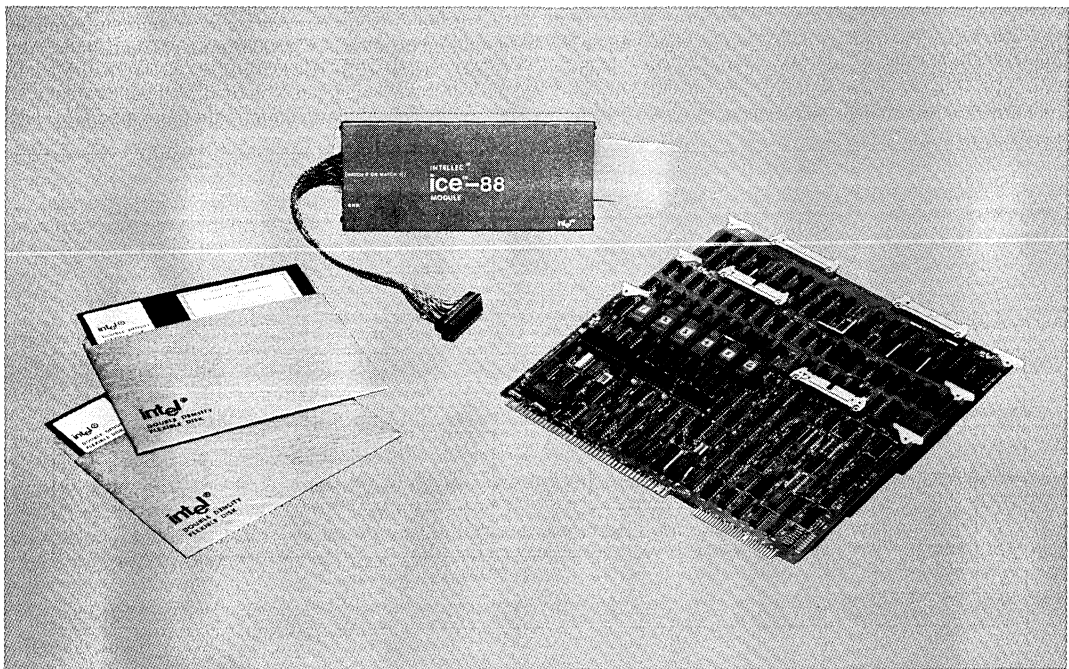# intel®

ICE-88™
8088 IN-CIRCUIT EMULATOR

- Hardware In-Circuit Emulation
- Full Symbolic Debugging
- Breakpoints to Halt Emulation on a Wide Variety of Conditions
- Comprehensive Trace of Program Execution, Both Conditional and Unconditional
- Disassembly of Trace or Memory from Object Code into Assembler Mnemonics

- 2K Bytes of High Speed ICE-88™ Mapped Memory
- Software Debugging with or without User System
- Handles Full 1 Megabyte Addressability of 8088
- Compound Commands
- Command Macros

The ICE-88 module provides In-Circuit Emulation for the 8088 microprocessor. It includes three circuit boards which reside in Intellec® Microcomputer Development Systems. A cable and buffer box connect the Intellec system to the user system by replacing the user's 8088. Powerful Intellec debug functions are thus 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 blocks of Intellec system memory for user equivalents. Breakpoints allow the user to stop emulation on user-specified conditions, and the trace capability gives a detailed history of the program execution prior to the break. All user access to the prototype system software may be done symbolically by referring to the source program variables and labels.

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INTEGRATED HARDWARE/SOFTWARE DEVELOPMENT

The ICE-88 emulator allows hardware and software development to proceed interactively. This is more effective than the traditional method of independent hardware and software development followed by system integration. With the ICE-88 module, prototype hardware can be added to the system as it is designed. Software and hardware testing occurs while the product is being developed.

Conceptually, the ICE-88 emulator assists three stages of development:

1. It can be operated without being connected to the user's system, so ICE-88 debugging capabilities can be used to facilitate program development before any of the user's hardware is available.

2. Integration of software and hardware can begin when any functional element of the user system hardware is connected to the 8088 socket. Through ICE-88 mapping capabilities, Intellec memory, ICE memory, or diskette memory can be substituted for missing prototype memory. Time-critical program modules are debugged before hardware implementation by using the 2K-bytes of high-speed ICE-resident memory. As each section of the user's hardware is completed, it is added to the prototype. Thus each section of the hardware and software is "system" tested as it becomes available.

3. When the user's prototype is complete, it is tested with the final version of the user system software. The ICE-88 module is then used for real time emulation of the 8088 to debug the system as a completed unit.

Thus the ICE-88 module 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.

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 the user program. Thus the user need not remember the addresses of variables or program subroutines.

Symbols can be used to reference variables, procedures, program labels, and source statements. 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 simplifies both tracing and breakpoint setting. Disassembly of a section of code from either trace or program memory into its assembly mnemonics is readily accomplished.

Furthermore, each symbol may have associated with it one of the data types BYTE, WORD, INTEGER, SINTEGER (for short, 8-bit integer) or POINTER. Thus the user need not remember the type of a source program variable when examining or modifying it. 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.

The user symbol table generated along with the object file during a PL/M-86 compilation or an ASM-86 assembly is loaded into memory 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 useful during system debugging.

The ICE-88 module provides access through symbolic definition to all of the 8088 registers and flags. The READY, NMI, TEST, HOLD, RESET, INTR, and MN/MX pins of the 8088 can also be read. Symbolic references to key ICE-88 emulation information are also provided.
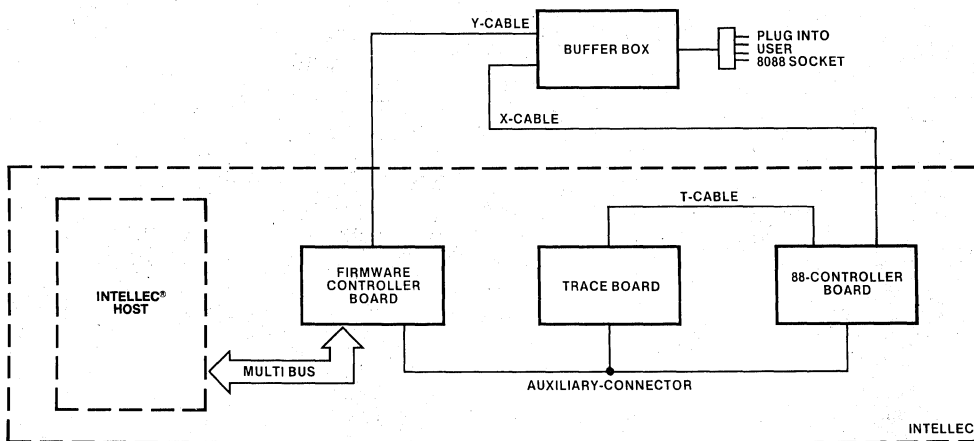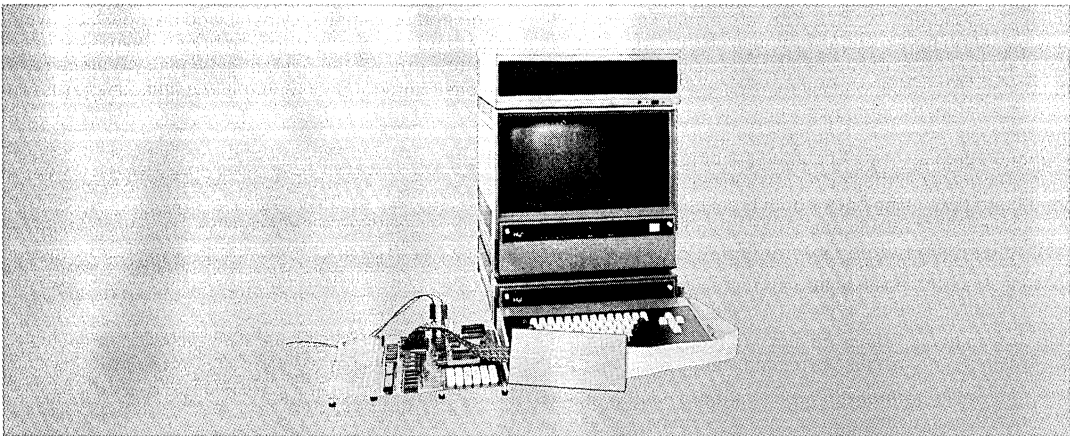

Figure 1. ICE-88™ Emulator Block Diagram

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A typical ICE-88 development configuration. It is based on a Model 235 Development System, which also includes a Double Density Diskette Operating System and a Model 201 Expansion Chassis (which holds the ICE-88 emulator). The ICE-88 module is shown connected to a user prototype system.

MACROS AND COMPOUND COMMANDS

The ICE-88 module provides a programmable diagnostic facility which allows the user to tailor its operation using macro commands and compound commands.

A macro is a set of ICE-88 commands which is given a single name. Thus, a sequence of commands which is executed frequently may be invoked simply by typing in a single command. The user first defines the macro by entering the entire sequence of commands which he wants to execute. He then names the macro and stores it for future use. He executes the macro by typing its name and passing up to ten parameters to the commands in the macro. Macros may be saved on a disk file for use in subsequent debugging sessions.

Compound commands provide conditional execution of commands (IF), and execution of commands until a condition is met or until they have been executed a specified number of times (COUNT, REPEAT).

Compound commands and macros may be nested any number of times.

MEMORY MAPPING

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

The ICE-88 emulator allows the memory which is addressed by the 8088 to be mapped in 1K-byte blocks to:

1. Physical memory in the user's system,

2. Either of two 1K-byte blocks of ICE-88 high-speed memory,

3. Intellec memory,

4. A random-access diskette file.

The user can also designate a block of memory as non-existent. The ICE-88 module issues an error message when any such "guarded" memory is addressed by the user program.

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.

Table 1. Summary of ICE-88 Emulation Commands.

OPERATION MODES

The ICE-88 software is a RAM-based program that provides the user with easy-to-use commands for initiating emulation, defining breakpoints, controlling trace data collection, and displaying and controlling system parameters. 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.

Emulation

Emulation commands to the ICE-88 emulator control the process of setting up, running and halting an emulation of the user's 8088. Breakpoints and tracepoints enable ICE-88 to halt emulation and provide a detailed trace of execution in any part of the user's program. A summary of the emulation commands is shown in Table 1.

Breakpoints — The ICE-88 module has two breakpoint registers that allow the user to halt emulation when a

specified condition is met. The breakpoint registers may be set up for execution or non-execution breaking. An execution breakpoint consists of a single address which causes a break whenever the 8088 executes from its queue an instruction byte which was obtained from the address. A non-execution breakpoint causes an emulation break when a specified condition other than an instruction execution occurs. A non-execution break-point condition, using one or both breakpoint registers, may be specified by any one of or a combination of:

1. *A set of address values.* Break on a set of address values has three valuable features:
   a. Break on a single address.

   b. The ability to set any number of breakpoints within a limited range (1024 bytes maximum) of memory.

   c. The ability to break in an unlimited range. Execution is halted on any memory access to an address greater than (or less than) any 20-bit breakpoint address.

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* (features comparable to break on a set of address values, explained in point one).

4. *A segment register* (break occurs when the register is used in an effective address calculation).

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

Tracepoints — The ICE-88 module has two tracepoint registers which establish match conditions to condi-tionally start and stop trace collection. The trace infor-mation is gathered at least twice per bus cycle, first when the address signals are valid and second when the data signals are valid. If the 8088 execution queue is otherwise active, additional frames of trace are col-lected.

Each trace frame contains the 20 address/data lines and detailed information on the status of the 8088. The trace memory can store 1,023 frames, or an average of about 300 bus cycles, providing ample data for determining how the 8088 was reacting prior to emulation break. The trace memory contains the last 1,023 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 ASM-86 Assembler mnemonics. Unless the user chooses to disable trace, the trace information is always available after an emulation.

Interrogation and Utility

Interrogation and utility commands give the user con-venient access to detailed information about the user program and the state of the 8088 that is useful in debugging hardware and software. Changes can be made in both memory and the 8088 registers, flags, input pins, and I/O ports. Commands are also provided for various utility operations such as loading and saving

program files, defining symbols and macros, displaying trace data, setting up the memory map, and returning control to the ISIS-II operating system. A summary of the basic interrogation and utility commands is shown in Table 2.

Memory/Register Commands

   Display or change the contents of:
- Memory
- 8088 Registers
- 8088 Status flags
- 8088 Input pins
- 8088 I/O ports
- ICE-88 Pseudo-Registers (e.g. emulation timer)

Memory Mapping Commands

   Display, declare, set, or reset the ICE-88 memory mapping.

Symbol Manipulation Commands

   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 state-ments.

   Change the value of any symbol.

TYPE

   Assign or change the type of any symbol in the symbol table.

ASM

   Disassemble user program memory into ASM-86 Assembler mnemonics.

PRINT

   Display the specified portion of the trace memory.

LOAD

   Fetch user symbol table and object code from the input file.

SAVE

   Send user symbol table and object code to the output file.

LIST

   Send 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

   Display the value of an expression in binary, octal, decimal, hexadecimal, and ASCII.

SUFFIX/BASE

   Establish the default base for numeric values in input text/output display (binary, octal, decimal, or hexadecimal).

CLOCK

   Select the internal (ICE-88 provided, for stand-alone mode only) or an external (user-provided) system clock.

RWTIMEOUT

   Allows the user to time out READ/WRITE command signals based on the time taken by the 8088 to access Intellec memory or diskette memory.

ENABLE/DISABLE RDY

   Enable or disable logical AND of ICE-88 Ready with the user Ready signal for accessing Intellec memory, ICE memory, or diskette memory.

Table 2. Summary of Basic ICE-88 Interrogation and Utility Commands.

DIFFERENCES BETWEEN ICE-88™ EMULATION AND THE 8088 MICROPROCESSOR

The ICE-88 module emulates the actual operation of the 8088 microprocessor with the following exceptions:

- The ICE-88 module will not respond to a user system NMI or RESET signal when it is out of emulation.

- Trap is ignored in single step mode and on the first instruction step of an emulation.

- The MIN/MAX line, which chooses the "minimum" or "maximum" configuration of the 8088, must not change dynamically in the user system.

- In the "minimum" mode, the user HOLD signal must remain active until HLDA is output by the ICE-88 emulator.

- The $\overline{RQ}/\overline{GT}$ lines in the "maximum" configuration are not supported.

The speed of run emulation by the ICE-88 module depends on where the user has mapped his memory. As the user prototype progresses to include memory, emulation becomes real time.

Memory Mapped To	Estimated Speed
User System	100% of real time*, up to 5 MHz clock
ICE	2 wait states per 8088-controlled bus cycle
Intellec	Approximately 0.02% of real time at 5 MHz clock
Diskette	**

  * 100% of real time is emulation at the user system clock rate with no wait states.

** The emulation speed from diskette is comparable to Intellec memory, but emulation must wait when a new page is accessed on the diskette.

DC CHARACTERISTICS OF ICE-88™ USER CABLE

1. Output Low Voltages [V_{OL}(Max) = 0.4V]

	I_{OL}(Min)
AD0-AD7, A8-A15, $\overline{SS0}$, A16/S3-A19/S7, $\overline{RD}$, $\overline{LOCK}$, QS0, QS1, $\overline{S0}$, $\overline{S1}$, $\overline{S2}$, $\overline{WR}$, M/$\overline{IO}$, DT/$\overline{R}$, $\overline{DEN}$, ALE, $\overline{INTA}$	8mA (16mA @ 0.5V)
HLDA	5mA
MATCH0 OR MATCH1 (on buffer box)	16mA

2. Output High Voltages [V_{OH}(Min) = 2.4V]

	I_{OH}(Min)
AD0-AD7, A8-A15 A16/S3-A19/S7, $\overline{SS0}$, $\overline{RD}$, $\overline{LOCK}$, QS0, QS1, $\overline{S0}$, $\overline{S1}$, $\overline{S2}$, $\overline{WR}$, M/$\overline{IO}$, DT/$\overline{R}$, $\overline{DEN}$, ALE, $\overline{INTA}$	−2.0mA
HLDA	−3.0mA
MATCH0 OR MATCH1 (on buffer box)	−0.8mA

3. Input Low Voltages [V_{IL}(Max) = 0.8V]

	I_{IL}(Max)
AD0-AD7	−0.2mA
NMI, CLK	−0.4mA
READY	−0.8mA
INTR, HOLD, $\overline{TEST}$, RESET	−1.4mA
MN/$\overline{MX}$ (0.1μf to GND)	−3.3mA

4. Input High Voltages [V_{IH}(Min) = 2.0V]

	I_{IH}(Max)
AD0-AD7	80μA
NMI, CLK	20μA
READY	60μA
INTR, HOLD, $\overline{TEST}$, RESET	−0.4mA
MN/$\overline{MX}$ (0.1μF to GND)	−1.1mA

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

Operating Environment

Required Hardware

Intellec microcomputer development system with:

1. Three adjacent slots for the ICE-88 module. (Series II requires Model 201 Expansion Chassis).
2. 64K bytes of Intellec memory. If user prototype program memory is desired, additional memory above the basic 64K is required.

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, diskette-based

Emulation Clock

User system clock up to 5 MHz or 2 MHz ICE-88 internal clock in stand-alone 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: 9.00 lb (4.10 kg)

Electrical Characteristics

DC Power

$V_{CC} = +5V +5\% - 1\%$
$I_{CC} = 15A$ maximum; 11 A typical
$V_{DD} = +12V \pm 5\%$
$I_{DD} = 120 mA$ maximum; 80 mA typical
$V_{BB} = -10V \pm 5\%$ or $-12V \pm 5\%$ (optional)
$I_{BB} = 25 mA$ maximum; 12 mA typical

Environmental Characteristics

Operating Temperature: 0° to 40°C

Operating Humidity: Up to 95% relative humidity without condensation.

ORDERING INFORMATION

Part Number   Description

MDS-88-ICE*   8088 CPU in-circuit emulator

*MDS is an ordering code only and is not used as a product name or trademark. MDS® is a registered trademark of Mohawk Data Science Corporation.