



80C86A

16-BIT CHMOS MICROPROCESSOR

- Pin-for-Pin and Functionally Compatible to Industry Standard HMOS 8086
- Fully Static Design with Frequency Range from D.C. to:
 - 8 MHz for 80C86A-2
- Low Power Operation
 - Operating $I_{CC} = 10 \text{ mA/MHz}$
 - Standby $I_{CCS} = 500 \mu\text{A max}$
- Bus-Hold Circuitry Eliminates Pull-Up Resistors
- Direct Addressing Capability of 1 MByte of Memory
- Architecture Designed for Powerful Assembly Language and Efficient High Level Languages
- 24 Operand Addressing Modes
- Byte, Word and Block Operations
- 8 and 16-Bit Signed and Unsigned Arithmetic
 - Binary or Decimal
 - Multiply and Divide
- Available in 40-Lead Plastic DIP

The Intel 80C86A is a high performance, CHMOS version of the industry standard HMOS 8086 16-bit CPU. The 80C86A available in 8 MHz clock rates, offers two modes of operation: MINimum for small systems and MAXimum for larger applications such as multiprocessing. It is available in 40-pin DIP package.

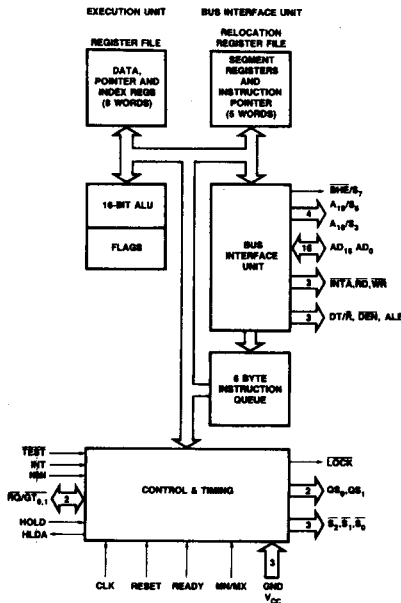


Figure 1. 80C86A CPU Block Diagram

240029-1

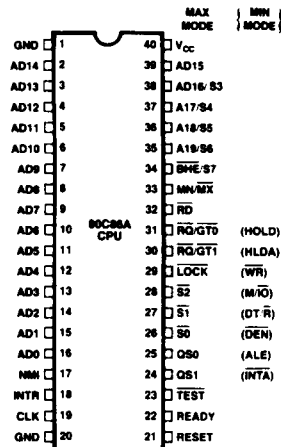


Figure 2. 80C86A 40-Lead DIP Configuration

240029-2

Table 1. Pin Description

The following pin function descriptions are for 80C86AA systems in either minimum or maximum mode. The "Local Bus" in these descriptions is the direct multiplexed bus interface connection to the 80C86A (without regard to additional bus buffers).

Symbol	Pin No.	Type	Name and Function																		
AD ₁₅ -AD ₀	2-16, 39	I/O	<p>ADDRESS DATA BUS: These lines constitute the time multiplexed memory/I/O address (T₁) and data (T₂, T₃, T_W, T₄) bus. A₀ is analogous to $\overline{\text{BHE}}$ for the lower byte of the data bus, pins D₇-D₀. It is LOW during T₁ when a byte is to be transferred on the lower portion of the bus in memory or I/O operations. Eight-bit oriented devices tied to the lower half would normally use A₀ to condition chip select functions. (See $\overline{\text{BHE}}$.) These lines are active HIGH and float to 3-state OFF⁽¹⁾ during interrupt acknowledge and local bus "hold acknowledge."</p>																		
A ₁₉ /S ₆ , A ₁₈ /S ₅ , A ₁₇ /S ₄ , A ₁₆ /S ₃	35-38	O	<p>ADDRESS/STATUS: During T₁ these are the four most significant address lines for memory operations. During I/O operations these lines are LOW. During memory and I/O operations, status information is available on these lines during T₂, T₃, T_W, and T₄. The status of the interrupt enable FLAG bit (S₅) is updated at the beginning of each CLK cycle. A₁₇/S₄ and A₁₆/S₃ are encoded as shown.</p> <p>This information indicates which relocation register is presently being used for data accessing.</p> <p>These lines float to 3-state OFF⁽¹⁾ during local bus "hold acknowledge."</p> <table border="1" data-bbox="501 901 1157 1106"> <thead> <tr> <th>A₁₇/S₄</th> <th>A₁₆/S₃</th> <th>Characteristics</th> </tr> </thead> <tbody> <tr> <td>0 (LOW)</td> <td>0</td> <td>Alternate Data</td> </tr> <tr> <td>0</td> <td>1</td> <td>Stack</td> </tr> <tr> <td>1 (HIGH)</td> <td>0</td> <td>Code or None</td> </tr> <tr> <td>1</td> <td>1</td> <td>Data</td> </tr> <tr> <td colspan="3">S₆ is 0 (LOW)</td> </tr> </tbody> </table>	A ₁₇ /S ₄	A ₁₆ /S ₃	Characteristics	0 (LOW)	0	Alternate Data	0	1	Stack	1 (HIGH)	0	Code or None	1	1	Data	S ₆ is 0 (LOW)		
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1	1	Data																			
S ₆ is 0 (LOW)																					
$\overline{\text{BHE}}$ /S ₇	34	O	<p>BUS HIGH ENABLE/STATUS: During T₁ the bus high enable signal ($\overline{\text{BHE}}$) should be used to enable data onto the most significant half of the data bus, pins D₁₅-D₈. Eight-bit oriented devices tied to the upper half of the bus would normally use $\overline{\text{BHE}}$ to condition chip select functions. $\overline{\text{BHE}}$ is LOW during T₁ for read, write, and interrupt acknowledge cycles when a byte is to be transferred on the high portion of the bus. The S₇ status information is available during T₂, T₃, and T₄. The signal is active LOW, and floats to 3-state OFF⁽¹⁾ in "hold." It is LOW during T₁ for the first interrupt acknowledge cycle.</p> <table border="1" data-bbox="501 1369 1157 1574"> <thead> <tr> <th>$\overline{\text{BHE}}$</th> <th>A₀</th> <th>Characteristics</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>0</td> <td>Whole word</td> </tr> <tr> <td>0</td> <td>1</td> <td>Upper byte from/ to odd address</td> </tr> <tr> <td>1</td> <td>0</td> <td>Lower byte from/ to even address</td> </tr> <tr> <td>1</td> <td>1</td> <td>None</td> </tr> </tbody> </table>	$\overline{\text{BHE}}$	A ₀	Characteristics	0	0	Whole word	0	1	Upper byte from/ to odd address	1	0	Lower byte from/ to even address	1	1	None			
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Table 1. Pin Description (Continued)

Symbol	Pin No.	Type	Name and Function
\overline{RD}	32	O	<p>READ: Read strobe indicates that the processor is performing a memory of I/O read cycle, depending on the state of the S_2 pin. This signal is used to read devices which reside on the 80C86A local bus. \overline{RD} is active LOW during T_2, T_3 and T_W of any read cycle, and is guaranteed to remain HIGH in T_2 until the 80C86A local bus has floated.</p> <p>This floats to 3-state OFF in "hold acknowledge."</p>
READY	22	I	<p>READY: is the acknowledgement from the addressed memory or I/O device that it will complete the data transfer. The READY signal from memory/IO is synchronized by the 82C84A Clock Generator to form READY. This signal is active HIGH. The 80C86A READY input is not synchronized. Correct operation is not guaranteed if the setup and hold times are not met.</p>
INTR	18	I	<p>INTERRUPT REQUEST: is a level triggered input which is sampled during the last clock cycle of each instruction to determine if the processor should enter into an interrupt acknowledge operation. A subroutine is vectored to via an interrupt vector lookup table located in system memory. It can be internally masked by software resetting the interrupt enable bit. INTR is internally synchronized. This signal is active HIGH.</p>
TEST	23	I	<p>TEST: input is examined by the "Wait" instruction. If the TEST input is LOW execution continues, otherwise the processor waits in an "Idle" state. This input is synchronized internally during each clock cycle on the leading edge of CLK.</p>
NMI	17	I	<p>NON-MASKABLE INTERRUPT: an edge triggered input which causes a type 2 interrupt. A subroutine is vectored to via an interrupt vector lookup table located in system memory. NMI is not maskable internally by software. A transition from a LOW to HIGH initiates the interrupt at the end of the current instruction. This input is internally synchronized.</p>
RESET	21	I	<p>RESET: causes the processor to immediately terminate its present activity. The signal must be active HIGH for at least four clock cycles. It restarts execution, as described in the Instruction Set description, when RESET returns LOW. RESET is internally synchronized.</p>
CLK	19	I	<p>CLOCK: provides the basic timing for the processor and bus controller. It is asymmetric with a 33% duty cycle to provide optimized internal timing.</p>
V_{CC}	40		<p>V_{CC}: +5V power supply pin.</p>
GND	1, 20		<p>GROUND: Both must be connected.</p>
MN/\overline{MX}	33	I	<p>MINIMUM/MAXIMUM: indicates what mode the processor is to operate in. The two modes are discussed in the following sections.</p>

Table 1. Pin Description (Continued)

The following pin function descriptions are for the 80C86A/82C88 system in maximum mode (i.e., $MN/\overline{MX} = V_{SS}$). Only the pin functions which are unique to maximum mode are described; all other pin functions are as described above.

Symbol	Pin No.	Type	Name and Function			
$\overline{S_2}, \overline{S_1}, \overline{S_0}$	26-28	O	<p>STATUS: active during T_4, T_1, and T_2 and is returned to the passive state (1,1,1) during T_3 or during T_W when READY is HIGH. This status is used by the 82C88 Bus Controller to generate all memory and I/O access control signals. Any change by $\overline{S_2}, \overline{S_1}, \overline{S_0}$ during T_4 is used to indicate the beginning of a bus cycle, and the return to the passive state in T_3 or T_W is used to indicate the end of a bus cycle. These signals float to 3-state OFF⁽¹⁾ in "hold acknowledge." These status lines are encoded as shown.</p>			
			$\overline{S_2}$	$\overline{S_1}$	$\overline{S_0}$	Characteristics
			0 (LOW)	0	0	Interrupt Acknowledge
0	0	1	Read I/O Port			
0	1	0	Write I/O Port			
0	1	1	Halt			
1 (HIGH)	0	0	Code Access			
1	0	1	Read Memory			
1	1	0	Write Memory			
1	1	1	Passive			
$\overline{RQ}/\overline{GT_0}$, $\overline{RQ}/\overline{GT_1}$	30, 31	I/O	<p>REQUEST/GRANT: pins are used by other local bus masters to force the processor to release the local bus at the end of the processor's current bus cycle. Each pin is bidirectional with $\overline{RQ}/\overline{GT_0}$ having higher priority than $\overline{RQ}/\overline{GT_1}$. $\overline{RQ}/\overline{GT}$ has an internal pull-up resistor so may be left unconnected. The request/grant sequence is as follows (see timing diagram):</p> <ol style="list-style-type: none"> 1. A pulse of 1 CLK wide from another local bus master indicates a local bus request ("hold") to the 80C86A (pulse 1). 2. During a T_4 or T_1 clock cycle, a pulse 1 CLK wide from the 80C86A to the requesting master (pulse 2), indicates that the 80C86A has allowed the local bus to float and that it will enter the "hold acknowledge" state at the next CLK. The CPU's bus interface unit is disconnected logically from the local bus during "hold acknowledge." 3. A pulse 1 CLK wide from the requesting master indicates to the 80C86A (pulse 3) that the "hold" request is about to end and that 80C86A can reclaim the local bus at the next CLK. <p>Each master-master exchange of the local bus is a sequence of 3 pulses. There must be one dead CLK cycle after each bus exchange. Pulses are active LOW.</p> <p>If the request is made while the CPU is performing a memory cycle, it will release the local bus during T_4 of the cycle when all the following conditions are met:</p> <ol style="list-style-type: none"> 1. Request occurs on or before T_2. 2. Current cycle is not the low byte of a word (on an odd address). 3. Current cycle is not the first acknowledge of an interrupt acknowledge sequence. 4. A locked instruction is not currently executing. 			

Table 1. Pin Description (Continued)

Symbol	Pin No.	Type	Name and Function															
			If the local bus is idle when the request is made the two possible events will follow: 1. Local bus will be released during the next clock. 2. A memory cycle will start within 3 clocks. Now the four rules for a currently active memory cycle apply with condition number 1 already satisfied.															
LOCK	29	O	LOCK: output indicates that other system bus masters are not to gain control of the system bus while LOCK is active LOW. The LOCK signal is activated by the "LOCK" prefix instruction and remains active until the completion of the next instruction. This signal is active LOW, and floats to 3-state OFF(1) in "hold acknowledge."															
QS ₁ , QS ₀	24, 25	O	QUEUE STATUS: The queue status is valid during the CLK cycle after which the queue operation is performed. QS ₁ and QS ₀ provide status to allow external tracking of the internal 80C86A instruction queue.															
			<table border="1"> <thead> <tr> <th>QS₁</th> <th>QS₀</th> <th>Characteristics</th> </tr> </thead> <tbody> <tr> <td>0 (LOW)</td> <td>0</td> <td>No Operation</td> </tr> <tr> <td>0</td> <td>1</td> <td>First Byte of Op Code from Queue</td> </tr> <tr> <td>1 (HIGH)</td> <td>0</td> <td>Empty the Queue</td> </tr> <tr> <td>1</td> <td>1</td> <td>Subsequent Byte from Queue</td> </tr> </tbody> </table>	QS ₁	QS ₀	Characteristics	0 (LOW)	0	No Operation	0	1	First Byte of Op Code from Queue	1 (HIGH)	0	Empty the Queue	1	1	Subsequent Byte from Queue
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3

The following pin function descriptions are for the 80C86A in minimum mode (i.e., $MN/\overline{MX} = V_{CC}$). Only the pin functions which are unique to minimum mode are described; all other pin functions are described above.

M/ \overline{IO}	28	O	STATUS LINE: logically equivalent to S ₂ in the maximum mode. It is used to distinguish a memory access from an I/O access. M/ \overline{IO} becomes valid in the T ₄ preceding a bus cycle and remains valid until the final T ₄ of the cycle (M = HIGH, IO = LOW). M/ \overline{IO} floats to 3-state OFF(1) in local bus "hold acknowledge."
\overline{WR}	29	O	WRITE: indicates that the processor is performing a write memory or write I/O cycle, depending on the state of the M/ \overline{IO} signal. \overline{WR} is active for T ₂ , T ₃ and T _W of any write cycle. It is active LOW, and floats to 3-state OFF(1) in local bus "hold acknowledge."
\overline{INTA}	24	O	\overline{INTA} is used as a read strobe for interrupt acknowledge cycles. It is active LOW during T ₂ , T ₃ and T _W of each interrupt acknowledge cycle.
ALE	25	O	ADDRESS LATCH ENABLE: provided by the processor to latch the address into an address latch. It is a HIGH pulse active during T ₁ of any bus cycle. Note that ALE is never floated.
DT/ \overline{R}	27	O	DATA TRANSMIT/RECEIVE: needed in minimum system that desires to use a data bus transceiver. It is used to control the direction of data flow through the transceiver. Logically DT/ \overline{R} is equivalent to $\overline{S_1}$ in the maximum mode, and its timing is the same as for M/ \overline{IO} . (T = HIGH, R = LOW.) This signal floats to 3-state OFF(1) in local bus "hold acknowledge."

Table 1. Pin Description (Continued)

Symbol	Pin No.	Type	Name and Function
\overline{DEN}	26	O	DATA ENABLE: provided as an output enable for the transceiver in a minimum system which uses the transceiver. \overline{DEN} is active LOW during each memory and I/O access and for \overline{INTA} cycles. For a read or \overline{INTA} cycle it is active from the middle of T_2 until the middle of T_4 , while for a write cycle it is active from the beginning of T_2 until the middle of T_4 . \overline{DEN} floats to 3-state OFF ⁽¹⁾ in local bus "hold acknowledge."
HOLD, HLDA	31, 30	I/O	HOLD: indicates that another master is requesting a local bus "hold." To be acknowledged, HOLD must be active HIGH. The processor receiving the "hold" request will issue HLDA (HIGH) as an acknowledgement in the middle of a T_4 or T_1 clock cycle. Simultaneous with the issuance of HLDA the processor will float the local bus and control lines. After HOLD is detected as being LOW, the processor will LOWER the HLDA, and when the processor needs to run another cycle, it will again drive the local bus and control lines. The same rules as for $\overline{RQ}/\overline{GT}$ apply regarding when the local bus will be released. HOLD is not an asynchronous input. External synchronization should be provided if the system cannot otherwise guarantee the setup time.

NOTE:

1. See the section on Bus Hold Circuitry.

FUNCTIONAL DESCRIPTION**STATIC OPERATION**

All 80C86A circuitry is of static design. Internal registers, counters and latches are static and require no refresh as with dynamic circuit design. This eliminates the minimum operating frequency restriction placed on other microprocessors. The CMOS 80C86A can operate from DC to the appropriate upper frequency limit. The processor clock may be stopped in either state (high/low) and held there indefinitely. This type of operation is especially useful for system debug or power critical applications.

The 80C86A can be single stepped using only the CPU clock. This state can be maintained as long as is necessary. Single step clock operation allows simple interface circuitry to provide critical information for bringing up your system.

Static design also allows very low frequency operation. In a power critical situation, this can provide extremely low power operation since 80C86A power dissipation is directly related to operating frequency. As the system frequency is reduced, so is the operating power until, ultimately, at a DC input frequency, the 80C86A power requirement is the standby current.

INTERNAL ARCHITECTURE

The internal functions of the 80C86A processor are partitioned logically into two processing units. The first is the Bus Interface Unit (BIU) and the second is the Execution Unit (EU) as shown in the block diagram of Figure 1.

These units can interact directly but for the most part perform as separate asynchronous operational processors. The bus interface unit provides the functions related to instruction fetching and queuing, operand fetch and store, and address relocation. This unit also provides the basic bus control. The overlap of instruction pre-fetching provided by this unit serves to increase processor performance through improved bus bandwidth utilization. Up to 6 bytes of the instruction stream can be queued while waiting for decoding and execution.

The instruction stream queuing mechanism allows the BIU to keep the memory utilized very efficiently. Whenever there is space for at least 2 bytes in the queue, the BIU will attempt a word fetch memory cycle. This greatly reduces "dead time" on the memory bus. The queue acts as a First-In-First Out (FIFO) buffer, from which the EU extracts instruction bytes as required. If the queue is empty (following a branch instruction, for example), the first byte into the queue immediately becomes available to the EU.

Memory Reference Need	Segment Register Used	Segment Selection Rule
Instructions	CODE (CS)	Automatic with all instruction prefetch.
Stack	STACK (SS)	All stack pushes and pops. Memory references relative to BP base register except data references.
Local Data	DATA (DS)	Data references when: relative to stack, destination of string operation, or explicitly overridden.
External (Global) Data	EXTRA (ES)	Destination of string operations: Explicitly selected using a segment override.

The execution units receives pre-fetched instructions from the BIU queue and provides un-relocated operand addresses to the BIU. Memory operands are passed through the BIU for processing by the EU, which passes results to the BIU for storage. See the Instruction Set description for further register set and architectural descriptions.

MEMORY ORGANIZATION

The processor provides a 20-bit address to memory which locates the byte being referenced. The memory is organized as a linear array of up to 1 million bytes, addressed as 00000(H) to FFFFF(H). The memory is logically divided into code, data, extra data, and stack segments of up to 64k bytes each, with each segment falling on 16-byte boundaries. (See Figure 3a.)

All memory references are made relative to base addresses contained in high speed segment registers. The segment types were chosen based on the addressing needs of programs. The segment register to be selected is automatically chosen according to the rules of the following table. All information in one segment type share the same logical attributes (e.g. code or data). By structuring memory into relocatable areas of similar characteristics and by automatically selecting segment registers, programs are shorter, faster, and more structured.

3

Word (16-bit) operands can be located on even or odd address boundaries and are thus not constrained to even boundaries as is the case in many 16-bit computers. For address and data operands, the least significant byte of the word is stored in the lower valued address location and the most significant byte in the next higher address location. The BIU automatically performs the proper number of memory accesses, one if the word operand is on an even byte boundary and two if it is on an odd byte boundary. Except for the performance penalty, this double access is transparent to the software. This performance penalty does not occur for instruction fetches, only word operands.

Physically, the memory is organized as a high bank (D₁₅-D₈) and a low bank (D₇-D₀) of 512k 8-bit bytes addressed in parallel by the processor's address lines.

A₁₉-A₁. Byte data with even addresses is transferred on the D₇-D₀ bus lines while odd addressed byte data (A₀ HIGH) is transferred on the D₁₅-D₈ bus lines. The processor provides two enable signals, BHE and A₀, to selectively allow reading from or writing into either an odd byte location, even byte location, or both. The instruction stream is fetched by the processor to the byte level as necessary.

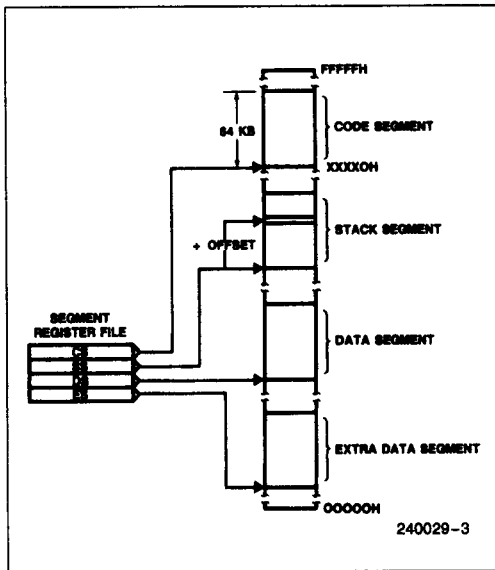


Figure 3a. Memory Organization

In referencing word data the BIU requires one or two memory cycles depending on whether or not the starting byte of the word is on an even or odd address, respectively. Consequently, in referencing

word operands performance can be optimized by locating data on even address boundaries. This is an especially useful technique for using the stack, since odd address references to the stack may adversely affect the context switching time for interrupt processing or task multiplexing.

Certain locations in memory are reserved for specific CPU operations (see Figure 3b.) Locations from address FFFF0H through FFFFFH are reserved for operations including a jump to the initial program loading routine. Following RESET, the CPU will always begin execution at location FFFF0H where the jump must be. Locations 00000H through 003FFH are reserved for interrupt operations. Each of the 256 possible interrupt types has its service routine pointed to by a 4-byte pointer element consisting of a 16-bit segment address and a 16-bit offset address. The pointer elements are assumed to have been stored at the respective places in reserved memory prior to occurrence of interrupts.

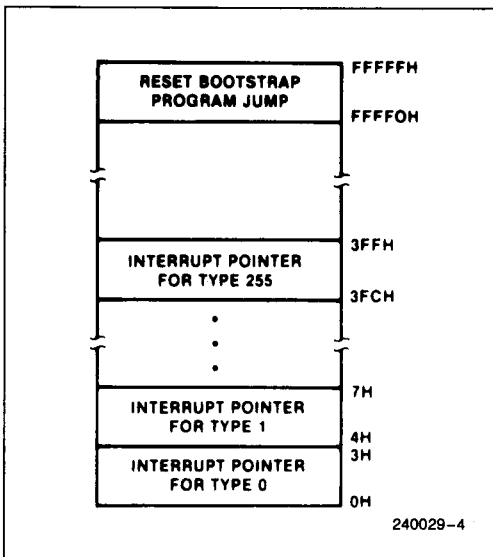


Figure 3b. Reserved Memory Locations

MINIMUM AND MAXIMUM MODES

The requirements for supporting minimum and maximum 80C86A systems are sufficiently different that

they cannot be done efficiently with 40 uniquely defined pins. Consequently, the 80C86A is equipped with a strap pin (MN/MX) which defines the system configuration. The definition of a certain subset of the pins changes dependent on the condition of the strap pin. When MN/MX pin is strapped to GND, the 80C86A treats pins 24 through 31 in maximum mode. An 82C88 bus controller interprets status information coded into \overline{S}_0 , \overline{S}_1 , \overline{S}_2 to generate bus timing and control signals compatible with the MULTIBUS architecture. When the MN/MX pin is strapped to V_{CC} , the 80C86A generates bus control signals itself on pins 24 through 31, as shown in parentheses in Figure 2. Examples of minimum mode and maximum mode systems are shown in Figure 4.

BUS OPERATION

The 80C86A has a combined address and data bus commonly referred to as a time multiplexed bus. This technique provides the most efficient use of pins on the processor. This "local bus" can be buffered directly and used throughout the system with address latching provided on memory and I/O modules. In addition, the bus can also be demultiplexed at the processor with a single set of address latches if a standard non-multiplexed bus is desired for the system.

Each processor bus cycle consists of at least four CLK cycles. These are referred to as T_1 , T_2 , T_3 and T_4 (see Figure 5). The address is emitted from the processor during T_1 and data transfer occurs on the bus during T_3 and T_4 . T_2 is used primarily for changing the direction of the bus during read operations. In the event that a "NOT READY" indication is given by the addressed device, "Wait" states (T_W) are inserted between T_3 and T_4 . Each inserted "Wait" state is of the same duration as a CLK cycle. Periods can occur between 80C86A bus cycles. These are referred to as "Idle" states (T_i) or inactive CLK cycles. The processor uses these cycles for internal housekeeping.

During T_1 of any bus cycle the ALE (Address Latch Enable) signal is emitted (by either the processor or the 82C88 bus controller, depending on the MN/MX strap). At the trailing edge of this pulse, a valid address and certain status information for the cycle may be latched.

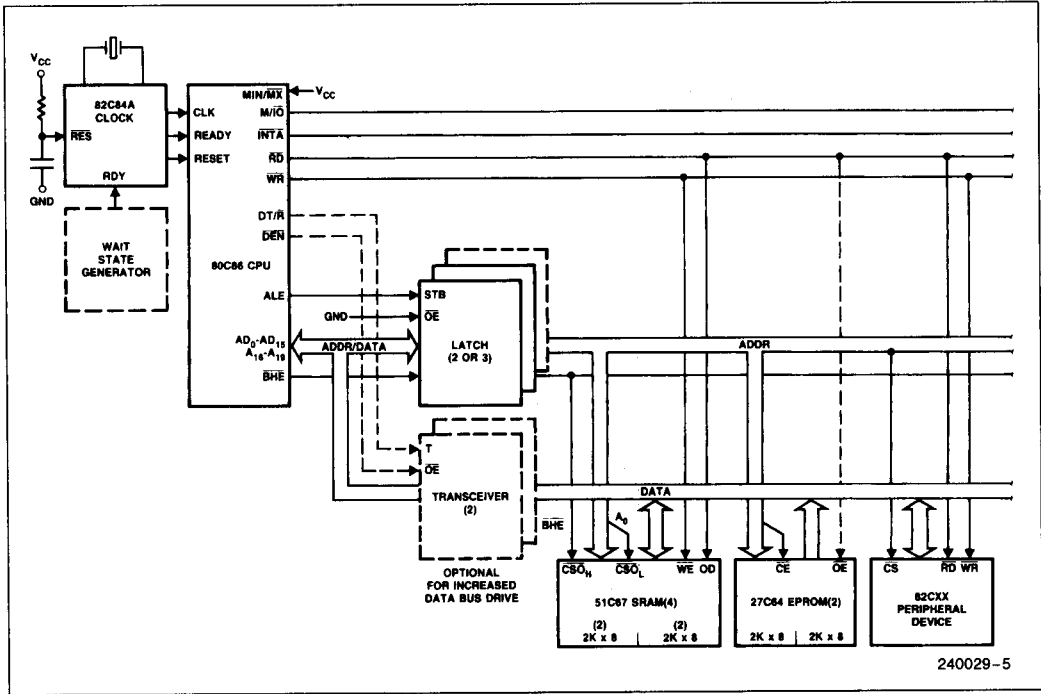


Figure 4a. Minimum Mode IAPX 80C86A Typical Configuration

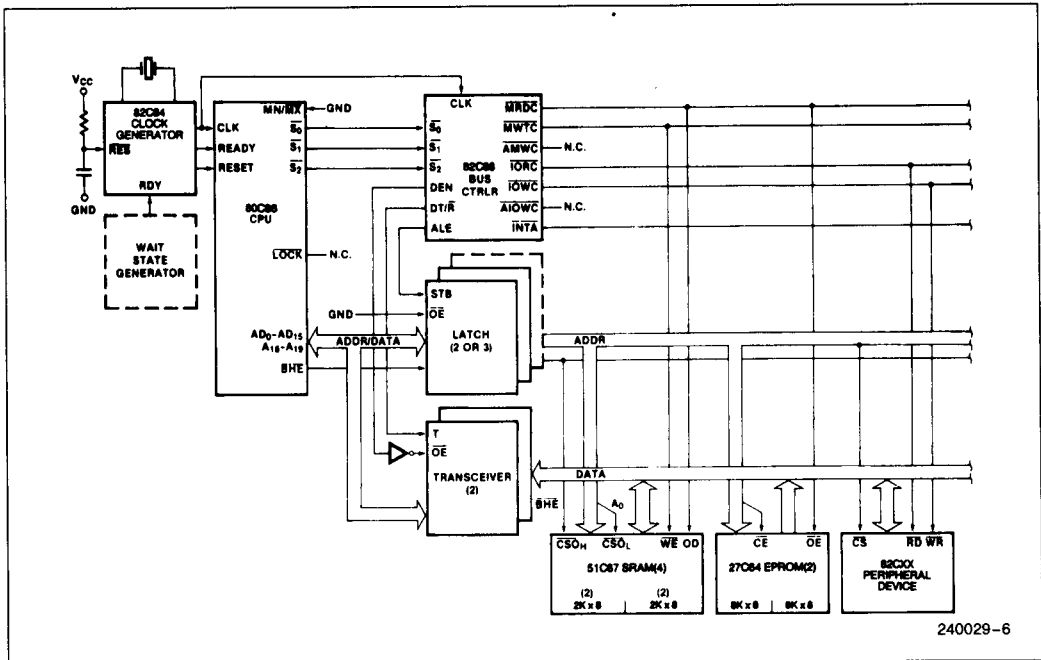


Figure 4b. Maximum Mode 80C86A Typical Configuration

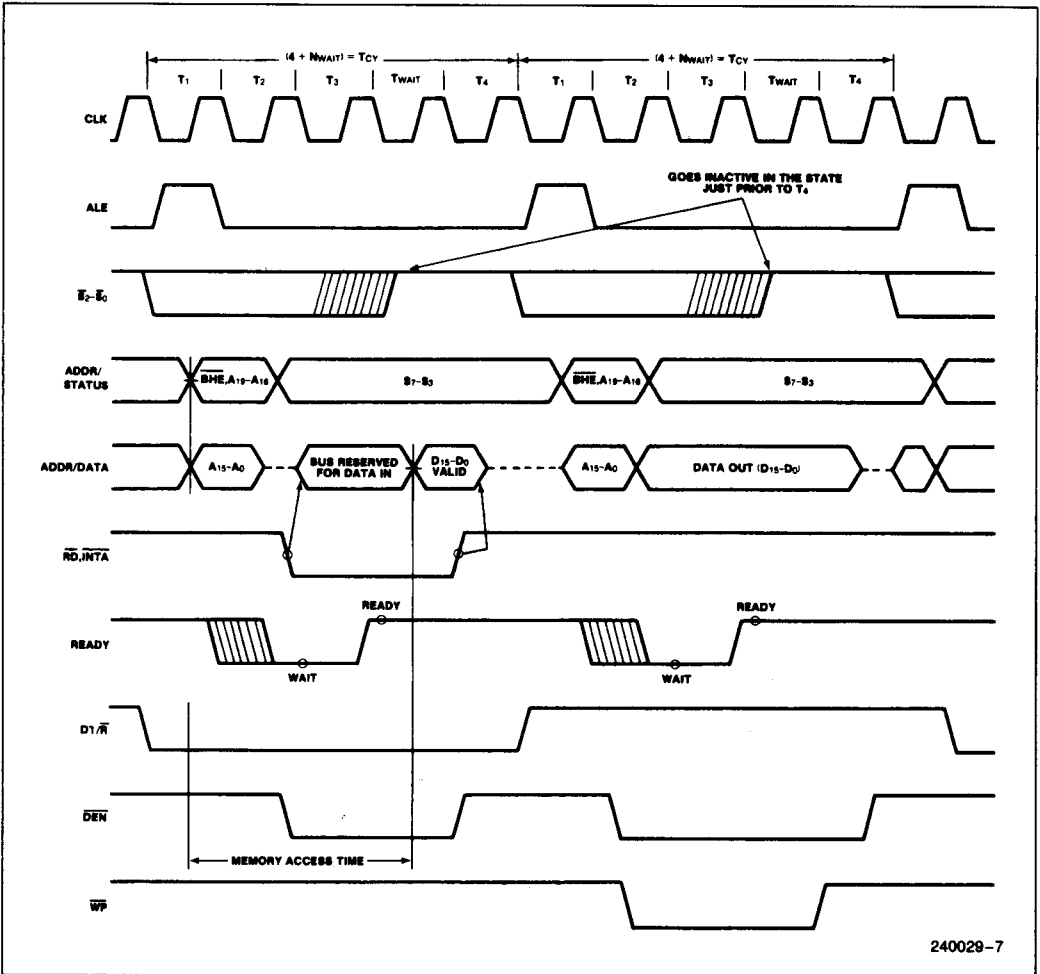


Figure 5. Basic System Timing

Status bits \bar{S}_0 , \bar{S}_1 , and \bar{S}_2 are used, in maximum mode, by the bus controller to identify the type of bus transaction according to the following table:

\bar{S}_2	\bar{S}_1	\bar{S}_0	Characteristics
0 (LOW)	0	0	Interrupt Acknowledge
0	0	1	Read I/O
0	1	0	Write I/O
0	1	1	Halt
1 (HIGH)	0	0	Instruction Fetch
1	0	1	Read Data from Memory
1	1	0	Write Data to Memory
1	1	1	Passive (no bus cycle)

therefore valid during T_2 through T_4 . S_3 and S_4 indicate which segment register (see Instruction Set description) was used for this bus cycle in forming the address, according to the following table:

S_4	S_3	Characteristics
0 (LOW)	0	Alternate Data (extra segment)
0	1	Stack
1 (HIGH)	0	Code or None
1	1	Data

S_5 is a reflection of the PSW interrupt enable bit. $S_6 = 0$ and S_7 is a spare status pin.

Status bits S_3 through S_7 are multiplexed with high-order address bits and the \bar{BHE} signal, and are

I/O ADDRESSING

In the 80C86A, I/O operations can address up to a maximum of 64k I/O byte registers or 32k I/O word registers. The I/O address appears in the same format as the memory address on bus lines A₁₅-A₀. The address lines A₁₉-A₁₆ are zero in I/O operations. The variable I/O instructions which use register DX as a pointer have full address capability while the direct I/O instructions directly address one or two of the 256 I/O byte locations in page 0 of the I/O address space.

I/O ports are addressed in the same manner as memory locations. Even addressed bytes are transferred on the D₇-D₀ bus lines and odd addressed bytes on D₁₅-D₈. Care must be taken to assure that each register within an 8-bit peripheral located on the lower portion of the bus be addressed as even.

EXTERNAL INTERFACE

PROCESSOR RESET AND INITIALIZATION

Processor initialization or start up is accomplished with activation (HIGH) of the RESET pin. The 80C86A RESET is required to be HIGH for four or more CLK cycles. The 80C86A will terminate operations on the high-going edge of RESET and will remain dormant as long as RESET is HIGH. The low-going transition of RESET triggers an internal reset sequence for approximately 7 CLK cycles. After this interval the 80C86A operates normally beginning with the instruction in absolute location FFFF0H (see Figure 3b). The details of this operation are specified in the Instruction Set description of the MCS[®]-86 Family User's Manual. The RESET input is internally synchronized to the processor clock. At

initialization the HIGH-to-LOW transition of RESET must occur no sooner than 50 μs after power-up, to allow complete initialization of the 80C86A.

NMI asserted prior to the 2nd clock after the end of RESET will not be honored. If NMI is asserted after that point and during the internal reset sequence, the processor may execute one instruction before responding to the interrupt. A hold request active immediately after RESET will be honored before the first instruction fetch.

All 3-state outputs float to 3-state OFF⁽¹⁾ during RESET. Status is active in the idle state for the first clock after RESET becomes active and then floats to 3-state OFF⁽¹⁾. ALE and HLDA are driven low.

NOTE:

1. See the section on Bus Hold Circuitry.

BUS HOLD CIRCUITRY

To avoid high current conditions caused by floating inputs to CMOS devices and eliminate the need for pull-up/down resistors, "bus-hold" circuitry has been used on the 80C86A pins 2-16, 26-32, and 34-39 (Figures 6a, 6b). These circuits will maintain the last valid logic state if no driving source is present (i.e. an unconnected pin or a driving source which goes to a high impedance state). To overdrive the "bus hold" circuits, an external driver must be capable of supplying 350 μA minimum sink or source current at valid input voltage levels. Since this "bus hold" circuitry is active and not a "resistive" type element, the associated power supply current is negligible and power dissipation is significantly reduced when compared to the use of passive pull-up resistors.

3

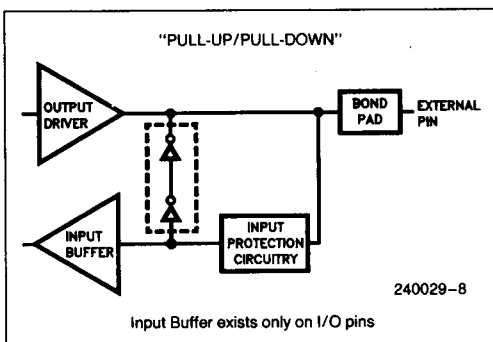


Figure 6a. Bus hold circuitry pin 2-16, 34-39.

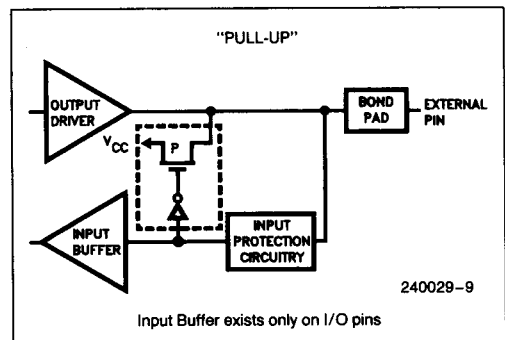


Figure 6b. Bus hold circuitry pin 26-32.

INTERRUPT OPERATIONS

Interrupt operations fall into two classes; software or hardware initiated. The software initiated interrupts and software aspects of hardware interrupts are specified in the Instruction Set description. Hardware interrupts can be classified as non-maskable or maskable.

Interrupts result in a transfer of control to a new program location. A 256-element table containing address pointers to the interrupt service program locations resides in absolute locations 0 through 3FFF (see Figure 3b), which are reserved for this purpose. Each element in the table is 4 bytes in size and corresponds to an interrupt "type". An interrupting device supplies an 8-bit type number, during the interrupt acknowledge sequence, which is used to "vector" through the appropriate element to the new interrupt service program location.

NON-MASKABLE INTERRUPT (NMI)

The processor provides a single non-maskable interrupt pin (NMI) which has higher priority than the maskable interrupt request pin (INTR). A typical use would be to activate a power failure routine. The NMI is edge-triggered on a LOW-to-HIGH transition. The activation of this pin causes a type 2 interrupt. (See Instruction Set description.) NMI is required to have a duration in the HIGH state of greater than two CLK cycles, but is not required to be synchronized to the clock. Any high-going transition of NMI is latched on-chip and will be serviced at the end of the current instruction or between whole moves of a block-type instruction. Worst case response to NMI would be for multiply, divide and variable shift instructions. There is no specification on the occurrence of the low-going edge; it may occur before, during, or after the servicing of NMI. Another high-going edge triggers another response if it occurs after the start of the NMI procedure. The signal must be free of logical spikes in general and be free of bounces on the low-going edge to avoid triggering extraneous responses.

MASKABLE INTERRUPT (INTR)

The 80C86A provides a single interrupt request input (INTR) which can be masked internally by software

with the resetting of the interrupt enable FLAG status bit. The interrupt request signal is level triggered. It is internally synchronized during each clock cycle on the high-going edge of CLK. To be responded to, INTR must be present (HIGH) during the clock period preceding the end of the current instruction or the end of a whole move for a block-type instruction. During the interrupt response sequence further interrupts are disabled. The enable bit is reset as part of the response to any interrupt (INTR, NMI, software interrupt or single-step), although the FLAGS register which is automatically pushed onto the stack reflects the state of the processor prior to the interrupt. Until the old FLAGS register is restored the enable bit will be zero unless specifically set by an instruction.

During the response sequence (Figure 7) the processor executes two successive (back-to-back) interrupt acknowledge cycles. The 80C86A emits the LOCK signal from T_2 of the first bus cycle until T_2 of the second. A local bus "hold" request will not be honored until the end of the second bus cycle. In the second bus cycle a byte is fetched from the external interrupt system (e.g., 82C59 PIC) which identifies the source (type) of the interrupt. This byte is multiplied by four and used as a pointer into the interrupt vector lookup table. An INTR signal left HIGH will be continually responded to within the limitations of the enable bit and sample period. The INTERRUPT RETURN instruction includes a FLAGS pop which returns the status of the original interrupt enable bit when it restores the FLAGS.

HALT

When a software "HALT" instruction is executed the processor indicates that it is entering the "HALT" state in one of two ways depending upon which mode is strapped. In minimum mode, the processor issues one ALE with no qualifying bus control signals. In Maximum Mode, the processor issues appropriate HALT status on \overline{S}_2 , \overline{S}_1 and \overline{S}_0 and the 82C88 bus controller issues one ALE. The 80C86A will not leave the "HALT" state when a local bus "hold" is entered while in "HALT". In this case, the processor reissues the HALT indicator. An interrupt request or RESET will force the 80C86A out of the "HALT" state.

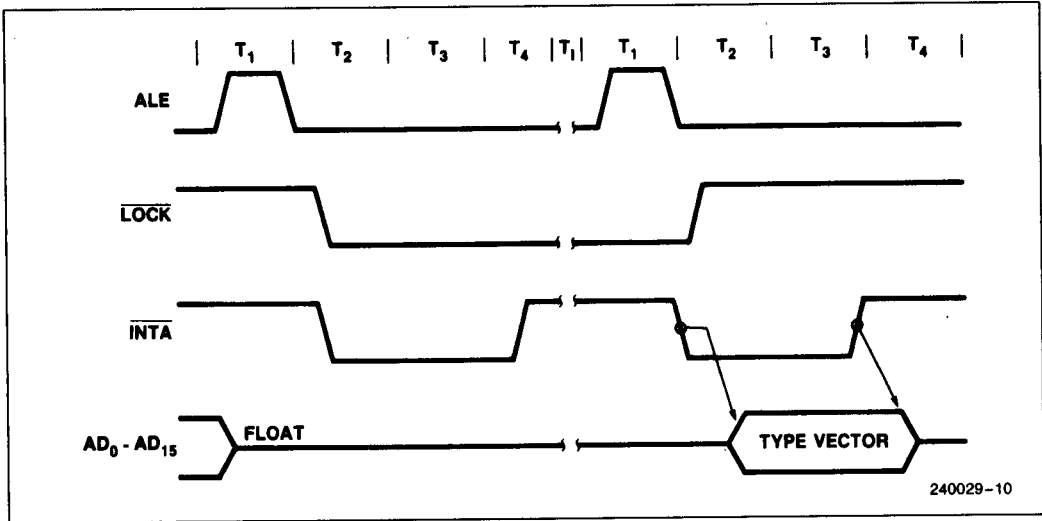


Figure 7. Interrupt Acknowledge Sequence

3

READ/MODIFY/WRITE (SEMAPHORE) OPERATIONS VIA LOCK

The $\overline{\text{LOCK}}$ status information is provided by the processor when directly consecutive bus cycles are required during the execution of an instruction. This provides the processor with the capability of performing read/modify/write operations on memory (via the Exchange Register With Memory instruction, for example) without the possibility of another system bus master receiving intervening memory cycles. This is useful in multiprocessor system configurations to accomplish "test and set lock" operations. The $\overline{\text{LOCK}}$ signal is activated (forced LOW) in the clock cycle following the one in which the software "LOCK" prefix instruction is decoded by the EU. It is deactivated at the end of the last bus cycle of the instruction following the "LOCK" prefix instruction. While $\overline{\text{LOCK}}$ is active a request on a RQ/GT pin will be recorded and then honored at the end of the LOCK.

EXTERNAL SYNCHRONIZATION VIA TEST

As an alternative to the interrupts and general I/O capabilities, the 80C86A provides a single software-testable input known as the TEST signal. At any time the program may execute a WAIT instruction. If at that time the TEST signal is inactive (HIGH), pro-

gram execution becomes suspended while the processor waits for TEST to become active. It must remain active for at least 5 CLK cycles. The WAIT instruction is re-executed repeatedly until that time. This activity does not consume bus cycles. The processor remains in an idle state while waiting. All 80C86A drivers go to 3-state OFF if bus "Hold" is entered. If interrupts are enabled, they may occur while the processor is waiting. When this occurs the processor fetches the WAIT instruction one extra time, processes the interrupt, and then re-fetches and re-executes the WAIT instruction upon returning from the interrupt.

BASIC SYSTEM TIMING

Typical system configurations for the processor operating in minimum mode and in maximum mode are shown in Figures 4a and 4b, respectively. In minimum mode, the MN/ $\overline{\text{MX}}$ pin is strapped to V_{CC} and the processor emits bus control signals in a manner similar to the 8085. In maximum mode, the MN/ $\overline{\text{MX}}$ pin is strapped to V_{SS} and the processor emits coded status information which the 82C88 bus controller uses to generate MULTIBUS compatible bus control signals. Figure 5 illustrates the signal timing relationships.

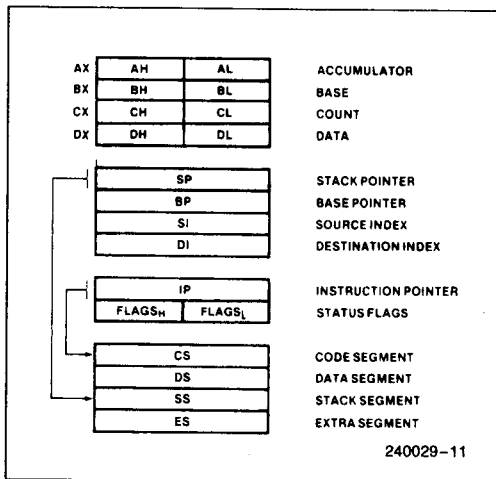


Figure 8. 80C86A Register Model

SYSTEM TIMING—MINIMUM SYSTEM

The read cycle begins in T_1 with the assertion of the Address Latch Enable (ALE) signal. The trailing (low-going) edge of this signal is used to latch the address information, which is valid on the local bus at this time, into a latch. The \overline{BHE} and A_0 signals address the low, high, or both bytes. From T_1 to T_4 the M/\overline{IO} signal indicates a memory or I/O operation. At T_2 the address is removed from the local bus and the bus goes to a high impedance state. The read control signal is also asserted at T_2 . The read (\overline{RD}) signal causes the addressed device to enable its data bus drivers to the local bus. Some time later valid data will be available on the bus and the addressed device will drive the READY line HIGH. When the processor returns the read signal to a HIGH level, the addressed device will again 3-state its bus drivers. If a transceiver is required to buffer the 80C86A local bus, signals DT/\overline{R} and \overline{DEN} are provided by the 80C86A.

A write cycle also begins with the assertion of ALE and the emission of the address. The M/\overline{IO} signal is again asserted to indicate a memory or I/O write operation. In the T_2 immediately following the address emission the processor emits the data to be written into the addressed location. This data remains valid until the middle of T_4 . During T_2 , T_3 , and T_W the processor asserts the write control signal. The write (\overline{WR}) signal becomes active at the beginning of T_2 as opposed to the read which is delayed somewhat into T_2 to provide time for the bus to float.

The \overline{BHE} and A_0 signals are used to select the proper byte(s) of the memory/I/O word to be read or written according to the following table:

\overline{BHE}	A_0	Characteristics
0	0	Whole word
0	1	Upper byte from/ to odd address
1	0	Lower byte from/ to even address
1	1	None

I/O ports are addressed in the same manner as memory location. Even addressed bytes are transferred on the D_7 - D_0 bus lines and odd addressed bytes on D_{15} - D_8 .

The basic difference between the interrupt acknowledge cycle and a read cycle is that the interrupt acknowledge signal (\overline{INTA}) is asserted in place of the read (\overline{RD}) signal and the address bus is floated. (See Figure 7.) In the second of two successive \overline{INTA} cycles, a byte of information is read from bus lines D_7 - D_0 as supplied by the interrupt system logic (i.e., 82C59A Priority Interrupt Controller). This byte identifies the source (type) of the interrupt. It is multiplied by four and used as a pointer into an interrupt vector lookup table, as described earlier.

BUS TIMING—MEDIUM SIZE SYSTEMS

For medium size systems the MN/\overline{MX} pin is connected to V_{SS} and the 82C88 Bus Controller is added to the system as well as a latch for latching the system address, and a transceiver to allow for bus loading greater than the 80C86A is capable of handling. Signals ALE, DEN, and DT/\overline{R} are generated by the 82C88 instead of the processor in this configuration although their timing remains relatively the same. The 80C86A status outputs (S_2 , S_1 , and S_0) provide type-of-cycle information and become 82C88 inputs. This bus cycle information specifies read (code, data, or I/O), write (data or I/O), interrupt acknowledge, or software halt. The 82C88 thus issues control signals specifying memory read or write, I/O read or write, or interrupt acknowledge. The 82C88 provides two types of write strobes, normal and advanced, to be applied as required. The normal write strobes have data valid at the leading edge of write. The advanced write strobes have the same timing as read strobes, and hence data isn't valid at the leading edge of write. The transceiver receives the usual T and OE inputs from the 82C88 DT/\overline{R} and DEN.

The pointer into the interrupt vector table, which is passed during the second \overline{INTA} cycle, can derive from an 82C59A located on either the local bus or the system bus. If the master 82C59A Priority Interrupt Controller is positioned on the local bus, a TTL gate is required to disable the transceiver when reading from the master 82C59A during the interrupt acknowledge sequence and software "poll".

ABSOLUTE MAXIMUM RATINGS*

Supply Voltage (With respect to ground)	-0.5 to 7.0V
Input Voltage Applied (w.r.t. ground)	-0.5 to $V_{CC} + 0.5V$
Output Voltage Applied (w.r.t. ground)	-0.5 to $V_{CC} + 0.5V$
Power Dissipation	1.0W
Storage Temperature	-65°C to 150°C
Ambient Temperature Under Bias	0°C to 70°C

NOTICE: This is a production data sheet. The specifications are subject to change without notice.

**WARNING: Stressing the device beyond the "Absolute Maximum Ratings" may cause permanent damage. These are stress ratings only. Operation beyond the "Operating Conditions" is not recommended and extended exposure beyond the "Operating Conditions" may affect device reliability.*

D.C. CHARACTERISTICS

($T_A = 0^\circ\text{C}$ to 70°C , $V_{CC} = 5V \pm 5\%$)

Symbol	Parameter	80C86A-2		Units	Test Conditions
		Min	Max		
V_{IL}	Input Low Voltage	-0.5	+0.8	V	
V_{IH}	Input High Voltage (All inputs except clock)	2.0		V	
V_{CH}	Clock Input High Voltage	$V_{CC} - 0.8$		V	
V_{OL}	Output Low Voltage		0.45	V	$I_{OL} = 2.5\text{ mA}$
V_{OH}	Output High Voltage	3.0 $V_{CC} - 0.4$		V	$I_{OH} = -2.5\text{ mA}$ $I_{OH} = -100\ \mu\text{A}$
I_{CC}	Power Supply Current		10 mA/MHz		$V_{IL} = \text{GND}$, $V_{IH} = V_{CC}$
I_{CCS}	Standby Supply Current		500	μA	$V_{IN} = V_{CC}$ or GND Outputs Unloaded CLK = GND or V_{CC}
I_{LI}	Input Leakage Current		± 1.0	μA	$0V \leq V_{IN} \leq V_{CC}$
I_{BHL}	Input Leakage Current (Bus Hold Low)	50	400	μA	$V_{IN} = 0.8V$ (Note 4)
I_{BHH}	Input Leakage Current (Bus Hold High)	-50	-400	μA	$V_{IN} = 3.0V$ (Note 5)
I_{BHLO}	Bus Hold Low Overdrive		600	μA	(Note 2)
I_{BHHO}	Bus Hold High Overdrive		-600	μA	(Note 3)
I_{LO}	Output Leakage Current		± 10	μA	$V_{OUT} = \text{GND}$ or V_{CC}
C_{IN}	Capacitance of Input Buffer. (All inputs except AD ₀ -AD ₁₅ , RQ/GT)		5	pF	(Note 1)
C_{IO}	Capacitance of I/O Buffer (AD ₀ -AD ₁₅ , RQ/GT)		20	pF	(Note 1)
C_{OUT}	Output Capacitance		15	pF	(Note 1)

NOTES:

1. Characterization conditions are a) Frequency = 1 MHz; b) Unmeasured pins at GND; c) V_{IN} at +5.0V or GND.
2. An external driver must source at least I_{BHLO} to switch this node from LOW to HIGH.
3. An external driver must sink at least I_{BHHO} to switch this node from HIGH to LOW.
4. Test Condition is to lower V_{IN} to GND and then raise V_{IN} to 0.8V on pins 2-16 & 34-39.
5. Test Condition is to raise V_{IN} to V_{CC} and then lower V_{IN} to 3.0V on pins 2-16, 26-32 & 34-39.

3

A.C. CHARACTERISTICS(T_A = 0°C to 70°C, V_{CC} = 5V ± 5%)**MINIMUM COMPLEXITY SYSTEM TIMING REQUIREMENTS**

Symbol	Parameter	80C86A-2		Units	Test Conditions
		Min	Max		
TCLCL	CLK Cycle Period	125	D.C.	ns	
TCLCH	CLK Low Time	68		ns	
TCHCL	CLK High Time	44		ns	
TCH1CH2	CLK Rise Time		10	ns	From 1.0V to 3.5V
TCL2CL1	CLK Fall Time		10	ns	From 3.5V to 1.0V
TDVCL	Data in Setup Time	20		ns	
TCLDX	Data in Hold Time	10		ns	
TR1VCL	RDY Setup Time into 82C84A (Notes 1, 2)	35		ns	
TCLR1X	RDY Hold Time into 82C84A (Notes 1, 2)	0		ns	
TRYHCH	READY Setup Time into 80C86A	68		ns	
TCHRYX	READY Hold Time into 80C86A	20		ns	
TRYLCL	READY Inactive to CLK (Note 3)	-8		ns	
THVCH	HOLD Setup Time	20		ns	
TINVCH	INTR, NMI, $\overline{\text{TEST}}$ Setup Time (Note 2)	15		ns	
TILIH	Input Rise Time (Except CLK)		15	ns	
TIHIL	Input Fall Time (Except CLK)		15	ns	From 2.0V to 0.8V

A.C. CHARACTERISTICS (Continued)

 $(T_A = 0^\circ\text{C to } 70^\circ\text{C}, V_{CC} = 5\text{V} \pm 5\%)$
Timing Responses

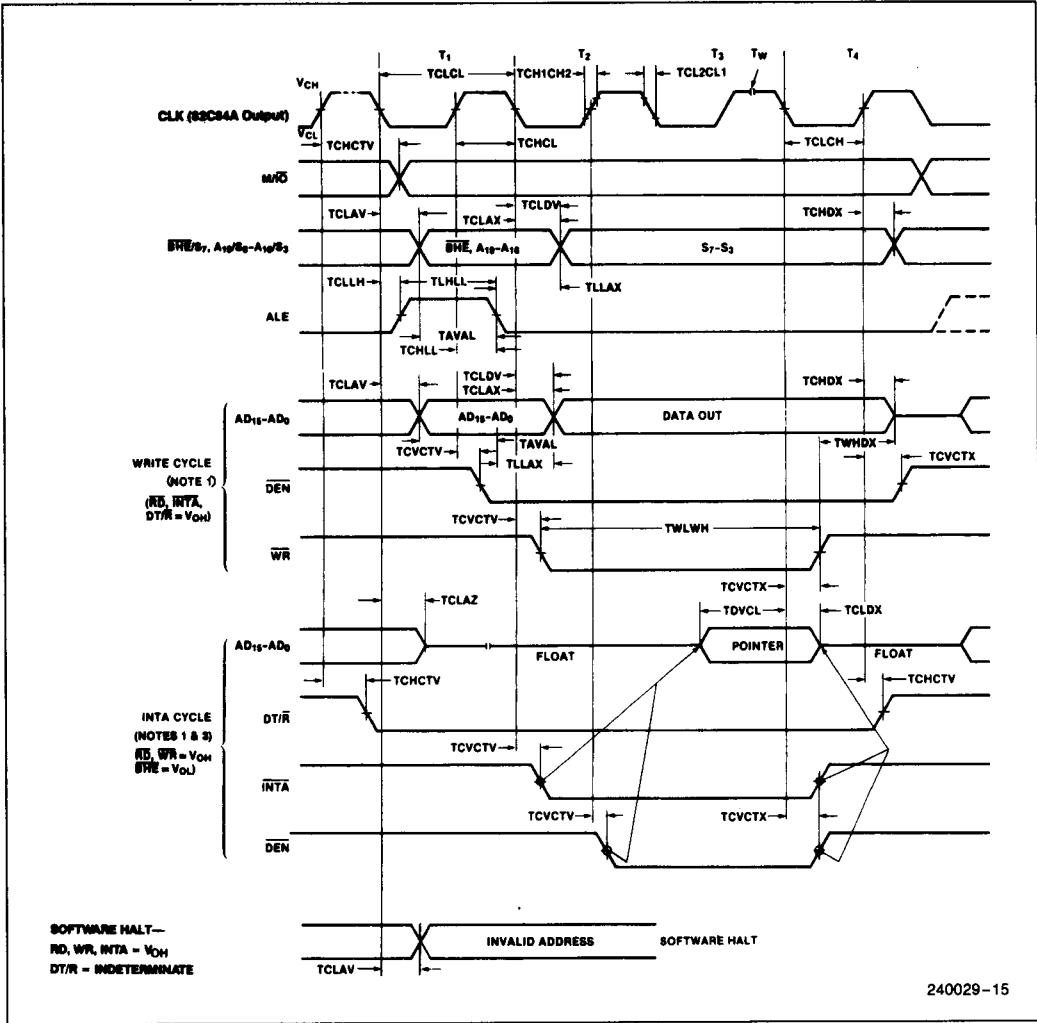
Symbol	Parameter	80C86A-2		Units	Test Conditions	
		Min	Max			
TCLAV	Address Valid Delay	10	60	ns		
TCLAX	Address Hold Time	10		ns		
TCLAZ	Address Float Delay	TCLAX	50	ns		
TLHLL	ALE Width	TCLCH - 10		ns		
TCLLH	ALE Active Delay		50	ns		
TCHLL	ALE Inactive Delay		55	ns		
TLLAX	Address Hold Time to ALE Inactive	TCHCL - 10		ns		
TCLDV	Data Valid Delay	10	60	ns		
TCHDX	Data Hold Time	10		ns		
TWHDX	Data Hold Time After WR	TCLCH - 30		ns		
TCVCTV	Control Active Delay 1	10	70	ns		
TCHCTV	Control Active Delay 2	10	60	ns		
TCVCTX	Control Inactive Delay	10	70	ns		
TAZRL	Address Float to READ Active	0		ns		
TCLRL	\overline{RD} Active Delay	10	100	ns		
TCLRH	\overline{RD} Inactive Delay	10	80	ns		
TRHAV	\overline{RD} Inactive to Next Address Active	TCLCL - 40		ns		
TCLHAV	HLDA Valid Delay	10	100	ns		
TRLRH	\overline{RD} Width	2TCLCL - 50		ns		
TWLWH	\overline{WR} Width	2TCLCL - 40		ns		
TAVAL	Address Valid to ALE Low	TCLCH - 40		ns		
TOLOH	Output Rise Time		15	ns		From 0.8V to 2.0V
TOHOL	Output Fall Time		15	ns		From 2.0V to 0.8V

3
NOTES:

1. Signal at 82C84A shown for reference only. See 82C84A data sheet for the most recent specifications.
2. Setup requirement for asynchronous signal only to guarantee recognition at next CLK.
3. Applies only to T2 state. (8 ns into T3).

WAVEFORMS (Continued)

MINIMUM MODE (Continued)



3

NOTES:

1. All output timing measurements are made at 1.5V unless otherwise noted.
2. RDY is sampled near the end of T₂, T₃, T_W to determine if T_W machines states are to be inserted.
3. Two INTA cycles run back-to-back. The 80C86A local ADDR/DATA BUS is floating during both INTA cycles. Control signals shown for second INTA cycle.
4. Signals at 82C84A are shown for reference only.

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A.C. CHARACTERISTICS

MAX MODE SYSTEM (USING 82C88 BUS CONTROLLER) TIMING REQUIREMENTS

Symbol	Parameter	80C86A-2		Units	Test Conditions	
		Min	Max			
TCLCL	CLK Cycle Period	125	D.C.	ns		
TCLCH	CLK Low Time	68		ns		
TCHCL	CLK High Time	44		ns		
TCH1CH2	CLK Rise Time		10	ns	From 1.0V to 3.5V	
TCL2CL1	CLK Fall Time		10	ns	From 3.5V to 1.0V	
TDVCL	Data in Setup Time	20		ns		
TCLDX	Data in Hold Time	10		ns		
TR1VCL	RDY Setup Time into 82C84A (Notes 1, 2)	35		ns		
TCLR1X	RDY Hold Time into 82C84A (Notes 1, 2)	0		ns		
TRYHCH	READY Setup Time into 80C86A	68		ns		
TCHRYX	READY Hold Time into 80C86A	20		ns		
TRYLCL	READY Inactive to CLK (Note 4)	-8		ns		
TINVCH	Setup Time for Recognition (INTR, NMI, TEST) (Note 2)	15		ns		
TGVCH	$\overline{RQ}/\overline{GT}$ Setup Time	15		ns		
TCHGX	\overline{RQ} Hold Time into 80C86A	30		ns		
TILIH	Input Rise Time (Except CLK) (Note 5)		15	ns		From 0.8V to 2.0V
TIHIL	Input Fall Time (Except CLK) (Note 5)		15	ns		From 2.0V to 0.8V

A.C. CHARACTERISTICS (Continued)

TIMING RESPONSES

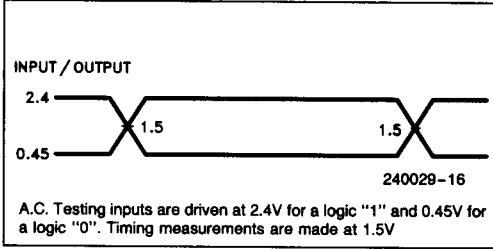
Symbol	Parameter	80C86A-2		Units	Test Conditions	
		Min	Max			
TCLML	Command Active Delay (Note 1)	5	35	ns		
TCLMH	Command Inactive Delay (Note 1)	5	35	ns		
TRYHSH	READY Active to Status Passive (Note 3)		65	ns		
TCHSV	Status Active Delay	10	60	ns		
TCLSH	Status Inactive Delay	10	70	ns		
TCLAV	Address Valid Delay	10	60	ns		
TCLAX	Address Hold Time	10		ns		
TCLAZ	Address Float Delay	TCLAX	50	ns		
TSVLH	Status Valid to ALE High (Note 1)		20	ns		
TSVMCH	Status Valid to MCE High (Note 1)		30	ns		
TCLLH	CLK Low to ALE Valid (Note 1)		20	ns		
TCLMCH	CLK Low to MCE High (Note 1)		25	ns		
TCHLL	ALE Inactive Delay (Note 1)	4	18	ns		
TCLDV	Data Valid Delay	10	60	ns		
TCHDX	Data Hold Time	10		ns		
TCVNV	Control Active Delay (Note 1)	5	45	ns		
TCVNX	Control Inactive Delay (Note 1)	10	45	ns		
TAZRL	Address Float to Read Active	0		ns		
TCLRL	RD Active Delay	10	100	ns		
TCLRH	RD Inactive Delay	10	80	ns		
TRHAV	RD Inactive to Next Address Active	TCLCL - 40		ns		
TCHDTL	Direction Control Active Delay (Note 1)		50	ns		
TCHDTH	Direction Control Inactive Delay (Note 1)		30	ns		
TCLGL	GT Active Delay	0	50	ns		
TCLGH	GT Inactive Delay	0	50	ns		
TRLRH	RD Width	2TCLCL - 50		ns		
TOLOH	Output Rise Time		15	ns		From 0.8V to 2.0V
TOHOL	Output Fall Time		15	ns		From 2.0V to 0.8V

3

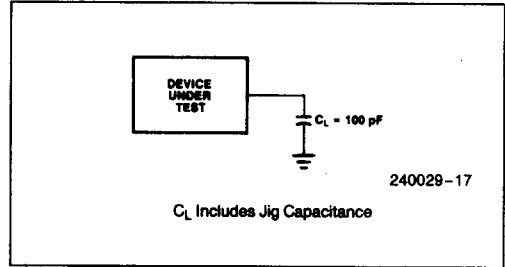
NOTES:

1. Signal at 82C84A or 82C88 shown for reference only. See 82C84A and 82C88 for the most recent specifications.
2. Setup requirement for asynchronous signal only to guarantee recognition at next CLK.
3. Applies only to T3 and wait states.
4. Applies only to T2 state (8 ns into T3).
5. These parameters are characterized and not 100% tested.

A.C. TESTING INPUT, OUTPUT WAVEFORM

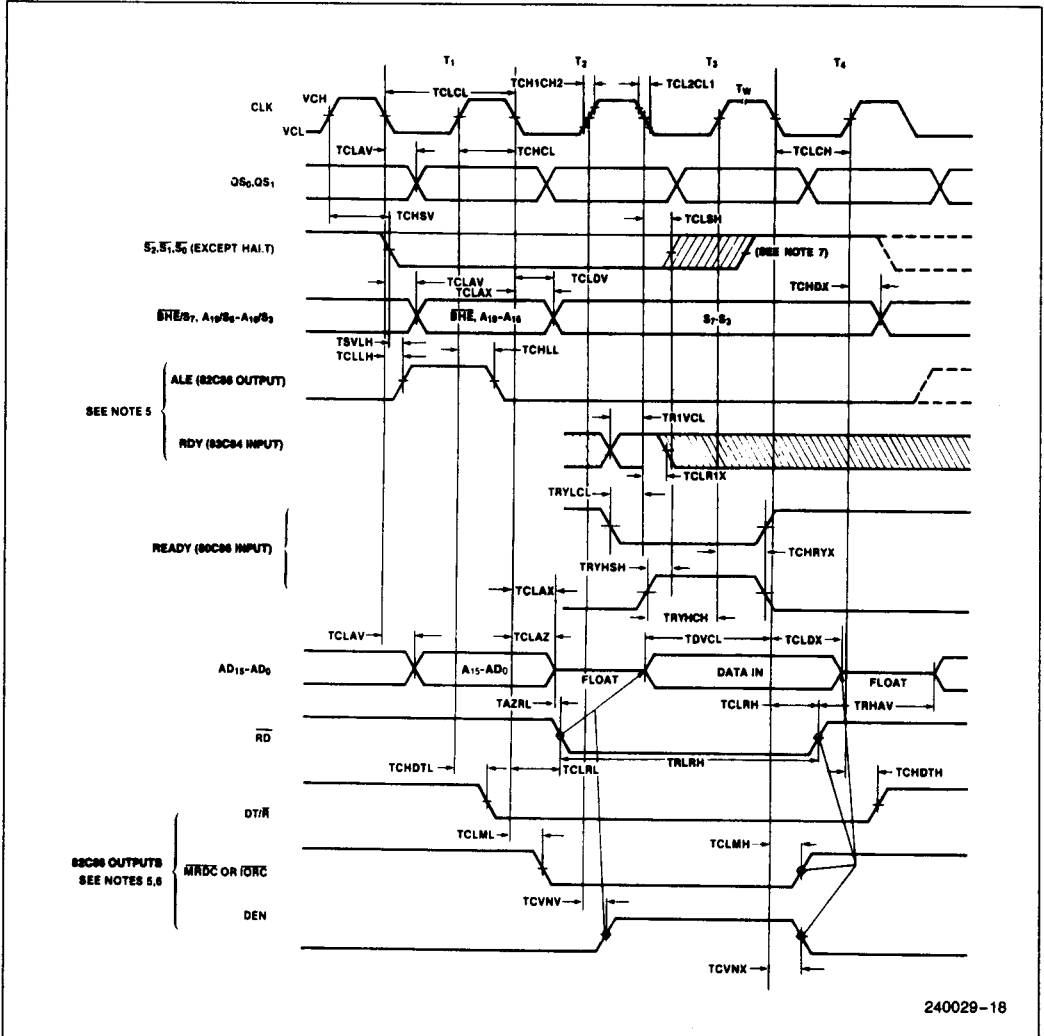


A.C. TESTING LOAD CIRCUIT



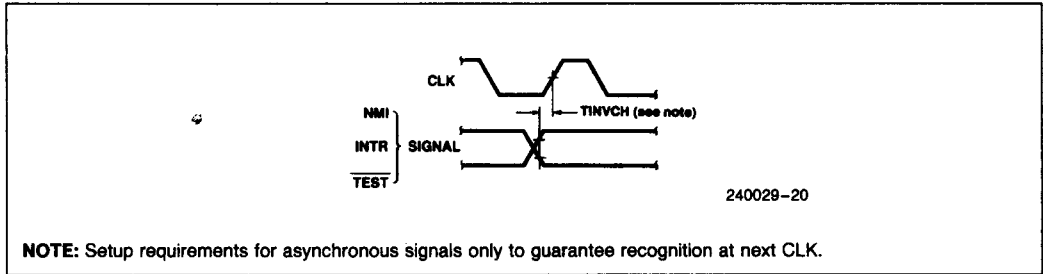
WAVEFORMS

MAXIMUM MODE

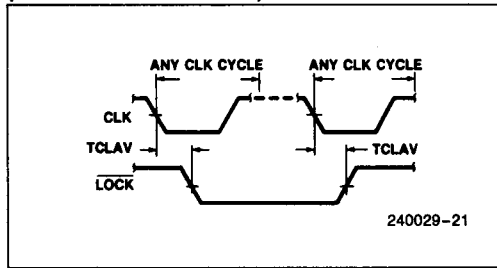


WAVEFORMS (Continued)

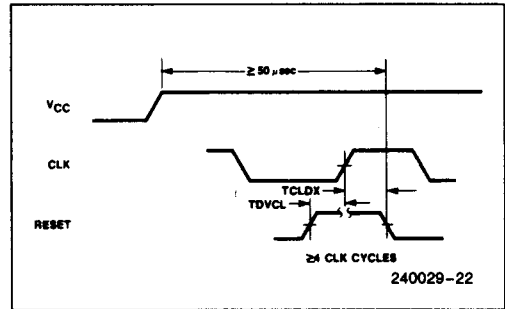
ASYNCHRONOUS SIGNAL RECOGNITION



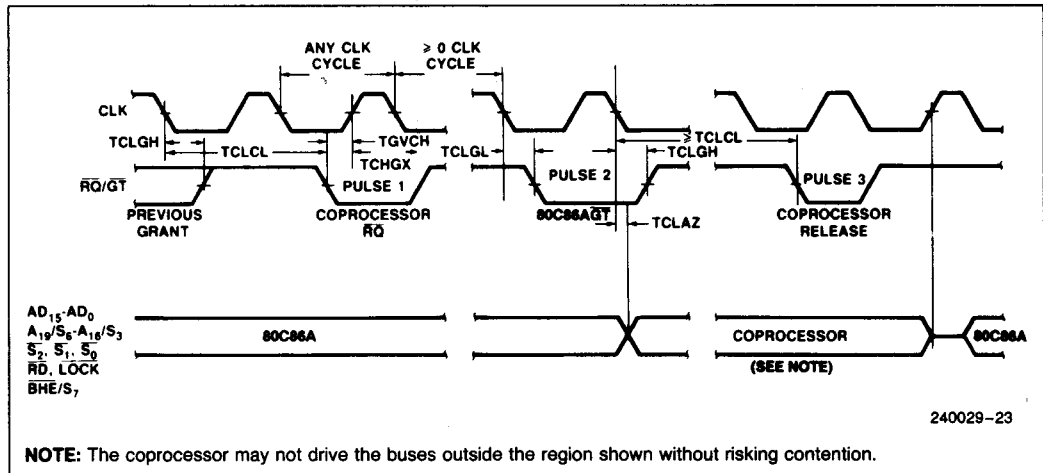
BUS LOCK SIGNAL TIMING (MAXIMUM MODE ONLY)



RESET TIMING

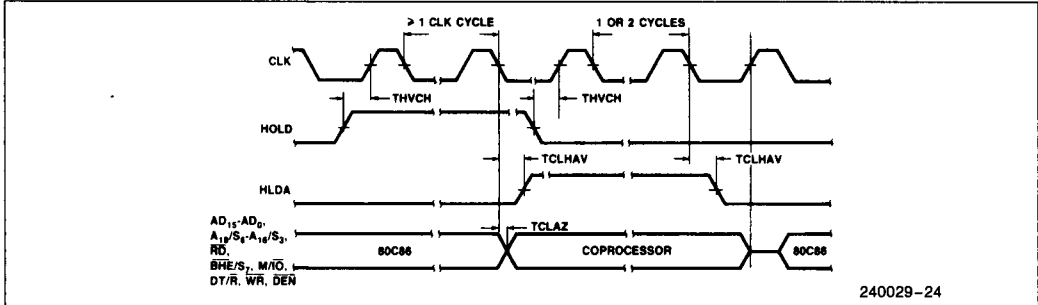


REQUEST/GRANT SEQUENCE TIMING (MAXIMUM MODE ONLY)



WAVEFORMS (Continued)

HOLD/HOLD ACKNOWLEDGE TIMING (MINIMUM MODE ONLY)



240029-24

Table 2. Instruction Set Summary

Mnemonic and Description	Instruction Code			
DATA TRANSFER				
MOV = Move:	7 6 5 4 3 2 1 0	7 6 5 4 3 2 1 0	7 6 5 4 3 2 1 0	7 6 5 4 3 2 1 0
Register/Memory to/from Register**	1 0 0 0 1 0 d w	mod reg r/m		
Immediate to Register/Memory	1 1 0 0 0 1 1 w	mod 0 0 0 r/m	data	data if w = 1
Immediate to Register	1 0 1 1 w reg	data		data if w = 1
Memory to Accumulator	1 0 1 0 0 0 0 w	addr-low		addr-high
Accumulator to Memory	1 0 1 0 0 0 1 w	addr-low		addr-high
Register/Memory to Segment Register**	1 0 0 0 1 1 1 0	mod 0 reg r/m		
Segment Register to Register/Memory	1 0 0 0 1 1 0 0	mod 0 reg r/m		
PUSH = Push:				
Register/Memory	1 1 1 1 1 1 1 1	mod 1 1 0 r/m		
Register	0 1 0 1 0 reg			
Segment Register	0 0 0 reg 1 1 0			
POP = Pop:				
Register/Memory	1 0 0 0 1 1 1 1	mod 0 0 0 r/m		
Register	0 1 0 1 1 reg			
Segment Register	0 0 0 reg 1 1 1			
XCHG = Exchange:				
Register/Memory with Register	1 0 0 0 0 1 1 w	mod reg r/m		
Register with Accumulator	1 0 0 1 0 reg			
IN = Input from:				
Fixed Port	1 1 1 0 0 1 0 w	port		
Variable Port	1 1 1 0 1 1 0 w			
OUT = Output to:				
Fixed Port	1 1 1 0 0 1 1 w	port		
Variable Port	1 1 1 0 1 1 1 w			
XLAT = Translate Byte to AL	1 1 0 1 0 1 1 1			
LEA = Load EA to Register	1 0 0 0 1 1 0 1	mod reg r/m		
LDS = Load Pointer to DS	1 1 0 0 0 1 0 1	mod reg r/m		
LES = Load Pointer to ES	1 1 0 0 0 1 0 0	mod reg r/m		
LAHF = Load AH with Flags	1 0 0 1 1 1 1 1			
SAHF = Store AH into Flags	1 0 0 1 1 1 1 0			
PUSHF = Push Flags	1 0 0 1 1 1 0 0			
POPF = Pop Flags	1 0 0 1 1 1 0 1			

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Table 2. Instruction Set Summary (Continued)

Mnemonic and Description	Instruction Code			
	76543210	76543210	76543210	76543210
ARITHMETIC				
ADD = Add:				
Reg./Memory with Register to Either	00000dw	mod reg r/m		
Immediate to Register/Memory	10000sw	mod 000 r/m	data	data if sw = 01
Immediate to Accumulator	0000010w	data	data if w = 1	
ADC = Add with Carry:				
Reg./Memory with Register to Either	000100dw	mod reg r/m		
Immediate to Register/Memory	10000sw	mod 010 r/m	data	data if sw = 01
Immediate to Accumulator	0001010w	data	data if w = 1	
INC = Increment:				
Register/Memory	1111111w	mod 000 r/m		
Register	01000reg			
AAA = ASCII Adjust for Add	00110111			
DAA = Decimal Adjust for Add	00100111			
SUB = Subtract:				
Reg./Memory and Register to Either	001010dw	mod reg r/m		
Immediate from Register/Memory	10000sw	mod 101 r/m	data	data if sw = 01
Immediate from Accumulator	0010110w	data	data if w = 1	
SBB = Subtract with Borrow				
Reg./Memory and Register to Either	000110dw	mod reg r/m		
Immediate from Register/Memory	10000sw	mod 011 r/m	data	data if sw = 01
Immediate from Accumulator	0001110w	data	data if w = 1	
DEC = Decrement:				
Register/Memory	1111111w	mod 001 r/m		
Register	01001reg			
NEG = Change Sign	1111011w	mod 011 r/m		
CMP = Compare:				
Register/Memory and Register	001110dw	mod reg r/m		
Immediate with Register/Memory	10000sw	mod 111 r/m	data	data if sw = 01
Immediate with Accumulator	0011110w	data	data if w = 1	
AAS = ASCII Adjust for Subtract	00111111			
DAS = Decimal Adjust for Subtract	00101111			
MUL = Multiply (Unsigned)	1111011w	mod 100 r/m		
IMUL = Integer Multiply (Signed)	1111011w	mod 101 r/m		
AAM = ASCII Adjust for Multiply	11010100	00001010		
DIV = Divide (Unsigned)	1111011w	mod 110 r/m		
IDIV = Integer Divide (Signed)	1111011w	mod 111 r/m		
AAD = ASCII Adjust for Divide	11010101	00001010		
CBW = Convert Byte to Word	10011000			
CWD = Convert Word to Double Word	10011001			

Table 2. Instruction Set Summary (Continued)

Mnemonic and Description	Instruction Code			
	7 6 5 4 3 2 1 0	7 6 5 4 3 2 1 0	7 6 5 4 3 2 1 0	7 6 5 4 3 2 1 0
LOGIC				
NOT = Invert	1 1 1 1 0 1 1 w	mod 0 1 0 r/m		
SHL/SAL = Shift Logical/Arithmetic Left	1 1 0 1 0 0 v w	mod 1 0 0 r/m		
SHR = Shift Logical Right	1 1 0 1 0 0 v w	mod 1 0 1 r/m		
SAR = Shift Arithmetic Right	1 1 0 1 0 0 v w	mod 1 1 1 r/m		
ROL = Rotate Left	1 1 0 1 0 0 v w	mod 0 0 0 r/m		
ROR = Rotate Right	1 1 0 1 0 0 v w	mod 0 0 1 r/m		
RCL = Rotate Through Carry Flag Left	1 1 0 1 0 0 v w	mod 0 1 0 r/m		
RCR = Rotate Through Carry Right	1 1 0 1 0 0 v w	mod 0 1 1 r/m		
AND = And:				
Reg./Memory and Register to Either	0 0 1 0 0 0 d w	mod reg r/m		
Immediate to Register/Memory	1 0 0 0 0 0 w	mod 1 0 0 r/m	data	data if w = 1
Immediate to Accumulator	0 0 1 0 0 1 0 w	data	data if w = 1	
TEST = And Function to Flags, No Result:				
Register/Memory and Register	1 0 0 0 0 1 0 w	mod reg r/m		
Immediate Data and Register/Memory	1 1 1 1 0 1 1 w	mod 0 0 0 r/m	data	data if w = 1
Immediate Data and Accumulator	1 0 1 0 1 0 0 w	data	data if w = 1	
OR = Or:				
Reg./Memory and Register to Either	0 0 0 0 1 0 d w	mod reg r/m		
Immediate to Register/Memory	1 0 0 0 0 0 w	mod 0 0 1 r/m	data	data if w = 1
Immediate to Accumulator	0 0 0 0 1 1 0 w	data	data if w = 1	
XOR = Exclusive OR:				
Reg./Memory and Register to Either	0 0 1 1 0 0 d w	mod reg r/m		
Immediate to Register/Memory	1 0 0 0 0 0 w	mod 1 1 0 r/m	data	data if w = 1
Immediate to Accumulator	0 0 1 1 0 1 0 w	data	data if w = 1	
STRING MANIPULATION				
REP = Repeat	1 1 1 1 0 0 1 z			
MOVS = Move Byte/Word	1 0 1 0 0 1 0 w			
CMPS = Compare Byte/Word	1 0 1 0 0 1 1 w			
SCAS = Scan Byte/Word	1 0 1 0 1 1 1 w			
LODS = Load Byte/Wd to AL/AX	1 0 1 0 1 1 0 w			
STOS = Stor Byte/Wd from AL/A	1 0 1 0 1 0 1 w			
CONTROL TRANSFER				
CALL = Call:				
Direct Within Segment	1 1 1 0 1 0 0 0	disp-low	disp-high	
Indirect Within Segment	1 1 1 1 1 1 1 1	mod 0 1 0 r/m		
Direct Intersegment	1 0 0 1 1 0 1 0	offset-low	offset-high	
		seg-low	seg-high	
Indirect Intersegment	1 1 1 1 1 1 1 1	mod 0 1 1 r/m		

Table 2. Instruction Set Summary (Continued)

Mnemonic and Description	Instruction Code		
CONTROL TRANSFER (Continued)			
JMP = Unconditional Jump:	7 6 5 4 3 2 1 0	7 6 5 4 3 2 1 0	7 6 5 4 3 2 1 0
Direct Within Segment	1 1 1 0 1 0 0 1	disp-low	disp-high
Direct Within Segment-Short	1 1 1 0 1 0 1 1	disp	
Indirect Within Segment	1 1 1 1 1 1 1 1	mod 1 0 0 r/m	
Direct Intersegment	1 1 1 0 1 0 1 0	offset-low	offset-high
		seg-low	seg-high
Indirect Intersegment	1 1 1 1 1 1 1 1	mod 1 0 1 r/m	
RET = Return from CALL:			
Within Segment	1 1 0 0 0 0 1 1		
Within Seg. Adding Immed to SP	1 1 0 0 0 0 1 0	data-low	data-high
Intersegment	1 1 0 0 1 0 1 1		
Intersegment Adding Immediate to SP	1 1 0 0 1 0 1 0	data-low	data-high
JE/JZ = Jump on Equal/ Zero	0 1 1 1 0 1 0 0	disp	
JL/JNGE = Jump on Less/Not Greater or Equal	0 1 1 1 1 1 0 0	disp	
JLE/JNG = Jump on Less or Equal/ Not Greater	0 1 1 1 1 1 1 0	disp	
JB/JNAE = Jump on Below/Not Above or Equal	0 1 1 1 0 0 1 0	disp	
JBE/JNA = Jump on Below or Equal/ Not Above	0 1 1 1 0 1 1 0	disp	
JP/JPE = Jump on Parity/Parity Even	0 1 1 1 1 0 1 0	disp	
JO = Jump on Overflow	0 1 1 1 0 0 0 0	disp	
JS = Jump on Sign	0 1 1 1 1 0 0 0	disp	
JNE/JNZ = Jump on Not Equal/Not Zero	0 1 1 1 0 1 0 1	disp	
JNL/JGE = Jump on Not Less/Greater or Equal	0 1 1 1 1 1 0 1	disp	
JNLE/JG = Jump on Not Less or Equal/ Greater	0 1 1 1 1 1 1 1	disp	
JNB/JAE = Jump on Not Below/Above or Equal	0 1 1 1 0 0 1 1	disp	
JNBE/JA = Jump on Not Below or Equal/Above	0 1 1 1 0 1 1 1	disp	
JNP/JPO = Jump on Not Par/Par Odd	0 1 1 1 1 0 1 1	disp	
JNO = Jump on Not Overflow	0 1 1 1 0 0 0 1	disp	
JNS = Jump on Not Sign	0 1 1 1 1 0 0 1	disp	
LOOP = Loop CX Times	1 1 1 0 0 0 1 0	disp	
LOOPZ/LOOPE = Loop While Zero/Equal	1 1 1 0 0 0 0 1	disp	
LOOPNZ/LOPNE = Loop While Not Zero/Equal	1 1 1 0 0 0 0 0	disp	
JCXZ = Jump on CX Zero	1 1 1 0 0 0 1 1	disp	
INT = Interrupt			
Type Specified	1 1 0 0 1 1 0 1	type	
Type 3	1 1 0 0 1 1 0 0		
INTO = Interrupt on Overflow	1 1 0 0 1 1 1 0		
IRET = Interrupt Return	1 1 0 0 1 1 1 1		

Table 2. Instruction Set Summary (Continued)

Mnemonic and Description	Instruction Code	
	7 6 5 4 3 2 1 0	7 6 5 4 3 2 1 0
PROCESSOR CONTROL		
CLC = Clear Carry	1 1 1 1 1 0 0 0	
CMC = Complement Carry	1 1 1 1 0 1 0 1	
STC = Set Carry	1 1 1 1 1 0 0 1	
CLD = Clear Direction	1 1 1 1 1 1 0 0	
STD = Set Direction	1 1 1 1 1 1 0 1	
CLI = Clear Interrupt	1 1 1 1 1 0 1 0	
STI = Set Interrupt	1 1 1 1 1 0 1 1	
HLT = Halt	1 1 1 1 0 1 0 0	
WAIT = Wait	1 0 0 1 1 0 1 1	
ESC = Escape (to External Device)	1 1 0 1 1 x x x	mod x x x r/m
LOCK = Bus Lock Prefix	1 1 1 1 0 0 0 0	

NOTES:

- AL = 8-bit accumulator
- AX = 16-bit accumulator
- CX = Count register
- DS = Data segment
- ES = Extra segment
- Above/below refers to unsigned value.
- Greater = more positive;
- Less = less positive (more negative) signed values
- if d = 1 then "to" reg; if d = 0 then "from" reg
- if w = 1 then word instruction; if w = 0 then byte instruction
- if mod = 11 then r/m is treated as a REG field
- if mod = 00 then DISP = 0*, disp-low and disp-high are absent
- if mod = 01 then DISP = disp-low sign-extended to 16 bits, disp-high is absent
- if mod = 10 then DISP = disp-high: disp-low
- if r/m = 000 then EA = (BX) + (SI) + DISP
- if r/m = 001 then EA = (BX) + (DI) + DISP
- if r/m = 010 then EA = (BP) + (SI) + DISP
- if r/m = 011 then EA = (BP) + (DI) + DISP
- if r/m = 100 then EA = (SI) + DISP
- if r/m = 101 then EA = (DI) + DISP
- if r/m = 110 then EA = (BP) + DISP*
- if r/m = 111 then EA = (BX) + DISP
- DISP follows 2nd byte of instruction (before data if required)
- *except if mod = 00 and r/m = 110 then EA = disp-high: disp-low.
- **MOV CS, REG/MEMORY not allowed.

- if s w = 01 then 16 bits of immediate data form the operand
- if s w = 11 then an immediate data byte is sign extended to form the 16-bit operand
- if v = 0 then "count" = 1; if v = 1 then "count" in (CL) register
- x = don't care
- z is used for string primitives for comparison with ZF FLAG

SEGMENT OVERRIDE PREFIX

```
0 0 1 reg 1 1 0
```

REG is assigned according to the following table:

16-Bit (w = 1)	8-Bit (w = 0)	Segment
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	

Instructions which reference the flag register file as a 16-bit object use the symbol FLAGS to represent the file:
 FLAGS = X:X:X:(OF):(DF):(IF):(TF):(SF):(ZF):X:(AF):X:(PF):X:(CF)

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DATA SHEET REVISION REVIEW

The following list represents key differences between this and the -001 data sheet. Please review this summary carefully.

1. In the Pin Description Table (Table 1), the description of the HLDA signal being issued has been corrected. HLDA will be issued in the middle of either the T₄ or T₁ state.

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