



PRELIMINARY

## 8XC196MC INDUSTRIAL MOTOR CONTROL MICROCONTROLLER

87C196MC 16 Kbytes of On-Chip OTPROM\*  
87C196MC, ROM 16 Kbytes of On-Chip Factory-Programmed OTPROM  
80C196MC ROMless

- High-Performance CHMOS 16-Bit CPU
- 16 Kbytes of On-Chip OTPROM/  
Factory-Programmed OTPROM
- 488 bytes of On-Chip Register RAM
- Register to Register Architecture
- Up to 53 I/O Lines
- Peripheral Transaction Server (PTS)  
with 11 Prioritized Sources
- Event Processor Array (EPA)
  - 4 High Speed Capture/Compare  
Modules
  - 4 High Speed Compare Modules
- Extended Temperature Standard
- Two 16-Bit Timers with Quadrature  
Decoder Input
- 3-Phase Complementary Waveform  
Generator
- 13 Channel 8/10-Bit A/D with Sample/  
Hold with Zero Offset Adjustment H/W
- 14 Prioritized Interrupt Sources
- Flexible 8-/16-Bit External Bus
- 1.75  $\mu$ s 16 x 16 Multiply
- 3  $\mu$ s 32/16 Divide
- Idle and Power Down Modes

The 8XC196MC is a 16-bit microcontroller designed primarily to control 3 phase AC induction and DC brushless motors. The 8XC196MC is based on Intel's MCS<sup>®</sup> 96 16-bit microcontroller architecture and is manufactured with Intel's CHMOS process.

The 8XC196MC has a three phase waveform generator specifically designed for use in "Inverter" motor control applications. This peripheral allows for pulse width modulation, three phase sine wave generation with minimal CPU intervention. It generates 3 complementary non-overlapping PWM pulses with resolutions of 0.125  $\mu$ s (edge trigger) or 0.250  $\mu$ s (centered).

The 8XC196MC has 16 Kbytes on-chip OTPROM/ROM and 488 bytes of on-chip RAM. It is available in three packages; PLCC (84-L), SDIP (64-L) and EIAJ/QFP (80-L).

Note that the 64-L SDIP package does not include P1.4, P2.7, P5.1 and the CLKOUT pins.

Operational characteristics are guaranteed over the temperature range of  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$ .

The 87C196MC contains 16 Kbytes on-chip OTPROM. The 83C196MC contains 16 Kbytes on-chip ROM. All references to the 80C196MC also refers to the 83C196MC and 87C196MC unless noted.

\*OTPROM (One Time Programmable Read Only Memory) is the same as EPROM but it comes in an unwindowed package and cannot be erased. It is user programmable.

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April 1994  
Order Number: 270946-005

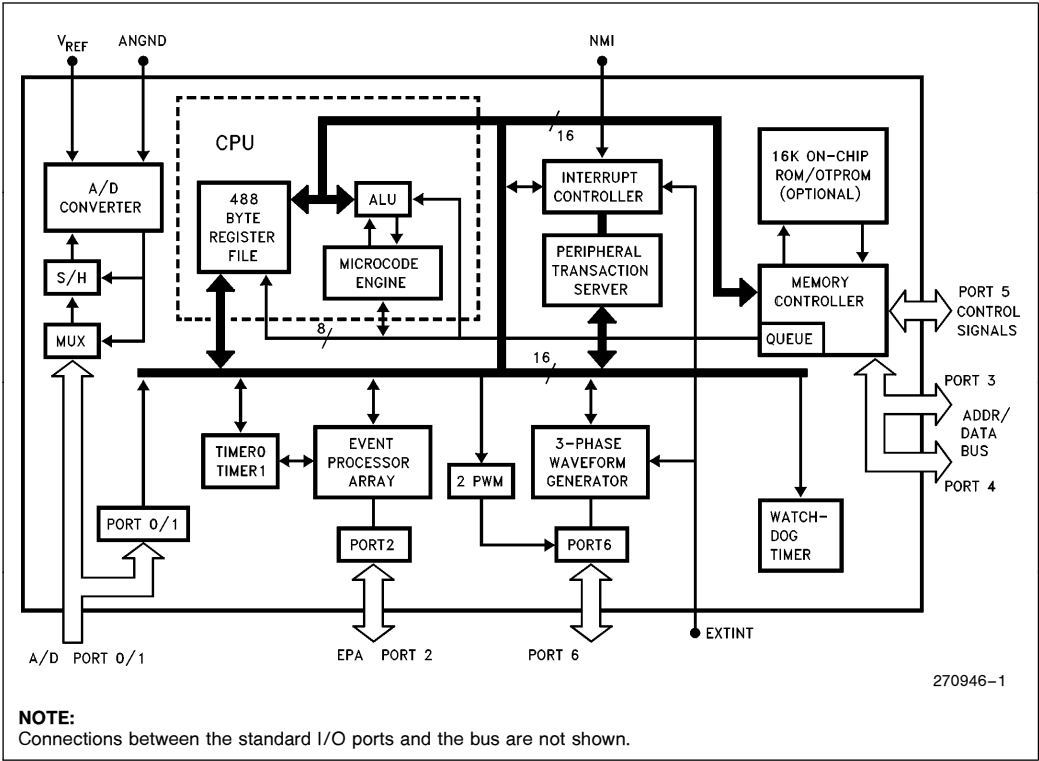


Figure 1. 87C196MC Block Diagram

## PROCESS INFORMATION

This device is manufactured on PX29.5, a CHMOS III-E process. Additional process and reliability information is available in Intel's *Components Quality and Reliability Handbook*, Order Number 210997.

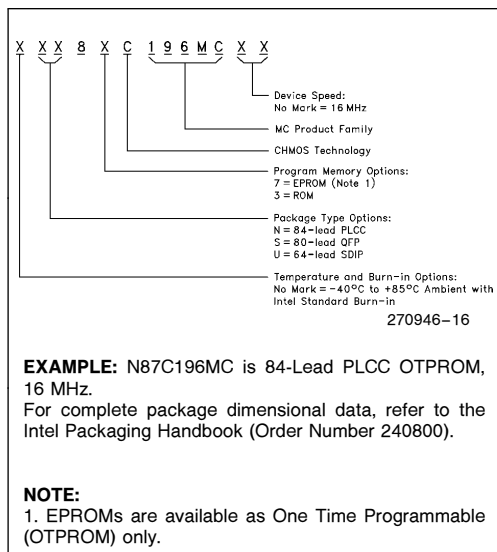


Figure 3. The 8XC196MC Family Nomenclature

### Thermal Characteristics

| Package Type | $\theta_{ja}$ | $\theta_{jc}$ |
|--------------|---------------|---------------|
| PLCC         | 35°C/W        | 13°C/W        |
| QFP          | 56°C/W        | 12°C/W        |
| SDIP         | TBD           | TBD           |

All thermal impedance data is approximate for static air conditions at 1W of power dissipation. Values will change depending on operation conditions and application. See the Intel *Packaging Handbook* (order number 240800) for a description of Intel's thermal impedance test methodology.

### 8XC196MC Memory Map

| Description                                                       | Address          |
|-------------------------------------------------------------------|------------------|
| External Memory or I/O                                            | 0FFFFH<br>06000H |
| Internal ROM/EPROM or External Memory (Determined by $\bar{E}A$ ) | 5FFFH<br>2080H   |
| Reserved. Must contain FFH. (Note 5)                              | 207FH<br>205EH   |
| PTS Vectors                                                       | 205DH<br>2040H   |
| Upper Interrupt Vectors                                           | 203FH<br>2030H   |
| ROM/EPROM Security Key                                            | 202FH<br>2020H   |
| Reserved. Must contain FFH. (Note 5)                              | 201FH<br>201CH   |
| Reserved. Must Contain 20H (Note 5)                               | 201BH            |
| CCB1                                                              | 201AH            |
| Reserved. Must Contain 20H (Note 5)                               | 2019H            |
| CCB0                                                              | 2018H            |
| Reserved. Must contain FFH. (Note 5)                              | 2017H<br>2014H   |
| Lower Interrupt Vectors                                           | 2013H<br>2000H   |
| SFR's                                                             | 1FFFFH<br>1F00H  |
| External Memory                                                   | 1EFFFH<br>0200H  |
| 488 Bytes Register RAM (Note 1)                                   | 01FFFH<br>0018H  |
| CPU SFR's (Notes 1, 3)                                            | 0017H<br>0000H   |

#### NOTES:

- Code executed in locations 0000H to 03FFH will be forced external.
- Reserved memory locations must contain 0FFH unless noted.
- Reserved SFR bit locations must contain 0.
- Refer to 8XC196KC for SFR descriptions.
- WARNING:** Reserved memory locations must not be written or read. The contents and/or function of these locations may change with future revisions of the device. Therefore, a program that relies on one or more of these locations may not function properly.

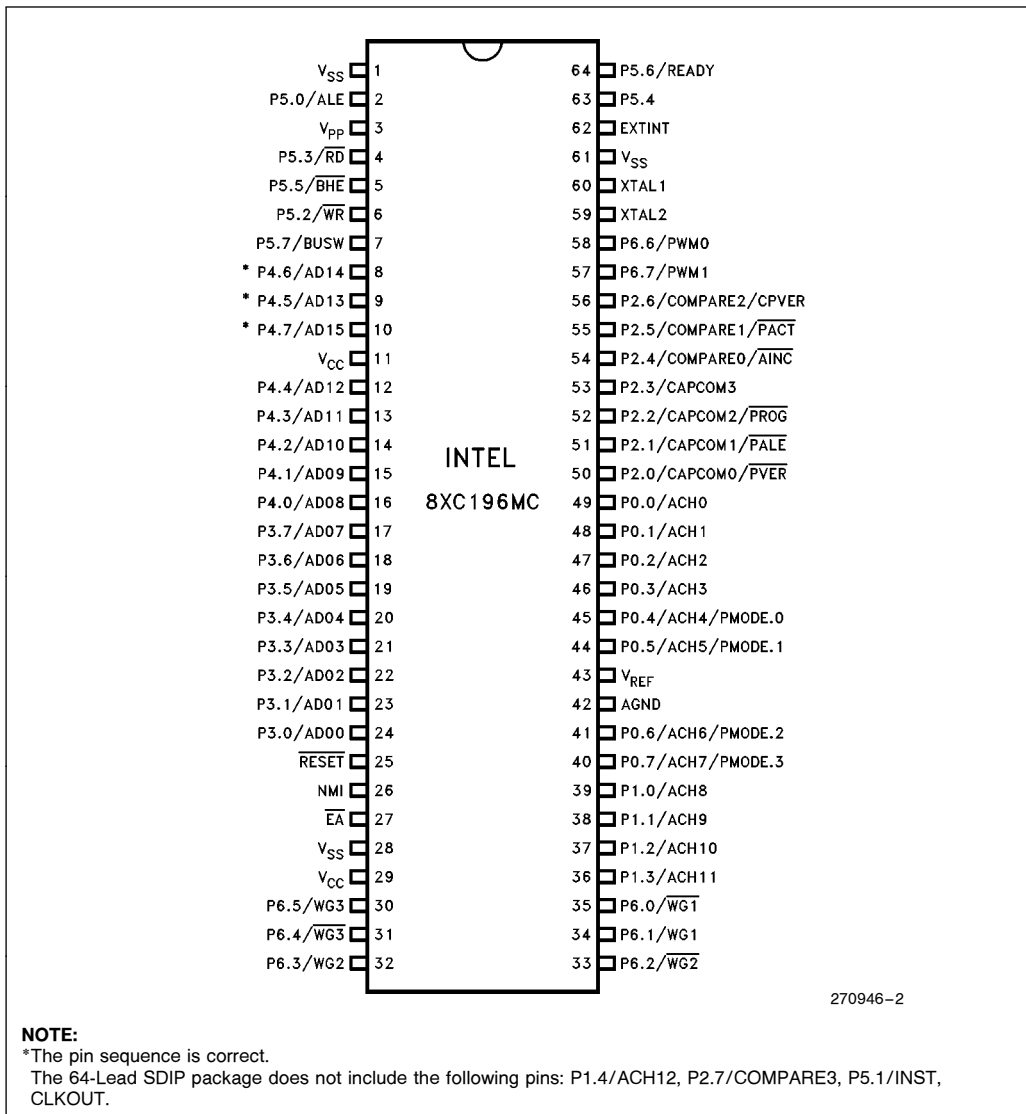


Figure 2. 64-Lead Shrink DIP (SDIP) Package



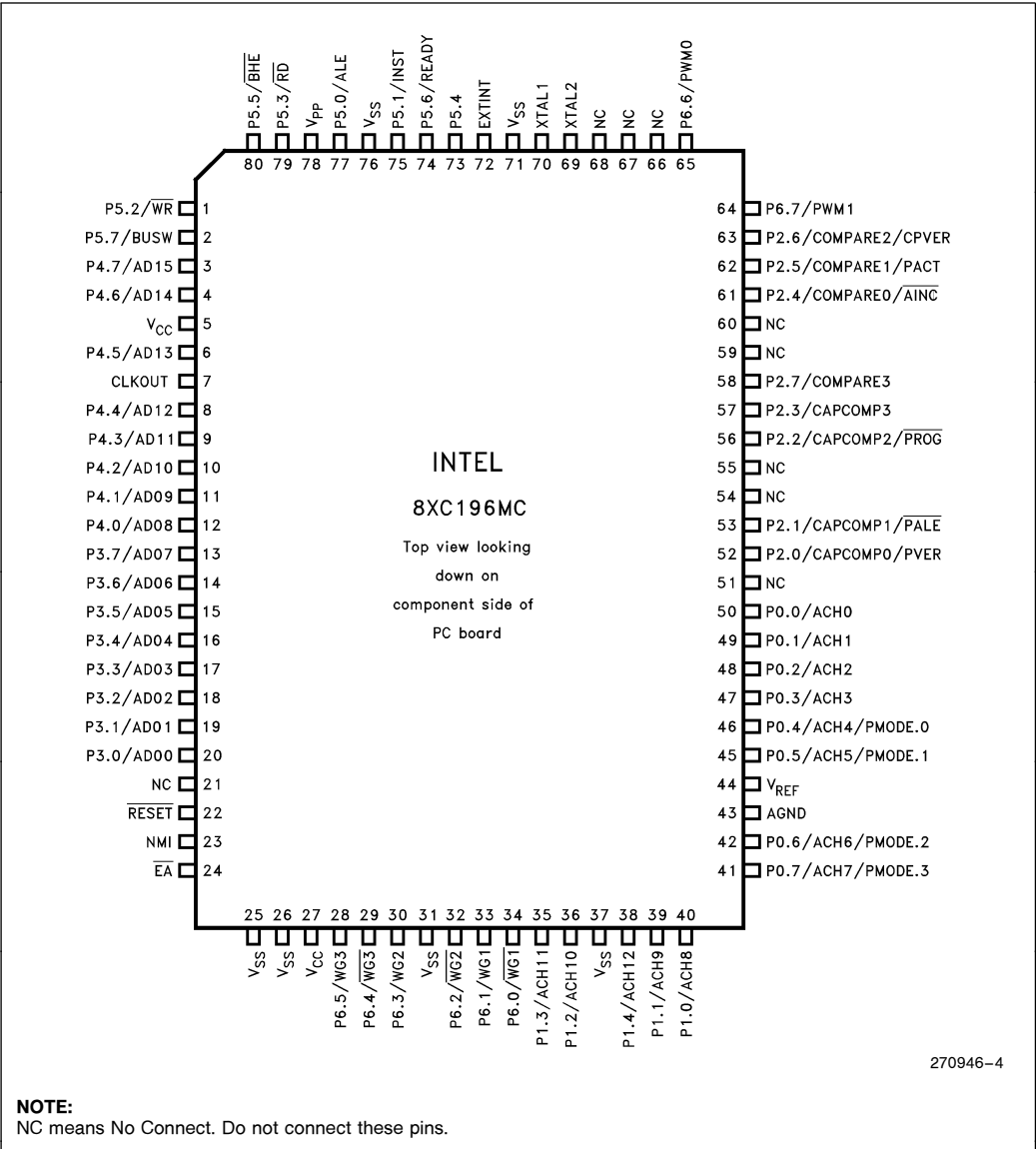


Figure 4. 80-Lead Shrink EIAJQFP (Quad Flat Pack)

## PIN DESCRIPTIONS (Alphabetically Ordered)

| Symbol                                     | Function                                                                                                                                                                                                                                                                                                                                                                                          |
|--------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| ACH0–ACH12<br>(P0.0–P0.7, P1.0–P1.4)       | Analog inputs to the on-chip A/D converter. ACH0–7 share the input pins with P0.0–7 and ACH8–12 share pins with P1.0–4. If the A/D is not used, the port pins can be used as standard input ports.                                                                                                                                                                                                |
| ANGND                                      | Reference ground for the A/D converter. Must be held at nominally the same potential as $V_{SS}$ .                                                                                                                                                                                                                                                                                                |
| ALE/ $\overline{ADV}$ (P5.0)               | Address Latch Enable or Address Valid output, as selected by CCR. Both options allow a latch to demultiplex the address/data bus on the signal's falling edge. When the pin is $\overline{ADV}$ , it goes inactive (high) at the end of the bus cycle. ALE/ $\overline{ADV}$ is active only during external memory accesses. Can be used as standard I/O when not used as ALE/ $\overline{ADV}$ . |
| $\overline{BHE}$ / $\overline{WRH}$ (P5.5) | Byte High Enable or Write High output, as selected by the CCR. $\overline{BHE}$ will go low for external writes to the high byte of the data bus. $\overline{WRH}$ will go low for external writes where an odd byte is being written. $\overline{BHE}$ / $\overline{WRH}$ is activated only during external memory writes.                                                                       |
| BUSWIDTH (P5.7)                            | Input for bus width selection. If CCR bits 1 and 2 = 1, this pin dynamically controls the bus width of the bus cycle in progress. If BUSWIDTH is low, an 8-bit cycle occurs. If it is high, a 16-bit cycle occurs. This pin can be used as standard I/O when not used as BUSWIDTH.                                                                                                                |
| CAPCOMP0–CAPCOMP3<br>(P2.0–P2.3)           | The EPA Capture/Compare pins. These pins share P2.0–P2.3. If not used for the EPA, they can be configured as standard I/O pins.                                                                                                                                                                                                                                                                   |
| CLKOUT                                     | Output of the internal clock generator. The frequency is $\frac{1}{2}$ of the oscillator frequency. It has a 50% duty cycle.                                                                                                                                                                                                                                                                      |
| COMPARE0–COMPARE3<br>(P2.4–P2.7)           | The EPA Compare pins. These pins share P2.4–P2.7. If not used for the EPA, they can be configured as standard I/O pins.                                                                                                                                                                                                                                                                           |
| $\overline{EA}$                            | External Access enable pin. $\overline{EA} = 0$ causes all memory accesses to be external to the chip. $\overline{EA} = 1$ causes memory accesses from location 2000H to 5FFFH to be from the on-chip OTPROM/QROM. $\overline{EA} = 12.5V$ causes execution to begin in the programming mode. $\overline{EA}$ is latched at reset.                                                                |
| EXTINT                                     | A programmable input on this pin causes a maskable interrupt vector through memory location 203CH. The input may be selected to be a positive/negative edge or a high/low level using WG_PROTECT (1FCEH).                                                                                                                                                                                         |
| INST (P5.1)                                | INST is high during the instruction fetch from the external memory and throughout the bus cycle. It is low otherwise. This pin can be configured as standard I/O if not used as INST.                                                                                                                                                                                                             |
| NMI                                        | A positive transition on this pin causes a non-maskable interrupt which vectors to memory location 203EH. If not used, it should be tied to $V_{SS}$ . May be used by Intel Evaluation boards.                                                                                                                                                                                                    |
| PORT0                                      | 8-bit high impedance input-only port. Also used as A/D converter inputs. Port0 pins should not be left floating. These pins also used to select programming modes in the OTPROM devices.                                                                                                                                                                                                          |
| PORT1                                      | 5-bit high impedance input-only port. P1.0–P1.4 are also used as A/D converter inputs. In addition, P1.2 and P1.3 can be used as Timer 1 clock input and direction select respectively.                                                                                                                                                                                                           |
| PORT2                                      | 8-bit bidirectional I/O port. All of the Port2 pins are shared with the EPA I/O pins (CAPCOMP0–3 and COMPARE0–3).                                                                                                                                                                                                                                                                                 |
| PORT3<br>PORT4                             | 8-bit bidirectional I/O ports with open drain outputs. These pins are shared with the multiplexed address/data bus which uses strong internal pullups.                                                                                                                                                                                                                                            |
| PORT5                                      | 8-bit bidirectional I/O port. 7 of the pins are shared with bus control signals (ALE, INST, WR, RD, $\overline{BHE}$ , READY, BUSWIDTH). Can be used as standard I/O.                                                                                                                                                                                                                             |

**PIN DESCRIPTIONS** (Alphabetically Ordered) (Continued)

| Symbol                                                      | Function                                                                                                                                                                                                                                                                                 |
|-------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| PORT6                                                       | 8-bit output port. P6.6 and P6.7 output PWM, the others are used as the Wave Form Generator outputs. Can be used as standard output ports.                                                                                                                                               |
| PWM0, PWM1<br>(P6.6, P6.7)                                  | Programmable duty cycle, Programmable frequency Pulse Width Modulator pins. The duty cycle has a resolution of 256 steps, and the frequency can vary from 122 Hz to 31 KHz (16 MHz input clock). Pins may be configured as standard output if PWM is not used.                           |
| $\overline{RD}$ (P5.3)                                      | Read signal output to external memory. $\overline{RD}$ is low only during external memory reads. Can be used as standard I/O when not used as $\overline{RD}$ .                                                                                                                          |
| READY (P5.6)                                                | Ready input to lengthen external memory cycles. If READY = 0, the memory controller inserts wait states until the next positive transition of CLKOUT occurs with READY = 1. Can be used as standard I/O when not used as READY.                                                          |
| $\overline{RESET}$                                          | Reset input to and open-drain output from the chip. Held low for at least 16 state times to reset the chip. Input high for normal operation. $\overline{RESET}$ has an Ohmic internal pullup resistor.                                                                                   |
| T1CLK<br>(P1.2)                                             | Timer 0 Clock input. This pin has two other alternate functions: ACH10 and P1.2.                                                                                                                                                                                                         |
| T1DIR<br>(P1.3)                                             | Timer 0 Direction input. This pin has two other alternate functions: ACH11 and P1.3.                                                                                                                                                                                                     |
| $V_{PP}$                                                    | The programming voltage is applied to this pin. It is also the timing pin for the return from Power Down circuit. Connect this pin with a 1 $\mu$ F capacitor to $V_{SS}$ and a 1 M $\Omega$ resistor to $V_{CC}$ . If the Power Down feature is not used, connect the pin to $V_{CC}$ . |
| WG1–WG3/ $\overline{WG1}$ – $\overline{WG3}$<br>(P6.0–P6.5) | 3 phase output signals and their complements used in motor control applications. The pins can also be configured as standard output pins.                                                                                                                                                |
| $\overline{WR}$ / $\overline{WRL}$ (P5.2)                   | Write and Write Low output to external memory. $\overline{WR}$ will go low every external write. $\overline{WRL}$ will go low only for external writes to an even byte. Can be used as standard I/O when not used as $\overline{WR}$ / $\overline{WRL}$ .                                |
| XTAL1                                                       | Input of the oscillator inverter and the internal clock generator. This pin should be used when using an external clock source.                                                                                                                                                          |
| XTAL2                                                       | Output of the oscillator inverter.                                                                                                                                                                                                                                                       |
| PMODE<br>(P0.4–7)                                           | Determines the EPROM programming mode.                                                                                                                                                                                                                                                   |
| $\overline{PACT}$<br>(P2.5)                                 | A low signal in Auto Programming mode indicates that programming is in process. A high signal indicates programming is complete.                                                                                                                                                         |
| $\overline{PALE}$<br>(P2.1)                                 | A falling edge in Slave Programming Mode and Auto Configuration Byte Programming Mode indicates that ports 3 and 4 contain valid programming address/command information (input to slave).                                                                                               |
| $\overline{PROG}$<br>(P2.2)                                 | A falling edge in Slave Programming Mode begins programming. A rising edge ends programming.                                                                                                                                                                                             |
| PVER<br>(P2.0)                                              | A high signal in Slave Programming Mode and Auto Configuration Byte Programming Mode indicates the byte programmed correctly.                                                                                                                                                            |
| CPVER<br>(P2.6)                                             | Cumulative Program Verification. Pin is high if all locations since entering a programming mode have programmed correctly.                                                                                                                                                               |
| $\overline{AINC}$<br>(P2.4)                                 | Auto Increment. Active low input enables the auto increment mode. Auto increment will allow reading or writing of sequential EPROM locations without address transactions across the PBUS for each read or write.                                                                        |

## ABSOLUTE MAXIMUM RATINGS

|                                                               |                   |
|---------------------------------------------------------------|-------------------|
| Ambient Temperature                                           |                   |
| Under Bias                                                    | −40°C to +85°C    |
| Storage Temperature                                           | −65°C to +150°C   |
| Voltage from $\overline{EA}$ or $V_{PP}$ to $V_{SS}$ or ANGND | +13.00V           |
| Voltage on $V_{PP}$ or $\overline{EQ}$ to $V_{SS}$ or ANGND   | −0.5V to 13.0V    |
| Voltage on Any Other Pin to $V_{SS}$ or ANGND                 | −0.5V to +7.0V(1) |
| Power Dissipation                                             | 1.5W(2)           |

### NOTES:

1. This includes  $V_{PP}$  and  $\overline{EA}$  on ROM or CPU only devices.
2. Power dissipation is based on package heat transfer limitations, not device power consumption.

NOTICE: This data sheet contains preliminary information on new products in production. The specifications are subject to change without notice. Verify with your local Intel Sales office that you have the latest data sheet before finalizing a design.

*\*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.*

## OPERATING CONDITIONS

| Symbol    | Description                    | Min  | Max  | Units |
|-----------|--------------------------------|------|------|-------|
| $T_A$     | Ambient Temperature Under Bias | −40  | +85  | °C    |
| $V_{CC}$  | Digital Supply Voltage         | 4.50 | 5.50 | V     |
| $V_{REF}$ | Analog Supply Voltage          | 4.00 | 5.50 | V     |
| $F_{OSC}$ | Oscillator Frequency           | 8    | 16   | MHz   |

### NOTE:

ANGND and  $V_{SS}$  should be nominally at the same potential. Also  $V_{SS}$  and  $V_{SS1}$  must be at the same potential.

## DC ELECTRICAL CHARACTERISTICS (Over Specified Operating Conditions)

| Symbol              | Parameter                                                 | Min                                                | Max                | Units       | Test Conditions                                                                 |
|---------------------|-----------------------------------------------------------|----------------------------------------------------|--------------------|-------------|---------------------------------------------------------------------------------|
| $V_{IL}$            | Input Low Voltage                                         | −0.5                                               | $0.3 V_{CC}$       | V           |                                                                                 |
| $V_{IH}$            | Input High Voltage                                        | $0.7 V_{CC}$                                       | $V_{CC} + 0.5$     | V           |                                                                                 |
| $V_{OL}$            | Output Low Voltage<br>Port 2 and 5, P6.6, P6.7,<br>CLKOUT |                                                    | 0.3<br>0.45<br>1.5 | V<br>V<br>V | $I_{OL} = 200 \mu A$<br>$I_{OL} = 3.2 \text{ mA}$<br>$I_{OL} = 7 \text{ mA}$    |
| $V_{OL1}$           | Output Low Voltage on Port 3/4                            |                                                    | 1.0                | V           | $I_{OL} = 15 \text{ mA}$                                                        |
| $V_{OL2}$           | Output Low Voltage on Port 6.0–6.5                        |                                                    | 0.45               | V           | $I_{OL} = 10 \text{ mA}$                                                        |
| $V_{OH}$            | Output High Voltage                                       | $V_{CC} - 0.3$<br>$V_{CC} - 0.7$<br>$V_{CC} - 1.5$ |                    | V<br>V<br>V | $I_{OH} = -200 \mu A$<br>$I_{OH} = -3.2 \text{ mA}$<br>$I_{OH} = -7 \text{ mA}$ |
| $V_{th+} - V_{th-}$ | Hysteresis Voltage Width on RESET                         | 0.2                                                |                    | V           | Typical                                                                         |

**DC ELECTRICAL CHARACTERISTICS** (Over Specified Operating Conditions) (Continued)

| Symbol    | Parameter                                         | Min | Typ | Max      | Units    | Test Conditions                                       |
|-----------|---------------------------------------------------|-----|-----|----------|----------|-------------------------------------------------------|
| $I_{LI}$  | Input Leakage Current on All Input Only Pins      |     |     | $\pm 10$ | $\mu A$  | $0V < V_{IN} < V_{CC}-0.3V$ (in RESET)                |
| $I_{LI1}$ | Input Leakage Current on Port0 and Port1          |     |     | $\pm 3$  | $\mu A$  | $0V < V_{IN} < V_{REF}$                               |
| $I_{IL}$  | Input Low Current on BD Ports (Note 1)            |     |     | -70      | $\mu A$  | $V_{IN} = 0.3 V_{CC}$                                 |
| $I_{IL1}$ | Input Low Current on P5.4 and P2.6 during Reset   |     |     | -7       | mA       | $0.2 V_{CC}$                                          |
| $I_{OH}$  | Output High Current on P5.4 and P2.6 during Reset | -2  |     |          | mA       | $0.7 V_{CC}$                                          |
| $I_{CC}$  | Active Mode Current in Reset                      |     | 50  | 70       | mA       | XTAL1 = 16 MHz,<br>$V_{CC} = V_{PP} = V_{REF} = 5.5V$ |
| $I_{REF}$ | A/D Conversion Reference Current                  |     | 2   | 5        | mA       |                                                       |
| $I_{IDL}$ | Idle Mode Current                                 |     | 15  | 30       | mA       |                                                       |
| $I_{PD}$  | Power-Down Mode Current                           |     | 5   | 50       | $\mu A$  | $V_{CC} = V_{PP} = V_{REF} = 5.5V$                    |
| $R_{RST}$ | RESET Pin Pullup Resistor                         | 6k  |     | 65k      | $\Omega$ |                                                       |
| $C_S$     | Pin Capacitance (Any Pin to $V_{SS}$ )            |     |     | 10       | pF       | $F_{TEST} = 1.0 \text{ MHz}$                          |

**NOTES:**

- BD (Bidirectional ports) include:  
P2.0–P2.7, except P2.6  
P3.0–P3.7  
P4.0–P4.7  
P5.0–P5.3  
P5.5–P5.7
- During normal (non-transient) conditions, the following total current limits apply:  
P6.0–P6.5     $I_{OL}$ : 40 mA     $I_{OH}$ : 28 mA  
P3             $I_{OL}$ : 90 mA     $I_{OH}$ : 42 mA  
P4             $I_{OL}$ : 90 mA     $I_{OH}$ : 42 mA  
P5, CLKOUT     $I_{OL}$ : 35 mA     $I_{OH}$ : 35 mA  
P2, P6.6, P6.7     $I_{OL}$ : 63 mA     $I_{OH}$ : 63 mA

## EXPLANATION OF AC SYMBOLS

Each symbol is two pairs of letters prefixed by "T" for time. The characters in a pair indicate a signal and its condition, respectively. Symbols represent the time between the two signal/condition points.

### Conditions:

H — High  
L — Low  
V — Valid  
X — No Longer Valid  
Z — Floating

### Signals:

A — Address  
B —  $\overline{BHE}$   
C — CLKOUT  
D — DATA  
G — Buswidth  
H —  $\overline{HOLD}$   
HA —  $\overline{HLDA}$   
L —  $\overline{ALE/ADV}$   
BR —  $\overline{BREQ}$   
R —  $\overline{RD}$   
W —  $\overline{WR/WRH/WRL}$   
X — XTAL1  
Y — READY  
Q — Data Out

## AC ELECTRICAL CHARACTERISTICS (Over Specified Operating Conditions)

Test Conditions: Capacitive load on all pins = 100 pF, Rise and fall times = 10 ns,  $F_{OSC}$  = 16 MHz.

The system must meet the following specifications to work with the 87C196MC:

| Symbol            | Parameter                                  | Min                   | Max                     | Units | Notes |
|-------------------|--------------------------------------------|-----------------------|-------------------------|-------|-------|
| FXTAL             | Frequency on XTAL1                         | 8                     | 16                      | MHz   | 3     |
| T <sub>OSC</sub>  | 1/FXTAL                                    | 62.5                  | 125                     | ns    |       |
| T <sub>AVYV</sub> | Address Valid to READY Setup               |                       | 2 T <sub>OSC</sub> – 75 | ns    |       |
| T <sub>LLYV</sub> | ALE Low to READY Setup                     |                       | T <sub>OSC</sub> – 70   | ns    | 4     |
| T <sub>LYLH</sub> | Not READY Time                             | No Upper Limit        |                         | ns    |       |
| T <sub>CLYX</sub> | READY Hold after CLKOUT Low                | 0                     | T <sub>OSC</sub> – 30   | ns    | 1     |
| T <sub>LLYX</sub> | READY Hold after ALE Low                   | T <sub>OSC</sub> – 15 | 2 T <sub>OSC</sub> – 40 | ns    | 1     |
| T <sub>AVGV</sub> | Address Valid to BUSWIDTH Setup            |                       | 2 T <sub>OSC</sub> – 75 | ns    |       |
| T <sub>LLGV</sub> | ALE Low to BUSWIDTH Setup                  |                       | T <sub>OSC</sub> – 60   | ns    | 4     |
| T <sub>CLGX</sub> | Buswidth Hold after CLKOUT Low             | 0                     |                         | ns    |       |
| T <sub>AVDV</sub> | Address Valid to Input Data Valid          |                       | 3 T <sub>OSC</sub> – 55 | ns    | 2     |
| T <sub>RLDV</sub> | $\overline{RD}$ Active to Input Data Valid |                       | T <sub>OSC</sub> – 22   | ns    | 2     |
| T <sub>CLDV</sub> | CLKOUT Low to Input Data Valid             |                       | T <sub>OSC</sub> – 50   | ns    |       |
| T <sub>RHDZ</sub> | End of $\overline{RD}$ to Input Data Float |                       | T <sub>OSC</sub>        | ns    |       |
| T <sub>RDX</sub>  | Data Hold after $\overline{RD}$ Inactive   | 0                     |                         | ns    |       |

### NOTES:

1. If Max is exceeded, additional wait states will occur.
2. If wait states are used, add 2 T<sub>OSC</sub> \* N, where N = number of wait states.
3. Testing performed at 8 MHz. However, the device is static by design and will typically operate below 1 Hz.
4. These timings are included for compatibility with older –90 and BH products. They should not be used for newer high-speed designs.

**AC ELECTRICAL CHARACTERISTICS** (Continued)

Test Conditions: Capacitive load on all pins = 100 pF, Rise and fall times = 10 ns,  $F_{OSC} = 16$  MHz.

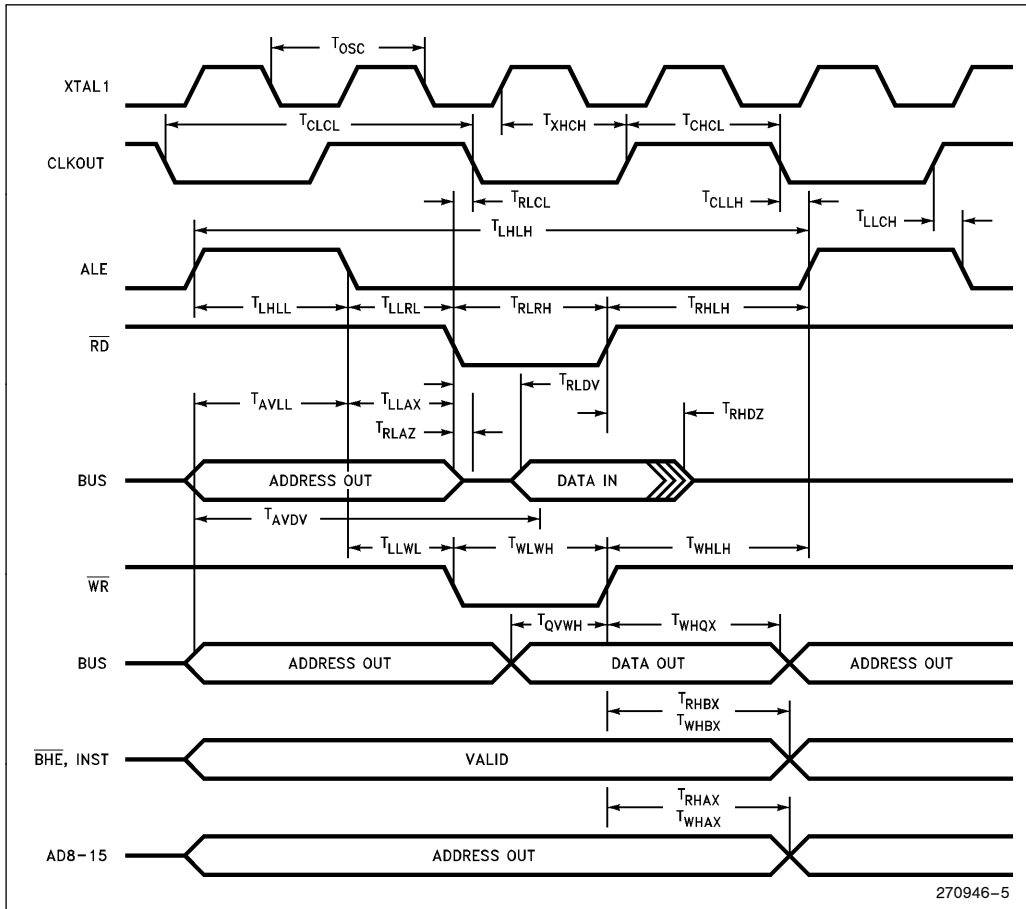
The 87C196MC will meet the following timing specifications:

| Symbol     | Parameter                                                 | Min            | Max            | Units | Notes |
|------------|-----------------------------------------------------------|----------------|----------------|-------|-------|
| $T_{XHCH}$ | XTAL1 to CLKOUT High or Low                               | 30             | 110            | ns    |       |
| $T_{CLCL}$ | CLKOUT Cycle Time                                         | $2 T_{OSC}$    |                | ns    |       |
| $T_{CHCL}$ | CLKOUT High Period                                        | $T_{OSC} - 10$ | $T_{OSC} + 15$ | ns    |       |
| $T_{CLLH}$ | CLKOUT Falling Edge to ALE Rising                         | -5             | 15             | ns    |       |
| $T_{LLCH}$ | ALE Falling Edge to CLKOUT Rising                         | -20            | 15             | ns    |       |
| $T_{LHLH}$ | ALE Cycle Time                                            | $4 T_{OSC}$    |                | ns    | 3     |
| $T_{LHLL}$ | ALE High Period                                           | $T_{OSC} - 10$ | $T_{OSC} + 10$ | ns    |       |
| $T_{AVLL}$ | Address Setup to ALE Falling Edge                         | $T_{OSC} - 15$ |                | ns    |       |
| $T_{LLAX}$ | Address Hold after ALE Falling                            | $T_{OSC} - 40$ |                | ns    |       |
| $T_{LLRL}$ | ALE Falling Edge to $\overline{RD}$ Falling               | $T_{OSC} - 30$ |                | ns    |       |
| $T_{RLCL}$ | $\overline{RD}$ Low to CLKOUT Falling Edge                | 4              | 30             | ns    |       |
| $T_{RLRH}$ | $\overline{RD}$ Low Period                                | $T_{OSC} - 5$  | $T_{OSC} + 25$ | ns    | 3     |
| $T_{RHLH}$ | $\overline{RD}$ Rising Edge to ALE Rising Edge            | $T_{OSC}$      | $T_{OSC} + 25$ | ns    | 1     |
| $T_{RLAZ}$ | $\overline{RD}$ Low to Address Float                      |                | 5              | ns    |       |
| $T_{LLWL}$ | ALE Falling Edge to $\overline{WR}$ Falling               | $T_{OSC} - 10$ |                | ns    |       |
| $T_{CLWL}$ | CLKOUT Low to $\overline{WR}$ Falling Edge                | 0              | 25             | ns    |       |
| $T_{QVWH}$ | Data Stable to $\overline{WR}$ Rising Edge                | $T_{OSC} - 23$ |                | ns    |       |
| $T_{CHWH}$ | CLKOUT High to $\overline{WR}$ Rising Edge                | -10            | 15             | ns    |       |
| $T_{WLWH}$ | $\overline{WR}$ Low Period                                | $T_{OSC} - 30$ |                | ns    | 3     |
| $T_{WHQX}$ | Data Hold after $\overline{WR}$ Rising Edge               | $T_{OSC} - 25$ |                | ns    |       |
| $T_{WHLH}$ | $\overline{WR}$ Rising Edge to ALE Rising Edge            | $T_{OSC} - 10$ | $T_{OSC} + 15$ | ns    | 1     |
| $T_{WHBX}$ | $\overline{BHE}$ , INST Hold after $\overline{WR}$ Rising | $T_{OSC} - 10$ |                | ns    |       |
| $T_{WHAX}$ | AD8-15 Hold after $\overline{WR}$ Rising                  | $T_{OSC} - 30$ |                | ns    | 2     |
| $T_{RHBX}$ | $\overline{BHE}$ , INST Hold after $\overline{RD}$ Rising | $T_{OSC} - 10$ |                | ns    |       |
| $T_{RHAX}$ | AD8-15 Hold after $\overline{RD}$ Rising                  | $T_{OSC} - 30$ |                | ns    | 2     |

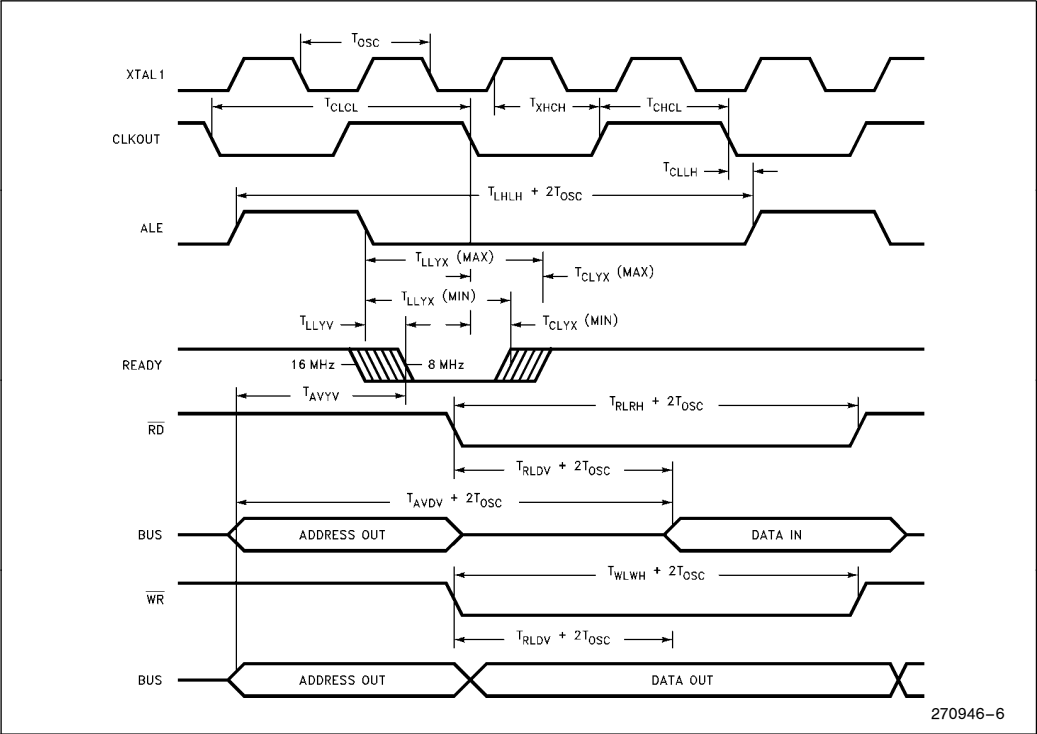
**NOTES:**

1. Assuming back to back cycles.
2. 8-bit bus only.
3. If wait states are used, add  $2 T_{OSC} * N$ , where N = number of wait states.

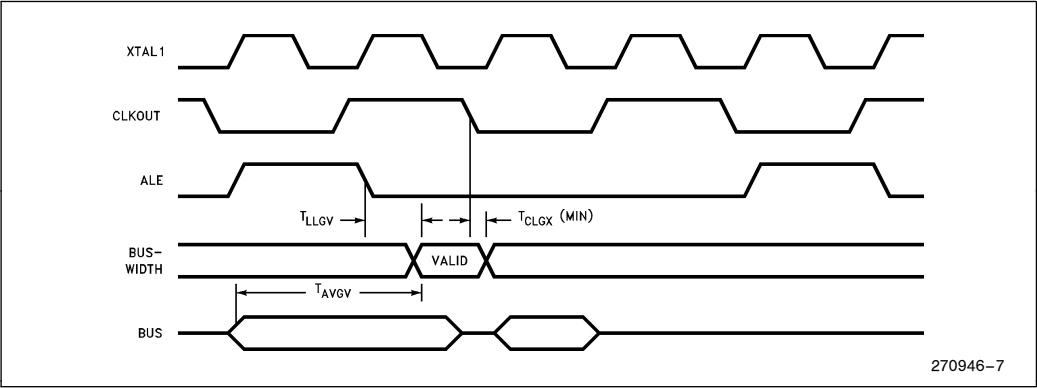
SYSTEM BUS TIMINGS



READY TIMINGS (One Wait State)



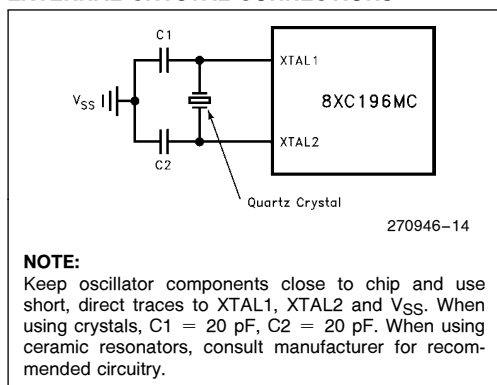
BUSWIDTH TIMINGS



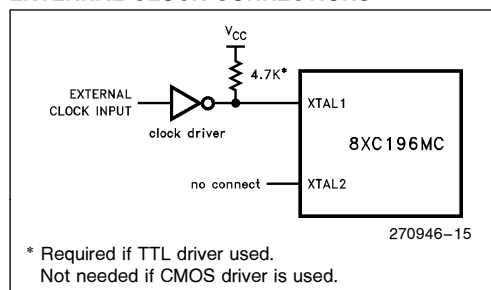
## EXTERNAL CLOCK DRIVE

| Symbol       | Parameter            | Min  | Max  | Units |
|--------------|----------------------|------|------|-------|
| $1/T_{XLXL}$ | Oscillator Frequency | 8    | 16.0 | MHz   |
| $T_{XLXL}$   | Oscillator Period    | 62.5 | 125  | ns    |
| $T_{XHXX}$   | High Time            | 22   |      | ns    |
| $T_{XLXX}$   | Low Time             | 22   |      | ns    |
| $T_{XLXH}$   | Rise Time            |      | 10   | ns    |
| $T_{XHXL}$   | Fall Time            |      | 10   | ns    |

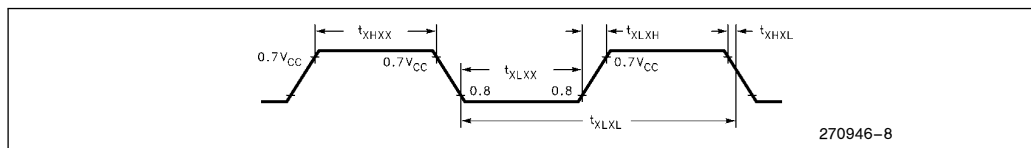
## EXTERNAL CRYSTAL CONNECTIONS



## EXTERNAL CLOCK CONNECTIONS

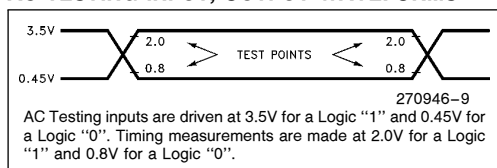


## EXTERNAL CLOCK DRIVE WAVEFORMS

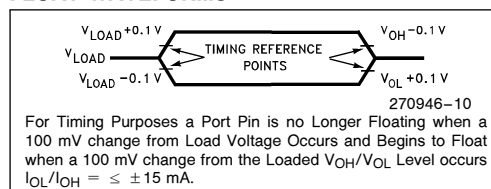


An external oscillator may encounter as much as a 100 pF load at XTAL1 when it starts-up. This is due to interaction between the amplifier and its feedback capacitance. Once the external signal meets the  $V_{IL}$  and  $V_{IH}$  specifications the capacitance will not exceed 20 pF.

## AC TESTING INPUT, OUTPUT WAVEFORMS



## FLOAT WAVEFORMS



### A TO D CHARACTERISTICS

The sample and conversion time of the A/D converter in the 8-bit or 10-bit modes is programmed by loading a byte into the AD\_\_TIME Special Function Register. This allows optimizing the A/D operation for specific applications. The AD\_\_TIME register is functional for all possible values, but the accuracy of the A/D converter is only guaranteed for the times specified in the operating conditions table.

The value loaded into AD\_\_TIME bits 5, 6, 7 determines the sample time,  $T_{SAM}$ , and is calculated using the following formula:

$$SAM = \frac{(T_{SAM} \times F_{OSC}) - 2}{8}$$

$T_{SAM}$  = Sample time,  $\mu s$   
 $F_{OSC}$  = Processor frequency, MHz  
 SAM = Value loaded into AD\_\_TIME bits 5, 6, 7

SAM must be in the range 1 through 7.

The value loaded into AD\_\_TIME bits 0–5 determines the conversion time,  $T_{CONV}$ , and is calculated using the following formula:

$$CONV = \frac{(T_{CONV} \times F_{OSC}) - 3}{2B} - 1$$

$T_{CONV}$  = Conversion time,  $\mu s$   
 $F_{OSC}$  = Processor frequency, MHz  
 B = 8 for 8-bit conversion  
 B = 10 for 10-bit conversion  
 CONV = Value loaded into AD\_\_TIME bits 0–5

CONV must be in the range 2 through 31.

The converter is ratiometric, so absolute accuracy is dependent on the accuracy and stability of  $V_{REF}$ .  $V_{REF}$  must be close to  $V_{CC}$  since it supplies both the resistor ladder and the analog portion of the converter and input port pins. There is also an AD\_\_TEST SFR that allows for conversion on ANGND and  $V_{REF}$  as well as adjusting the zero offset. The absolute error listed is WITHOUT doing any adjustments.

### A/D CONVERTER SPECIFICATION

The specifications given assume adherence to the operating conditions section of this data sheet. Testing is performed with  $V_{REF} = 5.12V$  and 16.0 MHz operating frequency. After a conversion is started, the device is placed in the IDLE mode until the conversion is complete.

## 10-BIT MODE A/D OPERATING CONDITIONS

| Symbol            | Description            | Min  | Max  | Units |
|-------------------|------------------------|------|------|-------|
| T <sub>A</sub>    | Ambient Temperature    | − 40 | + 85 | °C    |
| V <sub>CC</sub>   | Digital Supply Voltage | 4.50 | 5.50 | V     |
| V <sub>REF</sub>  | Analog Supply Voltage  | 4.00 | 5.50 | V(1)  |
| T <sub>SAM</sub>  | Sample Time            | 1.0  |      | μs(2) |
| T <sub>CONV</sub> | Conversion Time        | 10.0 | 20.0 | μs(2) |
| F <sub>OSC</sub>  | Oscillator Frequency   | 8.0  | 16.0 | MHz   |

### NOTES:

ANGND and V<sub>SS</sub> should nominally be at the same potential.

1. V<sub>REF</sub> must be within 0.5V of V<sub>CC</sub>.

2. The value of AD\_TIME is selected to meet these specifications.

## 10-BIT MODE A/D CHARACTERISTICS (Over Specified Operating Conditions)

| Parameter                                                                       | Typical(1)              | Min         | Max                    | Units*                  |
|---------------------------------------------------------------------------------|-------------------------|-------------|------------------------|-------------------------|
| Resolution                                                                      |                         | 1024<br>10  | 1024<br>10             | Levels<br>Bits          |
| Absolute Error                                                                  |                         | 0           | ± 4                    | LSBs                    |
| Full Scale Error                                                                | 0.25 ± 0.5              |             |                        | LSBs                    |
| Zero Offset Error                                                               | 0.25 ± 0.5              |             |                        | LSBs                    |
| Non-Linearity                                                                   | 1.0 ± 2.0               |             | ± 4                    | LSBs                    |
| Differential Non-Linearity                                                      |                         | > − 1       | + 2                    | LSBs                    |
| Channel-to-Channel Matching                                                     | ± 0.1                   | 0           | ± 1.0                  | LSBs                    |
| Repeatability                                                                   | ± 0.25                  | 0           |                        | LSBs                    |
| Temperature Coefficients:<br>Offset<br>Full Scale<br>Differential Non-Linearity | 0.009<br>0.009<br>0.009 |             |                        | LSB/C<br>LSB/C<br>LSB/C |
| Off Isolation                                                                   |                         | − 60        |                        | dB(2, 3)                |
| Feedthrough                                                                     | − 60                    |             |                        | dB(2)                   |
| V <sub>CC</sub> Power Supply Rejection                                          | − 60                    |             |                        | dB(2)                   |
| Input Series Resistance                                                         |                         | 750         | 2K                     | Ω(4)                    |
| Voltage on Analog Input Pin                                                     |                         | ANGND − 0.5 | V <sub>REF</sub> + 0.5 | V(5, 6)                 |
| Sampling Capacitor                                                              | 3                       |             |                        | pF                      |
| DC Input Leakage                                                                | ± 1                     | 0           | ± 3.0                  | μA                      |

### NOTES:

\*An “LSB”, as used here has a value of approximately 5 mV. (See Embedded Microcontrollers and Processors Handbook for A/D glossary of terms).

1. These values are expected for most parts at 25°C but are not tested or guaranteed.

2. DC to 100 KHz.

3. Multiplexer Break-Before-Make is guaranteed.

4. Resistance from device pin, through internal MUX, to sample capacitor.

5. These values may be exceeded if the pin current is limited to ±2 mA.

6. Applying voltages beyond these specifications will degrade the accuracy of other channels being converted.

7. All conversions performed with processor in IDLE mode.

**8-BIT MODE A/D OPERATING CONDITIONS**

| Symbol     | Description            | Min  | Max  | Units       |
|------------|------------------------|------|------|-------------|
| $T_A$      | Ambient Temperature    | -40  | +85  | °C          |
| $V_{CC}$   | Digital Supply Voltage | 4.50 | 5.50 | V           |
| $V_{REF}$  | Analog Supply Voltage  | 4.00 | 5.50 | V(1)        |
| $T_{SAM}$  | Sample Time            | 1.0  |      | $\mu s$ (2) |
| $T_{CONV}$ | Conversion Time        | 7.0  | 20.0 | $\mu s$ (2) |
| $F_{OSC}$  | Oscillator Frequency   | 8.0  | 16.0 | MHz         |

**NOTES:**

ANGND and  $V_{SS}$  should nominally be at the same potential.

1.  $V_{REF}$  must be within 0.5V of  $V_{CC}$ .

2. The value of AD\_TIME is selected to meet these specifications.

**8-BIT MODE A/D CHARACTERISTICS** (Over the Above Operating Conditions)

| Parameter                                                                       | Typical(1)                  | Min            | Max             | Units*                  |
|---------------------------------------------------------------------------------|-----------------------------|----------------|-----------------|-------------------------|
| Resolution                                                                      |                             | 256<br>8       | 256<br>8        | Level<br>Bits           |
| Absolute Error                                                                  |                             | 0              | $\pm 1$         | LSBs                    |
| Full Scale Error                                                                | $\pm 0.5$                   |                |                 | LSBs                    |
| Zero Offset Error                                                               | $\pm 0.5$                   |                |                 | LSBs                    |
| Non-Linearity                                                                   |                             | 0              | $\pm 1$         | LSBs                    |
| Differential Non-Linearity                                                      |                             | $> -1$         | +1              | LSBs                    |
| Channel-to-Channel Matching                                                     |                             | 0              | $\pm 1.0$       | LSBs                    |
| Repeatability                                                                   | $\pm 0.25$                  |                |                 | LSBs                    |
| Temperature Coefficients:<br>Offset<br>Full Scale<br>Differential Non-Linearity | <br>0.003<br>0.003<br>0.003 |                |                 | LSB/C<br>LSB/C<br>LSB/C |
| Off Isolation                                                                   |                             | -60            |                 | dB(2, 3)                |
| Feedthrough                                                                     | -60                         |                |                 | dB(2)                   |
| $V_{CC}$ Power Supply Rejection                                                 | -60                         |                |                 | dB(2)                   |
| Input Series Resistance                                                         |                             | 750            | 2K              | $\Omega$ (4)            |
| Voltage on Analog Input Pin                                                     |                             | $V_{SS} - 0.5$ | $V_{REF} + 0.5$ | V(5, 6)                 |
| Sampling Capacitor                                                              | 3                           |                |                 | pF                      |
| DC Input Leakage                                                                | $\pm 1$                     | 0              | $\pm 3.0$       | $\mu A$                 |

**NOTES:**

\*An "LSB" as used here, has a value of approximately 20 mV. (See Embedded Microcontrollers and Processors Handbook for A/D glossary of terms).

1. These values are expected for most parts at 25°C but are not tested or guaranteed.

2. DC to 100 KHz.

3. Multiplexer Break-Before-Make is guaranteed.

4. Resistance from device pin, through internal MUX, to sample capacitor.

5. These values may be exceeded if the pin current is limited to  $\pm 2$  mA.

6. Applying voltages beyond these specifications will degrade the accuracy of other channels being converted.

7. All conversions performed with processor in IDLE mode.

## EPROM SPECIFICATIONS

### OPERATING CONDITIONS

| Symbol           | Description                                                 | Min   | Max   | Units |
|------------------|-------------------------------------------------------------|-------|-------|-------|
| T <sub>A</sub>   | Ambient Temperature during Programming                      | 20    | 30    | °C    |
| V <sub>CC</sub>  | Supply Voltage during Programming                           | 4.5   | 5.5   | V(1)  |
| V <sub>REF</sub> | Reference Supply Voltage during Programming                 | 4.5   | 5.5   | V(1)  |
| V <sub>PP</sub>  | Programming Voltage                                         | 12.25 | 12.75 | V(2)  |
| V <sub>EA</sub>  | EA Pin Voltage                                              | 12.25 | 12.75 | V(2)  |
| F <sub>OSC</sub> | Oscillator Frequency during Auto and Slave Mode Programming | 6.0   | 8.0   | MHz   |
| T <sub>OSC</sub> | Oscillator Frequency during Run-Time Programming            | 6.0   | 12.0  | MHz   |

#### NOTES:

1. V<sub>CC</sub> and V<sub>REF</sub> should nominally be at the same voltage during programming.
2. V<sub>PP</sub> and V<sub>EA</sub> must never exceed the maximum specification, or the device may be damaged.
3. V<sub>SS</sub> and ANGND should nominally be at the same potential (0V).
4. Load capacitance during Auto and Slave Mode programming = 150 pF.

### AC EPROM PROGRAMMING CHARACTERISTICS

| Symbol                           | Parameter                                                          | Min  | Max | Units            |
|----------------------------------|--------------------------------------------------------------------|------|-----|------------------|
| T <sub>SHLL</sub>                | Reset High to First $\overline{\text{PALE}}$ Low                   | 1100 |     | T <sub>OSC</sub> |
| T <sub>LLLH</sub>                | $\overline{\text{PALE}}$ Pulse Width                               | 50   |     | T <sub>OSC</sub> |
| T <sub>AVLL</sub>                | Address Setup Time                                                 | 0    |     | T <sub>OSC</sub> |
| T <sub>LLAX</sub>                | Address Hold Time                                                  | 100  |     | T <sub>OSC</sub> |
| T <sub>PLDV</sub>                | $\overline{\text{PROG}}$ Low to Word Dump Valid                    |      | 50  | T <sub>OSC</sub> |
| T <sub>PHDX</sub>                | Word Dump Data Hold                                                |      | 50  | T <sub>OSC</sub> |
| T <sub>DVPL</sub>                | Data Setup Time                                                    | 0    |     | T <sub>OSC</sub> |
| T <sub>PLDX</sub>                | Data Hold Time                                                     | 400  |     | T <sub>OSC</sub> |
| T <sub>PLPH</sub> <sup>(1)</sup> | $\overline{\text{PROG}}$ Pulse Width                               | 50   |     | T <sub>OSC</sub> |
| T <sub>PHLL</sub>                | $\overline{\text{PROG}}$ High to Next $\overline{\text{PALE}}$ Low | 220  |     | T <sub>OSC</sub> |
| T <sub>LHPL</sub>                | $\overline{\text{PALE}}$ High to $\overline{\text{PROG}}$ Low      | 220  |     | T <sub>OSC</sub> |
| T <sub>PHPL</sub>                | $\overline{\text{PROG}}$ High to Next $\overline{\text{PROG}}$ Low | 220  |     | T <sub>OSC</sub> |
| T <sub>PHIL</sub>                | $\overline{\text{PROG}}$ High to AINC Low                          | 0    |     | T <sub>OSC</sub> |
| T <sub>ILIH</sub>                | $\overline{\text{AINC}}$ Pulse Width                               | 240  |     | T <sub>OSC</sub> |
| T <sub>ILVH</sub>                | PVER Hold after $\overline{\text{AINC}}$ Low                       | 50   |     | T <sub>OSC</sub> |
| T <sub>ILPL</sub>                | $\overline{\text{AINC}}$ Low to $\overline{\text{PROG}}$ Low       | 170  |     | T <sub>OSC</sub> |
| T <sub>PHVL</sub>                | $\overline{\text{PROG}}$ High to PVER Valid                        |      | 220 | T <sub>OSC</sub> |

#### NOTE:

1. This specification is for the Word Dump Mode. For programming pulses, use the Modified Quick Pulse Algorithm.

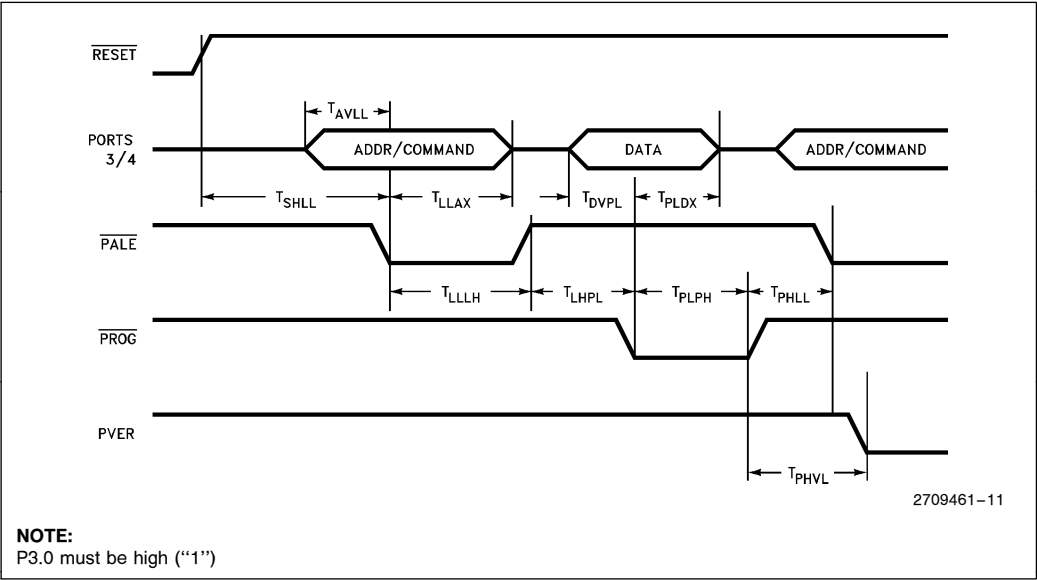


DC EPROM PROGRAMMING CHARACTERISTICS

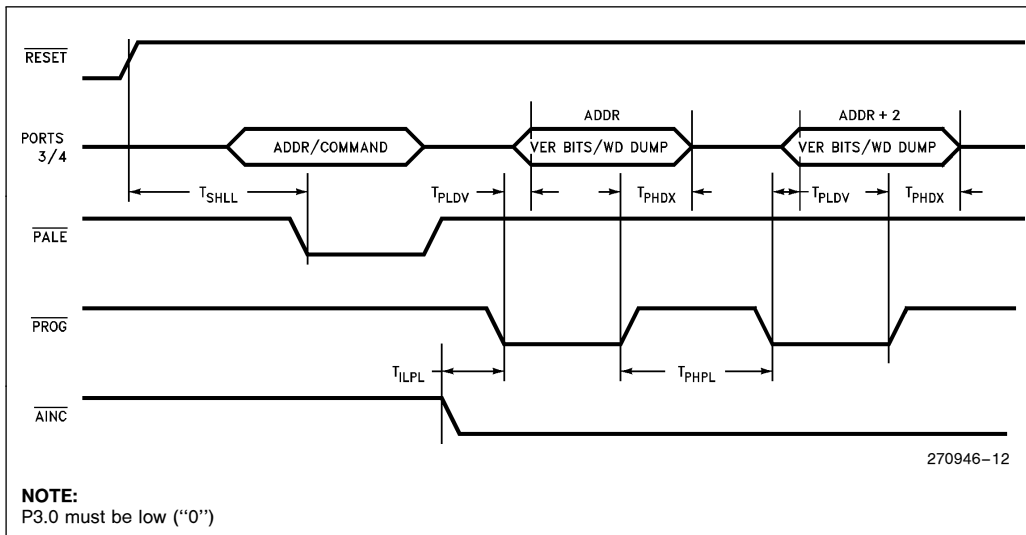
| Symbol   | Parameter                                  | Min | Max | Units |
|----------|--------------------------------------------|-----|-----|-------|
| $I_{PP}$ | $V_{PP}$ Supply Current (When Programming) |     | 100 | mA    |

**NOTE:**  
Do not apply  $V_{PP}$  until  $V_{CC}$  is stable and within specifications and the oscillator/clock has stabilized or the device may be damaged.

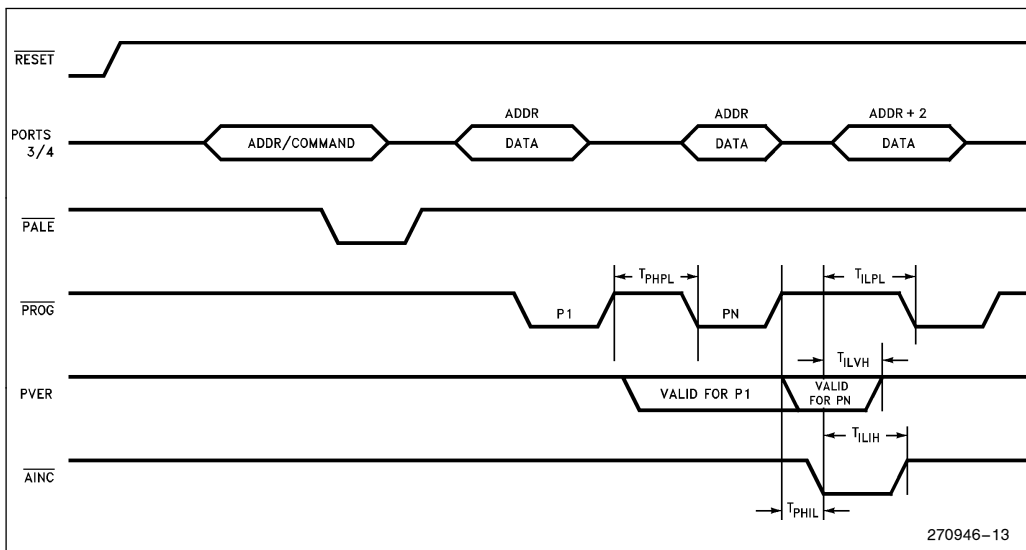
SLAVE PROGRAMMING MODE DATA PROGRAM MODE WITH SINGLE PROGRAM PULSE



### SLAVE PROGRAMMING MODE IN WORD DUMP WITH AUTO INCREMENT



### SLAVE PROGRAMMING MODE TIMING IN DATA PROGRAM WITH REPEATED PROG PULSE AND AUTO INCREMENT



## 87C196MC DESIGN CONSIDERATIONS

When an indirect shift during divide occurs the upper 3 bits of the shift count are not masked completely. If the shift count register has the value  $32 \cdot n$  where  $n = 1, 3, 5$  or  $7$ , the operand will be shifted 32 times. This should have resulted in no shift taking place.

## DATA SHEET REVISION HISTORY

This data sheet (270946-004) is valid for devices with a "B" at the end of the topside tracking number. Data sheets are changed as new device information becomes available. Verify with your local Intel sales office that you have the latest version before finalizing a design or ordering devices.

The following important differences exist between this data sheet (270946-002) and the previous version (270946-003):

1. The data sheet was reorganized to standard format.
2. Added 83C196MC device.
3. Added package thermal characteristics.
4. Added note on missing pins on SDIP package.
5. Removed SFR maps (now in user's manual).
6. Added note on  $T_{LLYV}$  and  $T_{LLGV}$  specifications.
7. Changed 10-bit mode  $T_{CONV}$  (MIN) to  $10.0 \mu s$  from  $15.0 \mu s$ .
8. Changed 10-bit mode  $T_{CONV}$  (MAX) to  $20.0 \mu s$  from  $18.0 \mu s$ .
9. Changed VREF (MIN) in 8- and 10-bit mode to  $4.0V$  from  $4.5V$ .

The following important differences exist between data sheet 270946-003 and the previous version (270946-002):

1. The data sheet title was changed to better reflect the purpose of the 87C196MC as an AC Inverter/DC Brushless Motor Control Microcontroller.
2. The standard temperature range for this part now covers  $-40^{\circ}C$  to  $+85^{\circ}C$ .

3. EXTINT function description now includes WG\_PROTECT (1FCEH) as the name and address of the register used to select positive/negative or high/low detection for EXTINT.
4. The memory range 01F00H–01FBFH was added to the SFR map as RESERVED.
5.  $I_{IL}$  changed from  $-60 \mu A$  to  $-70 \mu A$ .
6.  $I_{REF}$  changed from  $5 mA$  to  $2 mA$  maximum and the typical specification was removed.
7. The READY description of the READY TIMINGS (One Wait State) graphic was modified to denote the shifting of the leading edge of READY versus frequency. At  $16 MHz$  the falling edge of READY occurs before the falling edge of ALE.
8. AC Testing Input, Output Waveform was changed to reflect inputs driven at  $3.5V$  for a Logic "1" and  $.45V$  for a Logic "0" and timing measurements made at  $2.0V$  for a Logic "1" and  $0.8V$  for a Logic "0".
9. Float Waveform was changed from  $I_{OL}/I_{OH} = \pm 15 mA$  to  $I_{OL}/I_{OH} \leq \pm 15 mA$ .
10. AD\_TIME register for 10-bit conversions was changed from 0C7H to 0D8H. The number of sample time states was changed from 24 to 25 states, the conversion time states was changed from 80 to 240 states, and the total conversion time for  $AD\_TIME = D8H$  replaced the total conversion time for  $AD\_TIME = C7H$ .
11. The number of sample time states for an 8-bit conversion was changed from 20 states to 21 states.
12. There is a single entry in the ERRATA section of this version of the data sheet concerning the results of an indirect shift during divide.

The following important differences exist between this data sheet (270946-002) and the previous version (270946-001):

1.  $T_A$  Ambient Temperature Under Bias Min changed from  $-20^{\circ}C$  to  $-40^{\circ}C$ .
2.  $I_{REF}$  A/D Conversion Reference Current Max changed from  $5 mA$  to  $2 mA$ .
3. Testing levels changed from TTL values to CMOS values.
4. A/D Input Series Resistance Max changed from  $1.2 K\Omega$  to  $2 K\Omega$ .