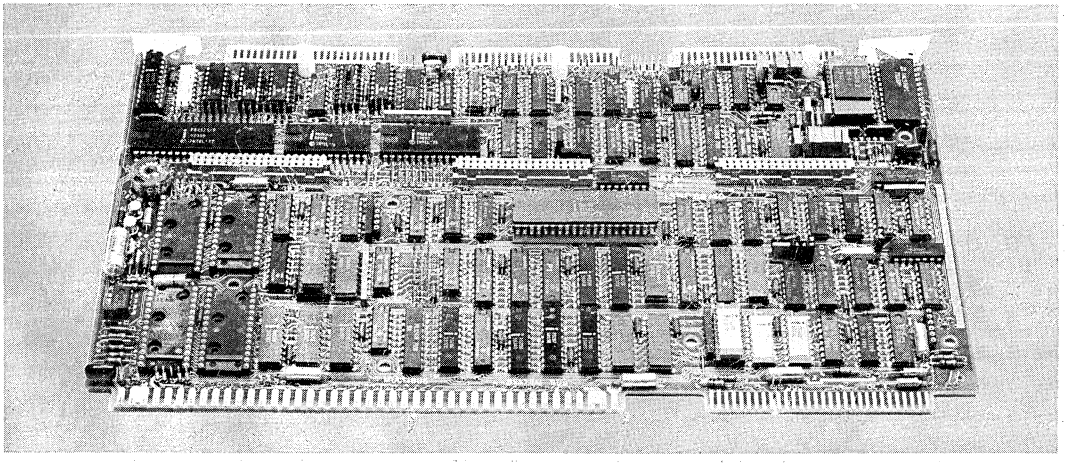
iSBC 88/40
MEASUREMENT AND CONTROL COMPUTER

- **High performance 5 MHz iAPX 88/10 8-bit HMOS processor**
- **12-bit, 20 kHz analog-to-digital converter with programmable gain control**
- **16 differential/32 single-ended analog input channels**
- **Three iSBX MULTIMODULE connectors for analog, digital, and other I/O expansion**
- **4K bytes static RAM, expandable via iSBC 301 MULTIMODULE RAM to 8K bytes (1K byte dual-ported)**
- **Four ERPOM/E²PROM sockets for up to 32K bytes, expandable to 64K bytes with iSBC 341 expansion MULTIMODULE**
- **On-board 21-volt power supply for E²PROM modification under program control**
- **MULTIBUS Intelligent Slave or Multimaster**

The Intel iSBC 88/40 Measurement and Control Computer is a member of Intel's large family of Single Board Computers that takes full advantage of Intel's VLSI technology to provide an economical self-contained computer based solution for applications in the areas of process control and data acquisition. The on-board iAPX 88/10 processor with its powerful instruction set allows users of the iSBC 88/40 board to update process loops as much as 5–10 times faster than previously possible with other 8-bit microprocessors. For example, the high performance iSBC 88/40 can concurrently process and update 16 control loops in less than 200 milliseconds using a traditional PID (Proportional-Integral-Derivative) control algorithm. The iSBC 88/40 board consists of a 16 differential/32 single ended channel analog multiplexer with input protected circuits, A/D converter, programmable central processing unit, dual port and private RAM, read only memory sockets, interrupt logic, 24 channels of parallel I/O, three programmable timers and MULTIBUS control logic on a single 6.75 by 12.00-inch printed circuit card. The iSBC 88/40 board is capable of functioning by itself in a stand-alone system or as a multimaster or intelligent slave in a large MULTIBUS system.



FUNCTIONAL DESCRIPTION

Three Modes of Operation

The iSBC 88/40 Measurement and Control Computer (MACC) is capable of operating in one of three modes: stand-alone controller, bus multimaster or intelligent slave. A block diagram of the iSBC 88/40 Measurement and Control Computer is shown in Figure 1.

Stand-Alone Controller

The iSBC 88/40 Measurement and Control Computer may function as a stand-alone single board controller with CPU, memory and I/O elements on a single board. The on-board 4K bytes of RAM and up to 32K bytes of read only memory, as well as the analog-to-digital converter and programmable parallel I/O lines allow significant control and monitoring capabilities from a single board.

Bus Multimaster

In this mode of operation the iSBC 88/40 board may interface and control a wide variety of iSBC memory and I/O boards or even with additional iSBC 88/40 boards or other single board computer masters or intelligent slaves.

Intelligent Slave

The iSBC 88/40 board can perform as an intelligent slave to any Intel 8 or 16-bit MULTIBUS master CPU by not only offloading the master of the analog data collection, but it can also do a significant amount of pre-processing and decision making on its own. The distribution of processing tasks to intelligent slaves frees the system master to do other system functions. The dual port RAM with flag bytes for signalling allows the iSBC 88/40 board to process and store data without MULTIBUS memory or bus contention.

Central Processing Unit

The central processor unit for the iSBC 88/40 board is a powerful 8-bit HMOS iAPX 88/10 microprocessor. The 22.5 sq. mil. chip contains approximately 29,000 transistors and has a clock rate of 8 MHz. The architecture includes four (4) addressable data registers and two (2) 16-bit memory base pointer registers and two (2) 16-bit index registers, all accessed by a total of 24 operand addressing modes for complex data handling and very flexible memory addressing.

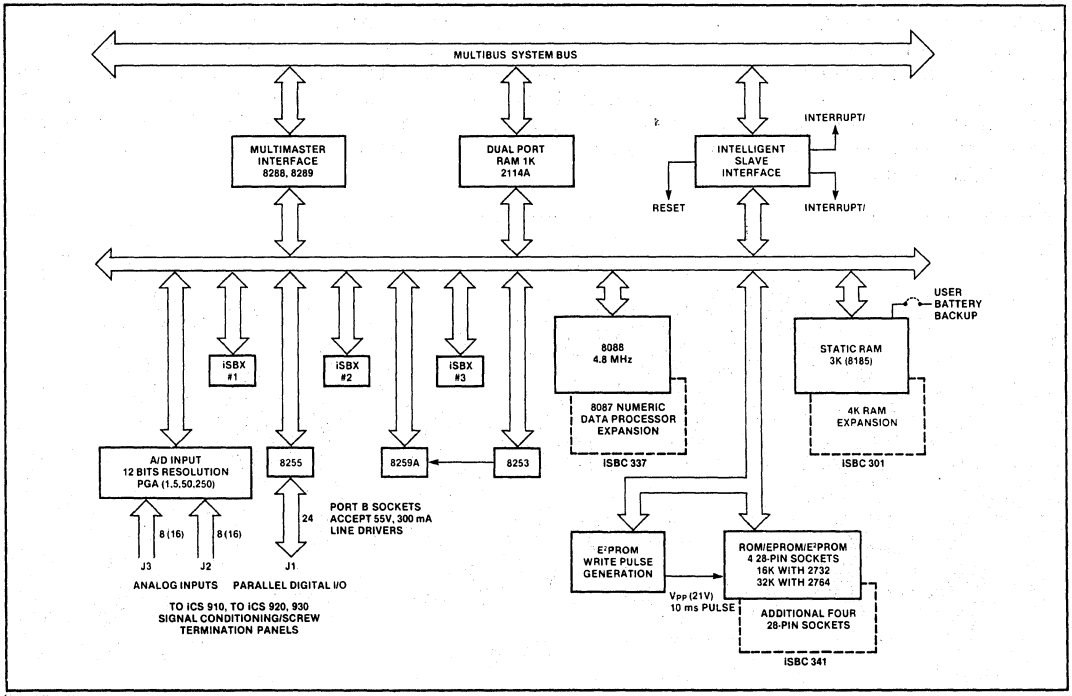


Figure 1. iSBC 88/40 Measurement and Control Computer Block Diagram

INSTRUCTION SET — The iAPX 88/10 instruction repertoire includes variable length instruction format (including double operand instructions), 8-bit and 16-bit signed and unsigned arithmetic operators for binary, BCD and unpacked ASCII data, and iterative word and byte string manipulation functions. The instruction set of the iAPX 88/10 is a superset of the 8080A/8085A family and with available software tools, programs written for the 8080A/8085A can be easily converted and run on the iAPX 88/10 processor. Programs can also be run that are implemented on the iAPX 86/10 with little or no modification.

ARCHITECTURAL FEATURES — A 4-byte instruction queue provides pre-fetching of sequential instructions and can reduce the 750 nsec minimum instruction cycle to 250 nsec for queued instructions. The stack oriented architecture facilitates nested subroutines and co-routines, reentrant code and powerful interrupt handling. The memory expansion capabilities offer a 1 megabyte addressing range. The dynamic relocation scheme allows ease in segmentation of pure procedure and data for efficient memory utilization. Four segment registers (code, stack, data, extra) contain program loaded offset values which are used to map 16-bit addresses to 20-bit addresses. Each register maps 64K bytes at a time and activation of a specific register is controlled explicitly by program control and is also selected implicitly by specific functions and instructions.

Bus Structure

The iSBC 88/40 single board computer has three buses: 1) an internal bus for communicating with on-board memory, analog-to-digital converter, iSBX MULTIMODULES and I/O options; 2) the MULTIBUS system bus for referencing additional memory and I/O options, and 3) the dual-port bus which allows access to RAM from the on-board CPU and the MULTIBUS system bus. Local (on-board) accesses do not require MULTIBUS communication, making the system bus available for use by other MULTIBUS masters (i.e. DMA devices and other single board computers transferring to additional system memory). This feature allows true parallel processing in a multiprocessor environment. In addition, the MULTIBUS interface can be used for system expansion through the use of other 8- and 16-bit iSBC computers, memory and I/O expansion boards.

RAM Capabilities

DUAL-PORT RAM — The dual-port RAM of the iSBC 88/40 board consists of 1K bytes of static RAM, implemented with Intel 2114A chips. The on-board base addess of this RAM is 00C00 (3K) normally; it is relocated to 01C00 (7K) when the iSBC 301 MULTIMODULE RAM is added to the protected RAM. The MULTIBUS port base address of the dual-port RAM can be jumpered to any 1K byte boundary in the 1M byte address space. The dual-port RAM can be accessed in a byte-wide fashion from the MULTIBUS system bus. When accessed from the MULTIBUS system bus, the dual-port RAM decode logic will generate INH1/ (Inhibit RAM) to allow dual-port RAM to overlay other system RAM. The dual-port control logic is designed to favor an on-board RAM access. If the dual-port is not currently performing a memory cycle for the MULTIBUS sytem port, only one wait state will be required. The on-board port may require more than one wait state if the dual-port RAM was busy when the on-board cycle was requested. The LOCK prefix facility of the iAPX 88/10 assembly language will disallow system bus accesses to the dual-port RAM. In addition, the on-board port to the dual-port RAM can be locked by other compatible MULTIBUS masters, which allows true symmetric semaphore operation. When the board is functioning in the master mode, the LOCK prefix will additionally disable other masters from obtaining the system bus.

PRIVATE RAM — In addition to the 1K byte dual-port RAM, there is a 3K byte section of private static RAM not accessible from the system bus. This RAM has a base address of 00000, and consists of three Intel 8185 RAM chips which are interfaced to the multiplexed address/data bus of the iAPX 88/10 microprocessor. Expansion of this private RAM from 3K to 7K bytes can be accomplished by the addition of an iSBC 301 MULTIMODULE RAM (4K bytes). When the 301 is added, protected RAM extends from 0 to 7K, and the base address of the dual-port RAM is relocated from 3K (00C00) to 7K (01C00). All protected RAM accesses require one wait state. The private RAM resides on the local on-board bus, which eliminates contention problems between on-board accesses to private RAM and system bus accesses to dual-port RAM. The private RAM can be battery backed (up to 16K bytes).

Additional RAM can be added by utilizing JEDEC-compatible static or pseudo-static RAMs in the available EPROM sockets.

Parallel I/O Interface

The iSBC 88/40 single board computer contains 24 programmable parallel I/O lines implemented using the Intel 8255A Programmable Peripheral In-

terface. The system software is used to configure the I/O lines in any combination of unidirectional input/output and bidirectional ports indicated in Table 1. There the I/O interface may be customized to meet specific peripheral requirements. In order to take full advantage of the large number of possible I/O configurations, sockets are provided for interchangeable I/O line drivers and terminators. Port 2 can also accept TTL compatible peripheral drives, such as 75461/462, 75471/472, etc. These are open collector, high voltage drivers (up to 55 volts) which can sink 300 mA. Hence, the flexibility of the I/O interface is further enhanced by the capability of selecting the appropriate combination of optional line drivers and terminators to provide the required sink current, polarity, and drive/termination characteristics for each application. The 24 programmable I/O lines and signal ground lines are brought out to a 50-pin edge connector that mates with flat, woven, or round cable. This edge connector is also compatible with the Intel iCS 920 Digital I/O and iCS 930 AC Signal Conditioning/Termination Panels, for field wiring, optical isolation and high power (up to 3 amp) power drive.

EPROM Capabilities

Four (4) 28-pin sockets are provided for the use of Intel 2716s, 2732s, 2764s, future JEDEC-compatible 128K and 256K bit EPROMs and their respective ROMs. When using 2764s the on-board EPROM capacity is 32K bytes. Read only memory expansion is available through the use of the iSBC 341 EPROM/ROM memory expansion MULTIMODULE. When the iSBC 341 is used an additional four (4) EPROM sockets are made available, for a total iSBC 88/40 board capacity of 64K bytes EPROM with Intel 2764s.

E²PROM Capabilities

The four 28-pin sockets can also accommodate Intel 2816 E²PROMs, for dynamic storage of control loop setpoints, conversion parameters, or other data (or programs) that change periodically but must be kept in nonvolatile storage. To give the user dynamic control of this nonvolatile memory, the iSBC 88/40 board also contains an on-board DC to DC converter which under program control will furnish the voltage necessary for modifying the contents of Intel 2816/2815 E²PROMs.

Timing Logic

The iSBC 88/40 board provides an 8253-5 Programmable Interval Timer, which contains three independent, programmable 16-bit timers/event counters. All three of these counters are available to generate time intervals or event counts under software control. The outputs of the three counters may be independently routed to the interrupt matrix. The inputs and outputs of timers 0 and 1 can be connected to parallel I/O lines on the J1 connector, where they replace 8255A port C lines. The third counter is also used for timing E²PROM write operations.

Interrupt Capability

The iSBC 88/40 board provides 9 vectored interrupt levels. The highest level is the NMI (Nonmaskable Interrupt) line which is directly tied to the iAPX 88/10 CPU. This interrupt cannot be inhibited by software and is typically used for signalling catastrophic events (i.e., power failure). On servicing this interrupt, program control will be implicitly transferred through location 00008_H. The Intel 8259A Programmable Interrupt Controller (PIC) provides vectoring for the next eight interrupt levels. As shown in Table 2, a selection

Table 1. Input/Output Port Modes of Operation

Port	Lines (qty)	Mode of Operation					
		Unidirectional				Bidirectional	Control
		Input		Output			
		Latched	Latched & Strobed	Latched	Latched & Strobed		
1	8	X	X	X	X	X	
2	8	X	X	X	X		
3	4	X		X			X[1]
	4	X		X			X[1]

NOTE:

1. Part of port 3 must be used as a control port when either port 1 or port 2 are used as a latched and strobed input or a latched and strobed output port or port 1 is used as a bidirectional port.

of four priority processing modes is available to the designer to match system requirements. Operating mode and priority assignments may be reconfigured dynamically via software at any time during system operation. The PIC accepts interrupt requests from the programmable parallel and/or iSBX interfaces, the programmable timers, the system bus, or directly from peripheral equipment. The PIC then determines which of the incoming requests is of the highest priority, determines whether this request is of higher priority than the level currently being serviced, and, if appropriate, issues an interrupt to the CPU. Any combination of interrupt levels may be masked, via software, by storing a single byte in the interrupt mask register of the PIC. The PIC generates a unique memory address for each interrupt level. These addresses are equally spaced at 4-byte intervals. This 32-byte block may begin at any 32-byte boundary in the lowest 1K bytes of memory*, and contains unique instruction pointers and code segment offset values (for expanded memory operation) for each interrupt level. After acknowledging an interrupt and obtaining a device identifier byte from the 8259A PIC, the CPU will store its status flags on the stack and execute an indirect CALL instruction through the vector location (derived from the device identifier) to the interrupt service routine.

***NOTE:** The first 32 vector locations are reserved by Intel for dedicated vectors. Users who wish to maintain compatibility with present and future Intel products should not use these locations for user-defined vector addresses.

Table 2. Programmable Interrupt Modes

Mode	Operation
Fully nested	Interrupt request line priorities fixed at 0 as highest, 7 as lowest.
Auto-rotating	Equal priority. Each level, after receiving service, becomes the lowest priority level until next interrupt occurs.
Specific priority	System software assigns lowest priority level. Priority of all other levels based in sequence numerically on this assignment.
Polled	System software examines priority-encoded system interrupt status via interrupt status register.

INTERRUPT REQUEST GENERATION — Interrupt requests may originate from 26 sources. Two jumper selectable interrupt requests can be automatically generated by the programmable peripheral interface when a byte of information is ready to be transferred to the CPU (i.e., input buffer is full) or a byte of information has been transferred to a peripheral device (i.e., output buffer is empty). A jumper selectable request can be generated by each of the programmable timers. An additional interrupt request line may be jumpered directly from the parallel I/O driver terminator section. Eight prioritized interrupt request lines allow the iSBC 88/40 board to recognize and service interrupts originating from peripheral boards interfaced via the MULTIBUS system bus. The fail safe timer can be selected as an interrupt source. Also, interrupts are provided from the iSBX connectors (6), end-of-conversion, PFIN and from the power line clock.

Power-Fail Control

Control logic is also included to accept a power-fail interrupt in conjunction with the AC-low signal from the iSBC 635, iSBC 640, and iCS 645 Power Supply or equivalent.

iSBX MULTIMODULE Expansion Capabilities

Three iSBX MULTIMODULE connectors are provided on the iSBC 88/40 board. Up to three (3) single wide MULTIMODULE or one (1) double wide and one (1) single wide iSBX MULTIMODULE can be added to the iSBC 88/40 board. A wide variety of peripheral controllers, analog and digital expansion options are available. For more information on specific iSBX MULTIMODULES consult the Intel OEM Microcomputer System Configuration Guide.

Processing Expansion Capabilities

The addition of a iSBC 337 Multimodule Numeric Data Processor offers high performance integer and floating point math functions to users of the iSBC 88/40 board. The iSBC 337 incorporates the Intel 8087 and because of the MULTIMODULE implementation, it allows on-board expansion directly on the iSBC 88/40 board, eliminating the need for additional boards for floating point requirements.

MULTIBUS Expansion

Memory and I/O capacity may be expanded further and additional functions added using Intel MULTIBUS compatible expansion boards. Memory may be expanded by adding user specified combinations of RAM boards, EPROM boards, or memory combination boards. Input/output capacity may be increased by adding digital I/O and analog I/O MULTIBUS expansion boards. Mass storage capability may be acheived by adding single or double density diskette controllers, or hard disk con-

trollers either through the use of expansion boards and iSBX MULTIMODULES. Modular expandable backplanes and cardcages are available to support multiboard systems.

NOTE: Certain system restrictions may be incurred by the inclusion of some of the iSBC 80 family options in an iSBC 88/40 system. Consult the Intel OEM Microcomputer System Configuration Guide for specific data.

Analog Input Section

The analog section of the iSBC 88/40 board receives all control signals through the local bus to initiate channel selection, gain selection, sample and hold operation, and analog-to-digital conversion. See Figure 2.

INPUT CAPACITY — 32 separate analog signals may be randomly or sequentially sampled in single-ended mode with the 32 input multiplexers and a common ground. For noiser environments, differential input mode can be configured to achieve 16 separate differential signal inputs, or 32 pseudo differential inputs.

RESOLUTION — The analog section provides 12-bit resolution with a successive approximation analog-to-digital converter. For bipolar operation (−5 to +5 or −10 to +10 volts) it provides 11 bits plus sign.

SPEED — The A-to-D converter conversion speed is 50 μs (20 kHz samples per second). Combined with the programming interface, maximum throughput via the local bus and into memory will be 55 microseconds per sample, or 18 kHz samples per second, for a single channel, a random channel, or a sequential channel scan at a gain of 1, 5 ms at a gain of 5, 250 ms at a gain of 50, and 20 ms at a gain of 250. A-to-D conversion is initiated via a programmed command from the iAPX 88/10 central processor. Interrupt on end-of-conversion is a standard feature to ease programming and timing constraints.

ACCURACY — High quality components are used to achieve 12 bits resolution and accuracy of 0.035% full scale range ± ½ LSB. Offset is adjustable under program control to obtain a nominal ± 0.024% FSR ± ½ LSB accuracy at any fixed temperature between 0°C and 60°C (gain = 1). See specifications for other gain accuracies.

GAIN — To allow sampling of millivolt level signals such as strain gauges and thermocouples, gain is made configurable via user program commands up to 250× (20 millivolts full scale input range). User can select gain ranges of 1 (5V), 5 (1V), 50 (100 mV), 250 (20 mV) to match his application.

OPERATIONAL DESCRIPTION — The iSBC 88/40 single board computer addresses the analog-to-digital converter by executing IN or OUT instructions to the port address. Analog-to-digital conversions can be programmed in either of two modes: 1) start conversion and poll for end-of-conversion (EOC), or 2) start conversion and wait for interrupt at end of conversion. When the conversion is complete as signaled by one of the above techniques, INput instructions read two bytes (low and high bytes) containing the 12-bit data word as shown on the following page.

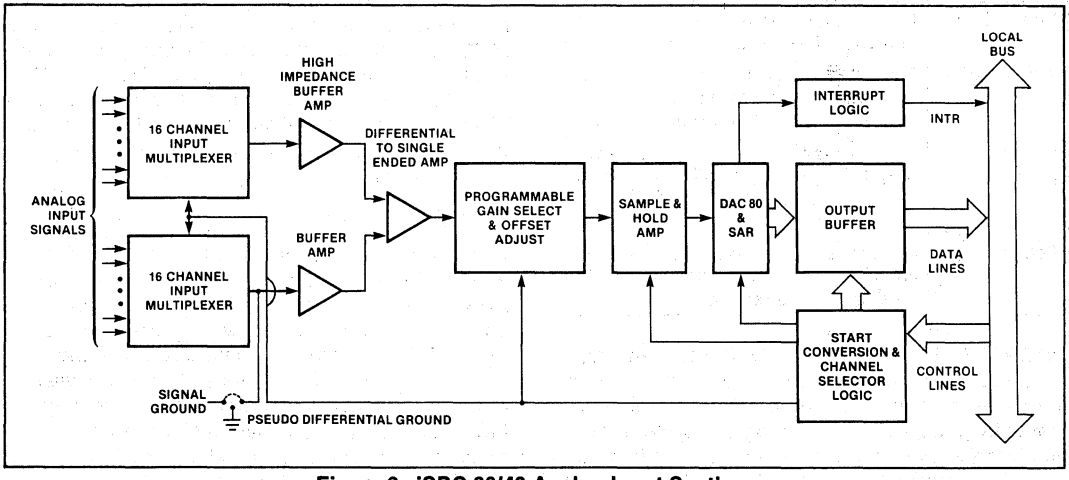


Figure 2. iSBC 88/40 Analog Input Section

Output Command — Select input channel and start conversion.

	GAIN		CONNECTOR		CHANNEL SELECT			
BIT POSITION	7	6	5	4	3	2	1	0
INPUT CHANNEL	G1	G2		J	C3	C2	C1	C0

Input Data — Read converted data (low byte) or Read converted data (high byte).

	DATA							
BIT POSITION	7	6	5	4	3	2	1	0
LOW/STATUS BYTE	D3	D2	D1	D0				EOC

	DATA							
HIGH BYTE	D11	D10	D9	D8	D7	D6	D5	D4

Offset Correction — At higher gains (×50, ×250) the voltage offset tempco in the A/D circuitry can sometimes cause unacceptable inaccuracies. To correct for this offset, one channel can be dedicated to be used as a reference standard. This channel can be read from the program to determine the amount of offset. The reading from this channel will then be subtracted from all other channel readings, in effect eliminating the offset tempco.

System Software Development

The development cycle of the iSBC 88/40 board may be significantly reduced using an Intel Intellec Microcomputer Development System with the optional iAPX 88/iAPX 86 Software Development package.

The iAPX 88/iAPX 86 Software Development package includes Intel's high-level programming language, PL/M 86. PL/M 86 provides the capability to program in a natural, algorithmic language and eliminates the need to manage register usage or allocate memory. PL/M 86 programs can be written in a much shorter time than assembly language programs for a given application.

SPECIFICATIONS

Word Size

Instruction — 8, 16, or 32 bits

Data — 8 bits

Instruction Cycle Time

417 nanoseconds for fastest executable instruction (assumes instruction is in the queue). 1.04 microseconds for fastest executable instruction (assumes instruction is not in the queue).

Memory Capacity

On-board ROM/EPROM/E²PROM

Up to 32K bytes; user installed in 2K, 4K or 8K byte increments or up to 64K if iSBC 341 MULTIMODULE EPROM option installed. Up to 8K bytes of E²PROM using Intel 2816s may be user-installed in increments of 2, 4 or 8K bytes.

On-board RAM

4K bytes or 8K bytes if the iSBC 301 MULTIMODULE RAM is installed. Integrity maintained during power failure with user-furnished batteries. 1K bytes are dual-ported.

Off-board Expansion

Up to 1 megabyte of user-specified combination of RAM, ROM, and EPROM.

Memory Addressing

On-board ROM/EPROM

FE000-FFFFF (using 2716 EPROMs)
FC000-FFFFF (using 2732 EPROMs)
F8000-FFFFF (using 2764 EPROMs)

On-board ROM/EPROM (With iSBC 341 MULTIMODULE EPROM option installed)

FC000-FFFFF (using 2716 EPROMs)
F8000-FFFFF (using 2732 EPROMs)
F0000-FFFFF (using 2764 EPROMs)

On-board RAM (CPU Access)

00000-00FFF

00000-01FFF (if iSBC 301 MULTIMODULE RAM option installed)

On-board RAM

Jumpers allow 1K bytes of RAM to act as slave RAM for access by another bus master. Addressing may be set within any 1K boundary in the 1-megabyte system address space.

Slave RAM Access

Average; 350 nanoseconds

Interval Timer

Output Frequencies —

Function	Single Timer		Dual Timers (Two Timers Cascaded)
	Min.	Max.	
Real-Time Interrupt Interval	0.977 μs	64 ms	69.9 minutes maximum
Rate Generator (Frequency)	15.625 Hz	1024 kHz	0.00024 Hz minimum

iAPX 88/10 CPU Clock

4.8 MHz ± 0.1%

I/O Addressing

All communications to parallel I/O ports, iSBX bus, A/D port, timers, and interrupt controller are via read and write commands from the on-board iAPX 88/10 CPU.

Interface Compatability

Parallel I/O — 24 programmable lines (8 lines per port); one port includes a bidirectional bus driver. IC sockets are included for user installation of line drivers and/or I/O terminators and/or peripheral drivers as required for interface ports.

iSBX Bus Connectors — Three iSBX bus connectors are provided. These connectors accept 8-bit iSBX MULTIMODULE boards. One set of the three iSBX MULTIMODULE connectors will accept a double wide iSBX MULTIMODULE board.

Interrupts

iAPX 88/10 CPU includes a non-maskable interrupt (NMI). NMI interrupt is provided for catastrophic events such as power failure. The on-board 8259A PIC provides 8-bit identifier of interrupting device to CPU. CPU multiplies identifier by four to derive vector address. Jumpers select interrupts from 26 sources without necessity of external hardware. PIC may be programmed to accommodate edge-sensitive or level-sensitive inputs.

Analog Input

16 differential (bipolar operation) or 32 single-ended (unipolar operation).

Full Scale Voltage Range — −5 to +5 volts (bipolar), 0 to +5 volts (unipolar).

Gain — Program selectable for gain of 1, 5, 50, or 250.

Resolution — 12 bits (11 bits plus sign for ±5, ±10 volts).

Accuracy — Including noise and dynamic errors

Gain	25°C
1	±0.05% FSR*
5	±0.075% FSR*
50	±0.085% FSR*
250	±0.12% FSR*

***NOTE:** FSR = Full Scale Range ± ½ LSB. Figures are in percent of full scale reading. At any fixed temperature between 0°C and 60°C, the accuracy is adjustable to ±0.05% of full scale.

Gain TC (at gain = 1) — 30 PPM (typical), 56 PPM (max) per degree centigrade, 40 PPM at other gains.

Offset TC — (in % of FSR/°C)	Gain	Offset TC (typical)
	1	0.0018%
	5	0.0036%
	50	0.024%
	250	0.12%

Sample and Hold-sample Time — 15 μs

Aperature-hold Aperature Time — 120 ns

Input Overvoltage Protection — 30 volts

Input Impedance — 20 megohms (min.)

Conversion Speed — 50 μs (max.) at gain = 1

Common Mode Rejection Ratio — 60 dB (min.)

Physical Characteristics

Width — 30.48 cm (12.00 in.)

Length — 17.15 cm (6.75 in.)

Height — 1.78 cm (0.7 in.)
2.82 cm (1.13 in.) with iSBC Memory Expansion, MULTIMODULES, iSBX Numeric Data Processor or iSBX MULTIMODULES.

Electrical Requirements

Power Requirements (Maximum) —

Configuration	+5V		+5V Aux		+12V		−12V	
	Typ	Max	Typ	Max	Typ	Max	Typ	Max
iSBC 88/40[1,2]	4	5.5	100	150	80	120	30	40

NOTES:
1. The current requirement includes one worst case (active-standby) EPROM current.
2. If +5V Aux is supplied by the iSBC 88/40 board, the total +5V current is the sum of the +5V and the +5V Aux.

Environmental Requirements

Operating Temperature — 0° to 55°C (32°C to 131°F) with 200 lfm air flow

Relative Humidity — to 90% without condensation

Equipment Supplied

The following are supplied with the iSBC 88/40 board:

a. Schematic diagram

b. Assembly drawing

Reference Manuals

124978-001 — iSBC 88/40 Measurement and Control Computer Hardware Reference Manual (NOT SUPPLIED).

Manuals may be ordered from an Intel sales representative, distributor office or from Intel Literature Department, 3065 Bowers Avenue, Santa Clara, California 95051.

ORDERING INFORMATION

Part Number	Description
SBC 88/40	Measurement and Control Computer