the ESC key. This command has no effect if no block is specified.

4.6.8 Miscellaneous Commands

Table 4-8 explains the remaining editor commands.

Table 4-8. Editor Miscellaneous Commands

Command	Keys	Description
Abort	ESC	Halts an operation in progress. The editor regularly checks the keyboard buffer for the abort command. If it finds one, the editor empties the buffer and stops the operation.
Exit editor	ALT-X	Exits to DOS. If an editor file has been modified, a prompt asks whether to save the file. If you respond yes, the editor saves the file before exiting to DOS.
Exit editor (automatic save)	<CTRL>KD	Exits the editor, saving the current file. If an original file exists, this command renames it FILENAME.BAK.
Find	<CTRL>QF	Searches for a string as long as 67 characters globally, backwards, within the current block, or ignoring case. See text immediately following this table for more details of the find command.
Find and replace	<CTRL>QA	Searches for a string and replaces it with another string. See text immediately following this table for more details of the find-and-replace command.
Find next	<CTRL>L	Repeats the last find or find-and-replace command.

Table 4-8. Editor Miscellaneous Commands (continued)

Command	Keys	Description
Restore line	<CTRL>QL	Undoes any changes to the line that contains the cursor. If the cursor has left the line, this command does not work.
Save to file	<CTRL>KN	Prompts for a file name, then saves the file in the current window to the specified file. This becomes the new file in the current window. (This is particularly useful for NONAME.ASM files.)
Set undo limit	<CTRL>JU	Sets the size of the undo buffer, which stores deleted lines. The default value is 40 lines.
Show version	<CTRL>JV	Displays the current version of the assembler.
Toggle autoindent	<CTRL>QI	Enables or disables autoindent. When autoindent is enabled, <CR> or <CTRL>M jumps to the next line, to the column of the first non-blank character of the current line. *Indent* shows on the status line.
Toggle fixed tabs	<CTRL>QT	Enables fixed tabs or smart tabs. When fixed tabs are enabled, *Tab* shows on the status line.

Table 4-8. Editor Miscellaneous Commands (continued)

Command	Keys	Description
Toggle insert mode	Insert or <CTRL>V	Enables insert mode or overwrite mode. In insert mode, existing text moves right as new text is entered, and *Insert* shows in the status line. In overwrite mode, new text replaces existing text.
Undo last deletion	<CTRL>QU	Restores lines deleted via the delete or delete-line command. This command does not restore single characters or words. (To undo changes to the current line, use the restore-line command. To specify the size of the undo buffer, use the set-undo-limit command.)

4.6.8.1 The Find Command

The find command, as well as the find-and-replace command, needs additional explanation.

When you enter the find command, the status line clears and a prompt asks for the search string (as long as 67 characters). If you have used this command before, the prompt includes the most recent search string. To select the same search string, press <CR>. To edit or replace the search string, use these commands:

Backspace Deletes the character to the left

<CTRL>R Restores the previous string

<CTRL>S Moves cursor left

<CTRL>D Moves cursor right

ESC Cancels the command

<CTRL>P Enters a control character

After you enter the search string, a prompt asks for options. (The editor displays any options of the most recent search; you may use them again or edit them.) Search options are:

B Backwards search from cursor position

G Global search from start of file (or from end of file for a backwards search)

L Search only currently marked block

U Treat all characters as upper case

When you specify options, the search begins. If a matching pattern is found, the cursor appears at the end of the pattern.

4.6.8.2 The Find-and-Replace Command

This command is similar to the find command. However, after you specify the search string, this command prompts for a replacement string. Like the search string, the replacement string may be as long as 67 characters. The prompt includes the replacement string (if any) from a previous use of this command. You may accept, edit, or replace the replacement string, just as you can the search string.

After you specify the search and replacement strings, the option prompt appears. All the find-command options are available, plus one more:

N Replace without a prompt

When you specify options, the search begins. If the search finds a matching pattern and the N option is not in effect, a prompt requests confirmation that you want the replacement. Respond **Y** (replace), **N** (skip), or **A** (replace this and all subsequent matches without prompts).

If you specify the N option, replacement of the search string happens without any confirmation prompts. The screen does not update until all file updates are done.

To abort a find-and-replace operation, press Q or ESC.

4.7 ASSEMBLER

The assembler assembles the file currently in the editor. The assembler produces object or listing files according to the control option values. The assembler always produces map files, when invoked via MASM16. The source file uses factory standard mnemonics. See the environment's help screens for a list of acceptable mnemonics.

A source program is a sequence of assembly-language statements. Each source statement occupies one line, and can be a blank, a comment, an executable instruction, an assembler directive, a macro definition, or a macro call. A source statement contains as many as four fields, in this order:

```
label    operation operand ;comment
```

Paragraphs 4.7.1 through 4.7.4 explains these fields.

4.7.1 Labels

Labels identify memory locations in program or memory areas of the assembly module. You may define labels for all instructions; you also may define labels for directives that allocate and optionally initialize data. Labels have values, usually that of the location counter for the instruction or directive. If a label memory location is in a relocatable section, the label value is relative to that program section; otherwise, the label value is absolute.

A label, if present, must start in column 1. A label consists of one or more characters, provided it fits on one line. A label must start with a letter (either upper or lower case) or an underscore. The second and subsequent characters may be letters, digits, dollar signs, periods, or underscores. You may add a colon to the end of a label, but this is optional; a space suffices.

Examples of labels are:

```
Label:
ThisIsALabel:
Loop_1
```

NOTE

In addition to user-defined labels, the assembler recognizes external labels and reserved register identifiers. For more information, see the assembler user's manual.

4.7.2 Operations

An operation is an instruction mnemonic, a directive name, or a macro mnemonic. An instruction mnemonic is a standard factory opcode. A directive is an instruction to the assembler, not something to be translated into object code. (Paragraph 4.7.5 gives more information about directives.) A macro mnemonic is a user-defined identifier.

If present, an operation may not begin in column 1. If the operation follows a label, a space must separate the label and the operation.

4.7.3 Operands

Operands are numeric constants, ASCII literals, or absolute symbols, as defined by the opcode. If present, an operand must follow an operation; a space must separate the operation and the operand.

An operand may even be an expression containing arithmetic, logic, or shift operators. The assembler evaluates such an expression during assembly.

Operands may *not* contain embedded spaces.

4.7.3.1 Constants

Numeric constants may be in any of four bases. Qualifier prefixes for binary, octal, decimal, and hexadecimal are %, @, !, and $, respectively. For example, %10010111 = @227 = !151 = $97.

The default base is decimal: if you enter a number value without a prefix, the assembler treats it as decimal. (A command-line option lets you make the default base hexadecimal.)

To use one or more ASCII characters as a constant, enclose them in single or double quotes.

4.7.3.2 Operators

During assembly, the assembler evaluates expressions containing any of these operators:

+	addition
-	subtraction or unary minus
*	multiplication
/	division (truncated integer result)
!^	exponentiation
>> or !>	right shift
<< or !<	left shift
& or !.	logical and
! or !+	logical or
!x or !X	logical exclusive or
~	ones complement
PAGE	lower 4 bits of operand are page number
<	force byte value
>	force word value

The assembler evaluates expressions, using this order of precedence:

- unary minus
- shift
- and, or
- exponentiation
- multiplication, division
- addition, subtraction

For operators of equal precedence, the assembler evaluates expressions from left to right. Use parentheses to change the order of evaluation, if necessary.

4.7.4 Comments

Comments in a program clarify program flow and the purpose of statements. Except for including comments in the assembly listing, the assembler ignores comments. A semicolon (;) delineates comments, which may start in any column and go until the end of the line. An asterisk (*) or semicolon in column 1 makes the entire line a comment.

4.7.5 Assembler Directives

Directives are instructions to the assembler, not statements to be translated into object code. Table 4-9 lists these directives. Note from the syntax that directives may not start in column 1 (labels must start in column 1).

For complete information, see the *ToolWare™ M68HC16 Macro Assembler User's Manual for MS-DOS, M68HCASM/D2.*

Table 4-9. Assembler Directives

Class	Directive	Syntax and Function
Assembly Control	EVEN	EVEN Forces the instruction or data allocation to the next even address.
	INCLUDE	INCLUDE <*file spec*> Inserts the specified file in the source input stream.
	ORG (Origin)	ORG <*expression*> Fills the object file to the location counter <*expression*> specifies.
	END	END Terminates assembly by indicating the end of source code.
Label Definition	EQU (Equate)	<*label*> EQU <*expression*> Assigns the <*expression*> value to the <*label*> exclusively.
	SET	<*label*> SET <*expression*> Assigns the <*expression*> value to the <*label*>, but permits redefinition of the <*label*> by subsequent SET directives in the program.

Table 4-9. Assembler Directives (continued)

Class	Directive	Syntax and Function
Data Definition or Allocation	DC (Define Constant)	[<*label*>] DC[.<*size*>] <*expression*>[,<*expression*>] Defines a constant in a memory block for each <*expression*>. Each <*expression*> can be a value or a symbol or expression the assembler evaluates. Values for <*size*> are B, W, or L (byte, word, or longword); B is the default.
	DCB (Define Constant Block)	[<*label*>] DCB[.<*size*>] <*count*>,<*value*> Allocates one or more memory blocks, initialized with <*value*>. Values for <*size*> are B, W, or L (byte, word, or longword); B is the default. Value of <*count*> must be greater than zero; <*count*> times <*size*> determines the block length.
	DS (Define Storage)	[<*label*>] DS[.<*size*>] <*count*> Reserves memory locations without initializing them. Values for <*size*> are B, W, or L (byte, word, or longword); B is the default. Value of <*count*> must be greater than zero; <*count*> times <*size*> determines the number of locations reserved.
	BSZ (Block Set to Zero)	[<*label*>] BSZ <*count*> Allocates a block of memory <*count*> bytes long, set to zero.
	FCB (Form Constant Byte)	[<*label*>] FCB <*expression*>[,<*expression*>] Defines a byte constant in a memory block for each <*expression*>. Each <*expression*> can be a value or a symbol or expression the assembler evaluates. (Equivalent to the DC.B directive.)
	FCC (Form Character String Constant)	[<*label*>] FCC <*string*> Allocates and initializes a byte for each character of <*string*>. (Equivalent to the DC.B directive with an ASCII string operand.)

Table 4-9. Assembler Directives (continued)

Class	Directive	Syntax and Function
Data Definition or Allocation (continued)	FDB (Form Double Byte)	[<*label*>] FDB <*expression*>[,<*expression*>] Defines a word constant in a memory block for each <*expression*>. Each <*expression*> can be a value or a symbol or expression the assembler evaluates. (Equivalent to the DC.W directive.)
	RMB (Reserve Memory Bytes)	[<*label*>] RMB <*count*> Allocates a block of memory <*count*> bytes long. (Equivalent to the DS.B directive.)
Listing Control	FAIL (Programmer Generated Error)	FAIL [<*arg*>|<*string*>] With no <*arg*> value, aborts the assembly. If the <*arg*> value is less than 500, the assembler issues the <*string*> message with the directive line number, then completes assembly without writing an object file. Otherwise, the assembler issues the <*string*> message with the directive line number, then aborts the assembly.
	LIST	LIST Prints the assembly listing (until an END or NOLIST directive).
	NOLIST	NOLIST or NOL Suppresses printing the assembly listing (until a LIST directive).
	SPC (Space Between Lines)	SPC <*count*> Inserts <*count*> blank lines in the assembly listing.
	TTL (Provide Title in Listing)	TTL <*title*> Prints the <*title*> at the start of the listing file. If used, this directive must be the first source-code line. A title is a character string enclosed in quotes (").
	PAGE	PAGE Advances to the top of the next page.

Table 4-9. Assembler Directives (continued)

Class	Directive	Syntax and Function
Listing Control (continued)	NOPAGE (Suppress Pagination)	NOPAGE Lists program lines continuously, without headings or top or bottom margins.
	LLEN (Line Length)	LLEN <*n*> Sets the number of characters per line to <*n*>. The maximum value of <*n*>, 132, also is the default value.
	PLEN (Page Length)	PLEN <*n*> Sets the number of lines per page to <*n*>. The maximum value of <*n*>, 65, also is the default value.
	TABS (Tab Stop Multiple)	TABS <*n*> Sets to <*n*> the tab stop multiple (the number of spaces between tab stops). The default value of <*n*> is 8.

4.7.6 Include

When the assembler encounters the INCLUDE directive, it takes source code from the specified file. This continues until the end of the specified file or until the assembler encounters another INCLUDE directive. If the assembler reaches the end of the specified file, it continues taking source code from the file that contained the INCLUDE directive.

The file specification must be in quotes (single or double). If the file is not in the current directory, the specification must be a full path name.

An example of an INCLUDE directive is:

```
INCLUDE "..\equates\register.h"
```

4.7.7 Macros

The assembler supports macros: named sets of instructions. If a source-code statement contains a macro name in the operation field, the assembler invokes the macro. This means that the assembler generates source-code statements, then assembles these statements.

A macro can include conditionally assembled instructions. A macro can include variable operands; each time such a macro is used in a file, it has different parameter values.

A simple macro definition is:

```
SAVE1       MACRO
            LDX    SAVET
            LDAA   \1
            STAA   0,X      SAVE 1ST ARGUMENT
            LDAA   \2
            STAA   1,X      SAVE 2ND ARGUMENT
            LDAA   \3
            STAA   2,X      SAVE 3RD ARGUMENT
            ENDM
```

A calling statement for this macro is:

```
SAVE1 ARG1,ARG2,ARG3
```

For more information on defining and using macros, see the *ToolWare™ M68HC16 Macro Assembler User's Manual for MS-DOS, M68HCASM/D2.*

4.7.8 Conditional Assembly

The assembler lets you specify blocks of source code to be assembled according to the values of one or two specified expressions. This is conditional assembly.

The assembler evaluates a single expression by comparing its value to zero. If the value relates to zero in the way the conditional-assembly instruction specifies, assembly of the block of source code takes place. Otherwise, the assembler skips over the block of source code.

A simple example of such conditional assembly is:

```
IFEQ  FLAG1           ;IF FLAG1 = 0
      LDD #1          ;LOAD ERROR INDICATOR 1
      STD ERROR1      ;STORE IN ERROR1
ENDC                  ;END CONDITIONAL ASSEMBLY
```

The assembler evaluates two string expressions by seeing if the strings match. If the string expressions match, assembly of the block of source code takes place. Otherwise, the assembler skips over the block of source code.

For more information on conditional assembly, see the *ToolWare™ M68HC16 Macro Assembler User's Manual for MS-DOS, M68HCASM/D2.*

CHAPTER 5
FUNCTIONAL DESCRIPTION

5.1 INTRODUCTION

This chapter is an overall description of the EVB, including a block diagram (Figure 5-1) of circuits. This chapter also includes a memory map diagram (Figure 5-2).

5.2 EVB DESCRIPTION

The EVB uses its resident MC68HC16Z1 MCU to evaluate operation of a user-developed circuit based on an M068H016Z1 MCU. The EVB16 software package allows modification of user memory and execution of user programs.

Figure 5-1 is a block diagram of EVB functionality. The EVB has these functional circuits:

- MCU and control
- User memory
- Host computer I/O port
- Logic analyzer pods
- Data conversion circuitry

5.2.1 MCU and Control Circuits

The EVB contains a resident MC68HC16Z1 MCU and associated control circuits, which provide the capabilities for evaluating user-developed circuits and software routines.

Figure 5-1 shows the specific control circuits implemented into the EVB:

- Memory configuration
- Logic analyzer
- Data conversion

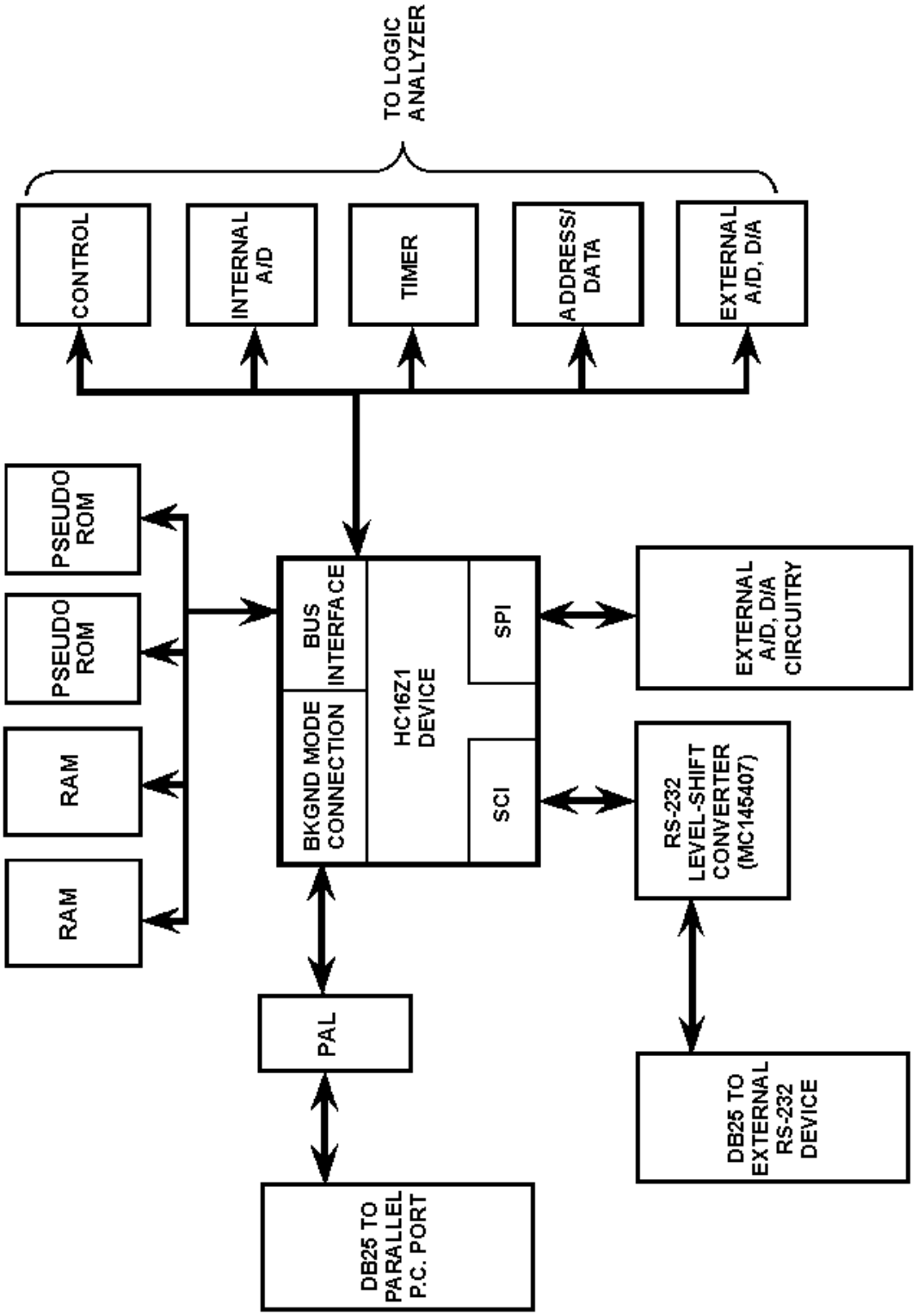


Figure 5-1. HC16Z1EVB Block Diagram

5.2.2 User Memory

Figure 5-2 shows the user map areas: MCU I/O ports, MCU internal registers, and user RAM. The shaded areas of the memory map are not available to the user. The exception vectors *must* remain in the block 00000-001 FF. Also note that the ADC, GPT, SIM, standby RAM, and OSM *must* remain at their factory-configured locations.

The five-digit memory addresses of Figure 5-2 are consistent with addresses that appear in EVB1 6 screen windows. Note that these five digits correspond to 20 of the total 24 intermodule bus (1MB) address lines. The MC68HC16Z1 technical summary (document BR754/D) explains extended addressing (from 20 to 24 bits), and gives additional information about the memory map.

User program space either is pseudo ROM (RAM) or is configured for ROM (EPROM). All programs must be ROMable to protect against program errors that otherwise would overwrite the program space.

As shipped from the factory, the EVB contains RAM in board locations U2 and U4. These devices are 32K x 8, configured as 32K x 16.

NOTE

RAM space at board locations U2 and U4 is pseudo ROM, controlled by the CSBOOT chip select lines. Motorola recommends using these devices for program storage only.

EVB internal RAM is byte accessible, so you may use it for stack and temporary locations.

Table 2-2 explains the different ways to access memory devices.

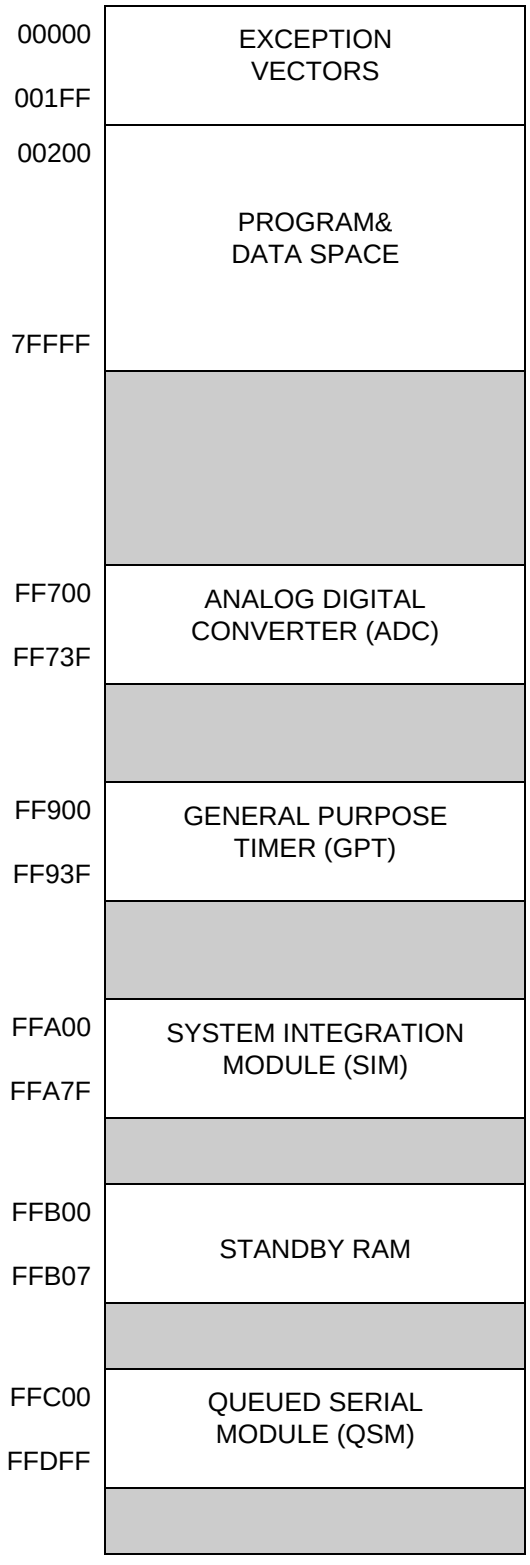


Figure 5-2. HC16Z1 Memory Map

5.2.3 Terminal I/O Port

The terminal I/O port (connector P1O) connects to the on-chip SCI port via an MC145407 level translation device. To use this connector, refer to the HC16Z1 technical summary or user's manual for proper setup of baud rates and data terminals.

CHAPTER 6
SUPPORT INFORMATION

6.1 INTRODUCTION

The tables of this chapter describe EVB connector signals.

6.2 CONNECTOR SIGNAL DESCRIPTIONS

Connectors P1 through P7 connect a logic analyzer to the EVB. Connector P8 connects external power to the EVB.

The EVB has two RS-232C I/O ports (connectors P9 and P10) to connect the EVB to a host computer.

Tables 6-1 through 6-10 list pin assignments for these connectors:

Table 6-1. Logic analyzer connector P1

Table 6-2. Logic analyzer connector P2

Table 6-3. Logic analyzer connector P3

Table 6-4. Logic analyzer connector P4

Table 6-5. Logic analyzer connector P5

Table 6-6. Logic analyzer connector P6

Table 6-7. Logic analyzer connector P7

Table 6-8. Input power connector P8

Table 6-9. PC printer port connector P9

Table 6-10. User interface port connector P10

Table 6-11. D/A conversion power connector P11

The tables identify connector signals by pin number, signal mnemonic, and signal name and description.

Table 6-1. Logic Analyzer Connector P1 Pin Assignments

Pin Number	Signal Mnemonic	Signal Name and Description
1	+5V	+5 VDC POWER - Input voltage (+5 Vdc @ 1.0 A) used by the EVB logic circuits.
2	SPARE	No connection
3	DSACK1	DATA AND SIZE ACKNOWLEDGE 1 - Active-low input signal that allows asynchronous data transfers and dynamic bus sizing between the MCU and external devices.
4—19	A15—A0	ADDRESSES (Bits 15—0) - Three-state output address bus.
20	GND	GROUND

Table 6-2. Logic Analyzer Connector P2 Pin Assignments

Pin Number	Signal Mnemonic	Signal Name and Description
1	+5V	+5 VDC POWER - Input voltage (+5 Vdc @ 1.0 A) used by the EVB logic circuits.
2	SPARE	No connection
3	AS	ADDRESS STROBE - Active-low output signal that indicates whether a valid address is on the address bus.
4—19	D15—D0	DATA BUS (Bits 15—0) - Buffered bi-directional data bus lines.
20	GND	GROUND

Table 6-3. Logic Analyzer Connector P3 Pin Assignments

Pin Number	Signal Mnemonic	Signal Name and Description
1, 2	SPARE	No connection
3	DSACK0	DATA AND SIZE ACKNOWLEDGE 0 - Active-low input signal that allows asynchronous data transfers and dynamic bus sizing between the MCU and external devices.
4	AVEC	AUTOVECTOR - Active-low input signal that requests an automatic vector during an interrupt acknowledge cycle.
5	HALT	HALT - Active-low input/output signal that suspends external bus activity for single-step operation or, used with the BERR signal, to request a retry.
6	AS	ADDRESS STROBE - Active-low output signal that indicates whether a valid address is on the address bus.
7	DS	DATA STROBE - Active-low output signal. During a read cycle, indicates that an external device should place valid data on the data bus. During a write cycle, indicates that valid data is on the data bus.
8	BR/ CS0	BUS REQUEST - Active-low input signal that indicates an external device request for bus mastership. CHIP SELECT 0 - Output signal that selects peripheral or memory devices at programmed addresses.
9	BG/ CS1	BUS GRANT - Active-low output signal that indicates completion of the current bus cycle and MCU relinquishment of the bus. CHIP SELECT 1 - Output signal that selects peripheral or memory devices at programmed addresses.

Table 6-3. Logic Analyzer Connector P3 Pin Assignments (continued)

Pin Number	Signal Mnemonic	Signal Name and Description
10	CSBOOT	BOOT CHIP SELECT - Active-low output chip select.
11	CLKOUT	SYSTEM CLOCK OUTPUT - MCU internal clock output signal.
12—16	A23/CS10, A22/CS9, A21/CS8, A20/CS7, A19/CS6	ADDRESS BUS 23—19 - Five bits of the 24-bit address bus. CHIP SELECTS 10—6 - Output signals that enable peripheral devices at programmed addresses.
17—19	A18—A16	ADDRESS BUS 18—16 - Three bits of the 24-bit address bus.
20	GND	GROUND

Table 6-4. Logic Analyzer Connector P4 Pin Assignments

Pin Number	Signal Mnemonic	Signal Name and Description
1—4	SPARE	No connection
5	TSTME/	TEST MODE ENABLE - Hardware enable for test mode; an active-low input signal.
	TSC	THREE STATE CONTROL - When 10 volts (twice the VDD), this input signal forces all output drivers to a high impedance state.
6	RESET	RESET - Active-low system reset signal.
7	RXD	RECEIVE DATA - Serial data input line.
8	PCLK	AUXILIARY TIMER CLOCK INPUT - External input clock source for the general purpose timer (GPT).
9	PWMB	PULSE WIDTH MODULATION B - Repetitive output signal; the CPU can control the high-time/low-time ratio of this signal.
10	PWMA	PULSE WIDTH MODULATION A - Repetitive output signal; the CPU can control the high-time/low-time ratio of this signal.
11	PAI	PULSE ACCUMULATOR INPUT - Input signal that increments an 8-bit counter.
12	IC4/	INPUT CAPTURE 4 - Programmable input signal that latches the contents of the GPT timer counter into the input capture register TI405 when a selected edge occurs at the pin.
	OC5	OUTPUT COMPARE 5 - Programmable output signal generated when the GPT timer counter and the TI405 comparator register contain the same value.

Table 6-4. Logic Analyzer Connector P4 Pin Assignments (continued)

Pin Number	Signal Mnemonic	Signal Name and Description
13—16	OC4—OC1	OUTPUT COMPARE 4—1 - Selected-edge output signals generated when the GPT timer counter and the TOC4—TOC1 comparator registers contain the same values.
17—19	IC3—IC1	INPUT CAPTURE 3—1 - Input signals that latch the contents of the GPT timer counter into input capture registers TIC3—TIC1 when a selected edge occurs at a pin.
20	GND	GROUND

Table 6-5. Logic Analyzer Connector P5 Pin Assignments

Pin Number	Signal Mnemonic	Signal Name and Description
1	+5V	+5 VDC POWER - Input voltage (+5 Vdc @ 1.0 A) used by the EVB logic circuits.
2	SPARE	No connection
3	CLKOUT	SYSTEM CLOCK OUT - Output signal that is the MCU internal system clock.
4	BERR	BUS ERROR - Active-low signal that indicates the attempt of an erroneous bus operation.
5	BKPT/ DSCLK	BREAKPOINT - Active-low input signal that puts the CPU16 in background debug mode. DEVELOPMENT SYSTEM CLOCK - Serial input clock for background debug mode.
6	FREEZE	FREEZE - Signal that indicates CPU breakpoint acknowledgement or background mode entry.
7, 8	IPIPE0, IPIPE1 LATCHED	INSTRUCTION PIPE 0, 1 LATCHED - Active-low, latched output signals that track movement of words through the instruction pipeline.
9, 10	IPIPE0, 1, DSO, DSI	INSTRUCTION PIPE 0, 1, DEVELOPMENT SERIAL OUT, IN - Serial data output and input signals for background debug mode.
11, 12	DSACK1, DSACK0	DATA AND SIZE ACKNOWLEDGE 1, 0 - Active-low input signals that allow asynchronous data transfers and dynamic bus sizing between the MCU and external devices.

Table 6-5. Logic Analyzer Connector P5 Pin Assignments (continued)

Pin Number	Signal Mnemonic	Signal Name and Description
13—15	FC2/CS5, FC1/CS4, FC0/CS3	FUNCTION CODES 2—0 - Three-state output signals that identify the processor state and address space of the current bus cycle. CHIP SELECTS 5—3 - Output signals that select peripheral or memory devices at programmed addresses.
16, 17	SIZ1, SIZ0	TRANSFER SIZE - Active-high output signals that indicate the number of bytes still to be transferred during this cycle.
18	R/W	READ/WRITE - Active-high output signal that indicates the direction of data transfer on the bus.
19	BGACK/ CS2	BUS GRANT ACKNOWLEDGE - Active-low input signal that indicates that an external device has assumed control of the bus. CHIP SELECT 2 - Output signal that selects peripheral or memory devices at programmed addresses.
20	GND	GROUND

Table 6-6. Logic Analyzer Connector P6 Pin Assignments

Pin Number	Signal Mnemonic	Signal Name and Description
1	+5V	+5 VDC POWER - Input voltage (+5 Vdc @ 1.0 A) used by the EVB logic circuits.
2	SPARE	No connection
3	DS	DATA STROBE - Active-low output signal. During a read cycle, indicates that an external device should place valid data on the data bus. During a write cycle, indicates that valid data is on the data bus.
4	MODCK	CLOCK MODE SELECT - Active-high input signal that selects the source of the internal system clock.
5—11	IRQ1—IRQ7	TARGET INTERRUPT REQUEST 1—7 - Active-low input signals from the target that asynchronously apply MCU interrupts. IRQ1 has the lowest priority, IRQ7 has the highest.
12	TXD	TRANSMIT DATA - Serial data output line.
13	PSC0/ SS	PERIPHERAL CHIP SELECT 0 - Active-low output QSPI peripheral chip select signal. SLAVE SELECT - Bi-directional, active-low signal that puts the QSPI in slave mode.
14—16	PSC1—PSC3	PERIPHERAL CHIP SELECT 1—3 - Active-low output peripheral chip select signals.
17	SCK	QSPI SERIAL CLOCK - In master mode, the clock signal from the QSPI; in slave mode the clock signal to the QSPI.

Table 6-6. Logic Analyzer Connector P6 Pin Assignments (continued)

Pin Number	Signal Mnemonic	Signal Name and Description
18	MISO	MASTER-IN, SLAVE-OUT - In master mode, serial input to the QSPI; in slave mode, serial output from the QSPI.
19	MOSI	MASTER-OUT, SLAVE-IN - In master mode, serial output from the QSPI; in slave mode, serial input to the QSPI.
20	GND	GROUND

Table 6-7. Logic Analyzer Connector P7 Pin Assignments

Pin Number	Signal Mnemonic	Signal Name and Description
1	+10V	+10 VOLTS - Power supplied from the MC145407 device: total power for RS-232 port plus wire-wrap use. (Per data sheet, typical supply is 9 Vdc at 10 ma.)
2	-10V	-10 VOLTS - Power supplied from the MC145407 device: total power for RS-232 port plus wire-wrap use. (Per data sheet, typical supply is -8.6 Vdc at 10 ma.)
3	VRHP	VOLTAGE REFERENCE HIGH - Input reference supply voltage (high) line.
4	VLRP	VOLTAGE REFERENCE LOW - Input reference supply voltage (low) line.
5—12	AD7—AD0	ANALOG INPUTS 7—0 - Analog input lines to the HC16 device.
13—15, 17, 18	SPARE	No connection
16	DAC1OUT	D/A OUTPUT 1 - Analog output of the D/A converter of the PCM56P (U12).
19, 20	AGND	ANALOG GROUND

Table 6-8. Input Power Connector P8 Pin Assignments

Pin Number	Signal Mnemonic	Signal Name and Description
1	GND	GROUND
2	+5V	+5 VDC POWER - Input voltage (+5 Vdc @ 1.0 A) used by the EVB logic circuits.

Table 6-9. PC Printer Port Connector P9 Pin Assignments

Pin Number	Signal Mnemonic	Signal Name and Description
1	-----	Not used
2—9	DATA0—DATA7	DATA 0—7 - Signals that transmit data to be printed.
10	ACK	ACKNOWLEDGE - Active-low signal, to the computer, that the printer received the data.
11	BUSY	BUSY - Signal to the computer that the printer is busy.
12	PE	PAPER END - Ground from the EVB board.
13	SLCT	SELECT - VCC or +5 Vdc power from the EVB board.
14—17	-----	Not used
18—25	GND	GROUND

Table 6-10. User Interface Port Connector P10 Pin Assignments

Pin Number	Signal Mnemonic	Signal Name and Description
1, 7	GND	GROUND
2	TXD	TRANSMIT DATA - Serial data output line.
3	RXD	RECEIVE DATA - Serial data input line.
4, 9—19, 21—25	-----	No connection
5	CTS	CLEAR TO SEND - Output signal that indicates ready-to-transfer data status.
6	DSR	DATA SET READY - Output signal (held high) that indicates on-line/in-service/active status.
8	DCD	DATA CARRIER DETECT - Output signal (held high) that indicates detection of an acceptable carrier signal.
20	DTR	DATA TERMINAL READY - Output line that indicates on-line/in-service/active status.

Table 6-11. D/A Conversion Power Connector P11 Pin Assignments

Pin Number	Signal Mnemonic	Signal Name and Description
1	GND	GROUND
2	-7V	-8 to -15 VDC POWER - Input voltage for optional D/A conversion.

APPENDIX A
S-RECORD INFORMATION

A.1 INTRODUCTION

The S-record format *for* output modules encodes programs or data files in a printable format for transportation between computer Systems. This facilitates S-record editing and permits visual monitoring of the transportation process

A.2 S-RECORD CONTENT

S-records are character strings of five fields: record type, record length memory address, *code/data,* and checksum Each byte of binary data is encoded as a two-character hexadecimal number: the first character represents the high- order four bits, and the second character represents the low- order four bits of the byte.

The diagram below shows the S-record layout. Table A-1 shows the composition of each field

TYPE	RECORD LENGTH	ADDRESS	CODE/DATA	CHECKSUM

There are three possible terminators for an S-record: CR, LF, and NULL. Additionally, an S-record may have an optional initial field to accommodate such other data as line numbers generated by sometime-sharing systems An S-record file is a normal ASCII text file in the operating system in which it resides.

The record length (byte count) and checksum fields ensure accuracy of transmission.

Table A-1. S-Record Field Composition

Field	Printable Characters	Contents
Type	2	S-record type SC, S1 etc.
Record length	2	Number of character pairs in the record, excluding type and record length pairs.
Address	4,6, or S	The %, 3-, or 4-byte address at which the data field is to be loaded into memory.
Code/data	O—n	From C to n bytes of executable code, memory-loadable data, or descriptive information. For compatibility with teletypewriters, some programs may limit the number of bytes to as few as 28 (of 56 printable characters in the S-record)
Checksum	2	The least significant byte of the one's complement of the sum of the values represented by the pairs of characters making up the records length, address, and the code/data fields.

A.3 S-RECORD TYPES

There are eight types of S-records] to accommodate the various needs of the encoding, transportation and decoding functions The various Motorola upload] download and other record transportation control programs, as well as cross assemblers, linkers and other file-creating or debugging programs, use only the S-record types that serve the purpose of the program For specific information on which S-records a particular program supports, consult the user manual for that program EVB1 S supports the S-record types listed in Table A-2.

Table A-2. S-Record Types

Type	Description
SO	The header record for each block of S-records The code/data field may contain any descriptive information identifying the following block of S-records. The address field is normally zeros.
S1	A record containing code/data and the 2-byte address at which the code/data is to reside.
82	A record containing code/data and the S-byte address at which the code/data is to reside.
83	A record containing code/data and the 4-byte address at which the code/data is to reside
SI	A termination record for a block of 53 records. The address field may optionally contain the 4-byte address of the instruction to which control is to be passed There is no code/data field
SS	A termination record for a block of S2 records The address field may optionally contain the 3-byte address of the instruction to which control is to be passed There is no code/data field.
59	A termination record for a block of S1 records The address field may optionally contain the 2-byte address of the instruction to which control is to be passed If such an address is not specified, the first entry point specification encountered in the object module input will be used. There is no code/data field.

There is only one termination record for each block of S-records. The usual reason to use S7 or S8 records is when control is to be passed to a 3- or 4-byte address. Normally, there is only one header record, although multiple header records are possible.

A.4 S-RECORD CREATION

Several dump utilities, debuggers. linkage editors, cross assemblers, or cross linkers may produce S-record format programs. Several programs are available for downloading a file in S-record format from a host system to a microprocessor-based system.

A.5 S-RECORD EXAMPLE

The following example shows how a typical S-record format module is printed or displayed. The module consists of one S0, four S1, and one S9 records.

```
S00600004844521B
S1130000285F245F2212226A000424290008237C2A
S11300100002000800082629001853812341001813
S113002041E900084E42234300182342000824A952
S113003000144ED492
S9030000FC
```

The S0 record consists of these character pairs:

S0	Type indicator SO, identifying a header record.
06	Hexadecimal value 06, indicating that six character pairs (or ASCII bytes) follow.
00 00	Four-character 2-byte address field; zeros
48 44 52	ASCII H, D, and R — "HDR"
1B	Checksum of the SO record

The explanation of the first S1 code/data record is:

S1	S-record type S1, indicating a code/data record to be loaded/verified at a 2-byte address.
13	Hexadecimal 13, indicating that 19 character pairs, - representing 19 bytes of binary data, follow.
00 00	Four-character, 2-byte. address field; hexadecimal address C00C, where the following data is to be loaded.

The next 16 character pairs of the first S1 record are the ASCII bytes of the actual program code/data.

2A The checksum of the first S1 record.

The second and third S1 records each also contain $13 (19) character pairs. These records end with checksums 13 and 52, respectively. The fourth S1 record contains 07 character pairs and has a checksum of 92.

The explanation of the S9 termination record is:

S9 S-record type S9, indicating that it is a termination record.

03 Hexadecimal 03, indicating that three character pairs (3 bytes) follow.

00 The address field, zeros.
00

FC Checksum of the 89 record.

Each printable character in an S-record is encoded in a hexadecimal representation (ASCII in this example) of the binary bits actually transmitted. For example, below is a diagram of the first S1 record described above.

TYPE				LENGTH				ADDRESS								CODE/DATA										CHECKSUM			
S		1		1		3		0		0		0		0		2		8		5		F		•••		2		A	
5	3	3	1	3	1	3	3	3	0	3	0	3	0	3	0	3	2	3	8	3	5	4	6	•••		3	2	4	1
0101	0011	0011	0001	0011	0001	0011	0011	0011	0000	0011	0000	0011	0000	0011	0000	0011	0010	0011	1000	0011	0101	0100	0110	•••		0011	0010	0100	0001