ICE-88™ IN-CIRCUIT EMULATOR OPERATING INSTRUCTIONS FOR ISIS-II USERS

Manual Order Number 9800949-01

i	iSBC	Multimodule
ICE	Library Manager	PROMPT
iCS	MCS	Promware
Insite	Megachassis	RMX
Intel	Micromap	UPI
Intellec	Multibus	μScope

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PREFACE

This document describes the purpose and the use of the ICE-88 In-Circuit Emulator for the Intel 8088 microprocessor.

The ICE-88 module is an optional addition to the Intellec Microcomputer Development System. The ICE-88 module aids in testing and modification of the hardware and software for new products designed around the 8088 microprocessor.

Chapter 1 describes the mission of the ICE-88 emulator as a developmental aid for system designs based on Intel's 8088 microprocessor.

Chapter 2 gives step-by-step instructions for installing the ICE-88 hardware in the Intellec chassis and connecting the ICE-88 emulator to the user prototype system.

Chapter 3 presents a hands-on debugging session with the ICE-88 emulator.

Chapter 4 describes the elements of the ICE-88 emulator command language, and the notations, conventions, and syntactic rules used in this manual.

Chapter 5 defines the operands, operators, and expressions used in the ICE-88 commands.

Chapter 6 contains discussions and specifications of the emulation and trace control commands.

Chapter 7 contains discussions and specifications of the interrogation and utility commands.

Chapter 8 contains discussions and specifications of the compound and macro commands used in ICE-88 emulator operation.

Appendix A is a list of all the ICE-88 emulator keywords (literals), and their abbreviations, in alphabetical order.

Appendix B is a list of ICE-88 emulator error and warning messages with interpretations.

Appendix C contains a syntactic summary of the ICE-88 emulator commands.

Appendix D presents the electrical and physical characteristics of the ICE-88 emulator.

Appendix E presents the 8088 assembler instructions in hexadecimal order.

To use this manual effectively, you need to understand the 8086/8088 architecture and the technique of programming and debugging. The following publications contain detailed information related to this manual:

ISIS-II User's Guide	9800306
8080/8085 Assembly Language Programming Manual	9800301
ISIS-II 8080/8085 Macro Assembler Operator's Manual	9800292
MCS-86™ Assembly Language Reference Manual	9800640
MCS-86™ Assembler Operating Instructions for ISIS-II Users	9800641
MCS-86™ User's Manual	9800722
PL/M-86 Programming Manual	9800466
PL/M-86 Operator's Manual	9800478
MCS-86™ Software Development Utilities Operating for ISIS-II Users	9800639
Intellec® Microcomputer Development Systems Hardware Reference Manual	9800132
Intellec® Microcomputer Development Systems Operator's Manual	9800129
Intellec® Series II Hardware Reference Manual	9800556
Intellec® Series II Installation and Service Manual	9800559
A Guide to Intellec® Microcomputer Development Systems	9800565

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CHAPTER 1 INTRODUCTION

This manual presents the operation of the ICE-88 In-Circuit Emulator for the Intel 8088 microprocessor. As an introduction to the use of this microprocessor design aid, this chapter contains a brief discussion of integrated hardware/software development, in-circuit emulation, and the ICE-88 architecture. Also, a generalized development cycle with the ICE-88 emulator and a generalized emulation session are presented.

ICE-88 In-Circuit Emulator

The ICE-88 module provides in-circuit emulation for 8088 microprocessor-based systems. Figure 1-1 shows the functional block diagram of the 8088 CPU. The ICE-88 module consists of three circuit boards which reside in the Intellec Microcomputer Development System. A cable and buffer box connect the Intellec system to the user system by replacing the user's 8088. In this manner the Intellec debug functions are extended into the user system. Using the ICE-88 module, the designer can execute prototype software in continuous or single-step mode and can substitute Intellec equivalents for user devices, such as memory.

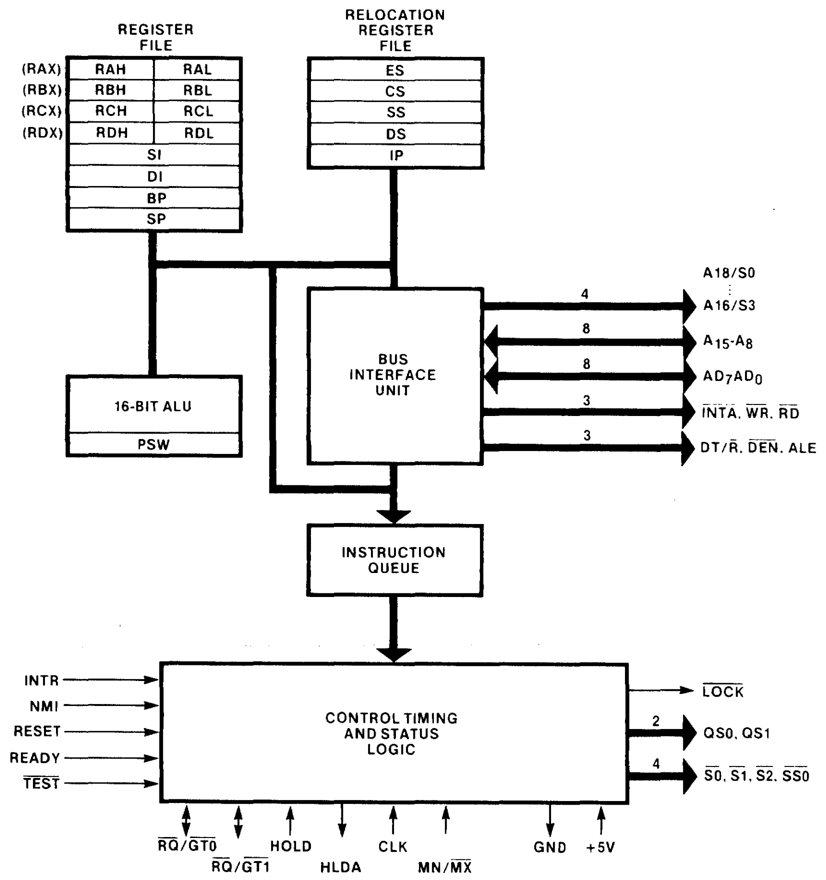


Figure 1-1. 8088 CPU Functional Block Diagram

Integrated Hardware/Software Development

The ICE-88 emulator allows hardware and software development to proceed concurrently. This is more effective than the traditional method of independent hardware and software development followed by a system integration phase. With the ICE-88 emulator, prototype hardware can be added to the system as it is designed. The software and hardware can be used to test each other as the product is developed.

Conceptually, the ICE-88 emulator can be viewed as assisting three stages of development:

1. The ICE-88 emulator can be operated without being connected to the user's system, so its debugging capabilities can be used to facilitate software development before any of the user's hardware is available.
2. To begin integration of software and hardware development efforts, the user's prototype need consist of no more than an 8088 CPU socket. Through the ICE-88 emulator's mapping capabilities, Intellec system equivalents (such as Intellec memory) can be substituted for missing prototype hardware. As each section of the user's hardware is completed, it can be added to the prototype, replacing the Intellec equivalent. Thus each section of the hardware and software can be "system" tested as it becomes available.
3. When the user's prototype is complete, it can be tested using the system software which will drive the final product. The ICE-88 emulator can be used for real time emulation of the 8088 to debug the system as a complete unit.

Thus the ICE-88 emulator provides the user with the ability to debug a prototype or production system at any stage in its development without introducing extraneous hardware or software test tools.

In-Circuit Emulation

The ICE-88 In-Circuit Emulator is a diagnostic tool that is used for testing and debugging the hardware and software of user-designed 8088 microcomputer-based systems. Such testing may begin during the early phases of user system development and may continue throughout the life cycle of the user's system.

The interface between the in-circuit emulator and the user system is implemented at the connector pins of the user system microprocessor chip. These pins carry the information that establishes the characteristics and status of the user system. The interface makes it possible for the in-circuit emulator to continually monitor user operations and to provide control of these operations. More specifically, the in-circuit emulator monitors execution of the user program and controls the conditions under which the user program execution is initiated and terminated.

User Program Execution Control

Starting and stopping execution of the user program at predefined points or conditions is an essential task of the in-circuit emulator as it is often not feasible or desirable to execute the entire user program. For example, a single routine may be executed because either other routines have not yet been coded or because a fault (bug) has been isolated to that routine.

The starting address for execution is readily established by loading a known value into the program counter of the user processor while the processor is inactive. Termination of execution is a more involved procedure which requires the in-circuit emulator to halt the processor when a predetermined multi-condition state exists at the 8088 pins. This process requires prior storage of state values within the in-circuit emulator hardware and dynamic comparison of these values with the states of specified data, address and/or status pins of the processor. The point at which the user program execution is terminated is known as the breakpoint.

A breakpoint may be specified to cause the user program to halt execution when a given memory location is addressed during a processor fetch (i.e., loaded into the 8088 execution queue). However, very often the operator is more interested in the data value of a memory location or an I/O port. In the latter cases both the type of instruction (read, write, input, or output) and the data value are prespecified and are dynamically compared with the processor pin states. It is also possible to specify "don't care" comparisons with the data pins and thereby halt execution whenever the designated type of instruction is extracted from the queue for execution.

A wide range of breakpoint conditions are possible through comparison of the processor chip states with predesignated values. The full range of breakpoint conditions that may be specified by the operator are presented in subsequent chapters.

Memory Mapping

Memory for the user system can be resident in the user system or "borrowed" from the Intellec System through the ICE-88 emulator's mapping capability.

The ICE-88 emulator allows 1 megabyte of user memory to be addressed by the 8088. This user memory space consists of 1024 1K byte segments that can be mapped in 1K blocks to:

1. Physical memory in the user's system,
2. Either of two 1K blocks of the ICE-88 emulator high speed memory,
3. Intellec expansion memory,
4. A random access diskette file.

The first 64K of Intellec RAM memory is dedicated to Intellec system software. Therefore the RAM boards within the Intellec system that are used by the ICE-88 emulator to store the user program employ effective addresses beyond the 64K byte memory accessable to Intellec system software.

Mapping consists of specifying where each "logical" memory block that the 8088 addresses will physically exist within various physical memories. During emulation the memory map is used to determine the existence and physical location of the logical memory space being referenced by the user program.

If a logical segment of addresses is not activated by associating the segment with a physical memory, the segment is "guarded." A guarded segment is logically nonexistent and any reference to the segment by the user program results in an error. Thus, the ICE-88 emulator can trap memory accesses outside the intended memory for program and data. All blocks are initially guarded following system reset and any segment may be guarded on command after its initial activation.

Mapping enables the user to allocate segments of user memory space to physical memories other than the RAM/ROM of the user system. This feature permits testing of the user program prior to installation of user memory and also provides a convenient means of executing modified code in "borrowed" memory while the bulk of user program is resident within the user system.

Symbolic Debugging

Symbols and PL/M statement numbers may be substituted for numeric values in any of the ICE-88 commands. This allows the user to make symbolic references to I/O ports, memory addresses, and data in a user program. Thus the user need not search listings for addresses of variables or program subroutines.

Symbols can be used to reference variables, procedures, program labels, and source statements. Thus a variable can be displayed or changed by referring to it by name rather than by its absolute location in memory. Using symbols for statement labels, program labels, and procedure names allows the user to set breakpoints or disassemble a section of code into its assembly mnemonics much more easily.

Furthermore, each symbol may have associated with it one of the types BYTE, WORD, INTEGER, SINTEGER (for short, 8-bit integer) or POINTER. Thus when the user examines or modifies a variable from the source program, he doesn't need to remember its type. For example, the command "!VAR" displays the value in memory of variable VAR in a format appropriate to its type, while the command "!VAR = !VAR + 1" increments the value of the variable by one.

The user symbol table generated along with the object file during a PL/M-86 compilation or by the 8086 Assembler is loaded into the ICE-88 emulator along with the user program which is to be emulated. The user may add to this symbol table any additional symbolic values for memory addresses, constants, or variables that are found to be useful during system debugging.

In addition, the ICE-88 emulator provides access to all the 8088 registers and flags through mnemonic reference. The READY, NMI, $\overline{\text{TEST}}$, HOLD, RESET, INTR, and MN/$\overline{\text{MX}}$ pins can also be read.

Display

Three basic types of data are available for display: trace data, 8088 termination conditions, and test parameters. Trace data is collected from the 8088 pins during execution of the user program. Trace data collection can be continuous or selective. Tracepoints allow the user to selectively turn trace off and on as desired during emulation. The tracepoints are stored by the ICE-88 hardware on command prior to emulation. If trace data collected exceeds the capacity of the trace buffer, the older trace data is overwritten by current data. Trace buffer pointers entered by the operator permit selection of the trace information for display.

The 8088 termination conditions are the status values of the 8088 processor that are accessable following termination of user program execution. The 8088 termination conditions include the values of registers, flags, input pins, I/O ports, status information, and the contents of the logical user memory space locations currently activated by the memory map. Some of this information is the same as that collected in the trace buffer. All 8088 termination conditions are displayed by console entry of the memory or port address or the name of the register, flag, or input pin.

Hardware resident test parameters are entered by the operator and stored within the ICE-88 emulator hardware. Such information includes breakpoints, tracepoints, the memory map, and the tracepointer used for control of trace data display. The operator displays this information to verify the correct entry or to determine the values of test parameters that were previously entered.

Software resident test parameters are entered by the operator and stored within ICE-88 software. These parameters are used to establish values that affect hardware only upon entry of other commands. For example, the symbol manipulation commands establish the relationship between the object code of the user program and symbols, statement numbers, and module names that are used by the operator to reference the user program code and data symbolically.

Operating Modes

The ICE-88 software is a development system-based program which provides the user with easy-to-use commands for defining breakpoints, initiating emulation, and interrogating and altering user status recorded during emulation. ICE-88 commands are configured with a broad range of modifiers which provide the user with maximum flexibility in describing the operation to be performed.

There are two distinct phases of operation when the ICE-88 emulator is used for debugging. The interval when the user program is being executed is referred to as the emulation phase. The interval when the operator establishes and modifies test parameters and displays (or prints) test results is the interrogation phase.

Emulation

Emulation commands to the ICE-88 emulator control the process of setting up and running an emulation of the user's program and examining the results of the emulation. Breakpoints and tracepoints enable the ICE-88 emulator to halt and provide a detailed trace in any part of the user's program. A summary of the emulation commands is shown in table 1-1.

Breakpoints. The ICE-88 emulator has two breakpoint registers which allow the user to halt emulation when a specified condition is met. The breakpoint registers may be set up as execution or non-execution breakpoints. An execution breakpoint consists of a single address which causes a break whenever the 8088 executes an instruction byte which was obtained from that address. A non-execution breakpoint causes an emulation break when a specified condition other than an instruction execution occurs. This condition can contain up to four parts:

1. A set of address values,
2. A particular status of the 8088 bus (one or more of memory or I/O read or write, instruction fetch, halt, or interrupt acknowledge),
3. A set of data values,
4. A segment register (break occurs when the register is used in an effective address calculation).

Break on a set of address values has three capabilities:

1. To break on a single address.
2. To set any number of breakpoints within a limited range (1024 bytes) of memory.
3. To break in an unlimited range. Execution is halted on any memory access to an address greater than or equal to (or less than or equal to) the breakpoint address.

An external breakpoint match output for user access is provided on the buffer, which allows synchronization of other test equipment when a break occurs.

Tracepoints. The ICE-88 emulator has two tracepoint registers which establish match conditions to conditionally start and stop trace collection. The trace information is gathered at least twice per bus cycle, first when the address signals are valid and second when the data signals are valid. Trace information is also collected each CPU cycle during which the execution queue is active.

Each trace frame contains the 20 address/data line values and detailed information on the status of the 8088. The trace memory can store up to 1023 frames, or an average of about 300 bus cycles, of trace data. The trace memory contains the last 1023 frames of trace data collected, even if this spans several separate emulations. The user has the option of displaying each frame of the trace data or displaying by instruction in actual 8086 Assembler mnemonics. The trace data can be made available after an emulation.

Table 1-1. Summary of Emulation Commands

Command	Description
GO	Initializes emulation and allows the user to specify the starting point and breakpoints. Example: GO FROM .START TILL. DELAY EXECUTED where START and DELAY are statement labels.
STEP	Allows the user to single-step through the program.
GR	Sets the GO-register to a set of one or more breakpoint conditions or causes the display of the current GO-register settings.
ENABLE/DISABLE TRACE	Turn trace data collection on or off.
TRACE	Set trace display mode to display trace data in frame or instruction format or display current trace display mode.
OLDEST	Move trace buffer pointer to top of trace buffer.
NEWEST	Move trace buffer pointer to bottom of trace buffer.
MOVE	Move trace buffer pointer forward or backwards in buffer a specified number or buffer entries.
PRINT	Display one or more entries from the trace data buffer.
CLOCK	Specify system clock as internal (8088-provided) or external (user-provided) or cause current clock setting to be displayed.
RWTIMEOUT	Allows the user to time out READ/WRITE command signals based on the time taken by the 8088 to access expansion Intellec memory or disk-based memory.
ENABLE/DISABLE RDY	Allows the user to enable or disable the user ready signal for accessing Intellec resident memory or disk memory.

Interrogation and Utility

Interrogation and utility commands give the user convenient access to detailed information about the program and the state of the 8088 which is useful in debugging hardware and software. Changes can be made in both user program memory and the state of the 8088. Commands are also provided for various utility operations such as loading and saving program files, defining symbols and macros, setting up the memory map, and returning control to ISIS-II. A summary of the basic interrogation and utility commands is shown in table 1-2.

Table 1-2. Summary of Basic Interrogation and Utility Commands

Command	Description
Memory/Register Commands	Display or change the contents of: • Memory • 8088 Registers • ICE-88 Pseudo-Registers • 8088 Status flags • 8088 Input pins • 8088 I/O ports
Memory Mapping Commands	Display, declare, set, or reset the ICE-88 memory mapping.
ASM	Disassembles the memory into 8086 assembler mnemonics.
LOAD	Fetches user symbol table and object code from the input file.
SAVE	Sends user symbol table and object code to the output file.
LIST	Sends a copy of all output (including prompts, input line echos, and error messages) to the chosen output device (e.g., disk, printer) as well as the console.
EVALUATE	Displays the value of an expression in binary, octal, decimal, hexadecimal, and ASCII.
Symbol Manipulation Commands	These commands allow the user to: Display any or all symbols, program modules, and program line numbers and their associated values (locations in memory). Set the domain (choose the particular program module) for the line numbers. Define new symbols as they are needed in debugging. Remove any or all symbols, modules, and program statements. Change the value or type of any symbol.
TYPE	Assigns or changes the type of any symbol in the symbol table.
SUFFIX/BASE	Establishes the default base for numeric values in input text/output display (binary, octal, decimal, or hexadecimal).

Macro and Compound Commands

The ICE-88 emulator allows the user to program the operation by using macros and compound commands.

A macro consists of a set of ICE-88 commands with up to ten command parameters and is typically used to perform any task that is required frequently. Commands are provided to define, display, and delete macros, to invoke macros with an optional list of arguments, and to save macros in a diskette file or to load previously created macros from a diskette file.

As an example, the following macro may be used to emulate a user program from a start address until a breakpoint is encountered, then to continue until a condition is satisfied:

```
DEFINE MACRO GO
    IP = OFFSET %0             ;DISPLACEMENT OF START ADDRESS
    CS = SEGMENT %0            ;BASE OF START ADDRESS
    REPEAT
        GO TILL %1             ;EMULATE TO BREAKPOINT
        :DISPLAY               ;INVOKE MACRO TO DISPLAY
                                 VARIABLES OF INTEREST
        UNTIL %2               ;CONTINUE UNTIL SOME CONDITION
    ENDR
EM

  :GO .START, #20 EXECUTED OR .A LEN 10T READ, !FLAG = 0
```

The last line invokes macro GO, causing emulation to begin at label START, to break whenever statement #20 is executed or any element of a 10-byte array A is read, and then to continue unless the variable FLAG has a value of zero.

Compound commands are control structures to either conditionally execute other commands (IF), or to execute other commands until some condition is met or the commands have been executed a certain number of times (COUNT, REPEAT).

For example, the following compound command is used to repeat a set of commands until a condition is met:

```
IP = OFFSET .START             ;DISPLACEMENT OF START ADDRESS
CS = SEGMENT .START            ;BASE OF START ADDRESS
REPEAT
    UNTIL IP = 1000H           ;BREAK CONDITION
    STEP                       ;SINGLE STEP
ENDR
```

In this command the condition IP = 1000H is tested every STEP. If the sequence of STEPs reaches IP = 1000H, the loop will terminate.

ICE-88 Architecture

This section contains a brief description of the software, firmware and hardware that compose the ICE-88 emulator. The information serves as an introduction to more detailed information presented in the remaining chapters of this manual.

Software

The ICE-88 software together with ISIS-II and the user program symbol table is resident within the 64K byte memory of the Intellec system. None of this space is available to user program code. User program address space mapped to the Intellec system resides in RAM boards (i.e., extended Intellec memory) whose physical addresses are above the reserved 64K byte address range.

The functions performed by the software are dependent on the ICE-88 emulator operating mode. In the interrogation mode, the software provides arithmetic and logical conversions as necessary to establish compatibility between the ICE-88 hardware and the operator. This task includes conversion of operator commands to a form usable by the firmware and the evaluation of symbolic entries as necessary to provide absolute address and data values to the hardware. The software also reconverts hardware supplied information (trace data, error codes, map data, etc.) to forms that are meaningful to the operator. In the emulation mode, the software supports the accessing of user code from the diskette. In this mode the software also terminates emulation when directed by the hardware (breakpoint) or the operator (ESCape key).

Firmware commands are hardware related commands that are sent to the ICE-88 firmware to initiate a specific action. In general, each ICE-88 (operator-entered) command is an element of higher level language that is converted to a specific series of lower level firmware commands (assuming that the command requires a hardware action). Thus, while the LOAD command merely specifies loading of a user program into user address space, the actual process requires reading of the memory map and writing of the user code into user, ICE memory, Intellec memory, or diskette memory as indicated by the map. Not only are multiple firmware commands required, but the set of firmware commands issued is dependent on the parameters included within the command.

ICE-88 Firmware

The ICE-88 firmware consists of a 12K-byte ROM-resident program that is executed by an 8080 "ICE processor" of the ICE-88 hardware. The firmware performs three major functions. During start-up or system reset, the firmware resets all hardware test parameters and performs a series of go/no-go tests to ensure proper operations of the hardware. In the interrogation mode, the firmware decodes the firmware commands and initiates the specified hardware operations, including the sequencing of data transfers to and from the software. In the emulation mode, the firmware supports user program activities that require use of Intellec resources such as the transfer of user code from diskette or extended Intellec memory.

Hardware

The ICE-88 hardware consists of five circuit boards, a buffer box assembly, and four cables. Three of the circuit boards plug into the Intellec chassis:

- FM Controller Board
- 88 Controller Board
- Trace Board

Two smaller circuit boards are housed within the buffer box assembly:

- Buffer Board 1
- Buffer Board 2

The buffer box cable assembly interconnects the user hardware and the ICE-88 emulator circuit boards within the Intellec chassis. Connection to the user system is made by this cable via the 40-pin socket that normally contains the 8088 user processor. When the ICE-88 emulator is thus connected to the user system, the functions of the user processor are assumed by an 8088 located within the buffer box assembly. The 8088 in the buffer box assembly is called the user processor within this manual. The buffer box assembly is located near the user end of this cable assembly.

X and Y cables interconnect the buffer box and two circuit boards in the Intellec chassis. The T cable provides direct connection between the 88 Controller Board and the Trace Board.

A block diagram of the ICE-88 hardware is shown in figure 1-2.

Generalized Development Cycle with ICE-88

Figure 1-3 diagrams a generalized product development cycle using the ICE-88 emulator as a design aid. The sequence of events in developing a new product using the Intellec system with the ICE-88 emulator is approximately as follows.

- Complete the specifications for the prototype hardware design, software control logic, and integrated system performance.
- Organize both the hardware and software designs into logical blocks that are readily understandable, have well-defined inputs and outputs, and are easy to test. Breaking down the design is an interactive process, but is extremely valuable in reducing the time required for prototyping, programming, testing, and modification.

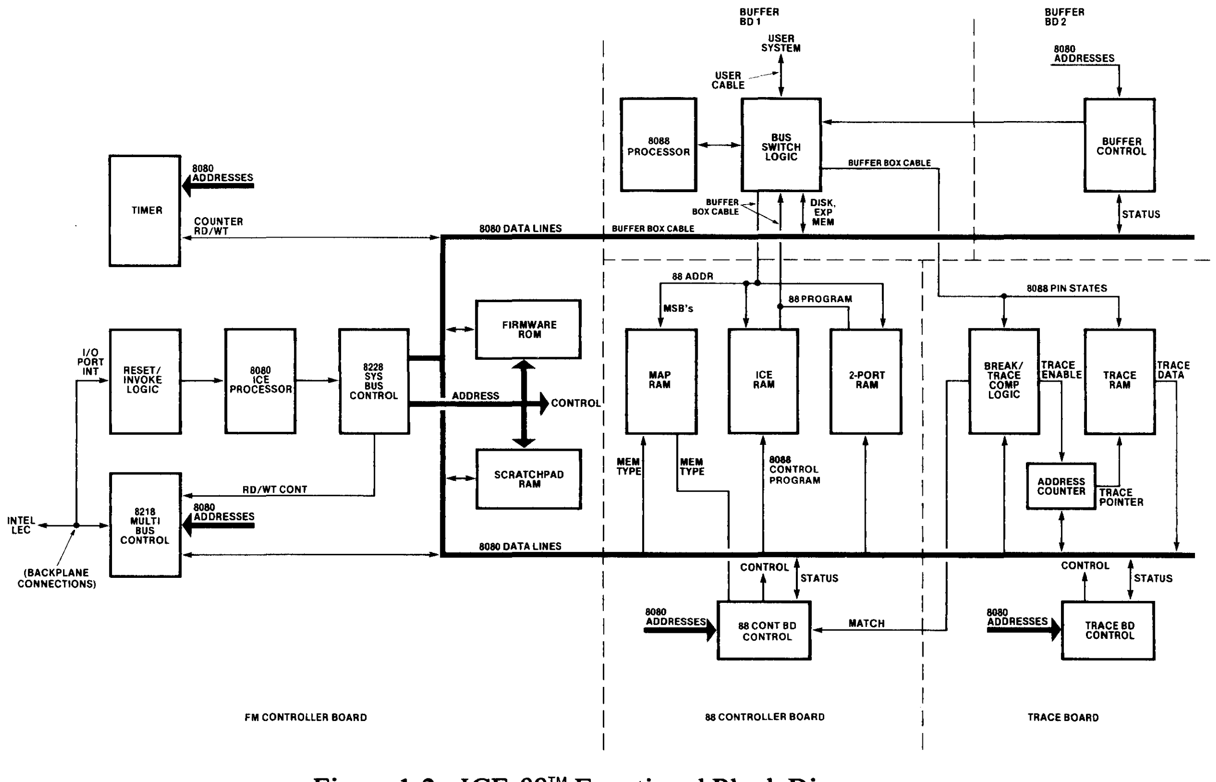


Figure 1-2. ICE-88™ Functional Block Diagram

- Program the software modules in PL/M-86 and/or in ASM-86 assembly language, naming and storing the programmed modules as files under ISIS-II. Compile or assemble the modules, linking and loading the combinations you are ready to test, creating an object-code (machine language) version. Desk-check each module as it is completed.
- As software modules are ready for testing, load them into ICE, Intellec system or diskette and emulate them via the ICE processor, using the ICE-88 emulator in the 'software' mode. The ICE-88 system allows you to use ICE-supplied memory as part of the "prototype" system. The advantages of this feature to software development include:
  1. You do not have to be concerned about overflowing your prototype system memory in the initial stages of software development. You have the freedom to test the program and compact it later without having to make room for extra memory in your prototype.
  2. You may test your program in RAM memory, and make patches quickly and easily without having to erase and reprogram PROM memory. In later test phases, the ICE module can control program execution from PROM or ROM in your prototype. The ICE module can map RAM memory to ICE- supplied memory to replace prototype memory in set increments to test out software changes before reprogramming.
- As software modules pass initial stages of check-out, they can be loaded in the 2K of ICE-88 memory for emulation and testing in "real-time."
- Hardware prototyping can begin with just a 8088 CPU socket. Through ICE-88 emulator mapping capabilities, ICE-supplied equivalents can be substituted for missing prototype hardware. As each module of the user's hardware becomes available, it can be added to the prototype, replacing the ICE-supplied equivalent. In this way, modules of software and hardware can be system-tested as they become available.
- You can use memory in ICE-supplied systems to check the interaction of prototype hardware and proven software. The ability to map memory is helpful in isolating system problems. You can exercise all prototype memory from a program residing initially ICE-supplied memory, and reassign memory block-by-block to the user's system as code is verified. Hardware failures can then be isolated quickly, because interactions between prototype parts occur only at your command. You do not have to use the prototype to debug itself.
- The debugging/testing process can proceed through each hardware and software module, using ICE-88 commands to control execution and check that each module gets data or control information from the correct locations, and places correct data or other signals in the proper cells or output locations for subsequent modules to use.

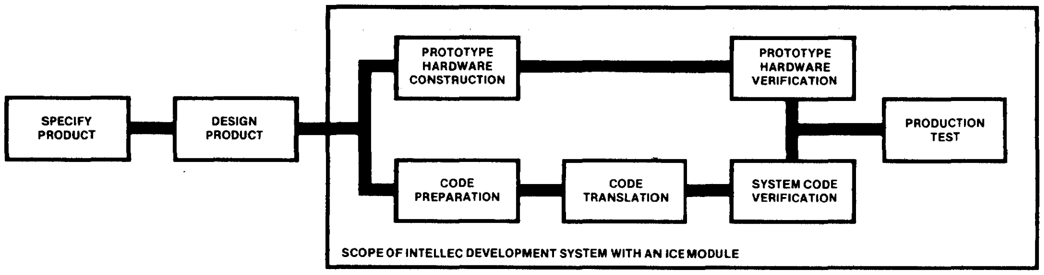

SPECIFY PRODUCT
DESIGN PRODUCT
PROTOTYPE HARDWARE CONSTRUCTION
PROTOTYPE HARDWARE VERIFICATION
PRODUCTION TEST
CODE PREPARATION
CODE TRANSLATION
SYSTEM CODE VERIFICATION
SCOPE OF INTELLEC DEVELOPMENT SYSTEM WITH AN ICE MODULE

Figure 1-3. Typical Development Cycle with ICE™ Module

- Eventually, you test all hardware and software together. The program can reside in RAM or PROM in your system, or in RAM in Intellec systems. All other hardware can be in the prototype. The ICE-88 emulator connected to the system through the microprocessor socket can emulate, test, and trace all the operations of the system.
- After the prototype has been completely tested, the ICE-88 emulator can be used to verify the product in production test. The test procedures you developed for the final prototype testing can serve as the basis for production test routines, running the program from metal-masked ROM in the production system.

A Generalized Emulation Session

This section describes the main steps in an emulation session. You may not always perform all the procedures given here in every emulation session, but the main outline is the same in all sessions. The discussion emphasizes some of the features of the ICE-88 emulator that have not been presented earlier. For the details of the command language, see Chapters 4 through 8.

1. Install the ICE-88 hardware in the Intellec chassis (see Chapter 2).
2. If you are using any prototype hardware, remove socket protector and attach the cable that connects the user hardware to the ICE-88 circuit boards to the prototype via the 40-pin socket. Otherwise leave socket protector attached to the cable.
3. Boot the system, and obtain the hyphen prompt from the ISIS-II system. Enter the ICE-88 command, and obtain the asterisk prompt from the ICE-88 emulator.
4. From the software to be tested, determine how many memory addresses in the Intellec system are required to perform the current emulation. For example, if your program presently uses 3K of memory but your prototype has only 1K installed, you need to "borrow" 2K of memory from the ICE-88 emulator.

   ICE-88 system memory is available from three sources: 2K of "real-time" ICE memory, extended Intellec RAM memory, and diskette memory. This memory is available for user program mapping and is organized in blocks of 1K (1024) bytes of contiguous memory. 1024 such blocks are logically available; the amount that is physically available depends upon what you have installed in the Intellec system.

   The ICE memory provides you with 2K of RAM memory that enables you to run object code at approximately real-time speed.

   Intellec memory is capable of providing 960 1K blocks of logical address space. The Intellec system software occupies the lowest 64K of Intellec RAM memory. Therefore, any Intellec memory available to the user programs must be mapped to addresses above 64K (extended Intellec memory). The amount of Intellec memory physically available is dependent upon the number of card slots available in the Intellec system and the memory physically installed. (Do not use 016 memory boards.) If diskette memory is used, the full range of 1024 blocks of logical memory is available to the user program up to the size of the diskette.

   Typically, your program occupies logical locations in low memory. If you intend to use Intellec memory for this emulation, you must map the memory space used by your program into extended Intellec memory. The ICE-88 emulator stores the mapping in its memory map, and refers each memory reference in your program to the proper physical location in Intellec memory.

For example, suppose your code requires absolute addresses 0000H to 0FFFH (the H means hexadecimal radix), or 4096 contiguous locations beginning at location 0; the lowest address in memory. To map these addresses into the beginning of extended Intellec memory, the mapping command would be:

```
MAP INTELLEC = 64 LENGTH 62
```

This command declares that 62K of RAM memory is physically available in extended Intellec memory starting at the lower boundary of extended memory.

```
MAP 0 LENGTH 4 = INTELLEC
```

This command maps the logical memory required by your program to the address space in lower Intellec extended memory.

5. Load your program from diskette into the memory locations you have mapped, using the LOAD command.
6. The ICE-88 emulator has three modes of operation: interrogation, continuous emulation, and single-step emulation. The asterisk prompt signals that the ICE-88 emulator is in the interrogation mode, ready to accept any command.
7. In the interrogation mode, prepare the system for emulation by defining symbols and setting emulation breakpoints and tracepoints.

   ICE-88 software provides keywords for all 8088 registers and flags. In addition, you may use symbols to refer to memory locations and contents. The user symbol table is generated along with the object file during PL/M compilation or ASM assembly. This table can be loaded into Intellec memory when the user program is loaded.

   You are encouraged to add to this symbol table any additional symbolic values for memory addresses, constants, or variables that you may find useful during system debugging. Symbols may be substituted for numeric values in any of the ICE-88 commands.

   Symbolic reference is a great advantage to the designer. You do not need to recall or look up the addresses of key locations in your program, as they change with each assembly; you can use meaningful symbols from your source program instead. This facility is especially valuable for high-level language debugging. You can completely debug a program written in PL/M by referencing symbols defined in the source code. You do not need to become involved with the machine level code generated by the compiler. For example, the command:

   ```
   GO FROM .START TILL .RSLT WRITTEN
   ```

   begins real-time emulation of the program at the address referenced by the label START in the designer's PL/M-86 program. The command also specifies that the program is to break emulation when the 8088 microprocessor writes to the memory location referenced by RSLT. You do not have to be concerned with the physical locations of START and RSLT. The ICE-88 software supplies them automatically from information stored in the symbol table.
8. Enter a GO command to begin real-time emulation. The ICE-88 emulator uses a pseudo-register called the GO-register to contain the halting conditions that you have specified, either in the GO command or previously.
9. When emulation halts, you display the trace data collected during that emulation. The ICE-88 emulator loads trace data into a trace buffer. Using ICE-88 commands, you can position the trace buffer pointer to the information that you desire to review, and display one, several, or all the entries in the buffer. You can set the display mode to one frame per line or one instruction per line of display.

10. To control emulation more precisely and to obtain more detailed trace data than with continuous emulation, you can command the ICE-88 emulator to execute single-step emulation. After each step emulated, you can display the current entry in the trace buffer and the current settings of the 8088 registers and pins.
11. You can examine and change memory locations, 8088 registers and flags, and I/O ports, to provide you with valuable information on program operation. You may alter data or register values to observe their effect on the next emulation, or you can patch in changes to your program code itself. You can display and change symbolic values in the symbol table and breakpoint and tracepoint values.
12. Alternate between interrogation and emulation until you have checked everything you want to check.
13. At the end of the emulation session, you can save your debugged code on an ISIS-II diskette file, using the ICE-88 SAVE command. The operation can be specified to save program code, symbol tables, and (for PL/M programs) the source code line number table.

    You can start another session immediately, resetting all parameters to their initial values with a few simple commands, or you can exit to ISIS-II to terminate the session.

This introduction is intended to show you some of the scope and power of the ICE-88 emulator in operation, and to suggest how this integrated software/hardware design aid can fit into your development cycle. Chapter 2 contains installation instructions. Chapter 3 contains a hands-on tutorial involving a sample program to be debugged. Chapter 4 describes the meta-notation used in this manual to specify command syntax and semantics. Chapter 5 presents a detailed description of expressions used in this manual. The remaining chapters present the details of the command language in a format and sequence designed for reference.

CHAPTER 2
ICE-88 INSTALLATION PROCEDURES

This chapter contains information on the installation of the ICE-88 emulator.

ICE-88 Components

The following items are included in the ICE-88 package.

- FM Controller board (PN 1002609): A circuit board that plugs into the Intellec chassis. The FM Controller contains the 8080 ICE processor, 12K-byte firmware ROM, and 3K-byte scratchpad RAM.
- 88 Controller board (PN 1002585): A circuit board that plugs into the Intellec chassis. The 88 Controller contains the 2K-byte ICE RAM, 1K by 6-bit MAP memory, and 512 byte 2-Port memory.
- Trace board (PN 1001849): A circuit board that plugs into the Intellec chassis. The Trace board contains RAM for trace data, tracepoints, and breakpoints.
- ICE-88 Buffer Box Assembly (PN 4002604): A cable assembly that contains the ICE-88 Buffer Box Assembly. The Buffer Box contains two small circuit boards that contain the 8088 user processor and gating and control logic for communications with the user system, MAP RAM, ICE RAM, 2-Port RAM, and Trace RAM. The cable assembly also contains the user cable that plugs into the 40-pin receptacle that normally houses the user's 8088, the X cable that attaches to the 88 Controller board, and the Y cable that attaches to the FM Controller board.
- Intellec Microcomputer Development System 800 Triple Auxiliary Connector (PN 1001854 or 1001855) and Intellec Series II Triple Auxiliary Connector (PN 1001858): Each connector consists of a set of three parallel circuit board connectors that provide electrical interconnection between the FM Controller, Trace board and the 88 Controller when they are installed in the Intellec chassis.
- Ground Cable (PN 4000481): A cable that provides signal ground to the ICE-88 Buffer Box Assembly from the user system.
- Required software files on the ICE-88 diskette:

• ICE88	• ICE88.OV5
• ICE88.OV0	• ICE88.OV6
• ICE88.OV1	• ICE88.OV7
• ICE88.OV2	• ICE88.OV8
• ICE88.OV3	• ICE88.OVE
• ICE88.OV4	

Required and Optional Hardware

ICE-88 emulators require one of the following hardware configurations:

- Intellec model 800 with:

  CRT

  MDS-2DS or DDS

  64K of RAM

  3 adjacent card slots available on the motherboard
- Intellec model 888 with 64K of RAM
- Intellec Series II, model 220 or 230 with:

  3 adjacent card slots available in the expansion chassis and 64K of RAM

The following are optional enhancements to an ICE-88 system:

- Serial or parallel printer for hard-copy output
- One or more boards of Intellec expansion memory. If Intellec expansion memory is to be used for emulating 8088 program memory, additional card slots are needed for iSBC-32 or iSBC-64 memory boards. If Intellec expansion memory is used, it is recommended that all Intellec memory consist of iSBC-32 and/or iSBC-64 memory boards. iSBC-16 memory boards contain only 16 bits of address. Therefore, if any iSBC-16 boards are present when expansion memory is being used, each 16K RAM board will be duplicated on each 64K page of addressable memory making these duplicated areas unusable for program storage.

NOTE

The Monitor in the Intellec model 800 and 888 occupies the upper 2K of the first 64K of Intellec memory. This address space will be duplicated on each 64K page of Intellec expansion memory used and therefore is unusable for user program storage.

Hardware Installation Procedures

The installation procedures of the ICE-88 emulator are presented in the next two sections as follows: the procedure for Intellec model 800 and 888; and the procedure for Intellec Series II, model 220 and 230.

Installation Procedure for Intellec Model 800 and 888

1. Disconnect the power cords of the Intellec system and the user system.
2. Install the Intellec peripherals (diskette drives, CRT, printer), following the instruction guidelines given in the *Intellec Microcomputer Development System Hardware Reference Manual*.
3. Inspect the ICE-88 components for damage.
4. Remove the top cover of the Intellec chassis.
5. Mount shorting plug P1 to terminal E5-E6, setting device code to 2. (When shipped, P1 is mounted to E5-E6.) Mount shorting plug P2 to terminal E7-E8, to select −10V as −5V power source. (When shipped, P2 is mounted to E7-E8.) Mount and align the lowest position of the MDS Triple Auxiliary Connector (PN 1001854 or 1001855) on the FM Controller. Then insert them into an odd-numbered card slot.
6. Mount the Trace board into the middle slot of the Triple Auxiliary Connector.
7. Mount the 88 Controller board into the highest numbered slot of the Triple Auxiliary Connector.
8. MOUNT THE T CABLE ASSEMBLY CONNECTING THE ICE TRACE BOARD TO THE 88 CONTROLLER BOARD, MATING THE MISSING PIN ON THE TERMINAL WITH THE BLOCKED INSERT ON THE RECEPTACLE.
9. Expand the Intellec memory as required for user software.
10. ATTACH THE RIBBON CABLE MARKED X TO THE CABLE RECEPTACLE ON THE 88 CONTROLLER BOARD MARKED X MATING THE MISSING PIN ON THE TERMINAL WITH THE BLOCKED INSERT ON THE RECEPTACLE.
11. ATTACH THE RIBBON CABLE MARKED Y TO THE CABLE RECEPTACLE ON THE FM CONTROLLER BOARD MARKED Y MATING THE MISSING PIN ON THE TERMINAL WITH THE BLOCKED INSERT ON THE RECEPTACLE.

12. If a user prototype is to be connected, remove the Socket Protector Assembly from the user end of the ICE-88 Buffer Box Assembly and insert the 40-pin cable terminal into the 8088 socket on the user system. The Socket Protector Assembly guards the terminal pins from damage and inadvertent grounding.
13. Mount the male plug of the Ground Connector into the female receptacle of the 68-136 Terminal Pin at the user end of the cable assembly.
14. Mount the clip end of the Ground Connector to an appropriate point in the user system to provide signal ground.
15. Replace the top cover of the Intellec chassis.
16. Insert the power cords of the Intellec system and the user system into their sockets. Connect both to power sources.

Installation Procedure for Intellec Series II Model 220 and 230

1. Disconnect the power cords of the Intellec chassis and user system.
2. Install the Intellec peripherals (diskette drives, CRT, printer), following the instruction guidelines given in the Intellec Series II Installation and Service Manual.
3. Inspect the ICE-88 components for damage.
4. Remove the front cover of the expansion chassis to be used to house the ICE-88 circuit boards.
5. Mount shorting plug P1 to terminal E5-E6, setting device code to 2. (When shipped, P1 is mounted to E5-E6.) Mount shorting plug P2 to terminal E7-E8 to select −10V as −5V power source. (When shipped, P2 is mounted to E7-E8.) Mount and align the lowest position of the EMDS Triple Auxiliary Connector (PN 1001858) on the FM Controller. Then insert them into a card slot.
6. Mount the ICE-88 Trace board into the middle slot of the Triple Auxiliary Connector.
7. Mount the 88 Controller board into the highest numbered slot of the Triple Auxiliary Connector.
8. MOUNT THE ICE-88 T CABLE ASSEMBLY CONNECTING THE ICE TRACE BOARD TO THE 88 CONTROLLER BOARD, MATING THE MISSING PIN ON THE TERMINAL WITH THE BLOCKED INSERT ON THE RECEPTACLE.
9. Expand the Intellec memory as required for user software.
10. ATTACH THE RIBBON CABLE MARKED X TO THE CABLE RECEPTACLE ON THE 88 CONTROLLER BOARD MARKED X MATING THE MISSING PIN ON THE TERMINAL WITH THE BLOCKED INSERT ON THE RECEPTACLE.
11. ATTACH THE RIBBON CABLE MARKED Y TO THE CABLE RECEPTACLE ON THE FM CONTROLLER BOARD MARKED Y MATING THE MISSING PIN ON THE TERMINAL WITH THE BLOCKED INSERT ON THE RECEPTACLE.
12. If a user prototype is to be connected, remove the Socket Protector Assembly from the user end of the ICE-88 Buffer Box Assembly and insert the 40-pin cable terminal into the 8088 socket on the user system. The Socket Protector Assembly guards the terminal pins from damage and inadvertent grounding.
13. Mount the male plug of the Ground Connector into the female receptacle of the 68-136 Terminal Pin at the user end of the cable assembly.
14. Mount the clip end of the Ground Connector to an appropriate point in the user system to provide signal ground.

15. Replace the front cover of the expansion chassis.
16. Insert the power cords of the Intellec system and the user system into their sockets. Connect both to power sources.

    The distance between the two connectors of the T ribbon cable can be adjusted by bending the cable to match the spacing between the Trace board and the 88 Controller board.

NOTE

Keep Socket Protector Assembly mounted on the end of the ICE Buffer Box Assembly whenever the terminal is not attached to a user system. This will prevent inadvertant pin damage.

When removing the Socket Protector Assembly from the end of the ICE Buffer Box Assembly, use care to prevent pin damage.

Confidence Testing

At the conclusion of the installation procedures for the Intellec Model 800 or 888, or the Intellec Series II, execute the DIAG88 confidence program. The DIAG88 program resets and invokes the ICE-88 emulator, executes a set of hardware confidence tests, and terminates by returning a set of "PASS" or "FAIL" display messages. Execute the following sequence to run the confidence tests:

- Boot the system to run under ISIS-II and wait for the hyphen prompt from the ISIS-II system.
- Enter the command CONF and wait for the prompt, *.
- Enter the command INIT DIAG88.CON and wait for the prompt, *.
- Enter the command TEST to cause DIAG88 to execute the confidence tests. Wait for the test message displays. DIAG88 will display a "PASS/FAIL" message for each diagnostic test contained in DIAG88. If any displayed test message denotes a "FAIL," the installed hardware is not operating properly. Inspect the hardware for improper installation and rerun DIAG88. If all the displayed test messages denote "PASS,", the hardware has been installed correctly and is operating properly.
- Enter the command EXIT to return control to the ISIS-II system.

CHAPTER 3
SAMPLE ICE-88 SESSIONS AT THE TERMINAL

This chapter introduces a few useful ICE-88 commands and provides hands-on experience with the ICE-88 emulator. To reduce the need for cross-reference, this chapter includes brief discussions of the commands used in the examples. The user program to be simulated is a simple traffic light controller. The user program logic is described before the hands-on session to help you understand what is going on.

How To Use This Chapter

- To use this program as a hands-on tutorial, you must enter the source code for the two modules using the ISIS text editor on your system. Omit the line number and nesting information that is on the listing; these values are assigned by the compiler and assembler.
- Compile the CARS module with the PL/M-86 compiler program. Assuming that the source file is named CARS.SRC, the compile step could look like:

  ```
  -PLM86 :F1:CARS.SRC PRINT(:F1:CARS.PRT) DEBUG
  ```

  The object file created by PL/M-86 is named CARS.OBJ. (The DEBUG control generates the symbol table for use by the ICE-88 emulator.)
- Assemble the DELAY module with the ASM86 assembler. Assuming that the source file is named DELAY.SRC, the assemble step could look like:

  ```
  -ASM86 :F1:DELAY.SRC PRINT(:F1:DELAY.PRT) OBJECT(:F1:DELAY.OBJ) DEBUG
  ```

  As indicated, the object module is named DELAY.OBJ.
- Link and Locate CARS and DELAY using the MCS-86 utility QRL86. The command we used looks like:

  ```
  -QRL86 :F1:CARS.OBJ, :F1:DELAY.OBJ TO :F1:CARS &
  **ORIGIN (0) PRINT(:F1:CARS.QRL) MAP
  ```

  The ampersand (&) is entered before the carriage return to request a continuation line. The beginning of the continuation line is indicated by a double asterisk prompt (**).

  The executable file is now named CARS; program addresses start at zero (0) because of the ORIGIN control in the QRL86 invocation.
- For further information on the procedures for editing, compiling, assembling, linking, and locating programs for the MCS-86 Microprocessor, refer to the following manuals:

Text Editor:	*ISIS-II System User's Guide*
PL/M-86 Compiler:	*PL/M-86 Programming Manual* *PL/M-86 Operator's Manual*
ASM-86 Assembler	*MCS-86™ Assembly Language Reference Manual* *MCS-86™ Assembler Operating Instructions for ISIS-II Users*
QRL86	*MCS-86™ Software Development Utilities Operating Instructions for ISIS-II Users.*

- Study the logic of CARS, the program to be emulated. The material includes text discussion and program listings.
- Install the ICE-88 hardware, following the procedure given in Chapter 2. Leave the socket protector on to protect the pins at the end of the cable.
- Insert an ISIS-II system diskette in drive 0 and boot ISIS.

- Copy CARS to the diskette containing the ICE-88 program. Insert this diskette in drive 1.
- Enter the command

  ```
  :F1:ICE88
  ```

  to load the ICE software and start it executing. The ICE-88 emulator signals readiness to accept commands by displaying an asterisk prompt (*).
- To obtain a diskette copy of the session, enter the command:

  ```
  LIST :F1:OUTPUT.LOG
  ```

  Of course, you can give your list file any name you desire instead of OUTPUT.LOG.
- Enter the commands as shown, and obtain the results shown in the listing.

Analysis of the Sample Program

The application presented is a simple traffic light controller. Imagine an intersection of a main street and a side street. The desired operation is that the light should stay green on the main street until a decision involving the number of cars waiting on the side street and the amount of time they have been waiting has been satisfied. We suppose that there is a sensor in the pavement on the side street that sends an interrupt to the computer when a car arrives. We do not include the control of a yellow light on either street.

Refer to the following figures:

Figure 3-1. CARS Module Listing
Figure 3-2. Delay Module Listing

Associated with each street is a time called the cycle length. In the program, the variable named SIDE$CYCLE$LENGTH controls the fixed length of time the light is green on the side street when that cycle is called into action. Even though the light stays green on the main street until the decision rule is satisfied, we need a variable MAIN$CYCLE$LENGTH that is involved in the decision rule.

The decision rule is as follows. The side street gets a green light if either of the following two conditions is satisfied.

1. Two or more cars are waiting on the side street, and the main street has had the green light for a period of time greater than or equal to the variable MAIN$CYCLE$LENGTH.
2. One car is waiting on the side street, and the main street has had the green light for a period of time equal to or greater than two times the variable MAIN$CYCLE$LENGTH.

The system has one input and one output. The input is a signal that a car has arrived on the side street since the last time we sampled the input. The variable CARS$WAITING contains the number of cars waiting on the side street. The output goes to the traffic light controller. We assume that sending the controller a 1 makes the light on the main street green and the light on the side street red; sending it a 0 makes the light on the main street red and the light on the side street green. The variable LIGHT$STATUS represents this output.

```
           /*  TRAFFIC LIGHT CONTROLLER PROGRAM */

 1         CARS:
           DO;
 2  1          DECLARE (MAIN$TIME, SIDE$TIME) BYTE;
 3  1          DECLARE MAIN$CYCLE$LENGTH BYTE DATA(8), SIDE$CYCLE$LENGTH BYTE DATA(5);
 4  1          DECLARE CARS$WAITING BYTE;
 5  1          DECLARE LIGHT$STATUS BYTE;
 6  1          DECLARE FOREVER LITERALLY 'WHILE I';

 7  1          SIDE$STREET$CAR:
               PROCEDURE;
 8  2              CARS$WAITING = CARS$WAITING + 1;
 9  2          END SIDE$STREET$CAR;

               /* FOLLOWING PROCEDURE CODED IN ASSEMBLY LANGUAGE AND LINKED IN */
10  1          DELAY:
               PROCEDURE(TIME$HUNDREDTHS) EXTERNAL;
11  2              DECLARE TIME$HUNDREDTHS BYTE;
12  2          END DELAY;

13  1          DISPLAY:
               PROCEDURE (CYCLE$TIME);
14  2              DECLARE CYCLE$TIME BYTE;
15  2              LIGHT$STATUS = LIGHT$STATUS;
16  2          END DISPLAY;

17  2          CYCLE:
               PROCEDURE;
18  2              LIGHT$STATUS = 0;   /* MAIN RED, SIDE GREEN */
19  2              SIDE$TIME = 0;
20  2              DO WHILE SIDE$TIME <= SIDE$CYCLE$LENGTH;
21  3                 CALL DISPLAY(SIDE$TIME);
22  3                 CALL DELAY(100);
23  3                 SIDE$TIME = SIDE$TIME * 1;
24  3              END;
25  2              LIGHT$STATUS = 1;   /* MAIN GREEN, SIDE RED */
26  2          END CYCLE;

           /* MAIN PROGRAM — EXECUTION BEGINS HERE */

27  1      LIGHT$STATUS = 1;   /* START WITH MAIN GREEN */
28  1          CARS$WAITING = 0;
29  1          MAIN$TIME = 0;
30  1          DO FOREVER;
31  2              CALL DISPLAY(MAIN$TIME);
32  2              CALL DELAYI(100);
33  2              MAIN$TIME = MAIN$TIME * 1;
34  2              IF      (CARS$WAITING >= 2) AND (MAIN$TIME >= MAIN$CYCLE$LENGTH)
                      OR  (CARS$WAITING = 1) AND (MAIN$TIME >= 2 * MAIN$CYCLE$LENGTH) THEN
35  2              DO;
36  3                 CALL CYCLE;
37  3                 CARS$WAITING = 0;
38  3                 MAIN$TIME = 0;
39  3              END;
40  2          END;

41  1      END CARS;
```

Figure 3-1. CARS Module Listing

```
LOC   OBJ             LINE  SOURCE

                         1  CGROUP   GROUP     ABS_0,CODE,CONST,DATA,STACK,MEMORY
                         2  DGROUP   GROUP     ABS_0,CODE,CONST,DATA,STACK,MEMORY
                         3           ASSUME    DS:DGROUP,CS:CGROUP,SS:DGROUP
----                     4  CONST    SEGMENT   WORD PUBLIC 'CONST'
----                     5  CONST    ENDS
----                     6  DATA     SEGMENT   WORD PUBLIC 'DATA'
----                     7  DATA     ENDS
----                     8  STACK    SEGMENT   WORD STACK 'STACK'
0000                     9  STACK_BASE         LABEL  BYTE
----                    10  STACK    ENDS
----                    11  MEMORY   SEGMENT   WORD MEMORY 'MEMORY'
0000                    12  MEMORY_LABEL       BYTE
----                    13  MEMORY   ENDS
----                    14  ABS_0    SEGMENT   BYTE AT 0
0000                    15  M        LABEL     BYTE
                        16                                  ; TIME DELAY SUBROUTINE
                        17                                  ;
----                    18  ABS_0    ENDS
----                    19  CODE     SEGMENT   WORD PUBLIC 'CODE'
                        20           PUBLIC    DELAY
0000  58                21  DELAY: POP BX   ;POP RETURN ADDR. OFF STACK
0000  59                22            POP CX  ;POP ARGUMENT OFF STACK INTO CX REG.
0002  53                23            PUSH BX  ;REPLACE RETURN ADDR. ON STACK
0003  8AC1              24           MOV       AL,CL         ; PL/M LINKAGE CONVENTION
0005  B5FF              25           MOV       CH,255
0007  8ACD              26  LAB1:    MOV       CL,CH
0009  FEC9              27  LAB2:    DEC       CL
000B  891E2300     R    28           MOV       TEMP,BX       ; WASTE
000F  891E2300     R    29           MOV       TEMP,BX       ; DITTO
0013  891E2300     R    30           MOV       TEMP,BX       ;
0017  891E2300     R    31           MOV       TEMP,BX       ;
001B  90                32           NOP                     ;
001C  75EB              33           JNZ       LAB2
001E  FEC8              34           DEC       AL
0020  75E5              35           JNZ       LAB1
0022  C3                36           RET
                        37                                   ;
0023                    38  TEMP     LABEL     WORD
0023  (2                39           DB        2 DUP
      ??
      )
----                    40  CODE     ENDS
                        41           END
```

Figure 3-2. DELAY Module Listing

The program is initialized with constants and variables set as follows.

MAIN$CYCLE$LENGTH = 8 seconds
SIDE$CYCLE$LENGTH = 5 seconds
MAIN$TIME = 0 (Time since last change to MAIN GREEN, SIDE RED)
SIDE$TIME = not set yet. (Time since last change to SIDE GREEN)
LIGHT$STATUS = 1 (MAIN GREEN, SIDE RED)
CARS$WAITING = 0

The CARS program contains a procedure CYCLE to change the lights back and forth. CYCLE holds the side street light green (main red) until its counter, SIDETIME, exceeds the SIDECYCLELENGTH (nominally 5 seconds).

The ICE-88 test suite includes commands that simulate the arrival of cars on the side street, and that display the values of the program variables involved in the light change logic. The procedure SIDESTREETCAR represents the nucleus of the interrupt routine that would handle the sensor interrupts in a real traffic light controller program. The interrupt-enabling logic is omitted for simplicity. Procedure DISPLAY is a "vestige" of a previous version of CARS. CARS also calls DELAY when a "one-second" timer is required.

Hands-On Demonstration

This demonstration involves the one program CARS. The version we ran did not have any serious logic errors, so that the effects of the ICE-88 commands could be clearly seen. The length of the delay produced by the DELAY routine is longer than desired; you may adjust the calling parameter if you desire a "true" one-second delay.

The material represents two separate sessions at the terminal. The beginning and end of each session is clearly indicated. By using two sessions we can demonstrate the use of the PUT and INCLUDE commands.

The pair of sessions is organized as follows—session 1 shows how to define and save macros on file; the macros defined in this session are of two kinds: general purpose MCS-86 utilities (PUSH88, POP88, SETIP) and macros that are particular to CARS, the demonstration program.

The demonstration emphasizes the ICE-88 macro facility, showing how four basic ICE operations (initialize, emulate, display, change) can be organized into named blocks—the building blocks of test sequences.

The define macro command has the syntax:

DEFINE MACRO *macro-name cr*

[*command cr*]...

EM

The commands inside a macro definition (including calls to other macros) are not examined or executed by the ICE-88 emulator until the macro is invoked. A macro call has the format: *:macro-name*. More details on commands are given in the following discussion.

Session 1

0 We begin the session by entering :F1:ICE88 to ISIS-II (hyphen prompt), and receive the ICE-88 sign-on message and asterisk prompt. To record the session on diskette file, we enter a LIST command with the drive and filename that is to contain the output of the ICE-88 operations (including error messages if any).

Many of the commands include comments. A comment is preceded by a semicolon (;) to separate it from the command.

The discussion is keyed to the listing by margin numbers.

1 Macro PUSH88 simulates the MCS-86 PUSH instruction. SP is the stack pointer; SS is the base address of the stack segment.

POP88 is the reverse procedure, simulating the MCS-86 POP instruction.

The parameter %0 in both PUSH88 and POP88 lets us "push" or "pop" any register (or expression, etc.) as long as it can be expressed as a WORD-type quantity.

2 Macro SETIP resets the instruction pointer CS:IP to the address (symbol, expression, etc.) passed as a parameter when the macro is invoked. CS is the base of the code segment and IP is the instruction pointer relative to CS. Like PUSH88 and POP88, SETIP is a useful macro for restarting emulation at a desired point (without "softwiring" start addresses into your emulation macros).

3 Macro TYPES demonstrates how to set up to use typed memory references. A symbol that stands for the address of a variable (not a procedure name) can be defined or assigned a *memory-type*. Examples of memory-types are BYTE, WORD, and POINTER. In our CARS program, all the key variables are of type BYTE. Since the symbols are loaded with the program rather than being DEFINED, we assign types to the variable with the commands of the form:

TYPE *.symbol-name = memory-type*

Then, as shown later on (e.g., in macro VARIABLES, step 6 of session 1) we can refer to the *contents* of any typed variable with a typed memory reference of the form

!*symbol-name*

The contents produced by a typed memory reference are automatically of the type assigned or declared.

See Chapter 7 for more details on memory types.

```
0  -:F1:ICE88
   ISIS-II ICE-88 V1.0
   *
   *LIST :F1:DEC10.LOG        ;SESSION ONE
   *
1  *DEFINE MACRO PUSH88
   •*SP = SP — 2T             ;MOVE POINTER TO NEW TOP OF STACK
   •*WORD SS:SP = %0         ;PUSH PARAMETER ON STACK
   •*EM                       ;END OF MACRO PUSH88
   *
   *DEFINE MACRO POP88
   •*%0 = WORD SS:SP          ;POP PARAMETER OFF STACK
   •*SP = SP + 2T             ;MOVE POINTER TO NEW TOP OF STACK
   •*EM                       ;END OF MACRO POP88
   *
2  *DEFINE MACRO SETIP
   •*CS = SEG (%0)
   •*IP = OFF (%0)
   •*EM        ;END OF MACRO SETIP
   *
3  *DEFINE MACRO TYPES
   •*TYPE .MAINTIME = BYTE       ;FROM PLM LISTING
   •*TYPE .SIDETIME  = BYTE      ;FROM PLM LISTING
   •*TYPE .MAINCYCLELENGTH = BYTE       ;FROM PLM LISTING
   •*TYPE .SIDECYCLELENGTH  = BYTE      ;FROM PLM LISTING
   •*TYPE .CARSWAITING = BYTE       ;FROM PLM LISTING
   •*TYPE .LIGHTSTATUS  = BYTE      ;FROM PLM LISTING
   •*EM                             ;END OF MACRO TYPES
```

4 We define a macro INIT to handle the map and load steps for our program, CARS.

In the macro INIT, the command MAP 0 LENGTH 2 = ICE 0 assigns two memory blocks (1K segments) to ICE memory. The CARS program was LOCATed at ORIGIN 0 (QRL step discussed above) to facilitate mapping to ICE memory.

INIT defines a useful symbol, .START = CS:IP. After LOAD, CS:IP points to the first executable instruction in the user program. CS is the base of the code segment and IP is the instruction pointer (relative to CS).

Then, INIT calls the TYPES macro defined in step 3. This macro will become part of INIT whenever INIT is called. Until INIT is called, however, the call to TYPES is not executed.

Finally, INIT displays the symbol and statement number tables, to verify that the LOAD step has been completed, and that the TYPES macro has executed.

5 Macro EXAM is designed to test the logic that controls the light change. Basically, the macro block is an indefinite REPEAT loop (the block beginning with REPEAT and ending with ENDREPEAT). On each iteration a single step is emulated (one instruction). Following that, we use an IF command to look for certain addresses and take appropriate actions. The action taken in all cases is to display the PL/M statement or an equivalent message using the WRITE command (see step 6 for more on the WRITE command). In addition, we skip both DELAY and DISPLAY by popping the return address and call parameter off the stack.

```
4  *DEFINE MACRO INIT
   •*MAP 0 LENGTH 2 = ICE 0      ;MEMORY SPACE FOR CARS PROGRAM
   •*MAP 0 LENGTH 2              ;DISPLAY WHAT WE MAPPED
   •*LOAD :F1:CARS
   •*DEFINE .START = CS:IP       ;HANDY SYMBOL FOR RESTARTING
   •*:TYPES                      ;MACRO FOR TYPE DEFINITIONS
   •*SYMBOLS
   •*LINES                       ;DISPLAY SYMBOL AND LINE NUMBER TABLES
   •*EM                          ;END OF MACRO INIT
   *
5  *DEFINE MACRO EXAM
   •*REPEAT
   •*STEP
   •*IF CS = SEG(.DISPLAY) AND IP = OFF(.DISPLAY) THEN
   •*WRITE 'CALL DISPLAY'
   •*:POP88 IP                 ;RESTORE RETURN ADDRESS
   •*SP = SP + 2T              ;DISCARD PARAMETER
   •*ORIF CS = SEG(.DELAY) AND IP = OFF(.DELAY) THEN
   •*WRITE 'CALL DELAY'
   •*:POP88 IP
   •*SP = SP + 2T
   •*ORIF CS = SEG(..CARS#30) AND IP = OFF(..CARS#30) THEN
   •*WRITE 'STARTING MAIN LOOP'
   •*ORIF CS = SEG(..CARS#34) AND IP = OFF(..CARS#34) THEN
   •*WRITE 'START OF IF TEST'
   •*:VARIABLES
   •*ORIF CS = SEG(.CYCLE) AND IP = OFF(.CYCLE) THEN
   •*WRITE 'CALL CYCLE'
   •*ENDIF
   •*ENDREPEAT
   •*EM        ;END OF MACRO EXAM
```

6 Macro VARIABLES employs the WRITE command to display the key program variables with identifiers. The general syntax of WRITE is:

WRITE *element* [, *element*]...

The elements to be "written" (displayed at the console) can be strings (e.g., 'SIDETIME') enclosed in single quotes, expressions, or constants of the form BOOL *expression*. Two or more elements can be combined by listing them in the order you desire, separated by commas. The strings in our commands serve to label the displays.

VARIABLES also uses typed memory references; they have the format:

!*symbol-name*

Note that each of the *symbol names* in VARIABLES must be assigned a type (by macro TYPES) before LOOK can be called. Then, the typed reference produces the *contents* of the given address. For example, if symbol .A is the address of a variable of type BYTE, !A means the same thing as BYTE.A; if .A is a WORD-type variable, however, !A means WORD.A.

The display produced by VARIABLES is shown in session 2 below.

7 Macro TEST combines several macros and simple commands in a test suite. First we initialize the system be executing GO FROM START TILL ..CARS#30 EXECUTED. Statement #30 in the beginning of the main loop.

Next, TEST uses a parameter to assign a value to CARSWAITING. When we call TEST, we supply any value we wish as a parameter.

Last, TEST calls EXAM to single step through the program displaying any calls that occur.

8 The DIR MAC command produces a display of the titles of all the macros we defined, in the order they were defined.

9 To display the definition of any macro, use a command with the form:

MACRO *macro-name*

Using this command, we display the definition of macro SETIP.

10 We save our macro definition on a permanent file for use in later sessions.

11 The EXIT command closes all files and returns us to ISIS-II (hyphen prompt).

```
6   *DEFINE MACRO VARIABLES
    •*WRITE 'LIGHTSTATUS = ',!LIGHTSTATUS,', CARSWAITING = ',!CARSWAITING
    •*WRITE 'MAINCYCLELENGTH = ',!MAINCYCLELENGTH,', MAINTIME = ',!MAINTIME
    •*WRITE 'SIDECYCLELENGTH = ',!SIDECYCLELENGTH,', SIDETIME = ',!SIDETIME
    •*EM            ;END OF MACRO VARIABLES
    *
7   *DEFINE MACRO TEST
    •*GO FROM .START TILL ..CARS#30 EXECUTED
    •*!CARSWAITING = %0
    •*:VARIABLES
    •*:EXAM
    •*EM            ;END OF MACRO TEST
    *
8   *DIR MAC
    PUSH88
    POP88
    SETIP
    TYPES
    INIT
    EXAM
    VARIABLES
    TEST
    *
9   *MACRO SETIP
    DEFINE MACRO SETIP
    CS = SEG (%0)
    IP = OFF (%0)
    EM              ;END OF MACRO SETIP
    *
10  *PUT :F1:TEST.INC MACRO
    *
11  *EXIT
    —
```

Session 2

0 We call up the ICE-88 program and specify a LIST file as before.

1 The INCLUDE command causes the ICE-88 emulator to read commands from a file rather than from the console. The form of this command is just:

```
INCLUDE :drive: filename
```

In our case, the file :F1:TEST.INC contains the macro definitions from session 1. Thus, when we enter the command:

```
INCLUDE :F1:TEST.INC
```

The ICE-88 emulator reads in all the macro definitions from PUSH88 through TEST, then returns control to the console.

```
0  -:F1:ICE88
   ISIS-II ICE-88 V1.0
   *
   *LIST :F1:DEC11.LOG          ;SESSION TWO
   *
1  *INCLUDE :F1:TEST.INC
   *DEFINE MACRO PUSH88
   •*SP = SP — 2T         ;MOVE POINTER TO NEW TOP OF STACK
   •*WORD SS:SP = %0      ;PUSH PARAMETER ON STACK
   •*EM                   ;END OF MACRO PUSH88
   *DEFINE MACRO POP88
   •*%0 = WORD SS:SP ;POP PARAMETER OFF STACK
   •*SP = SP + 2T         ;MOVE POINTER TO NEW TOP OF STACK
   •*EM                   ;END OF MACRO POP88
   *DEFINE MACRO SETIP
   •*CS = SEG (%0)
   •*IP = OFF (%0)
   •*EM        ;END OF MACRO SETIP
   *DEFINE MACRO TYPES
   •*TYPE .MAINTIME = BYTE   ;FROM PLM LISTING
   •*TYPE .SIDETIME  BYTE   ;FROM PLM LISTING
   •*TYPE .MAINCYCLELENGTH = BYTE      ;FROM PLM LISTING
   •*TYPE .SIDECYCLELENGTH  = BYTE     ;FROM PLM LISTING
   •*TYPE .CARSWAITING = BYTE     ;FROM PLM LISTING
   •*TYPE .LIGHTSTATUS = BYTE     ;FROM PLM LISTING
   •*EM                           ;END OF MACRO TYPES
   *DEFINE MACRO INIT
   •*MAP 0 LENGTH 2 = ICE 0       ;MEMORY SPACE FOR CARS PROGRAM
   •*MAP 0 LENGTH 2               ;DISPLAY WHAT WE MAPPED
   •*LOAD :F1:CARS
   •*DEFINE .START = CS:IP        ;HANDY SYMBOL FOR RESTARTING
   •*:TYPES                       ;MACRO FOR TYPE DEFINITIONS
   •*SYMBOLS
   •*LINES                        ;DISPLAY SYMBOL AND LINE NUMBER TABLES
   •*EM                           ;END OF MACRO INIT
   *DEFINE MACRO EXAM
   •*REPEAT
   •*STEP
   •*IF CS = SEG(.DISPLAY) AND IP = OFF(.DISPLAY) THEN
   •*WRITE 'CALL DISPLAY'
   •*:POP88 IP                 ;RESTORE RETURN ADDRESS
   •*SP = SP + 2T              ;DISCARD PARAMETER
   •*ORIF CS = SEG(.DELAY) AND IP = OFF(.DELAY) THEN
   •*WRITE 'CALL DELAY'
   •*:POP88 IP
   •*SP = SP + 2T
   •*ORIF CS = SEG(..CARS#30) AND IP = OFF(..CARS#30) THEN
   •*WRITE 'STARTING MAIN LOOP'
   •*ORIF CS = SEG(..CARS#34) AND IP = OFF(..CARS#34) THEN
   •*WRITE 'START OF IF TEST'
   •*:VARIABLES
   •*ORIF CS = SEG(.CYCLE) AND IP = OFF(.CYCLE) THEN
   •*WRITE 'CALL CYCLE'
   •*ENDIF
   •*ENDREPEAT
   •*EM        ;END OF MACRO EXAM
   *DEFINE MACRO VARIABLES
   •*WRITE 'LIGHTSTATUS = '.!LIGHTSTATUS,', CARSWAITING = ',!CARSWAITING
   •*WRITE 'MAINCYCLELENGTH = ',!MAINCYCLELENGTH,', MAINTIME = ',!MAINTIME
   •*WRITE 'SIDECYCLELENGTH = ',!SIDECYCLELENGTH,', SIDETIME = ',!SIDETIME
   •*EM        ;END OF MACRO VARIABLES
   *DEFINE MACRO TEST
   •*GO FROM .START TILL ..CARS#30 EXECUTED
   •*!CARSWAITING = %0
   •*:VARIABLES
   •*:EXAM
   •*EM        ;END OF MACRO TEST
   *
```

2 We invoke macro INIT with a macro call of the form:

```
:macro-name
```

In our example, the call is:

```
:INIT
```

First, the macro is "expanded" to form a block of executable commands. The expansion of INIT involves expanding the macro TYPES, at the point that TYPES is called within INIT (see the definition of INIT on the previous page). As INIT is expanded, each command is checked for syntax; any error here would abort the macro call. However, no errors occur and we reach the EM token marking the end of the macro expansion.

3 The commands in INIT now execute. The MAP commands allocate space in ICE memory for our code and display the resulting map (T indicates decimal radix):

```
0000T=ICE 0000T   0001T=ICE 0001T
```

The SYMBOLS command displays the symbol table; the listing shows the symbol names and corresponding addresses. We see that .START is present in an unnamed module at the head of the table, and other symbols are listed in the order they appear within the two program modules, ..CARS and ..DELAY. Note the type specifications on the program variables named in the macro TYPES.

The LINES command displays the statement numbers and corresponding addresses from CARS. DELAY has no line numbers because the assembler does not produce a line number table.

```
2  *:INIT
   •*MAP 0 LENGTH 2 = ICE 0          ;MEMORY SPACE FOR CARS PROGRAM
   •*MAP 0 LENGTH 2                  ;DISPLAY WHAT WE MAPPED
   •*LOAD :F1:CARS
   •*DEFINE .START = CS:IP           ;HANDY SYMBOL FOR RESTARTING
   •*:TYPES                          ;MACRO FOR TYPE DEFINITIONS
   ••*TYPE .MAINTIME = BYTE   ;FROM PLM LISTING
   ••*TYPE .SIDETIME  = BYTE  ;FROM PLM LISTING
   ••*TYPE .MAINCYCLELENGTH = BYTE      ;FROM PLM LISTING
   ••*TYPE .SIDECYCLELENGTH  BYTE     ;FROM PLM LISTING
   ••*TYPE .CARSWAITING = BYTE      ;FROM PLM LISTING
   ••*TYPE .LIGHTSTATUS = BYTE      ;FROM PLM LISTING
   ••*EM                            ;END OF MACRO TYPES
   •*SYMBOLS
   •*LINES                          ;DISPLAY SYMBOL AND LINE NUMBER TABLES
   •*EM                             ;END OF MACRO INIT
3  0000T=ICE 0000T     0001T=ICE 0001T
   •START=0002H
   MODULE ..CARS
   •MEMORY=0120H
   •MAINTIME=0106H OF BYT
   •SIDETIME=0107H OF BYT
   •MAINCYCLELENGTH=0104H OF BYT
   •SIDECYCLELENGTH=0105H OF BYT
   •CARSWAITING=0108H OF BYT
   •LIGHTSTATUS=0109H OF BYT
   •SIDESTREETCAR=008EH
   •DISPLAY=0098H
   •CYCLE=00A7H
   MODULE ..DELAY
   •DELAY=00DEH
   •LAB1=00E5H
   •LAB2=00E7H
   •M=0000H
   •MEMORY_=0012:0000H
   •STACK_BASE=0011:0010H
   •TEMP=0101H
   MODULE ..CARS
   #1=008EH
   #2=008EH
   #3=008EH
   #4=008EH
   #5=008EH
   #6=008EH
   #7=008EH
   #8=0091H
   #9=0096H
   #11=0098H
   #12=0098H
   #13=0098H
   #14=009BH
   #15=009BH
   #16=00A3H
   #17=00A7H
   #18=00AAH
   #19=00AFH
   #20=00B4H
   #21=00C1H
   #22=00CBH
   #23=00CEH
   #24=00D3H
   #25=00D6H
   #26=00DBH
   #27=0002H
   #28=0015H
   #29=001AH
   #30=001FH
   #31=001FH
   #32=0026H
   #33=002CH
   #34=0037H
   #35=007CH
```

4. We now invoke macro TEST to exercise the program logic. We wish to demonstrate that the code will branch to CYCLE when either of the following two conditions is true:

   1) CARSWAITING = 1 AND MAINTIME >= 16 seconds

   2) CARSWAITING >= 2 AND MAINTIME >= 8 seconds

   In the definition of TEST (look back at step 1) the second command is:

   ```
   !CARSWAITING = %0
   ```

   The parameter %0 lets us set the contents of CARSWAITING to any BYTE quantity we require. Thus we test condition 1 by our command:

   ```
   TEST 1
   ```

   This results in the expansion:

   ```
   !CARSWAITING = 1
   ```

   The expansion of TEST involves the expansion of the macros VARIABLES and EXAM at the point each is called in the body of TEST.

   Macro TEST now begins to execute. To help us follow the displays, we can identify some key addresses in the portions of code we are checking, as shown in table 3-1.

Table 3-1. Key Addresses in CARS Logic

ADDRESS (IP)	LINE # NUMBER	PLACE IN CARS CODE
0002H	#27	START OF MAIN PROGRAM (.START)
001FH	#30, 31	START OF MAIN 'DO' BLOCK
0037H	#34	START OF IF TEST
007CH	#35, 36	START OF CONDITIONAL 'DO' BLOCK
007FH	#37	POINT OF RETURN FROM 'CALL CYCLE'
0089H	#39, 40	END OF BOTH CONDITIONAL AND MAIN 'DO' BLOCKS
0098H	#13	BEGINNING OF DISPLAY (SKIPPED)
00A7H	#17	BEGINNING OF CYCLE
00DBH	#26	END OF CYCLE
00DEH	(#17)	BEGINNING OF DELAY (SKIPPED)

```
    #36=007CH
    #37=007FH
    #38=0084H
    #39=0089H
    #40=0089H
    #41=00BCH
    MODULE ..DELAY


    *
4   *:TEST 1
    •*GO FROM .START TILL ..CARS#30 EXECUTED
    •*!CARSWAITING = 1
    •*:VARIABLES
    ••*WRITE 'LIGHTSTATUS = ',!LIGHTSTATUS,', CARSWAITING = ',!CARSWAITING
    ••*WRITE 'MAINCYCLELENGTH = ',!MAINCYCLELENGTH,', MAINTIME = ',!MAINTIME
    ••*WRITE 'SIDECYCLELENGTH  = ',!SIDECYCLELENGTH,', SIDETIME = ',!SIDETIME
    ••*EM          ;END OF MACRO VARIABLES
    •*:EXAM
    ••*REPEAT
    •••*STEP
    •••*IF CS = SEG(.DISPLAY) AND IF = OFF(.DISPLAY) THEN
    ••••*WRITE 'CALL DISPLAY'
    ••••*:POP88 IP                     ;RESTORE RETURN ADDRESS
    •••••*IP = WORD SS:SP           ;POP PARAMETER OFF STACK
    •••••*SP = SP + 2T              ;MOV POINTER TO NEW TOP OF STACK
    •••••*EM                        ;END OF MACRO POP88
    ••••*SP = SP + 2T                  ;DISCARD PARAMETER
    ••••*ORIF CS = SEG(.DELAY) AND IP = OFF(.DELAY) THEN
    ••••*WRITE 'CALL DELAY'
    ••••*:POP88 IP
    •••••*IP = WORD SS:SP           ;POP PARAMETER OFF STACK
    •••••*SP = SP + 2T              ;MOVE POINTER TO NEW TOP OF STACK
    •••••*EM                        ;END OF MACRO POP88
    ••••*SP = SP + 2T
    ••••*ORIF CS = SEG(..CARS#30) AND IP = OFF(..CARS#30) THEN
    ••••*WRITE 'STARTING MAIN LOOP'
    ••••*ORIF CS = SEG(..CARS#34) AND IP = OFF(..CARS#34) THEN
    ••••*WRITE 'START OF IF TEST'
    ••••*:VARIABLES
    •••••*WRITE 'LIGHTSTATUS = ',!LIGHTSTATUS,', CARSWAITING = ',!CARSWAITING
    •••••*WRITE 'MAINCYCLELENGTH = ',!MAINCYCLELENGTH,', MAINTIME = ',!MAINTIME
    •••••*WRITE 'SIDECYCLELENGTH = ',!SIDECYCLELENGTH,', SIDETIME = ',!SIDETIME
    •••••*EM          ;END OF MACRO VARIABLES
    ••••*ORIF CS =(.CYCLE) AND IP = OFF(.CYCLE) THEN
    ••••*WRITE 'CALL CYCLE'
    ••••*ENDIF
    •••*ENDREPEAT
    ••*EM          ;END OF MACRO EXAM
    •*EM          ;END OF MACRO TEST
```

5 The messages 'EMULATION BEGUN' and 'EMULATION TERMINATED, CS:IP = 0000:0023' are produced by the command 'GO FROM .START TILL ..CARS#30 EXECUTED.'

6 The next three display lines are produced by macro VARIABLES. We see that LIGHTSTATUS is 1 (main street green), and that CARSWAITING has been set to 1 by the command '!CARSWAITING = 1' in TEST. MAINCYCLELENGTH and SIDECYCLELENGTH are constants at 8 and 5 respectively. MAINTIME and SIDETIME both are zero.

7 This is the beginning of the REPEAT loop in macro EXAM. The first STEP ends with address 0098H in the instruction pointer; this is the beginning of DISPLAY and macro EXAM displays the 'CALL DISPLAY' message.

8 When the beginning of DELAY appears in CS:IP, EXAM displays 'CALL DELAY'.

9 Address 0037H is the address of the first instruction generated by the IF statement on line #34 of CARS. EXAM displays the message 'START OF IF TEST', and also displays (via a call to macro VARIABLES) the values of the variables involved in the IF condition. The only change since the last such display is that MAINTIME has been incremented to 1.

```
5  EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0023H
6  LIGHTSTATUS = 0001H, CARSWAITING = 0001H
   MAINCYCLELENGTH = 0008H, MAINTIME = 0000H
   SIDECYCLELENGTH = 0005H, SIDETIME = 0000H
7  EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0098H
   CALL DISPLAY
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0028H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0029H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:00DEH
8  CALL DELAY
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0030H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0033H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0037H
9  START OF IF TEST
   LIGHTSTATUS = 0001H, CARSWAITING = 0001H
   MAINCYCLELENGTH = 0008H, MAINTIME = 0001H
   SIDECYCLELENGTH = 0005H, SIDETIME = 0000H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:003CH
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:003EH
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0040H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0045H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0046H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:004AH
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:004CH
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:004EH
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0050H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0052H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0053H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0058H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:005AH
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:005DH
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:005EH
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0062H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0064H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0066H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0068H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:006AH
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:006CH
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:006EH
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0070H
   EMULATION BEGUN
```

10 The previous twenty-eight STEPs comprise the IF-test. Address 0079H is the end of the IF test, and 0089H is the end of the main loop. Since address 007CH did not appear, we know that the conditional loop did not execute.

11 Here we are at the beginning of the main loop in CARS.

12 This time through the IF test, MAINTIME is 2. We omit most of the STEPs through the test (address 003CH to 0079H) from the text; these are identical to the series shown at step 9.

13 The start of the main loop again; still no light change.

```
   EMULATION TERMINATED, CS:IP=0000:0072H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0073H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0075H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0077H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0079H
   EMULATION BEGUN
10 EMULATION TERMINATED, CS:IP=0000:0089H


11 EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:001FH
   STARTING MAIN LOOP
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0023H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0098H
   CALL DISPLAY
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0028H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0029H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:00DEH
   CALL DELAY
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0030H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0033H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0037H
12 START OF IF TEST
   LIGHTSTATUS = 0001H, CARSWAITING = 0001H
   MAINCYCLELENGTH = 0008H, MAINTIME = 0002H
   SIDECYCLELENGTH = 0005H, SIDETIME = 0000H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:003CH
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:003EH
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0040H
   EMULATION BEGUN

   •
   •
   •

   EMULATION TERMINATED, CS:IP=0000:0077H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0079H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0089H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:001FH
13 STARTING MAIN LOOP
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0023H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0098H
   CALL DISPLAY
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0028H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0029H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:00DEH
   CALL DELAY
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0030H
```

14 MAINTIME equals 3; still a long way to go until MAINTIME equals 16. We now omit all steps from the text except the beginning and end of the IF test, so that we can concentrate on the value of MAINTIME.

15 MAINTIME equals 4.

16 MAINTIME equals 5.

```
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0033H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0037H
    START OF IF TEST
14  LIGHTSTATUS = 0001H, CARSWAITING = 0001H
    MAINCYCLELENGTH = 0008H, MAINTIME = 0003H
    SIDECYCLELENGTH = 0005H, SIDETIME = 0000H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:003CH
    EMULATION BEGUN

    •
    •
    •


    •
    •
    •
    EMULATION TERMINATED, CS:IP=0000:0077H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0079H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0089H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:001FH
    STARTING MAIN LOOP
    EMULATION BEGUN

    •
    •
    •

    EMULATION TERMINATED, CS:IP=0000:0037H
    START OF IF TEST
15  LIGHTSTATUS = 0001H, CARSWAITING = 0001H
    MAINCYCLELENGTH = 0008H, MAINTIME = 0004H
    SIDECYCLELENGTH = 0005H, SIDETIME = 0000H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:003CH
    EMULATION BEGUN

    •
    •
    •

    EMULATION TERMINATED, CS:IP=0000:0079H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0089H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:001FH
    STARTING MAIN LOOP
    EMULATION BEGUN

    •
    •
    •

    EMULATION TERMINATED, CS:IP=0000:0037H
    START OF IF TEST
16  LIGHTSTATUS = 0001H, CARSWAITING = 0001H
    MAINCYCLELENGTH = 0008H, MAINTIME = 0005H
    SIDECYCLELENGTH = 0005H, SIDETIME = 0000H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:003CH
    EMULATION BEGUN

    •
    •
    •
```

17 MAINTIME equals 6.

18 MAINTIME equals 7.

19 MAINTIME equals 8.

```
     EMULATION TERMINATED, CS:IP=0000:0079H
     EMULATION BEGUN
     EMULATION TERMINATED, CS:IP=0000:0089H
     EMULATION BEGUN
     EMULATION TERMINATED, CS:IP=0000:001FH
     STARTING MAIN LOOP
     EMULAITON BEGUN

     •
     •
     •

     EMULATION TERMINATED, CS:IP=0000:0037H
     START OF IF TEST
17   LIGHTSTATUS = 0001H, CARSWAITING = 0001H
     MAINCYCLELENGTH = 0008H, MAINTIME = 0006H
     SIDECYCLELENGTH = 0005H, SIDETIME = 0000H
     EMULATION BEGUN
     EMULATION TERMINATED, CS:IP=0000:003CH
     EMULATION BEGUN

     •
     •
     •


     •
     •
     •

     EMULATION TERMINATED, CS:IP=0000:0079H
     EMULATION BEGUN
     EMULATION TERMINATED, CS:IP=0000:0089H
     EMULATION BEGUN
     EMULATION TERMINATED, CS:IP=0000:001FH
     STARTING MAIN LOOP
     EMULATION BEGUN

     •
     •
     •

     EMULATION TERMINATED, CS:IP=0000:0037H
     START OF IF TEST
18   LIGHTSTATUS = 0001H, CARSWAITING = 0001H
     MAINCYCLELENGTH = 0008H, MAINTIME = 0007H
     EMULATION BEGUN
     EMULATION TERMINATED, CS:IP=0000:003CH
     EMULATION BEGUN

     •
     •
     •

     EMULATION TERMINATED, CS:IP=0000:0079H
     EMULATION BEGUN
     EMULATION TERMINATED, CS:IP=0000:0089H
     EMULATION BEGUN
     EMULATION TERMINATED, CS:IP=0000:001FH
     STARING MAIN LOOP
     EMULATION BEGUN

     •
     •
     •

     EMULATION TERMINATED, CS:IP=0000:0037H
     START OF IF TEST
19   LIGHTSTATUS = 0001H, CARSWAITING = 0001H
     MAINCYCLELENGTH = 0008H, MAINTIME = 0008H
     SIDECYCLELENGTH = 0005H, SIDETIME = 0000H
     EMULATION BEGUN
```

20 MAINTIME equals 9.

21 MAINTIME equals 10 (0AH).

```
    EMULATION TERMINATED, CS:IP=0000:003CH
    EMULATION BEGUN

    •
    •
    •

    EMULATION TERMINATED, CS:IP=0000:0079H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0089H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:001FH
    STARTING MAIN LOOP
    EMULATION BEGUN

    •
    •
    •

    EMULATION TERMINATED, CS:IP=0000:0037H
    START OF IF TEST
20  LIGHTSTATUS = 0001H, CARSWAITING = 0001H
    MAINCYCLELENGTH = 0008H, MAINTIME = 0009H
    SIDECYCLELENGTH = 0005H, SIDETIME = 0000H
    EMULATION BEGUN

    •
    •
    •

    EMULATION TERMINATED, CS:IP=0000:0079H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0089H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:001FH
    STARTING MAIN LOOP
    EMULATION BEGUN

    •
    •
    •

    EMULATION TERMINATED, CS:IP=0000:0037H
    START OF IF TEST
21  LIGHTSTATUS = 0001H, CARSWAITING = 0001H
    MAINCYCLELENGTH = 0008H, MAINTIME = 000AH
    SIDECYCLELENGTH = 0005H, SIDETIME = 0000H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:003CH
    EMULATION BEGUN

    •
    •
    •

    EMULATION TERMINATED, CS:IP=0000:0079H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0089H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:001FH
    STARTING MAIN LOOP
    EMULATION BEGUN

    •
    •
    •
```

22 MAINTIME equals 11 (0BH).

23 MAINTIME equals 12 (0CH).

24 MAINTIME equals 13 (0DH).

```
    EMULATION TERMINATED, CS:IP=0000:0037H
    START OF IF TEST
22  LIGHTSTATUS = 0001H, CARSWAITING = 0001H
    MAINCYCLELENGTH = 0008H, MAINTIME = 000BH
    SIDECYCLELENGTH = 0005H, SIDETIME = 0000H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:003CH
    EMULATION BEGUN

    •
    •
    •

    EMULATION TERMINATED, CS:IP=0000:0079H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0089H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:001FH
    STARTING MAIN LOOP
    EMULATION BEGUN

    •
    •
    •

    EMULATION TERMINATED, CS:IP=0000:0037H
    START OF IF TEST
23  LIGHTSTATUS = 0001H, CARSWAITING = 0001H
    MAINCYCLELENGTH = 0008H, MAINTIME = 000CH
    SIDECYCLELENGTH = 0005H, SIDETIME = 0000H
    EMULATION BEGUN

    •
    •
    •


    •
    •
    •

    EMULATION TERMINATED, CS:IP=0000:0079H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0089H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:001FH
    STARTING MAIN LOOP
    EMULATION BEGUN

    •
    •
    •

    EMULATION TERMINATED, CS:IP=0000:0037H
    START OF IF TEST
24  LIGHTSTATUS = 0001H, CARSWAITING = 0001H
    MAINCYCLELENGTH = 0008H, MAINTIME = 000DH
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:003CH
    EMULATION BEGUN

    •
    •
    •

    EMULATION TERMINATED, CS:IP=0000:0079H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0089H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:001FH
    STARING MAIN LOOP
    EMULATION BEGUN
```

25 MAINTIME equals 14 (0EH).

26 MAINTIME equals 15 (0FH).

27 Finally, MAINTIME equals 16 or two times MAINCYCLELENGTH. This time the condition 'CARSWAITING = 1 AND MAINTIME >= 2 * MAINCYCLELENGTH' is TRUE and we should see a call to CYCLE at the end of the IF test.

```
       •
       •
       •

       EMULATION TERMINATED, CS:IP=0000:0037H
       START OF IF TEST
25     LIGHTSTATUS = 0001H, CARSWAITING = 0001H
       MAINCYCLELENGTH = 0008H, MAINTIME = 000EH
       SIDECYCLELENGTH = 0005H, SIDETIME = 0000H
       EMULATION BEGUN
       EMULATION TERMINATED, CS:IP=0000:003CH
       EMULATION BEGUN

       •
       •
       •

       EMULATION TERMINATED, CS:IP=0000:0079H
       EMULATION BEGUN
       EMULATION TERMINATED, CS:IP=0000:0089H
       EMULATION BEGUN
       EMULATION TERMINATED, CS:IP=0000:001FH
       STARTING MAIN LOOP
       EMULATION BEGUN

       •
       •
       •

       EMULATION TERMINATED, CS:IP=0000:0037H
       START OF IF TEST
26     LIGHTSTATUS = 0001H, CARSWAITING = 0001H
       MAINCYCLELENGTH = 0008H, MAINTIME = 000FH
       SIDECYCLELENGTH = 0005H, SIDETIME = 0000H
       EMULATION BEGUN

       •
       •
       •

       EMULATION TERMINATED, CS:IP=0000:0079H
       EMULATION BEGUN
       EMULATION TERMINATED, CS:IP=0000:0089H
       EMULATION BEGUN
       EMULATION TERMINATED, CS:IP=0000:001FH
       STARTING MAIN LOOP
       EMULATION BEGUN

       •
       •
       •


       •
       •
       •

       EMULATION TERMINATED, CS:IP=0000:0037H
       START OF IF TEST
27     LIGHTSTATUS = 0001H, CARSWAITING = 0001H
       MAINCYCLELENGTH = 0008H, MAINTIME = 0010H
       SIDECYCLELENGTH = 0005H, SIDETIME = 0000H
       EMULATION BEGUN
       EMULATION TERMINATED, CS:IP=0000:003CH
       EMULATION BEGUN
       EMULATION TERMINATED, CS:IP=0000:003EH
       EMULATION BEGUN
       EMULATION TERMINATED, CS:IP=0000:0040H
       EMULATION BEGUN
       EMULATION TERMINATED, CS:IP=0000:0045H
       EMULATION BEGUN
       EMULATION TERMINATED, CS:IP=0000:0046H
```

28 Address 7CH in the beginning of the conditional 'DO' loop.

29 Here is the beginning of CYCLE (0A7H). CYCLE is a loop controlled by the statement 'DO WHILE SIDETIME <= SIDECYCLELENGTH'; SIDECYCLELENGTH is 5, so the loop should exit when SIDETIME equals 6. We could have included ICE-88 commands in macro EXAM to examine CYCLE more closely (LIGHTSTATUS should be set to zero, and SIDETIME should increment on each iteration). In our example, however, we simply wait for CYCLE to return to the main program. The rest of the display on this page shows two iterations of CYCLE. We have omitted the printout of the remaining iterations.

```
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:004AH
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:004CH
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:004FH
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0050H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0052H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0053H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0058H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:005AH
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:005DH
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:005EH
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0062H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0064H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0066H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0068H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:006AH
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:006CH
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:006FH
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0070H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0072H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0073H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0075H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0077H
    EMULATION BEGUN
28  EMULATION TERMINATED, CS:IP=0000:007CH
    EMULATION BEGUN


29  EMULATION TERMINATED, CS:IP=0000:00A7H
    CALL CYCLE
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:00A8H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:00AAH
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:00AFH
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:00B4H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:00B8H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:00BCH
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:00C1H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:00C5H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0098H
    CALL DISPLAY
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:00CAH
```

30 Address 0DBH is the end of CYCLE. Two steps later, 07FH is the return address from the call to cycle.

```
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:00CBH
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:00DEH
   CALL DELAY
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:00D3H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:00B4H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:00B8H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:00BCH
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:00C1H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:00C5H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0098H
   CALL DISPLAY
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:00CAH
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:00CBH
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:00DEH
   CALL DELAY
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:00D3H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:00B4H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:00B8H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:00BCH
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:00C1H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:00C5H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:0098H
   CALL DISPLAY
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:00CAH

   •
   •
   •

   EMULATION TERMINATED, CS:IP=0000:0098H
   CALL DISPLAY
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:00CAH
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:00CBH
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:00DEH
   CALL DELAY
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:00D3H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:00B4H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:00B8H
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:00BCH
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:00BEH
   EMULATION BEGUN
   EMULATION TERMINATED, CS:IP=0000:00D6H
   EMULATION BEGUN
30 EMULATION TERMINATED, CS:IP=0000:00DBH
   EMULATION BEGUN
```

31 Here we are back at the start of the main loop.

32 The display of variables shows LIGHTSTATUS at 1 and CARSWAITING at zero. SIDETIME is 6 as we expected. MAINTIME is 1 and will continue to increment as long as we allow the program to emulate.

33 We consider this test "successful," and abort the emulation by pressing the ESC key.

34 Now to test the second condition. The macro call 'TEST 2' produces an expansion of macro TEST; this time CARSWAITING is set to 2. Otherwise, the expansion produces an executable macro identical to 'TEST 1' shown in step 4.

```
       EMULATION TERMINATED, CS:IP=0000:00DCH
       EMULATION BEGUN
       EMULATION TERMINATED, CS:IP=0000:007FH
       EMULATION BEGUN
       EMULATION TERMINATED, CS:IP=0000:0084H
       EMULATION BEGUN
       EMULATION TERMINATED, CS:IP=0000:0089H
       EMULATION BEGUN
       EMULATION TERMINATED, CS:IP=0000:001FH
31     STARTING MAIN LOOP
       EMULATION BEGUN
       EMULATION TERMINATED, CS:IP=0000:0023H
       EMULATION BEGUN
       EMULATION TERMINATED, CS:IP=0000:0098H
       CALL DISPLAY
       EMULATION BEGUN
       EMULATION TERMINATED, CS:IP=0000:0028H
       EMULATION BEGUN
       EMULATION TERMINATED, CS:IP=0000:0029H
       EMULATION BEGUN
       EMULATION TERMINATED, CS:IP=0000:00DEH
       CALL DELAY
       EMULATION BEGUN
       EMULATION TERMINATED, CS:IP=0000:0030H
       EMULATION BEGUN
       EMULATION TERMINATED, CS:IP=0000:0033H
       EMULATION BEGUN
       EMULATION TERMINATED, CS:IP=0000:0037H
       START OF IF TEST
32     LIGHTSTATUS = 0001H, CARSWAITING = 0000H
       MAINCYCLELENGTH = 0008H, MAINTIME = 0001H
       SIDECYCLELENGTH = 0005H, SIDETIME = 0006H
       EMULATION BEGUN
       EMULATION TERMINATED, CS:IP=0000:003CH
       EMULATION BEGUN
       EMULATION TERMINATED, CS:IP=0000:003EH
33     PROCESSING ABORTED
       *


34     *:TEST 2
       •*GO FROM .START TILL ..CARS#30 EXECUTED
       •*!CARSWAITING = 2
       •*:VARIABLES
       ••*WRITE 'LIGHTSTATUS =',!LIGHTSTATUS,', CARSWAITING = ',!CARSWAITING
       ••*WRITE 'MAINCYCLELENGTH =',!MAINCYCLELENGTH,', MAINTIME = ',!MAINTIME
       ••*WRITE 'SIDECYCLELENGTH =',!SIDECYCLELENGTH,', SIDETIME =',!SIDETIME
       ••*EM         ;END OF MACRO VARIABLES
       •*:EXAM
       ••*REPEAT
       •••*STEP
       •••*IF CS =SEG(.DISPLAY) AND IP = OFF(.DISPLAY) THEN
       ••••*WRITE 'CALL DISPLAY'
       ••••*:POP88 IP                  ;RESTORE RETURN ADDRESS
       •••••*IP = WORD SS:SP      ;POP PARAMETER OFF STACK
       •••••*SP = SP + 2T         ;MOVE POINTER TO NEW TOP OF STACK
       •••••*EM                   ;END OF MACRO POP88
       ••••*SP = SP + 2T               ;DISCARD PARAMETER
       ••••*ORIF CS = SEG(.DELAY) AND IP = OFF(.DELAY) THEN
       ••••*WRITE 'CALL DELAY'
       ••••*:POP88 IP
       •••••*IP = WORD SS:SP      ;POP PARAMETER OFF STACK
       •••••*SP = SP + 2T         ;MOVE POINTER TO NEW TOP OF STACK
       •••••*EM                   ;END OF MACRO POP88
       ••••*SP = SP + 2T
       ••••*ORIF CS = SEG(..CARS#30) AND IP = OFF(..CARS#30) THEN
       ••••*WRITE 'STARTING MAIN LOOP'
       ••••*ORIF CS = SEG(..CARS#34) AND IP = OFF(..CARS#34) THEN
       ••••*WRITE 'START OF IF TEST'
       ••••*:VARIABLES
       •••••*WRITE 'LIGHTSTATUS = ',!LIGHTSTATUS,', CARSWAITING = ',!CARSWAITING
       •••••*WRITE 'MAINCYCLELENGTH = ',!MAINCYCLELENGTH,', MAINTIME = ',!MAINTIME
```

35 We emulate to the start of the main loop, as before. This time CARSWAITING is 2, and we should CALL CYCLE as soon as MAINTIME equals 8. We omit the intermediate steps.

36 MAINTIME is 8, equal to MAINCYCLELENGTH.

```
     •••••*WRITE 'SIDECYCLELENGTH = ',!SIDECYCLELENGTH,', SIDETIME = ',!SIDETIME
     •••••*EM       ;END OF MACRO VARIABLES
     ••••*ORIF CS = SEG(.CYCLE) AND IP = OFF(.CYCLE) THEN
     ••••*WRITE 'CALL CYCLE'
     ••••*ENDIF
     •••*ENDREPEAT
     ••*EM       ;END OF MACRO EXAM
35   EMULATION BEGUN
     EMULATION TERMINATED, CS:IP=0000:0023H
     LIGHTSTATUS = 0001H, CARSWAITING = 0002H
     MAINCYCLELENGTH = 0008H, MAINTIME = 0000H
     SIDECYCLELENGTH = 0005H, SIDETIME = 0006H
     EMULATION BEGUN
     EMULATION TERMINATED, CS:IP=0000:0098H
     CALL DISPLAY
     EMULATION BEGUN
     EMULATION TERMINATED, CS:IP=0000:0028H
     EMULATION BEGUN
     EMULATION TERMINATED, CS:IP=0000:0029H
     EMULATION BEGUN
     EMULATION TERMINATED, CS:IP=0000:00DEH
     CALL DELAY
     EMULATION BEGUN
     EMULATION TERMINATED, CS:IP=0000:0030H
     EMULATION BEGUN
     EMULATION TERMINATED, CS:IP=0000:0033H
     EMULATION BEGUN
     EMULATION TERMINATED, CS:IP=0000:0037H
     START OF IF TEST
     LIGHTSTATUS = 0001H, CARSWAITING = 0002H
     MAINCYCLELENGTH = 0008H, MAINTIME = 0001H
     SIDECYCLELENGTH = 0005H, SIDETIME = 0006H
     EMULATION BEGUN
     EMULATION TERMINATED, CS:IP=0000:003CH
     EMULATION BEGUN

     •
     •
     •

36   START OF IF TEST
     LIGHTSTATUS = 0001H, CARSWAITING = 0002H
     MAINCYCLELENGTH = 0008H, MAINTIME = 0008H
     SIDECYCLELENGTH = 0005H, SIDETIME = 0006H
     EMULATION BEGUN
     EMULATION TERMINATED, CS:IP=0000:003CH
     EMULATION BEGUN
     EMULATION TERMINATED, CS:IP=0000:003EH
     EMULATION BEGUN
     EMULATION TERMINATED, CS:IP=0000:0041H
     EMULATION BEGUN
     EMULATION TERMINATED, CS:IP=0000:0045H
     EMULATION BEGUN
     EMULATION TERMINATED, CS:IP=0000:0046H
     EMULATION BEGUN
     EMULATION TERMINATED, CS:IP=0000:004AH
     EMULATION BEGUN
     EMULATION TERMINATED, CS:IP=0000:004CH
     EMULATION BEGUN
     EMULATION TERMINATED, CS:IP=0000:004FH
     EMULATION BEGUN
     EMULATION TERMINATED, CS:IP=0000:0050H
     EMULATION BEGUN
     EMULATION TERMINATED, CS:IP=0000:0052H
     EMULATION BEGUN
     EMULATION TERMINATED, CS:IP=0000:0053H
     EMULATION BEGUN
     EMULATION TERMINATED, CS:IP=0000:0058H
     EMULATION BEGUN
     EMULATION TERMINATED, CS:IP=0000:005AH
     EMULATION BEGUN
     EMULATION TERMINATED, CS:IP=0000:005CH
```

37 And here's the beginning of CYCLE. Once more we omit the steps in CYCLE from the test.

38 This is the end of CYCLE, and the return to the main program.

39 Back to the start of the main loop.

```
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:005EH
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0062H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0064H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0066H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0068H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:006AH
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:006CH
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:006EH
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0070H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0072H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0073H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0075H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0077H
    EMULATION BEGUN
37  EMULATION TERMINATED, CS:IP=0000:007CH
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:00A7H
    CALL CYCLE
    EMULATION BEGUN

    •
    •
    •

    EMULATION TERMINATED, CS:IP=0000:00B8H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:00BCH
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:00BEH
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:00D6H
    EMULATION BEGUN
38  EMULATION TERMINATED, CS:IP=0000:00DBH
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:00DCH
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:007FH
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0084H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0089H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:001FH
39  STARTING MAIN LOOP
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0023H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0098H
    CALL DISPLAY
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0028H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0029H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:00DEH
    CALL DELAY
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0030H
```

40 We consider this test "successful," abort emulation, and exit from the ICE-88 emulator back to ISIS-II (hyphen prompt).

```
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0033H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:0037H
    START OF IF TEST
40  LIGHTSTATUS = 0001H, CARSWAITING = 0000H
    MAINCYCLELENGTH = 0008H, MAINTIME = 0001H
    SIDECYCLELENGTH = 0005H, SIDETIME = 0006H
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:003CH
    EMULATION BEGUN
    EMULATION TERMINATED, CS:IP=0000:003EH
    PROCESSING ABORTED
    *
    *EXIT
```

CHAPTER 4 ELEMENTS OF THE ICE-88™ COMMAND LANGUAGE

Introduction

The ICE-88 software provides you with an easy-to-use English language command set for controlling ICE-88 emulator execution in a variety of functional modes.

The commands enable you to:

- Initialize the ICE-88 system; map your program to memory in your system, ICE-88 memory, disk memory, or in the Intellec Microcomputer Development System; and load your program from a diskette file.
- Specify starting and stopping conditions for emulation.
- Execute real-time emulation of your software (and hardware).
- Execute single-step emulation.
- Specify conditions for trace data collection.
- Collect and display trace data on conditions occurring during emulation.
- Display and alter 8088 registers, memory locations, and I/O ports.
- Copy the (modified) program from mapped memory to a diskette file, and exit the ICE-88 system.

An example of one complete command, in this case one of the forms of the GO command, is shown in figure 4-1. This command causes emulation to start and specifies the conditions that will halt emulation. The command is made up of ten separate "words" (character strings that are referred to as tokens): GO, FROM, 0123H, TILL, 1000H, TO, 1100H, READ, USING, and CS. Each of these tokens provides a particular element of information necessary to inform the ICE-88 emulator of the specific command functions (see table 4-1). The tokens also form the following command components: the FROM clause, match-range, match-status, segment-register-usage, match-condition, and TILL clause. This string of tokens requests the ICE-88 emulator to "start emulation at location 0123H and to continue emulation until data is read from any memory location within the match-range (partition) of addresses 1000H through 1100H using the CS segment register in the effective address calculation." Each command is composed of one or more such tokens.

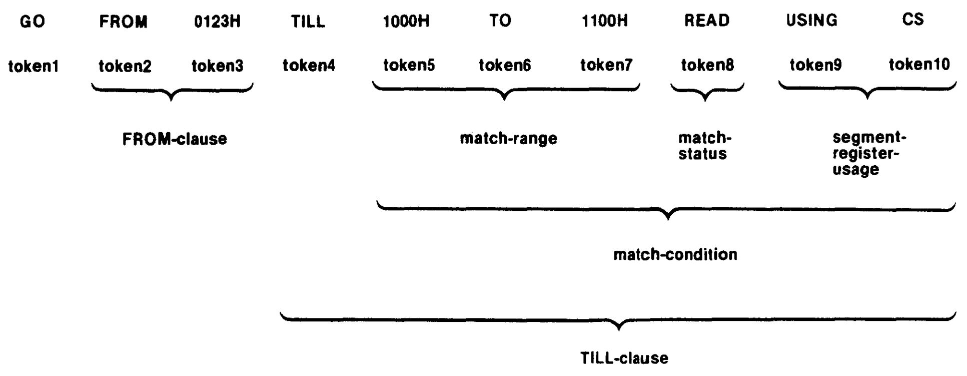


Figure 4-1. Example of a GO Command

Table 4-1. Definition of GO Command Functions

Token Number	Name	Function
1	GO	GO command specifier; requests and initiates emulation.
2	FROM	Indicates that the next token or expression is the starting address for emulation.
3	0123H	Starting address in hexadecimal radix.
2,3	FROM clause	FROM 0123H causes the instruction pointer (IP) to be loaded with 0123H, the starting address for emulation. Also, the code segment register (CS) is loaded with 0.
4	TILL	Indicates that the breakpoint (halting) parameters are to follow.
5	1000H	Specifies the lowest address of a range of memory locations. This parameter is the lower bound of a memory partition.
6	TO	Indicates that the upper bound (address) of the range (partition) of memory locations is to follow.
7	1100H	Specifies the highest address of the range of memory locations.
5,6,7	match-range	Emulation is to halt if an access to any memory location whose address falls within the range of 1000H to 1100H.
8	READ	Emulation is to halt if any of the above memory locations are read.
9	USING	Indicates a segment register is to follow.
10	CS	The code segment register(CS) must be used in the effective address calculation in order to match.
9,10	segment-register-usage	Emulation is to halt if the CS is used.
5 thru 10	match-condition	Emulation is to halt if data is read from any memory location in the match-range.
4 thru 10	TILL clause	TILL 1000H TO 1100H READ USING CS specifies that the emulation is to halt whenever the match-condition is met. This clause is also called the "GO-register" in the ICE-88 language.

Note: The match-condition consists of the three sub-conditions: match-range (tokens 5,6,7), match-status (token 8), and segment-register-usage (tokens 9,10). All three of these conditions must be matched for emulation to halt.

As briefly indicated in figure 4-1, the commands are written in an ICE-88 command language composed of a unique character set and vocabulary of tokens augmented by a particular set of syntactic rules. The tokens are constructed from the character set and in turn are used to construct commands. The tokens consist of a set of predefined literals augmented by user-defined literals that provide symbolic references. Table 4-1 contains the definition of each token shown in figure 4-1.

The purpose of this chapter is to present a detailed specification of the ICE-88 command language. The language consists of two parts, a vocabulary that is used to convey elements of information to the ICE-88 emulator and a "grammar" (syntactic rules) used to group command words into command constructs such as the FROM clause shown in figure 4-1. The remainder of this chapter is devoted to the presentation of the command language. The initial discussion deals with class-names and the notation used to describe the language and will include a listing of the syntactic rules that govern command construction. This will be followed by a presentation of the command literals (keywords) and a discussion of symbolic references.

Notation and Conventions Used in This Manual

This manual employs a set of notational symbols and conventions to describe the structure of commands and other language constructs. The features of this notation are described in the following paragraphs. Table 4-2 contains the notational symbols used to define and describe the command structures.

Table 4-2. Notational Symbols

Symbol	Meaning
≡	"is defined as"
::	Mutual exclusion
...	May be repeated indefinitely
{ } ...	At least one entry must be selected. If more than one entry is selected, they may be selected in any order.
{ }	One of the enclosed entries must be selected.
[ ]...	Selection of the enclosed entries is optional. If more than one entry is selected, they may be selected in any order.
[ ]	Selection of the enclosed entries is optional but only one entry may be selected. If this symbol encloses only one entry, that entry is optional.

In addition to the above notational symbols, a set of class-names is used to assist in the definition and description of entities in the ICE-88 command language. Each class-name is an identifier for a specific set of characters, mnemonics, or constructs, and is always shown in *lower-case italics*. Any character string not in lower-case italics is a specific character, mnemonic or construct. For example, the class-name *segment-register* refers to the entire class of segment registers. The character string CS refers to the Code Segment Register, which is one of the four segment registers.

As shown in figure 4-1, the smallest meaningful unit of information contained within a command is a mnemonic character string that is the equivalent of a word. Examples are: GO, 0123H, and FROM. These mnemonics are assigned the class-name: *token*. In addition to these basic elements, the tokens are combined into multi-token forms such as the FROM clause and match-condition shown in figure 4-1.

The ICE-88 vocabulary is made up of two classes of mnemonics: *tokens* and *special- tokens:*

token ≡ *constant* ∷ *keyword* ∷ *symbol* ∷ *string* ∷ *operand*
special-token ≡ *operator* ∷ *punctuation-mark* ∷ *delimiter* ∷ *terminator*

The notational symbol (∷) specifies mutual exclusion. That is, a token is a *constant* or *keyword* or *symbol* or *string* or *operand*.

Each of the above classes of tokens and special-tokens is defined later in this chapter or in the next chapter in the discussion of expressions.

Syntactic Rules Used in the Manual

This manual employs a set of conventions to describe the structure of commands and other ICE-88 language forms. Items 1 and 2 below specify the use of class-names and tokens respectively. The features of this notation system are as follows:

1. A *lower-case italicized* entry in the description of a command is the class-name for a set or class of tokens. To create an actual operable command, you must enter a particular member of this class. A class-name never appears in an actual operable command. For example, the lower-case entry:

   breakpoint-register

   means that the command will accept any of the three tokens: BR0, BR1 or BR (BR means BR0 and BR1). Classes of tokens that have generalized usage, such as the classes of reference keywords and command keywords, are explained and assigned class-names in this chapter. Additional classes of tokens that appear in the syntax descriptions of particular commands are explained in the discussion of semantics that accompanies those commands.

2. An upper-case entry is a token that must be used literally as given. A valid abbreviation of that token may substitute for the full token as given. The token may be a command word, or it may be a particular member of a class of references. For example, the upper-case entry

   DEFINE

   is a command word that must be used as given unless abbreviated. The abbreviation DEF may be used in place of DEFINE. As another example, the upper-case entry

   BR1

   means that breakpoint register 1 must be named as and where given.

3. A single required entry is shown without any enclosures, whereas a single optional entry is denoted by enclosing in brackets. For example, in the command syntax

   STEP [FROM *address*]

   the token STEP is required. The significance of the brackets around the entry: FROM *address* means that its selection is optional in this command.

4. Where only one entry must be selected from a menu of two or more entries, the choices for the required entry are denoted by enclosing them in braces. For example,

$$\text{TRACE} = \begin{Bmatrix} \text{FRAME} \\ \text{INSTRUCTION} \end{Bmatrix}$$

indicates that FRAME or INSTRUCTION must be selected; the tokens TRACE and = are required as given.

5. An optional entry is enclosed in brackets [ ]. For example,

STEP [FROM *address*]

means that the commmand word STEP is required but the clause FROM *address* is optional in this command.

Where a choice exists for an optional entry, the choices are given in a vertical arrangement enclosed in brackets. For example, the command

$$\text{DEFINE [module-name] symbol = expr} \begin{bmatrix} \text{OF BYTE} \\ \text{OF WORD} \\ \text{OF SINTEGER} \\ \text{OF INTEGER} \\ \text{OF POINTER} \end{bmatrix}$$

means that DEFINE, *symbol*, =, and *expr* are required in this command and *module-name* is optional. The brackets around the vertical arrangement of memory type designators denotes that selection of a memory type designator is optional but only one designator may be selected per DEFINE command.

6. A group of required inclusive choices is given in a vertical arrangement and enclosed in braces ($\{\ \}$) followed by a repeat symbol (...). "Inclusive" means that more than one of the items can be entered in the same command, and items can appear in any order; no item can be entered more than once. The menu of inclusive items represents a required entry or entries. For example:

$$\textit{match-status-list} \equiv \begin{Bmatrix} \text{READ} \\ \text{WRITTEN} \\ \text{INPUT} \\ \text{OUTPUT} \\ \text{FETCHED} \\ \text{HALT} \\ \text{ACKNOWLEDGE} \end{Bmatrix}, \ldots$$

This notation indicates that one or more items from the vertical list is required to specify a match-status-list. If more than one item is used, they can be in any order and must be separated by commas.

To complete the example:

WRITTEN, HALT, READ, FETCHED

is a valid match-status-list.

7. A group of optional inclusive choices is given in a vertical arrangement and enclosed in brackets and followed by a repeat symbol (...). "Inclusive" means that more than one of the items can be entered in the same command, and the items can appear in any order; no item can be used more than once. The menu of inclusive items represent an optional entry or entries. For example:

   $$\text{LOAD } \textit{path-name} \begin{bmatrix} \text{NOCODE} \\ \text{NOSYMBOL} \\ \text{NOLINE} \end{bmatrix} \ \ldots$$

   This notation indicates that none, one, or more than one choice of NOCODE, NOSYMBOL, and/or NOLINE may be included in one LOAD command; if more than one is used, the entries can be in any order.

   To complete the example:

   ```
   LOAD :F0:TEST NOSYMBOL NOCODE NOLINE
   ```

   is a valid command.

8. Where mutually exclusive entries can be shown on one line, the following shorthand notation can be used:

   ```
   SUFFIX = Y :: O :: Q :: T :: H
   ```

   This example is equivalent to

   $$\text{SUFFIX} = \begin{Bmatrix} \text{Y} \\ \text{O} \\ \text{Q} \\ \text{T} \\ \text{H} \end{Bmatrix}$$

9. Where an entry can be repeated indefinitely at the user's option, the syntax is notated by enclosing the repeatable entry in brackets [ ] followed by an ellipsis ... . For example,

   operand [*operator operand*] ...

   indicates that *operator operand* can be repeated as many times as desired.

Character Set

The valid characters in the ICE-88 command language include upper and lower case alphabetic ASCII characters A through Z and the set of digits 0 through 9. The space serves as a delimiter for tokens, and carriage-return/line-feed characters are also valid, delimiting command lines. A question mark, ?, @ sign, $ sign, and underscore (_) are also valid in user-defined names entered in the command language.

The *algebraic operators* + and − (binary and unary), the asterisk (*), slash (/), *relational operators* (=, <, >), the ampersand, semicolon, colon, period, parentheses, exclamation mark (!), pound sign (#), percent sign (%) and comma, constitute the only other valid ASCII characters for the ICE-88 emulator. Nonprinting characters are ignored, except tabs, form feed, etc. are treated as spaces. Other characters are errors.

alphabetic characters:

ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz@?_

numeric characters:

0 1 2 3 4 5 6 7 8 9 (A B C D E F: hexadecimal characters)

special characters:

+ − < = > $ ' &) . (; * / # ! : , %

This character set is used to construct the vocabulary that constitutes the command language.

Introduction to Tokens

A *token* in the ICE-88 command language is roughly equivalent to a "word" in the English language. It consists of a string of alphanumeric characters that may be augmented by a one or two special character prefix that serves as a *token identifier.* Tokens are divided into the following types: *keywords, user-names,* and *special-tokens.* Examples are:

REGISTERS, .START, ..MODULE, .SAM, 0400, 123AH.

Keywords

The ICE-88 emulator recognizes a general class of predefined *tokens* that are fixed in the command language. They provide two functions. *Reference keywords* are used to specify locations having unique predefined functions. *Command keywords* specify command type and subfunctions within a command. The following sections define and describe these keyword classes. Each class and associated keyword set is presented in the following paragraphs. Appendix A contains a listing of ICE-88 keywords and their abbreviations.

The reason for discussing the various classes and subsets here is to smooth the later discussions of commands, where the class-names are used to show what elements may appear in which commands.

Reference Keywords

The command language contains a set of system defined mnemonic *tokens* that are used to address system objects. Each device such as the accumulator or a register is assigned a specific mnemonic that is to be used to address and access the contents of that device. These identifiers are called *reference keywords. Reference keywords* are used in commands to refer to 8088 processor registers and flags, emulation registers, memory locations, and I/O ports.

The total set of *reference keywords* is subdivided by types, each of which is referenced by a class name. Class names are always shown in lower case italics. For example, the class name *general-register* denotes the set of four 16-bit general work registers in the 8088 processor. A reference keyword is assigned to each element within the given class and is always shown in upper case. For example, "RAX" denotes the contents of the accumulator (RAX register) of the general register set.

Registers

The 8088 register structure contains three files of four 16-bit registers, a set of miscellaneous registers, and a set of four pseudo-registers. The three files of registers are the general register file, the pointer and index file, and the segment register file (see table 4-3). The miscellaneous set consists of the instruction pointer, flag register, CAUSE register, OPCODE register, PIP register, TIMER register, HTIMER register, BUFFERSIZE register, LOWER register, and UPPER register. The pseudo-register set consists of the breakpoint and trace point registers. The miscellaneous register set and the pseudo-registers provide a variety of functions to the ICE-88 emulator that are described in the appropriate command sections of this manual. The register structures are described in the following paragraphs.

Table 4-3. Classes of Hardware Elements

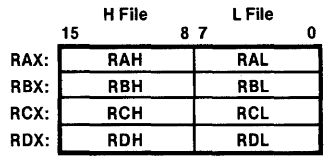
Class Name	Hardware Elements
general-register	8-bit and 16-bit work register
pointer-register	16-bit address register
index-register	16-bit address register
segment-register	16-bit segment reference register
status-register	8 and 16-bit status registers
emulation-register	breakpoint and tracepoint registers

General Register File. The RAX, RBX, RCX, and RDX registers compose the General Register File. These registers participate interchangeably in 8088 arithmetic and logical operations. These registers are assigned the following mnemonics:

RAX:	Accumulator
RBX:	Base Register
RCX:	Count Register
RDX:	Data Register

Note: these are the 8088 AX, BX, CX, DX registers (i.e., the ICE-88 software requires 'R' to be prefixed to the 8088 names).

The general registers are unique within the 8088 as their upper and lower bytes are individually addressable. Thus, each of the general registers contains two 8-bit register files called the H file and L file as illustrated below.

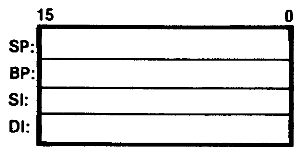


General Register File

Pointer and Index Register File. The BP, SP, SI, and DI registers are called the Pointer and Index Register File. The registers in this group are similar in that they generally contain offset addresses used for addressing within a segment. They can participate interchangeably in 16-bit arithmetic and logical operations and can also be used in address computation. The mnemonics associated with these registers are:

SP:	Stack Pointer
BP:	Base Pointer
SI:	Source Index
DI:	Destination Index

The pointer and index registers are illustrated below.



Point and Index Register File

Segment Register File. The CS, DS, SS, and ES registers constitute the Segment Register File. These registers provide a significant function in the memory addressing mechanisms of the 8088. They are similar in that they are used in all memory address computations. The mnemonics associated with these registers are:

CS:	Code Segment Register
DS:	Data Segment Register
SS:	Stack Segment Register
ES:	Extra Segment Register

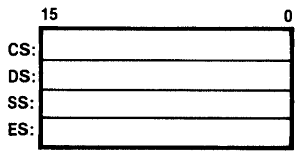
The contents of the CS register define the current code segment. All instruction fetches are taken to be relative to CS using the instruction pointer (IP) as an offset.

The contents of the DS register define the current data segment. All data references except those involving BP, SP, or DI in a string instruction are taken by default to be relative to DS.

The contents of the SS register define the current stack segment. All data references which implicitly or explicitly involve SP or BP are taken by default to be relative to SS.

The contents of the ES register define the current extra segment. The extra segment has no specific use, although it is usually treated as an additional data segment.

The segment registers are illustrated below



Segment Register File

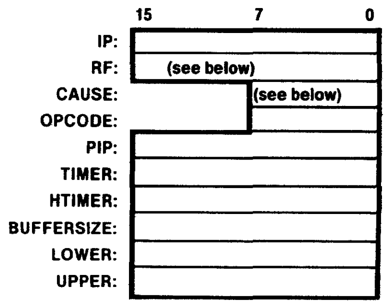
Status Registers

The instruction pointer, flag register, CAUSE register, OPCODE register, PIP register, TIMER register, HTIMER register, BUFFERSIZE register, LOWER register, and UPPER register, constitute the status register set. These registers provide a variety of functions to the ICE-88 emulator. These registers are assigned the following mnemonics:

IP: Instruction Pointer
RF: Flag Register
CAUSE: CAUSE Register
OPCODE: OPCODE Register
PIP: Previous Instruction Register
TIMER: TIMER Register
HTIMER: HTIMER Register
BUFFERSIZE: BUFFERSIZE Register
LOWER: LOWER Register
UPPER: UPPER Register

The contents of the IP register define the offset to the CS register in instruction address computations. The Flag Register contains the status flag values in the same format as that pushed by the 8088 PUSHF instruction. The CAUSE register retains the cause of the last break in emulation and the OPCODE register stores the opcode fetched in the last instruction-fetch cycle in trace data. The Previous Instruction Register stores the displacement part of the address of the last instruction-fetch in trace data. TIMER contains the low-order 16 bits of the 2-MHz timer indicating how long emulation has run (read only). HTIMER contains the high-order 16 bits of the timer (read-only). BUFFERSIZE contains the count (displayed in decimal only) of frames of valid trace data collected in the trace buffer (16 bit, read-only). LOWER contains the lowest available address in Intellec memory above the ICE-88 software (16 bit, read-only). UPPER contains the highest available address in Intellec system memory below the user's symbol table (16 bit, read-only).

The status registers are illustrated below.



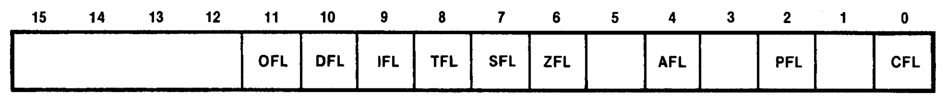
Status Registers

The Flag Register contains nine status bits. The following mnemonics are assigned to each of the status values in the register:

AFL:	Auxiliary-carry out of low byte to high byte
CFL:	Carry or borrow out of high bit
DFL:	Direction of string manipulation instruction
IFL:	Interrupt-enable (external)

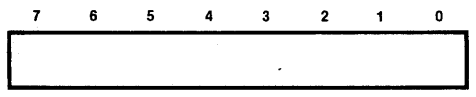
OFL: Overflow flag for signed arithmetic
PFL: Parity
SFL: Sign of the result of an operation
TFL: Trap used to place processor in single step mode for debug
ZFL: Zero indicates a zero value result of an instruction

AFL is set if an instruction caused a carry out of bit 3 and into bit 4 of a resulting value. CFL is set if an instruction caused a carry or a borrow out of the high order bit. DFL controls the direction of the string manipulation instructions. IFL enables or disables external interrupts. OFL denotes an overflow condition in a signed arithmetic operation. SFL indicates the sign of the result of an operation. TFL places the processor in a single-step mode for program debugging. ZFL indicates a zero valued result of an instruction. The positions of the status bits in the RF Register are shown below.



Flag Register

The CAUSE Register stores the cause for the last break in emulation. The contents of this register are defined below.



Cause Register

The byte returned by the "Read Break Cause" hardware command contains the following bit values (if bit = 1, then the specified condition is true, otherwise false):

Bit Position	Condition
0	Breakpoint 0 matched
1	Breakpoint 1 matched
2	Both breakpoints matched sequentially
3	Guarded memory access occurred
4	User aborted processing
5	Timeout on user READY
6	Timeout on user HOLD

8088 Pin References

The ICE-88 emulator provides access to seven 8088 pins. The pin names reference 1-bit values. Pin names are read-only references only. The following mnemonics are assigned to reference the 8088 processor pins shown below.

Mnemonic	8088 Pin	Meaning
RDY	READY	Acknowledgement from addressed memory or I/O device that it has completed data transfer.
NMI	NMI	Non-maskable interrupt.

TEST	TEST	Used by the wait-for-signal instruction for processor synchronization purposes.
HOLD	HOLD	Request for local bus "hold."
RST	RESET	Causes processor to immediately terminate present activity.
MN	MN/$\overline{MX}$	Specifies minimum/maximum configuration (1 = minimum).
IR	INTR	Maskable interrupt request.

Emulation Registers

The emulation registers consist of the breakpoint registers and the trace registers.

Type	Class Name	Keywords
Breakpoint register	*break-reg*	BR0, BR1, BR
Trace point register	*trace-reg*	ONTRACE, OFFTRACE
GO register	*go-reg*	GR

The term *break-reg* is the class name for the two breakpoint registers used to halt emulation. The term *trace-reg* is the class name for the two registers that control tracing. The term *go-reg* refers to the GO-register, an ICE-88 pseudo-register that controls the breaking of real-time emulation.

Command Keywords

The command keywords specify command types and command functions to be executed. ICE-88 commands are of three major types: simple commands, compound commands, and macro commands. The following sections define the associated command formats and illustrate the use of keywords in each of the command types. Each of the formats is specified and illustrated by example using appropriate command keywords. The full vocabulary of command keywords is presented following the command descriptions.

Simple Commands

Simple commands are of one of three types.

- Set/change commands
- Display commands
- Execution commands

The following sections describe the formats and provides examples of each of these simple commands.

Set/Change Commands. The set/change commands have the following format:

item-type [*item-qualifier*]... = *new-setting*

where

item-type	A keyword or user name of an alterable element.
item-qualifier	A keyword, user name or value used to provide further specification of the particular element that is to be set or altered.
new-setting	The value that the specified item is to be set to.

Examples:

```
BR0 = 1000H EXECUTED
BYTE 10FFH = 3AH
..MOD1 .SYMBA .SYMBB = 10FFH
```

Display Commands. The display commands have the following format:

item-type [*item-qualifier*]...

where

item-type	A keyword or user name of a displayable element or set of displayable elements.
item-qualifier	A keyword, user name or value used to provide further specification of the particular element(s) to be displayed.

Examples:

```
BR0
BYTE 10FFH
..MOD1.SYMBA.SYMBB
REGISTER
RAX
FLAG
STACK 10
```

Execution Commands. The execution commands have the following format:

command-verb [*command-parameter*]...

where

command-verb	A command keyword that describes an action that is to be performed.
command-parameter	A keyword that specifies the objects of the action denoted by the *command-verb.*

Examples:

```
GO
GO FROM .START
GO FROM .START TILL 1000H EXECUTED
TRACE
PRINT ALL
PRINT 10
MOVE -10
```

Compound Commands

Complete description of the formats of the compound commands and the use of keywords with these commands is contained in Chapter 8.

Macro Commands

Complete description of the formats of the macro commands and the use of keywords with these commands is contained in Chapter 8.

Utility Command Keywords

The Intel Systems Implementation Supervisor (ISIS-II) is the diskette operating system for the Intellec Microcomputer Development System. The ICE-88 emulator runs under ISIS-II control, and can call upon ISIS-II for file management functions through the utility commands. These commands employ the following command keywords:

Keyword	Function
EXIT	Commands control to be returned to ISIS-II.
LIST	Commands emulation output to be copied to printer or file.
LOAD	Commands user program to load into memory accessed by the ICE-88 emulator.
NOCODE	A Modifier specifying that program code is not to be saved.
NOLINE	A Modifier specifying that the line number table is not to be saved.
NOSYMBOL	A Modifier specifying that the symbol table is not to be saved to diskette.
SAVE	Commands user program to be saved on an external device.

Number Base and Radix Commands

The ICE-88 emulator commands and displays involve several different number bases (radixes). This section describes the command keywords and radixes used to control the number base.

Keyword	Function
BASE	Set or display console output radix.
SUFFIX	Set or display console input radix.
EVALUATE	Commands a numeric constant or expression to be displayed in all five possible output radixes.
H	Hexadecimal (base 16).
O	Octal (base 8).
Q	Octal (base 8).
T	Decimal (base 10).
Y	Binary (base 2).
ASCII	ASCII character code.

Memory Mapping Command Keywords

These commands display, declare, set or reset the ICE-88 memory mapping. The ICE-88 emulator uses these maps to determine what memory is installed on a prototype system and what memory resources are being "borrowed" from the Intellec system and ICE-88 emulator for testing purposes. These commands employ the following keywords:

Keyword	Function
DISK	Maps logical memory segments into a diskette file.
GUARDED	Declares memory segments to be guarded. Accesses to addresses in these segments are error conditions.
ICE	Maps memory segments into ICE "real-time" memory.
INTELLEC	Maps memory segments to expanded Intellec memory.
MAP	Commands the ICE-88 emulator to display, declare, set, or reset memory mapping.
NOVERIFY	Specifies that the normal read-after-write verification of data loaded into memory be suppressed.
RESET	Resets the memory mapping.
USER	Maps logical segments into user's prototype memory.

Hardware Register Command Keywords

This section presents the keywords used in the ICE-88 emulator to specify and modify hardware register commands.

Keyword	Function
CLOCK	Command keyword indicating that a system clock specification is to follow.
DISABLE	Command keyword indicating that a command function is to be disabled.
DONE	Command modifier setting timeout on DONE.
ENABLE	Command keyword indicating that a command function is to be enabled.
ERROR	Command modifier specifying that an error is to be reported whenever the command signal times out.
EXTERNAL	The ICE-88 emulator is to operate from an external (user-provided) clock.
FLAG	Contents of the 9 flags are to be displayed.
HARDWARE	Reset command modifier, causes a hardware reset.
INFINITE	Set command signal timeout to "infinite," disabling timeout.
INTERNAL	The ICE-88 emulator is to operate from an internal (8088-provided) clock.
NOERROR	Specifies that the command signal is not to halt emulation.
PIN	Contents of the six 8088-input pins are to be displayed.
REGISTER	Contents of the thirteen 16-bit 8088 registers and RF are to be displayed.
RWTIMEOUT	Used to enable or disable memory access timeout.

Memory and Port Contents Command Keywords

These commands give access to the content or current value stored in designated memory locations or input/output ports.

Keyword	Function
ABSOLUTE	Display all addresses as 20-bit numbers.
BASE	Display all addresses in base and displacement format.
BOOL	Display expression as a boolean value.
BYTE	1-byte, unsigned integer value
INTEGER	2-byte, signed value
LENGTH	Indicates that an integer value denoting the length of a partition is to follow.
ASM	Indicates that a range of memory is to be disassembled into 8088 assembly language mnemonics.
NESTING	Indicates that the starting and return addresses of all currently active procedures are to be displayed.
POINTER	4-byte, pointer value
PORT	Reference to 8-bit I/O ports.
SINTEGER	1-byte, signed integer value.
STACK	Indicates that words from the user's stack is to be displayed.
SYMBOLICALLY	Causes each numeric value output to be displayed as a symbol or source statement number plus a remainder.
WORD	2-byte, unsigned integer value.
WPORT	Reference to 16-bit I/O ports.

Symbol Table and Statement Number Table Command Keywords

The ICE-88 emulator maintains a symbol table and source program statement number table to enable the user to refer to memory addresses and other values by using symbolic references and statement number references in ICE-88 commands. The following are command keywords contained in these commands:

Keyword	Function
DEFINE	Command keyword used to define a symbol.
DOMAIN	Keyword used to establish a default module for source statement number references.
LINE	Specifies the display of all of the source statement number table.
MODULE	Command modifer for the ICE-88 module table.
OF	Specifies that a memory type designation is to follow.
REMOVE	Specifies that symbolic reference(s) is/are to be deleted.
SYMBOL	Command modifier for the entire ICE-88 symbol table.
TYPE	Indicates an assignment or change of memory type to a symbolic reference.

Emulation Control Command Keywords

The emulation control commands permit the user to specify the starting address where emulation is to begin, and to specify and display the software or hardware conditions for halting emulation and returning control to the console for further commands. These commands employ the following keywords:

Keyword	Function
ACKNOWLEDGE	Match on 8088 interrupt acknowledge.
AND	Indicates a match on both breakpoint registers required to halt emulation.
DOWN	Less than or equal to the referenced address or data value.
EXECUTED	An instruction fetch out of the execution queue.
FOREVER	All break conditions disabled.
FETCHED	Memory read into the execution queue.
FROM	Keyword introducing a starting address.
GO	Command keyword that starts emulation.
HALT	8088 processor halt.
INPUT	I/O port read.
LOCATION	Denotes the following constant or expression to be an address.
OR	Indicates that a match on either breakpoint register will halt emulation.
OBJECT	Indicates that a memory reference or typed memory reference is to follow.
OUTPUT	I/O port write.
READ	Memory read.
STEP	Single-step emulation command.
TILL	A keyword introducing one or more match or halt conditions.
UP	Greater than or equal to the referenced address or data value.
USING	Indicates that a segment register is to be specified.
VALUE	Denotes the following constant or expression to be a data value.
WRITTEN	Memory write.

Trace Control Commands

The trace control commands allow the user to display or change the match condition in either or both of two tracepoint registers and to establish a tracepoint to conditionally start and stop trace collection. These commands employ the following keywords:

Keyword	Function
ADDR	20-bit address in hexadecimal format.
ALL	A function keyword indicating that the entire trace buffer contents are to be displayed.
CONDITIONALLY	Indicates trace is to be turned on when ONTRACE matches and turned off when OFFTRACE matches.
DMUX	Type of frame.
FRAME	Indicates that a trace reference is to follow or that the trace buffer is to be displayed frame by frame.
INSTRUCTION	A function keyword indicating that data in the trace buffer is to be displayed in instruction format.
MARK	Equals 1 if trace was turned off before current frame or if emulation broke before current frame.
MOVE	Command keyword moves the trace buffer pointer.
NEWEST	Moves trace buffer pointer to bottom of buffer.
NOW	Indicates trace setting for beginning of next emulation.
OFF	Indicates trace turned off.
OLDEST	Moves trace buffer pointer to top of buffer.
ON	Indicates trace turned on.
PRINT	Command keyword calling for a display of one or more entries from the trace data buffer.
QDEPTH	Queue depth.
QSTS	2 queue status bits, QS1, QS0.
STS	3 status bits $\overline{S2}$, $\overline{S1}$, $\overline{S0}$.
TRACE	Command keyword indicating that the mode of display for trace data is to be set.

User Names

The command language permits the programmer and operator to employ symbolic addressing through the use of user-generated tokens as opposed to system-generated tokens (keywords). The language permits four types of *user names: symbols, module names, statement numbers,* and *macro names* (see Chapter 8).

Symbols

A *symbol* is a sequence of contiguous alphanumeric characters, prefixed by a period (.), that references a location in a symbol table. The *symbol* has two uses. The referenced table location always contains a number; it may be an address of an instruction or variable in a program module, or it may be used directly as a numerical value. In the first case, the *symbol* is an alternative method of program addressing (symbolic as opposed to direct numeric addresses). In the second case, it provides a method for storing and retrieving data values symbolically into/from the table itself.

As an example, consider the *symbol* .BEGIN in module ..MAINLOOP. The entire reference to this occurrence of .BEGIN is:

```
..MAINLOOP.BEGIN
```

where

the double period (..) designates MAINLOOP as a *module name* and

the single period (.) designates BEGIN as a *symbol name*.

Statement Numbers

In the process of compiling a source module in DEBUG mode, the PL/M compiler generates a set of (source) *statement numbers,* one for each source statement in the module. Each *statement number* is linked to the absolute address of the first instruction generated by the PL/M compiler for the associated source statement in the source program. Each compiled program will contain a table of *statement numbers* and absolute addresses. Items (addresses) in the table are referenced by entering the associated *statement number.*

The form of reference is

module-name # decimal-10

where

# is the 'number' sign; this designates the reference as a *statement number* and

decimal-10 is the (source) *statement number* (a numeric constant). The default suffix of *decimal-10* is always decimal.

For example,

```
..MAINLOOP#123
```

#123 is *statement number* 123 in the source program MAINLOOP. This reference would obtain the *address* of the first instruction generated by source statement 123 of module MAINLOOP.

Statement numbers are an alternative to program addressing, as opposed to labels in the program.

Special Tokens

The command language contains two *special token* sets that provide special functions: *operators* and *punctuation.*

Operators

Type	Class Name	Operators
relational	*rel-op*	=, <, >, <=, < >, >=
plus	*plus-op*	+, −, (binary and unary)
mult	*multi-op*	*, /, MOD, MASK
logical	*log-op*	NOT, AND, OR, XOR

Punctuation

Type	Class Name	Punctuation Characters
Punctuation	*punct-op*	' & . , ; : !) ($ CR LF SP % # .. !!

The use of punctuation characters are defined in those sections that define command formats.

Entering Commands at the Console

The ICE-88 emulator displays an asterisk prompt (*) at the left margin when it is ready to accept a command from the console.

Each command is entered as a *command line*, which consists of one or more *input lines*; the length of an input line is limited to the number of characters that one line of the console display can contain.

The ICE-88 emulator recognizes the carriage return as the terminator for a command line. If it is necessary to use more than one input line to enter a command, each intermediate input line should end with an ampersand (&). When the ICE-88 emulator encounters the ampersand, it suppresses the interpretation of the command that would occur on encountering the carriage return that follows. After the carriage return is executed, the ICE-88 emulator displays a double asterisk prompt (**) to acknowledge the continuation of the command line.

Tokens in the command are separated by blanks, unless the construct requires another form of separator. For example, tokens in a list are separated by commas; in this case, blanks (spaces) may be inserted for clarity but are not required.

Any input line may include comments. The comments are preceded by a semicolon (;), and must appear after any portion of the command that is in that input line; in other words, if the first character in an input line is a semicolon (;), the entire input line is comments. Characters in a comment are not interpreted by ICE-88 and are not stored internally except in a DEFINE MACRO command. The main use of comments is to document an emulation session while it is in progress.

Comments may not be continued from input line to input line. If an ampersand is used to continue a command line that also contains comments, the ampersand must come before the comment. An ampersand that is embedded in a comment is ignored by the ICE-88 emulator.

You can use ISIS-II editing capabilities to correct errors in the current input line. The line-editing characters are as follows:

Characters	Result
RUBOUT	Delete last character entered in input line. The deleted character is echoed immediately. The RUBOUT function can be repeated, deleting one character each time it is pressed.
CTRL X	Delete entire input line. (CRTL Z gives the same result.)
CTRL R	Display entire input line as entered so far. This is useful after a RUBOUT, to review which characters have been deleted.

ESC	Cancel entire command being entered.
CRTL P	Input next character literally.
Carriage Return	Terminate input line or command line.
Line Feed	Terminate input line

Once a line terminator (carriage return or line feed) has been entered, that line can no longer be edited.

The dollar sign ($) is ignored by the ICE-88 emulator in identifiers. You can use it as a separator when you want to combine two words into one token. For example, suppose you wanted to combine the two system groups DATA and STS into one symbol for your use. Instead of DATAANDSTS, you can use the $ character as a separator: DATA$AND$STS.

CHAPTER 5 EXPRESSIONS

An expression is a formula that evaluates to a number. The formula can contain operands, operators, and parentheses. Expressions and operands appear in the ICE-88 emulator as command arguments to specify numeric values or boolean conditions. Depending on the command context, the resulting number is interpreted either as a numeric value or as a logical state (TRUE/FALSE). All expressions and operands represent one of the following:

- Pointer: a pair of 16-bit unsigned integers. One integer is called the base (b) and the other integer is called the displacement (d). This manual uses the notation *b*:*d* to denote a pointer with a base *b* and displacement *d*. The ':' operator is a base-displacement integer connector (see table 5-3). Pointers may be used as memory addresses; then the 20-bit absolute address is 16**b* + *d*.
- Integer: a single 16-bit unsigned integer treated modulo 65536. This is a special case of a pointer, with the base value equal to 0.

The ICE-88 emulator provides only unsigned-integer arithmetic on pointers and integers. The arithmetic operations are always applied separately to bases and displacements (i.e., integer arithmetic is always 16-bit). Signed arithmetic is not provided.

A few examples are all that is necessary to illustrate the concept of expressions.

1. The simplest form of an expression is a single value. That is, an expression that contains only one operand and no operators or parentheses.

   ```
   3
   FFFFH
   127Q
   ```

2. The following expressions contain both operands and operators.

   ```
   2 + 3
   1001110011101111Y - 101Y
   127/44
   0100:00FFH
   ```

3. The following expressions contain operands, operators and parentheses.

   ```
   2 * (6 + 4)
   (127 + 44)/20
   ```

4. The use of symbols to reference numeric values represents a significant capability of the ICE-88 emulator. The following examples illustrate the use of symbols in expressions.

   ```
   .SYMBA OR .SYMBC
   (!VAR1 + 10)/(!VAR2 - .SYMBD)
   ```

This introduction to expressions is sufficient for the first reading of this manual or if the reader is familiar with previous ICE products. Therefore, you may skip the remainder of this chapter and read the remaining chapters using the examples to gain further familiarity with the use of expressions in ICE-88 commands. The remainder of this chapter describes how expressions are constructed by representing the types of operands and operators that can be used, and provides the rules and some examples to explain how expressions are evaluated. The chapter also describes numeric and logical (boolean) command contexts, and gives a condensed syntax summary for expressions.

Operands

All operands are composed of either pointers or unsigned integers. Operands can be specified by any of the following references:

- numeric constant
- masked constant
- keyword reference
- symbolic reference
- statement number reference
- memory reference
- typed memory reference
- port reference
- string
- (expression)

The following paragraphs define and explain each of the above operand types and formats.

Numeric Constants

A numeric constant produces a 16-bit integer value and is specified by a sequence composed of decimal digits and the letters "A" through "F" (hexadecimal digits), and optionally a suffix to specify explicitly the constant's radix:

numeric-constant ≡ *digit* ... [*suffix*]

Where:

digit ≡ 0 :: 1 :: 2 :: 3 :: 4 :: 5 :: 6 :: 7 :: 8 :: 9 :: A :: B :: C :: D :: E :: F

And:

suffix ≡ H :: T :: O :: Q :: Y

In the absence of a suffix, the default input radix for the current context is used. In most cases this is the radix set by the SUFFIX command; however, some commands may default their parameters to other radices. The allowed radices and their suffixes are: hexadecimal ("H"), decimal ("T"), octal ("O" or "Q"), and binary ("Y"). The radix determines which characters are valid in the constant. Numeric constants represent fixed unsigned integer values. The elements of numeric constants are summarized in table 5-1; examples are as follows:

Examples:

```
1001111010100111Y
1234
1974T
A2EH
177Q
```

Table 5-1. Elements of Numeric Constants

Number Base	Valid Digits	Explicit Radix	Examples
Binary (base 2)	0,1	Y	1100111010110101Y
Octal (base 8)	0 - 7	Q, O	4726Q
Decimal (base 10)	0 - 9	T	397T
Hexadecimal (base 16)	0 - 9, A - F	H	00FE3H
(multiple of 1024)	0 - 9	—	64

A numeric constant entered through the console with an explicit radix is interpreted accordingly. If it contains any digits that are invalid for that radix, an error results.

A numeric constant entered from the console without an explicit radix is interpreted according to the implicit radix that applies to the context. In most contexts, the implicit radix is initially hexadecimal (H); in these contexts, the implicit radix can be set to Y, Q, O, T or H by using the SUFFIX command.

Masked Constants

A *masked constant* is syntactically identical to a *numeric constant* except it may not contain the "T" suffix and must contain one or more "X" characters. Each "X" character represents a 'don't care' digit (1, 3, or 4 bits depending upon whether the *radix* is binary, octal, or hexadecimal). The *radix*, either explicit or implicit (i.e., previously specified), must be binary, octal or hexadecimal. The following are examples of *masked constants* :

10X1X01Y	(binary - 2 don't care bits shown explicitly)
3X4Q	(octal - 3 don't care bits implicit because each octal numeral represents 3 bits; equivalent to 011XXX100Y)
6FX1H	(hexadecimal - 4 don't care bits, implicit because each hexadecimal numerical represents 4 bits; equivalent to 01101111XXXX0001Y)

Keyword References

Keyword references are used to gain access to all of the system variables, including registers, status flags, input pins, and status information. When one is used in a command, the value returned is a 16-bit integer and is the current contents of the referenced object. Thus indirection through referenced variables is obtained. The values of system variables may be used in boolean conditions in control structures. A keyword reference may reference a value less than 16 bits.

If the keyword reference returns a value of less than 16 bits, the value is coerced to 16 bits by right-justifying it and filling the high-order bits with zeroes. (Refer to Chapter 4 for a listing and description of reference keywords.)

Examples:

SP = SP - 2	(decrement the contents of the Stack Pointer)
RAX	(display the contents of the Accumulator)
TIMER	(display the contents of the TIMER register)
AFL OR OFL	(''OR'' Auxiliary-carry and Overflow flags)

Symbolic References

A symbolic reference points to a entry in the ICE-88 symbol table. Corresponding to each symbol table entry is a pointer value that represents an address or a constant. When a symbol reference is entered as an operand, its corresponding value is obtained from the referenced table location and used in the associated expression. A symbolic reference is specified in the following format:

symbolic-ref ≡ [*module-ref*] *symbol* ...

Module references and symbols are both user-assigned. Module names are LOADed with a program—they cannot be assigned from the ICE-88 emulator. Most symbols are also LOADed. The module name identifies a particular symbol table that contains the symbols associated with a particular program module. The symbol table contains the symbols that are used by that program. Module names and symbols are composed of user names and identifying prefixes. User names are composed of character strings where each character may be an alphabetic character, digit, ''@'', underscore (_), or ''?'' with the exception that the first character in the string may not be a digit. The module name is prefixed by a double period (''..''):

module-ref ≡ *..module-name*

A symbol is identified by a single period prefix (''.''):

symbol ≡ *.symbol-name*

Therefore the format for a symbolic reference can be shown as follows:

symbolic-ref ≡ [*..module-name*] *.symbol-name...*

If a module name is present, then only the referenced module's symbol table is searched; otherwise all of the current symbol table is scanned for the referenced symbol. If more that one symbol is referenced, the symbol table is scanned for the occurrence of the first symbol in the list. Then the table is scanned for the first occurrence of the second symbol following the entry for the first symbol. This is repeated in sequence for all the symbols in the list. The value returned is the pointer containing the base and displacement address values for the entry specified by the symbolic reference.

The use of the symbol table provides you with considerable freedom in referencing and retrieving user variables. The ability to assign symbolic names to variables, procedures, and module names allows you to assign them names that can be associated with their functions and interrelations within the program. For example, assume that the symbol .X represents a variable that is used in procedures PROCX, PROCY, and PROCZ of module MODABLE. Then the value of variable X in PROCY can be retrieved with the following symbolic reference:

```
..MODABLE.PROCY.X
```

whereas the value of variable X in PROCZ is obtained by:

```
.MODABLE..PROCZ.X
```

Statement Number Reference

A statement number reference points to the address of the first instruction generated by the compiler for the source statement specified by the associated statement number. Statement number information for each compiled program module is stored in its statement number table. Therefore program locations can be referenced symbolically via statement number. The LINK process can combine different modules, each with its own set of statement numbers. Therefore, a statement number reference may require a module reference in the same format as that used in a symbolic reference. A statement number reference uses the following format:

source-statement-ref ≡ [*..module-name*] # *statement-number*

The statement number is an integer value that specifies the number of the source statement. If the statement number does not have an explicit suffix, the default suffix is decimal. If more than one program module is currently loaded into ICE-88 memory, a module reference is required to distinguish the reference from identical reference numbers in other modules. Examples are:

```
#45
..TEST1 #12FH
```

The value returned is a pointer value that is the absolute address of the first instruction generated by the compiler for the source statement referenced by the statement number.

Memory References

References to memory specify the type of reference as well as the memory location (address) required. A memory reference uses the following format:

memory-ref≡reference-type address

reference-type	*Definition*
BYTE	1-byte integer value at location "address."
WORD	2-byte integer value with low byte at "address" and high byte at "address" + 1.
SINTEGER	Same as BYTE.
INTEGER	Same as WORD.
POINTER	4-byte pointer value located at "address" through "address" + 3.

When changing memory or referencing it in an expression, BYTE is equivalent to SINTEGER and WORD to INTEGER. However, when displaying memory, the format of the display is either unsigned (BYTE, WORD) or signed (SINTEGER, INTEGER). (See Display Memory command, Chapter 7.)

Examples:

```
BYTE 1000H
BYT 0100:0000H
WORD 101
INTEGER .ABLE
POINTER CS:IP
```

Typed Memory Reference

A typed memory reference employs the symbols contained in the ICE-88 symbol table to obtain both location and type of memory reference. Each symbol has one of the following types of memory references or has no type:

BYTE	1-byte integer value
WORD	2-byte integer value
SINTEGER	Same as BYTE
INTEGER	Same as WORD
POINTER	4-byte pointer value

If a symbol has a memory reference type, the symbol represents a memory reference. If the symbol has no memory reference type, the symbol represents a label, procedure name, or a constant. If the source language translator generates type information in the object file, then the type values are loaded with the symbols in the ICE-88 emualtor. The user may also specify memory reference type when defining symbols or when using the ICE-88 TYPE command.

A typed memory reference is executed with the following format:

typed-mem-ref ≡ [!!*module-name*] !*symbol-name* ...

Example:

Assume symbol table ..SAM contains:

Symbol	Type	Base Value	Displacement Value
.X	BYTE	100H	0
.Y	WORD	100H	0
.Z	POINTER	100H	0

Also assume:

Memory Location	Content
1000H	21
1001H	43
1002H	65
1003H	87

Therefore:

```
!!SAM !X = 21
!!SAM !Y = 4321
!!SAM !Z = 8765:4321
```

Port References

The ICE-88 emulator supports a maximum of 64K 8-bit or 32K 16-bit I/O ports. These ports are referenced in the following format:

port-ref ≡PORT *address* ::WPORT *address*

PORT references an 8-bit I/O port at location "address." WPORT references a 16-bit I/O port at location "address." The value of "address" must be an integer. The port is read or written immediately when referenced.

Examples:

```
PORT 123
PORT RDX
WPORT 1FFH
```

String Constants

Any one of the ASCII characters (ASCII codes 00H through 7FH) can be entered as a string constant by enclosing the character in single quotes. The operand value of a string constant is a 16-bit integer with the high-order bits set to 0, and the 7-bit ASCII code in the low-order seven bits. For example, the string constant "A" has the value 0000000001000001Y (0041H).

In data communications usage, an ASCII-coded character consists of seven low-order data bits (bits 0-6), and a parity bit (bit 7). Thus another way to describe the operand value of an ASCII string constant is as a two-byte integer; the high byte is all zeros and the low byte contains the 8-bit ASCII value with the parity bit set to 0.

Table 5-2 gives the printing ASCII characters with their corresponding hexadecimal codes (codes 20H through 7EH). Note that some console keyboards output upper case ASCII characters only, or lack keys for some of the non-printing ASCII codes.

Table 5-2. ASCII Printing Characters and CODES (20H—7EH)

Character	Hex Code	Character	Hex Code	Character	Hex Code
Space (SP)	20	@	40		60
!	21	A	41	a	61
’’	22	B	42	b	62
#	23	C	43	c	63
$	24	D	44	d	64
%	25	E	45	e	65
&	26	F	46	f	66
’	27	G	47	g	67
(	28	H	48	h	68
)	29	I	49	i	69
*	2A	J	4A	j	6A
+	2B	K	4B	k	6B
,	2C	L	4C	l	6C
—	2D	M	4D	m	6D
.	2E	N	4E	n	6E
/	2F	O	4F	o	6F
0	30	P	50	p	70
1	31	Q	10	q	71
2	32	R	52	r	72
3	33	S	53	s	73
4	34	T	54	t	74
5	35	U	55	u	75
6	36	V	56	v	76
7	37	W	57	w	77
8	38	X	58	x	78
9	39	Y	59	y	79
:	3A	Z	5A	z	7A
;	3B	]	5B	{	7B
<	3C	/	5C	|	7C
=	3D	[	5D	}	7D
>	3E	∧(↑)	5E		7E
?	3F	—(←)	5F		

Parenthesized Expressions

(exp): an *operand* whose value is the value of the parenthesized expression, e.g., (1+2+3) = 6 (operand value).

Operators

An expression can contain any combination of unary and binary operators. Table 5-3 describes all the operators available to the ICE-88 emulator. The operators are ranked in order of precedence from highest (1) to lowest (10). Other things being equal, the operator with the highest precedence is evaluated first. The operators are shown in the table as they are to be entered in expressions. The class content- operators has too many details to fit the table; see table 5-5. The table identifies each operator as unary or binary. A unary operator takes one operand, and a binary operator takes two operands.

Classes of Operators

For discussion, the operators are classed as shown in table 5-4. Table 5-6 specifies the arithmetic and logical semantic rules for operators.

Arithmetic Operators

The ICE scanner distinguishes unary "+" and "−" from binary "+" and "−" by context. Unary "+" is superfluous, since it is a no-operation.

A unary "−" applied to an integer means "2's complement *modulo* 65536." In other words, (−N) evaluates to (65536 − N). As the ICE-88 emulator uses only unsigned arithmetic, unary "−" does not apply to pointers. The unary "−" is also used in the MOVE and PRINT commands (see MOVE and PRINT commands in Chapter 6).

Binary "+" applies to pointer and integer values only and results in the arithmetic sum of its two operands. In the case of the sum of two integers, the result is treated *modulo* 65536 (any high-order bits after the sixteenth bit are dropped). In the case of the sum of a pointer and an integer, the displacement value of the pointer is summed with the integer *modulo* 65536 and the base value of the pointer is unchanged.

Binary "−" applies to pointer and integer values only and results in the arithmetic difference of the two operands. In the case of the difference of two integers, the result is the 2's complement difference of the two integers; this result is also treated *modulo* 65536, so that a "negative" result (−N) ends up as (65536 − N). An integer may also be subtracted from a pointer. In this case, the result is the 2's complement difference of the pointer displacement and the integer *modulo* 65536 and the base value of the pointer remains unchanged. The "−" can be used to obtain the arithmetic difference of two pointers but only if they have the same base value. In this case the result is the 2's complement difference of the displacements *modulo* 65536 and the resulting base value is set equal to zero. An error occurs if the base values of the pointers are not equal.

The operators "*", "/", "MOD", and "MASK" can be applied only to integer operands and return only integer results.

Binary "*" results in the multiplication of two integer operands, truncated to the low-order 16 bits.

Binary "/" causes the first integer operand to be divided by the second. The result is the integer quotient; the remainder, if any, is lost. Thus, (5/3) evaluates to (1).

Binary "MOD" returns the remainder after integer division as an integer result, and the quotient part of the division is lost. Thus, (5 MOD 3) evaluates to (2), the remainder of (5/3).

Binary "MASK" performs a bitwise logical AND on two integer operands. If either corresponding bit is a 1, or if both are 1's, the result has 1 in that bit; if both are 0, the result has 0 in that bit. MASK is identical to the boolean "AND" operator, except that MASK has higher precedence.

:, SEGMENT, OFFSET have the highest precedence of the arithmetic operators. Binary "*", "/", and "MOD" have equal precedence, lower than unary "–". Binary "+" and "–" have equal precedence, lower than "*", "/", and "MOD". "MASK" has lowest precedence of the arithmetic operators (see table 5-3).

Table 5-3. ICE^{TM} Operators

Precedence[1]	Operator	Unary Binary[2]	Effect[3]
1	:	u	Base, displacement integer connector for a pointer (e.g., 1234:5678 or CS:IP).
	OFFSET	u	Designates integer value that is the displacement of a pointer (e.g., OFFSET 1234:5678 is 5678).
	SEGMENT	u	Designates integer value that is the base of a pointer (e.g., SEGMENT 1234:5678 is 1234).
2	+	u	Unary plus.
	–	u	Unary minus, (–N) means (65536-N), the 2's complement of N, modulo 2^{16}
3	*	b	Integer multiplication.
	/	b	Integer division. The result is the integer quotient; the remainder (if any) is lost.
	MOD	b	Modulo reduction. The remainder after division, expressed as an integer.
4	+	b	Addition.
	–	b	Subtraction.
5	MASK	b	Bitwise AND. Higher precedence than identical operation AND (see below).
6	content-operator[4]	u	Treats operand as memory or port address, returns the content of that address.
7	=	b	Is equal to. Result is either TRUE (FFFFH) or FALSE (0).

Table 5-3. ICE^{TM} Operators (Cont'd.)

Precedence[1]	Operator	Unary Binary[2]	Effect[3]
7	>	b	Is greater than. Result is TRUE or FALSE.
	<	b	Is less than. Result is TRUE or FALSE.
	<>	b	Is not equal to. Result is TRUE or FALSE.
	>=	b	Is greater than or equal to. Result is TRUE or FALSE.
	<=	b	Is less than or equal to. Result is TRUE or FALSE.
8	NOT	u	Unary Logical (1's) complement. Bitwise 1 becomes 0, 0 becomes 1; TRUE becomes FALSE, FALSE becomes TRUE.
9	AND	b	Bitwise AND. If *both* corresponding bits are 1's, result has 1 in that bit; else 0. TRUE AND TRUE yields a TRUE result; any other combination is FALSE.
10	OR	b	Bitwise inclusive OR. If *either* corresponding bit is a 1, result has 1 in that bit; else 0. If either operand is TRUE, result is TRUE; else FALSE.
	XOR	b	Bitwise exclusive OR. If corresponding bits are different, result has 1 in that bit; else 0. If one operand is TRUE and the other is FALSE, result is TRUE; if both are TRUE or both are FALSE, result is FALSE.

Notes:

[1]1 = highest precedence (evaluated first), 10 = lowest precedence.

[2]u = unary, b = binary.

[3]Refer to text for additional details.

[4]content-operator is one of the tokens BYTE, WORD, SINTEGER, INTEGER, POINTER, PORT, or WPORT.

Table 5-4. Classes of Operators

Class	Operators
(Numeric)	
Arithmetic	
unary	+, −, SEGMENT, OFFSET,
binary	*, /, MOD, +, −, MASK, :
Content	
unary	*content-operators*
(Boolean)	
Relational	
binary	=, >, <, <>, >=, <=
Logical	
unary	NOT
binary	AND, OR, XOR
Unary	+, −, SEGMENT, OFFSET, *content-operators*, NOT
Binary	*, /, MOD, +, −, MASK, :, *relational-operators*, AND, OR, XOR

Content Operators

Content operators are keywords that refer to the contents of memory locations and I/O ports. In expressions, they function as unary operators with precedence immediately below "MASK." Table 5-5 summarizes the content operators for the ICE-88 emulator.

Table 5-5. Content Operators

Operator	Content Returned
BYTE	1-byte integer value from the addressed location in user memory.
WORD	2-byte integer value from the addressed location in user memory.
SINTEGER	Same as BYTE.
INTEGER	Same as WORD.
POINTER	4-byte pointer value from the addressed location in user memory.
PORT	1-byte value from addressed 8-bit I/O port.
WPORT	2-byte value from addressed 16-bit I/O port.

To be used in an expression, a content operator must precede a single operand that can be interpreted as a valid address. A partition of addresses (using a keyword such as TO or LENGTH) cannot be used in an expression. Furthermore, the address given must be accessible (not GUARDED) if it uses the memory map (see MAP commands in Chapter 7).

Relational Operators

A relational operator calls for a comparison of the values of its two operands. The six possible relational operations are shown in table 5-4. Each comparison is either true when the expression is evaluated, or it is false. The result is correspondingly TRUE (FFFFH) or FALSE (0).

Logical Operators

The "NOT" logical operator results in a 1's complement of an operand; a 16-bit operand is assumed. The following are examples of "NOT" logical operations:

Operand	Operation	Result
0	NOT	FFFFH
1	NOT	FFFEH
11110110Y	NOT	1111111100001001Y
FFFFH	NOT	0
FFFEH	NOT	1

ANDing two operands results in the following values depending upon bit pair values:

bit 1	bit 2	Result
0	0	0
0	1	0
1	0	0
1	1	1

Examples:

Logical Operation	Result
0 AND 0	0
1010Y AND 1001Y	1000Y
FFFFH AND 0	0
FFFFH AND FFFFH	FFFFH
1 AND 0	0

ORing two operands results in the following values depending upon bit pair values:

bit 1	bit 2	Result
0	0	0
0	1	1
1	0	1
1	1	1

Examples:

Logical Operation	Result
0 OR 0	0
1 OR 0	1
1010Y OR 1001Y	1011Y
FFFFH OR 0	FFFFH
FFFFH OR FFFFH	FFFFH

The result of an "XOR" operation is as follows:

bit 1	bit 2	Result
0	0	0
0	1	1
1	0	1
1	1	0

Examples:

Logical Operation	Result
0 XOR 0	0
1 XOR 0	1
1010Y XOR 1001Y	11Y
FFFFH XOR 0	FFFFH
FFFFH XOR FFFFH	0

Arithmetic and Logical Semantic Rules

Table 5-6 provides a summary of the semantic rules that apply to arithmetic and logical operations. The table specifies the function performed by each type of arithmetic and logical operation, the input required, and the result of the operation (output).

Table 5-6. Arithmetic and Logical Semantic Rules

Operation	Operators	Input	Output	Function
logical	AND, OR, XOR, MASK	2 integers	integer	Bitwise conjunction or disjunction of integers.
not	NOT	integer	integer	One's complement of an integer.
relational	<, >, <=, >=, <>, =	(1) 2 pointers, same base (2) 2 integers	integer integer	Logical test of relational expression. If the displacement integer values satisfy relational operation (true), then the output integer value = FFFFH. If the displacement integer values do not satisfy the realtional operation (false), the output integer = 0. If the base values of the input pointers are not equal, an error occurs.
arithmetic	*, /, MOD	2 integers	integer	Unsigned product (*), quotient(/), or remainder(MOD) of two integers.
memory-content	BYTE, WORD, INTEGER, SINTEGER	pointer or integer	integer	Fetches content of memory location addressed by input value.
memory-content	POINTER	pointer or integer	pointer	Fetches content of memory location addressed by input value.
I/O-content	PORT, WPORT	integer	integer	Fetches content of I/O port (8-bit or 16-bit) addressed by input value.
+(binary)	+	(1) pointer, integer (2)integer, integer	pointer integer	Sum of the displacement values, same base as the pointer. Sum of the integers.
−(binary)	-	(1) 2 pointers with = base values (2) pointer & integer	integer pointer	Two's complement difference of displacement values. Error occurs if base values are unequal. Two's complement difference of pointer displacement value and integer input, same base as the pointer.
−(unary)	-	integer	integer	Two's complement of the input integer.
+(unary)	+	All types	same	No change.
override base/ construct pointer	:	(1) integer & pointer (2) 2 integers	pointer pointer	Replaces current base value of pointer with input integer value. Constructs new pointer with base value set to first input integer value and displacement set to second integer.
offset	OFFSET	pointer	integer	Generates integer value whose value is the displacement value of the input pointer.
segment	SEGMENT	pointer	integer	Generates integer whose value is the base value of the input pointer.

How Expressions are Evaluated

This section provides a simple conceptual model of how the ICE-88 emulator evaluates an expression. The model involves a loop that scans the expression iteratively (figure 5-1). The loop terminates in either of two ways:

- When the expression resolves to a single numeric value.
- When a syntax error (or other error) occurs.

The ICE-88 emulator goes through the scan loop once for each operator in the expression. On each scan, the operator (unary or binary) that must be applied next is identified.

The next operator is always:

- the leftmost operator
- with highest precedence (table 5-3)
- that is enclosed in the innermost pair of parentheses.

If this next operator is unary, and has a numeric operand, the operation is performed on the operand to produce a numeric result. If the next operator is binary, and has a pair of operands, the operation is performed on the pair of operands to produce a numeric result. If the next operator does not have the required number of numeric operands, a syntax error results, and the loop terminates.

A pair of parentheses is "cleared" when it contains just a single numeric value; that is:

(*numeric-value*) → *numeric-value*

After performing any operation, the numeric result becomes an operand for the next scan. Parentheses are cleared before the next scan begins.

"Case Studies" in Evaluating Expressions

Here are some representative cases of expressions showing how they are evaluated by the ICE-88 emulator. In some examples, the steps in evaluation are shown, but most show just the overall result. Table 5-7 summarizes the cases. The EVALUATE (EVA) command used in these examples performs the evaluation and displays the result in the four numeric radixes (Y, Q, T, and H), plus the ASCII printing equivalent (if any) in single quotes. The examples in this section assume the initial conditions shown in table 5-8. This table also describes the special notation used in some of the examples. The examples also assume SUFFIX = T; that is, any number without an explicit radix is *decimal*.

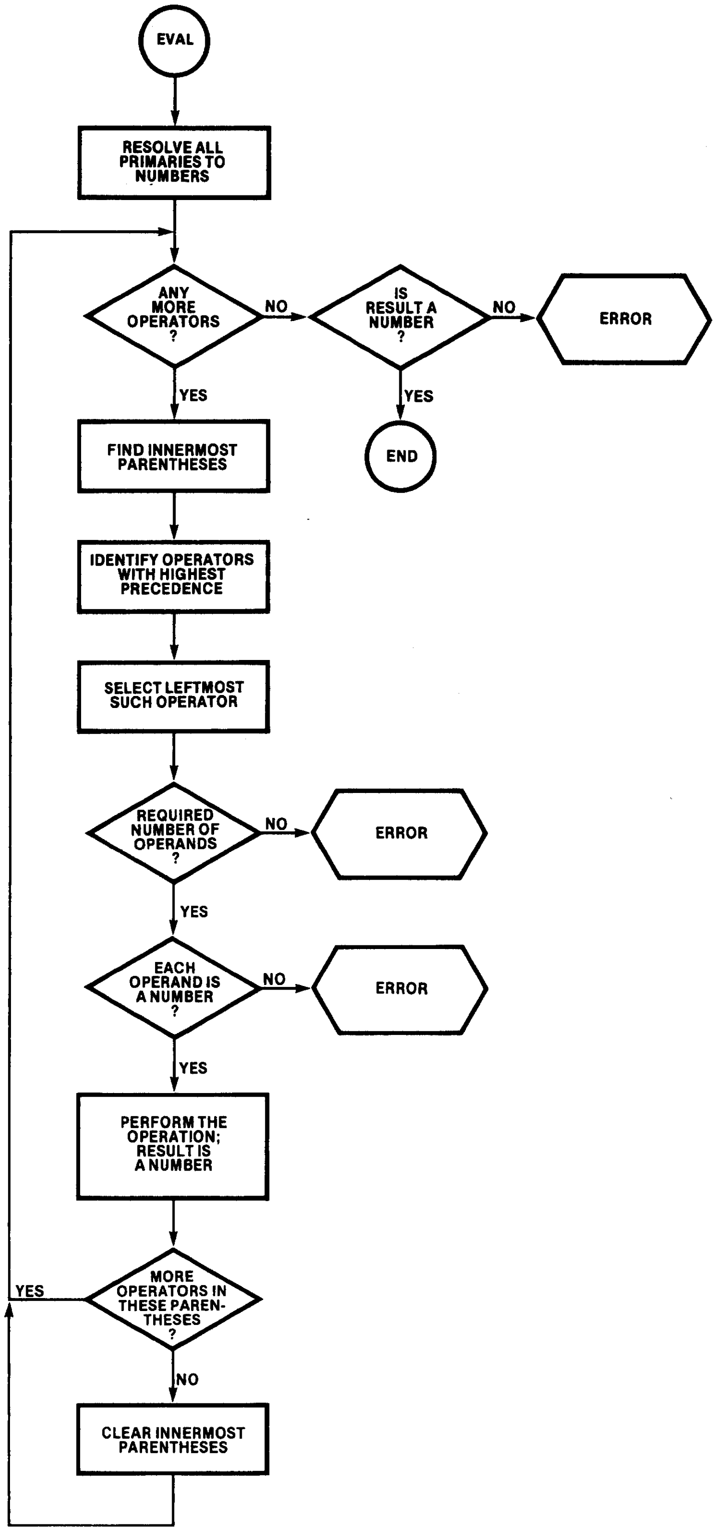

EVAL
RESOLVE ALL PRIMARIES TO NUMBERS
ANY MORE OPERATORS ?
NO
IS RESULT A NUMBER ?
NO
ERROR
YES
END
YES
FIND INNERMOST PARENTHESES
IDENTIFY OPERATORS WITH HIGHEST PRECEDENCE
SELECT LEFTMOST SUCH OPERATOR
REQUIRED NUMBER OF OPERANDS ?
NO
ERROR
YES
EACH OPERAND IS A NUMBER ?
NO
ERROR
YES
PERFORM THE OPERATION; RESULT IS A NUMBER
MORE OPERATORS IN THESE PAREN-THESES ?
YES
NO
CLEAR INNERMOST PARENTHESES

Figure 5-1. A Simple Model of Evaluation

Table 5-7. Conditions and Notation for Examples

Conditions
All memory locations are accessible (none are GUARDED). SUFFIX = T (implicit radix is decimal). IP = 1000H DEFINE .AA = 2000H DEFINE . BB = FFFFH BYTE 1000H = 3EH BYTE 2000H = 23H

Notation	
>>	has higher precedence than.
>>=	has higher or equal precedence.
u1,u2,...	unary operators
b1,b2,...	binary operators

Case 1: EVALUATE *operand*

An expression can be composed of just a single operand, requiring at most a lookup to produce a numeric result.

Examples:

```
EVA 10 (input)
1010Y  12Q  10T  AH  ''  (display)

EVA IP (input)
1000000000000Y  10000Q  4096T  1000H  ''  (display)

EVA .AA (input)
10000000000000Y  20000Q  8192T  2000H  ''  (display)

EVA 1234H:5678H  (input)
1234:5678H 179BBH  (display)
```

Case 2: EVALUATE *unary-operator operand*

A unary operator with a single primary operand evaluates to a number.

Examples:

```
EVA −2 (input)
1111111111111110Y  17776Q  65534T  FFFEH  '↑'  (display)

EVA BYTE .AA (input)
100011Y  43Q  35T  23H  '#'  (display)

EVA NOT IP (input)
1110111111111111Y  167777Q  61439T  EFFFH  '0'  (display)
```

Case 3: EVALUATE *operand binary-operator operand*

The binary operator is applied to its two operands to produce a numeric result.

Examples:

```
EVA 10 + 20 (input)
11110Y  36Q  30T  1EH  ''

EVA .AA > 10 (input)
1111111111111111Y  177777Q  65535T  FFFFH  ''  (display)
```

Table 5-8. Representative Cases of Expressions

Case	Expression	Precedence	Result of Lookup Plus One Scan
1	operand	None	number
2	unary-operator operand	Any	number
3	operand binary-operator operand	Any	number
4	operand b1 operand b2 operand	b1 >>= b2	number b2 number (case 3)
		b2 >> b1	number b1 number (case 3)
5	operand b1 (operand b2 operand)	b2 >> b1	number b1 number (case 3)
		b1 >>= b2	number b1 number (case 3)
6	u1 operand b1 operand	u1 >> b1	number b1 number (case 3)
		b1 >> u1	u1 number (case 2)
7	operand b1 u1 operand	u1 >> b1	number b1 number (case 3)
		b1 >> u1	ERROR (See case 8)
8	operand b1 (u1 operand)	u1 >> b1	number b1 number (case 3)
		b1 >> u1	number b1 number (case 3)
9	u1 u2 operand	u2 >> u1	u1 number (case 2)
		u1 >>= u2	ERROR (See case 10)
10	u1 (u2 operand)	u2 >> u1	u1 number (case 2)
		u1 >>= u2	u1 number (case 2)

```
EVA .AA OR IP (input)
11000000000000Y  30000Q  12288T  3000H  '0'  (display)

EVA 0100H:0010H + .AA (input)
0100:2010H 03010H (display)
```

Case 4: EVALUATE *operand* b1 *operand* b2 *operand*

The binary operator with the highest precedence is evaluated first. If they have equal precedence, b1 (the leftmost) is evaluated first.

A. b1 >>= b2

Examples:

```
EVA 10 + .AA – IP (input)
1000000001010Y  10012Q  4106T  100AH  ''  (display)

EVA 10 * .AA – IP (input)
11000000000000Y  30000Q  12288T  3000H  '0'  (display)

EVA IP = .AA OR . BB (input)
1111111111111111Y  177777Q  65535T  FFFFH  ''

EVA 1 + 2 – 3 (input)
0Y  0Q  0T  0H  ''  (display)

EVA 3 * 2 + 1 (input)
111Y  7Q  7T  7H  ''  (display)
```

B. b2>>b1

Examples:

```
EVA 2 + 3 * 4 (input)
1110Y  16Q  14T  EH  ''  (display)

EVA .BB OR .AA AND IP (input)
1111111111111111Y  177777Q  65535T  FFFFH  ''  (display)

EVA 1 OR 2 AND 3 (input)
11Y  3Q  3T  3H  ''  (display)
```

Case 4 also fits expressions of any length that use only binary operators. Here is an example showing the steps in the evaluation.

Step	Operation	Result
0	Expression	.BB OR IP = .AA AND AFAFH XOR .AA MOD 277
1	Lookup	FFFFH OR 1000H = 2000H AND AFAFH XOR 2000H MOD 277
2	MOD	FFFFH OR 1000H = 2000H AND AFAFH XOR 9FH
3	=	FFFFH OR 0 AND AFAFH XOR 9FH
4	AND	FFFFH OR 0 XOR 9FH
5	OR	FFFFH XOR 9FH
6	XOR	FF60H

More examples:

```
EVA 2 XOR 3 MASK 41 MOD 33
10Y  2Q  2T  2H  ''

EVA 2 * 3 + 5 / 3 + 6
1101Y  15Q  13T  DH  ''

EVA 2 + 3 * 5 + 7
11000Y  30Q  24T  18H  ''
```

Case 5: EVALUATE *operand* b1 *(operand* b2 *operand)*

Binary operator b2 is evaluated first, even if it has lower precedence than b1. Use parentheses when b2 must be evaluated before b1.

Examples:

```
EVA 2 * (3 + 5)
10000Y  20Q  16T  10H  ''

EVA .BB / (.AA MASK AFAFH)
111Y  7Q  7T  7H  ''
```

This case can be generalized to include any number of binary operators and any arrangement of parentheses. For example:

Step	Operation	Result
0	Expression	10 * (44 + (17 * 15 – 6) / 7)
1	2nd*	10 * (44 + (255 – 6) / 7)
2	–	10 * (44 + (249) / 7)
3	Clear ()	10 * (44 + 249 / 7)
4	/	10 * (44 + 35)
5	+	10 * (79)
6	Clear ()	10 * 79
7	1st*	790

Case 6: EVALUATE u1 *operand* b1 *operand*

Precedence decides which operator is evaluated first.

A. u1 >> b1

Examples:

```
EVA −10 + 22
1100Y  14Q  12T  CH  ''

EVA BYTE .AA OR .BB
1111111111111111Y  177777Q  65535T  FFFFH  ''

EVA NOT .BB AND AFAFH
0Y  0Q  0T  0H  ''
```

B. b1 >> u1

Examples:

```
EVA BYTE .AA − 1000H
111110Y  76Q  62T  3EH  '>'

EVA NOT .BB/23
1111010011011110Y  172336Q  62686T  F4DEH  'T↑'
```

Case 7: EVALUATE *operand* b1 u1 *operand*

The unary operator must have higher precedence than the binary operator.

A. u1 >> b1 is valid.

Examples:

```
EVA 10 * −2
1111111111101100Y  177754Q  65516T  FFECH  'L'

EVA .AA AND NOT .BB
0Y  0Q  0T  0H  ''
```

B. b1 >> u1

This produces an error. The operator b1 must be evaluated next, and requires two numeric operands, but u1 *operand* has not yet been evaluated to a numeric result.

Examples:

```
EVA 10 + BYTE .AA
SYNTAX ERROR

EVA .AA MASK NOT .BB
SYNTAX ERROR
```

Case 8: EVALUATE *operand* b1 (u1 *operand*)

Unary operator u1 is evaluated first, even if it has lower precedence than binary operator b1. Parentheses must be used when u1 has lower precedence than b1.

Examples:

```
EVA 10 + (BYTE .AA)
101101Y  55Q  45T  2DH '-'

EVA .AA MASK (NOT .BB)
0Y  0Q  0T  0H  ''
```

Case 9: EVALUATE u1 u2 *operand*

Unary operator u2 must have higher precedence than u1 to evaluate without an error.

A. u1 >> u1 is valid.

Examples:

```
EVA BYTE -F000H
111110Y  76Q  62T  3EH  '>'

EVA NOT BYTE .AA
1111111110111100Y  177734Q  65500T  FFDCH  ''
```

B. u1 >>= u2

Examples of this case shown below result in an error.

Examples:

```
EVA BYTE NOT .AA
SYNTAX ERROR

EVA - BYTE .AA
SYNTAX ERROR

EVA BYTE BYTE 1000H
SYNTAX ERROR

EVA - - 5
SYNTAX ERROR
```

Case 10: EVALUATE u1 (u2 *operand*)

Unary operator u2 is evaluated first, even if it has lower precedence than u1. Parentheses must be used when u2 has lower precedence than u1.

Examples:

```
EVA BYTE (NOT .AA)
111101Y  75Q  61T  3DH  '='

EVA - (BYTE .AA)
1111111110111101Y  177735Q  65501T  FFDDH  ']'
```

```
EVA BYTE (BYTE 1000H)
11111110Y  376Q  254T  FEH  '↑'

EVA – (– 5)
101Y  5Q  5T  5H  ''
```

Two other "cases" can be diagrammed as:

operand b1 b2 *operand*
operand u1 b2 *operand*

Both forms produce an error no matter which operator has higher precedence, and no arrangement of parentheses can resolve the error.

These examples show the basic ways to control evaluation with and without parentheses. Parentheses must be used when two operators are concatenated and the second operator has lower precedence than the first.

Command Contexts

All expressions produce numeric values as results. The interpretation or use of the result depends upon the command that contains the expression. The term *numeric-expression* means an expression in a numeric command context. Numeric command contexts treat the result as an numeric value; all bits are significant.

The term *boolean-expression* means an expression in a boolean command context. Only integer values may be used in boolean contexts. Boolean command contexts test only the least significant bit (LSB) of the result, to obtain a TRUE or FALSE value. The result of a boolean expression is TRUE if its LSB is 1, FALSE if its LSB is 0. Thus, any number can have a boolean interpretation.

The BOOL command can be used instead of the EVALUATE command to display the evaluation of an expression as TRUE or FALSE.

A boolean expression uses relational and logical operators to manipulate TRUE/FALSE values. When a relational operator is evaluated, the result is always either 0 (FALSE) or FFFFH (TRUE). These results can have a numeric interpretation, but relational operators have limited usefulness in numeric contexts.

When logical operators are applied to TRUE/FALSE values, the results are also boolean. Specifically:

```
NOT:    NOT FALSE → TRUE
        NOT TRUE → FALSE

AND:    TRUE AND TRUE → TRUE
        TRUE AND FALSE → FALSE
        FALSE AND TRUE → FALSE
        FALSE AND FALSE → FALSE

OR:     TRUE OR TRUE → TRUE
        TRUE OR FALSE → TRUE
        FALSE OR TRUE → TRUE
        FALSE OR FALSE → FALSE
```

XOR: TRUE XOR TRUE → FALSE
TRUE XOR FALSE → TRUE
FALSE XOR TRUE → TRUE
FALSE XOR FALSE → FALSE

In addition to numeric and boolean contexts, there are several other contexts that control the interpretation or use of a number or expression. These contexts are summarized in table 5-9 for reference.

Table 5-9. Command Contexts

Type of Entry	Contexts	Interpretation	Limitations	Examples of Use
Numeric expression	Set and change commands, etc.	16-bit unsigned number; bit size may be reduced to fit destination.	All operands and operators allowed. Numeric constant without suffix is interpreted in current default radix.	IP = .AA*256T + 10FFFH

Boolean expression	BOOL, IF, UNTIL, WHILE	LSB = 0 → FALSE
		LSB = 1 → TRUE
			All operands and operators allowed. Numeric constants without suffix are interpreted in current default radix.	.AA AND .BB AND NOT .CC

Address	FROM, content-operator, partition, SAVE	Pointer to memory or 16-bit (or fewer) address in memory or I/O	Only arithmetic operators are allowed outside of the outermost parentheses. Constant without suffix is interpreted in the current default radix.	GO FROM .BB + 10
Decimal number	statement-number, MOVE, PRINT	positive number	No operators are allowed outside the outermost parentheses. All constants without suffix are decimal.	PRINT 10

CHAPTER 6 EMULATION AND TRACE CONTROL COMMANDS

Chapter 6 contains discussions, examples, and syntax summaries for each of the ICE-88 emulation and trace control commands.

The following brief outline of Chapter 6 shows how the emulation and trace control commands have been classified.

Emulation Control Commands

Set Breakpoint Register Command
Set Tracepoint Register Command
GO Command
GR Command
STEP Command
Display Emulation Register Command
Set CLOCK Command
Display CLOCK
Set RWTIMEOUT Command
Display RWTIMEOUT Command
ENABLE/DISABLE RDY Command

Trace Control Commands

Set TRACE Display Command
ENABLE/DISABLE TRACE Command
Display TRACE
MOVE, OLDEST, and NEWEST Commands
PRINT Command

Emulation Control Commands

The ICE-88 emulator contains an 8088 as the emulation processor. During emulation, this processor executes the instructions in the user program that have been mapped and loaded into the ICE-88 system. The operations of the user system can be monitored through the 8088 processor signals. The commands in this section allow you to specify the starting address where emulation is to begin, and to specify and display the software or hardware conditions for halting emulation and returning control to the console for further commands.

The commands in this section are as follows:

COMMAND	PURPOSE
Set Breakpoint-Register	Set match condition for halting emulation.
Set Tracepoint-Register	Set match condition for starting or halting trace data collection.
GO command	Begin real-time emulation.
GR command	Enable or set and enable breakpoint registers to halt emulation.
STEP command	Execute single-step emulation.
Display Emulation Register	Display GO-register, breakpoint and tracepoint register settings.
Set CLOCK	Designate system clock.
Display CLOCK	Display clock setting.
Set RWTIMEOUT	Enable or disable halting of emulation and error message on memory access timeout.
Display RWTIMEOUT	Display current setting of memory access timeout.
ENABLE/DISABLE RDY	Enable or disable user ready signal for memory access.

Discussion

The emulation control commands tell the ICE-88 emulator where to start emulation and when to halt emulation. After the ICE-88 emulator has been loaded by ISIS-II, the following initialization is executed:

- The GO-register (GR) is set to FOREVER. The setting of GR identifies the combination of factors that are enabled to halt emulation. The setting FOREVER means no factors are enabled.
- Both breakpoint registers (BR0 and BR1) are set to don't care and initially disabled.

To initialize for emulation, you map the locations in prototype and ICE-supplied memory that are to be accessible to the ICE-88 emulator, and load your program code into mapped locations. After the code has been loaded, the ICE-88 emulator initializes for emulation as follows:

- The instruction pointer (IP) and code segment register (CS) are loaded with the address of the first executable instruction in your program.

Now you can begin emulation by entering the command GO, followed by a carriage return. At the command GO, the following occurs:

- Emulation begins with the instruction at the address that is in the IP and CS; this is the first executable instruction in your program.

- The message EMULATION BEGUN is displayed at the console.
- Emulation continues until you press the ESC key, or until a fatal error occurs. (See Appendix B for error messages.)

Now if you press the ESC key, the following happens.

- The ICE-88 emulator completes executing the current instruction.
- Emulation halts; the IP and CS contain the address of the next instruction to be executed.
- The message EMULATION TERMINATED, CS:IP=bbbb:ddddH is displayed. The value displayed is the address of the next instruction to be executed.
- The message PROCESSING ABORTED is displayed, acknowledging the user abort (ESC key).

This is the simplest case of starting and stopping emulation. When the GO-register is set to FOREVER, you can enter the command GO to start emulation at the current CS:IP address, and press the ESC key to halt emulation.

Instead of starting wherever the CS:IP happens to be, you may specify the starting address you want for each GO command. There are two ways to do this. First, you can set the CS:IP directly to any desired address with commands of the form CS = expr, IP = expr, then enter the GO command to start emulation at that address. Second, you can specify the starting address as part of the GO command; this form of the GO command is as follows:

GO [FROM *address*]

The meta-term *address* means the following type of entry.

numeric-expression	A numeric expression is evaluated to give the address (see Chapter 5). (Table 5-9 specifies restrictions.)

For example, to start emulation with the instruction at memory location 3000H, you could enter:

```
CS = 0
IP = 3000H
GO
```

Or, you can enter:

```
GO FROM 3000H
```

The effect is the same either way.

The following form of the GO command is also valid.

GO [FROM *address*] FOREVER

This form of the GO command enables you to optionally select the starting address and to disable the factors that halt emulation. For example, to start emulation with the instruction at memory location 3000H and to set the GO-register to FOREVER, you can enter:

```
GO FROM 3000H FOREVER
```

The effect of this command is to start emulation with the instruction at location 3000H. Emulation will stop only when you abort processing.

The ICE-88 emulator has two breakpoint registers, BR0 and BR1. Each of these registers can be set to hold a "match condition" that can be used to halt real-time emulation when the register is enabled. A second form of the GO command can be used to both load and enable breakpoint registers. This form of the GO command is:

GO [FROM *address*] [TILL *match-condition* [$\begin{Bmatrix}\text{OR}\\ \text{AND}\end{Bmatrix}$ *match-condition*]]

This command loads the *match-conditions* into the breakpoint registers and enables the registers to halt emulation on the desired set of system conditions contained in these *match-conditions* . Match conditions are of two types:

match-condition ≡ $\begin{Bmatrix}\textit{execution-match-condition}\\ \textit{non-execution-match-condition}\end{Bmatrix}$

The breakpoint registers may be set to contain either type of match-condition.

Execution Match Condition

An *execution-match-condition* consists of a single 20-bit field plus the keyword EXECUTED, where each address bit can take any one of three values: 0, 1, or "don't care." An execution match condition is examined when the 8088 CPU executes an instruction byte, that is, when the byte is fetched from the 8088 instruction queue. The condition "matches" when the executed instruction byte was obtained from a memory location whose 20-bit address matches the contents of the selected breakpoint register.

execution-match-condition ≡ $\begin{Bmatrix}\textit{address}\ \text{EXECUTED}\\ \textit{masked-const}\ \text{EXECUTED}\end{Bmatrix}$

Entering an *address* causes all 20 bits of the match condition to be loaded with 0 and 1 bit values. The *address* contains a base and displacement (e.g., .X or 50:3000H); note that a single constant is evaluated modulo 65536 (e.g., 12345H is the same as 2345H—use 1234:5H to get all 20 bits). Entering a *masked-constant* causes the 20 bit field to contain 0, 1, or "don't care" values. The "don't care" values are ignored. The masked-constant can be 20 bits in length.

The following examples illustrate the use of this form of the GO command. The examples assume that the initial contents of the breakpoint registers are as shown below:

BR0 = XXXXXH (all bits set to "don't care")
BR1 = XXXXXH (all bits set to "don't care")

Also, in these examples, the address of .START is 0000:0002H, .DELAY is at 0000:00DEH, and .DISPLAY is at 0000:0098H. Each example will list a GO command followed by the contents of the breakpoint registers as set by the command.

1. Go from .START until the first instruction in .DELAY is executed.

   GO FROM .START TILL .DELAY EXECUTED

   BR0 = 000DEH E (000DEH is the 20-bit address of .DELAY, the last E specifies "EXECUTED")
   BR1 = XXXXXH (BR1 is unchanged)

This command loads BR0 with the given match condition: ".DELAY EXECUTED".

2. Go from .START until address 0200H is executed.

```
GO FROM .START TILL 0200H EXEC

BR0 = 00200H E
BR1 = XXXXXH
```

This command loads the numeric address and "executed" status into BR0 and leaves BR1 unchanged.

3. Go from .START until address 100:0200H is executed.

```
GO FROM .START TILL 100:0200H EXEC

BR0 = 01200H E
BR1 = XXXXXH
```

The pointer address 100:0200H and "executed" status are loaded into BR0 and BR1 is unchanged.

4. Go from .START until an address in an address range specified by a masked constant is executed.

```
GO FROM .START TILL 10XXH EXECUTED

BR0 = 010XXH E
BR1 = XXXXXH
```

The masked constant address loaded into BR0 specifies a range of addresses: 01000H through 010FFH. BR0 remains unchanged.

5. Load two execution match conditions, one in each breakpoint register, and "OR" the conditions.

```
GO FROM .START TILL .DELAY EXEC OR .DISPLAY EXEC

BR0 = 000DEH E   (Halt when .DELAY is executed.)
BR1 = 00098H E   (Halt when .DISPLAY is executed.)
```

This command sets emulation to halt when either the instruction located at location 000DEH (.DELAY) or location 00098H (.DISPLAY) is executed.

6. Load two execution match conditions and "AND" them.

```
GO FROM .START TILL .DELAY EXEC AND .DISPLAY EXEC

BR0 = 000DEH E      (Halt when .DELAY is executed.)
BR1 = 00098H E   (Halt when .DISPLAY is executed.)

ERR AE:INVALID "AND" IN GO-REG (Error message generated by
this command)
```

This command attempts to set emulation to halt when the instruction located at location 000DEH (.DELAY) "AND" the instruction located at location 00098H (.DISPLAY) are executed. Execution of two separate instructions can not occur at the same time. Therefore an error message is generated by this command and the command is not executed.

Non-Execution Match Condition

The *non-execution-match-condition* must contain one or more of four types of fields: a set of addresses, a list of bus status types, a set of data values, and a segment register designation. A *non-execution-match-condition* matches whenever a breakpoint that contains a set of one or more of the above fields matches corresponding state values in the user system during real-time or single step emulation.

$$\textit{non-execution-match-condition} \equiv \left\{\begin{array}{l} \textit{address-match-range} \\ \textit{match-status-list} \\ \textit{data-match-range} \\ \textit{segment-register-usage} \end{array}\right\} \ldots$$

Address-match-range, match-status-list, data-match-range, and segment-register-usage must be used in the order shown. At least one of these fields must be entered in a given command to establish a non-execution match condition.

Address Match Range

An *address-match-range* may consist of a single address or masked constant, an "unlimited" range of addresses, or a set of match partitions. If an "unlimited" range of addresses are to be entered, an address value modified by the mnemonic UP or DOWN is entered. UP implies any address value equal to or greater than the stated address. DOWN implies any address value equal to or less than the stated address. The match partition may be any of three types: partitions, memory references, and/or typed memory references. If the *address-match range* contains more than one partition, all partitions must have the same base and their displacements must lie within a 1K-byte range. If there is only a single partition, it must lie within a 1K-byte range to be contained in a single breakpoint register. If the partition does not lie within a 1K range, two registers are required to hold the partition. Therefore an *address-match range* can be defined as:

$$\textit{address-match-range} \equiv \left[\begin{array}{l} \textit{address} :: \textit{masked-const} \\ \\ \textit{address}\ \mathrm{UP} :: \textit{address}\ \mathrm{DOWN} \\ \\ \left[\begin{array}{l} \textit{partition} \\ \mathrm{OBJECT}\ \textit{memory-reference} \\ \mathrm{OBJECT}\ \textit{typed-memory-reference} \end{array}\right] , \ldots \end{array}\right]$$

By expanding the definition of partitions and memory reference to their component parts, the definition of *address-match range* becomes:

$$\textit{address-match-range} \equiv \left[\begin{array}{l} \textit{address} :: \textit{masked-const} \\ \\ \textit{address}\ \mathrm{UP} :: \textit{address}\ \mathrm{DOWN} \\ \\ \left[\begin{array}{l} \textit{address}\ \mathrm{TO}\ \textit{address} \\ \textit{address}\ \mathrm{LENGTH}\ \textit{length} \\ \mathrm{OBJECT\ BYTE}\ \textit{address} \\ \mathrm{OBJECT\ WORD}\ \textit{address} \\ \mathrm{OBJECT\ SINTEGER}\ \textit{address} \\ \mathrm{OBJECT\ INTEGER}\ \textit{address} \\ \mathrm{OBJECT\ POINTER}\ \textit{address} \\ \mathrm{OBJECT}\ \textit{typed-memory-ref} \end{array}\right] , \ldots \end{array}\right]$$

For example, an *address-match-range* of a single address would be 3000H, whereas using the masked constant 30XXH would result in a match range of 3000H through 30FFH. Two examples of the use of partitions in a match range are:

```
4000 TO 4100
```

and

```
4000 LENGTH 101
```

Both of these partition specifications result in the range of addresses 4000 through 4100.

A sequence of discontinuous addresses can be specified by:

```
OBJECT BYTE 4000, OBJECT WORD 3188, OBJECT !!MOD1 !SYMSAM, ...
```

This would result in a string of discontinuous match addresses, the third address in the above string being specified by a typed memory reference. OBJECT indicates a partition beginning at the low address of the memory object and whose length is the length of the object. In the above example, "OBJECT BYTE 4000" specifies a one-byte partition whose address is 4000. "OBJECT WORD 3188" specifies a two-byte partition starting at 3188 and ending at 3189. "OBJECT .. MOD1 .SYMSAM" specifies a partition starting at the address given in the symbol table for !!MOD1 !SYMSAM and whose length is specified by the memory type of symbol .SYMSAM. For example if .SYMSAM is type WORD, the partition will be two bytes in length.

Match Status List

The *match-status-list* field matches whenever the 8088 bus status is any of those listed in the match status list:

READ	match on memory read other than an instruction fetch.
WRITTEN	match on memory write.
INPUT	match on an I/O read.
OUTPUT	match on an I/O write.
FETCHED	match on a memory read into the execution queue.
HALT	match on 8088 halt.
ACKNOWLEDGE	match on 8088 interrupt acknowledge.

A match-status-list may consist of one or more of the above bus status types and they may be listed in any order:

$$\textit{match-status-list} \equiv \begin{bmatrix} \text{READ} \\ \text{WRITTEN} \\ \text{INPUT} \\ \text{OUTPUT} \\ \text{FETCHED} \\ \text{HALT} \\ \text{ACKNOWLEDGE} \end{bmatrix}, \ldots$$

An example of a match-status-list would be:

```
FETCHED, READ, HALT, WRITTEN, ACKNOWLEDGE
```

Data Match Range

The *data-match-range* field can be used to specify data values. The syntax is similar to *address-match-range*, except the OBJECT form is not allowed. In this case, the values specified by address will be treated as data values and used to match against values on the 8088 address/data lines at data time.

```
                         ┌ address :: masked-const       ┐
data-match-range ≡ VALUE │ address UP :: address DOWN    │
                         └ [partition] , ...             ┘
```

Data values must be integers. The set of values which match this field is the same as for *address-match-range*. Since the 8088 deals only with 8-bit data values, only the low order 8 bits in the data values are significant.

Segment Register Usage

The *segment-register-usage* field is used to specify one of the four segment registers. A match occurs whenever the segment register used in an effective address calculation is the one specified in the *segment-register-usage* field. Segment register usage occurs at data time.

```
                           ┌ USING SS ┐
segment-register-usage ≡   │ USING CS │
                           │ USING DS │
                           └ USING ES ┘
```

Match Condition Restrictions

Figure 6-1 illustrates a detailed specification of the *non-execution-match-condition*. The following examples illustrate a set of restrictions that must be observed in the use of match conditions in emulation commands.

Data values, bus status and segment register usage come out of the 8088 at data-time. Address values and bus status are available at address-time. The following restrictions apply to match conditions.

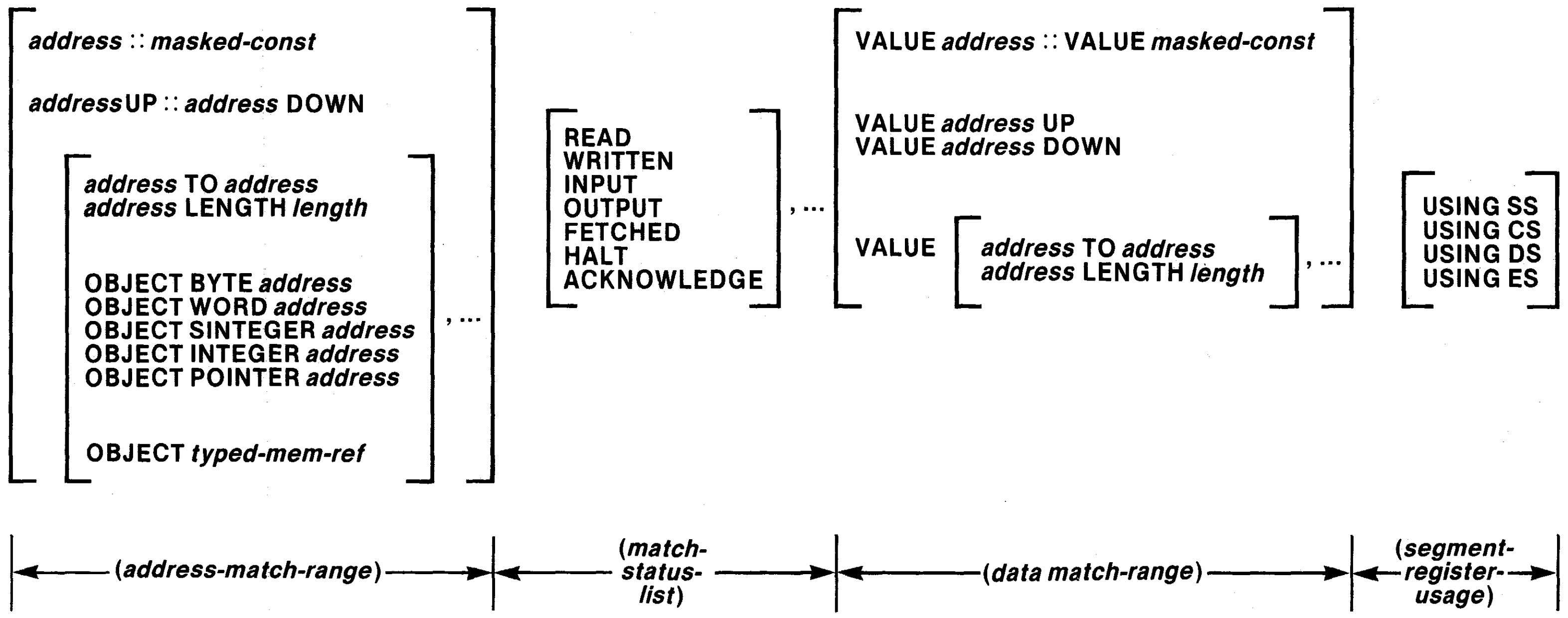
- Breakpoint register BR0 cannot contain data-time values and breakpoint register BR1 contain address-time values if the two registers are ANDed (the reverse is permissible).
- Neither BR0 nor BR1 may contain an *execution-match-condition* if they are to be ANDED.

A warning message is issued after a Set BR command or a Set GR command if the command results in either of the above conditions. An Error is issued on a GO command if the command results in either of the above conditions.

- If a match-condition specifies both address and data or segment register usage, the match condition requires both breakpoint registers; hence this match-condition cannot OR/AND with another match-condition.

All partitions in a multi-partition match condition must have the same base value. For example, the following command generates the error message shown.

```
GO FROM .START TILL 0:0000 LEN 2, 100:1000H READ
ERR AD:DIFFERING BASIS  (error message)
```



Note: (*address-match-range*), (*match-status-list*), (*data-match-range*), and (*segment*-register-usage) must be used in the order shown. At least one of these field must be entered in a given command and no filed may be repeated in the command.

Figure 6-1. Non-Execution Match Condition

All the displacement values must be within a 1K-byte range to be contained in a single breakpoint register. Displacements which exceed 1K must be contained in a single partition.

The following match condition cannot be contained in one breakpoint register.

```
GO FROM .START TILL 0:0000 LENGTH 2048T WRITTEN
```

The above command would require both breakpoint registers as the partition is 2K-bytes in length.

The following command would generate an error as two partitions are specified and the displacements exceed 1K.

```
GO FROM .START TILL 0, 2048T WRITTEN
```

The following command would generate an error as the partition requires both breakpoint registers. Therefore the *partition* ".BEGIN" cannot be entered.

```
GO FROM .START TILL 0 LEN 2048T, .BEGIN W
```

Segment register usage can only be used in conjunction with a single match value as illustrated in the example below.

```
GO FROM .DELAY TILL .MAINTIME READ USING DS
```

The last form of the GO command is in the following format:

$$\text{GO [FROM } \textit{address}\text{] [TILL } \textit{break-reg} \left[\begin{Bmatrix}\text{AND}\\ \text{OR}\end{Bmatrix} \textit{break-reg} \right]\text{]}$$

where *break-reg* references breakpoint register BR0, BR1 or BR. This command form is used when the breakpoint registers have been set prior to the entering of this command. The command enables the referenced breakpoint register but does not set its contents. The Set Breakpoint command, GR command, or a previous GO command must be used to set the required breakpoint registers. Care is required in ANDing two breakpoint registers in this command. Only two *non-execution-match-conditions* can be "anded." An error results if either of the conditions described below occur.

- BR0 contains data values or segment register usage and BR1 contains address values.
- Either of the breakpoint registers contains an *execution-match-condition.*

Setting the Go-Register

To enable either (or both using BR) of the breakpoint registers as a halt condition, you can use a set GR command of the form:

GR = *halt-go-condition*

The meta-term *halt-go-condition* means any of three exclusive types of halt conditions:

$$\textit{halt-go-condition} \equiv \begin{Bmatrix} \text{FOREVER} \\ \text{TILL } \textit{break-reg} \left[\begin{Bmatrix}\text{AND}\\ \text{OR}\end{Bmatrix} \textit{break-reg} \right] \\ \text{TILL } \textit{match-cond} \left[\begin{Bmatrix}\text{AND}\\ \text{OR}\end{Bmatrix} \textit{match-cond} \right] \end{Bmatrix}$$

Using the FOREVER condition in the Go-Register command:

```
GR = FOREVER
```

would disable both breakpoint registers.

The following command would enable BR1:

```
GR = TILL BR1
```

Both registers can be enabled and ORed with the following command:

```
GR = TILL BR1 OR BR0
```

BR0 would be loaded with a match condition and enabled with the following command:

```
GR = TILL 3000H WRITTEN, FETCHED
```

The following command would load BR0 with the first match condition and BR1 with the second stated match condition:

```
GR = TILL 3000H WRITTEN, FETCHED OR INPUT VALUE 01 USING DS
```

BR0 would contain the match condition 3000H WRITTEN, FETCHED and BR1 would contain the match condition INPUT VALUE 01 USING DS and both registers would be enabled and ORed.

The following command would require both breakpoint registers to contain the match condition:

```
GR = TILL .DELAY FETCHED OR READ VALUE .MAINTIME USING DS
```

BR0 would contain the match condition .DELAY FETCHED and BR1 would contain the match condition READ VALUE .MAINTIME USING DS.

The following command would require both breakpoint registers to contain match conditions that are "anded":

```
GR = TILL !SIDETIME READ AND VALUE 8
```

BR0 would contain the condition .SIDETIME READ and BR1 would contain the match condition VALUE 8 . These conditions are ANDED.

Setting Tracepoint Registers

The ICE-88 emulator has two tracepoint registers, ONTRACE and OFFTRACE. A tracepoint register may only contain a non-execution match condition. Also the match range may only contain an address, masked constant, or data, and segment register usage may not be used with an address condition. For example, the following commands are valid:

```
ONT = 3000H WRITTEN, FETCHED
OFF = INPUT VALUE 01 USING DS
```

However, the commands:

```
OFFTRACE = 3000H EXECUTED
ONTRACE = 3000H READ USING CS
```

are invalid as EXECUTED is invalid in a tracepoint, and the segment register CS is specified with an address condition.

Command Signal Timeout

When the 8088 accesses INTELLEC- or DISK-mapped memory, a command signal timer starts counting. If the access is not completed before it times out, the ICE-88 emulator will cause the READ and WRITE command signals to go inactive to the user system. The RWTIMEOUT commands are used to set and display the current setting of the command signal timer.

Emulation Timer

An emulation timer is enabled when emulation is running. The timer can be used to determine how long it takes the ICE-88 emulator to emulate a given segment of code. The timer is a 2-MHz clock (i.e., counts are intervals of 500 ns), derived from the crystal on the Control board.

The timer starts when the GO command is entered, starting emulation. The timer starts counting at the first T3 state of the first instruction emulated. HTIMER stops counting where a maximum count of approximately 33 minutes is reached. TIMER continues counting modulo 65536.

The timer is reset to 0 (before starting to count) when the GO command is entered with a FROM clause or when CS,IP is changed or when ENABLE/DISABLE TRACE. If you want to reset the timer without changing the current program counter, enter a command such as GO FROM CS:IP.

After emulation halts, you can display the value of the timer in the current output radix. The display command TIMER displays the low 16 bits of the timer value; the command HTIMER displays the high 16 bits of the timer value. The tokens TIMER and HTIMER can also be used as keyword references in commands and expressions.

With the timer, you can measure the real elapsed time required to emulate a given code sequence. The elapsed time can then be compared to the calculated time based on the number of clock states in each instruction and the speed of the system clock. Note that code mapped to user runs at real-time; the timer value for code mapped to prototype memory is the real-time value.

Set Breakpoint Register Command

(1) *break-reg* = *address* EXECUTED :: *masked-const* EXECUTED

(2) *break-reg* = [*address-match-range*] [*match-status-list*] [*data-match-range*][*seg-reg-usage*]

NOTE

Form (2) requires that the address-match-range, match-status-list, data-match-range, and seg-reg-usage fields be used in the order shown. At least one field is required in a given command and no field may be repeated in the command. Restriction: the fields selected must fit in one breakpoint register.

Examples:

```
BR0 = 1XXXH EXECUTED
BR1 = 3000H UP WRITTEN
BR  = 3000H TO 30FFH READ
BR = 3000H LENGTH FEH, OBJECT !VAR WRITTEN
```

break-reg	The name of one of the breakpoint registers (BR0, BR1) or BR to set both registers to the same match condition.
=	The assignment operator.
address	The address of the memory location or I/O port, or a data value.
masked-const	A masked constant used to define a range of memory locations or data values.
EXECUTED	Denotes that the match condition is the execution (CPU fetch of the instruction byte from the instruction queue) of the instruction byte whose address is given by address or masked-const.
address-match-range	A set of one or more addresses. (See page 6-6.)
match-status-list	A set of bus status conditions to be used as match parameters. (See page 6-7.)
data-match-range	A set of data values to be used as match parameters. (See page 6-8.)
seg-reg-usage	A specification of one of the segment registers to be used as a match parameter. (See page 6-8.)

Set Tracepoint Register Command

```
                                  ┌ READ          ┐
                                  │ WRITTEN       │
┌                         ┐       │ INPUT         │       ┌                        ┐ ┌ USING SS ┐
│                 address │       │ OUTPUT        │       │ VALUE address          │ │ USING CS │
│ trace-reg =             │       │ FETCHED       │ , ... │                        │ │ USING DS │
│           masked-const  │       │ HALT          │       │ VALUE masked-const     │ │ USING ES │
└                         ┘       └ ACKNOWLEDGE   ┘       └                        ┘ └          ┘

                (address-         (match-                 (data-match-range)         (segment-
                match )           status-                                            register-
                range)            list)                                              usage)
```

NOTE

The *address-match-range*, *match-status-list*, *data-match-range*, and *segment-register-usage* fields must be used in a command in the order shown. At least one field is required in a given command and no field may be repeated in the command. A *segment-register-usage* field or *data-match-range* may not be used with an address condition (*address-match-range* field); because you cannot mix address-time fields with data-time fields.

Examples:

```
ONTRACE = 2340 READ, ACKNOWLEDGE
OFFTRACE = INPUT, OUTPUT VALUE 1234H
ONTRACE = !X FETCHED
ONTRACE = R,W VALUE 40XX USING ES
OFFTRACE = USING ES
```

trace-reg	The name of one of the tracepoint registers, ONTRACE or OFFTRACE.
=	The assignment operator.
address	The address of the memory location or I/O port, or a data value (see Data Match Range).
masked-const	A masked constant used to define a range of memory locations or data values.
match-status-list	See Match Status List. (See page 6-7.)
data-match-range	See Data-Match Range. (See page 6-8.)
segment-register-usage	See Segment Register Usage. (See page 6-8.)

Go Command

```
     ┌ FROM address                                        ┐
     │                                                     │
     │ ⎧FOREVER                                            │
 GO  │ ⎨TILL break-reg   [ {AND} break-reg   ]  ⎫          │
     │ ⎪                 [ {OR }             ]  ⎬          │
     │ ⎩TILL match-cond  [ {AND} match-cond  ]  ⎭          │
     │                   [ {OR }             ]             │
     └                                                     ┘
```

Examples:

```
GO
 GO FROM 3000H
 GO FROM .START TILL BR0
 GO FROM 3000H TILL 3000H EXECUTED
 GO TILL INPUT VALUE 10
 GO FROM 1000H TILL 3000H TO 30FFH READ USING DS
 GO FROM 3000H TILL OBJECT POINTER .START READ
```

GO	Command keyword that starts emulation, subject to the current start and halt conditions.
FROM	Keyword introducing a starting address.
address	The address of the memory location of the first instruction to emulate, i.e., the start address.
FOREVER	Disables all breakpoint conditions; emulation can be stopped only by user aborting processing.
TILL	A keyword introducing one or more match or halt conditions.
break-reg	One of the breakpoint registers (BR0, BR1), or BR to set both registers to the same match setting.
match-cond	One of the following forms of breakpoint register settings. 1. execution-match-condition. (See page 6-4.) 2. non-execution-match-condition. (See page 6-6.)

NOTES

The ICE-88 emulator cannot enter GO or STEP with the 8088 Trap Flag (TFL) set. Therefore a warning message will be issued whenever GO or STEP commands are executed with TFL =1 , and TFL will be set to 0.

If either breakpoint register contains a match range other than a single match-value and the breakpoint register has changed since the last GO command, the message "LOADING RANGE BREAKPOINTS" is issued and, it takes approximately 10 seconds to load breakpoints and hardware before emulation begins.

Set GO-Register (GR) Command

$$\text{GR} = \left\{ \begin{array}{l} \text{FOREVER} \\ \text{TILL } \textit{break-reg} \quad \left[\begin{Bmatrix} \text{AND} \\ \text{OR} \end{Bmatrix} \textit{break-reg} \right] \\ \text{TILL } \textit{match-cond} \left[\begin{Bmatrix} \text{AND} \\ \text{OR} \end{Bmatrix} \textit{match-cond} \right] \end{array} \right\}$$

Examples:

```
GR = FOREVER
GR = TILL BR1
GR = TILL BR0 OR BR1
GR = TILL OBJECT !ABLE1
GR = TILL OBJECT POINTER 0123 READ, WRITTEN VALUE 30 USING DS
```

GR	Command keyword referring to the GO-register (halting conditions for emulation).
=	The assignment operator.
FOREVER	Disables all breakpoint conditions; emulation can be stopped only by user aborting processing.
TILL	A keyword introducing one or more match or halt conditions.
break-reg	One of the breakpoint registers, BR0 or BR1 (or BR to denote both breakpoint registers) that is to be enabled.
match-cond	One of the following forms of breakpoint register settings: 1. execution-match-condition. (See page 6-4.) 2. non-execution-match-condition. (See page 6-6.)

STEP Command

```
STEP [FROM address]
```

Examples:

```
STEP
STEP FROM 1FFFH
STEP FROM ..MOD.GO
STEP FROM !PTR
STEP FROM #123 + 10
STEP FROM CS:(WORD .X) ;SHORT JUMP INDIRECT THROUGH .X
```

STEP	A command keyword that causes the ICE-88 emulator to execute a single step of emulation.
FROM	A function keyword introducing the address where a single step of emulation is to be executed.
address	See address. (See page 6-14.)

The STEP command causes the ICE-88 emulator to execute one single step of emulation. If FROM address is not included in the command, the emulation step is executed from the current address. If FROM address is included in the command, the value of the address is loaded into the CS and IP and the step is executed from this location.

NOTE

The STEP command is very useful in repeat loops and macros (see Chapter 8), where terminating condition can be given (UNTIL or WHILE) and system status and values can be displayed after each step. However, the user is cautioned that a hardware reinitialization occurs intermittently with a reset timeout when the RESET pin is pulsed during a repeat of the STEP command.

Display Emulation Register Command

```
GR
break-reg [ABSOLUTE   ]
          [BASE [expr]]

trace-reg [ABSOLUTE   ]
          [BASE [expr]]
```

Examples:

```
GR
BR1
BR0 BASE CS
BR0 BASE CS
BR BASE
OFFTRACE
OFF ABSOLUTE
ONT BASE DS
ONTRACE BASE DS
```

GR	A command keyword that causes the content of the GO-register (factors enabled to halt emulation) to be displayed.
break-reg	One of the breakpoint register keywords BR0 or BR1, to obtain a display of the register setting, or the keyword BR to cause the display of the settings of both breakpoint registers.
trace-reg	One of the tracepoint register keywords ONTRACE or OFFTRACE to command the display of the content of the designated register.
ABSOLUTE	Display all addresses as 20-bit numbers (this is the default).
BASE	Display all addresses in base and displacement format (e.g., 0000:1000H). If no *expr* is given, display with the base that was used to set the register.
expr	An integer value that specifies that all addresses are to be displayed as their displacement from (*expr*)*16. An error occurs if an address needs a displacement of less than 0 or greater than 65535 from the base (*expr*). Typically *expr* will be a segment register name; thus "BR0 BASE CS" displays the displacements of the addresses in BR0 using the current code segment register. If no *expr* is given, use the base that the register was set with.

NOTE

Data values are always displayed as 8-bit numbers, masked-constants as 8-bit, 16-bit or 20-bit strings with Xs (in hexadecimal if possible, or else in binary).

Internal to the ICE-88 emulator, match addresses are stored as 20-bit numbers. Thus "GO TILL 20:8 R" breaks whenever 208H is read, even if it is read as 10:108H.

Set CLOCK Command

$$\text{CLOCK} = \begin{bmatrix}\text{INTERNAL}\\ \text{EXTERNAL}\end{bmatrix}$$

Examples:

```
CLOCK = INTERNAL
CLOCK = EXTERNAL
```

CLOCK	This command keyword enables the user to designate the type of clock being used in the system: user-provided clock or ICE-provided clock.
=	The assignment operator.
INTERNAL	Designates that the ICE-provided clock is being selected. This is necessary whenever the cable is not plugged into user system. When clock is set to Internal, the ICE-88 emulator is operated in stand-alone mode. The Socket Protector should be mounted on user cable in this mode of operation.
EXTERNAL	Designates the clock to be user supplied. This is necessary whenever the cable is plugged into a user system.

Display CLOCK Command

```
CLOCK
```

Examples:

```
CLOCK
```

CLOCK	A command keyword that causes the display of the clock setting.

Set RWTIMEOUT Command

$$\text{RWTIMEOUT} = \left\{\begin{array}{l}\text{INFINITE}\\ \textit{expr-10}\ \text{[ERROR]}\\ \textit{expr-10}\ \text{NOERROR}\end{array}\right\}$$

Examples:

```
RWTIMEOUT = INFINITE          ;DISABLE RWTIMEOUT
RWTIMEOUT = 500 ERROR         ;SET TIMEOUT TO HALT EMULATION W/REPORT
RWTIMEOUT = 500               ;HALT EMULATION WITH ERROR REPORT
RWTIMEOUT = 1500 NOERROR      ;SET TIMER BUT DO NOT HALT EMULATION WHEN IT
                              ;TIMES OUT
```

RWTIMEOUT	A command keyword denoting that a command signal timeout function is to be set.
=	Denotes that the command is a set signal timeout command.
INFINITE	Sets command signal timeout to "infinite" effectively disabling the timeout.
expr-10	An integer value that specifies the timeout value in microseconds. The integer value must be greater than 0 and less than 32K, and the default suffix when evaluating *expr-10* is decimal.
ERROR	Specifies that error is to be reported whenever command signal times out.
NOERROR	Specifies that command signal timeout is not to halt emulation.

Display RWTIMEOUT Command

```
RWTIMEOUT
```

RWTIMEOUT	Causes the current setting of the command signal timeout to be displayed.

ENABLE/DISABLE RDY Command

1. ENABLE RDY
2. DISABLE RDY

ENABLE	A command keyword denoting that an ICE-88 element is to be enabled.
DISABLE	A command keyword denoting that an ICE-88 element is to be disabled.
RDY	A reference keyword specifying the user ready signal for memory access.

The ICE-88 emulator allows the user to enable and disable the user ready signal. If RDY is enabled, the ready signal to the 8088 is a local ready (generated by the ICE-88 emulator) AND user ready; otherwise ready to the 8088 is either the local ready when mapped to local memory or user ready when mapped to user memory. RDY is initially enabled.

NOTE

Must disable RDY if clock is INTERNAL and you are using INTELLEC memory or DISK memory. When emulating in the user memory with DISABLE RDY invoked, the user ready pin must be active to continue emulation.

Trace Control Commands

The ICE-88 emulator can record program execution through the collection of trace data in a trace buffer during real-time and single-step emulation. The commands in this section allow you to specify the conditions for enabling and disabling trace data collection during emulation and to control the display of trace data.

The commands in this section are as follows:

COMMAND	PURPOSE
Set TRACE Display Mode	Establishes trace data that will be displayed as frames or instructions.
ENABLE/DISABLE TRACE	Enables or disables the collection of trace data.
Display TRACE Mode	Causes the display of the current display mode.
MOVE, OLDEST, NEWEST	Set trace buffer pointer to entry to be displayed.
PRINT	Display one or more entries from the trace buffer.

Discussion

The unit of emulation is the instruction. During real-time and single-step emulation, the ICE-88 emulator traces program execution twice per 8088 bus cycle: first when the address signals are valid and then when the data signals are valid. It also traces each CPU clock cycle during which the execution queue is active.

The ICE-88 emulator contains a trace buffer used to collect trace data (frames) during real-time and single-step emulation. The trace buffer holds a total of 1023 frames or approximately 300 bus cycles of typical trace information. Each entry in the buffer is a frame, and is either half a bus cycle or contains queue status, or both. Each frame contains:

bit-size	purpose
20	Address/data
3	Bus status ($\overline{S0}$, $\overline{S1}$, $\overline{S2}$)
2	Queue Status (QS0, QS1)
3	Queue depth
2	Frame type indicator: address, data, or queue status
1	Start/stop trace marker for conditional trace

Trace is initially unconditionally on and the buffer is initially empty. The buffer is cleared whenever the user changes the IP or CS, either by a FROM clause on a GO or STEP command or by a Change command. Otherwise new trace data is appended to the end of existing trace data and the most recent 1023 frames are retained in the buffer. Similarly, the TIMER and HTIMER registers are reset to zero each time the user changes the IP or CS register. Also, whenever the user issues an enable/disable trace command, the trace buffer is cleared to empty and TIMER and HTIMER are reset to zero when the user next enters emulation.

The user can control the collection of trace data using the tracepoint registers. The enable/disable trace command enables trace conditionally and unconditionally or disables trace unconditionally:

ENABLE TRACE	Turns trace on unconditionally during subsequent emulations.
ENABLE TRACE CONDITIONALLY [NOW {ON | OFF}]	Trace will be turned on whenever the ONTRACE register matches and turned off whenever the OFFTRACE register matches.

NOW ON indicates that trace is turned on for the beginning of the next emulation; NOW OFF indicates it is off; if neither is present the trace is left in its current state.

DISABLE TRACE	Turns trace off unconditionally during subsequent emulations.

The trace display command allows the user to examine collected trace data displayed in one of two modes: as "raw" data or disassembled with instructions appearing as 8086 assembler mnemonics.

Instructions in the trace buffer are counted by occurrences of queue status indicating "first instruction byte out of queue" (i.e., QS0=1 and QS1=0). Since the 8088 defines instruction prefix bytes as well as the first non-prefix byte as "first instruction bytes," an 8088 instruction with one prefix byte counts as two instructions when using the MOVE or PRINT commands. However, if a PRINT command prints the requested number of instructions and ends up after a prefix byte but before the non-prefix instruction, it completes printing the entire non-prefix instruction. When the user switches from frames to instructions mode, if the buffer pointer is not at the oldest or newest frame, then the pointer is moved to a "first byte out of queue" frame if it is not already pointing at one before beginning to MOVE or PRINT the requested number of instructions.

Trace Display Mode

The trace display mode controls the type of an *entry* to be displayed or located in the trace buffer. An *entry* can be a frame, or an instruction. The initial trace display mode is INSTRUCTION. To set the trace display mode, use one of the following commands.

```
TRACE = FRAME
TRACE = INSTRUCTION
```

To display an entry from the buffer, move the pointer to the desired entry and enter a PRINT command. However, it is not necessary to move the pointer if you use a PRINT ALL or PRINT-*decimal* command.

Moving the Buffer Pointer

The pointer movement commands are MOVE, OLDEST, and NEWEST.

The command OLDEST (followed by carriage return) moves the pointer to the top of the buffer, in any trace display mode. The NEWEST command moves the pointer to the bottom of the buffer (i.e., after the last instruction or frame). "Top" refers to the oldest trace data, "bottom" refers to the newest trace data.

The MOVE command has the following form:

```
MOVE [[+ :: -] decimal ]
```

The meta-term *decimal* means any numeric quantity; if no explicit input-radix is given, the ICE-88 emulator assumes decimal radix. The value of *decimal* is the number of entries between the current pointer position and the desired position. Movement in a plus (+) direction is toward the bottom (newest point) of the buffer; if neither (+) nor (–) is entered, a forward movement is assumed as the default. Movement in a minus (–) direction is toward the top (oldest point) of the buffer. The size of the move does not count the entry under the pointer when the MOVE command is given.

For example, assuming FRAME mode, if the pointer is pointing at frame 100 and you issue the command "MOVE 10", the pointer is moved to point to frame 110. Under the same initial conditions, if you issue the command "MOVE –10", the pointer is moved to point to frame 90. If *decimal-number* is larger than the number of entries between the current pointer location and the bottom (for "+") or top (for "–"), the pointer is moved only to the bottom or top, respectively. In short, you cannot move the pointer outside the range of buffer locations.

If the MOVE command has no number following it, "MOVE 1" is executed.

The trace display mode in effect controls the size of each move. Under FRAME mode, the command MOVE 10 moves down ten frames; under instruction, the same command moves down ten instructions.

Displaying Trace Data

The PRINT command displays one or more entries from the buffer. This command has the form:

```
PRINT [[+ :: -] decimal ]::PRINT ALL
```

With (+) or no sign, *decimal* entries lower (toward the bottom) than the current pointer position are displayed. With (–), decimal entries above (toward the top) the current pointer position are displayed. The command PRINT without a *decimal* modifier is equivalent to PRINT 1 (one entry is displayed).

The PRINT command displays the number of entries requested, then moves the pointer to point to the next entry just past the last one displayed. As an illustration, the commands:

```
OLDEST
PRINT 10
PRINT 10
```

are equivalent to the commands

```
OLDEST
PRINT 20
```

The command PRINT ALL displays the entire trace buffer; PRINT ALL is equivalent to the commands:

```
OLDEST
PRINT 1023
```

TRACE Display Formats

Display of Trace Data in Frames Mode

The display has one frame per line. The header at the top of display has the following format (one line of display shown also):

```
FRAME  ADDR    STS  QSTS  QDEPTH  DMUX  MARK
0000:  0002CH  F    N     0       A     0
```

How to interpret the Frames mode display:

Header entry	*Meaning*
FRAME	Frame number; decimal number from 0000 to 1022. The colon separates the frame number from the next entry (ADDR).
ADDR	The 20-bit address in Hexadecimal radix (five digits plus suffix H) when DMUX = A (address frame). When DMUX = D (data frame), the last 2 digits (8 bits) of this number are data, and the first digit is status: S6, S5, S4, S3 (MSB to LSB). Bits S4 and S3 are the segment register used in effective address calculation:

S4	*S3*	*Segment Register*
0	0	ES
0	1	SS
1	0	CS or none
1	1	DS

STS — A one-character display of processor action, as follows:

A	Interrupt Acknowledge
F	Instruction Fetch
H	Halt
I	Input
O	Output
R	Read (Memory)
W	Write (Memory)
?	Passive State

STS is valid on ADDR and DATA frames only (DMUX = A or D).

QSTS — Queue status; a one-character display, as follows:

E	Empty the queue
F	First byte of opcode executed out of queue
N	Nothing coming out of queue
S	Subsequent byte of opcode executed out of queue

QDEPTH — Number of bytes in queue (decimal number). Valid on ADDR frames only (DMUX = A).

DMUX — Type of frame; a one-character display as follows:

A	Address
D	Data
Q	Queue
S	Stop emulation

MARK — 1 if trace was turned off before this frame or if emulation broke before this frame.

Display of Trace Data in Instructions Mode

The display shows the disassembled instruction mnemonic and any operands, and any succeeding cycles. Each instruction combines several frames of trace data. Machine cycles after the instruction fetch are displayed four cycles per display line, using as many lines as necessary.

First, we discuss the header and the instruction display. Display of cycles is discussed later on. The headers apply to the first line of the display entry—the line with the frame numbers. The Instructions mode header has the following format (two instructions are also shown):

```
FRAME  ADDR      PREFIX        MNEMONIC     OPERANDS          COMMENTS
0006:  000E7H                    DEC        CL
0010:  000E9H                    MOV        WORD PTR [0101H],BX
       00101H-W-  2CH-DS       00102H-W-  00H-DS
```

Header entry	*Meaning*
FRAME	The (decimal) number of the frame where the first byte (or prefix) of the instruction came out of the 8088 execution queue.
ADDR	Address of first byte (or prefix) of instruction; 20-bit number in Hexadecimal radix (five Hex digits plus suffix H).
PREFIX	Prefix other than segment-override (LOCK, REPE, REPNE) if specified in assembly language else blank.
MNEMONIC	MCS-86 assembler mnemonic for the instruction.
OPERANDS	Zero, one, or two operands separated by commas. The formats for the operand fields are discussed below.
COMMENTS	The word ";SHORT" for a JMP or CALL instruction to an address within the same segment of field bytes that contains the instruction's address, or the word ";LONG" for a branch to a different segment, or the characters ";?" for an opcode value that does not correspond to a valid instruction.

Operand fields

1. Registers: the MCS-86 register identifiers are displayed:

```
RAL, RAH, RBL, RBH, RCL, RCH, RDL, RDH,
RAX, RBX, RCX, RDX
```

Example (comments field omitted):

```
FRAME  ADDR       PREFIX     MNEMONIC    OPERANDS
0003:  00206H                  MOV       AL,BYTE PTR [0000H]
       00200H-R-  34H-DS
```

2. Memory operands have the following display format:

$$\left[\left\{\begin{matrix}\text{CS}\\\text{DS}\\\text{ES}\\\text{SS}\end{matrix}\right\}:\right]\left\{\begin{matrix}\text{BYTE}\\\text{WORD}\\\text{DWORD}\\?\end{matrix}\right\}\text{PTR}\left[\begin{matrix},\ ,\\ {[}\\ \\ \end{matrix}\left\{\begin{matrix}\text{BX}\\\text{BP}\\ \\ \end{matrix}\right\}\begin{matrix},\ ,\\ {]}\\ \\ \end{matrix}\right]\left[\begin{matrix},\ ,\\ {[}\\ \\ \end{matrix}\left\{\begin{matrix}\text{DI}\\\text{SI}\\ \\ \end{matrix}\right\}\begin{matrix},\ ,\\ {]}\\ \\ \end{matrix}\right]\left[\begin{matrix},\ ,\\ {[}\\ \\ \end{matrix}\left\{\begin{matrix}xxxx\text{H}\\ \\ +xx\text{H}\\ -xx\text{H}\end{matrix}\right\}\begin{matrix},\ ,\\ {]}\\ \\ \end{matrix}\right]$$

Example: the display ES:BYTE PTR [BX] [SI] [+01H]
represents the operand BYTE ES:(BX+SI+1)

More examples showing memory operand display.

```
FRAME   ADDR     PREFIX  MNEMONIC   OPERANDS
0000:   FF380H             ADD      ES:BYTE PTR [BX] [SI], AL
***
0025:   FF480H             ADD      ES:BYTE PTR [BX] [SI] [+01H], AL
***
0050:   FF580H             MOV      AL, BYTE PTR [0001H]
```

Notes on the memory operand format:

- The first field is the segment register field. It is only displayed if the instruction has a segment-override prefix.
- In the second field, an entry "? PTR" means that the type of the pointer cannot be determined from the context.

  Example: `LEA AX,? PTR [34A0H]`
- The base register (BX, BP) and index register (DI, SI) fields are not displayed for direct memory operands. When these fields are displayed, they are enclosed in brackets (shown as "[" and "]" in the format given earlier).
- The last field is either a 16-bit unsigned (word) number, or a signed 8-bit (byte) number. The entry is displayed enclosed in brackets.
- At least one of the last three fields (base register, index register, number) is displayed for any memory operand.

3. Immediate data is displayed as a byte or word number, without brackets.

   Example:

```
FRAME  ADDR   PREFIX  MNEMONIC  OPERANDS
0932:  FF391H           TEST    AL, 07H
```

4. Labels for the JUMP and CALL instructions:

   •Within 128 bytes of current address—$ ± *xx*H

   Example:

```
0934:  FF393H        JE     $-06H
```

   •Within same 64K segment as current address—$ +*xxxx*H

   Example:

```
0000:  FF000H       JMP    $+1005H
```

   •To a different segment—*base:displacement*

   Example:

```
0978:  FFFF0H       JMP    FF00:0096H
```

Note: the first two labels represent "SHORT" (intra-segment) branches, the third is a "LONG" (inter-segment) branch.

Display of Cycles in Instruction Mode. After the instruction mnemonic and operands are displayed, the display shows succeeding cycles performed by the current instruction. Four cycles are shown per line of display; the display uses as many lines as needed to show all cycles.

The general format for cycles display is:

address-status-data-segment

Examples:

•*Read/Write*:

```
12345H-R- 34H-DS      (8-bit read of data 34H from address 12345H using DS)
45100H-W- 70H-SS      (8-bit write of data 70H to address 45100H using SS)
```

•*Input/Output*: (no segment register; 16-bit address)

```
FF00H-I-01H     (8-bit input of data 01H from port FF00H)
FFDAH-O-34H     (8-bit output of data 34H to port FFDAH)
```

•*Interrupt Acknowledge*: no address field, "A" for "acknowledge" status, 8-bit interrupt type.

Example:

```
FRAME ADDR       PREFIX      MNEMONIC    OPERANDS             COMMENTS
0971:  FF391H                  TEST       AL,07H
0977:  FF393H                  JE         $-06H                ; SHORT
0986:  FF38DH                  MOV        DX,FFEAH
0995:  FF390H                  IN         AL,DX
        FFEAH-I-  00H
               A- FFH
               A- FFH    003FCH-R-  0H-CS  003FDH-R-  00H-CS    003FEH-R-  FFH-CS
       003FFH-R-  FFH-CS 000BAH-W-  46H-SS 000BBH-W-  F2H-SS  000BCH-W-  00H-SS
       000B9H-W-  FFH-SS
```

Note that:

a. The I cycle is part of the IN instruction; the rest of the cycles are the interrupt.

b. The "A" cycle is traced twice; ignore the first one.

c. Interrupt is type 0FFH

d. The five cycles after the "A" cycle are as follows:

   —Read IP of interrupt vector
   —Read CS of interrupt vector
   —Write flags to stack
   —Write old CS to stack
   —Write old IP to stack

- *Fetch* cycles do not appear as cycles; they are used to display the opcode mnemonic and operands.
- *Halt* cycles never appear as cycles; they appear as the mnenonic HLT.

Gaps in Trace in Instruction Mode. In Instruction mode, a gap in trace data is shown as three asterisks (***). A gap in trace is produced by tracepoints or by buffer overflow.

A gap in trace data also is reflected by a MARK = 1 in Frames mode.

Extended Example of Trace Displays

The following example (from SDK-86 Monitor) shows most of the features of trace displays discussed in this section.

```
*ONTRACE=FF00:96
*OFFTRACE=FFFF:0
*ONT
ONT=FF096H A,I,O,H,F,R,W
*OFFT
OFFT=FFFF0H A,I,O,H,F,R,W
*ENABLE TRACE CONDITIONALLY NOW ON
*GO TILL FF00:9F EXECUTED
EMULATION BEGUN
EMULATION TERMINATED, CS:IP=FF00:00A1H
*BUF
BUF=03FDH
*P-20
FRAME  ADDR       PREFIX     MNEMONIC    OPERANDS          COMMENTS
0876:  FF390H                  IN        AL,DX
         FFEAH-I-  00H
0880:  FF391H                  TEST      AL,07H
0886:  FF393H                  JE        $-06H              ; SHORT
0895:  FF38DH                  MOV       DX,FFEAH
0904:  FF390H                  IN        AL,DX
         FFEAH-I-  00H
0908:  FF391H                  TEST      AL,07H
0914:  FF393H                  JE        $-06H              ; SHORT
0923:  FF38DH                  MOV       DX,FFEAH
0932:  FF390H                  IN        AL,DX
         FFEAH-I-  00H
0936:  FF391H                  TEST      AL,07H
0942:  FF393H                  JE        $-06H              ; SHORT
0951:  FF38DH                  MOV       DX,FFEAH
0960:  FF390H                  IN        AL,DX
         FFEAH-I-  00H
0964:  FF39IH                  TEST      AL,07H
0970:  FF393H                  JE        $-06H              ; SHORT
***
0985:  FF098H                  MOV       SS,WORD PTR [0092H]
       FF092H-R-07H-CS  FF093H-R-00-CS
1004:  FF09CH                  MOV       SP,0050H
1012:  FF09FH                  MOV       BP,SP
*;TRACE TURNED OFF AT FFFF:0, BACK ON AT FF00:96, BREAK AT FF00:9F
*BR0
BR0=FF09EH E
*ONT
ONT=FF096H A,I,O,H,F,R,W
*OFFT
OFFT=FFFF0H A,I,O,H,F,R,W
*TRA=FRA
*P-25
FRAME   ADDR    STS  QSTS  QDEPTH  DMUX  MARK
0996:  FF09CH    F    N      1      A     0
0997:  2F09CH    F    S      1      Q     0
0998:  2F0BCH    F    N      1      D     0
0999:  FF092H    R    N      1      A     0
1000:  2F007H    R    N      1      D     0
1001:  FF093H    R    N      1      A     0
1002:  2F000H    R    N      1      D     0
1003:  FF09DH    F    N      1      A     0
1004:  2F050H    F    F      1      D     0
1005:  FF09EH    F    N      1      A     0
1006:  2F09EH    F    S      1      Q     0
1007:  2F000H    F    N      1      D     0
1008:  FF09FH    F    N      1      A     0
1009:  2F09FH    F    S      1      Q     0
1010:  2F08BH    F    N      1      D     0
1011:  FF0A0H    F    N      1      A     0
1012:  2F0A8H    F    F      1      Q     0
1013:  2F0ECH    F    N      1      D     0
```

```
1014:   FF0A1H   F   N   1   A   0
1015:   2F0A9H   F   S   1   Q   0
1016:   2F02EH   F   N   1   D   0
1017:   FF0A2H   F   N   1   A   0
1018:   2F08EH   F   N   2   D   0
1019:   FF0A3H   F   N   2   A   0
1020:   2F01EH   F   N   3   D   0
```

Set TRACE Display Mode Command

```
TRACE =  {FRAME      }
         {INSTRUCTION}
```

Examples:

```
TRACE = FRAME
TRACE = INSTRUCTION
```

TRACE	A command keyword indicating that the mode of display for trace data is to be set.
FRAME	A function keyword indicating that data in the trace buffer is to be displayed frame by frame.
INSTRUCTION	A function keyword indicating that data in the trace buffer is to be displayed by instruction. Each instruction is equivalent to one or more machine cycles.

In the FRAME mode, trace data is displayed one frame per line, with fields for frame number, address/data, bus status, queue status, queue depth, type of frame (address, data or queue) and start/stop trace marker.

In the INSTRUCTION mode, trace is disassembled with instructions appearing as 8086 assembler mnemonics. All other cycle data other than instruction fetches, the address, status and data of the cycle are displayed. Memory fetches into the execution queue and queue activity are not shown explicitly. Instead, they are used to find the instruction bytes that were executed when the instruction is taken from the queue. Whenever it is impossible to disassemble frames, immediately before or after a frame with the START/STOP trace marker set, the gap is indicated by a line containing three asterisks ("***"). In either mode, status appears as "F," "R," "W," "I," "O," "H," or "A" corresponding to the match status(es) set in the tracepoint register, and addresses are displayed as 20-bit numbers is the displacement of the address from that base.

ENABLE/DISABLE TRACE Command

```
1.   ENABLE TRACE  [CONDITIONALLY  [NOW ON ]]
                                   [NOW OFF]
2.   DISABLE TRACE
```

Examples:

```
ENABLE TRACE
ENABLE TRACE CONDITIONALLY
ENABLE TRACE CONDITIONALLY NOW ON
ENABLE TRACE CONDITIONALLY NOW OFF
DISABLE TRACE
```

ENABLE	A command keyword that causes trace data collection to be conditionally or unconditionally enabled.
DISABLE	A command keyword that causes trace data collection to be disabled.
CONDITIONALLY	A command modifier that specifies that trace will be turned on whenever the ONTRACE register matches and turned off whenever the OFFTRACE register matches.
NOW ON	Indicates that trace is turned on for the beginning of the next emulation (see Note).
NOW OFF	Indicates that trace is turned off for the beginning of the next emulation (see Note).
TRACE	Command modifier denoting that trace is to be enabled/disabled.

NOTE

If ENABLE TRACE CONDITIONALLY, the tracepoints will inadvertently match and turn trace on or off when entering emulation if the tracepoint is set to match on a Fetch at address 00008 or 00009, and when exiting emulation if the tracepoint is set to match on a Read at address 00008 or 00009. Conditional trace should not be set-up ONTRACE/OFFTRACE tracepoints at memory locations 00008 or 00009 as the ICE-88 emulator uses these two memory locations when emulation is broken.

If neither NOW ON or NOW OFF is selected (i.e., ENABLE TRACE CONDITIONALLY), trace is left in its current state.

Display TRACE Command

```
TRACE
```

Example:

```
TRACE
```

TRACE	A command keyword that, if entered from the keyboard as a single token, causes the current TRACE mode (FRA for FRAME or INS for INSTRUCTIONS) to be displayed.

MOVE, OLDEST, and NEWEST Commands

MOVE [[+ : :–]*decimal*]
OLDEST
NEWEST

Example:

```
MOVE
MOVE +6
MOVE -11
OLDEST
NEWEST
```

MOVE	A command keyword that moves the buffer pointer one or more entries forward (toward the most recent entries) or backward (toward the earliest entries). An entry is a frame or instruction, depending on the TRACE mode in effect.
+	A unary operator specifying a forward movement. Plus is the default.
–	A unary operator specifying a backward movement.
decimal	A number, evaluated in decimal radix (if no explicit suffix is given), that gives the number of entries to be included in the MOVE.
OLDEST	A command keyword that moves the pointer to the earliest entry in the buffer.
NEWEST	A command keyword that moves the pointer to the latest entry in the buffer.

PRINT Command

```
1. PRINT ALL
2. PRINT [[+::-]decimal]
```

Example:

```
PRINT
PRINT ALL
PRINT +5
PRINT 5
PRINT -10
```

PRINT	A command keyword calling for a display of one or more entries from the trace data buffer. The entries are displayed as frames or instructions, depending on the current trace mode.
ALL	A function keyword indicating that the entire trace buffer contents are to be displayed.
+	A unary operator directing the display of *decimal* entries below (entered later then) the current buffer pointer location. See DISCUSSION (page 6-24) for details. Plus is the default.
−	A unary operator directing the display of decimal-number entries above (entered earlier than) the current buffer pointer location. See DISCUSSION (page 6-24) for details.
decimal	A numeric constant, evaluated in decimal suffix, giving the number of entries to be displayed.

CHAPTER 7 INTERROGATION AND UTILITY COMMANDS

Chapter 7 contains discussions, examples and syntax summaries for each of the ICE-88 interrogation and utility commands.

The following brief outline of Chapter 7 shows how the interrogation and utility commands have been clasified.

Utility Commands Involving ISIS-II

ICE88 Command
EXIT Command
LOAD Command
SAVE Command
LIST Command

Number Bases and Radix Commands

Set or Display Console Input Radix Commands
Set or Display Console Output Radix Commands

Hardware Register Commands

Set Register Command
RESET HARDWARE Command

Memory Mapping Commands

MAP DISK Command
MAP INTELLEC Command
Set MAP Status Command
Display MAP Status Command
RESET MAP Command

Set Memory and Port Content Commands

Set Memory Command
Set Input/Output Port Command

Symbol Table and Statement Number Table Commands

DEFINE Symbol Command
Display Symbols Command
Display Statement Numbers Command
Display Modules Command
Change Symbol Command
REMOVE Symbols Command
REMOVE Modules Command
TYPE Command
Set DOMAIN Command
RESET DOMAIN Command

Display Commands

Display Processor and Status Registers Command
Display Memory Command
Display I/O Command
Display STACK Command
Display Boolean Command
Display NESTING Command
Evaluate Command

Utility Commands Involving ISIS-II

The Intel Systems Implementation Supervisor (ISIS-II) is the diskette operating system for the Intellec Microcomputer Development System. The ICE-88 emulator runs under ISIS-II control, and can call upon ISIS-II for file management function.

The following commands are included in this section:

Command	Purpose
ICE88	Load ICE-88 program from diskette.
EXIT	Return control to ISIS-II.
LOAD	Load user program into memory accessed by ICE-88 emulator.
SAVE	Copy user program from memory onto diskette.
LIST	Copy ICE-88 emulation output to printer or file.

Discussion

ICE-88 commands can use ISIS-II *pathnames* to direct ISIS-II to a desired diskette file or other output device.

For diskette files, the format of *pathname* is as follows.

:drive:filename

The entry *:drive:* stands for one of the references to ISIS disk drives, as follows.

:F0:	drive 0
:F1:	drive 1
:F2:	drive 2
:F3:	drive 3
:F4: :F5: :F6: :F7:	Single-density or double density drives on a double-density system

The entry *filename* must follow the second colon (after *drive*) without any intervening spaces. A filename has the following components.

identifier [*.extension*]

The entry *identifier* is a name assigned by the user, and is made up of one to six alphanumeric characters. The *extension* is an optional part of the filename, consisting of one to three alphanumeric characters preceded by a single period. The extension must be used if it is present in the directory listing of the file on the diskette. If used, the extension follows the identifier without any spaces. Some extensions (e.g., .BAK) are assigned by system processors; others can be assigned at the desire of the user. An extension provides a second level of file identification; it can be used to identify different versions of the same program, or to give supplemental information about the file (e.g., author, data, version).

Fully compiled or assembled programs ready to run (emulate) do not have system-assigned extensions, although they may have extensions assigned by the user.

For devices other than diskette files, the format of *pathname* is as follows.

:device:

The following devices are commonly accessed in ICE-88 commands.

:Device:	*Output Device*
:LP:	Line printer
:HP:	High-speed paper tape punch
:TO:	Teletypewriter printer
:CO:	Console display

For more information on ISIS-II filenames and device codes, refer to the *ISIS-II System User's Guide.*

The ICE88 command, entered after an ISIS-II prompt, directs ISIS-II to load the ICE-88 program from the specified diskette drive, into a reserved area in Intellec memory. The ICE-88 emulator begins operation as soon as it is loaded, initializing its hardware and program variables, and signaling readiness to accept ICE-88 commands by displaying an asterisk prompt.

NOTE

Inspect disk containing ICE-88 program prior to loading into the disk drive. If the diskette contains a write protect tab, remove the tab to write-enable the disk. If the ICE-88 program is loaded from a disk containing a write-protect tab, an ISIS ERR 24 (write protect) will results.

The EXIT command ends the emulation session and returns control to ISIS-II. The command issues a hardware reset before exiting.

The LOAD command loads the object code from the named file and drive into the areas of memory specified by the memory map. Modules are loaded in the order of their appearance in the source file. The modules names, symbols, and statement numbers are placed in reserved areas of Intellec memory. Symbols and statement numbers are grouped into tables by module, in the order in which they appear. Both a base value and a displacement value are loaded for all symbols and statement numbers. Any symbol that has no type information is given no type specification in the symbol table. If no exclude modifiers are included in the command, module names are loaded into the ICE-88 module table in the order in which they appear following any module names already in the table, symbols and their types (if present) local to each module are loaded into that module's symbol table in the order in which they appear, and statement numbers local to each module are loaded into that module's statement table (for PL/M 86 programs) in the order in which they appear.

The command can include one or more exclude modifiers to control what is to be loaded. If NOCODE is included, the program code is omitted from the load, e.g., it is already in ROM. If NOLINE is included, the program statement number table is not loaded. If NOSYMBOL is included, the program symbol table is not loaded. Any combination of one, two, or three exclusion modifiers may be included, although the command with all three modifiers represents a "null" command. No modifier may be named twice in the same load command.

The SAVE command copies the user program currently loaded from memory onto the specified file and drive. If the diskette installed on the given drive does not have the named file in its directory, ISIS-II creates the file and opens it for write. If the named file does exist on the diskette, the file is overwritten and the previous contents are lost. If no explicit drive number is given, drive 0 is assumed.

The command can include one or more modifiers to control what is to be saved. If NOSYMBOL is included, the symbol table is not copied from memory to diskette. If NOLINE is included, the statement number table (for PL/M-86 programs) is not saved. The modifiers NOCODE and *partition* are mutually exclusive: if one is used, the other may not be included. If NOCODE is included, the program object code is not copied to diskette. If *partitions* are included, only the code stored in the memory addresses in the partitions (ranges of addresses) are saved. If neither NOCODE nor Partition appears in the command, any code between the lower and highest addresses in each 1K segment that has been previously loaded is saved. If no code has been loaded, no code is saved. When more than one modifier is used, separate them with spaces. No modifier may be used twice in the same SAVE command. The SAVE operation does not alter the program code, symbol table, or statement number table in memory.

The LIST command saves a record of the emulation session, including high-volume data such as trace data, on a hard-copy device or on a diskette file in addition to sending it to the console. Only one device or file other than the console can be specified (active) at a given time.

The initial device is :CO:, output to the console. Other devices that can be specified are a line printer (:LP:), high-speed paper tape punch (:HP:), and teletypewriter printer (:TO:).

Instead of a hard-copy device, a diskette file can be specified. If the output is to a diskette file, the file is opened when the LIST command is invoked, and output is stored from the beginning of the file, writing over any existing data. Specifying a new file or device in a later LIST command closes any existing open file and avoids over-writing any more data. Specifying the same file in a later LIST causes the delete of the file and starting over.

When LIST is in effect (with a device or file other than :CO:), all output from the ICE-88 emulator, including system prompts, commands, and error messages, is sent both to the named device or file and to the console display. To restore output to the console only (no other device), use the command LIST :CO:.

ICE88 Command

```
[:drive: ]ICE88 [WORKFILES(:alt. drive:)]
```

Examples:

```
:F1:ICE88
:F1:ICE88 WORKFILES(:F2:)
```

:drive:	The number of the diskette drive containing the ICE-88 software diskette. The number is preceded by the letter F, and enclosed in colons. This drive is also the default drive for the ICE temporary workfile.
ICE88	The name of the ICE-88 program file under ISIS-II. The filename follows the second colon without any intervening spaces.
WORKFILES	Control keyword specifying that an alternate disk drive is to be used for the ICE temporary workfile
:alt. drive:	The number of the diskette drive containing the diskette where the temporary workfile is to be stored. The number is preceded by the letter F, and enclosed in colons.

NOTE

Inspect the diskette containing the ICE-88 program prior to loading into the diskette drive. If the WORKFILES control is specified, the diskette containing the ICE-88 program may be write protected. If the WORKFILES control is not specified, the diskette containing the ICE-88 program must *not* be write protected or an ISIS ERR24 (write protect) will result. In this case, if the diskette contains a write protect tab, remove the tab to write-enable the diskette.

EXIT Command

```
EXIT
```

Example:

```
EXIT
```

EXIT	A command keyword that returns control from the ICE-88 emulator to ISIS-II. The command issues a hardware reset before exiting, and leaves the file used for DISK-mapped memory intact.

LOAD Command

```
LOAD[:drive:]filename ⎡NOCODE  ⎤
                      ⎢NOSYMBOL⎥
                      ⎣NOLINE  ⎦
```

Examples:

```
LOAD :F0:TEST.VR1
LOAD :F1:MYPROG NOLINE
LOAD :F2:COUNT. ONE NOCODE NOLINE
LOAD :F3:NEWCOD NOSYMBOL
```

LOAD	A command keyword that loads the software on the given file and drive into the combination of prototype and Intellec memory specified by a previous MAP command.
:drive :	The diskette drive (:F0:, :F1:, :F2:, or :F3:) that contains the target file. If no drive is given, :F0: (drive 0) is the default.
filename	The name of the desired program as compiled or assembled, linked, and located. The filename follows the second colon with no intervening spaces.
NOCODE	A modifier specifying that program code is not to be loaded.
NOSYMBOL	A modifier specifying that the program symbol table is not to be loaded.
NOLINE	A modifier specifying that the program line number table (for PL/M-86 programs) is not to be loaded.

SAVE Command

```
SAVE [:drive:]filename NOCODE::partition [,partition ]...
                       NOSYMBOL
                       NOLINE
```

Examples:

```
    SAVE :F1:TEST
    SAVE :F0:MYPROG 0800 TO 0FFF NOLINE
    SAVE :F2:COUNT.TWO NOLINE NOSYMBOL
    SAVE :F3:NEWSYM NOCODE NOLINE
    SAVE :F1:TEST #1 TO #50,..SUBR #1 TO ..SUBR #20
```

SAVE	The command keyword that directs the ICE-88 emulator to write the designated software elements to the indicated file and drive.
:drive :	The diskette drive (:F0:, :F1:, :F2:, :F3:) holding the diskette that is to contain the saved software. If no explicit drive number is given, drive 0 is the default.
filename	The name of the file that is to receive the saved information. The name of the file, including the extension if present, must follow the rules for naming files under ISIS-II. The filename immediately follows the second colon. If the filename does not exist on the designated diskette, ISIS-II creates the file and opens it for write. If it does exist, the current file is destroyed.
NOCODE	A modifier specifying that program code is not to be saved.
partition	A construct specifying a range of one or more contiguous locations in memory; the contents of the specified locations are saved, but code in other locations is not copied.
NOSYMBOL	A modifier specifying that the symbol table is not to be saved to diskette.
NOLINE	A modifier specifying that the line number table (for PL/M-86 programs) is not to be saved.

LIST Command

(a) LIST *:device:*

(b) LIST [*:drive*]*filename*

Examples:

```
LIST :LP:
LIST :CO:
LIST :F1:ICEFIL
```

LIST	The command keyword directing all ICE-88 emulator output to be sent to the specified device or file, and to the console.
:device:	An ISIS-II device code, indicating a hard-copy output device to receive the output.
:drive:	The diskette drive holding the diskette on which output is to be written. If no explicit drive is given, drive 0 is assumed.
filename	The name of the file on the target diskette. The filename immediately follows the second colon, without intervening spaces.

Number Bases and Radix Commands

ICE-88 commands and displays involve several different number bases (*radixes*). This section describes the various radixes used by the ICE-88 emulator and the commands used to control some of them. Most radixes are set by the ICE-88 emulator and cannot be changed, but others are under your control.

This section gives details on the following commands.

Command	**Purpose**
SUFFIX	Set or display console input radix.
BASE	Set or display console output radix.

Discussion

The commands given in detail in this section refer to the radixes used for console input and console output.

Console Input Radixes; SUFFIX Command

Any number entered from the console can include an *explicit* input radix. An explicit input radix consists of one of the following alphabet characters appended directly to the number as entered.

Explicit Radix	**Example**	**Radix Specified**
Y	1001Y	Binary (base 2)
Q, O	11Q	Octal (base 8)
T	9T	Decimal (base 10)
H	9H	Hexadecimal (base 16)
K	3K	Multiple of 1024 decimal

The *implicit* input radix is the base used by the ICE-88 emulator to interpret numbers entered from the console without an explicit radix.

To display the current implicit input radix, enter the command token SUFFIX followed by a carriage return. The implicit input radix can be Y, Q, T, or H, as defined earlier. The initial implicit radix is hexadecimal.

You can change the implicit input radix by entering a command with the form SUFFIX = *suffix* , where *suffix* is any of the characters Y, Q, O, T, or H. This SUFFIX command can be used where several numbers are to be entered in the same radix.

Note that K (multiple of 1024) cannot be specified as an implicit input radix.

For some kinds of entries from the console, the implicit input radix is always decimal (T). Entries with implicit decimal radix are:

- Numbers entered after MOVE and PRINT keywords.
- Program statement numbers.
- Value in COUNT command.
- Timeout value in RWTIMEOUT
- Segment numbers in MAP.

An explicit radix always takes precedence over the implicit radix. If the digits in the number entered cannot be interpreted in either the explicit or the implicit radix, an error message is displayed.

Console Output Radixes; BASE Command

Numeric information such as memory and register contents, and data, is displayed in the current console output radix. The console output radix can be one of the following.

Output Radix	Radix Specified
Y	Binary
Q, O	Octal
T	Decimal
H	Hexadecimal
ASCII	ASCII character for each byte

The initial output radix is hexadecimal (H).

To display the current console output radix, enter the command token BASE followed by carriage return. The display consists of a single character, Y, Q, T, H, or A (for ASCII).

You can change the console output radix by entering a command with the form BASE = *base*, where *base* is one of the single characters Y, Q, O, T, or H, or the token ASCII. Once the radix is set with a BASE command, it stays in effect until another BASE command is entered.

Set or Display Console Input Radix Commands

```
SUFFIX

SUFFIX = Y::Q::O::T::H
```

Examples:

```
SUFFIX

SUFFIX = Y
```

SUFFIX	A command keyword referring to the implicit console input radix. The token SUFFIX alone displays the current setting (Y, Q, T, or H).
=	The assignment operator, indicating that the new setting is to follow.
Y	Binary radix.
Q, O	Octal radix.
T	Decimal radix.
H	Hexadecimal radix.

Set or Display Console Output Radix Commands

```
BASE

BASE = Y::Q::O::T::H::ASCII
```

Examples:

```
BASE

BASE = Q
```

BASE	A command keyword referring to the system console output radix. The token BASE alone displays the current setting (Y, Q, T, H, or A).
=	The assignment operator, indicating that the new setting is to follows.
Y	Binary radix.
Q, O	Octal radix.
T	Decimal radix.
H	Hexadecimal radix.
ASCII	Each byte represented by its corresponding ASCII character, without separators.

Hardware Register Commands

This section presents the keywords used in the ICE-88 emulator to refer to the following types of hardware registers and signals.

- 8088 Processor Register
- 8088 Status Flags
- ICE-88 Status Registers
- 8088 Pin Signals

The following commands that refer to hardware registers and signals are discussed in this section.

Command	Purpose
Set Register	Set (change) the contents of any of the writeable 8088 registers.
RESET HARDWARE	Reset ICE-88 hardware to initial state.

Discussion

Tables 7-1 through 7-6 show the tokens used to refer to any 8088 8-bit register, 16-bit register or pin signal.

Meta-term	Class of tokens
general-register	16-bit and 8-bit work registers
pointer-register	16-bit pointer registers
index-register	16-bit index registers
segment-register	16-bit segment reference registers
status-register	8- and 16-bit status registers
pin-reference	8088 pin signals
flag-reference	8088 status flags

Table 7-1. 8088 General Registers

reference	8088 Register and Interpretation
RAX	16-bit Accumulator
RAH	High 8 bits of Accumulator
RAL	Low 8 bits of Accumulator
RBX	16-bit Base Register
RBH	High 8 bits of Base Register
RBL	Low 8 bits of Base Register
RCX	16-bit Count Register
RCH	High 8 bits of Count Register
RCL	Low 8 bits of Count Register
RDX	16-bit Data Register
RDH	High 8 bits of Data Register
RDL	Low 8 bits of Data Register

Table 7-2. Pointer Registers

reference	**8088 Register and Interpretation**
SP	16-bit Stack Pointer
BP	16-bit Base Pointer

Table 7-3. Index Registers

reference	**8088 Register and Interpretation**
SI	16-bit Source Index
DI	16-bit Destination Register

Table 7-4. Segment Registers

reference	**8088 Register and Interpretation**
CS	16-bit Code Segment Register
DS	16-bit Data Segment Register
SS	16-bit Stack Segment Register
ES	16-bit Extra Segment Register

Table 7-5. Status Registers

reference	**Register and Interpretation**
IP	16-bit Instruction Pointer Register
RF	16-bit Flag Register
CAUSE (Read only)	8-bit Cause of last break in emulation
OPCODE (Read only)	8-bit Previous opcode executed
PIP (Read only)	16-bit Previous Instruction Pointer Register
TIMER (Read only)	Low 16 bits of emulation timer
HTIMER (Read only)	High 16 bits of emulation timer
BUFFERSIZE (Read only)	16-bit trace buffer size Register
LOWER (Read only)	16-bit Intellec address register
UPPER (Read only)	16-bit Intellec address register (displayed in decimal only)

Table 7-6. Pin References

reference	**8088 Pin (Read only)**
RDY	READY
NMI	NMI
TEST	TEST
HOLD	HOLD
RST	RESET
MN	MN/MN (minimum/maximum configuration)
IR	INTR

Table 7-7. Flag References

reference	**Flag**
AFL	Auxiliary-carry out of low byte to high byte
CFL	Carry or borrow out of high byte
DFL	Direction of string manipulation instruction
IFL	Interrupt-enable (external)
OFL	Overflow flag in signed arithmetic
PFL	Parity
SFL	Sign of the result of an operation
TFL	Trap used to place processor in single step mode for debug
ZFL	Zero indicates a zero value result of an operation

To set (change) the content of one of the processor registers, use a command with the form:

reference = expr

Where *expr* is a numerical constant or numerical expression giving the desired new contents. Each of the registers that can be changed with this command has a definite size (16, 8, or 1 bits). If the new contents represents fewer bits than the destination register, the bits are right-justified in the register, and the remaining bits are set to zero. In other words the ICE-88 emulator assumes that the quantity represents the lowest-order bits, and sets any unspecified high-order bits to zero.

The RESET HARDWARE command is used to restore the ICE-88 hardware to the initial program load condition. One use for this command might be to reset the hardware when reconfiguring. The EXIT command includes the RESET HARDWARE function.

When a RESET HARDWARE command is issued, the ICE-88 emulator attempts to reset the hardware without disturbing any internal controls or user specified setup (breakpoints, map, or enable/disable trace conditionally). If this attempt is successful, the ICE-88 emulator returns a prompt to the user immediately:

```
*CLOCK = INTERNAL
*RESET HARDWARE                   ;This reset will not encounter any problems.
*                                 ;Prompt appears immediately, no internal setup
*                                 ;affected.
```

The user may now continue his processing.

If, however, this attempt is unsuccessful, the ICE-88 emulator will warn the user that it is beginning to reinitialize the hardware. It then attempts to reset the hardware by using initialization procedures and then restoring internal controls and setup to the pre-reset state (trace, however, cannot be restored to its previous state, and will be enabled unconditionally). Although no internal registers or flags are changed, the integrity of user memory, ICE memory, and current disk-mapped memory cannot be guaranteed. If this attempt to reset the hardware is successful, the ICE-88 emulator will return a warning to the user that the hardware has been initialized followed by a prompt. The user may then examine memory for integrity, reload memory or continue processing.

NOTE

If the above reinitialization is successful, the ICE-88 emulator may require up to approximately 30 seconds to fully restore the map.

If the ICE-88 emulator detects an error during this attempt, it will return an error message and a prompt to the user. No warning that the hardware has been reinitialized will be returned. The user should attempt to resolve the error condition and MUST reissue the RESET HARDWARE command. The ICE-88 emulator will then go through the reinitialization as described above. The following example illustrates the procedure required to respond to an error condition:

```
*CLOCK = EXTERNAL                 ;This command forces an error condition.
ERR 40:NO USER CLOCK              ;Error response.
*RESET HARDWARE                   ;Not able to reset, tries to reinitialize.
WARN C8:REINITIALIZING - FAULT
ERR 40:NO USER CLOCK              ;Reports an error and no warning that hardware
*                                 was reinitialized; thus, reinitialization was not able
*                                 to complete. The user must clear the error
*                                 condition and then reset the hardware again in
*                                 ;order to get the hardware into a known state.
*CLO = INT                        ;Clears the error condition, must reset again.
*RESET HARDWARE                   ;This reset must clear the incomplete reset from
*                                 ;above.
~~WARN C8:REINITIALIZING - FAULT~~
WARN C6:HARDWARE REINITIALIZED    ;Note that the user is informed that the hardware
*                                 ;has been reinitialized and that the user specified
*                                 ;setup (map, breakpoints, etc.) has been restored.
*                                 ;Memory contents (ICE memory, user memory,
*                                 ;and current disk-mapped memory) cannot be
*                                 guaranteed. The user must verify the contents or
*                                 reload his code and data.
```

Set Register Command

reference = contents

Examples:

```
RAX = 0000H
IP = F23AH
IP = IP + 1
RDL = FFH
CS = WORD .SAM
```

reference	The keyword name of any of the writeable registers, as follows: general registers (see table 7-1). pointer registers (see table 7-2). index registers (see table 7-3). segment registers (see table 7-4). status registers (see table 7-5).
=	The assignment operator.
contents	A numeric expression.

RESET HARDWARE Command

```
RESET HARDWARE
```

Example:

```
RESET HARDWARE
```

RESET	A command keyword restoring its object to a reset condition.
HARDWARE	A function keyword restoring ICE-88 hardware to the reset condition that occurs after the initial ICE-88 emulator invocation.

Memory Mapping Commands

The commands in this section control ICE-88 memory map. The ICE-88 emulator uses the map to identify what user memory is installed and what types and sizes of memory are being "borrowed" from the ICE-88 emulator for testing purposes.

This section gives details on the following commands.

Command	Purpose
MAP DISK	Declare which disk file is available for mapping to.
MAP INTELLEC	Declare which physical Intellec segments are available for mapping memory to.
Set MAP Status	Assign up to 1024 1K segments of memory locations to USER, ICE, INTELLEC, DISK, or GUARDED status.
Display MAP Status	Display status of one or more memory segments.
RESET MAP	Restore the memory map to its initial condition, all GUARDED.

Discussion

A maximum of 1M byte (megabyte or 1,048,576 bytes) locations are accessible with the 20-bit addressing scheme used by the 8088 processor. The MAP commands allow this 1M logical address space to be mapped in 1K-byte segments (on 1K boundaries) to any of (1) physical memory in the user's system, (2) either of two 1K-byte segments of ICE-88 "real-time" memory, (3) a random-access disk file, (4) any 1K-byte segment in expansion Intellec memory (addresses at 64K or above), or (5) as guarded (i.e., the logical addresses do not physically exist).

The ICE-88 module supplies 2K bytes of high-speed static memory which may be mapped for "real-time" execution. The speed of this memory will allow near real-time operation. The 2K bytes may be mapped in 1K-byte segments into appropriate address space within the 8088's 1M byte address space.

Disk-based memory and expansion Intellec memory both provide substantially slower execution speeds since all accesses to these memories require additional processing by the ICE-88 emulator. The first 64K of Intellec memory is reserved for system and ICE-88 software. Therefore, any memory assigned to the user must reside in expansion Intellec memory above 64K.

The MAP commands are used to declare, set, display, and reset the ICE-88 memory mapping. The ICE-88 emulator has 1M logical addresses divided into 1024 logical address segments, each starting on a 1K boundary and representing 1K bytes of memory. Each segment is addressed by a decimal segment number, *n* . The value of *n* is an integer value between 0 and 1023. For any given segment *n*, that segment contains addresses nK through nK + 1023. For example, the lowest logical segment in memory space contains addresses 0 through 1023 (0K through 0K + 1023). In a like manner, logical segment 10 would contain addresses 10240 through 11263 (10K through 10K + 1023). All *partitions* used in MAP commands must contain segment numbers whose values lie between 0 and 1023.

If the diskette is to be used for user memory, the MAP DISK command must be used to declare the disk file to be used. The syntax of the MAP DISK command is:

MAP DISK = [:*drive*:] *filename*

The command opens the ISIS-II file specified by *file-name* , checks how may physical segments will fit on the diskette, and reports this number to you. MAP DISK may only be declared initially and once following each RESET MAP command.

If Intellec memory is to be used for user memory, the MAP INTELLEC command must be used to specify the physical memory segments in extended Intellec memory to be used by user programs. The syntax of the MAP INTELLEC command is:

MAP INTELLEC = *partition* [, *partition*]...

where *partition* is defined as:

$$partition \equiv \left\{ \begin{array}{ll} \textit{physical-segment-number} & [\text{TO } \textit{physical-segment-number}\,] \\ \textit{physical-segment-number} & \text{LENGTH } \textit{physical-segment-length} \end{array} \right\}$$

This command declares physical memory segments in expanded Intellec memory and checks that the memory physically exists by writing to it and reading back. An error occurs if any *partitions* extend below 64K as extended Intellec memory exists only at addresses 64K or above. Therefore the range of *physical-segment-number* values is 64-1023 (inclusive), the range of *physical-segment-length* values is 1-960 (inclusive). A warning is issued if the memory does not exist. INTELLEC declarations are cumulative between RESET MAP commands. Logical memory segments may not be set to Intellec or disk until the associated MAP INTELLEC or MAP DISK commands have been entered.

NOTE

When mapping to Intellec memory, the monitor prom circuitry does not decode the four high order bits of a 20-bit address. Therefore, addresses of the 20-bit form XXXX 1111 1XXX XXXX XXXX (where X is don't care) will be overshadowed by the monitor and should not be used as addresses to be mapped.

The Set MAP Status command is then used to map logical memory segments to physical segments. The syntax of the Set MAP Status command is:

$$\text{MAP } partition = \left\{ \begin{array}{l} \text{GUARDED} \\ \text{USER [NOVERIFY]} \\ \text{ICE } [\textit{physical-segment-number}] \text{ [NOVERIFY]} \\ \text{INTELLEC } [\textit{physical-segment-number}] \text{ [NOVERIFY]} \\ \text{DISK } \textit{physical-segment-number} \text{ [NOVERIFY]} \end{array} \right\}$$

where

$$partition \equiv \begin{array}{ll} \textit{logical-segment-number} & [\text{TO } \textit{logical-segment-number}] \\ \textit{logical-segment-number} & \text{LENGTH } \textit{logical-segment-length} \end{array}$$

The Set MAP Status command sets the memory map by assigning logical segments to physical addresses in memory:

USER	The logical segments specified are set to exist in the user's memory at the same physical addresses as those specified in the logical segments.
ICE	The logical segments specified are set to exist in ICE-88 "real-time" memory. The *partition* specified may only contain a maximum of two segments and the *physical-segment- number* value must be 0 or 1, if one is given.
INTELLEC	The logical segments specified in the *partition* are set to exist in extended Intellec memory starting in the physical segment specified by the *physical-segment-number* in the command, if one is given.
DISK	The logical segments specified in the *partition* are set to exist on the disk file starting at the physical segment specified by the *physical-segment-number* in the command, if one is given.
GUARDED	All accesses to memory addresses in the segments specified by the input parameter, *partition* are error conditions. All memory is initially GUARDED.
NOVERIFY	Specifies that write-verification will not be performed when using the ICE-88 Change command to change the contents of memory. This is useful when memory-mapped I/O is being used. Whenever a logical memory segment is mapped USER, ICE, INTELLEC, or DISK, it is write-verified unless explitly NOVERIFY.

When mapping to ICE memory, INTELLEC memory or DISK memory, if a *physical-segment-number* is given in the command, the first logical segment specified in the partition is set to the physical segment specified by the *physical-segment-number* and subsequent logical segments are set at subsequent physical segments. If more logical segments are specified than physical segments available, logical segment will be assigned to available physical segments and an error message is displayed indicating that the remaining logical segments are unassigned. If *physical-segment-number* is omitted in the command, the ICE emulator assigns from unassigned physical segments in the designated memory. If Intellec or disk memory is specified, an error occurs if the resulting physical segment is not one of those previously declared by a MAP INTELLEC or MAP DISK command. An error also occurs if there are insufficient physical segments unassigned to map the specified logical segments.

The Display MAP Status command displays the current setting of the map for the unguarded memory segments specified by *partition* , if given. If a *partition* is not given, all the unguarded segments for the entire range from 0 to 1023 are displayed. The display is to the following format. The segments are displayed, four segments per line, each of the form:

logical-segment = *type physical-segment* [N]

where:

logical-segment ≡ four decimal digits with T suffix

type ≡ ICE :: USE :: INT :: DIS

physical-segment ≡ four decimal digits with T suffix for ICE, INT, DIS and four blanks for USE

Example 1.

```
MAP 0 TO 3
```

Display:

```
0000T = USE      0001T = ICE 0000T 0002T = INT 0064T 0003 = DIS 0000T
```

Display:

```
0000T  =  USE           0001T  = ICE    0000T   0002T  = INT    0064T   0003   =  DIS    0000T
0004T  =  DIS   0001T   0004T  = DIS    0002T   0006T  = USE            0007   =  USE
  .       .       .       .       .       .       .       .               .       .       .
  .       .       .       .       .       .       .       .               .       .       .
  .       .       .       .       .       .       .       .               .       .       .
  .       .       .       .       .       .       .       .               .       .       .
1023T  =  DIS
```

The RESET MAP sets the memory map to its initial condition, all GUARDED, and "undeclares" the DISK and INTELLEC memory available. Multiple logical segments may be mapped to the same physical segment. Reassignment of a logical segment to a different physical segment causes the physical segment originally mapped to become "guarded," or unused, and reassignable, providing no other logical segment is currently mapped to it.

MAP DISK Command

```
MAP DISK = [:drive: ]filename
```

Examples:

```
MAP DISK = :F0: MYPROG
MAP DISK = :F1:TEST1
MAP DIS = TEST2
```

MAP	A command keyword referring to some operation on the ICE-88 memory map.
DISK	A command modifier that specifies that an ISIS-II disk file is to be opened and available for mapping user memory to.
:drive :	The disk drive (:F0:,:F1:,:F2:,or :F3:) that contains the target file. If no drive is specified, :F0: (drive 0) is the default.
filename	The name of the desired disk file that is to be opened. The filename follows the second colon with no intervening spaces.
=	The assignment operator.

MAP INTELLEC Command

```
                  {segmentno [TO segmentno ]         } [, segmentno [TO segmentno ]          ]
MAP INTELLEC =    {segmentno LENGTH segmentlen       } [, segmentno LENGTH segmentlen  ...   ]
```

Examples:

```
MAP INTELLEC = 73
MAP INTELLEC = 100 TO 123
MAP INT = 100 LENGTH 23
MAP INT = 65, 68 TO 76, 100 LEN 23
```

MAP	A command keyword referring to some operation on the ICE-88 memory map.
INTELLEC	A command modifier specifying Intellec memory.
segmentno	A segment number (64 to 1023) that specifies a physical memory segment in Intellec memory. It is used to map Intellec memory in one of the following ways: • As the address of a single physical segment in Intellec memory. • As the address of the first physical segment in Intellec memory of a *partition* of physical segments being mapped. • As the address of the last physical segment in Intellec memory of a *partition* of physical segments being mapped.
TO	A connector keyword that denotes that a segment number is to follow that defines the upper bound of a memory *partition*.
LENGTH	A connector keyword that denotes that a segment length value is to follow.
segmentlen	A segment length value (1 to 960) that defines the length of a *partition* of memory.
=	The assignment operator.

NOTE

All mapping to Intellec memory is contingent upon the amount of expanded Intellec memory a user has in his system.

Set MAP Status Command

```
MAP  { logsegmentno [TO logsegmentno ]        }  =  { GUARDED                                  }
     { logsegmentno LENGTH segmentlen         }     { USER [NOVERIFY]                          }
                                                    { ICE [physegmentno ] [NOVERIFY]           }
                                                    { INTELLEC [physegmentno] [NOVERIFY]       }
                                                    { DISK [physegmentno] [NOVERIFY]           }
```

Examples:

```
MAP 457 = ICE 0 NOVERIFY
MAP 100 TO 200 = USER
MAP 201 LEN 62 = INT 65 NOV
MAP 263 LENGTH 87 = DISK 100
MAP 351 TO 400 = DIS NOV
MAP 401 TO 456 = GUARDED
MAP 458 TO 1023 GUA
```

MAP	A command keyword refering to some operation on the ICE-88 memory map.
logsegmentno	A logical segment number (0 to 1023) that specifies a segment in logical address space. It is used to set the ICE-88 map in one of the following ways: • As the address of a single segment of logical addresses. • As the address of the first segment of a *partition* of logical addresses. • As the address of the last segment of a *partition* of logical addresses.
TO	A connector keyword that denotes that a logical segment number is to follow that defines the upper bound of a *partition* of logical segments.
LENGTH	A connector keyword that denotes that a logical segment length value is to follow defining a *partition* of logical segments.
segmentlen	A segment length [1 to 1024] that defines the length of *partition* of memory.
=	The assignment operator
GUARDED	The initial state of all memory segments. Any reference to a guarded address causes an error message. In the emulation mode accesses to a guarded location will cause emulation to terminate upon completion of the current instruction. In the interrogation mode, no access to the given location will be made.
USER	Refers to locations in user prototype memory.
ICE	Refers to locations in ICE-88 memory.
INTELLEC	Refers to locations in Intellec memory.

DISK	Refers to locations in diskette memory.
physegmentno	A physical segment number (0 to 1023) that specifies a physical segment of memory locations. Intellec expanded memory physical segment numbers are limited to a range of 1-960. If present in the command, the first logical segment in the *partition* is set equal to the value of *physegmentno* and the subsequent logical segments are set equal to the subsequent physical segment number values. If no *physegmentno* is entered, the ICE-88 emulator assigns physical segments from those declared but not yet mapped to.
NOVERIFY	A function keyword that suppresses the normal read-after-write verification of data loaded into the designated memory.

Display MAP Status Command

$$\text{MAP}\ \left\{\begin{array}{l}\textit{logsegmentno}\ [\text{TO}\ \textit{logsegmentno}] \\ \textit{logsegmentno}\ \text{LENGTH}\ \textit{logsegmentlen}\end{array}\right\}$$

Examples:

```
MAP
MAP 0 TO 100
MAP 123 LENGTH 200
MAP 300 LEN 400
```

MAP	A command keyword referring to some operation on the ICE-88 memory map.
logsegmentno	A segment number (0 to 1023) that specifies a segment of addresses in logical address space. It is used in the following ways: • As the address of a single segment of logical addresses. • As the address of the first logical segment of a *partition* of logical segments. • As the address of the last logical segment of a *partition* of logical segments.
TO	A connector keyword that denotes that segment number is to follow that defines the upper bound of a*partition* of logical segments.
LENGTH	A connector keyword that denotes that a segment length value that defines the length of a *partition* of logical segments.
logsegmentlen	A segment length [1 to 1024] that defines the length of a *partition* of memory.

RESET MAP Command

```
RESET MAP
```

Example:

```
RESET MAP
```

RESET	A command keyword that restores its object to its initial state, as after an initial ICE-88 invocation.
MAP	As the object of RESET, the token MAP causes the memory map to be set to its initial condition, all GUARDED. The available DISK and INTELLEC memory is deleted from the map.

Set Memory and Port Content Commands

The commands in this section set new values or change the current content stored in designated memory locations or input/output ports. The commands discussed in this section are as follows. The purpose of each command is indicated by its title.

Command
Set Memory Contents
Set Input/Output Port Contents

Discussion

Memory Content References

A memory content reference has the form:

memory-type address
[!!*mod-name*] !*symbol-name* ...

The meta-term *memory-type* means one of the following "content-of" modifiers for memory locations.

BYTE	The content of a single byte (8-bit) memory location. The *address* following BYTE is treated as a logical address; the physical address whose content is referenced is determined by look-up in the ICE-88 memory map (see Memory and I/O Port Mapping Commands).
WORD	The content of two adjacent bytes in memory. The most significant byte is located in the high address of the address pair; the least significant byte is stored in the low address of the pair. The *address* following WORD is treated as a logical address; the ICE-88 memory map is consulted to find the physical address whose content is referenced.
SINTEGER	The same as BYTE except when displaying.
INTEGER	The same as WORD except when displaying.
POINTER	The content of four adjacent bytes in memory, interpreted as a base and displacement. The displacement is located at the low 2 bytes of the 4 and the base is at the high 2 bytes. The *address* following POINTER is treated as a logical address; the ICE-88 memory map is consulted to find the physical address whose content is referenced.

The meta-term *address* means one of the following types of entries.

numeric-expression	The forms for numeric expressions are presented in Chapter 5. The result obtained when the expression is evaluated becomes an address modulo 64K.
(mem-type address)	A memory content reference with a form such as BYTE (WORD 1000) represents an indirect reference. The content of the address or address-pair inside the parentheses is treated as the address for the *mem-type* outside the parentheses.

To obtain the content of bytes, words, or pointers in a range of addresses, use the form:

memory-type partition

A *partition* can be a single address, or one of the following types of constructs.

address TO *address*

address LENGTH *number-of-bytes* (for BYTE and SINTEGER)

address LENGTH *number-of-words* (for WORD and INTEGER)

address LENGTH *number-of-double-words* (for POINTER)

The first form of *partition* uses the keyword TO. The address on the right of the keyword TO must be greater than or equal to the one on the left. With BYTE and SINTEGER, this form allows you to access the content of each byte location in the range; the range includes both the first and last address in the partition. With WORD or INTEGER, the first address is treated as the low address of the first address pair in the range; subsequent pairs of addresses are accessed until the second address is reached. If the second address is the low address of a pair, the word formed from the content of that address and the next consecutive higher address is accessed; if the second address is not the low address of a pair (that is, if it turns out to be the high address of a pair already accessed in the range), the access ends after the last complete pair has been accessed. Word-length accesses can begin on either an even-numbered or an odd-numbered address. With POINTER, the first address is treated as the low address of the first address quadruple in the range; subsequent quadruples of addresses are accessed until the second address is reached. If the second address is the low address of a quadruple, the pointer formed from the content of that address and the next three consecutive higher addresses is accessed; if the second address is not the low address of the quadruple, the access ends after the last quadruple has been accessed. Pointer length accesses can begin on either an even-numbered or an odd-numbered access.

The second, third, and fourth forms use the keyword LENGTH. The *address* preceding the keyword LENGTH is the starting address in the range, as with the first form (using TO). The number or expression following the keyword LENGTH gives the number of addresses (when the controlling *memory-type* is BYTE or SINTEGER), the number of address pairs (for WORD or INTEGER) or the number of addresses quadruples (for POINTER) (Must be an integer value).

Setting Memory Contents

To assign a new content to a byte, sinteger, word, integer, pointer or real location, use a command with the form:

$$\left\{\begin{array}{l}\textit{mem-type address}\\ [!!\textit{mod-name}\ ]\ !\text{symbol-name}\ldots\end{array}\right\} = \textit{new-content}$$

The meta-terms *mem-type* and *address* represent the types of entries discussed earlier in this section.

The meta-term *new-content* represents one of the following types of entries (for single addresses, setting the content of a range of addresses will be discussed later on).

numeric-expression	A numeric expression evaluated by the ICE-88 emulator to a single number.

If *mem-type* is a POINTER, *new-content* must be a pointer value. Otherwise, *new-content* must be an integer value.

When a single byte address is to be set, the ICE-88 emulator treats the *new-content* as an 8-bit quantity. If *new-content* has more than eight bits, the least significant eight bits in the quantity are used as the new content; and the other (higher) bits are lost. If *new-content* has fewer than eight bits, the bit values in the quantity are right-justified (placed in the low-order bits in the address), and the remaining (high) bits in the location are set to zeroes.

Here are some examples of setting byte contents. The first line of each example shows the command that sets the new contents; the second line gives a command that produces a display of the contents just set; the third line shows the resulting display. The output radix is assumed to be H (hexadecimal).

```
*BYTE 1000H = FFH              (or)   *BYTE 0100:0000 = FFH
*BYTE 1000H                           *BYTE 0100:0000
BYT 0000:1000H=FFH                    BYT 0100:0000H=FFH

*BYTE 1010H = RAL + 1          (or)   *BYT 100:10H = RAL + 1
*BYTE 1010H                           *BYT 100:10H
BYT 0000:1010H=F1H                    BYT 0100:0010H=F1H

*BYTE 1020H = FF11H            (or)   *BYTE 100:20 = FF11H
*BYTE 1020H                           *BYTE 100:20
BYT 0000:1020H=11H                    BYT 0100:0020H=11H

*BYTE 1030H = 1Y               (or)   *BYT 103:0 = 1Y
*BYTE 1030H                           *BYT 103:0H
BYT 0000:1030H=01H                    BYT 0103:0000H=01H

*BYTE 1040H = 'A'              (or)   *BYT 104:0 = 'A'
*BYTE 1040H                           *BYT 100:40
BYT 0000:1040H=41H                    BYT 0100:0040H=41H

*BYTE 1050H = BYTE 1000H       (or)   *BYTE 100:50H = BYT 100:0H
*BYTE 1050H                           *BYT 105:0
BYT 0000:1050H=FFH                    BYT 0100:0050=FFH
```

You can change the radix used to display the contents, using the Set Output Radix (BASE) command.

When a single word address is to be set, the ICE-88 emulator treats the *new- content* as a pair of bytes. The least significant byte is loaded into the low address in the pair, and the most significant byte is loaded into the high address in the pair. If *new-content* has fewer than 16 bits, the bit values are loaded starting with the low address, and right-justified. The remaining (high) bits in the address pair are set to zeroes. The following examples demonstrate some of the possibilities for the setting address pairs.

```
*WORD 1000H = 1122H                (or)   *WORD 0:1000H = 1122H
     *WORD 1000H                          *WOR 0:1000H
     WOR 0000:1000H=1122H                 WOR 0000:1000H=1122H

     *WORD 1010H = FFH             (or)   *WOR 101:0H =FFH
     *WORD 1010H                          *WORD 101:0
     WOR 0000:1010H=00FFH                 WOR 0101:0000H=00FFH

     *WORD 1030H = WORD 1000H      (or)   *WORD 0:1030H = WOR 0:1000H
     *WORD 1030H                          *WOR 103:0
     WOR 0000:1030H=1122H                 WOR 0103:0000H=1122H
```

When a single pointer is to be set, the ICE-88 emulator treats the *new-content* as a displacement and base. The least significant byte is loaded into the low address in the quadruple, and most significant byte is loaded into the high address. The following examples demonstrate some of the possibilities for setting pointers.

```
     *POINTER 1000H = 1122:3344H   (or)   *POI 100:0 = 1122:3344H
     *POINTER 10000H                      *POI 0:1000H
     POI 0000:1000H=1122:3344H            POI 0000:1000H=1122:3344H
```

A command of the form BYTE X =BYTE Y copies the content of the address Y to the content of address X where addresses X and Y are either integer or pointer values as shown in the examples above. A command of the form WORD X = WORD Y copies the content of address Y to location X, and the content of address (Y + 1) to location (X + 1). A command of the form POINTER X = POINTER Y copies the content of location Y through (Y + 3) to locations X through (X+3) respectively. A command of the form BYTE X = WORD Y copies the content of address Y to location X; the content of location (X + 1) is unchanged. A command of the form WORD X = BYTE Y copies the content of address Y to location X; the content of location (X + 1) is set to a byte of zeroes. POINTER X = BYTE Y copies (Y) to (X) zeroes in (X) + 1 to (X) + 3.

The commands used to set a range of addresses differ in some details.

One way to set a range of addresses is with the command of the form:

mem-type address =list of new-content values

With this form the *address* on the left side of the equals sign gives the starting location and the number of values in the list to the right of the equals sign tells the ICE-88 emulator how many consecutive addresses to load. Consecutive locations are changed to the values of the *new-contents* in left-to-right order. The list of new content values can consist of expressions, multi-character strings and memory partitions.

Here are some examples showing the use of this form of the set memory contents command.

```
*BYTE 1000H = 11H, 22H, 33H, 44H, 55H, 66H, 'AB'
*BYT 1000H LEN 8T
BYT 0000:1000H=11H 22H 33H 44H 55H 66H 41H 42H

*WOR 200:0H = FFFFH, WORD 100:0H
*WOR 200:0H LENGTH 4T
WOR 0200:0000H=FFFFH 2211H

*POI 4000:20H = 1122:3344H, WOR 1002H, BYT 1002
*POI 4000:20H
POI 4000:0020H=1122:3344 0000:4433 0000:0033
```

To set a range of addresses all to the same new value, use a command of the form:

mem-type partition = new-content

The forms of *partition* are discussed above in this section. All addresses in the partition are set to the single *new-content* value. The following examples show some of the possible results obtained with this command form.

```
*BYT 1000H TO 1005H =FFH
*BYTE 1000H LEN 5H
BYT 0000:1000H=FFH FFH FFH FFH FFH

*WORD 200:0 LENGTH 6T = AA00H
*WOR 200:0H TO 200AH
WOR 0200:0000H=AA00H AA00H AA00H AA00H AA00H AA00H

*POINTER 3000H LEN 3T = 1234:5678H
POI 0:3000H TO 0:300BH
WOR 0000:3000H=1234:5678 1234:5678 1234:5678
```

The last form of the set memory contents command sets the contents of each address in a range (*partition*) to the corresponding *new-content* in a list of values. This form is as follows.

mem-type partition =list of new-content values

This form combines the two forms discussed above. The list of new-content values can consist of expressions, multi-character strings and memory partitions.

If the number of locations in the partition is equal to the number of values in the *new-content* list, the addressed locations are set to the corresponding values in the list, in left-to-right order.

If the number of locations in the range is greater than the number of new values in the list, the locations are filled with the values from left-to-right, repeating the values in left-to-right order as necessary to fill all the locations. The maximum number of new content bytes that can be repeated is 128. With more than 128 bytes, the data is transferred but not repeated, and an error message is displayed.

If the number of new values in the list is greater than the number of locations in the *partition*, the lowest location receives the first value, and successive locations in the range receive values in left-to-right order until all locations in the range have received values. The excess values are then detected by the ICE-88 emulator as an error condition, and an error message is displayed. The excess values are lost.

Here are a few examples showing this form of command.

```
*BYT 1000H TO 1004H = 'ABCDE'
*BYT 1000H LEN 5T
BYT 0000:1000H=41H 42H 43H 44H 45H

*WORD 200:0H LENGTH 6T = 1122H, 'AB'
*WOR 200:0H TO 200:AH
WOR 0220:0000H=1122H 0041H 0042H 1122H 0041H 0042H

*BYTE 1000H TO 1002H = 11H, 22H, 33H, FFH
(an error message such as EXCESSIVE DATA is displayed)
*BYT 100:0 LEN 4T
BYT 1000:0000=11H 22H 33H 44H
```

In the third example, note that the byte at location 1003H retains the value set in the first example in the group of examples (44H rather than the FFH given in the command.)

Port Content References

The set port contents commands parallel those of the set memory contents commands with exception of port addressing. There are a total of 65536 8-bit ports available for input/output in the ICE-88 emulator. The ports are referenced by the mnemonic PORT. These ports can be referenced as 16-bit ports by the mnemonic WPORT. Each port is referenced by a *port-number* that is an integer value in the range of 0 through 65535.

To assign a new content to an 8-bit or 16-bit port, use the following command with the form:

port-type port-number = new-content

The meta-terms *port-type* and *port-number* are used to specify individual ports.

port-type	Defines the port type and size: PORT An 8-bit port. WPORT A 16-bit port.
port-number	An integer value specifying a specific port.

The following are examples of the use of this command form.

```
PORT 123 = FFH

WPORT 123 = FFFFH
```

One way of setting a range of ports is with the command of the form:

port-type port-number =list of new-content values

With this form the *port-number* on the left side of the equals sign gives the starting port location and the list to the right of the equals sign tells the ICE-88 emulator how many consecutive ports to load. Consecutive ports are changed to the values of the *new-contents* in left-to-right order.

Here are some examples showing the use of this form.

```
PORT 1000H = 11, 22, 33H, 44H, 55H, 66H

WPORT 1000H = 1122H, 3344H, 5566H
```

To set a range of ports all to the same new value, use a command of the form:

port-type partition = new-content

The following are examples of this form:

```
PORT 1000H TO 1005 = FFH

WPORT 2000H LENGTH 20H = FFFFH
```

The last form of the set port contents sets the contents of each port in a range (*partition*) to the corresponding *new-content* in a list of values. This form is as follows:

port-type partition = list of new-content values

If the number of ports in the partition is equal to the number of values in the *new-content* list, the addressed ports are set to the corresponding values in the list, in left-to-right order.

If the number of ports in the range is greater than the number of new values in the list, the ports are filled with the new values from left-to-right, repeating the values in left-to-right order as necessary to fill all the ports.

If the number of new values in the list is greater than the number of ports in the *partition*, the lowest numbered port receives the first value, and successive ports in the range receive values in left-to-right order until all ports in the range have received values. The excess values are then detected by the ICE-88 emulator as an error condition, and an error message is displayed. The excess values are lost.

Here are a few examples showing this form of command.

```
PORT 1000 TO 1005H = 'ABCDE'

WPORT 2000H LEN 6T = 1122H, 'AB'

PORT 1000H TO 1002H = 11H, 22H, 33H, FFH
```

(an error message such as EXCESSIVE DATA is displayed)

Set Memory Command

mem-type partition =new-content [, *new-content*] ...
typed-mem-ref = *numeric-expression*

Examples:

```
BYTE 0800H = FFH
BYTE 7000H LENGTH 16T = 00H
BYT 0800 TO 0805 = 12H, 34H, 56H, 78H, 9AH, BCH
WORD 70FFH = IP
WOR 7000H = PIP +1
POINTER 8000H = ABCD:1234H
BYTE 0800H = 'ABCDE'
POI 7000H = POI 4000H LEN 20H
BYT #56 = FAH
!VAR = 75
!X = !X + 1
!!MODA !PTR = SS:SP
```

mem-type	One of the six memory "content-of" modifiers BYTE, WORD, SINTEGER, INTEGER, or POINTER.
partition	One or more contiguous locations in memory.
new-content	One of the following types of entries, to be used as the new contents of the memory location:
	numeric-expression
	'*string* '
	mem-type partition
	port-type partition
typed-mem-ref	See page 5-6.

Set Input/Output Port Contents Command

port-type partition = *new-content* [, *new-content*]...

Examples:

```
PORT 0800H =FFH
PORT 7000H LENGTH 16T = 00H
POR 0880 TO 0885 = 12H, 34H, 56H, 78H, 9A, BCH
WPORT 70FFH = IP
WPO 7000H = PIP + 1
PORT 0800H = 'ABCDE'
PORT 56 = FAH
```

port-type	One of the two port "content-of" modifiers PORT or WPORT.
partition	One or more contiguous ports (must be integers).
new-content	One of the following types of entries, to be used as the new contents of the port:
	numeric-expression
	'string '
	mem-type partition
	port-type partition

Symbol Table and Statement Number Table Commands

The the ICE-88 emulator maintains a symbol table and source program statement number table to allow you to refer to memory addresses and other values by using symbolic references and statement references in the ICE-88 commands.

This section gives details on the following commands.

Command
DEFINE Symbol
Display Symbols
Display Statement Numbers
Display Modules
Change Symbol
REMOVE Symbols
REMOVE Module
TYPE
Set DOMAIN
RESET DOMAIN

Discussion

The ICE-88 symbol table receives symbols from two sources; the symbol table associated with the user program can be copied to the symbol table when the program is loaded, and the user can define additional symbols for use during the emulation session.

Corresponding to each symbol in the table is a number that you can interpret and use either as an address or as a numeric value (variable or constant). The next few paragraphs discuss the kinds of symbols that can appear in the table, and the interpretation of the corresponding symbol table quantity (address or value).

Instruction and statement labels are loaded with the program code. The symbol table gives the address of the instruction corresponding to the label.

A program variable is a symbol for a quantity that can have its value changed as a result of an instruction in the program. Program variables are LOADed with the program code. The symbol table gives the address where the variable value is stored.

A program constant is a symbol for a label set to a constant value (for example, using the assembler directive EQU or SET). Program constants are loaded into the symbol table when the program code is loaded. The symbol table gives the constant value associated with the symbol.

A module name is the label of a simple DO block that is not nested in any other block (for PL/M-86), or a label that is the object of a NAME directive (in 8086 assembly language). If no NAME directive is given, the module name is the same as the source file name without the extension. For example, if the source file name is ":F1:MYPROG.A88," the module name will be "MYPROG."

A module name itself does not have a corresponding address value in the symbol table. However, symbols contained in a module are considered to be "local" to that module; the ICE-88 emulator thus allows you to reference multiple occurrences of the same symbol name in different modules, by using the module name as a modifier in the *symbolic reference*.

The symbol table is organized to preserve the modular structure present in the program. Initially (before any code is loaded), the symbol table consists of one "unnamed" module. Any symbols defined without a specific module name are stored in the unnamed module in the order they were defined. The unnamed module is always the first module in the symbol table. Following the unnamed module, named modules are stored in the symbol table in the order that the modules were loaded into the ICE-88 emulator. Symbols local to each named module are stored in the order they appear in the module.

In addition to the symbols stored when the program code is loaded, you can use the DEFINE Symbol command to define new symbols for your use during the emulation session. The rules for user-defined symbols are as follows.

The name of the new symbol (*symbol-name*) can be defined with a maximum of 122 characters. However, the ICE-88 emulator truncates each symbol-name to the first 31 characters. Thus, to be different, two symbols must be unique in the first 31 characters.

The first character in the new *symbol-name* must be an alphabetic character, or one of the three characters @ or ? or underscore (_). The remaining characters after the first can be these characters or numeric digits.

You can specify the module that is to contain the new symbol you define. Symbols defined without a module are placed in the unnamed module at the head of the table, in the order they were defined. Symbols defined with an existing module name are placed in that module's section of the table; the module named must already exist in the table.

The new symbol name cannot duplicate a symbol name already present in the module specified. You can, however, have two or more symbols of the same name in different modules.

When you define a new symbol, you also specify the value corresponding to it in the table. You can treat the value you assign as an address or as a numeric value for use other than addressing.

The DEFINE Symbol command has the following form.

DEFINE *symbolic-reference* = *address*::*value* [OF *memory-type*]

The forms of *symbolic-reference* are shown in Table 7-8. The meaning of each form is as follows. Not all forms can be used in a DEFINE Symbol command.

A simple *symbolic-reference* has the form *.symbol-name.* the ICE-88 emulator searches for this form of reference starting with the first symbol in the unnamed module. If the symbol is not in the unnamed module, the ICE-88 emulator searches through the named modules in the order they were loaded, and takes the first occurrence of the symbol in the first (earliest) module that contains it.

When you define a symbol without a module, it is placed in the unnamed module.

The *symbolic-reference* can include a *module-reference*. The module reference immediately precedes the symbol name; the *module-name* is identified by a prefix consisting of a double period (..). When you define a symbol with a module reference, the symbol is added to the symbols under that module. A later reference to a symbol with a module name restricts the search to that module.

Table 7-8. Symbolic References and Statement References

Type of Reference	Meta-notation	Example	Display	DEFINE	Change	REMOVE
Symbolic	*.symbol-name*	.ABC	YES	YES	YES	YES
Symbolic	*..module.symbol-name*	..MAIN.DEF	YES, if module is already present in table.			
Symbolic	*.symbol-name.symbol-name*	.XX.YY	YES	NO	YES	YES
Statement	*#statement-number*	#56	YES	NO	NO	NO
Statement	*..module#stmt-number*	..MAIN#44	YES	NO	NO	NO

The meta-term *address/value* as used in the DEFINE Symbol command means one of the forms of numeric expressions given in Chapter 4.

The meta–term *memory-type* one of the following memory types: BYTE, WORD, SINTEGER, INTEGER, or POINTER.

Once a symbol has been defined or loaded, any reference to that symbol is equivalent to supplying its corresponding address or value.

To display the value from the symbol table corresponding to any symbol, enter the appropriate symbolic reference followed by a carriage return. The ICE-88 emulator displays the symbol table value on the next line.

To display the entire symbol table, enter the command SYMBOL followed by a carriage return. Symbols are displayed module by module, starting with the unnamed module. The *address/value* corresponding to each symbol is also displayed.

Example 1.

```
*.SAM                    (command)
.SAM=0200:1FE2H OF INT   (display)
```

Example 2.

```
*..MYPROG .SAM           (command)
.SAM=0200:1FE2H OF INT   (display)
```

Example 3.

```
*SYMBOL                     (command)
.TEMP=0000:0001H            (display)
MODULE..MAIN
.BEGIN= 0800:0050H
.VAR=0800:0100H OF BYT
MODULE..SUBR
.PROC=0800:0069H
.X=0800:0101H OF WOR
```

The ICE-88 emulator also maintains a statement number table for user programs written in PL/M-86 source code. The statement numbers are assigned by the PL/M-86 compiler. Corresponding to each source statement number in the table is the address of the first instruction generated by that source statement.

Table 7-8 shows the forms used to refer to statement number in the ICE-88 emulator. The simplest form is the statement-number prefixed by a number sign (#). A *module- reference* can precede the statement reference, since the statement number table preserves any modular structure in the program. Thus, two modules compiled separately can have the same statement numbers; the module reference tells the ICE-88 emulator which statement number to use.

To display the address corresponding to a statement-number, enter the appropriate statement number reference followed by a carriage return.

The ICE-88 emulator does not allow you to change the address corresponding to any existing statement number, to define any new statement numbers, or to delete (REMOVE) any statement numbers.

To display the value from the statement number table of any statement number, enter the appropriate statement number reference followed by a carriage return. The ICE-88 emulator displays the statement number value on the next line.

Example 1.

```
*#1                         (command)
#1=0800:0050H               (display)
```

Example 2.

```
*..MAIN #2                  (command)
#2=0800:0057H               (display)
```

To display the addresses of all the statement numbers in the statement number table, enter the keyword LINE. The ICE-88 emulator displays all the statement number addresses starting on the line following the command.

Example.

```
*LINE                       (command)
MODULE..MAIN                (display)
#1=0800:0050H
#2=0800:0057H
MODULE..SUBR
#1=1140:0012H
#2=1140:0037H
#3=1140:00DFH
```

To display the names of all the modules currently in the ICE-88 module table, enter the keyword MODULE. The ICE-88 emulator displays the names of all the modules currently in the table.

Example.

```
*MODULE              (command)
MODULE..MAIN         (display)
MODULE..SUBR
```

You can change the *address/value* corresponding to an existing symbol by entering a command of the form:

symbolic-reference=address::*value* [OF *memory-type*]

Any of the three forms of *symbolic-reference* shown in table 7-8 can be used to identify the symbol whose value is to be changed. The symbol must already exist as referenced.

The forms of *address*::*value* are discussed earlier in this section. Any of these forms may be used to change the value of an existing symbol.

Where multiple occurrences of the same symbol name exist in the table, the rules for table search given earlier determine which of the several instances of the symbol is to receive the new *address value* .

To delete one or more symbols from the table, use a command of the form:

REMOVE *list of symbolic-references*

The *symbolic-references* in the list are separated by commas. The ICE-88 emulator searches the table for each reference using the search rules given earlier, deleting the first occurrence of each symbol name that fits the type of reference given.

Note that deleting a symbol from the ICE-88 symbol table makes that symbol inaccessible to the ICE-88 emulator but does not affect the program code.

To delete the entire symbol table and the statement number table, enter the command REMOVE SYMBOL.

To delete one or more modules, enter the following command:

REMOVE MODULE *module-name* [, *module-name*]...

Removing a module removes all symbols and statement numbers in the module, but does not affect object code.

Example 1.

```
REMOVE MODULE ..MAIN
```

Example 2.

```
REM MOD ..MAIN, ..SUBR
```

The TYPE command allows you to assign or change the memory type of any symbol in the symbol table. The TYPE command is entered in the following format:

TYPE *symbolic-reference = memory-type*

The referenced symbol is assigned the memory type entered in the command.

Example.

```
    TYPE ..MYPROG .SAM = WORD
```

The symbol .SAM now is memory type WORD.

The Set DOMAIN command establishes a specified module as the default module for statement numbers. The RESET DOMAIN command establishes the first module in the module table after the unnamed module as the default for statement numbers, if there is a module other than the unnamed module; otherwise it establishes the unnamed module as the default. This is the initial domain.

Setting the domain should be especially useful for avoiding having to use module names on statement numbers from a particular module while debugging that portion of the program.

DEFINE Symbol Command

DEFINE [*module-name*] *symbol* = *expression* [OF *memory-type*]

Examples:

```
DEFINE ..MAIN .BEGIN = F3H OF BYTE
DEF .CAR = 0000:0F00H
DEF .VAR = 123T OF WOR
DEF .ENT1 = .VAR + 10 OF WOR
DEF .CAT2 = 0700:0050H OF POI
DEF ..SUBRA .CAT2 = 0000:00F0H OF POI
```

DEFINE	A command keyword that tells the ICE-88 emulator to enter the new symbol in the appropriate module table and assign the symbol the initial value given.
module-name	A sequence of contiguous alphanumeric characters, prefixed by a pair of periods (..) that references a program module.
symbol	A sequence of contiguous alphanumeric characters, prefixed by a period (.) that references a location in a symbol table.
=	The assignment operator.
expression	A numeric expression.
OF	A command modifier keyword denoting that a specification of memory type is to follow.
memory-type	A specification of the memory type of the symbol: BYTE, WORD, SINTEGER, INTEGER, or POINTER. If omitted, symbol has no type.

Display Symbols Command

```
SYMBOL

[module-name ] symbol [symbol ]...
```

Examples:

```
SYMBOL
.ABC
..MAIN.DEF
..XX.YY
.SUBR.ABC.DEF
```

SYMBOL	A command keyword that tells the ICE-88 emulator to display the entire ICE-88 symbol table, module by module.
module-name	A sequence of continuous alphanumeric characters, prefixed by a period (..) that references a program module.
symbol	A sequence of contiguous alphanumeric characters, prefixed by a period (.) that references a location in a symbol table.

Display Statement Numbers Command

```
LINE

[module-name] #decimal-10
```

Examples:

```
LINE
#54
..MAIN#44
```

LINE	A command keyword that tells the ICE-88 emulator to display all statement numbers and associated absolute addresses currently in the statement number table.
module-name	A sequence of contiguous alphanumeric characters, prefixed by a pair of periods (..) that reference a program module.
#	The "number" sign designating the reference as a statement number.
decimal-10	The (source) statement number (a numeric constant). The default suffix is always decimal.

Display Modules Command

```
MODULE
```

Example;

```
MODULE
```

MODULE	A command keyword that tells the ICE-88 emulator to display the names of all the modules currently in the module table.

Change Symbol Command

[*module-name*] *symbol* [*symbol*]... = *expression* [OF *memory-type*]

Examples:

```
.ABC = 2000H
..MAIN.DEF = AAFFH OF WOR
..SUBR.PARM = .ABC + 10
.TEMP = .ABC + ..MAIN.DEF OF WORD
```

module-name	A sequence of contiguous alphanumeric characters, prefixed by a pair of periods (..), that references a program module.
symbol	A sequence of alphanumeric characters, prefixed by a period (.) that references a location in the symbol table.
=	The assignment operator.
expression	A numeric expression.
OF	A command modifier keyword denoting that a specification of memory type is to follow.
memory-type	A specification of the memory type of the changed symbol: BYTE, WORD, SINTEGER, INTEGER, or POINTER. If omitted, do not change symbol's type.

REMOVE Symbols Command

REMOVE [*module-name*] *symbol* [*symbol*]...[, [*module-name*] *symbol* [*symbol*]...]...

REMOVE SYMBOL

REMOVE MODULE *module-name* [,*module-name*]...

Examples:

```
REMOVE .ABC
REMOVE ..MAIN.DEF
REMOVE .HIJ,.PARM1, ..MAIN.TWO,.CARS,.CARS1..SUBR.XX
REMOVE SYMBOL
REMOVE MODULE ..MAIN,..SUBR,..CALC
```

REMOVE	A command keyword causing the symbols that follow to be deleted from the ICE-88 symbol table.
module-name	A sequence of alphanumeric characters, prefixed by a pair of periods (..) that references a program module.
symbol	A sequence of alphanumeric characters, prefixed by a period (.) that references a location in the symbol table.
SYMBOL	A command modifier that tells the ICE-88 emulator to delete the entire current symbol table.
MODULE	A command modifier that tells the ICE-88 emulator to delete all the symbols and lines of the named module from the tables but does not affect object code.

TYPE Command

TYPE [*module-name*] *symbol* [*symbol*]... = *memory-type*

Examples:

```
TYPE
TYPE .ABC = POINTER
TYPE ..MAIN.DEF = WOR
TYPE ..SUBR.PARM.XX.YY = BYT
```

TYPE	A command keyword that allows the user to assign or change the memory type of any symbol in the symbol table.
module-name	A sequence of alphanumeric characters, prefixed by a pair of periods (..) that references a program module.
symbol	A sequence of alphanumeric characters prefixed by a period (.) that references a location in the symbol table.
=	The assignment operator.
memory-type	A specification of the memory type to be assigned to the referenced symbol: BYTE, WORD, SINTEGER, INTEGER, or POINTER.

Set DOMAIN Command

```
DOMAIN module-name
```

Example:

```
DOMAIN ..MAIN
```

DOMAIN	A command keyword that causes the ICE-88 emulator to establish the named module as the default module for statement numbers.
module-name	A sequence of alphanumeric characters prefixed by a pair of periods (..) that references a program module.

RESET DOMAIN Command

```
RESET DOMAIN
```

Example:

```
RESET DOMAIN
```

RESET	A command keyword restoring its object to a reset condition.
DOMAIN	A modifier keyword that causes the ICE-88 emulator to establish the first module after the unnamed module as the default module for statement numbers. If there are no named modules, the unnamed module is established as the default module.

Display Commands

This section presents the ICE-88 commands that allow you to reference and display the following systems elements.

- 8088 Processor Registers
- ICE-88 Status Registers
- 8088 Pin Signals
- Memory
- Ports
- Status Flags

The following commands are discussed in this section.

Command	Purpose
Display Processor and Status Registers	Display the current contents of any of the 8088 processor registers and ICE-88 status registers.
Display Memory	Display the contents of a range of memory.
Display I/O	Display the contents of a range of I/O locations.
Display STACK	Display the contents of the user's stack.
Display Boolean	Display boolean values.
Display NESTING	Display procedure starting and return addresses.
EVALUATE	Display numeric constant or expression in all five possible output radixes.

Discussion

Registers

The 8088 register structure contains three files of four 16-bit registers and a set of miscellaneous registers. The three files of registers are the general register file, the pointer and index file, and the segment register file. The miscellaneous set consists of the instruction pointer, flag register, CAUSE register, OPCODE register, PIP register, TIMER register, HTIMER register, BUFFERSIZE register, UPPER register and LOWER register. The register structures are described in the following paragraphs.

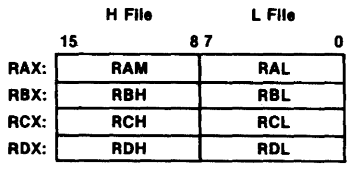
Table 7-9. Classes of Hardware Elements

Class Name	Hardware Elements
general-register	16-bit work register
pointer-register	16-bit address register
index-register	16-bit address register
segment-register	16-bit segment reference register
status-register	8 and 16-bit status registers

General Register File. The RAX, RBX, RCX, and RDX registers compose the General Register File. These registers participate interchangeably in 8088 arithmetic and logical operations. These registers are assigned the following mnemonics:

RAX: Accumulator
RBX: Base Register
RCX: Count Register
RDX: Data Register

The general registers are unique within the 8088 as their upper and lower bytes are individually addressable. Thus the general registers contain two 8-bit register files called the H file and L file as illustrated below:

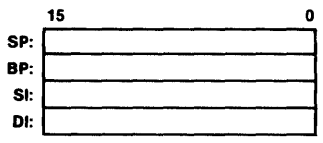


General Register File

Pointer and Index Register File. The BP,SP,SI, and DI set of 16-bit registers is called the Pointer and Index Register File. The registers in this group are similar in that they generally contain offset addresses used for addressing within a segment. They can participate interchangeably in 16-bit arithmetic and logical operations. They are also used in address computation. The mnemonics associated with these registers are:

SP: Stack Pointer
BP: Base Pointer
SI: Source Index
DI: Destination Index

The pointer and index registers are illustrated below:



Pointer and Index Register File

Segment Register File. The CS,DS,SS, and ES registers constitute the Segment Register File. These registers provide a significant function in the memory addressing mechanisms of the 8088. They are similar in that they are used in all memory address computations. The mnemonics associated with these registers are:

CS: Code Segment Register
DS: Data Segment Register
SS: Stack Segment Register
ES: Extra Segment Register

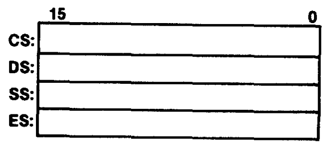
The contents of the CS register define the current code segment. All instruction fetches are taken to be relative to CS using the instruction pointer (IP) as an offset.

The contents of the DS register define the current data segment. All data references except those involving BP,SP, or DI in a string instruction, are taken by default to be relative to DS.

The contents of the SS register define the current stack segment. All data references which implicitly or explicitly involve SP or BP are taken by default to be relative to SS.

The contents of the ES register define the current extra segment. The extra segment has no specific use, although it is usually treated as an additional data segment.

The segment registers are illustrated below:



Segment Register File

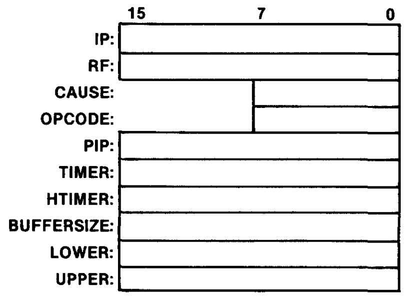
Status Register

The instruction pointer, flag register, CAUSE register, OPCODE register, PIP register, TIMER register, HTIMER register, BUFFERSIZE register UPPER register, and LOWER register constitute the status register set. These registers provide a variety of functions to the 8088. These registers are assigned the following mnemonics:

IP: Instruction Register
RF: Flag Register
CAUSE: CAUSE Register
OPCODE: OPCODE Register
PIP: Previous Instruction Register
TIMER: TIMER Register
HTIMER: HTIMER Register
BUFFERSIZE: BUFFERSIZE Register
LOWER: LOWER Register
UPPER: UPPER Register

The contents of the IP register defines the offset to the CS register in instruction address computations. The Flag Register contains the status flag values. The CAUSE register is used to retain the cause of the last break in emulation. The OPCODE register stores the opcode fetched in the last instruction-fetch cycle in trace data. The Previous Instruction Register is used to store the displacement part of the address of the last instruction-fetch in trace data. TIMER contains the low-order 16 bits of the 2-MHz timer indicating how long emulation has run (read only). HTIMER contains the high-order 16 bits of the timer (read only). BUFFERSIZE contains the count (displayed in decimal only) of frames of valid trace data collected in the trace buffer (16 bit, read only). The LOWER register contains the lowest available address in Intellec memory above the ICE-88 software (16 bit read only). The UPPER register contains the highest available address in Intellec memory below the user's symbol table (16 bit, read only).

The status registers are illustrated below:

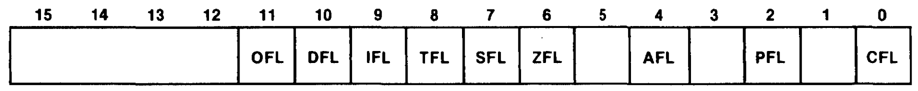


Status Registers

The Flag Register (RF) contains nine status values, each one a bit in length. The following mnemonics are assigned to each of the status values in the register:

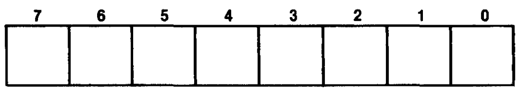
AFL: Auxiliary-carry
CFL: Carry
DFL: Direction
IFL: Interrupt-enable
OFL: Overflow
PFL: Parity
SFL: Sign
TFL: Trap
ZFL: Zero

AFL is set if an instruction caused a carry out of bit 3 and into bit 4 of a resulting value. CFL is set if an instruction caused a carry or a borrow out of the high order bit. DFL controls the direction of the string manipulation instructions. IFL enables or disables external interrupts. OFL is used to denote an overflow condition in a signed arithmetic operation. SFL is used to indicate the sign of the result of an operation. TFL is used to place the processor in a single-step mode for program debugging. ZFL is used to indicate a zero valued result of an instruction. The position of the status bits in the RF Register are shown below:



Flag Registers

The CAUSE Register is used to store the cause for the last break in emulation. The contents of this register is shown below:



Cause Register

The byte returned by the "Read Break Cause" hardware command contains the following bit values (if bit = 1, then the specified condition is true, otherwise false):

Bit Position	Condition
0	Breakpoint 0 matched
1	Breakpoint 1 matched
2	Both breakpoints matched sequentially
3	Guarded memory access occurred
4	User aborted processing
5	Timeout on user READY
6	Timeout on user HOLD

Pin References.

In addition to the status registers, the ICE-88 emulator provides access to six 8088 pins. The following mnemonics are assigned to reference the 8088 processor pins shown below:

Mnemonic	8088 Pin
RDY	READY
NMI	NMI
TEST	TEST
HOLD	HOLD
RST	RESET
MN	MN/$\overline{\text{MX}}$
IR	INTR

General Formats for Numeric Values

The ICE-88 emulator displays numeric values in a variety of formats depending upon the type of the numeric value. Table 7-10 defines the display formats for each of the numeric types.

Table 7-10. Numeric Value Display Formats

Type	Class Name	Definition
BYTE	*byte*	An 8-bit value displayed in the current base.
SINTEGER	*sinteger*	*sign byte-number* (short integer number)
WORD	*word*	A 16-bit value displayed in the current base.
INTEGER	*integer*	*sign word*
	sign	+ :: −
	bit	0 :: 1
POINTER	*pointer*	*base* : *displacement* H
	base	4 hexadecimal digits (the base value of pointer)
	displacement	4 hexadecimal digits (the displacement value of pointer)

If the high order bit of an INTEGER or SINTEGER is 1, the numeric value is complemented and the *sign* is set negative ("−"). For example, FFH is displayed as −01H as SINTEGER and F000H is displayed as −1000H as INTEGER.

In base ASCII, a pair of apostrophes enclose a single character in the case of a byte value or encloses two characters if a word value is to be displayed. In the case of a word, the high order byte appears on the left of the character pair.

In the four numeric bases, the BYTE and WORD values have a suffix and sufficient leading zeroes to contain the following number of digits.

	Hexidecimal	**Decimal**	**Octal**	**Binary**
BYTE	2	3	3	8
WORD	4	5	6	16

The Display Processor and Status Register Command allows you to display any of the 8-bit and 16-bit registers, the status flags and 8088 pin values. All referenced items are displayed on one line separated by spaces. However, if any displayed value would extend beyond column 80, a new line of display is initiated. Each reference is displayed according to the appropriate format shown below. The names are truncated to three characters.

8-bit-register-name = byte

16-bit-register-name = word

status-flag-name = bit

pin-name = bit

Example 1.

```
RAX, RBH, SP, CAUSE, AFL, HTIMER, BUFFERSIZE
```

Display:

```
RAX=0001H RBH=2FH SP=FFE7H CAU=00H AFL=1 HTI=008EH BUF=D1A2H
```

Example 2.

```
REGISTER
```

Display:

```
RAX=0000H RBX=00A2H RCX=0001H RDX=0010H SP=000AH BP= 0000H SI=0123H
DI=0000H CS=0000H DS=FF1EH SS= 0000H ES=0000H RF=0000H IP=FABCH
```

Example 3.

```
FLAG
```

Display:

```
CLF=0 PFL=0 AFL=0 ZFL=0 SFL=0 TFL=1 IFL=0 DFL=0 OFL=0
```

Example 4.

```
PIN
```

Display:

```
RDY=1 NMI=0 TES=1 HOL=0 RST=0 MN=1 IR=0
```

The Display Memory command enables you to display a range of one or more memory locations. When displaying memory, the format of the display depends upon the memory type, given either explicitly by a *mem-type* or implicity by the type of a symbol in a *typed-memory-reference* . For example, suppose that four consecutive bytes of memory contain A5H, 81H, 34H and 0C0H. The following are sample outputs in each of the four bases: hexadecimal, decimal, octal and binary:

Memory Type	Hexadecimal	Decimal	Octal	Binary
BYTE	A5H	165T	245Q	10100101Y
WORD	81A5H	33189T	100645 Q	1000000110100101Y
SINTEGER	-5BH	-91T	-133Q	-01011011Y
INTEGER	-7E5BH	-32347T	-77133 Q	-0111111001011011Y
POINTER	C034:81A5H			

Pointer type memory is always displayed in hexadecimal, regardless of the current output base. The Display memory command permits you to display more than one line of memory values. Each line of display contains the memory address of the first value displayed on that line followed by a maximum number of values as indicated by the following table.

Table 7-11. Display Values Per Line

	Hexadecimal	Decimal	Octal	Binary	ASCII
BYTE	16	8	8	4	64
WORD	8	8	8	2	32
SINTEGER	8	8	8	4	32
INTEGER	8	8	4	2	16
POINTER	4	—	—	—	—

Assume that the following memory locations contain the values shown below (in hexadecimal):

```
Address                         Content

00000H  00H  41H  42H  43H  45H  20H  30H  3DH 74H  68H  65H  72H  20H  43H  61H  6CH
00010H  69H  66H  6FH  72H  6EH  69H  61H  0DH 0AH  20H  20H  20H  20H  20H  20H  20H
00020H  20H  20H  20H  6CH  61H  77H  20H  70H  72H  6FH  76H  69H  64H  65H  64H  20H
00030H  66H  6FH  72H  20H  70H  72H  6FH  67H  72H  61H  6DH  73H  20H  6FH  66H  20H
00040H  74H  68H  69H  73H  20H  73H  6FH  72H  74H  2EH  20H  20H  54H  68H  69H  73H
```

The following commands display the above memory values with BASE = H.

Example 1.

```
BYTE 0000:0030
```

Display:

```
BYT 0000:0030H=66H
```

Example 2.

```
BYT 0:30 TO 0:3F
```

Display:

```
BYT 0000:0030H=66H 6FH 72H 20H 70H 72H 6FH 67H 72H 61H 6DH 73H 20H 6FH 66H 20H
```

Example 3.

```
WORD 0000:30
```

Display:

```
WOR 0000:0030H=6F66H
```

Example 4.

```
WOR 0:30 LEN 10H
```

Display:

```
WOR 0000:0030H= 6F66H 2072H 7270H 676FH 6172H 736DH 6F20H 2066H
WOR 0000:0040H= 6874H 7369H 7320H 726FH 2E74H 2020H 6854H 7369H
```

Example 5.

```
POINTER 0:30
```

Display:

```
POI 0000:0030H=2072:6F66H
```

Example 6.

```
POI 0:30 TO 0:3C
```

Display:

```
POI 0000:0030H=2072:6F66H  676F:7270  736D:6172H  2066:6F20H
```

Example 7.

```
POI 0:30 TO 0:4F
```

Display:

```
POI 0000:0030H=2072:6F66H  676F:7270H  736D:6172H  2066:6F20H
POI 0000:0040H=7369:6874H  726F:7320H  2020:2E74H  7369:6854H
```

The following examples illustrate display in decimal (BASE=T).

Example 8.

```
BYTE 0000:0030
```

Display:

```
BYT 0000:0030H=102T
```

Example 9.

```
BYT 0:30 TO 0:3F
```

Display:

```
BYT 0000:0030H=102T  111T  114T  032T  112T  114T  111T  103T
BYT 0000:0038H=114T  097T  109T  115T  032T  111T  102T  032T
```

Example 10.

```
WORD 0:30
```

Display:

```
WOR 0000:0030H=28518T
```

Example 11.

```
WORD 00:30 TO 00:4E
```

Display

```
WOR 0000:0030H= 28518T  08306T  29296T  26479T  24946T  29549T  28448T  08294T
WOR 0000:0040H= 26740T  29545T  29472T  29295T  11892T  08224T  26708T  29545T
```

Example 12.

```
POINTER 0:30
```

Display:

```
POI 0000:0030H=2072:6F66H
```

Example 13.

```
POINTER 0:30 TO 0:3C
```

Display:

```
POI 0000:0030H=2072:6F66H  676F:7270H  736D:6172H  2066:6F20H
```

The following examples illustrate memory displays in octal (BASE=Q).

Example 14.

```
BYTE 0000:0030
```

Display:

```
BYT 0000:0030H=146Q
```

Example 15.

```
BYT 0:30 LEN 10H
```

Display:

```
BYT 0000:0030H=146Q  157Q  162Q  040Q  160Q  162Q  157Q  147Q
BYT 0000:0038H=162Q  141Q  155Q  163Q  040Q  157Q  146Q  040Q
```

Example 16.

```
WOR 0:30
```

Display

```
WOR 0000:0030H=067546Q
```

Example 17:

```
WORD 0:30 LEN 10H
```

Display:

```
WOR 0000:0030H=067546Q  020162Q  071160Q  063557Q
WOR 0000:0038H=060562Q  071555Q  067440Q  020146Q
WOR 0000:0040H=064164Q  071551Q  071440Q  071157Q
WOR 0000:0048H=027164Q  020040Q  064124Q  071551Q
```

Example 18.

```
POINTER 0:30 LEN 4
```

Display:

```
POI  0000:0030H=2072:6F66H  676F:7270H  736D:6172H  2066:6F20H
```

The following examples illustrate memory displays in binary (BASE=Y).

Example 19.

```
BYTE 0:30
```

Display:

```
BYT 0000:0030H=01100110Y
```

Example 20.

```
BYTE 0:30 TO 0:3F
```

Display:

```
BYT 0000:0030H=01100110Y 01101111Y 01110010Y 00100000Y
BYT 0000:0034H=01110000Y 01110010Y 01101111Y 01100111Y
BYT 0000:0038H=01110010Y 01100001Y 01101101Y 01110011Y
BYT 0000:003CH=00100000Y 01101111Y 01100110Y 00100000Y
```

Example 21.

```
WOR 0:30
```

Display:

```
WOR 0000:0030H=0110111101100110Y
```

Example 22.

```
WOR 0:30 LEN 10H
```

Display:

```
WOR 0000:0030H=0110111101100110Y 0010000001110010Y
WOR 0000:0034H=0111001001110000Y 0110011101101111Y
WOR 0000:0038H=0110000101110010Y 0111001101101101Y
WOR 0000:003CH=0110111100100000Y 0010000001100110Y
WOR 0000:0040H=0110100001110100Y 0111001101101001Y
WOR 0000:0044H=0111001100100000Y 0111001001101111Y
WOR 0000:0048H=0010111001110100Y 0010000000100000Y
WOR 0000:004CH=0110100001010100Y 0111001101101001Y
```

Example 23.

```
POINTER 0:30
```

Display:

```
POI 0000:0030H=2072:6F66H (Always displayed in hexadecimal.)
```

The Display I/O command enables you to display byte ports (PORT) and word ports (WPORT) in a manner similar to the Display memory command. Single port contents or the contents of a range of ports may be displayed. However, only a single integer is required to specify the port address. The following examples illustrate the Display I/O command. The implied suffix in these examples is H (hexadecimal) for address specification.

Example 1.

```
BASE = Y
PORT 120H
```

Display:

```
POR 0120H=10111111Y
```

Example 2.

```
PORT 120 LEN 10
```

Display:

```
POR 0120H=10111111Y  10111111Y  10111111Y  01111111Y
POR 0124H=10111111Y  10111111Y  10111111Y  01111111Y
POR 0128H=10111111Y  10111111Y  10111111Y  01111111Y
POR 012CH=10111111Y  10111111Y  10111111Y  01111111Y
```

Example 3.

```
BASE = Q
PORT 120
```

Display:

```
POR 0120H=277Q
```

Example 4.

```
PORT 120 TO 12F
```

Display:

```
POR 0120H=227Q  177Q  277Q  177Q  277Q  177Q  277Q  177Q
POR 0128H=277Q  177Q  277Q  177Q  277Q  177Q  277Q  177Q
```

Example 5.

```
BASE =T
POR 120
```

Display

```
POR 0120H=191T
```

Example 6.

```
PORT 120 TO 12F
```

Display;

```
POR 0120H=191T  127T  191T  127T  191T  127T  191T  27T
POR 0127H=191T  127T  191T  127T  191T  127T  191T  127T
```

Example 7.

```
BASE = H
PORT 120
```

Display:

```
POR 0120H=BFH
```

Example 8.

```
PORT 120 TO 12F
```

Display:

```
POR 0120H=BFH 7FH BFH 7FH BFH 7FH BFH 7FH BFH 7FH BFH 7FH BFH 7FH BFH 7FH
```

Example 9.

```
BASE = Y
WPORT 120
```

Display:

```
WPO 0120H=0111101110111111Y
```

Example 10.

```
WPORT 120 TO 12E
```

Display:

```
WPO 0120H=0111101110111111Y  0111111110111111Y
WPO 0124H=0111111110111111Y  0111101110111111Y
WPO 0128H=0111111110111111Y  0111101110111111Y
WPO 012CH=0111101110111111Y  0111101110111111Y
```

Example 11.

```
BASE = Q
WPORT 120
```

Display

```
WPO 0120H=077677Q
```

Example 12.

```
WPORT 120 TO 13E
```

Display:

```
WPO 0120H=077677Q 077677Q 077677Q 075677Q 075677Q 077677Q 075677Q 0776 77Q
WPO 0130H=077677Q 077677Q 075677Q 077677Q 075677Q 077677Q 077677Q 0756 77Q
```

Example 13.

```
BASE = T
WPORT 120
```

Display:

```
WPO 0120H=32703T
```

Example 14.

```
WPORT 120 TO 13E
```

Display:

```
WPO 0120H= 32703T 32703T 32703T 31679T 31679T 32703T 31679T 32703T
WPO 0130H= 32703T 32703T 31679T 32703T 31679T 32703T 32703T 31679T
```

Example 15.

```
BASE = H
WPORT 120
```

Display:

```
WPO 0120H=7FBFH
```

Example 16.

```
WPORT 120 TO 13E
```

Display:

```
WPO 0120H=7FBFH 7FBFH 7FBFH 7BBFH 7BBFH 7FBFH 7BBFH 7FBFH
WPO 0130H=7FBFH 7FBFH 7BBFH 7FBFH 7BBFH 7FBFH 7FBFH 7BBFH
```

The Display STACK causes the top *n* words of the user's stack (i.e., user memory pointed at by SS:SP) where *n* is an integer value in the command that specifies the number words in the stack to be displayed.

Example

```
STACK 10
```

Display:

```
WOR 0000:0000H= 4100H 4342H 2045H 3D30H 6874H 265H 4320H 6C61H
WOR 0000:0010H= 6669H 726FH 696EH 0D61H 200AH 2020H 2020H 2020H
```

The Display Boolean command is used to display the boolean value of an integer value contained in the command:

Example:

```
BOOL FFH
```

Display:

```
TRUE
```

Example:

```
BOOL !X = !Y
```

Display:

```
FALSE
```

The Display NESTING Command

The Display NESTING command enables you to display the starting and return addresses of all procedures that are currently active. The user stack is scanned for procedure starting and return addresses as follows (all references to stack manipulations are restricted to the scope of the nesting module only):

1. Set b = CS

2. Set d = SP (word at the top of the user stack). If the 5 bytes from (b,d-5) through (b,d-1) can be interpreted as a short call (direct or indirect) (2,3, or 4 bytes), then b,d is assumed to be a return address.

3. Set WORD temp$b:d = next word on the user stack. If the 5 bytes from (temp$b,d-5) through (temp$b,d-1) can be interpreted as a long call (direct or indirect) (2,3,4 or 5 bytes), INT (1 or 2 bytes), or INTO, then b,d (and the next word in the stack for INT and INTO) can be assumed to be a return address.

4. The return address, type of call (i.e., short call direct), INT, or INTO, and the starting address (for direct only) are displayed.

The above procedure is repeated until 16 iterations fail to find a return address or the stack memory enters guarded memory. Care should be taken in using this command as the above method is susceptible to error.

The EVALUATE Command

The EVALUATE command handles the arithmetic computation involved in translating integers from one radix to another and computes the 20-bit address of a pointer. This command has the form EVALUATE *expr*, where *expr* is any numeric constant or numeric expression. Upon receiving this command, the ICE-88 emulator evaluates any expression to a single number. If it is an integer, it displays the result in the four bases Y, Q, T, and H, and the corresponding ASCII characters, all on one line. For ASCII, the characters are enclosed in single quotes (' '); printing characters are displayed (ASCII codes 20H through 7EH after bit 7 is masked off), while non-printing characters are suppressed.

When the EVALUATE command is followed by the keyword 'SYMBOLICALLY' (preceding the carriage return) the numeric value output by the command displayed as a *symbol* or *statement number* plus a remainder. The ICE-88 *symbols* and *statement numbers* are searched to find the one with the same base whose value is closest to but not greater than the value being output. In the event that a *symbol* and a *statement number* have the same value, the *symbol* is used. The value is then displayed as either the selected *symbol* plus a *numeric-constant* or the selected *statement number* plus a *numeric-constant* , where the *numeric-constant* is the remainder in the current output base. If no *symbol* or *statement number* has a value less than or equal to the number being output, the value is output as a numeric-constant. If the remainder is zero, the *numeric constant* is omitted.

If the *numeric expression* has a non-zero base, the value is displayed as a pointer (base:disp).

Here are several examples of the use of the EVALUATE command, with the display produced by each one.

Example 1:

```
    EVALUATE 123T
```

Display:

```
    1111011Y   173Q   123T   7BH   '{'
```

Example 2:

```
    EVA FFH + 256T
```

Display:

```
111111111Y   777Q   511T   1FFH   ''
```

Note that the addition was performed first, then the result was displayed in the four bases. The result contained only non-printing ASCII characters, displayed as empty quotes.

Example 3:

```
    EVA 111:0222H SYMBOLICALLY
```

Display:

```
    0111:0222H
```

This example assumes that no symbol or statement numbers match.

Example 4:

```
    EVA 111:222H SYM
```

Display:

```
    ..MOD1.SAM + 0021H
```

This example assumes that symbol ..MOD1.SAM is at address at 111:201 and no symbols or statement numbers exist in the interval 111:201 through 111:222.

Display Processor and Status Registers Command

$$\left\{\begin{array}{l} \textit{reference}\ [,\ \textit{reference}]\ldots \\ \text{REGISTER} \\ \text{FLAG} \\ \text{PIN} \end{array}\right\}$$

Examples:

```
RAX
RBH, SI, AFL, HOL
REGISTER
R
FLA
PIN
```

reference	Any of the reference keywords that reference processor registers, status registers and pins. Also can include memory and I/O in list.
REGISTER	A command keyword requesting the display of the thirteen 16-bit 8088 registers and RF.
FLAG	A command keyword requesting the display of the nine status flags.
PIN	A command keyword requesting the display of the contents of the seven input pins.

Display Memory Command

```
memory-designator address   [TO address     ]
                            [LENGTH length  ]

ASM address                 [TO address     ]
                            [LENGTH length  ]
```

Examples:

```
BYTE 1000:100H
WOR 0:123 TO 0:200
SIN 100:0 LENGTH 200
INT 200:200
POINTER 200:200
POI 200:200 TO 200:2FE
ASM 1000:123
ASM 1000:123 TO 1000:400
ASM 2000:000 LEN 100
```

memory-designator	One of the following keywords that specify the size and type of memory referenced:

BYTE	A 1-byte (8-bit) integer value.
WORD	A 2-byte (16-bit) integer value.
SINTEGER	A 1-byte (8-bit) short integer number (see Table 7-2).
INTEGER	A 2-byte (16-bit) integer value (see Table 7-2).
POINTER	A 4-byte (two 16-bit integer) value.

address	A pointer value containing a base and a displacement that together specify an address of a memory location.
TO	A *partition* keyword that denotes that an address is to follow. This address defines the upper bound of the required range of addresses in the partition.
LENGTH	A *partition* keyword that denotes that a *length* value is to follow.
length	An integer value specifying the number of addresses to be contained in the *partition* (bytes, words or pairs of words, depending on *memory-designator*).
ASM	A command keyword specifying the display of instructions in disassembled format. (See Display of Trace Data in Instructions Mode, page 6-26.)

Display I/O Command

```
{PORT }    address    [TO address    ]
{WPORT}               [LENGTH length ]
```

Examples:

```
PORT FF12H
POR FF00 TO FFFF
POR 1000 LEN 200
WPORT 123H
WPO 100 TO 200
WPO 100 LENGTH 101
```

PORT	Keyword reference to 8088 8-bit I/O port(s).
WPORT	Keyword reference to 8088 16-bit I/O port(s).
address	An integer value to that specifies the address of a 8088 port.
TO	A *partition* keyword that denotes that an address is to follow. This address defines the upper bound of the required range of port addresses in the *partition*.
LENGTH	A *partition* keyword that denotes that a *length* value is to follow.
length	An integer value specifying the number of port addresses (byte or word ports) to be contained in the partition.

Display STACK Command

STACK *expression*

```
STACK 10H
STA .SAM
STACK .SAM + 20
```

STACK	A command keyword that requests the display of the contents of the user's stack. The stack is located in user memory referenced by the pointer value SS:SP.
expression	An integer expression. The value of this expression defines the number of words at the top of the STACK that are to be displayed.

Display Boolean Command

BOOL *expression*

Examples:

```
BOOL FFH
BOO CS=DS AND IP > 50
BOO BYTE .X = F2H
BOOL !SAM
BOOL CFL
```

BOOL	A command keyword requesting the display of the boolean value (TRUE, FALSE) of the input value, *expression* .
expression	A boolean expression. The value of this expression is evaluated to a boolean value. If the least significant bit of the expression = 1, the boolean value is TRUE, otherwise the boolean value is FALSE.

Display NESTING Command

NESTING

Example:

```
NESTING
```

NESTING	A command keyword that causes the display of the starting and return address of all procedures that are currently active.

EVALUATE Command

```
EVALUATE numeric-expression  [SYMBOLICALLY]
```

Examples:

```
EVALUATE 123T

EVALUATE 4142H

EVALUATE FFH + 256T
```

EVALUATE	A command keyword that directs the ICE-88 emulator to evaluate the expression and display the result in all four number bases and ASCII.
numeric expression	A *numeric expression or numeric constant.*
SYMBOLICALLY	This keyword causes each numeric value output by the command to be displayed as a *symbol* or *source statement* number plus a remainder.

CHAPTER 8
ICE-88 ENHANCEMENTS

The command features described in this chapter enhance the operation of the ICE-88 emulator by extending the power of the simple ICE-88 commands.

ICE-88 enhancements are of two kinds: compound commands and macro commands. These features are as follows.

Compound commands:

REPEAT command
COUNT command
IF command

Macro commands:

DEFINE MACRO command
Invoke macro command
Display macro command
Macro directory command
REMOVE MACRO command
PUT MACRO command

Please note that the examples in this chapter are independent of each other. The introduction to each example gives the initial conditions for that example, and does not assume any results or conditions from any previous examples.

Compound Commands

A compound command is a control structure that contains zero or more commands. The compound commands discussed in this chapter are the REPEAT, COUNT, and IF commands; the DEFINE MACRO command is also a type of compound command. As the command titles indicate, REPEAT and COUNT are looping commands, and IF establishes conditional execution, and DEFINE MACRO establishes a named command block. All compound commands can have a "local" setting for the default SUFFIX (console input radix), as described under Local and Global Defaults in this chapter.

REPEAT Command

The REPEAT command executes zero or more ICE commands in a loop; the loop can also contain zero or more logical conditions for termination.

The REPEAT command consists of the REPEAT keyword, zero or more commands of any type, zero or more exit conditions using WHILE or UNTIL, and the keyword END. Enter each of these elements on its own line of the console display; terminate each input line with an intermediate carriage return (shown as *cr* in the command syntax). The syntax or REPEAT can be shown as follows:

```
REPEATcr
   [command cr                   ]
   [WHILE boolean-expression cr  ]  ...
   [UNTIL boolean-expression cr  ]
END
```

After each intermediate carriage return, the ICE emulator begins the next line with a period (giving an indented appearance), then the asterisk prompt to signal readiness to accept the next element. After the END keyword, enter a final carriage return to begin the sequence of execution. The final carriage return after END is not shown in the syntax, since all commands terminate with a final carriage return. The END keyword can be entered as ENDR or ENDREPEAT; the characters after END serve as a form of "comment" to indicate which loop is being terminated.

The elements to be repeated are shown in brackets in the syntax. Each element can be a command,a WHILE clause, or an UNTIL clause. You can mix these elements in any order, using any number of each type of element.

Each command is executed when it is encountered on each iteration. After the command has been completely executed, the loop proceeds to the next element.

The WHILE and UNTIL keywords introduce exit clauses. The WHILE clause terminates execution of the loop when its boolean-expression evaluates FALSE. The UNTIL clause terminates the loop when its boolean-expression evaluates TRUE.

In both the WHILE and UNTIL clauses, the boolean-expression is evaluated each time the clause is encountered; that is, once per iteration. Evaluation at each iteration involves looking up the values of any references in the expression. Thus, the result can change with each evaluation. Refer to Chapter 5 for an explanation of how expressions are evaluated.

The choice of WHILE or UNTIL is usually a matter of convenience — there is always a way to convert one into the other. For example, "WHILE bool-expr" is equivalent to "UNTIL NOT (bool-expr)."

NOTE

To terminate execution of a REPEAT (or COUNT) loop, press the ESC key at the console. The ICE command currently executing halts wherever it happens to be; if you are emulating, the current instruction is completed before the break. ICE responds to the ESC with the asterisk prompt.

Here are some brief examples of the REPEAT command.

Example 1: Generate an ASCII table similar to Table 5-2.

```
DEFINE .TEMP = 40H
REPEAT
    WHILE .TEMP <= 7EH
    EVALUATE .TEMP
    .TEMP = .TEMP + 1
ENDR
```

Example 2: Single-step through the user program and display the trace data collected for each instruction until a repetitious routine (.DELAY) is reached.

```
TRACE = INSTRUCTIONS
CS = SEG .START
IP = OFF .START
REPEAT
    UNTIL CS:IP = .DELAY
    STEP
    PRINT -1
ENDR
```

Example 3: Using a complex combination of conditions in the boolean expression.

```
REPEAT
    UNTIL (CS:IP > .END XOR !VAR1 = 0) AND (.TEMP > 0 XOR !VAR2 = 1)
    STEP
    REGISTER
ENDR
```

Example 4: Emulate from the start of the program (.START) until a breakpoint (.END EXECUTED) is reached, display status registers, then continue emulating, halting, and displaying status until a terminating condition (BYTE .VAR = 2) is reached.

```
CS = SEG .START
IP = OFF .START
REPEAT
    GO TILL .END EXECUTED
    REGISTER
    UNTIL !VAR = 2
ENDR
```

COUNT Command

Like REPEAT, the COUNT command sets up a loop. In addition to the WHILE and UNTIL clauses discussed under REPEAT, COUNT includes a loop counter that terminates the loop if no exit condition is met before the counter runs out.

The COUNT command has the form:

```
COUNT arithmetic expression cr
   [command cr                     ]
   |WHILE boolean-expression cr    |  ...
   [UNTIL boolean-expression cr    ]
END
```

The *arithmetic-expression* after COUNT controls the (maximum) number of iterations to be performed. If a numeric constant is used (for example, COUNT 10), the ICE emulator interprets it in implicit decimal radix; in other words, any number entered after COUNT without an explicit radix is interpreted as a decimal number.

If the entry after COUNT is an *arithmetic-expression,* it is evaluated to give the number of iterations. The COUNT expression is evaluated *once,* before any loop elements are encountered. It is not evaluated again on any interation. The COUNT expression uses the values of any references it contains as they stand at the time of evaluation. For example, consider the following command sequence:

```
DEFINE .XX = 2
COUNT .XX
    .XX = .XX + 1
END
```

This loop goes through *two* iterations, although .XX has value 4 when the loop terminates.

The loop terminates when the number of iterations given by the COUNT expression has been performed *or* when an exit condition is tested and causes exit, *whichever comes first*. The following example illustrates this concept.

```
DEFINE .XX = 1
COUNT 5
    .XX = .XX + 1
    WHILE .XX < 5
END
```

To show that the loop terminates on the WHILE condition before the COUNT expression is exhausted, we can "track" the loop in operation. Table 8-1 shows the track.

Table 8-1. Tracking a COUNT Command

Iteration	.XX	.XX < 5
1	2	TRUE
2	3	TRUE
3	4	TRUE
4	5	FALSE

The loop terminates during the fourth iteration, when .XX < 5 becomes FALSE.

Conversely, the COUNT expression specifies the maximum number of iterations to be performed in case no exit clause produces an exit on any iteration. For example:

```
TRACE = INSTRUCTION
CS = SEG .START
IP = OFF .START
COUNT 10
    UNTIL CS:IP = . DELAY
    STEP
    PRINT -1
END
```

In this command, the COUNT expression specifies a maximum of ten STEPs, in case the first instruction at .DELAY is not reached during any iteration.

With a REPEAT command or with a COUNT command that include one or more clauses, there may be no direct way to tell how many iterations occurred before the loop terminated. For these cases, you can insert a loop counter as a loop element. For example, to obtain table 8-1 as a display (or LIST file output) you could use the following sequence.

```
BASE = T
DEFINE . ITER = 0
DEFINE. XX = 1
COUNT 10
    .XX = .XX + 1
    .ITER = .ITER + 1
    .ITER
    .XX
    BOOL .XX < 5
    WHILE .XX < 5
END
```

The command BOOL .XX < 5 produces a display of TRUE or FALSE.

The following example emulates to a breakpoint, displays status registers, then continues emulating, breaking, and displaying status for a definite number of iterations:

```
CS = SEG .START
IP = OFF .START
COUNT 10
    GO TILL .PAUSE EXECUTED
    REGISTER
END
```

IF Command

The IF command permits conditional execution in a command sequence. The IF command has the form:

```
IF boolean-expression [THEN] cr
    [command cr] ...
[ORIF boolean-expression [THEN] cr]  ...
[    [command cr] ...              ]
[ELSE cr             ]
[    [command cr] ...]
END
```

The command must have the IF clause; the ORIF and ELSE clauses are optional. The command can include as many ORIF clauses as desired. The IF and ORIF clauses each contain a single condition (boolean expression). Any clause can contain none, one, or more commands. A clause with no commands simply produces an exit when its condition is TRUE.

ICE examines each boolean expression in turn, clause by clause, looking for the first TRUE condition. if a TRUE condition is found, the commands in that clause are executed and the IF command terminates. If none of the conditions is TRUE, the commands in the ELSE clause are executed and the IF command terminates. If the ELSE clause is omitted and no condition is TRUE, the IF command terminates with no commands executed.

The END keyword is required to close off the IF command; it can be written as ENDIF to clarify nesting.

Here is an example of the IF command.

```
BASE = T
IP = 1
IF IP < 1
    EVALUATE 1
ORIF IP < 2
    EVALUATE 2
ORIF IP < 3
    EVALUATE 3
ELSE
    EVALUATE 4
END
```

This example displays the result of EVALUATE 2 and then terminates. The first condition (IF IP < 1) is FALSE, so EVALUATE 1 is skipped. The second condition (ORIF IP < 2) is TRUE, so EVALUATE 2 is executed and the IF command terminates. The third condition (OPRIF IP < 3) is not tested, even though it happens to be TRUE.

In practice, however, the IF command is useful when it is nested in a REPEAT or COUNT loop rather than appearing at the "top" level. The reason for this is that you want to test conditions that can change (due to other commands in the loop), whereas at the top level the TRUE or FALSE state of any condition is known, or can be determined with the BOOL command. Thus, the result from the previous example can be obtained with fewer steps:

```
BOOL IP < 1   (Displays FALSE)
BOOL IP < 2   (Displays TRUE)
EVALUATE 2
```

Nesting Compound Commands

The REPEAT, COUNT, and IF commands can be nested to provide a variety of control structures.

Each nested compound command must have its own END keyword. When entering a nested command sequence, you may wish to use the keywords ENDR, ENDC, and ENDIF, to help you keep straight which command you intend to close off. The ICE-88 emulator does not check nesting levels at entry, and if an END is omitted, the resulting error makes it necessary to enter the entire command again.

Each nested REPEAT or COUNT command can contain its own exit clauses (WHILE or UNTIL). Each such exit clause can terminate the loop that contains it, but has no effect on any outer loops or commands.

As an example of nesting, suppose you want to STEP through a program with trace display, but skip a repetitive timeout routine, .DELAY, that is called with an 8088 short-call instruction several times during program execution. One way to achieve this effect is with the following command sequence:

```
TRACE = INSTRUCTION
CS = SEG .START
IP = OFF .START
REPEAT
    IF CS:IP = .DELAY
      IP = WORD SS:SP
      SP = SP + 2
    ENDIF
    STEP
    PRINT -1
ENDR
```

At each call to .DELAY in the program, the displacement of the return address for the call is pushed on the stack. The keyword SP refers to the stack pointer, and SS is the stack segment register; SS:SP is the address of the top of the stack where the return address is stored. The effects of the commands IP = WORD SS:SP and SP = SP + 2 are to load the return address back into IP and reset the stack pointer just as if the return instruction at the end of .DELAY had been executed.

As another example of nesting, suppose the user code at statements #21 and #22 is incorrect or not written yet. The following sequence emulates to the point where substitute code is to be inserted, inserts the code (equivalent to IF MARK > 0 THEN PTR = PTR + 2 in PL/M), then continues emulating beginning with statement #23 (the insertion is made any time emulation reaches statement #21):

```
GO FROM .START TILL #21 EXECUTED
REPEAT
    IF !MARK > 0
      !PTR = !PTR + 2
    ENDIF
    GO FROM #23
ENDR
```

An exit can be made only when a condition is *tested*, not when it occurs. To cause an exit, the test must be placed at the point in the loop where the condition occurs. For example, consider the following command sequence:

```
CS = SEG .START
IP = OFF .START
REPEAT
    UNTIL IP = 1000H
    STEP
ENDR
```

In this command the condition IP = 1000H is tested after every STEP. If the sequence of STEPs reaches IP = 1000H as the next instruction, the loop will terminate. By contrast, consider this example:

```
CS = SEG .START
IP = OFF .START
REPEAT
    UNTIL IP = 1000H
    COUNT 10
        STEP
    ENDC
ENDR
```

In the second example, the condition IP = 1000H is tested after every *ten* STEPs. The loop exits only if IP = 1000H occurs at the *end* of some group of ten instructions. If IP = 1000H occurs *during* one of the groups of ten STEPs, the loop does not terminate because that condition is changed by subsequent STEPs before the test can be made.

If the command has more than one exit clause, each exit clause is tested when it is encountered. If the result at the moment of the test causes an exit, the loop terminates; otherwise, the loop proceeds to the next element.

The loop exits only when the current test causes it, even though some other clause in the loop would cause an exit if it could be tested at that moment. Consider this (artificial) example:

```
DEFINE .ZZ = 0
CS = 0
IP = 0
REPEAT
    UNTIL IP > 10H
    COUNT 5
    STEP
    ENDC
    PRINT -10
    WHILE .ZZ = 0
    .ZZ = .ZZ + 1
ENDR
```

Assume for this example that the code being emulated (with STEP) contains only two-byte instructions. Then, after the first time through the loop, IP = 0AH (10T) and .ZZ = 1. On the second iteration, the test IP > 10H is FALSE when it is encountered, so the STEP and PRINT commands are executed again. At this point, IP > 10H is TRUE but since it is not tested, no exit occurs. Instead, the condition .ZZ = 0 is tested, found to be false, and the loop exits.

Macro Commands

A macro is a block of commands. When a block of commands is defined as a macro, it is stored on diskette so that it can be executed more than once without having to enter the commands each time. The macro commands described in this chapter allow you to perform the following functions:

- Define a macro, specifying the macro name, the command block, and any formal parameters (points where text can be filled in at the time of the macro call).
- Invoke (call) a macro by name, giving actual parameters to fill in the blank fields in the macro definition, to begin the execution of the command block.
- Display the text of any macro as it was defined.
- Display the names of all macros currently defined.
- Remove one or more macros.
- Save one or more macro definitions on an ISIS-II file.

In addition, the off-line facility (INCLUDE command) allows you to enter macro definitions from diskette files for use in the current test sequence.

Defining and Invoking Macros

Each macro is defined once in the test session. The syntax of the DEFINE MACRO (DEF MAC) command is as follows:

```
DEF MAC macro-name cr
  [command cr]...
EM
```

Once it is defined, you can invoke (call) a macro as often as desired. The syntax of a macro call is:

```
:macro-name[actual-parameter-list]
```

The macro definition command causes the macro name and block of commands to be stored in a table of macro definitions in a temporary ISIS-II file named MAC.TMP. (This file is removed by the ICE EXIT command).

WARNING

If you have a file on the ICE diskette named MAC.TMP it will be lost when you enter the ICE-88 emulator.

A *macro-name* must begin with an alphabet letter, or with one of the character "?" or "@". The characters after the first character can be alphabet letters, "?", "@", or numeric digits. The macro name must not duplicate a previously-defined macro name.

A macro definition may not appear within any other command (REPEAT, COUNT, IF, or another macro definition). The command block in the macro definition can include any command except another DEF MAC command or a REMOVE MACRO command.

The macro name in the macro invocation must be the name of a previously-defined macro. The form of *actual-parameter-list* is discussed later in this chapter.

Here is a simple macro definition:

```
DEF MAC GOER
  REPEAT
    GO FROM .START TILL BR0
  END
EM
```

To invoke this macro and cause its command block to begin executing, enter the macro name preceded by a colon (:). For example:

```
:GOER
```

A macro definition can include calls to other macros, but a macro cannot call itself recursively. Any macros called from within a macro must have been defined when the calling macro is invoked. Macro calls can be nested; i.e., one macro calls another, which calls another, and so on. The level of nesting is limited only by the memory space required to contain the macro expansions and "stack" the macro calls.

When a macro is called as an outer level command the following operations occur:

- System default (SUFFIX) is saved in case a new default is set inside the macro.
- The text of each actual parameter in the call is substituted for the corresponding formal parameter in the definition.
- The expanded command block is executed if all commands are valid as expanded.
- When the last command has finished, the former system default is restored.
- The macro exits. Control returns to the console (asterisk prompt).

The next several sections provide details on these operations, including the treatment of nested macro calls.

Local and Global Defaults

The system default can have a "local" setting within a macro; this default is as follows:

Default	**Refers to:**
SUFFIX	Default radix for console input.

When a macro is called (or any compound command is executed), the current "global" setting of SUFFIX, is saved so that it can be restored after the macro finishes executing its commands. The global default continues in effect within the macro unless and until a new (local) default is set with a SUFFIX command in the macro. Defaults other than SUFFIX are changed globally when they are set within a macro.

When the macro finishes executing its command block, the previous SUFFIX default is restored. Thus, any SUFFIX default that is set within a macro has no effect after that macro has exited.

Here is an (artificial) example of a macro with a local default:

```
DEF MAC SET0
  SUFFIX = H
  BYTE 0 TO 10 = 0
EM
```

Without the local SUFFIX command, the range of addresses to be set would depend on the global SUFFIX in effect when the macro SET0 is called. The global SUFFIX is restored after SET0 exits.

Formal and Actual Parameters

A formal parameter marks a place in an ICE command where variable text can be "filled in" when the macro is called. A formal parameter can represent part of a token or a field of one or more tokens. A macro definition can contain up to ten formal parameters. A formal parameter has the form:

%*n*

where *n* is a decimal digit, 0 to 9.

Formal parameters can appear in the macro definition in any order, and each one can appear any number of times. In most cases, the formal parameters form a complete numeric sequence with %0 as the lowest numbered parameter (even if % is not the first parameter to appear). However, one or more parameters can be omitted from the sequence; the effect of omitting a formal parameter from the sequence is to ignore the actual parameter in the call that corresponds to the omitted formal parameter.

The macro call can contain as many actual parameters as desired. Enter multiple parameters as a list, with entries separated by commas. The first actual parameter in the list is substituted at all points that %0 appears in the macro definition; the second parameter substitutes for %1, and so on.

An actual parameter can be "null," causing ICE to substitute a null for the formal parameter to which it corresponds. You can pass a null parameter to a macro in two ways:

- Enter no actual parameter between consecutive commas.
- Omit one or more parameters from the end of the list.

If too few actual parameters are entered, the ICE-88 emulator supplies nulls for the extra formal parameters. If too many actual parameters are entered, the extra actual parameters are ignored.

If any actual parameter contains a carriage return, a comma, or a single quote mark, the entire parameter must be enclosed in single quotes to identify it as a single actual parameter. In other words, parameters with these characters must be entered as *strings.* A single quote within a string is entered as ('').

Here are some examples to demonstrate the use of formal and actual parameters:

Example 1:

```
DEF MAC MEM
  %0INTEGER %1
EM
```

In the call to this macro, parameter %0 can become "S" or null. Parameter %1 can be any valid address or partition. Examples of calls to this macro:

Macro call	Expansion
:MEM S, 1000H	SINTEGER 1000H
:MEM, 1000H TO 100FH	INTEGER 1000H TO 100FH

Example 2:

```
DEF MAC RPT
  REPEAT
    %0
    %1
    %2
    %3
    %4
    %5
    %6
    %7
    %8
    %9
  END
EM
```

Macro RPT can accept up to ten commands to be repeated. For example:

```
:RPT GO TILL BR0, PRINT -1, REGISTERS, GO TILL BR1, PRINT -10
```

If fewer than ten commands are given, as in the example above, the extra formal parameters are ignored (treated as nulls). This shows how to do REPEAT on one line with no end required.

Example 3:

```
DEF MAC BRS
  BR%0 = %1
EM
```

Use of macro BRS may require parameters entered as strings, since some ways to set breakpoints involve embedded commas. For example:

```
:BRS 0, 1000H EXECUTED
```

This parameter is valid, but this one:

```
BRS 0, FFH, .START LEN 100H
```

results in the expansion:

```
BR0 = FFH
```

To obtain the correct expansion, make the parameter a string:

```
:BRS 0, 'FFH, .START LEN 100H'
```

This results in the expansion:

```
BR0 = FFH, .START LEN 100H
```

Details on Macro Expansion

The syntax and semantics of commands in a macro block are ignored at the point of definition; they are not determined until invocation, any may be different on each invocation through the use of formal parameters.

When a macro is called, its definition is expanded by adding the text of any actual parameters in the call at the points indicated by formal parameters in the definition. If the expanded macro contains any calls to other macros, the text of any such macros is also expanded, forming in effect one overall block of commands. The results of expansion are displayed at the console. Expansion continues until the last EM is reached. If the expansion results in a set of complete, valid commands, the commands are executed. An error results if any command is incomplete or invalid after expansion.

A macro invoked in a REPEAT, COUNT, or IF command is expanded immediately after the macro call command is entered. Thus, a macro called in a REPEAT or COUNT command is expanded only once, and a macro called in an IF command is expanded whether the condition in the IF or ORIF clause that contains the macro call is TRUE or FALSE.

Macro Table Commands

The macro table contains the name and text of all macros currently defined. The text is stored as it is defined, and does not contain any expansions.

The DEFINE MACRO (DEF MAC) command adds the macro defined to the end of the table. The syntax of this command appears earlier in this chapter. The DEF MAC command may not appear with any other command.

The REMOVE MACRO (REM MAC) command removes one or more macro definitions from the table. The syntax of this command is:

REM MAC [*macro-name*[,*macro-name*]...]

If the list of macro-names is omitted, all macros are removed. The REM MAC command may not appear within any other command.

The display macro command displays the name and definition of one or more macros from the macro table. The syntax is:

MAC [*macro-name*],*macro-name*]...]

If the list of macro-names is omitted the definitions of all macros in the table are displayed.

The macro directory command displays the names of all macros in the table. The syntax is:

```
DIR MAC
```

Here are some examples of these commands (assume that the table contains all the macro examples defined thus far in this chapter):

Example 1:

```
*DIR MAC                        (command)
GOER                            (display)
SET0
MEM
RPT
BRS
```

Example 2:

```
*MAC GOER                       (command)
DEF MAC GOER                    (display)
REPEAT
GO FROM .START TILL BR0
END
EM
```

Example 3:

```
REM MAC BRS                     (command)
```

Example 4:

```
*DIR MAC                        (Command)
GOER
SET0
MEM
RPT
```

Example 5:

```
*DEF MAC NULL                   (command)
*EM
```

Example 6:

```
*DIR MAC                        (command)
GOER                            (display)
SET0
MEM
RPT
NULL
```

Saving Macros

The PUT MACRO (PUT MAC) command causes one or more macro definitions to be copied from table to an ISIS-II diskette file. The syntax is:

PUT [*:drive:*] *filename* MACRO [*macro-name*[,*macro-name*]...]

If any macro names are entered, those macro definitions are saved. If no list of macro names is given, all macros in the table are saved. The definitions in the macro table are not affected by the operation.

The file containing the saved macro can later be edited or brought into another session with the INCLUDE command, discussed later in this chapter.

If the named file does not exist, it is created by the PUT command. If the file does exist on the diskette, the file is opened for input and the macros in the list are written on the file, destroying the previous contents of that file.

Further Examples

Here are a few more examples of macros. These macros simulate stack operations, calls, and returns in the ICE-88 emulator.

A stack is an area of memory, indexed (addressed) by a register called the stack pointer (SP) and stack segment register (SS). The stack is used to save status information required for an orderly return from a procedure call.

In the ICE-88 emulator, the stack is in mapped memory. The bottom (first available location) is the *highest* address in the stack area; the stack expands as needed into successively lower addresses. The stack pointer points to the address (word) at the top of the stack; this address contains the last item pushed on the stack. As each new word is pushed on the stack, SP is decremented to point to the new top address. Most of the values that need to be saved on the stack are 16-bit values. The high byte is stored in the address pointed to by (SS:SP − 1), and the low byte is stored in the next lower address (equivalent to SS:SP − 2).

The MCS-86 assembly language PUSH *rp* instruction sets SP to the next available word, then stores the content of the given register pair *rp* in adjacent addresses at that position. We can simulate this action with a macro, as follows:

```
DEF MAC PUSH88
  SP = SP - 2T         ;decrement SP
  WORD SS:SP =%0       ;low byte in low address, high byte in
EM                      high address.
```

The formal parameter %0 lets us use PUSH88 to save any register pair or other 16-bit value; for examples:

```
:PUSH88 IP     ;save instruction register
:PUSH88 RAX    ;save RAX
:PUSH88 RBX    ;save RBX
:PUSH88 RCX    ;save RCX
```

The complementary MCS-86 POP *rp* instruction copies the contents of the two top bytes pack into the given register pair, then increments SP to the new top of the stack. A macro for this function is:

```
DEF MAC POP88
  %0 = WORD SS:SP
  SP = SP + 2T
EM
```

Here are some calls to POP88, corresponding to the PUSH88 calls given earlier:

```
:POP88 RCX
:POP88 RBX
:POP88 RAX
:POP88 IP
```

Here are some macros that use PUSH88 and POP88.

1. Macro to "call" (short-call) a procedure:

```
DEF MAC CALL88
    :PUSH88 IP
    GO FROM CS:%0
EM
```

   This macro can be invoked with or without a halt condition:

```
:CALL88 .PROC or
:CALL88 .PROC TILL BR0
```

2. Macro to "call" (long-call) a procedure:

```
DEF MAC LCALL88
    :PUSH88 CS
    :PUSH88 IP
    GO FROM %0
EM
```

   To invoke this macro:

```
:LCALL88 .PROC or
:LCALL88 .PROC TILL BR1
```

3. Macro to "return" (short-return) from a procedure:

```
DEF MAC RET88
    :POP88 IP
    GO %0
EM
```

   To invoke this macro:

```
:RET88 or
:RET88 TILL BR0
```

4. Macro to "return" (long-return) from a procedure:

```
DEF MAC LRET88
    :POP88 IP
    :POP88 CS
    GO %0
EM
```

   To invoke this macro:

```
:LRET88 or
:LRET88 TILL BR0
```

5. Macro to single-step through user code, skipping over a specified procedure whenever that procedure is called from the user program, and printing the instruction just executed each time.

```
DEF MACRO SKIP
 REPEAT
   IF CS:IP = %0
     :POP88 IP             (short-called procedure)
   ENDIF
   STEP
   PRINT -1
 ENDR
EM

DEF MACRO LSKIP        (long-called procedure)
 REPEAT
   IF CS:IP = %0
     :POP88 IP
     :POP88 CS
   ENDIF
   STEP
   PRINT -1
 ENDR
EM
```

Suppose the user program contains a respective timer routine named DELAY that is called from several places in the program. The following macro invocation causes the ICE-88 emulator to step through the program without emulating the timer routine:

```
:SKIP .DELAY
```

Off-line Facilities

In addition to the compound and macro commands described above, the INCLUDE command allows you to access macro definitions stored in diskette files and to cause them to be executed from these files rather than the console.

INCLUDE Command

The INCLUDE command causes input to be taken from the file specified until the end-of-file, at which point input continues to be taken from the previous source, normally the console.

The syntax of the INCLUDE command is:

$$\text{INCLUDE} \left\{ \begin{array}{l} [:\textit{drive}:]\ \textit{filename} \\ :\textit{device}: \end{array} \right\}$$

Nesting of INCLUDE command is permitted. For example:

```
IP = .START
REPEAT
    UNTIL IP = .HALT
    INCLUDE PROGA.INC
      INCLUDE PROGB.INC
    ENDR
```

The console (:CI:) may be given as the *filename*, in which cases control-Z must be used as end-of-file. The files are echoed on the console.

As macros can be complex and editing may be required on the macro definition, the INCLUDE command allows you to access offline macro definitions and to create online macros, which combine to form the macro suite for a particular debugging session. However, command lines may appear in the INCLUDE file, not just macro definitions.

Write Command

The WRITE command writes one or more list elements to the console and to the list file at run time.

The syntax of the WRITE command is:

WRITE *list-element* [,*list-element*]

where

list-element ≡ *string* :: *expr* :: BOOL *expr*

For example:

WRITE $CTIME, 'SECONDS SINCE LIGHT CHANGE'

Would output a message showing the time in seconds (in CARS2) (see Chapter 3) since the traffic light changed.

This command writes the *list-element* (s) to the console all on the same line except when the *nest-element* will not fit into the remaining character space on the current line. In this event, a carriage return and a line feed will be inserted. If the *list-element* is a string, it will be displayed. If the *list-element* is an *expr*, the value of the expression is displayed in the current base. A single character string is displayed as a string. When a single character string is used in an expression, its corresponding hexadecimal value is used in evaluating the expression, and the value of the expression is displayed.

If the *list-element* is BOOL *expr*, ICE displays the boolean value TRUE when the least significant bit (LSB) of the result is 1, FALSE when the LSB is 0; no spaces are provided either before or after the boolean value.

APPENDIX A ICE-88 KEYWORDS AND THEIR ABBREVIATIONS

ABSOLUTE	ABS
ACKNOWLEDGE	ACK
ADDR	ADD
AFL	AFL
ALL	ALL
AND	AND
ASCII	ASC
ASM	ASM
BASE	BAS
BOOL	BOO
BP	BP
BR	BR
BR0	BR0
BR1	BR1
BUFFERSIZE	BUF
BYTE	BYT
CAUSE	CAU
CFL	CFL
CLOCK	CLO
CONDITIONALLY	CON
COUNT	COU,C
CS	CS
DEFINE	DEF
DFL	DFL
DI	DI
DIR	DIR
DISABLE	DIS
DISK	DIS
DMUX	DMU
DOMAIN	DOM
DOWN	DOW
DS	DS
ELSE	ELS
EM	EM
ENABLE	ENA
END	END
ERROR	ERR
ES	ES
EVALUATE	EVA
EXECUTED	EXE,E
EXIT	EXI
EXTERNAL	EXT
FETCHED	FET
FLAG	FLA
FOREVER	FOR
FRAME	FRA
FROM	FRO,F
GO	G
GR	G
GUARDED	GUA
H	H
HALT	HAL,H
HARDWARE	HAR
HOLD	HOL
HTIMER	HTI
ICE	ICE
IF	IF
IFL	IFL
INCLUDE	INC
INFINITE	INF
INPUT	INP,I
INSTRUCTION	INS
INTEGER	INT
INTELLEC	INT
INTERNAL	INT
IP	IP
IR	IR
LENGTH	LEN
LINE	LIN
LIST	LIS
LOAD	LOA
LOWER	LOW
MACRO	MAC
MAP	MAP
MARK	MAR
MASK	MAS
MATCH	MAT
MN	MN
MOD	MOD
MODULE	MOD
MOVE	MOV,M
NESTING	NES
NEWEST	NEW,N
NMI	NMI
NOCODE	NOC
NOERROR	NOE
NOLINE	NOL
NOSYMBOL	NOS
NOT	NOT
NOVERIFY	NOV
NOW	NOW
OBJECT	OBJ
OF	OF
OFF	OFF
OFFSET	OFF
OFFTRACE	OFF
OFL	OFL
OLDEST	OLD,O
ON	ON
ONTRACE	ONT
OPCODE	OPC
OR	OR
ORIF	ORI
OUTPUT	OUT,O
PFL	PFL
PIN	PIN
PIP	PIP
POINTER	POI
PORT	POR
PRINT	PRI,P
PUT	PUT
Q	Q
QDEPTH	QDE
QSTS	QST
RAH	RAH
RAL	RAL
RAX	RAX
RBH	RBH
RBL	RBL
RBX	RBX
RCH	RCH
RCL	RCL
RCX	RCX
RDH	RDH
RDL	RDL
RDX	RDX
RDY	RDY
READ	REA,R
REGISTER	REG,R
REMOVE	REM
REPEAT	REP
RESET	RES
RF	RF
RST	RST
RWTIMEOUT	RWT
SAVE	SAV
SEGMENT	SEG
SFL	SFL
SI	SI
SINTEGER	SIN
SP	SP
SS	SS
STACK	STA
STEP	STE,S
STS	STS
SUFFIX	SUF
SYMBOL	SYM
SYMBOLICALLY	SYM
T	T
TEST	TES
TFL	TFL
THEN	THE
TILL	TIL,T
TIMER	TIM
TO	TO
TRACE	TRA
TYPE	TYP
UNTIL	UNT
UP	UP
UPPER	UPP
USE	USE
USER	USE
VALUE	VAL
WHILE	WHI
WORD	WOR
WPORT	WPO
WRITE	WRI
WRITTEN	WRI,W
XOR	XOR
Y	Y
ZFL	ZFL

APPENDIX B ERROR MESSAGES

The following is a list of error messages.

ERR 10:RSLTS BLK INACCESSIBLE
A BUS TIMEOUT WAS DETECTED ON AN ATTEMPT TO WRITE THE RESULTS BLOCK.

ERR 11:XMIT BLK INACCESSIBLE
A BUS TIMEOUT WAS DETECTED ON AN ATTEMPT TO READ THE TRANSMIT BLOCK.

ERR 16:DVC CD FORMAT ERROR
THE FORMAT BYTE OF DEVICE CODE TABLE WAS DETERMINED TO BE NON-ZERO.

ERR 17:DVC NOT IN DVC CD TABLE
A DEVICE CODE CORRESPONDING TO THIS ICE WAS NOT FOUND IN THE DEVICE CODE TABLE.

ERR 21:COMMAND NOT ALLOWED NOW
THE COMMAND CODE IN THE PARAMETER BLOCK CANNOT BE PROCESSED AT THIS TIME.

ERR 30:PGM MEMORY FAILURE
DATA READ BACK FROM PROGRAM MEMORY DID NOT AGREE WITH DATA WRITTEN.

ERR 31:DATA MEMORY FAILURE
DATA READ BACK FROM DATA MEMORY DID NOT AGREE WITH DATA WRITTEN.

ERR 32:BREAKPOINT MEM FAILURE
DATA READ BACK FROM BREAKPOINT MEMORY DID NOT AGREE WITH DATA WRITTEN.

ERR 33:MEMORY MAP FAILURE
DATA READ BACK FROM MEMORY MAP DID NOT AGREE WITH DATA WRITTEN.

ERR 34:CABLE FAILURE
CABLE DIAGNOSTIC PROGRAM DETECTED A FAILURE IN THE CABLE.

ERR 35:CONTROL CIRCUIT FAILURE
CONTROL DIAGNOSTIC PROGRAM DETECTED A FAILURE IN THE CONTROL CIRCUITRY (SEE NOTE 1).

ERR 36:PAGE FAULT
NOT AN ERROR. ACCESS WAS MADE TO DISK MAPPED MEMORY AND FIRMWARE DOESN'T HAVE PAGE CONTAINING THAT LOCATION.

ERR 37:INTELLEC MEMORY FAILURE
INTELLEC MEMORY DOES NOT VERIFY WHEN WRITTEN TO: IT MAY BE MISSING, NON-WRITABLE, OR BAD MEMORY.

ERR 40:NO USER CLOCK
IN EXTERNAL CLOCK MODE, THE CPU CLOCK IS NOT PRESENT.

ERR 41:NO USER VCC
IN EXTERNAL CLOCK MODE, THE USER VCC IS NOT PRESENT.

ERR 42:GUARDED ACCESS
ACCESS WAS MADE TO A GUARDED MEMORY OR I/O LOCATION.

ERR 43:PROCESSOR NOT RUNNING
IN EXTERNAL CLOCK MODE, THE USER READY SIGNAL IS NOT PRESENT.

ERR 48:READY TIMEOUT
IN EXTERNAL CLOCK MODE WITH TIMEOUT ON READY SELECTED, A COMMAND TIMEOUT OCCURRED.

ERR 49:HOLD SEQUENCE ERROR
A HOLD REQUEST WAS INITIATED AND REMOVED BEFORE HOLD ACK BECAME ACTIVE (SEE NOTE 2).

ERR 4A:HOLD TIMEOUT
CANNOT EXIT EMULATION OR EXAMINE USER MEMORY BECAUSE HOLD IS INACTIVE TOO LONG IN THE USER SYSTEM (SEE NOTE 1).

ERR 4B:RESET TIMEOUT
CANNOT EXIT EMULATION BECAUSE RESET IS INACTIVE (SEE NOTE 1).

ERR 80:SYNTAX ERROR
THE TOKEN FLAGGED IS NOT ONE THAT IS ALLOWED IN THE CURRENT CONTEXT.

ERR 81:INVALID TOKEN
THE TOKEN FLAGGED DOES NOT FOLLOW THE RULES FOR A WELL-FORMED TOKEN.

ERR 82:NO SUCH LINE NUMBER
THE SPECIFIED LINE NUMBER DOES NOT EXIST IN THE CURRENT MODULE.

ERR 83:INAPPROPRIATE NUMBER
THE VALUE IS NOT APPROPRIATE IN THE CURRENT CONTEXT.

ERR 84:PARTITION BOUNDS ERROR
THE PARTITION VALUES ENTERED IN A COMMAND ARE NOT CORRECT. EITHER THE LEFT PART OF THE PARTITION IS GREATER THAN THE RIGHT PART OR THE VALUES OF THE PARTITION EXTREMES ARE OUT OF RANGE IN THE CURRENT CONTEXT.

ERR 85:ITEM ALREADY EXISTS
THE ITEM ENTERED IN A DEFINE COMMAND IS CURRENTLY DEFINED IN THE SYMBOL TABLE.

ERR 86:ITEM DOES NOT EXIST
THE ITEM PRINTED ON THE PRECEDING LINE DOES NOT RESIDE IN THE SYMBOL TABLE.

ERR 87:DUPLICATE CHANNEL
THE CHANNEL SPECIFIED APPEARS MORE THAN ONCE IN A CHANNEL LIST.

ERR 88:MACRO PARAMETER ERROR
TOO MANY MACRO PARAMETERS OR MACRO PARAMETER TOO LONG.

ERR 89:MISSING CR-LF IN FILE
INCLUDE FILE DOESN'T END IN CARRIAGE-RETURN LINE-FEED.

ERR 8A:FORMAT ALREADY EXISTS
THE FORMAT SPECIFIED IN A DEFINE COMMAND IS ALREADY DEFINED.

ERR 8B:FORMAT DOES NOT EXIST
THE FORMAT SPECIFIED HAS NOT BEEN DEFINED.

ERR 8C:COMPARE MODE NOT ACTIVE
FIND COMMAND WAS ISSUED WHILE COMPARE TRACE MODE WAS NOT ACTIVE.

ERR 8D:EMPTY TRACE BUFFER
TRACE BUFFER IS UNINITIALIZED.

ERR 8E:INVALID TRACE REFERENCE
TRACE REFERENCE MADE WHILE TRACE BUFFER UNINITIALIZED.

ERR 8F:NON-NULL STRING NEEDED
A NULL STRING WAS USED WHERE A NON-NULL STRING IS REQUIRED.

ERR 90:MEMORY OVERFLOW
MEMORY REQUIREMENTS OF ALL DYNAMIC TABLES EXCEED THE AMOUNT OF MEMORY AVAILABLE.

ERR 91:STACK OVERFLOW
THE CAPACITY OF A STATICALLY ALLOCATED STACK INTERNAL TO THE DIAGNOSTIC PROGRAM HAS BEEN EXCEEDED.

ERR 92:COMMAND TOO LONG
THE CAPACITY OF THE STATICALLY ALLOCATED INTERMEDIATE CODE BUFFER HAS BEEN EXCEEDED.

ERR 93:MODULE DOES NOT EXIST
MODULE SPECIFIED DOES NOT EXIST IN SYMBOL TABLE.

ERR 94:NON-CHANGEABLE ITEM
AN ATTEMPT WAS MADE TO CHANGE AN ITEM THAT MAY NOT BE CHANGED.

ERR 95:INVALID OBJECT FILE
FILE SPECIFIED IN A LOAD COMMAND IS NOT A VALID OBJECT FILE.

ERR 96:INVALID WITHIN ACTIVATE
THE COMMAND IS NOT VALID WITHIN AN ACTIVATE BLOCK.

ERR 97:EXCESSIVE DATA
THE AMOUNT OF DATA ATTEMPTED TO BE INSERTED INTO A PARTITION EXCEEDED THE SIZE OF THE PARTITION.

ERR 98:MORE THAN 16 CHANNELS
MORE THAN 16 CHANNELS SPECIFIED IN A CHANNEL LIST.

ERR 99:EXCESSIVE ITERATED DATA
THE AMOUNT OF DATA TO BE REPEATED THROUGHOUT A RANGE OF MEMORY EXCEEDS THE SIZE OF THE BUFFER ALLOCATED TO HOLD SUCH DATA.

ERR 9A:TOO MANY GROUPS
NUMBER OF GROUPS DEFINED BY USER MAY NOT EXCEED 43.

ERR 9B:TOO MANY CHANNELS
NUMBER OF CHANNELS DEFINED BY USER MAY NOT EXCEED 128.

ERR 9C:UNSUITABLE EXECUTE FILE
THE FILE REFERENCED IN AN EXECUTE COMMAND EITHER CONTAINS CODE THAT IS OUT-OF-BOUNDS FOR THE EXECUTE COMMAND OR IT IS A MAIN MODULE.

ERR 9D:LINE TOO LONG
COMMAND LINE WAS LONGER THAN 122 CHARACTERS.

ERR 9E:HOST-ONLY COMMAND
THE COMMAND ISSUED IS NOT ALLOWED IN AN ACTIVATION LIST.

ERR 9F:PROCESS ALREADY ACTIVE
ATTEMPT MADE TO ACTIVATE A PROCESS THAT WAS ALREADY ACTIVE.

ERR A0:TOO MANY PARTITIONS
NUMBER OF PARTITIONS OR SINGLE BREAKPOINTS IN A BREAKPOINT REGISTER EXCEED MAXIMUM PERMISSIBLE VALUE.

ERR A1:PARTITION CROSSES PAGE
BREAKPOINT PARTITION WAS NOT CONTAINED ON A SINGLE PAGE.

ERR A2:ILLEGAL CLOCK VALUE
VALUE SPECIFIED FOR CLOCK IS NOT A PERMISSIBLE VALUE.

ERR A3:PROCESS ALREADY DORMANT
ATTEMPT MADE TO SUSPEND OR TERMINATE A DORMANT PROCESS.

ERR A4:MACRO FILE FULL
MACRO FILE CONTAINS MORE THAN 64K CHARACTERS.

ERR A7:POINTER VALUE REQUIRED
A NON-POINTER VALUE WAS USED IN A CONTEXT THAT MUST USE A POINTER.

ERR A8:INTEGER VALUE REQUIRED
A NON-INTEGER (I.E., POINTER WITH NON-ZERO BASE) VALUE WAS USED IN A CONTEXT THAT MUST USE AN INTEGER.

ERR A9:CANNOT REDECLARE MAP
AN ATTEMPT WAS MADE TO DECLARE THE DISK MAP AFTER IT WAS ALREADY DECLARED—THE MAP MUST BE RESET IN ORDER TO REDECLARE.

ERR AA:MEMORY UNAVAILABLE
THE INTELLEC OR DISK MEMORY EXPLICITLY GIVEN IN A SET-MAP COMMAND WAS NEVER DECLARED; OR NO EXPLICIT MEMORY WAS GIVEN AND THERE IS NO MORE INTELLEC, DISK OR ICE MEMORY AVAILABLE FOR THE ICE-88 EMULATOR TO ASSIGN.

ERR AC:TAKES TOO MANY BRS
A MATCH CONDITION WAS GIVEN THAT REQUIRES MORE BREAKPOINT REGISTERS THAN IS ALLOWED IN THE CURRENT CONTEXT; EITHER IT REQUIRED MORE THAN ONE REGISTER IN A SET BREAKPOINT COMMAND, OR REQUIRED MORE THAN TWO REGISTERS IN A TILL CLAUSE.

ERR AD:DIFFERING BASES
TWO POINTERS WITH DIFFERENT BASES WERE USED IN A CONTEXT WHERE THEY MUST HAVE THE SAME BASE; E.G., THE LOWER AND UPPER BOUNDS OF A PARTITION.

ERR AE:INVALID "AND" IN GO-REG
THE GO-REGISTER IS "TILL BR0 AND BR1" DURING A GO COMMAND BUT EITHER (1) BR0 OR BR1 CONTAINS AN EXECUTION-TYPE MATCH CONDITION OR (2) BR0 CONTAINS A DATA-TIME CONDITION AND BR1 CONTAINS AN ADDRESS-TIME CONDITION.

ERR B2:INVALID BASE
THE BASE USED IN THE DISPLAY BREAKPOINT/TRACEPOINT COMMAND IS OUT OF RANGE FOR PART OR ALL OF THE ADDRESSES IN THE REGISTER (E.G., "BR0 BASE 0" WHEN BR0 CONTAINS ADDRESS 10000H).

ERR B3:SYMBOL HAS NO TYPE
A SYMBOL BEING USED IN A TYPED MEMORY REFERENCE (E.G., "!X") HAS NO TYPE.

ERR B5:BLOCK IS EMPTY

WARN C0:UNSATISFIED EXTERNALS
THE PROGRAM JUST LOADED CONTAINS EXTERNALS WHICH WERE NOT SATISFIED AT LINK TIME. THE PROGRAM WAS LOADED CORRECTLY EXCEPT FOR REFERENCES TO THE UNSATISFIED EXTERNALS.

WARN C1:MAPPING OVER SYSTEM
THE USER HAS MODIFIED THE MAP SO THAT PART OF HIS ADDRESS SPACE INCLUDES EITHER THE ISIS SYSTEM OR THE GID SOFTWARE PACKAGE.

WARN C2:HARDWARE MISSING
AT ATTEMPT WAS MADE TO INITIALIZE THE DEVICE WHOSE GENERIC DEVICE CODE NUMBER IS PRINTED ON THE PREVIOUS LINE BUT NO DEVICE RESPONDED. A GENERIC DEVICE CODE IS THE FIRST OF FOUR CONSECUTIVE DEVICE CODES RESERVED FOR A SPECIFIC TYPE OF DEVICE.

WARN C3:MULTIPLE HARDWARE
AN ATTEMPT WAS MADE TO INITIALIZE THE DEVICE WHOSE DEVICE CODE NUMBER IS PRINTED ON THE PREVIOUS LINE BUT MORE THAN ONE DEVICE RESPONDED.

WARN C4:INVALID "AND" IN GR
THE GO-REGISTER IS AS DESCRIBED FOR ERR AE AFTER GR, BR0 OR BR1 WAS CHANGED.

WARN C5:INTELLEC MEM FAILURE
THE INTELLEC MEMORY WHOSE PHYSICAL SEGMENT NUMBER IS ON PREVIOUS LINE DOES NOT VERIFY WHEN WRITTEN TO: IT MAY BE MISSING, NON-WRITABLE, OR BAD MEMORY.

WARN C6:HARDWARE REINITIALIZED
THE HARDWARE HAS BEEN REINITIALIZED, CLEARING THE MAP AND MAKING TRACE UNCONDITIONALLY ON.

WARN C7:CLEARING TFL TO 0

WARN C8:REINITIALIZING—FAULT
THE HARDWARE IS BEING REINITIALIZED

ERR E7:ILLEGAL FILENAME [4]
THE FILENAME SPECIFIED DOES NOT CONFORM TO A WELL-FORMED ISIS FILENAME.

ERR E8:ILLEGAL DEVICE [5]
ILLEGAL OR UNRECOGNIZED DEVICE IN FILENAME.

ERR E9:FILE OPEN FOR INPUT [6]
ATTEMPT TO WRITE TO A FILE OPEN FOR INPUT.

ERR EB:FILE OPEN FOR OUTPUT [8]

ERR EC:DIRECTORY FULL [9]

ERR EE:FILE ALREADY IN USE [11]

ERR EF:FILE ALREADY OPEN [12]
ATTEMPT TO OPEN A FILE THAT WAS ALREADY OPEN.

ERR F0:NO SUCH FILE [13]
THE FILE SPECIFIED DOES NOT EXIST.

ERR F1:WRITE-PROTECT FILE [14]
ATTEMPT TO OPEN A WRITE-PROTECTED FILE FOR THE PURPOSES OF WRITING DATA INTO IT.

ERR F3:CHECKSUM ERROR [16]
A CHECKSUM ERROR IN A HEX OBJECT FILE WAS ENCOUNTERED DURING LOADING.

ERR F6:DISK FILE REQUIRED [19]
ATTEMPT TO USE A NON-DISKETTE FILE WHERE A DISKETTE FILE WAS REQUIRED.

ERR F9:ILLEGAL ACCESS [22]
ATTEMPT TO OPEN A READ-ONLY FILE FOR THE PURPOSES OF STORING DATA (I.E., SPECIFYING :CI: AS THE LIST DEVICE) OR A WRITE-ONLY FILE AS A SOURCE OF DATA (I.E., :LP: IN A LOAD COMMAND).

ERR FA:NO FILE NAME [23]
NO FILENAME SPECIFIED FOR A DISKETTE FILE (I.E., NO FILENAME FOLLOWING :F1:).

ERR FD:"DONE" TIMED OUT
THE DEVICE WHOSE DEVICE CODE NUMBER IS PRINTED ON THE PRECEDING LINE WAS INVOKED BUT FAILED TO RETURN DONE WITHIN FIVE SECONDS.

ERR FE:"ACKNOWLEDGE" TIMED OUT
THE DEVICE WHOSE DEVICE CODE NUMBER IS PRINTED ON THE PRECEDING LINE WAS INVOKED BUT FAILED TO ACKNOWLEDGE WITHIN 5 MILLISECONDS.

ERR FF:NULL FILE EXTENSION [28]
A FILE WAS SPECIFIED SO AS TO CONTAIN AN EXTENSION BUT NO EXTENSION WAS SPECIFIED.

Note 1. If error 35, 4A, or 4B occurs during emulation, hardware will be reset as if a RESET HARDWARE was executed. The emulation will not be recoverable as all registers will be set to the values they contained at the beginning of emulation. Warning message C6 may be issued.

Note 2. Error 49 will cause emulation to exit properly and warning message C6 will be issued.

Note 3. Bracketed number following error message refers to the ISIS error identified by this number.

Note 4. Error messages other than those documented in this list should not occur. If you encounter such an error, please report it to Intel Corporation, MCSD Customer Marketing, 3065 Bowers Avenue, Santa Clara, CA 95051, or to your local Field Application Engineer.

APPENDIX C ICE-88 COMMAND SYNTAX SUMMARY

Command Summary

debug session ≡ [*top-level command* cr] ...

top-level command ≡ *define macro command* :: *remove macro command* :: *command*

command ≡ *compound command* :: *simple command*

compound command ≡ *if command* :: *repeat command* :: *count command* :: *write command*

simple command ≡ *display break/trace command* :: *set break/trace command* ::
go command :: *step command* :: *go-register command* ::
enable/disable trace command :: *trace command* :: *oldest command* ::
newest command :: *print command* :: *move command* :: *clock command* ::
command signal timeout command :: *enable/disable ready command* ::
display command :: *change command* :: *define command* ::
display symbols command :: *display lines command* ::
display modules command :: *change symbol command* ::
remove symbols command :: *set domain command* ::
reset domain command :: *display map command* ::
declare map command :: *set map command* :: *reset map command* ::
load command :: *save command* :: *suffix command* :: *base command* ::
evaluate command :: *list command* :: *exit command* ::
reset hardware command :: *display macro command* ::
put macro command :: *dir command* :: *include command*

Expressions

expr ≡ *boolean term* [*or-op boolean term*] ...

or-op ≡ OR :: XOR

boolean term ≡ *boolean factor* [AND *boolean factor*] ...

boolean factor ≡ [NOT] *boolean primary*

boolean primary ≡ *arith expr* [*rel-op arith expr*]

rel-op ≡ < :: > :: <= :: >= :: <> :: =

arith expr ≡ *memory reference* :: *port name* :: *address*

address ≡ *arith term* [MASK *arith term*] ...

arith term ≡ *term* [*plus-op term*] ...

plus-op ≡ + :: −

term ≡ *factor* [*mult-op factor*] ...

mult-op ≡ * :: / :: MOD

factor ≡ [*plus-op*] [*segment-op*] *primary*

segment-op ≡ *primary* : :: OFFSET :: SEGMENT

primary ≡ (*expr*) :: *numeric constant* :: *source statement number* :: *string* ::
symbolic reference :: *keyword reference*

symbolic reference ≡ [*module name*] *symbol* [*symbol*] ...

module name ≡ ..*identifier*

symbol ≡ .*identifier*

source statement number ≡ [*module name*] # *primary*-10

primary-10 ≡ *primary*

keyword reference ≡ *register name* :: *flag name* :: *pin name* :: *typed memory reference*

partition ≡ *address* [TO *address*] :: *address* LENGTH *address*

Keyword Operators

register name ≡ RAL :: RAH :: RBL :: RBH :: RCL :: RCH :: RDL :: RDH :: RAX :: RBX :: RCX :: RDX :: SP :: BP :: SI :: DI :: SS :: DS :: ES :: IP :: CAUSE :: OPCODE :: RF :: PIP :: TIMER :: HTIMER :: BUFFERSIZE:UPPER:LOWER

flag name ≡ AFL :: CFL :: DFL :: IFL :: OFL :: PFL :: SFL :: TFL :: ZFL

pin name ≡ RDY :: NMI :: TEST :: HOLD :: RST :: MN :: IR

port name ≡ PORT *address* :: WPORT *address*

memory reference ≡ *memory-designation address*

memory-designation ≡ BYTE :: WORD :: SINTEGER :: INTEGER :: POINTER

typed memory reference ≡ [!! *identifier*] ! *identifier* [! *identifier*] ...

Emulation Controls and Commands

display break/trace command ≡ *break/trace reg* [*display break/trace mode*]

set break/trace command ≡ *break/trace reg* = *match-cond*

break/trace reg ≡ *break reg* :: *trace reg*

break reg ≡ BR :: BR0 :: BR1

trace reg ≡ ONTRACE :: OFFTRACE

display break/trace mode ≡ ABSOLUTE :: BASE [*expr*]

match-cond ≡ *execution match code* :: *non-execution match cond*

execution match cond ≡ *match value* EXECUTED

non-execution match cond ≡ *address match range* [*match status list*] [*data match range*]
[*segment register usage*] :: *match status list* [*data match range*]
[*segment register usage*] :: *data match range*
[*segment register usage*] :: *segment register usage*

match value ≡ *address* :: *masked constant*

address match range ≡ *match range*

data match range ≡ VALUE *match range*

match range ≡ *match value* :: *match partition* [, *match partition*] ... :: *address up/down*

match partition ≡ *partition* :: OBJECT *memory reference* :: OBJECT *typed memory reference*

up/down ≡ UP :: DOWN

match status list ≡ *match status* [, *match status*] ...

match status ≡ READ :: WRITTEN :: INPUT :: OUTPUT :: FETCHED :: HALT :: ACKNOWLEDGE

segment register usage ≡ USING *segment register name*

segment register name ≡ SS :: CS :: DS :: ES

go command ≡ GO [FROM *address*] [go-register]

step command ≡ STEP [FROM *address*]

go-register command ≡ GR [= *go-register*] *go-register* ≡ FOREVER :: TILL *break*

break ≡ *break reg* [*and/or break reg*] :: *match-cond* [*and/or match-cond*]

and/or ≡ AND :: OR

enable/disable trace command ≡ ENABLE TRACE [CONDITIONALLY [NOW *initial trace*]] ::
DISABLE TRACE

initial trace ≡ ON :: OFF

trace command ≡ TRACE [= *trace mode*]

trace mode ≡ FRAME :: INSTRUCTION

oldest command ≡ OLDEST

newest command ≡ NEWEST

print command ≡ PRINT [[*plus-op*] *primary-10*] :: PRINT ALL

move command ≡ MOVE [[*plus-op*] *primary-10*]

clock command ≡ CLOCK [= *clock setting*]

clock setting ≡ INTERNAL :: EXTERNAL

command signal timeout command ≡ RWTIMEOUT [= *new signal*]

new signal ≡ INFINITE :: *expr*-10 [ERROR] :: *expr*-10 NOERROR

expr-10 ≡ *expr*

enable/disable ready command ≡ ENABLE RDY :: DISABLE RDY

Interrogation and Utility Commands

display command ≡ *reference* [, *reference*] ... :: *mem or i/o partition* :: ASM partition ::
REGISTER :: FLAG :: PIN :: STACK *expr* :: BOOL *expr*

mem or i/o ≡ *memory-designaltion* :: PORT :: WPORT

change command ≡ *reference* = *expr* :: *mem or i/o partition* = *change exp* [, *change exp*] ...

change exp ≡ *mem or i/o partition* :: *expr* :: *string*

define command ≡ DEFINE [*module name*] *symbol* = *expr* [OF *type*]

display symbols command ≡ SYMBOL :: *symbolic reference*

display lines command ≡ LINE :: *source statement number*

display modules command ≡ MODULE

change symbol command ≡ *symbolic reference* = *expr* [OF *type*]

remove symbols command ≡ REMOVE *symbolic reference* [, *symbolic reference*] ... ::
REMOVE SYMBOL ::
REMOVE MODULE *module name* [, *module name*] ...

type ≡ *memory desig*

set domain command ≡ DOMAIN *module name*

reset domain command ≡ RESET DOMAIN

display map command ≡ MAP [*partition*]

declare map command ≡ MAP DISK = *file name* :: MAP INTELLEC = *partition* [, *partition*]...

set map command ≡ MAP *partition* = *new memory map*

reset map command ≡ RESET MAP

new memory map ≡ GUARDED :: USER [NOVERIFY] :: ICE [*address*] [NOVERIFY] ::
INTELLEC [*address*] [NOVERIFY] :: DISK [*address*] [NOVERIFY]

load command ≡ LOAD *path name* $\left\{\begin{array}{l}\text{NOCODE}\\ \text{NOSYMBOL}\\ \text{NOLINE}\end{array}\right\}$

save command ≡ SAVE *path name* $\left\{\begin{array}{l}\textit{save code}\\ \text{NOSYMBOL}\\ \text{NOLINE}\end{array}\right\}$

save code ≡ NOCODE :: *parition* [, *partition*] ...

suffix command ≡ SUFFIX [= *suffix*]

base command ≡ BASE [= *base*]

suffix ≡ Y :: O :: Q :: T :: H

base ≡ *suffix* :: ASCII

display nesting command ≡ NESTING

evaluate command ≡ EVALUATE *expr* [SYMBOLICALLY]

list command ≡ LIST *path name*

exit command ≡ EXIT

reset hardware command ≡ RESET HARDWARE

cr ≡ *carriage-return line-feed*

Macro Definition Command

define macro command ≡ DEFINE MACRO *macro name cr macro body* EM

macro name ≡ *identifier*

macro body ≡ [*command cr*] ...

IF Command

if command ≡ IF *expr* [THEN] *cr true-list*
[ORIF *expr* [THEN] *cr true-list*] ...
[ELSE *cr false-list*]

true-list ≡ [*command cr*] ...

false-list ≡ [*command cr*] ...

end if ≡ END

Looping Commands

repeat command ≡ REPEAT *cr loop-list end-repeat*

end-repeat ≡ END

count command ≡ COUNT *expr*-10 *cr loop-list end-count*

expr-10 ≡ *expr*

end-count ≡ END

loop-list ≡ [*loop element cr*] ...

loop element ≡ *command* :: *loop exit*

loop exit ≡ WHILE *EXPR* :: UNTIL *expr*

Macro Invocation Command

macro invocation command ≡ *macro name* :: [*actual parameter list*]

actual parameter list ≡ *actual parameter* [, *actual parameter*] ...

actual parameter ≡ [*limited token*] ... :: *string*

limited token ≡ any token except *cr, string* or ","

Remove Macro Command

remove macro command ≡ REMOVE MACRO [*macro list*]

macro list ≡ *macro name* [, *macro name*] ...

Display Macro Command

display macro command ≡ MACRO [*macro list*]

Put Macro Command

put macro command ≡ PUT *file name* MACRO [*macro list*]

Director Command

dir command ≡ DIR *directory*

directory ≡ MACRO

Include Command

include command ≡ INCLUDE *file name*

Write Command

write command ≡ WRITE *list element* [, *list element*] ...

list element ≡ *string* :: *expr* :: BOOL *expr*

APPENDIX D ELECTRICAL AND PHYSICAL CHARACTERISTICS

DC Characteristics of ICE-88 User Cable

1. Output Low Voltages	V_{OL}(Max)	I_{OL}(Min)
AD0-AD7, A8-A15	0.4V	8 mA
A16/S3-A19/S6, $\overline{SSO}$, $\overline{RD}$, $\overline{LOCK}$, QS0, QS1, $\overline{S0}$, $\overline{S1}$, $\overline{S2}$, $\overline{WR}$, IO/$\overline{M}$, DT/$\overline{R}$, $\overline{DEN}$, ALE, $\overline{INTA}$	0.4V	8 mA
HLDA	0.4V	7 mA
$\overline{MATCH0}$	0.4V	16 mA

2. Output High Voltages	V_{OH}(Min)	I_{OH}(Min)
AD0-AD7, A8-A15	2.4V	− 2 mA
A16/S3-A19/S6, $\overline{SSO}$, $\overline{RD}$, $\overline{LOCK}$, QS0, QS1, $\overline{S0}$, $\overline{S1}$, $\overline{S2}$, $\overline{WR}$, IO/$\overline{M}$, DT/$\overline{R}$, $\overline{DEN}$, ALE, $\overline{INTA}$	2.4V	−2 mA
HLDA	2.4V	−3.0 mA
$\overline{MATCH0}$ OR $\overline{MATCH1}$	2.4V	−0.8 mA

3. Input Low Voltages	V_{IL}(Max)	I_{IL}(Max)
AD0-AD7, A8-A15	0.8V	−0.2 mA
NMI, CLK	0.8V	−0.4 mA
READY	0.8V	−0.8 mA
INTR, HOLD, $\overline{TEST}$, RESET	0.8V	−1.4 mA
MN/$\overline{MX}$ (0.1 μf to GND)	0.8V	−3.3 mA

4. Input High Voltages	V_{IH}(Min)	I_{IH}(Max)
AD0-AD7, A8-A15	2.0V	80 μA
NMI, CLK	2.0V	20 μA
READY	2.0V	60 μA
INTR, HOLD, TEST, RESET	2.0V	−0.4 mA
MN/$\overline{MX}$	2.0V	−1.1 mA

5. **$\overline{RQ}/\overline{GT0}$, $\overline{RQ}/\overline{GT1}$ are pulled up to +5V through a 5.6K ohm resistor. No current is taken from user circuit at V_{CC} pin.**

Specifications

ICE-88 Operating Environment

Required Hardware:

Intellec Microcomputer Development System with:

1. Three adjacent slots for ICE-88
2. 64K of Intellec Memory. If expansion memory is desired, no more than 32K may be 16K RAM boards.

System Console
Intellec Diskette Operating System
ICE-88 Module

Required Software:

System Monitor
ISIS-II, Version 3.4 or subsequent
ICE-88 Software

Equipment Supplied

Printed Circuit Boards (3)
Interface Cable and Emulation Buffer Module
Operator's Manual
ICE-88 Software

Emulation Clock

User system clock up to 5 MHz or 2 MHz internal clock in stand-along mode.

Physical Characteristics

Printed Circuit Boards:

Width	12.00 in	(30.48 cm)
Height	6.75 in	(17.15 cm)
Depth	0.50 in	(1.27 cm)
Packaged Weight	—	—

Electrical Characteristics

V_{CC}	= +5V ±1%
I_{CC}	= 16A maximum; 11A typical
V_{DD}	= +12V ±5%
I_{DD}	= 120 mA maximum; 80 mA typical
V_{BB}	= −10V ±5% or −12V ± 5% (optional)
I_{BB}	= 15 mA maximum; 12 mA typical

Environmental Characteristics

Operating Temperature: 0° to 40°C
Operating Humidity: Up to 95% relative humidity without condensation.

APPENDIX E INSTRUCTIONS IN HEXADECIMAL ORDER

00	00000000	MOD REGR/M	ADD	EA,REG	BYTE ADD (REG) TO EA
01	00000001	MOD REGR/M	ADD	EA,REG	WORD ADD (REG) TO EA
02	00000010	MOD REGR/M	ADD	REG,EA	BYTE ADD (EA) TO REG
03	00000011	MOD REGR/M	ADD	REG,EA	WORD ADD (EA) TO REG
04	00000100		ADD	AL,DATA8	BYTE ADD DATA TO REG AL
05	00000101		ADD	AX,DATA16	WORD ADD DATA TO REG AX
06	00000110		PUSH	ES	PUSH (ES) ON STACK
07	00000111		POP	ES	POP STACK TO REG ES
08	00001000	MOD REGR/M	OR	EA,REG	BYTE OR (REG) TO EA
09	00001001	MOD REGR/M	OR	EA,REG	WORD OR (REG) TO EA
0A	00001010	MOD REGR/M	OR	REG,EA	BYTE OR (EA) TO REG
0B	00001011	MOD REGR/M	OR	REG,EA	WORD OR (EA) TO REG
0C	00001100		OR	AL,DATA8	BYTE OR DATA TO REG AL
0D	00001101		OR	AX,DATA16	WORD OR DATA TO REG AX
0E	00001110		PUSH	CS	PUSH (CS) ON STACK
0F	00001111		(not used)		
10	00010000	MOD REGR/M	ADC	EA,REG	BYTE ADD (REG) W/ CARRY TO EA
11	00010001	MOD REGR/M	ADC	EA,REG	WORD ADD (REG) W/ CARRY TO EA
12	00010010	MOD REGR/M	ADC	REA,EA	BYTE ADD (EA) W/ CARRY TO REG
13	00010011	MOD REGR/M	ADC	REG,EA	WORD ADD (EA) W/ CARRY TO REG
14	00010100		ADC	AL,DATA8	BYTE ADD DATA W/CARRY TO REG AL
15	00010101		ADC	AX,DATA16	WORD ADD DATA W/ CARRY TO REG AX
16	00010110		PUSH	SS	PUSH (SS) ON STACK
17	00010111		POP	SS	POP STACK TO REG SS
18	00011000	MOD REGR/M	SBB	EA,REG	BYTE SUB (REG) W/ BORROW FROM EA
19	00011001	MOD REGR/M	SBB	EA,REG	WORD SUB (REG) W/ BORROW FROM EA
1A	00011010	MOD REGR/M	SBB	REG,EA	BYTE SUB (EA) W/ BORROW FROM REG
1B	00011011	MOD REGR/M	SBB	REG,EA	WORD SUB (EA) W/ BORROW FROM REG
1C	00011100		SBB	AL,DATA8	BYTE SUB DATA W/ BORROW FROM REG AL
1D	00011101		SBB	AX,DATA16	WORD SUB DATA W/ BORROW FROM REG AX
1E	00011110		PUSH	DS	PUSH (DS) ON STACK
1F	00011111		POP	DS	POP STACK TO REG DS
20	00100000	MOD REGR/M	AND	EA,REG	BYTE AND (REG) TO EA
21	00100001	MOD REGR/M	AND	EA,REG	WORD AND (REG) TO EA
22	00100010	MOD REGR/M	AND	REG,EA	BYTE AND (EA) TO REG
23	00100011	MOD REGR/M	AND	REG,EA	WORD AND (EA) TO REG
24	00100100		AND	AL,DATA8	BYTE AND DATA TO REG AL
25	00100101		AND	AX,DATA16	WORD AND DATA TO REG AX
26	00100110		ES:		SEGMENT OVERIDE W/ SEGMENT REG ES
27	00100111		DAA		DECIMAL ADJUST FOR ADD
28	00101000	MOD REGR/M	SUB	EA,REG	BYTE SUBTRACT (REG) FROM EA
29	00101001	MOD REGR/M	SUB	EA,REG	WORD SUBTRACT (REG) FROM EA
2A	00101010	MOD REGR/M	SUB	REG,EA	BYTE SUBTRACT (EA) FROM REG
2B	00101011	MOD REGR/M	SUB	REG,EA	WORD SUBTRACT (EA) FROM REG
2C	00101100		SUB	AL,DATA8	BYTE SUBTRACT DATA FROM REG AL
2D	00101101		SUB	AX,DATA16	WORD SUBTRACT DATA FROM REG AX
2E	00101110		CS:		SEGMENT OVERIDE W/ SEGMENT REG CS
2F	00101111		DAS		DECIMAL ADJUST FOR SUBTRACT
30	00110000	MOD REGR/M	XOR	EA,REG	BYTE XOR (REG) TO EA
31	00110001	MOD REGR/M	XOR	EA,REG	WORD XOR (REG) TO EA
32	00110010	MOD REGR/M	XOR	REG,EA	BYTE XOR (EA) TO REG
33	00110011	MOD REGR/M	XOR	REG,EA	WORD XOR (EA) TO REG
34	00110100		XOR	AL,DATA8	BYTE XOR DATA TO REG AL
35	00110101		XOR	AX,DATA16	WORD XOR DATA TO REG AX
36	00110110		SS:		SEGMENT OVERIDE W/ SEGMENT REG SS
37	00110111		AAA		ASCII ADJUST FOR ADD
38	00111000	MOD REGR/M	CMP	EA,REG	BYTE COMPARE (EA) WITH (REG)
39	00111001	MOD REGR/M	CMP	EA,REG	WORD COMPARE (EA) WITH (REG)
3A	00111010	MOD REGR/M	CMP	REG,EA	BYTE COMPARE (REG) WITH (EA)
3B	00111011	MOD REGR/M	CMP	REG,EA	WORD COMPARE (REG) WITH (EA)
3C	00111100		CMP	AL,DATA8	BYTE COMPARE DATA WITH (AL)
3D	00111101		CMP	AX,DATA16	WORD COMPARE DATA WITH (AX)
3E	00111110		DS:		SEGMENT OVERIDE W/ SEGMENT REG DS
3F	00111111		AAS		ASCII ADJUST FOR SUBTRACT
40	01000000		INC	AX	INCREMENT (AX)
41	01000001		INC	CX	INCREMENT (CX)

42	01000010				INC	DX	INCREMENT (DX)
43	01000011				INC	BX	INCREMENT (BX)
44	01000100				INC	SP	INCREMENT (SP)
45	01000101				INC	BP	INCREMENT (BP)
46	01000110				INC	SI	INCREMENT (SI)
47	01000111				INC	DI	INCREMENT (DI)
48	01001000				DEC	AX	DECREMENT (AX)
49	01001001				DEC	CX	DECREMENT (CX)
4A	01001010				DEC	DX	DECREMENT (DX)
4B	01001011				DEC	BX	DECREMENT (BX)
4C	01001100				DEC	SP	DECREMENT (SP)
4D	01001101				DEC	BP	DECREMENT (BP)
4E	01001110				DEC	SI	DECREMENT (SI)
4F	01001111				DEC	DI	DECREMENT (DI)
50	01010000				PUSH	AX	PUSH (AX) ON STACK
51	01010001				PUSH	CX	PUSH (CX) ON STACK
52	01010010				PUSH	DX	PUSH (DX) ON STACK
53	01010011				PUSH	BX	PUSH (BX) ON STACK
54	01010100				PUSH	SP	PUSH (SP) ON STACK
55	01010101				PUSH	BP	PUSH (BP) ON STACK
56	01010110				PUSH	SI	PUSH (SI) ON STACK
57	01010111				PUSH	DI	PUSH (DI) ON STACK
58	01011000				POP	AX	POP STACK TO REG AX
59	01011001				POP	CX	POP STACK TO REG CX
5A	01011010				POP	DX	POP STACK TO REG DX
5B	01011011				POP	BX	POP STACK TO REG BX
5C	01011100				POP	SP	POP STACK TO REG SP
5D	01011101				POP	BP	POP STACK TO REG BP
5E	01011110				POP	SI	POP STACK TO REG SI
5F	01011111				POP	DI	POP STACK TO REG DI
60	01100000				(not used)		
61	01100001				(not used)		
62	01100010				(not used)		
63	01100011				(not used)		
64	01100100				(not used)		
65	01100101				(not used)		
66	01100110				(not used)		
67	01100111				(not used)		
68	01101000				(not used)		
69	01101001				(not used)		
6A	01101010				(not used)		
6B	01101011				(not used)		
6C	01101100				(not used)		
6D	01101101				(not used)		
6E	01101110				(not used)		
6F	01101111				(not used)		
70	01110000				JO	DISP8	JUMP ON OVERFLOW
71	01110001				JNO	DISP8	JUMP ON NOT OVERFLOW
72	01110010				JB/JNAE	DISP8	JUMP ON BELOW/NOT ABOVE OR EQUAL
73	01110011				JNB/JAE	DISP8	JUMP ON NOT BELOW/ABOVE OR EQUAL
74	01110100				JE/JZ	DISP8	JUMP ON EQUAL/ZERO
75	01110101				JNE/JNZ	DISP8	JUMP ON NOT EQUAL/NOT ZERO
76	01110110				JBE/JNA	DISP8	JUMP ON BELOW OR EQUAL/NOT ABOVE
77	01110111				JNBE/JA	DISP8	JUMP ON NOT BELOW OR EQUAL/ABOVE
78	01111000				JS	DISP8	JUMP ON SIGN
79	01111001				JNS	DISP8	JUMP ON NOT SIGN
7A	01111010				JP/JPE	DISP8	JUMP ON PARITY/PARITY EVEN
7B	01111011				JNP/JPO	DISP8	JUMP ON NOT PARITY/PARITY ODD
7C	01111100				JL/JNGE	DISP8	JUMP ON LESS/NOT GREATER OR EQUAL
7D	01111101				JNL/JGE	DISP8	JUMP ON NOT LESS/GREATER OR EQUAL
7E	01111110				JLE/JNG	DISP8	JUMP ON LESS OR EQUAL/NOT GREATER
7F	01111111				JNLE/JG	DISP8	JUMP ON NOT LESS OR EQUAL/GREATER
80	10000000	MOD	000	R/M	ADD	EA,DATA8	BYTE ADD DATA TO EA
80	10000000	MOD	001	R/M	OR	EA,DATA8	BYTE OR DATA TO EA
80	10000000	MOD	010	R/M	ADC	EA,DATA8	BYTE ADD DATA W/ CARRY TO EA
80	10000000	MOD	011	R/M	SBB	EA,DATA8	BYTE SUB DATA W/ BORROW FROM EA
80	10000000	MOD	100	R/M	AND	EA,DATA8	BYTE AND DATA TO EA
80	10000000	MOD	101	R/M	SUB	EA,DATA8	BYTE SUBTRACT DATA FROM EA
80	10000000	MOD	110	R/M	XOR	EA,DATA8	BYTE XOR DATA TO EA
80	10000000	MOD	111	R/M	CMP	EA,DATA8	BYTE COMPARE DATA WITH (EA)
81	10000001	MOD	000	R/M	ADD	EA,DATA16	WORD ADD DATA TO EA
81	10000001	MOD	001	R/M	OR	EA,DATA16	WORD OR DATA TO EA
81	10000001	MOD	010	R/M	ADC	EA,DATA16	WORD ADD DATA W/ CARRY TO EA

81	10000001	MOD	011	R/M	SBB	EA,DATA16	WORD SUB DATA W/ BORROW FROM EA
85	10000001	MOD	100	R/M	AND	EA,DATA16	WORD AND DATA TO EA
81	10000001	MOD	101	R/M	SUB	EA,DATA16	WORD SUBTRACT DATA FROM EA
81	10000001	MOD	110	R/M	XOR	EA,DATA16	WORD XOR DATA TO EA
81	10000001	MOD	111	R/M	CMP	EA,DATA16	WORD COMPARE DATA WITH (EA)
82	10000010	MOD	000	R/M	ADD	EA,DATA8	BYTE ADD DATA TO EA
82	10000010	MOD	001	R/M	(not used)		
82	10000010	MOD	010	R/M	ADC	EA,DATA8	BYTE ADD DATA W/ CARRY TO EA
82	10000010	MOD	011	R/M	SBB	EA,DATA8	BYTE SUB DATA W/ BORROW FROM EA
82	10000010	MOD	100	R/M	(not used)		
82	10000010	MOD	101	R/M	SUB	EA,DATA8	BYTE SUBTRACT DATA FROM EA
82	10000010	MOD	110	R/M	(not used)		
82	10000010	MOD	111	R/M	CMP	EA,DATA8	BYTE COMPARE DATA WITH (EA)
83	10000011	MOD	000	R/M	ADD	EA,DATA8	WORD ADD DATA TO EA
83	10000011	MOD	001	R/M	(not used)		
83	10000011	MOD	010	R/M	ADC	EA,DATA8	WORD ADD DATA W/ CARRY TO EA
83	10000011	MOD	011	R/M	SBB	EA,DATA8	WORD SUB DATA W/ BORROW FROM EA
83	10000011	MOD	100	R/M	(not used)		
83	10000011	MOD	101	R/M	SUB	EA,DATA8	WORD SUBTRACT DATA FROM EA
83	10000011	MOD	110	R/M	(not used)		
83	10000011	MOD	111	R/M	CMP	EA,DATA8	WORD COMPARE DATA WITH (EA)
84	10000100	MOD	REG	R/M	TEST	EA,REG	BYTE TEST (EA) WITH (REG)
85	10000101	MOD	REG	R/M	TEST	EA,REG	WORD TEST (EA) WITH (REG)
86	10000110	MOD	REG	R/M	XCHG	REG,EA	BYTE EXCHANGE (REG) WITH (EA)
87	10000111	MOD	REG	R/M	XCHG	REG,EA	WORD EXCHANGE (REG) WITH (EA)
88	10001000	MOD	REG	R/M	MOV	EA,REG	BYTE MOVE (REG) TO EA
89	10001001	MOD	REG	R/M	MOV	EA,REG	WORD MOVE (REG) TO EA
8A	10001010	MOD	REG	R/M	MOV	REG,EA	BYTE MOVE (EA) TO REG
8B	10001011	MOD	REG	R/M	MOV	REG,EA	WORD MOVE (EA) TO REG
8C	10001100	MOD	0SR	R/M	MOV	EA,SR	WORD MOVE (SEGMENT REG SR) TO EA
8C	10001100	MOD	1--	R/M	(not used)		
8D	10001101	MOD	REG	R/M	LEA	REG,EA	LOAD EFFECTIVE ADDRESS OF EA TO REG
8E	10001110	MOD	0SR	R/M	MOV	SR,EA	WORD MOVE (EA) TO SEGMENT REG SR
8E	10001110	MOD	--	R/M	(not used)		
8F	10001111	MOD	000	R/M	POP	EA	POP STACK TO EA
8F	10001111	MOD	001	R/M	(not used)		
8F	10001111	MOD	010	R/M	(not used)		
8F	10001111	MOD	011	R/M	(not used)		
8F	10001111	MOD	100	R/M	(not used)		
8F	10001111	MOD	101	R/M	(not used)		
8F	10001111	MOD	110	R/M	(not used)		
8F	10001111	MOD	111	R/M	(not used)		
90	10010000				XCHG	AX,AX	EXCHANGE (AX) WITH (AX), (NOP)
91	10010001				XCHG	AX,CX	EXCHANGE (AX) WITH (CX)
92	10010010				XCHG	AX,DX	EXCHANGE (AX) WITH (DX)
93	10010011				XCHG	AX,BX	EXCHANGE (AX) WITH (BX)
94	10010100				XCHG	AX,SP	EXCHANGE (AX) WITH (SP)
95	10010101				XCHG	AX,BP	EXCHANGE (AX) WITH (BP)
96	10010110				XCHG	AX,SI	EXCHANGE (AX) WITH (SI)
97	10010111				XCHG	AX,DI	EXCHANGE (AX) WITH (DI)
98	10011000				CBW		BYTE CONVERT (AL) TO WORD (AX)
99	10011001				CWD		WORD CONVERT (AX) TO DOUBLE WORD
9A	10011010				CALL	DISP16,SEG16	DIRECT INTER SEGMENT CALL
9B	10011011				WAIT		WAIT FOR TEST SIGNAL
9C	10011100				PUSHF		PUSH FLAGS ON STACK
9D	10011101				POPF		POP STACK TO FLAGS
9E	10011110				SAHF		STORE (AH) INTO FLAGS
9F	10011111				LAHF		LOAD REG AH WITH FLAGS
A0	10100000				MOV	AL,ADDR16	BYTE MOVE (ADDR) TO REG AL
A1	10100001				MOV	AX,ADDR16	WORD MOVE (ADDR) TO REG AX
A2	10100010				MOV	ADDR16,AL	BYTE MOVE (AL) TO ADDR
A3	10100011				MOV	ADDR16,AX	WORD MOVE (AX) TO ADDR
A4	10100100				MOVS	DST8SRC8	BYTE MOVE, STRING OP
A5	10100101				MOVS	DST16,SRC16	WORD MOVE, STRING OP
A6	10100110				CMPS	SIPTR,DIPTR	COMPARE BYTE, STRING OP
A7	10100111				CMPS	SIPTR,DIPTR	COMPARE WORD, STRING OP
A8	10101000				TEST	AL,DATA8	BYTE TEST (AL) WITH DATA
A9	10101001				TEST	AX,DATA16	WORD TEST (AX) WITH DATA
AA	10101010				STOS	DST8	BYTE STORE, STRING OP
AB	10101011				STOS	DST16	WORD STORE, STRING OP
AC	10101100				LODS	SRC8	BYTE LOAD, STRING OP
AD	10101101				LODS	SRC16	WORD LOAD, STRING OP
AE	10101110				SCAS	DIPTR8	BYTE SCAN, STRING OP

AF 10101111		SCAS	DIPTR16	WORD SCAN, STRING OP
B0 10110000		MOV	AL,DATA8	BYTE MOVE DATA TO REG AL
B1 10110001		MOV	CL,DATA8	BYTE MOVE DATA TO REG CL
B2 10110010		MOV	DL,DATA8	BYTE MOVE DATA TO REG DL
B3 10110011		MOV	BL,DATA8	BYTE MOVE DATA TO REG BL
B4 10110100		MOV	AH,DATA8	BYTE MOVE DATA TO REG AH
B5 10110101		MOV	CH,DATA8	BYTE MOVE DATA TO REG CH
B6 10110110		MOV	DH,DATA8	BYTE MOVE DATA TO REG DH
B7 10110111		MOV	BH,DATA8	BYTE MOVE DATA TO REG BH
B8 10111000		MOV	AX,DATA16	WORD MOVE DATA TO REG AX
B9 10111001		MOV	CX,DATA16	WORD MOVE DATA TO REG CX
BA 10111010		MOV	DX,DATA16	WORD MOVE DATA TO REG DX
BB 10111011		MOV	BX,DATA16	WORD MOVE DATA TO REG BX
BC 10111100		MOV	SP,DATA16	WORD MOVE DATA TO REG SP
BD 10111101		MOV	BP,DATA16	WORD MOVE DATA TO REG BP
BE 10111110		MOV	SI,DATA16	WORD MOVE DATA TO REG SI
BF 10111111		MOV	DI,DATA16	WORD MOVE DATA TO REG DI
C0 11000000		(not used)		
C1 11000001		(not used)		
C2 11000010		RET	DATA16	INTRA SEGMENT RETURN, ADD DATA TO REG SP
C3 11000011		RET		INTRA SEGMENT RETURN
C4 11000100	MOD REGR/M	LES	REG,EA	WORD LOAD REG AND SEGMENT REG ES
C5 11000101	MOD REGR/M	LDS	REG,EA	WORD LOAD REG AND SEGMENT REG DS
C6 11000110	MOD 000 R/M	MOV	EA,DATA8	BYTE MOVE DATA TO EA
C6 11000110	MOD 001 R/M	(not used)		
C6 11000110	MOD 010 R/M	(not used)		
C6 11000110	MOD 011 R/M	(not used)		
C6 11000110	MOD 100 R/M	(not used)		
C6 11000110	MOD 101 R/M	(not used)		
C6 11000110	MOD 110 R/M	(not used)		
C6 11000110	MOD 111 R/M	(not used)		
C7 11000111	MOD 000 R/M	MOV	EA,DATA16	WORD MOVE DATA TO EA
C7 11000111	MOD 001 R/M	(not used)		
C7 11000111	MOD 010 R/M	(not used)		
C7 11000111	MOD 011 R/M	(not used)		
C7 11000111	MOD 100 R/M	(not used)		
C7 11000111	MOD 101 R/M	(not used)		
C7 11000111	MOD 110 R/M	(not used)		
C7 11000111	MOD 111 R/M	(not used)		
C8 11001000		(not used)		
C9 11001001		(not used)		
CA 11001010		RET	DATA16	INTER SEGMENT RETURN, ADD DATA TO REG SP
CB 11001011		RET		INTER SEGMENT RETURN
CC 11001100		INT	3	TYPE 3 INTERRUPT
CD 11001101		INT	TYPE	TYPED INTERRUPT
CE 11001110		INTO		INTERRUPT ON OVERFLOW
CF 11001111		IRET		RETURN FROM INTERRUPT
D0 11010000	MOD 000 R/M	ROL	EA,1	BYTE ROTATE EA LEFT 1 BIT
D0 11010000	MOD 001 R/M	ROR	EA,1	BYTE ROTATE EA RIGHT 1 BIT
D0 11010000	MOD 010 R/M	RCL	EA,1	BYTE ROTATE EA LEFT THRU CARRY 1 BIT
D0 11010000	MOD 011 R/M	RCR	EA,1	BYTE ROTATE EA RIGHT THRU CARRY 1 BIT
D0 11010000	MOD 100 R/M	SHL	EA,1	BYTE SHIFT EA LEFT 1 BIT
D0 11010000	MOD 101 R/M	SHR	EA,1	BYTE SHIFT EA RIGHT 1 BIT
D0 11010000	MOD 110 R/M	(not used)		
D0 11010000	MOD 111 R/M	SAR	EA,1	BYTE SHIFT SIGNED EA RIGHT 1 BIT
D1 11010001	MOD 000 R/M	ROL	EA,1	WORD ROTATE EA LEFT 1 BIT
D1 11010001	MOD 001 R/M	ROR	EA,1	WORD ROTATE EA RIGHT 1 BIT
D1 11010001	MOD 010 R/M	RCL	EA,1	WORD ROTATE EA LEFT THRU CARRY 1 BIT
D1 11010001	MOD 011 R/M	RCR	EA,1	WORD ROTATE EA RIGHT THRU CARRY 1 BIT
D1 11010001	MOD 100 R/M	SHL	EA,1	WORD SHIFT EA LEFT 1 BIT
D1 11010001	MOD 101 R/M	SHR	EA,1	WORD SHIFT EA RIGHT 1 BIT
D1 11010001	MOD 110 R/M	(not used)		
D1 11010001	MOD 111 R/M	SAR	EA,1	WORD SHIFT SIGNED EA RIGHT 1 BIT
D2 11010010	MOD 000 R/M	ROL	EA,CL	BYTE ROTATE EA LEFT (CL) BITS
D2 11010010	MOD 001 R/M	ROR	EA,CL	BYTE ROTATE EA RIGHT (CL) BITS
D2 11010010	MOD 010 R/M	RCL	EA,CL	BYTE ROTATE EA LEFT THRU CARRY (CL) BITS
D2 11010010	MOD 011 R/M	RCR	EA,CL	BYTE ROTATE EA RIGHT THRU CARRY (CL) BITS
D2 11010010	MOD 100 R/M	SHL	EA,CL	BYTE SHIFT EA LEFT (CL) BITS
D2 11010010	MOD 101 R/M	SHR	EA,CL	BYTE SHIFT EA RIGHT (CL) BITS
D2 11010010	MOD 110 R/M	(not used)		
D2 11010010	MOD 111 R/M	SAR	EA,CL	BYTE SHIFT SIGNED EA RIGHT (CL) BITS
D3 11010011	MOD 000 R/M	ROL	EA,CL	WORD ROTATE EA LEFT (CL) BITS
D3 11010011	MOD 001 R/M	ROR	EA,CL	WORD ROTATE EA RIGHT (CL) BITS

D3 11010011	MOD 010 R/M	RCL	EA,CL	WORD ROTATE EA LEFT THRU CARRY (CL) BITS
D3 11010011	MOD 011 R/M	RCR	EA,CL	WORD ROTATE EA RIGHT THRU CARRY (CL) BITS
D3 11010011	MOD 100 R/M	SHL	EA,CL	WORD SHIFT EA LEFT (CL) BITS
D3 11010011	MOD 101 R/M	SHR	EA,CL	WORD SHIFT EA RIGHT (CL) BITS
D3 11010011	MOD 110 R/M	(not used)		
D3 11010011	MOD 111 R/M	SAR	EA,CL	WORD SHIFT SIGNED EA RIGHT (CL) BITS
D4 11010100	00001010	AAM		ASCII ADJUST FOR MULTIPLY
D5 11010101	00001010	ADD		ASCII ADJUST FOR DIVIDE
D6 11010110		(not used)		
D7 11010111		XLAT	TABLE	TRANSLATE USING (BX)
D8 11011---	MOD --- R/M	ESC	EA	ESCAPE TO EXTERNAL DEVICE
E0 11100000		LOOPNZ/LOOPNE	DISP8	LOOP (CX) TIMES WHILE NOT ZERO/NOT EQUAL
E1 11100001		LOOPZ/LOOPE	DISP8	LOOP (CX) TIMES WHILE ZERO/EQUAL
E2 11100010		LOOP	DISP8	LOOP (CX) TIMES
E3 11100011		JCXZ	DISP8	JUMP ON (CX)=0
E4 11100100		IN	AL,PORT	BYTE INPUT FROM PORT TO REG AL
E5 11100101		IN	AX,PORT	WORD INPUT FROM PORT TO REG AX
E6 11100110		OUT	AL,PORT	BYTE OUTPUT (AL) TO PORT
E7 11100111		OUT	AX,PORT	WORD OUTPUT (AX) TO PORT
E8 11101000		CALL	DISP16	DIRECT INTRA SEGMENT CALL
E9 11101001		JMP	DISP16	DIRECT INTRA SEGMENT JUMP
EA 11101010		JMP	DISP16,SEG16	DIRECT INTER SEGMENT JUMP
EB 11101010		JMP	DISP8	DIRECT INTRA SEGMENT JUMP
EC 11101010		IN	AL,DX	BYTE INPUT FROM PORT (DX) TO REG AL
ED 11101010		IN	AX,DX	WORD INPUT FROM PORT (DX) TO REG AX
EE 11101010		OUT	DX	BYTE OUTPUT (AL) TO PORT (DX)
EF 11101010		OUT	DX	WORD OUTPUT (AX) TO PORT (DX)
F0 11110000		LOCK		BUS LOCK PREFIX
F1 11110001		(not used)		
F2 11110010		REPNZ		REPEAT WHILE (CX)≠0 AND (ZF)=0
F3 11110011		REPN		REPEAT WHILE (CX)≠0 AND (ZF)=1
F4 11110100		HLT		HALT
F5 11110101		CMC		COMPLEMENT CARRY FLAG
F6 11110110	MOD 000 R/M	TEST	EA,DATA8	BYTE TEST (EA) WITH DATA
F6 11110110	MOD 001 R/M	(not used)		
F6 11110110	MOD 010 R/M	NOT	EA	BYTE INVERT EA
F6 11110110	MOD 011 R/M	NEG	EA	BYTE NEGATE EA
F6 11110110	MOD 100 R/M	MUL	EA	BYTE MULTIPLY BY (EA), UNSIGNED
F6 11110110	MOD 101 R/M	IMUL	EA	BYTE MULTIPLY BY (EA), SIGNED
F6 11110110	MOD 110 R/M	DIV	EA	BYTE DIVIDE BY (EA), UNSIGNED
F6 11110110	MOD 111 R/M	IDIV	EA	BYTE DIVIDE BY (EA), SIGNED
F7 11110111	MOD 000 R/M	TEST	EA,DATA16	WORD TEST (EA) WITH DATA
F7 11110111	MOD 001 R/M	(not used)		
F7 11110111	MOD 010 R/M	NOT	EA	WORD INVERT EA
F7 11110111	MOD 011 R/M	NEG	EA	WORD NEGATE EA
F7 11110111	MOD 100 R/M	MUL	EA	WORD MULTIPLY BY (EA), UNSIGNED
F7 11110111	MOD 101 R/M	IMUL	EA	WORD MULTIPLY BY (EA), SIGNED
F7 11110111	MOD 110 R/M	DIV	EA	WORD DIVIDE BY (EA), UNSIGNED
F7 11110111	MOD 111 R/M	IDIV	EA	WORD DIVIDE BY (EA), SIGNED
F8 11111000		CLC		CLEAR CARRY FLAG
F9 11111001		STC		SET CARRY FLAG
FA 11111010		CLI		CLEAR INTERRUPT FLAG
FB 11111011		STI		SET INTERRUPT FLAG
FC 11111100		CLD		CLEAR DIRECTION FLAG
FD 11111101		STD		SET DIRECTION FLAG
FE 11111110	MOD 000 R/M	INC	EA	BYTE INCREMENT EA
FE 11111110	MOD 001 R/M	DEC	EA	BYTE DECREMENT EA
FE 11111110	MOD 010 R/M	(not used)		
FE 11111110	MOD 011 R/M	(not used)		
FE 11111110	MOD 100 R/M	(not used)		
FE 11111110	MOD 101 R/M	(not used)		
FE 11111110	MOD 110 R/M	(not used)		
FE 11111110	MOD 111 R/M	(not used)		
FF 11111111	MOD 000 R/M	INC	EA	WORD INCREMENT EA
FF 11111111	MOD 001 R/M	DEC	EA	WORD DECREMENT EA
FF 11111111	MOD 010 R/M	CALL	EA	INDIRECT INTRA SEGMENT CALL
FF 11111111	MOD 011 R/M	CALL	EA	INDIRECT INTER SEGMENT CALL
FF 11111111	MOD 100 R/M	JMP	EA	INDIRECT INTRA SEGMENT JUMP
FF 11111111	MOD 101 R/M	JMP	EA	INDIRECT INTER SEGMENT JUMP
FF 11111111	MOD 110 R/M	PUSH	EA	PUSH (EA) ON STACK
FF 11111111	MOD 111 R/M	(not used)		

REG IS ASSIGNED ACCORDING TO THE FOLLOWING TABLE:

16-BIT (W=1)		8-BIT (W=0)		SEGMENT REG	
000	AX	000	AL	00	ES
001	CX	001	CL	01	CS
010	DX	010	DL	10	SS
011	BX	011	BL	11	DS
100	SP	100	AH		
101	BP	101	CH		
110	SI	110	DH		
111	DI	111	BH		

EA IS COMPUTED AS FOLLOWS: (DISP8 SIGN EXTENDED TO 16 BITS)

00	000	(BX)+(SI)	DS
00	001	(BX)+(DI)	DS
00	010	(BP)+(SI)	SS
00	011	(BP)+(DI)	SS
00	100	(SI)	DS
00	101	(DI)	DS
00	110	DISP16 (DIRECT ADDRESS)	DS
00	111	(BX)	DS
01	000	(BX)+(SI)+DISP8	DS
01	001	(BX)+(DI)+DISP8	DS
01	010	(BP)+(SI)+DISP8	SS
01	011	(BP)+(DI)+DISP8	SS
01	100	(SI)+DISP8	DS
01	101	(DI)+DISP8	DS
01	110	(BP)+DISP8	SS
01	111	(BX)+DISP8	DS
10	000	(BX)+(SI)+DISP16	DS
10	001	(BX)+(DI)+DISP16	DS
10	010	(BP)+(SI)+DISP16	SS
10	011	(BP)+(DI)+DISP16	SS
10	100	(SI)+DISP16	DS
10	101	(DI)+DISP16	DS
10	110	(BP)+DISP16	SS
10	111	(BX)+DISP16	DS
11	000	REG AX / AL	
11	001	REG CX / CL	
11	010	REG DX / DL	
11	011	REG BX / BL	
11	100	REG SP / AH	
11	101	REG BP / CH	
11	110	REG SI / DH	
11	111	REG DI / BH	

FLAGS REGISTER CONTAINS:

X:X:X:X:(OF):(DF):(IF):(TF):(SF):(ZF):X:(AF):X:(PF):X:(CF)

SET MATRIX

Hi \ Lo	8	9	A	B	C	D	E	F
0	OR b.f.r/m	OR w.f.r/m	OR b.t.r/m	OR w.t.r/m	OR b.i	OR w.i	PUSH CS	
1	SBB b.f.r/m	SBB w.f.r/m	SBB b.t.r/m	SBB w.t.r/m	SBB b.i	SBB w.i	PUSH DS	POP DS
2	SUB b.f.r/m	SUB w.f.r/m	SUB b.t.r/m	SUB w.t.r/m	SUB b.i	SUB w.i	SEG =CS	DAS
3	CMP b.f.r/m	CMP w.f.r/m	CMP b.t.r/m	CMP w.t.r/m	CMP b.i	CMP w.i	SEG =DS	AAS
4	DEC AX	DEC CX	DEC DX	DEC BX	DEC SP	DEC BP	DEC SI	DEC DI
5	POP AX	POP CX	POP DX	POP BX	POP SP	POP BP	POP SI	POP DI
6								
7	JS	JNS	JP/ JPE	JNP/ JPO	JL/ JNGE	JNL/ JGE	JLE/ JNG	JNLE/ JG
8	MOV b.f.r/m	MOV w.f.r/m	MOV b.t.r/m	MOV w.t.r/m	**MOV sr,f,r/m**	LEA	**MOV sr,t,r/m**	POP r/m
9	CBW	CWD	CALL l.d	WAIT	PUSHF	POPF	SAHF	LAHF
A	**TEST b,i,a**	**TEST w,i,a**	**STOS**	**STOS**	**LODS**	**LODS**	**SCAS**	**SCAS**
B	MOV i → AX	MOV i → CX	MOV i → DX	MOV i → BX	MOV i → SP	MOV i → BP	MOV i → SI	MOV i → DI
C			RET. l.(i+SP)	RET l	INT Type 3	INT (Any)	INTO	IRET
D	ESC 0	ESC 1	ESC 2	ESC 3	ESC 4	ESC 5	ESC 6	ESC 7
E	CALL d	JMP d	JMP l.d	JMP si.d	**IN v,b**	**IN v,w**	**OUT v,b**	**OUT v,w**
F	CLC	STC	CLI	STI	CLD	STD	Grp 2 b.r/m	Grp 2 w.r/m

where:

mod☐r/m	000	001	010	011	100	101	110	111
Immed	ADD	OR	ADC	SBB	AND	SUB	XOR	CMP
Shift	ROL	ROR	RCL	RCR	SHL/SAL	SHR	—	SAR
Grp 1	TEST	—	NOT	NEG	MUL	IMUL	DIV	IDIV
Grp 2	INC	DEC	CALL id	CALL l.id	JMP id	JMP l.id	PUSH	—

8086 INSTRUCTION

Hi \ Lo	0	1	2	3	4	5	6	7
0	ADD b.f.r/m	ADD w.f.r/m	ADD b.t.r/m	ADD w.t.r/m	ADD b.ia	ADD w.ia	PUSH ES	POP ES
1	ADC b.f.r/m	ADC w.f.r/m	ADC b.t.r/m	ADC w.t.r/m	ADC b.i	ADC w.i	PUSH SS	POP SS
2	AND b.f.r/m	AND w.f.r/m	AND b.t.r/m	AND w.t.r/m	AND b.i	AND w.i	SEG =ES	DAA
3	XOR b.f.r/m	XOR w.f.r/m	XOR b.t.r/m	XOR w.t.r/m	XOR b.i	XOR w.i	SEG =SS	AAA
4	INC AX	INC CX	INC DX	INC BX	INC SP	INC BP	INC SI	INC DI
5	PUSH AX	PUSH CX	PUSH DX	PUSH BX	PUSH SP	PUSH BP	PUSH SI	PUSH DI
6								
7	JO	JNO	JB/ JNAE	JNB/ JAE	JE/ JZ	JNE/ JNZ	JBE/ JNA	JNBE/ JA
8	Immed b.r/m	Immed w.r/m	Immed b.r/m	Immed is.r/m	TEST b.r/m	TEST w.r/m	XCHG b.r/m	XCHG w.r/m
9	XCHG AX	XCHG CX	XCHG DX	XCHG BX	XCHG SP	XCHG BP	XCHG SI	XCHG DI
A	MOV m → AL	MOV m → AX	MOV AL → m	MOV AX → m	**MOVS**	**MOVS**	**CMPS**	**CMPS**
B	MOV i → AL	MOV i → CL	MOV i → DL	MOV i → BL	MOV i → AH	MOV i → CH	MOV i → DH	MOV i → BH
C			RET. (i+SP)	RET	LES	LDS	MOV b.i.r/m	MOV w.i.r/m
D	Shift b	Shift w	Shift b.v	Shift w.v	AAM	AAD		XLAT
E	LOOPNZ/ LOOPNE	LOOPZ/ LOOPE	LOOP	JCXZ	**IN b**	**IN w**	**OUT b**	**OUT w**
F	LOCK		REP	REP z	HLT	CMC	Grp 1 b.r/m	Grp 1 w.r/m

b = byte operation	m = memory
d = direct	r/m = EA is second byte
f = from CPU reg	si = short intrasegment
i = immediate	sr = segment register
ia = immed. to accum.	t = to CPU reg
id = indirect	v = variable
is = immed. byte, sign ext.	w = word operation
l = long ie. intersegment	z = zero

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