intel®

ICE-86A™ iAPX 86 IN-CIRCUIT EMULATOR

- **Real-Time In-Circuit Emulation of iAPX 86 Microsystems**
- **Emulate Both Minimum and Maximum Modes of 8086 CPU**
- **Full Symbolic Debugging**
- **Breakpoints to Halt Emulation on a Wide Variety of Conditions**
- **Comprehensive Trace of Program Execution**
- **Disassembly of Trace or Program Memory from Object Code into Assembler Mnemonics**
- **Software Debugging With or Without User System**
- **Handles Full 1 Megabyte Addressability of iAPX 86**
- **Enhance Existing ICE-86™ Emulators to ICE-86A™ Capabilities with ICE-86U™ Upgrade Package**

The Intel® ICE-86A In-Circuit Emulator provides sophisticated hardware and software debugging capabilities for iAPX 86 microsystems and iAPX 86 Single-Board Computers. These capabilities include In-Circuit Emulation for the 8086 Central Processing Unit plus extensions to debug systems including the 8089 I/O Processor and 8087 Numeric Processor Extension. The emulator includes three circuit boards which reside in any Intellec® Microcomputer Development System. A cable and buffer box connect the Intellec system to the user system by replacing the user's 8086, thus extending powerful Intellec system debugging functions into the user system. Using the ICE-86A module, the designer can execute prototype 8086 or 8089 software in continuous or single-step modes and can substitute blocks of Intellec system memory for user equivalents. Breakpoints allow the user to stop emulation on user-specified conditions of the iAPX 86 system, 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.

The ICE-86U In-Circuit Emulator upgrade package converts any existing ICE-86 module (non-A version) to the capabilities of an ICE-86A module.

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INTEGRATED HARDWARE/SOFTWARE DEVELOPMENT

The ICE-86A 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-86A 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-86A emulator assists three stages of development:

1. It can be operated without being connected to the user's system, so the ICE-86A module's 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 8086 socket. Through ICE-86A emulator mapping capabilities, Intellec memory, ICE module 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-86A module is then used for real-time emulation of the 8086 to debug the system as a completed unit.

Thus the ICE-86A 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-86A emulator 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.

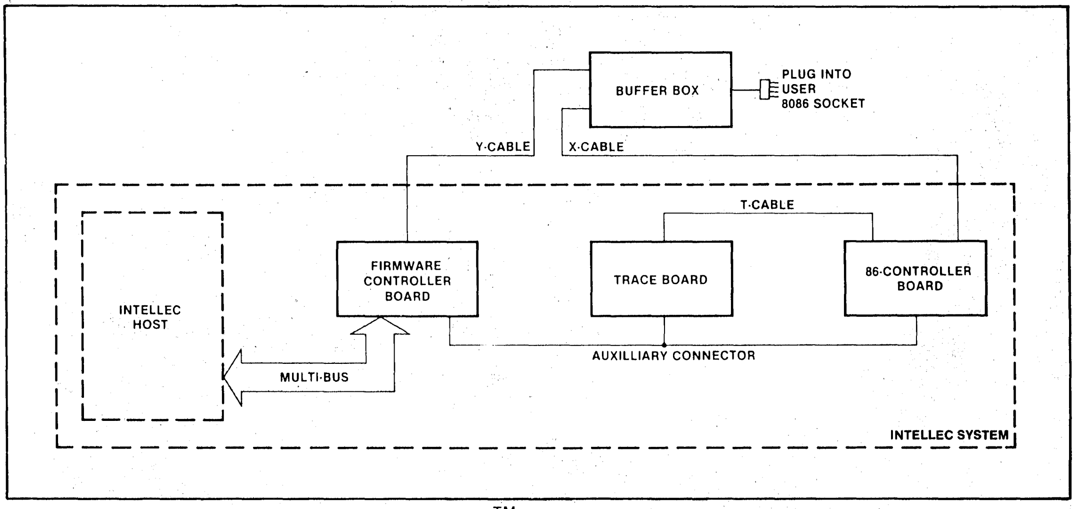
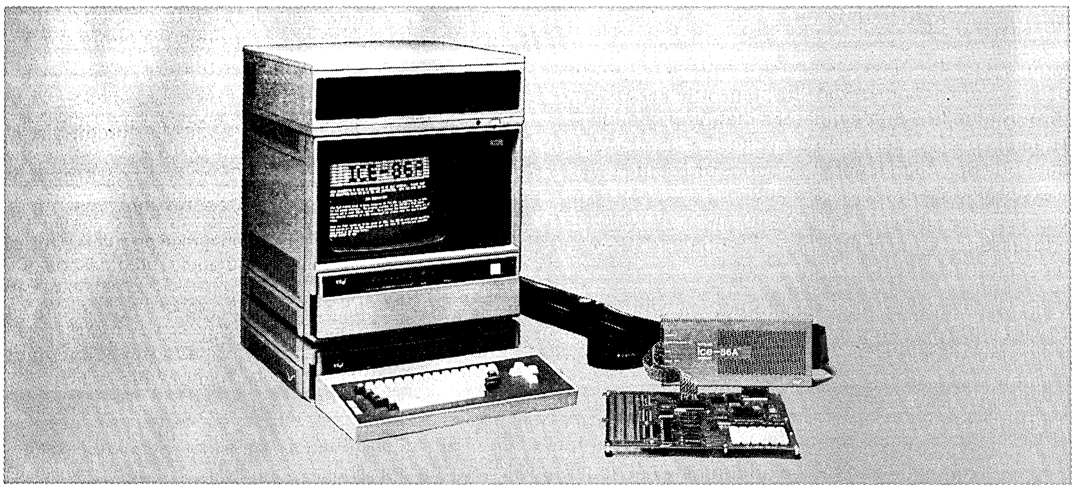


Figure 1. ICE-86A™ Emulator Block Diagram



A typical iAPX 86 development configuration. It is based on Intellec® Series III Development System, which hosts the ICE-86A™ emulator. The ICE-86A™ module is shown connected to a user prototype system, in this case, an SDK-86.

Furthermore, each symbol may have associated with it one of the data types BYTE, WORD, INTEGER, SINTEGER (for short, 8-bit integer), POINTER, REAL, DREAL, or TREAL. 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, PASCAL-86 or FORTRAN-86 compilation or an ASM-86 assembly is loaded into memory along with the user program which is to be emulated. The user can utilize the available symbol table space more efficiently by using the SELECT option to choose which program modules will have symbols loaded in the symbol table. The user may also add to this symbol table any additional symbolic values for memory addresses, constants, or variables that are found useful during system debugging.

The ICE-86A module provides access through symbolic definition to all of the 8086 registers and flags. The READY, NMI, $\overline{\text{TEST}}$, HOLD, RESET, INTR, MN/$\overline{\text{MX}}$, and $\overline{\text{RQ}}/\overline{\text{GT}}$ pins of the 8086 can also be read. Symbolic references to key ICE-86A emulation information are also provided.

MACROS AND COMPOUND COMMANDS

The ICE-86A 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-86A 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 the ICE-86A emulator's mapping capability. The speed of run emulation by the ICE-86A module depends on which mapping options are being used.

The ICE-86A emulator allows the memory which is addressed by the 8086 to be mapped in 1K-byte blocks to:

1. Physical memory in the user's system, which provides 100 percent real-time emulation at the user-system clock rate (up to 5 MHz) with no wait states.
2. Either of two 1K-byte blocks of ICE-86A module high-speed memory, which allow nearly full-speed emulation (with two additional wait states per 8086-controlled bus cycle).
3. Intellec System memory, which provides emulation at approximately 0.02 percent of real-time with a 5 MHz clock.
4. A random-access diskette file, with emulation speed comparable to Intellec System memory, except the emulation must wait when a new page is accessed on the diskette.

The user can also designate a block of memory as non-existent. The ICE-86A module issues an error message when any such "guarded" memory is addressed by the user program.

As the user prototype progresses to include memory, emulation becomes real time.

OPERATION MODES

The ICE-86A 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-86A 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-86A emulator control the process of setting up, running and halting an emulation of the user's iAPX 86 System. Breakpoints and tracepoints enable the ICE-86A module 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.

Table 1. Summary of ICE-86A™ 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.

Breakpoints: The ICE-86A 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 8086 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 breakpoint 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 8086 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).

Emulation break can also be set to occur on an external signal condition. An external breakpoint match output and emulation status lines are provided on the buffer box. These allow synchronization of other test equipment when a break occurs or when emulation is begun.

Tracepoints: The ICE-86A module 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. If the 8086 execution queue is otherwise active, additional frames of trace are collected.

Each trace frame contains the 20 address/data lines and detailed information on the status of the 8086. The trace memory can store 1,023 frames, or an average of about 300 bus cycles, providing ample data for detemining how the 8086 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 convenient access to detailed information about the user program and the state of the 8086 that is useful in debugging hardware and software. Changes can be made in both memory and the 8086 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 ISIS-II. A summary of the basic interrogation and utility commands is shown in Table 2.

Table 2. Selected ICE-86A™ Module Interrogation and Utility Commands

Memory/Register Commands
Display or change the contents of:
- Memory
- 8086 Registers
- 8086 Status flags
- 8086 Input pins
- 8086 I/O ports
- ICE-86A Pseudo-Registers (e.g. emulation timer)

Memory Mapping Commands
Display, declare, set, or reset the ICE-86A 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 statements.

Change the value of any symbol.

Select program modules whose symbols will be used in debugging.

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

DASM
Disassemble user program memory into ASM-86 Assembler mnemonics.

RQ/GT
Set or display the status of the Request/Grant facility which enables the ICE-86A module to share the system bus with coprocessors.

BUS
Display which device in the user's iAPX 86 system is currently master of the system bus.

CAUSE
Display the cause of the most recent emulation break.

PRINT
Display the specified portion of the trace memory.

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

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

CLOCK
Select the internal (ICE-86A module 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 8086 to access Intellec memory or diskette memory.

ENABLE/DISABLE RDY
Enable or disable logical AND of ICE-86A emulator Ready with the user Ready signal for accessing Intellec memory, ICE memory, or diskette memory.

iAPX 86/20 DEBUGGING

The ICE-86A module has the extended capabilities to debug iAPX 86/20 microsystems which contain both the 8086 microprocessor and the 8087 Numeric Processor Extension (NPX). An iAPX 86/20 system is configured in the 8086's "maximum" mode and communication between the processors is accomplished through the $\overline{RQ}/\overline{GT}$ signals. Debugging can be done either using the 8087 chip itself (in which case the 8086 ESCAPE instruction is interpreted as a floating point instruction) or using the 8087 software emulator E8087 (where the 8086 INTERRUPT instruction is interpreted as a floating point instruction). Three new data types are defined to use the NPX:

REAL (4 byte Short Real)
DREAL (8 byte Long Real)
TREAL (10 byte Temporary Real)

While the 8087 NPX is not a programmable part, it does interact closely with the 8086 and can execute instructions in parallel with it. The ICE-86A module provides information about the relative timing of instruction execution in each processor so that the complete system can be debugged. Other debugging capabilities available through the ICE-86A module are: symbolically disassemble NPX call instructions from memory or trace history; display or change the control, status and flag values of the NPX; display the NPX stack either in hexadecimal or disassembled form; and display the last instruction address, last operand, and last operand address.

iAPX 86/11 DEBUGGING

The 8089 Real-Time Breakpoint Facility (RBF-89) is an extension of the ICE-86A emulator that aids in testing and trouble-shooting iAPX 86/11 systems designed around a combination of the 8086 CPU and the 8089 Input/Output Processor (IOP). RBF-89 interrogates 8089 registers, sets breakpoints in 8089 programs, and performs its other functions by preparing special control blocks in application system memory. It then issues input/output channel-attention commands to the 8089 in the user's system to perform these functions. While using the RBF-89 extension, the user can also enter and execute the other standard ICE-86A emulator commands.

RBF-89 allows the user to load his application (channel) program from diskette into 8089 IOP memory and execute it in real time. The program can reside in either local (system) RAM (accessible by both the 8086 and 8089 microprocessors), or remote RAM (accessible by the 8089 IOP only). The user may request execution to begin at any location and continue until normal termination, a specified breakpoint is reached, or the program is otherwise aborted. If a program is modified during a debugging session, RBF-89 can save the latest version by copying it from application system memory to a diskette file.

Breakpoints

RBF-89 supports setting up to twelve breakpoints (six per 8089 channel) in the user program. RBF-89 implements each breakpoint by inserting a HALT instruction at the breakpoint location, while saving the overwritten instruction in temporary storage. When a breakpoint is reached during program execution the program halts. At this point the user can examine 8089 registers, flags, and memory, and optionally resume program execution. The invoked breakpoint address is recorded in one of two breakpoint registers—one register for each 8089 channel. Through simple RBF-89 commands the user can display or change the contents of these registers.

Symbolic Debugging

As in the ICE-86A emulator, the RBF-89 extension accepts symbolic references for variables and labels, including symbols in the symbol table generated by the ASM-89 assembler.

Through RBF-89, the user can display and change the contents of :

— memory, which can be displayed as either numeric data or disassembled (8089 assembly-language mnemonic) code.

— all 8089 registers except the channel control pointer (CCP) and status flags.

Multiprocessor Operation

The ICE-86A emulator and RBF-89 support 8089 configurations in both local and remote modes. The ICE-86A emulator may be operating either in minimum or maximum mode. In maximum mode, the 8086 $\overline{RQ}/\overline{GT}$ lines are employed. This is required for the 8089 local mode configuration to provide local bus arbitration between the two processors. Using RBF-89, the user can:

Set $\overline{RQ}/\overline{GT}$ to operate for a local or remote configuration.

Display status to determine which processor controls the system bus.

Start and halt 8089 channel programs.

RBF-89 permits the 8089 and emulated 8086 to run simultaneously as well as sequentially. The user can specify breakpoints and begin program execution in three operating sequences:

Set breakpoints, start the 8089, and return control to the console until a breakpoint is reached or the program runs to completion or is aborted. Use this sequence when the 8086 and 8089 programs do not need to be executed simultaneously.

Set breakpoints, start the 8089, return control to the console, and start the 8086. This sequence lets both microprocessors run simultaneously.

Set breakpoints, start the 8086, and allow that program to drive the 8089 program in a master/slave relationship. This sequence would be used, for instance, to verify the 8086 communication driver program.

RBF-89 System Components

RBF-89 is furnished as a superset of the ICE-86A emulator software. Its main components are:

A HOST PROGRAM that resides in Intellec development system RAM, where it serves as an extension of the ICE-86A emulator's software driver. This program, executed by the development system, translates the user's keyboard input into low-level directives that can be processed by the RBF-89 control program (described below), and converts information supplied by the control program into easily understood display output.

A CONTROL PROGRAM that resides in ICE-86A emulator memory. Running on the emulator's 8086 microprocessor, the control program monitors such operations as preparing program control blocks for communication with the 8089 microprocessor; issuing commands to the 8089 to start, terminate, and continue the 8089 task program; and directing the 8089 to start execution of the RBF-89 utility program (described below).

A UTILITY PROGRAM that resides in the 8089 RAM in the user's prototype application system. This program, running on the 8089, reads and writes data to and from 8089 memory and registers, and sets and removes breakpoints in the user's task program.

The 200 bytes of RAM required by the utility program must be accessible to both the ICE-86A emulator and the 8089.

DC CHARACTERISTICS OF THE ICE-86A™ MODULE USER CABLE

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

	I_{OL} (Min)
AD0-AD15	12 mA (24 mA @ 0.5V)
A16/S3-A19/S7, $\overline{BHE}$/S7, $\overline{RD}$, $\overline{LOCK}$, QS0, QS1, $\overline{S0}$, $\overline{S1}$, $\overline{S2}$, $\overline{WR}$, M/$\overline{IO}$, DT/$\overline{R}$, $\overline{DEN}$, ALE, $\overline{INTA}$	8 mA (16 mA @ 0.5V)
HLDA	7 mA
$\overline{RQ}/\overline{GT}$	16 mA

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

	I_{OH} (Min)
AD0-AD15	−3 mA
A16/S3-A19/S7, $\overline{BHE}$/S7, $\overline{RD}$, $\overline{LOCK}$, QS0, QS1, S0, $\overline{S1}$, $\overline{S2}$, $\overline{WR}$, M/IO, DT/R, $\overline{DEN}$, ALE, $\overline{INTA}$, HLDA	−2.6 mA
$\overline{RQ}/\overline{GT}$	250 mA

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

	I_{IL} (Max)
AD0-AD15	−0.2 mA
NMI, CLK	−0.4 mA
READY	−0.8 mA
INTR, HOLD, $\overline{TEST}$, RESET	−1.4 mA
MN/$\overline{MX}$ (0.1 μf to GND)	−3.3 mA

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

	I_{IH} (Max)
AD0-AD15	80 μA
NMI, CLK	20 μA
READY	40 μA
INTR, HOLD, $\overline{TEST}$, RESET	−0.4 mA
MN/$\overline{MX}$ (0.1 μF to GND)	−1.1 mA

5. No current is taken from the user circuit at V_{CC} pin.

SPECIFICATIONS

ICE-86A Operating Environment

REQUIRED HARDWARE

Intellec microcomputer development system with:

1. Three adjacent slots for the ICE-86A module.
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-86A module

REQUIRED SOFTWARE

System Monitor
ISIS-II, version 3.4 or subsequent
ICE-86A software

Equipment Supplied

Printed circuit boards (3)
Interface cable and emulation buffer module
Operator's manual
ICE-86A software, diskette-based

Emulation Clock

User system clock up to 5 MHz or 2 MHz ICE-86A 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} = 17A 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} = 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*-86A-ICE	iAPX 86 microsystem in-circuit emulator, cable assembly, and interactive software
MDS*-86U-ICE	Upgrade kit to convert ICE-86 emulators to ICE-86A emulator capabilities.

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