

# Addendum for New QFN Package Migration

This addendum provides the changes to the 98A case outline numbers for products covered in this book. Case outlines were changed because of the migration from gold wire to copper wire in some packages. See the table below for the old (gold wire) package versus the new (copper wire) package.

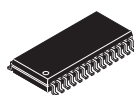
To view the new drawing, go to [Freescale.com](http://Freescale.com) and search on the new 98A package number for your device.

For more information about QFN package use, see EB806: *Electrical Connection Recommendations for the Exposed Pad on QFN and DFN Packages*.

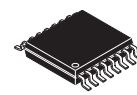
| Part Number   | Package Description | Original (gold wire)<br>package document number | Current (copper wire)<br>package document number |
|---------------|---------------------|-------------------------------------------------|--------------------------------------------------|
| MC68HC908JW32 | 48 QFN              | 98ARH99048A                                     | 98ASA00466D                                      |
| MC9S08AC16    |                     |                                                 |                                                  |
| MC9S908AC60   |                     |                                                 |                                                  |
| MC9S08AC128   |                     |                                                 |                                                  |
| MC9S08AW60    |                     |                                                 |                                                  |
| MC9S08GB60A   |                     |                                                 |                                                  |
| MC9S08GT16A   |                     |                                                 |                                                  |
| MC9S08JM16    |                     |                                                 |                                                  |
| MC9S08JM60    |                     |                                                 |                                                  |
| MC9S08LL16    |                     |                                                 |                                                  |
| MC9S08QE128   |                     |                                                 |                                                  |
| MC9S08QE32    |                     |                                                 |                                                  |
| MC9S08RG60    |                     |                                                 |                                                  |
| MCF51CN128    |                     |                                                 |                                                  |
| MC9RS08LA8    | 48 QFN              | 98ARL10606D                                     | 98ASA00466D                                      |
| MC9S08GT16A   | 32 QFN              | 98ARH99035A                                     | 98ASA00473D                                      |
| MC9S908QE32   | 32 QFN              | 98ARE10566D                                     | 98ASA00473D                                      |
| MC9S908QE8    | 32 QFN              | 98ASA00071D                                     | 98ASA00736D                                      |
| MC9S08JS16    | 24 QFN              | 98ARL10608D                                     | 98ASA00734D                                      |
| MC9S08QB8     |                     |                                                 |                                                  |
| MC9S08QG8     | 24 QFN              | 98ARL10605D                                     | 98ASA00474D                                      |
| MC9S08SH8     | 24 QFN              | 98ARE10714D                                     | 98ASA00474D                                      |
| MC9RS08KB12   | 24 QFN              | 98ASA00087D                                     | 98ASA00602D                                      |
| MC9S08QG8     | 16 QFN              | 98ARE10614D                                     | 98ASA00671D                                      |
| MC9RS08KB12   | 8 DFN               | 98ARL10557D                                     | 98ASA00672D                                      |
| MC9S08QG8     |                     |                                                 |                                                  |
| MC9RS08KA2    | 6 DFN               | 98ARL10602D                                     | 98ASA00735D                                      |



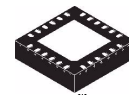
## MC9S08QB8



28 SOIC  
Case 751F



16-Pin TSSOP  
Case 948F



24 QFN  
Case 1982-01

## MC9S08QB8 Series

Covers: MC9S08QB8 and  
MC9S08QB4

### Features

- 8-Bit HCS08 Central Processor Unit (CPU)
  - Up to 20 MHz CPU at 3.6 V to 1.8 V across temperature range of  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$
  - HC08 instruction set with added BGND instruction
  - Support for up to 32 interrupt/reset sources
- On-Chip Memory
  - Up to 8 KB flash memory read/program/erase over full operating voltage and temperature
  - Up to 512 bytes random-access memory (RAM)
  - Security circuitry to prevent unauthorized access to RAM and flash contents
- Power-Saving Modes
  - Two very low power stop modes
  - Peripheral clock enable register can disable clocks to unused modules, thereby reducing currents
  - Low power run
  - Low power wait
  - 6  $\mu\text{s}$  typical wakeup time from stop3 mode
  - Typical stop current of 250 nA at 3 V,  $25^{\circ}\text{C}$
- Clock Source Options
  - Oscillator (XOSC) — Very low-power, loop-control Pierce oscillator; crystal or ceramic resonator range of 31.25 kHz to 38.4 kHz or 1 MHz to 16 MHz
  - Internal Clock Source (ICS) — Internal clock source module containing a frequency-locked-loop (FLL) controlled by internal reference; precision trimming of internal reference allows 0.2% resolution and 2% deviation over temperature and voltage; supports bus frequencies from 1 MHz to 10 MHz
- System Protection
  - Watchdog computer operating properly (COP) reset with option to run from dedicated 1 kHz internal clock source or bus clock
  - Low-voltage detection with reset or interrupt; selectable trip points
  - Illegal opcode detection with reset
  - Illegal address detection with reset
  - Flash block protection
- Development Support
  - Single-wire background debug interface
  - Breakpoint capability to allow single breakpoint setting during in-circuit debugging
- Peripherals
  - **ADC** — 8-channel, 12-bit resolution; 2.5  $\mu\text{s}$  conversion time; automatic compare function; 1.7 mV/ $^{\circ}\text{C}$  temperature sensor; internal bandgap reference channel; operation in stop3; fully functional from 3.6 V to 1.8 V.
  - **ACMP** — Analog comparator with selectable interrupt on rising, falling, or either edge of comparator output; compare option to fixed internal bandgap reference voltage; output can be tied internally to TPM input capture; operation in stop3
  - **TPM** — One 1-channel timer/pulse-width modulator (TPM) module; selectable input capture, output compare, or buffered edge- or center-aligned PWM on each channel; ACMP output can be tied internally to input capture
  - **MTIM** — 8-bit modulo timer module with optional prescaler
  - **RTC** — (Real-time counter) 8-bit modulo counter with binary or decimal based prescaler; external clock source for precise time base, time-of-day, calendar or task scheduling functions; free running on-chip low power oscillator (1 kHz) for cyclic wakeup without external components; runs in all MCU modes
  - **SCI** — Full duplex non-return to zero (NRZ); LIN master extended break generation; LIN slave extended break detection; wakeup on active edge
  - **KBI** — 8-pin keyboard interrupt with selectable edge and level detection modes
- Input/Output
  - 22 GPIOs and one input-only and one output-only pin.
  - Hysteresis and configurable pullup device on all input pins; configurable slew rate and drive strength on all output pins except PTA5.
- Package Options
  - 28-pin SOIC, 24-pin QFN, 16-pin TSSOP

This document contains information on a product under development. Freescale reserves the right to change or discontinue this product without notice.

# Table of Contents

|   |                                                 |    |                                           |    |
|---|-------------------------------------------------|----|-------------------------------------------|----|
| 1 | MCU Block Diagram                               | 3  | 3.11 Analog Comparator (ACMP) Electricals | 20 |
| 2 | Pin Assignments                                 | 4  | 3.12 ADC Characteristics                  | 20 |
| 3 | Electrical Characteristics                      | 7  | 3.13 Flash Specifications                 | 23 |
|   | 3.1 Introduction                                | 7  | 3.14 EMC Performance                      | 24 |
|   | 3.2 Parameter Classification                    | 7  | 4 Ordering Information                    | 25 |
|   | 3.3 Absolute Maximum Ratings                    | 7  | 5 Package Information                     | 25 |
|   | 3.4 Thermal Characteristics                     | 8  | 5.1 Mechanical Drawings                   | 25 |
|   | 3.5 ESD Protection and Latch-Up Immunity        | 9  |                                           |    |
|   | 3.6 DC Characteristics                          | 10 |                                           |    |
|   | 3.7 Supply Current Characteristics              | 13 |                                           |    |
|   | 3.8 External Oscillator (XOSC) Characteristics  | 15 |                                           |    |
|   | 3.9 Internal Clock Source (ICS) Characteristics | 16 |                                           |    |
|   | 3.10 AC Characteristics                         | 18 |                                           |    |
|   | 3.10.1 Control Timing                           | 18 |                                           |    |
|   | 3.10.2 TPM Module Timing                        | 19 |                                           |    |

## Revision History

To provide the most up-to-date information, the revision of our documents on the World Wide Web will be the most current. Your printed copy may be an earlier revision. To verify you have the latest information available, refer to:

<http://freescale.com/>

The following revision history table summarizes changes contained in this document.

| Rev | Date       | Description of Changes                                                                                                                                                                                                                                                                                                              |
|-----|------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | 10/22/2008 | Initial public released.                                                                                                                                                                                                                                                                                                            |
| 2   | 12/17/2008 | Completed all the TBDs in <a href="#">Table 8</a> .                                                                                                                                                                                                                                                                                 |
| 3   | 3/6/2009   | Corrected the 24-pin QFN package information.<br>Changed $V_{DDAD}$ and $V_{SSAD}$ to $V_{DDA}$ and $V_{SSA}$ separately.<br>In <a href="#">Table 7</a> , updated the $I_{IN}$ , $I_{OZ}$ and added $I_{OZTOT}$ .<br>In <a href="#">Table 11</a> , updated the DCO output frequency range-trimmed, and updated some of the symbols. |

## Related Documentation

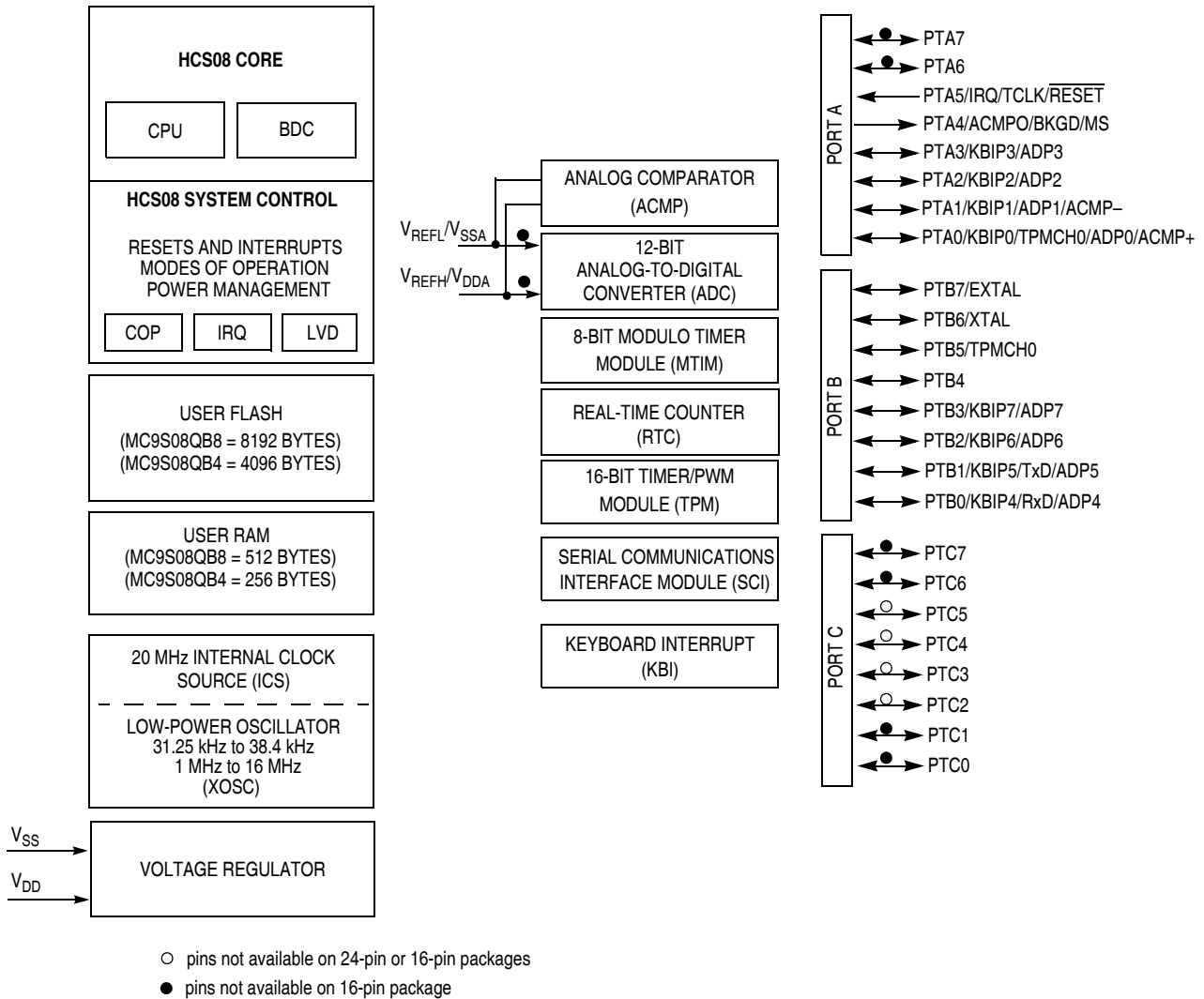
Find the most current versions of all documents at: <http://www.freescale.com>

### Reference Manual (MC9S08QB8RM)

Contains extensive product information including modes of operation, memory, resets and interrupts, register definition, port pins, CPU, and all module information.

# 1 MCU Block Diagram

The block diagram shows the structure of the MC9S08QB8 MCU.



<sup>1</sup>  $V_{DDA}/V_{REFH}$  and  $V_{SSA}/V_{REFL}$  are double bonded to  $V_{DD}$  and  $V_{SS}$  respectively in 16-pin package.

Figure 1. MC9S08QB8 Series Block Diagram

## 2 Pin Assignments

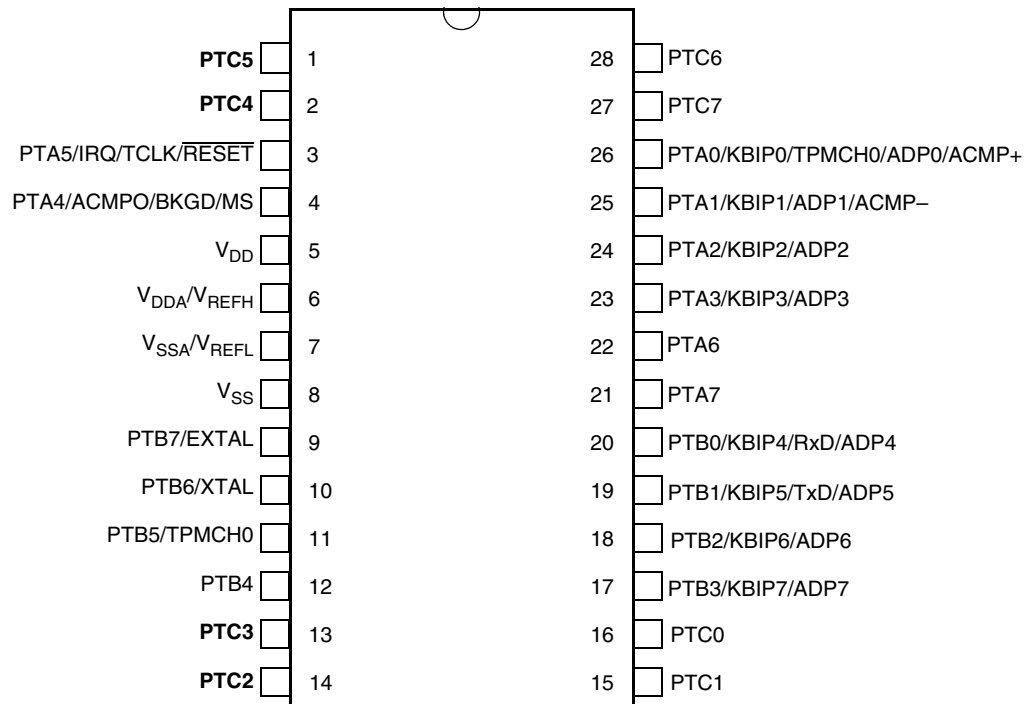
This chapter shows the pin assignments for the MC9S08QB8 series devices.

**Table 1. Pin Availability by Package Pin-Count**

| Pin Number |    |    | <-- Lowest Priority --> Highest |                     |        |                   |                                     |
|------------|----|----|---------------------------------|---------------------|--------|-------------------|-------------------------------------|
| 28         | 24 | 16 | Port Pin                        | Alt 1               | Alt 2  | Alt 3             | Alt 4                               |
| 1          | —  | —  | PTC5                            |                     |        |                   |                                     |
| 2          | —  | —  | PTC4                            |                     |        |                   |                                     |
| 3          | 23 | 1  | PTA5                            | IRQ                 | TCLK   | <u>RESET</u>      |                                     |
| 4          | 24 | 2  | PTA4                            | ACMPO               | BKGD   | MS                |                                     |
| 5          | 1  | 3  |                                 |                     |        |                   | V <sub>DD</sub>                     |
| 6          | 2  | —  |                                 |                     |        |                   | V <sub>DDA</sub> /V <sub>REFH</sub> |
| 7          | 3  | —  |                                 |                     |        |                   | V <sub>SSA</sub> /V <sub>REFL</sub> |
| 8          | 4  | 4  |                                 |                     |        |                   | V <sub>SS</sub>                     |
| 9          | 5  | 5  | PTB7                            |                     |        |                   | EXTAL                               |
| 10         | 6  | 6  | PTB6                            |                     |        |                   | XTAL                                |
| 11         | 7  | 7  | PTB5                            | TPMCH0 <sup>1</sup> |        |                   |                                     |
| 12         | 8  | 8  | PTB4                            |                     |        |                   |                                     |
| 13         | —  | —  | PTC3                            |                     |        |                   |                                     |
| 14         | —  | —  | PTC2                            |                     |        |                   |                                     |
| 15         | 9  | —  | PTC1                            |                     |        |                   |                                     |
| 16         | 10 | —  | PTC0                            |                     |        |                   |                                     |
| 17         | 11 | 9  | PTB3                            | KBIP7               |        | ADP7              |                                     |
| 18         | 12 | 10 | PTB2                            | KBIP6               |        | ADP6              |                                     |
| 19         | 13 | 11 | PTB1                            | KBIP5               | TxD    | ADP5              |                                     |
| 20         | 14 | 12 | PTB0                            | KBIP4               | RxD    | ADP4              |                                     |
| 21         | 15 | —  | PTA7                            |                     |        |                   |                                     |
| 22         | 16 | —  | PTA6                            |                     |        |                   |                                     |
| 23         | 17 | 13 | PTA3                            | KBIP3               |        | ADP3              |                                     |
| 24         | 18 | 14 | PTA2                            | KBIP2               |        | ADP2              |                                     |
| 25         | 19 | 15 | PTA1                            | KBIP1               |        | ADP1 <sup>2</sup> | ACMP <sup>-2</sup>                  |
| 26         | 20 | 16 | PTA0                            | KBIP0               | TPMCH0 | ADP0 <sup>2</sup> | ACMP <sup>+2</sup>                  |
| 27         | 21 | —  | PTC7                            |                     |        |                   |                                     |
| 28         | 22 | —  | PTC6                            |                     |        |                   |                                     |

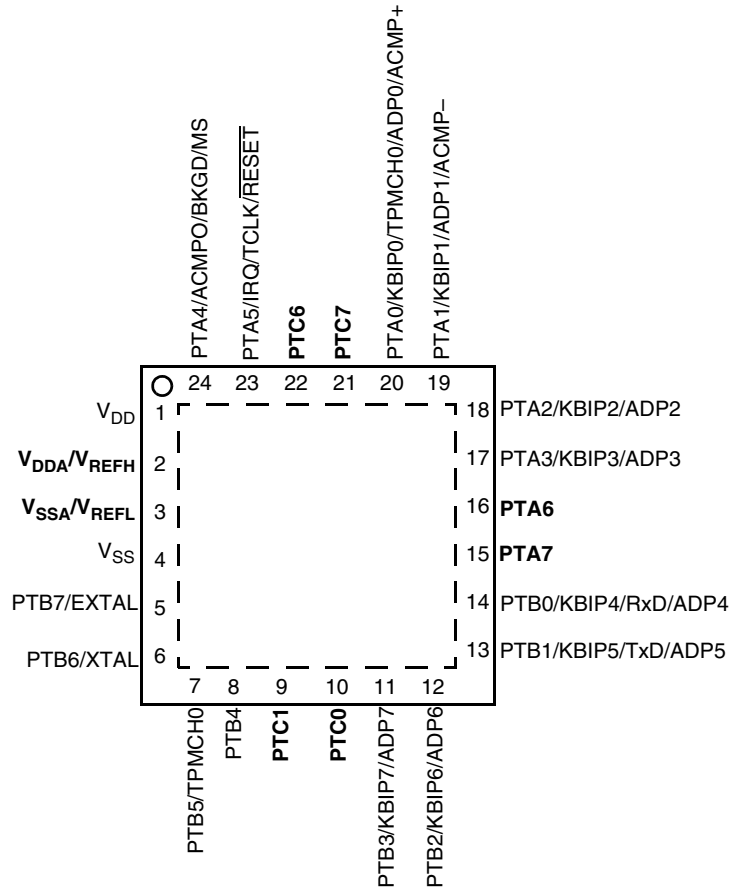
<sup>1</sup> TPMCH0 pin can be repositioned using at PTB5 TPMCH0PS in SOPT2, default reset location is PTA0.

<sup>2</sup> If ADC and ACMP are enabled, both modules will have access to the pin.



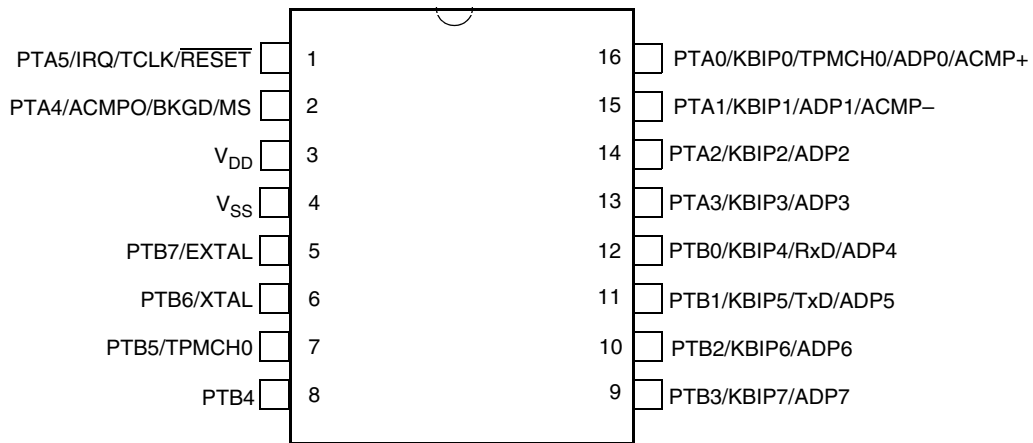
Pins shown in bold type are lost in the next lower pin count package.

**Figure 2. MC9S08QB8 Series in 28-Pin SOIC Package**



Pins shown in bold type are lost in the next lower pin count package.

**Figure 3. MC9S08QB8 Series in 24-Pin QFN Packages**



**Figure 4. MC9S08QB8 Series in 16-Pin TSSOP Package**



## 3 Electrical Characteristics

### 3.1 Introduction

This chapter contains electrical and timing specifications for the MC9S08QB8 series of microcontrollers available at the time of publication.

### 3.2 Parameter Classification

The electrical parameters shown in this supplement are guaranteed by various methods. To give the customer a better understanding the following classification is used and the parameters are tagged accordingly in the tables where appropriate:

**Table 2. Parameter Classifications**

|          |                                                                                                                                                                                                                        |
|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>P</b> | Those parameters are guaranteed during production testing on each individual device.                                                                                                                                   |
| <b>C</b> | Those parameters are achieved by the design characterization by measuring a statistically relevant sample size across process variations.                                                                              |
| <b>T</b> | Those parameters are achieved by design characterization on a small sample size from typical devices under typical conditions unless otherwise noted. All values shown in the typical column are within this category. |
| <b>D</b> | Those parameters are derived mainly from simulations.                                                                                                                                                                  |

#### NOTE

The classification is shown in the column labeled “C” in the parameter tables where appropriate.

### 3.3 Absolute Maximum Ratings

Absolute maximum ratings are stress ratings only, and functional operation at the maxima is not guaranteed. Stress beyond the limits specified in [Table 3](#) may affect device reliability or cause permanent damage to the device. For functional operating conditions, refer to the remaining tables in this section.

This device contains circuitry protecting against damage due to high static voltage or electrical fields; however, it is advised that normal precautions be taken to avoid application of any voltages higher than maximum-rated voltages to this high-impedance circuit. Reliability of operation is enhanced if unused inputs are tied to an appropriate logic voltage level (for instance, either  $V_{SS}$  or  $V_{DD}$ ) or the programmable pull-up resistor associated with the pin is enabled.

**Table 3. Absolute Maximum Ratings**

| Rating                                                                                          | Symbol    | Value                  | Unit |
|-------------------------------------------------------------------------------------------------|-----------|------------------------|------|
| Supply voltage                                                                                  | $V_{DD}$  | -0.3 to 3.8            | V    |
| Maximum current into $V_{DD}$                                                                   | $I_{DD}$  | 120                    | mA   |
| Digital input voltage                                                                           | $V_{In}$  | -0.3 to $V_{DD} + 0.3$ | V    |
| Instantaneous maximum current<br>Single pin limit (applies to all port pins) <sup>1, 2, 3</sup> | $I_D$     | ±25                    | mA   |
| Storage temperature range                                                                       | $T_{stg}$ | -55 to 150             | °C   |

- <sup>1</sup> Input must be current limited to the value specified. To determine the value of the required current-limiting resistor, calculate resistance values for positive ( $V_{DD}$ ) and negative ( $V_{SS}$ ) clamp voltages, then use the larger of the two resistance values.
- <sup>2</sup> All functional non-supply pins, except for PTA5 are internally clamped to  $V_{SS}$  and  $V_{DD}$ .
- <sup>3</sup> Power supply must maintain regulation within operating  $V_{DD}$  range during instantaneous and operating maximum current conditions. If positive injection current ( $V_{In} > V_{DD}$ ) is greater than  $I_{DD}$ , the injection current may flow out of  $V_{DD}$  and could result in external power supply going out of regulation. Ensure external  $V_{DD}$  load will shunt current greater than maximum injection current. This will be the greatest risk when the MCU is not consuming power. Examples are: if no system clock is present, or if the clock rate is very low (which would reduce overall power consumption).

### 3.4 Thermal Characteristics

This section provides information about operating temperature range, power dissipation, and package thermal resistance. Power dissipation on I/O pins is usually small compared to the power dissipation in on-chip logic and voltage regulator circuits, and it is user-determined rather than being controlled by the MCU design. To take  $P_{I/O}$  into account in power calculations, determine the difference between actual pin voltage and  $V_{SS}$  or  $V_{DD}$  and multiply by the pin current for each I/O pin. Except in cases of unusually high pin current (heavy loads), the difference between pin voltage and  $V_{SS}$  or  $V_{DD}$  will be very small.

**Table 4. Thermal Characteristics**

| Rating                                 | Symbol        | Value                       | Unit |
|----------------------------------------|---------------|-----------------------------|------|
| Operating temperature range (packaged) | $T_A$         | $T_L$ to $T_H$<br>-40 to 85 | °C   |
| Maximum junction temperature           | $T_{JM}$      | 95                          | °C   |
| Thermal resistance 28-pin SOIC         | $\theta_{JA}$ | 70                          | °C/W |
| Thermal resistance 24-pin QFN          |               | 92                          | °C/W |
| Thermal resistance 16-pin TSSOP        |               | 129                         | °C/W |

The average chip-junction temperature ( $T_J$ ) in °C can be obtained from:

$$T_J = T_A + (P_D \times \theta_{JA}) \quad \text{Eqn. 1}$$

where:

$T_A$  = Ambient temperature, °C

$\theta_{JA}$  = Package thermal resistance, junction-to-ambient, °C/W

$P_D = P_{int} + P_{I/O}$

$P_{int} = I_{DD} \times V_{DD}$ , Watts — chip internal power

$P_{I/O}$  = Power dissipation on input and output pins — user determined

For most applications,  $P_{I/O} \ll P_{int}$  and can be neglected. An approximate relationship between  $P_D$  and  $T_J$  (if  $P_{I/O}$  is neglected) is:

$$P_D = K \div (T_J + 273^\circ\text{C}) \quad \text{Eqn. 2}$$

Solving Equation 1 and Equation 2 for K gives:

$$K = P_D \times (T_A + 273^\circ\text{C}) + \theta_{JA} \times (P_D)^2 \quad \text{Eqn. 3}$$

where K is a constant pertaining to the particular part. K can be determined from equation 3 by measuring  $P_D$  (at equilibrium) for a known  $T_A$ . Using this value of K, the values of  $P_D$  and  $T_J$  can be obtained by solving Equation 1 and Equation 2 iteratively for any value of  $T_A$ .

### 3.5 ESD Protection and Latch-Up Immunity

Although damage from electrostatic discharge (ESD) is much less common on these devices than on early CMOS circuits, normal handling precautions should be taken to avoid exposure to static discharge. Qualification tests are performed to ensure that these devices can withstand exposure to reasonable levels of static without suffering any permanent damage.

All ESD testing is in conformity with AEC-Q100 Stress Test Qualification for Automotive Grade Integrated Circuits. During the device qualification, ESD stresses were performed for the human body model (HBM), the machine model (MM) and the charge device model (CDM).

A device is defined as a failure if after exposure to ESD pulses the device no longer meets the device specification. Complete DC parametric and functional testing is performed per the applicable device specification at room temperature followed by hot temperature, unless instructed otherwise in the device specification.

**Table 5. ESD and Latch-up Test Conditions**

| Model      | Description                 | Symbol | Value | Unit |
|------------|-----------------------------|--------|-------|------|
| Human Body | Series resistance           | R1     | 1500  | Ω    |
|            | Storage capacitance         | C      | 100   | pF   |
|            | Number of pulses per pin    | —      | 3     |      |
| Machine    | Series resistance           | R1     | 0     | Ω    |
|            | Storage capacitance         | C      | 200   | pF   |
|            | Number of pulses per pin    | —      | 3     |      |
| Latch-up   | Minimum input voltage limit |        | -2.5  | V    |
|            | Maximum input voltage limit |        | 7.5   | V    |

Table 6. ESD and Latch-Up Protection Characteristics

| No. | Rating <sup>1</sup>                          | Symbol    | Min        | Max | Unit |
|-----|----------------------------------------------|-----------|------------|-----|------|
| 1   | Human body model (HBM)                       | $V_{HBM}$ | $\pm 2000$ | —   | V    |
| 2   | Charge device model (CDM)                    | $V_{CDM}$ | $\pm 500$  | —   | V    |
| 3   | Latch-up current at $T_A = 85^\circ\text{C}$ | $I_{LAT}$ | $\pm 100$  | —   | mA   |

<sup>1</sup> Parameter is achieved by design characterization on a small sample size from typical devices under typical conditions unless otherwise noted.

### 3.6 DC Characteristics

This section includes information about power supply requirements and I/O pin characteristics.

Table 7. DC Characteristics

| Num | C | Characteristic                                                    | Symbol    | Condition                                              | Min                  | Typical <sup>1</sup> | Max                  | Unit |
|-----|---|-------------------------------------------------------------------|-----------|--------------------------------------------------------|----------------------|----------------------|----------------------|------|
| 1   | P | Operating Voltage                                                 | $V_{DD}$  | —                                                      | 1.8                  | —                    | 3.6                  | V    |
| 2   | C | Output high voltage<br>All I/O pins,<br>low-drive strength        | $V_{OH}$  | $V_{DD} > 1.8\text{ V},$<br>$I_{Load} = -2\text{ mA}$  | $V_{DD} - 0.5$       | —                    | —                    | V    |
|     | P |                                                                   |           | $V_{DD} > 2.7\text{ V},$<br>$I_{Load} = -10\text{ mA}$ | $V_{DD} - 0.5$       | —                    | —                    |      |
|     | C |                                                                   |           | $V_{DD} > 1.8\text{ V},$<br>$I_{Load} = -2\text{ mA}$  | $V_{DD} - 0.5$       | —                    | —                    |      |
| 3   | D | Output high current<br>Max total $I_{OH}$ for all ports           | $I_{OHT}$ | $V_{OUT} < V_{DD}$                                     | 0                    | —                    | -80                  | mA   |
| 4   | C | Output low voltage<br>All I/O pins,<br>low-drive strength         | $V_{OL}$  | $V_{DD} > 1.8\text{ V},$<br>$I_{Load} = 0.6\text{ mA}$ | —                    | —                    | 0.5                  | V    |
|     | P |                                                                   |           | $V_{DD} > 2.7\text{ V},$<br>$I_{Load} = 10\text{ mA}$  | —                    | —                    | 0.5                  |      |
|     | C |                                                                   |           | $V_{DD} > 1.8\text{ V},$<br>$I_{Load} = 3\text{ mA}$   | —                    | —                    | 0.5                  |      |
| 5   | D | Output low current<br>Max total $I_{OL}$ for all ports            | $I_{OLT}$ | $V_{OUT} > V_{SS}$                                     | 0                    | —                    | 80                   | mA   |
| 6   | P | Input high voltage<br>all digital inputs                          | $V_{IH}$  | $V_{DD} > 2.7\text{ V}$                                | $0.70 \times V_{DD}$ | —                    | —                    | V    |
|     | C |                                                                   |           | $V_{DD} > 1.8\text{ V}$                                | $0.85 \times V_{DD}$ | —                    | —                    |      |
| 7   | P | Input low voltage<br>all digital inputs                           | $V_{IL}$  | $V_{DD} > 2.7\text{ V}$                                | —                    | —                    | $0.35 \times V_{DD}$ | V    |
|     | C |                                                                   |           | $V_{DD} > 1.8\text{ V}$                                | —                    | —                    | $0.30 \times V_{DD}$ |      |
| 8   | C | Input hysteresis<br>all digital inputs                            | $V_{hys}$ | —                                                      | $0.06 \times V_{DD}$ | —                    | —                    | mV   |
| 9   | P | Input leakage current<br>all input only pins<br>(Per pin)         | $I_{In}$  | $V_{In} = V_{DD}$ or $V_{SS}$                          | —                    | —                    | 200                  | nA   |
| 10  | P | Hi-Z (off-state) leakage current<br>all input/output<br>(per pin) | $I_{OZ}$  | $V_{In} = V_{DD}$ or $V_{SS}$                          | —                    | —                    | 200                  | nA   |

Table 7. DC Characteristics (continued)

| Num | C | Characteristic                                                                                                    | Symbol              | Condition                             | Min  | Typical <sup>1</sup> | Max  | Unit      |
|-----|---|-------------------------------------------------------------------------------------------------------------------|---------------------|---------------------------------------|------|----------------------|------|-----------|
| 10  | C | Total leakage combined for all inputs and Hi-Z pins<br>All input only and I/O                                     | $I_{OZTOT}$         | $V_{IN} = V_{DD}$ or $V_{SS}$         | —    | —                    | 2    | $\mu A$   |
| 11  | P | Pullup, Pulldown resistors<br>all digital inputs except PTA5/IRQ/TCLK/RESET, when enabled                         | $R_{PU}$ , $R_{PD}$ | —                                     | 17.5 | —                    | 52.5 | $k\Omega$ |
| 12  | C | Pullup, Pulldown resistors<br>PTA5/IRQ/TCLK/RESET, when enabled <sup>2</sup>                                      | $R_{PU}$ , $R_{PD}$ | —                                     | 17.5 | —                    | 52.5 | $k\Omega$ |
| 13  | D | DC injection current <sup>3, 4, 5</sup><br>Single pin limit<br>Total MCU limit, includes sum of all stressed pins | $I_{IC}$            | $V_{IN} < V_{SS}$ , $V_{IN} > V_{DD}$ | —0.2 | —                    | 0.2  | $mA$      |
|     |   |                                                                                                                   |                     |                                       | —5   | —                    | 5    | $mA$      |
| 14  | C | Input Capacitance, all pins                                                                                       | $C_{In}$            | —                                     | —    | —                    | 8    | $pF$      |
| 15  | C | RAM retention voltage                                                                                             | $V_{RAM}$           | —                                     | —    | 0.6                  | 1.0  | V         |
| 16  | C | POR re-arm voltage <sup>6</sup>                                                                                   | $V_{POR}$           | —                                     | 0.9  | 1.4                  | 2.0  | V         |
| 17  | D | POR re-arm time                                                                                                   | $t_{POR}$           | —                                     | 10   | —                    | —    | $\mu s$   |
| 18  | P | Low-voltage detection threshold                                                                                   | $V_{LVD}$           | $V_{DD}$ falling<br>$V_{DD}$ rising   | 1.80 | 1.84                 | 1.88 | V         |
|     |   |                                                                                                                   |                     |                                       | 1.88 | 1.92                 | 1.96 |           |
| 19  | P | Low-voltage warning threshold                                                                                     | $V_{LVW}$           | $V_{DD}$ falling<br>$V_{DD}$ rising   | 2.08 | 2.14                 | 2.26 | V         |
|     |   |                                                                                                                   |                     |                                       | —    | 80                   | —    |           |
| 20  | C | Low-voltage inhibit reset/recover hysteresis                                                                      | $V_{hys}$           | —                                     | —    | 80                   | —    | $mV$      |
| 21  | P | Bandgap Voltage Reference <sup>7</sup>                                                                            | $V_{BG}$            | —                                     | 1.15 | 1.17                 | 1.18 | V         |

<sup>1</sup> Typical values are measured at 25 °C. Characterized, not tested

<sup>2</sup> The specified resistor value is the actual value internal to the device. The pullup or pulldown value may appear lower when measured externally on the pin.

<sup>3</sup> All functional non-supply pins, except for PTA5 are internally clamped to  $V_{SS}$  and  $V_{DD}$ .

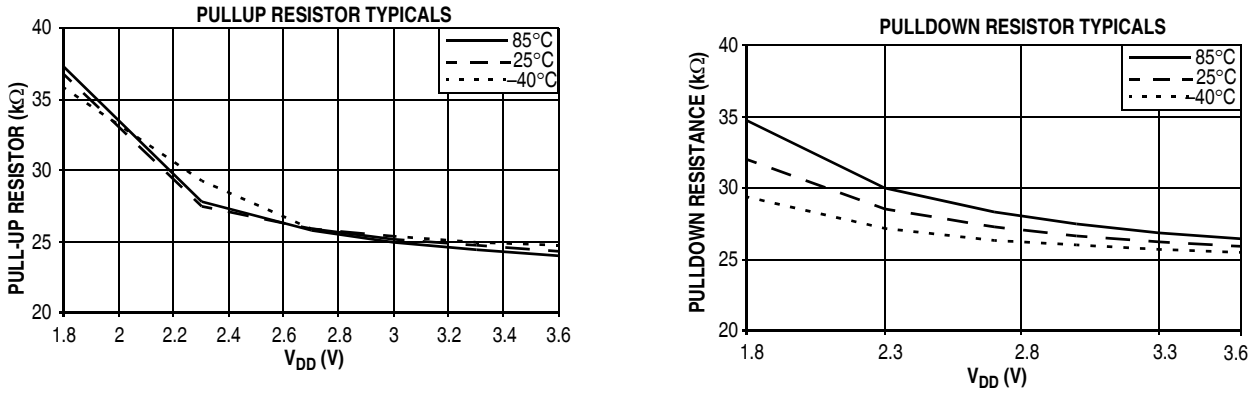
<sup>4</sup> Input must be current limited to the value specified. To determine the value of the required current-limiting resistor, calculate resistance values for positive and negative clamp voltages, then use the larger of the two values.

<sup>5</sup> Power supply must maintain regulation within operating  $V_{DD}$  range during instantaneous and operating maximum current conditions. If the positive injection current ( $V_{IN} > V_{DD}$ ) is greater than  $I_{DD}$ , the injection current may flow out of  $V_{DD}$  and could result in external power supply going out of regulation. Ensure that external  $V_{DD}$  load will shunt current greater than maximum injection current. This will be the greatest risk when the MCU is not consuming power. Examples are: if no system clock is present, or if clock rate is very low (which would reduce overall power consumption).

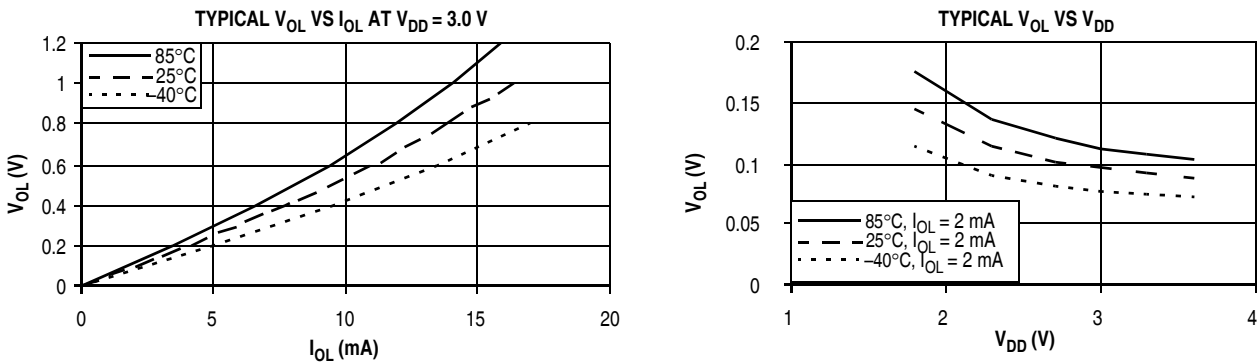
<sup>6</sup> Maximum is highest voltage that POR is guaranteed.

<sup>7</sup> Factory trimmed at  $V_{DD} = 3.0$  V, Temp = 25 °C

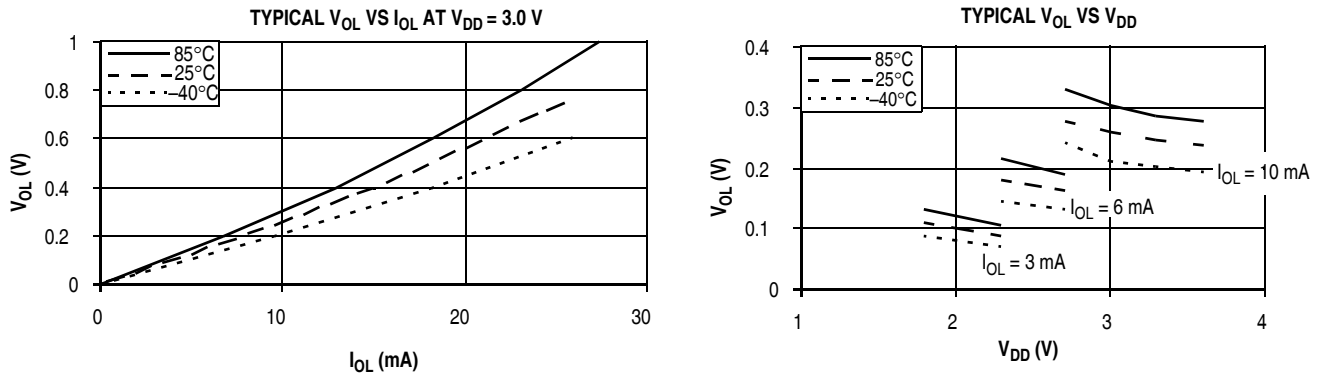
**Electrical Characteristics**



**Figure 5. Pullup and Pulldown Typical Resistor Values (V<sub>DD</sub> = 3.0 V)**



**Figure 6. Typical Low-Side Driver (Sink) Characteristics — Low Drive (PTxDSn = 0)**



**Figure 7. Typical Low-Side Driver (Sink) Characteristics — High Drive (PTxDSn = 1)**

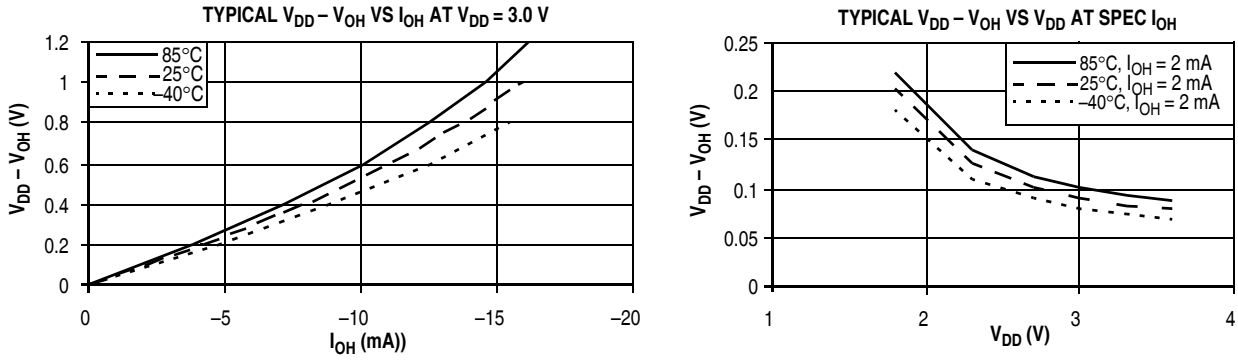


Figure 8. Typical High-Side (Source) Characteristics — Low Drive (PTxDSn = 0)

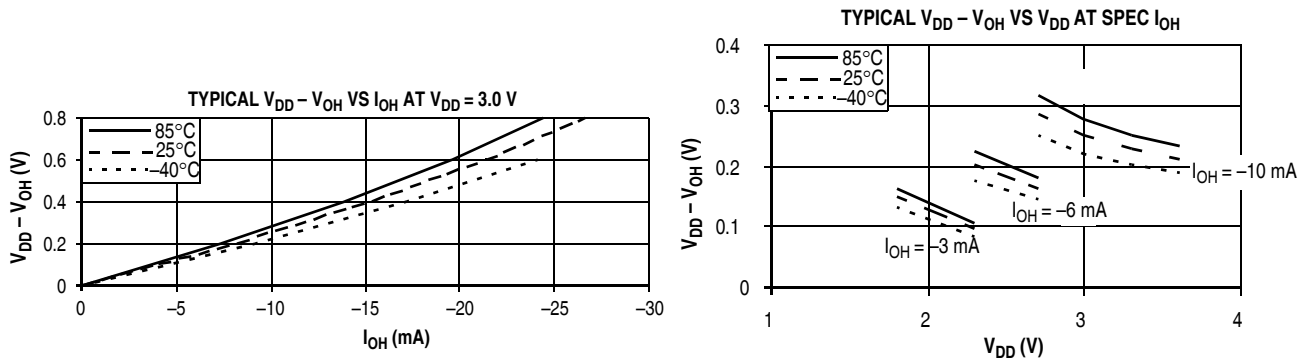


Figure 9. Typical High-Side (Source) Characteristics — High Drive (PTxDSn = 1)

### 3.7 Supply Current Characteristics

This section includes information about power supply current in various operating modes.

**Table 8. Supply Current Characteristics**

| Num | C | Parameter                                             | Symbol             | Bus Freq        | V <sub>DD</sub> (V) | Typical <sup>1</sup> | Max  | Unit | Temp (°C)   |
|-----|---|-------------------------------------------------------|--------------------|-----------------|---------------------|----------------------|------|------|-------------|
| 1   | P | Run supply current<br>FEI mode, all modules on        | R <sub>I</sub> DD  | 10 MHz          | 3                   | 5.60                 | 6    | mA   | -40 to 85°C |
|     | T |                                                       |                    | 1 MHz           |                     | 0.80                 | —    |      |             |
| 2   | T | Run supply current<br>FEI mode, all modules off       | R <sub>I</sub> DD  | 10 MHz          | 3                   | 3.60                 | —    | mA   | -40 to 85°C |
|     | T |                                                       |                    | 1 MHz           |                     | 0.75                 | —    |      |             |
| 3   | T | Run supply current<br>LPRS=0, all modules off         | R <sub>I</sub> DD  | 16 kHz<br>FBILP | 3                   | 165                  | —    | μA   | -40 to 85°C |
|     | T |                                                       |                    | 16 kHz<br>FBELP |                     | 105                  | —    |      |             |
| 4   | T | Run supply current<br>LPRS=1, all modules off         | R <sub>I</sub> DD  | 16 kHz<br>FBELP | 3                   | 7.3                  | —    | μA   | -40 to 85°C |
| 5   | T | Wait mode supply current<br>FEI mode, all modules off | W <sub>I</sub> DD  | 10 MHz          | 3                   | 570                  | —    | μA   | -40 to 85°C |
|     | T |                                                       |                    | 1 MHz           |                     | 290                  | —    |      |             |
| 6   | T | Wait mode supply current<br>LPRS = 1, all mods off    | W <sub>I</sub> DD  | 16 kHz<br>FBELP | 3                   | 1                    | —    | μA   | -40 to 85°C |
| 7   | P | Stop2 mode supply current                             | S2 <sub>I</sub> DD | —               | 3                   | 0.25                 | 0.65 | μA   | -40 to 25°C |
|     | C |                                                       |                    | —               |                     | 0.5                  | 0.8  |      | 70°C        |
|     | P |                                                       |                    | —               |                     | 1                    | 2    |      | 85°C        |
|     | C |                                                       |                    | —               | 2                   | 0.2                  | 0.5  |      | -40 to 25°C |
|     | C |                                                       |                    | —               |                     | 0.3                  | 0.6  |      | 70°C        |
|     | C |                                                       |                    | —               |                     | 0.7                  | 1.6  |      | 85°C        |
| 8   | P | Stop3 mode supply current<br>no clocks active         | S3 <sub>I</sub> DD | —               | 3                   | 0.45                 | 0.80 | μA   | -40 to 25°C |
|     | C |                                                       |                    | —               |                     | 1                    | 1.8  |      | 70°C        |
|     | P |                                                       |                    | —               |                     | 3                    | 5.8  |      | 85°C        |
|     | C |                                                       |                    | —               | 2                   | 0.3                  | 0.6  |      | -40 to 25°C |
|     | C |                                                       |                    | —               |                     | 0.8                  | 1.5  |      | 70°C        |
|     | C |                                                       |                    | —               |                     | 2.5                  | 5.0  |      | 85°C        |

<sup>1</sup> Data in Typical column was characterized at 3.0 V, 25 °C or is typical recommended value.

**Table 9. Stop Mode Adders**

| Num | C | Parameter             | Condition       | Temperature |      |      |      | Units |
|-----|---|-----------------------|-----------------|-------------|------|------|------|-------|
|     |   |                       |                 | -40°C       | 25°C | 70°C | 85°C |       |
| 1   | T | LPO                   | —               | 50          | 75   | 100  | 150  | nA    |
| 2   | T | ERREFSTEN             | RANGE = HGO = 0 | 1000        | 1000 | 1100 | 1500 | nA    |
| 3   | T | IREFSTEN <sup>1</sup> | —               | 63          | 70   | 77   | 81   | μA    |



Table 9. Stop Mode Adders (continued)

| Num | C | Parameter         | Condition                                              | Temperature |      |      |      | Units |
|-----|---|-------------------|--------------------------------------------------------|-------------|------|------|------|-------|
|     |   |                   |                                                        | -40°C       | 25°C | 70°C | 85°C |       |
| 4   | T | RTC               | Does not include clock source current                  | 50          | 75   | 100  | 150  | nA    |
| 5   | T | LVD <sup>1</sup>  | LVDSE = 1                                              | 90          | 100  | 110  | 115  | μA    |
| 6   | T | ACMP <sup>1</sup> | Not using the bandgap (BGBE = 0)                       | 18          | 20   | 22   | 23   | μA    |
| 7   | T | ADC <sup>1</sup>  | ADLPC = ADLSMP = 1<br>Not using the bandgap (BGBE = 0) | 95          | 106  | 114  | 120  | μA    |

<sup>1</sup> Not available in stop2 mode.

### 3.8 External Oscillator (XOSC) Characteristics

Reference [Figure 10](#) and [Figure 11](#) for crystal or resonator circuits.

Table 10. XOSCVLP and ICS Specifications (Temperature Range = -40 to 85°C Ambient)

| Num     | C | Characteristic                                                                                                                                              | Symbol                           | Min                                            | Typ <sup>1</sup> | Max             | Unit              |
|---------|---|-------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------|------------------------------------------------|------------------|-----------------|-------------------|
| 1       | C | Oscillator crystal or resonator (EREFS = 1, ERCLKEN = 1)                                                                                                    | $f_{lo}$<br>$f_{hi}$<br>$f_{hi}$ | 32<br>1<br>1                                   | —<br>—<br>—      | 38.4<br>16<br>8 | kHz<br>MHz<br>MHz |
|         |   | Low range (RANGE = 0)                                                                                                                                       |                                  |                                                |                  |                 |                   |
|         |   | High range (RANGE = 1), high gain (HGO = 1)<br>High range (RANGE = 1), low power (HGO = 0)                                                                  |                                  |                                                |                  |                 |                   |
| 2       | D | Load capacitors<br>Low range (RANGE=0), low power (HGO=0)<br>Other oscillator settings                                                                      | $C_1, C_2$                       | See Note <sup>2</sup><br>See Note <sup>3</sup> |                  |                 |                   |
| 3       | D | Feedback resistor<br>Low range, low power (RANGE = 0, HGO = 0) <sup>2</sup><br>Low range, high gain (RANGE = 0, HGO = 1)<br>High range (RANGE = 1, HGO = X) | $R_F$                            | —<br>—<br>—                                    | —<br>10<br>1     | —<br>—<br>—     | MΩ                |
| 4       | D | Series resistor —                                                                                                                                           | $R_S$                            | —                                              | —                | —               | kΩ                |
|         |   | Low range, low power (RANGE = 0, HGO = 0) <sup>2</sup>                                                                                                      |                                  | —                                              | 100              | —               |                   |
|         |   | Low range, high gain (RANGE = 0, HGO = 1)                                                                                                                   |                                  | —                                              | 0                | —               |                   |
|         |   | High range, low power (RANGE = 1, HGO = 0)                                                                                                                  |                                  | —                                              | 0                | 0               |                   |
|         |   | High range, high gain (RANGE = 1, HGO = 1)                                                                                                                  |                                  | —                                              | 0                | 10              |                   |
| ≥ 8 MHz | — | 0                                                                                                                                                           | 20                               |                                                |                  |                 |                   |
| 4 MHz   | — | 0                                                                                                                                                           | 10                               |                                                |                  |                 |                   |
| 1 MHz   | — | 0                                                                                                                                                           | 20                               |                                                |                  |                 |                   |
| 5       | C | Crystal start-up time <sup>4</sup>                                                                                                                          | $t_{CSTL}$<br>$t_{CSTH}$         | —                                              | 600              | —               | ms                |
|         |   | Low range, low power                                                                                                                                        |                                  | —                                              | 400              | —               |                   |
|         |   | Low range, high gain                                                                                                                                        |                                  | —                                              | 5                | —               |                   |
|         |   | High range, low power<br>High range, high gain                                                                                                              |                                  | —                                              | 15               | —               |                   |
| 6       | D | Square wave input clock frequency (EREFS = 0, ERCLKEN = 1)                                                                                                  | $f_{extal}$                      | 0.03125<br>0                                   | —<br>—           | 20<br>20        | MHz               |
|         |   | FEE mode<br>FBE or FBELP mode                                                                                                                               |                                  |                                                |                  |                 |                   |

## Electrical Characteristics

- <sup>1</sup> Data in Typical column was characterized at 3.0 V, 25 °C or is typical recommended value.
- <sup>2</sup> Load capacitors ( $C_1, C_2$ ), feedback resistor ( $R_F$ ) and series resistor ( $R_S$ ) are incorporated internally when RANGE = HGO = 0.
- <sup>3</sup> See crystal or resonator manufacturer's recommendation.
- <sup>4</sup> Proper PC board layout procedures must be followed to achieve specifications.

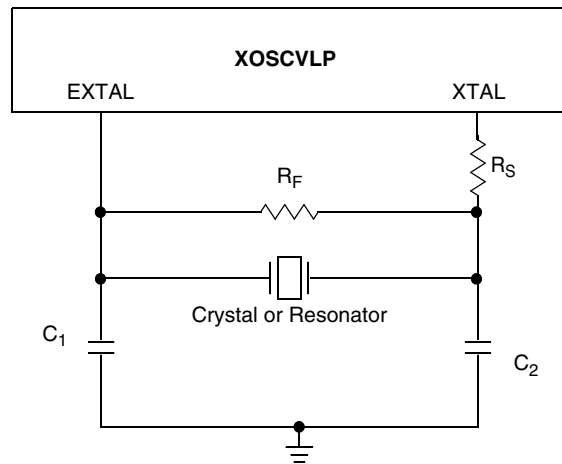


Figure 10. Typical Crystal or Resonator Circuit: High Range and Low Range/High Gain

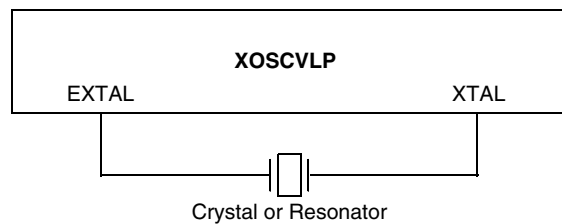


Figure 11. Typical Crystal or Resonator Circuit: Low Range/Low Power

## 3.9 Internal Clock Source (ICS) Characteristics

Table 11. ICS Frequency Specifications (Temperature Range = -40 to 85°C Ambient)

| Num | C | Characteristic                                                                                     | Symbol                   | Min.  | Typical <sup>1</sup> | Max.      | Unit        |
|-----|---|----------------------------------------------------------------------------------------------------|--------------------------|-------|----------------------|-----------|-------------|
| 1   | P | Average internal reference frequency — factory trimmed at $V_{DD} = 3.6$ V and temperature = 25 °C | $f_{int\_t}$             | —     | 32.768               | —         | kHz         |
| 2   | P | Internal reference frequency — user trimmed                                                        | $f_{int\_ut}$            | 31.25 | —                    | 39.06     | kHz         |
| 3   | T | Internal reference start-up time                                                                   | $t_{IRST}$               | —     | 60                   | 100       | $\mu$ s     |
| 4   | P | DCO output frequency range — Low range (DRS = 00) trimmed <sup>2</sup>                             | $f_{dco\_t}$             | 16    | —                    | 20        | MHz         |
| 5   | P | DCO output frequency <sup>2</sup><br>Reference = 32768 Hz and DMX32 = 1                            | $f_{dco\_DMX32}$         | —     | 19.92                | —         | MHz         |
| 6   | C | Resolution of trimmed DCO output frequency at fixed voltage and temperature (using FTRIM)          | $\Delta f_{dco\_res\_t}$ | —     | $\pm 0.1$            | $\pm 0.2$ | % $f_{dco}$ |

Table 11. ICS Frequency Specifications (Temperature Range = -40 to 85°C Ambient) (continued)

| Num | C | Characteristic                                                                                                                                                         | Symbol                          | Min. | Typical <sup>1</sup>     | Max.               | Unit               |
|-----|---|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------|------|--------------------------|--------------------|--------------------|
| 7   | C | Resolution of trimmed DCO output frequency at fixed voltage and temperature (not using FTRIM)                                                                          | $\Delta f_{\text{dco\_res\_t}}$ | —    | $\pm 0.2$                | $\pm 0.4$          | % $f_{\text{dco}}$ |
| 8   | C | Total deviation of DCO output from trimmed frequency <sup>3</sup><br>Over full voltage and temperature range<br>Over fixed voltage and temperature range of 0 to 70 °C | $\Delta f_{\text{dco\_t}}$      | —    | -1.0 to 0.5<br>$\pm 0.5$ | $\pm 2$<br>$\pm 1$ | % $f_{\text{dco}}$ |
| 10  | C | FLL acquisition time <sup>4</sup>                                                                                                                                      | $t_{\text{Acquire}}$            | —    | —                        | 1                  | ms                 |
| 11  | C | Long term jitter of DCO output clock (averaged over 2-ms interval) <sup>5</sup>                                                                                        | $C_{\text{Jitter}}$             | —    | 0.02                     | 0.2                | % $f_{\text{dco}}$ |

<sup>1</sup> Data in Typical column was characterized at 3.0 V, 25 °C or is typical recommended value.

<sup>2</sup> The resulting bus clock frequency should not exceed the maximum specified bus clock frequency of the device.

<sup>3</sup> This parameter is characterized and not tested on each device.

<sup>4</sup> This specification applies to any time the FLL reference source or reference divider is changed, trim value changed or changing from FLL disabled (FBELP, FBILP) to FLL enabled (FEI, FEE, FBE, FBI). If a crystal/resonator is being used as the reference, this specification assumes it is already running.

<sup>5</sup> Jitter is the average deviation from the programmed frequency measured over the specified interval at maximum  $f_{\text{BUS}}$ . Measurements are made with the device powered by filtered supplies and clocked by a stable external clock signal. Noise injected into the FLL circuitry via  $V_{\text{DD}}$  and  $V_{\text{SS}}$  and variation in crystal oscillator frequency increase the  $C_{\text{Jitter}}$  percentage for a given interval.

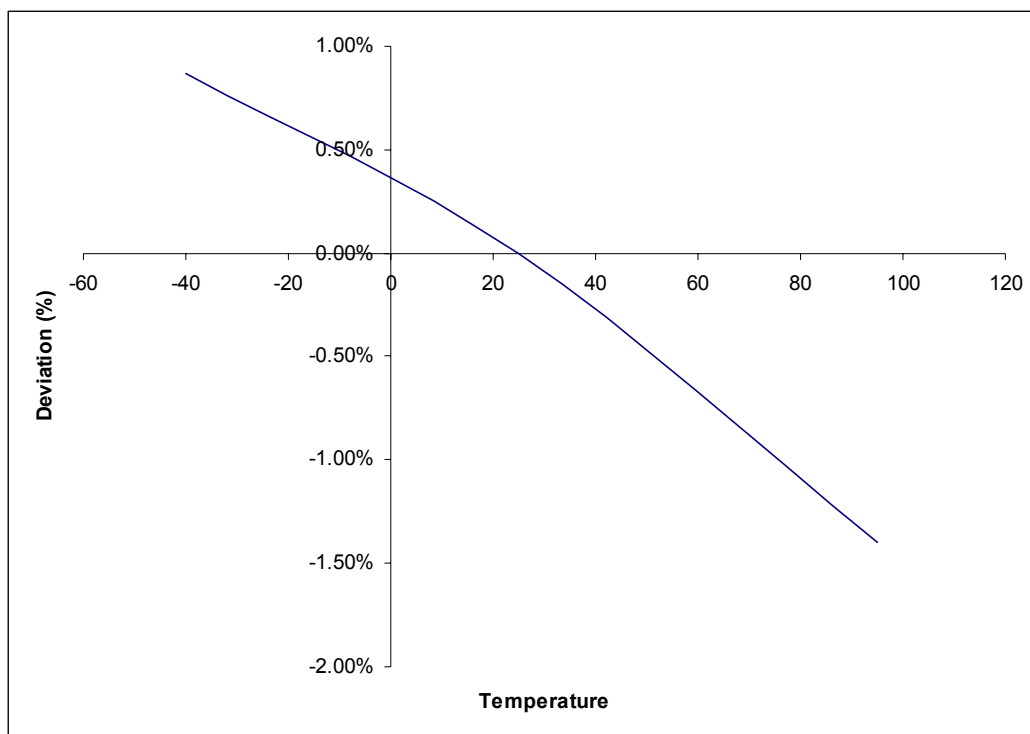


Figure 12. Deviation of DCO Output from Trimmed Frequency (20 MHz, 3.0 V)

## 3.10 AC Characteristics

This section describes timing characteristics for each peripheral system.

### 3.10.1 Control Timing

Table 12. Control Timing

| Num | C | Rating                                                                                                                                                                    | Symbol               | Min                         | Typical <sup>1</sup> | Max    | Unit    |
|-----|---|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|-----------------------------|----------------------|--------|---------|
| 1   | D | Bus frequency ( $t_{cyc} = 1/f_{Bus}$ )                                                                                                                                   | $f_{Bus}$            | DC                          | —                    | 10     | MHz     |
| 2   | D | Internal low power oscillator period                                                                                                                                      | $t_{LPO}$            | 700                         | —                    | 1300   | $\mu s$ |
| 3   | D | External reset pulse width <sup>2</sup>                                                                                                                                   | $t_{extrst}$         | 100                         | —                    | —      | ns      |
| 4   | D | Reset low drive                                                                                                                                                           | $t_{rstdrv}$         | $34 \times t_{cyc}$         | —                    | —      | ns      |
| 5   | D | BKGD/MS setup time after issuing background debug force reset to enter user or BDM modes                                                                                  | $t_{MSSU}$           | 500                         | —                    | —      | ns      |
| 6   | D | BKGD/MS hold time after issuing background debug force reset to enter user or BDM modes <sup>3</sup>                                                                      | $t_{MSH}$            | 100                         | —                    | —      | $\mu s$ |
| 7   | D | IRQ pulse width<br>Asynchronous path <sup>2</sup><br>Synchronous path <sup>4</sup>                                                                                        | $t_{LIH}, t_{IHIL}$  | 100<br>$1.5 \times t_{cyc}$ | —<br>—               | —<br>— | ns      |
| 8   | D | Keyboard interrupt pulse width<br>Asynchronous path <sup>2</sup><br>Synchronous path <sup>4</sup>                                                                         | $t_{LIH}, t_{IHIL}$  | 100<br>$1.5 \times t_{cyc}$ | —<br>—               | —<br>— | ns      |
| 9   | D | Port rise and fall time —<br>Low output drive (PTxDS = 0) (load = 50 pF) <sup>5</sup><br>Slew rate control disabled (PTxSE = 0)<br>Slew rate control enabled (PTxSE = 1)  | $t_{Rise}, t_{Fall}$ | —<br>—                      | 16<br>23             | —<br>— | ns      |
|     |   | Port rise and fall time —<br>High output drive (PTxDS = 1) (load = 50 pF) <sup>5</sup><br>Slew rate control disabled (PTxSE = 0)<br>Slew rate control enabled (PTxSE = 1) | $t_{Rise}, t_{Fall}$ | —<br>—                      | 5<br>9               | —<br>— | ns      |
| 10  | D | Voltage regulator recovery time                                                                                                                                           | $t_{VRR}$            | —                           | 4                    | —      | $\mu s$ |

<sup>1</sup> Typical values are based on characterization data at  $V_{DD} = 3.0 V$ ,  $25^\circ C$  unless otherwise stated.

<sup>2</sup> This is the shortest pulse that is guaranteed to be recognized as a reset pin request.

<sup>3</sup> To enter BDM mode following a POR, BKGD/MS should be held low during the power-up and for a hold time of  $t_{MSH}$  after  $V_{DD}$  rises above  $V_{LVD}$ .

<sup>4</sup> This is the minimum pulse width that is guaranteed to pass through the pin synchronization circuitry. Shorter pulses may or may not be recognized. In stop mode, the synchronizer is bypassed so shorter pulses can be recognized.

<sup>5</sup> Timing is shown with respect to 20%  $V_{DD}$  and 80%  $V_{DD}$  levels. Temperature range  $-40^\circ C$  to  $85^\circ C$ .

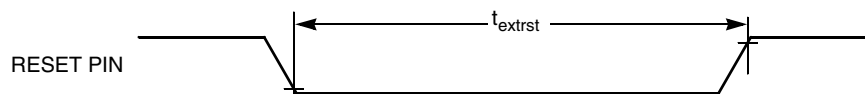


Figure 13. Reset Timing

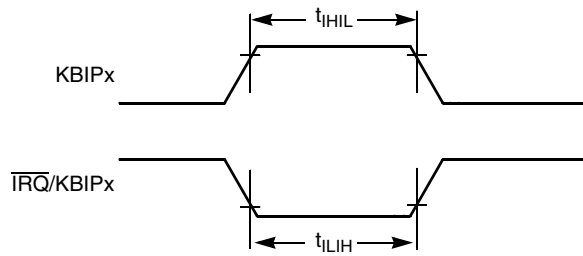


Figure 14.  $\overline{\text{IRQ}}/\text{KBIPx}$  Timing

### 3.10.2 TPM Module Timing

Synchronizer circuits determine the shortest input pulses that can be recognized or the fastest clock that can be used as the optional external source to the timer counter. These synchronizers operate from the current bus rate clock.

Table 13. TPM Input Timing

| No. | C | Function                  | Symbol             | Min | Max                 | Unit             |
|-----|---|---------------------------|--------------------|-----|---------------------|------------------|
| 1   | D | External clock frequency  | $f_{\text{TEXT}}$  | DC  | $1/4 f_{\text{op}}$ | MHz              |
| 2   | D | External clock period     | $t_{\text{TEXT}}$  | 4   | —                   | $t_{\text{CYC}}$ |
| 3   | D | External clock high time  | $t_{\text{TCLKH}}$ | 1.5 | —                   | $t_{\text{CYC}}$ |
| 4   | D | External clock low time   | $t_{\text{TCLKL}}$ | 1.5 | —                   | $t_{\text{CYC}}$ |
| 5   | D | Input capture pulse width | $t_{\text{ICPW}}$  | 1.5 | —                   | $t_{\text{CYC}}$ |

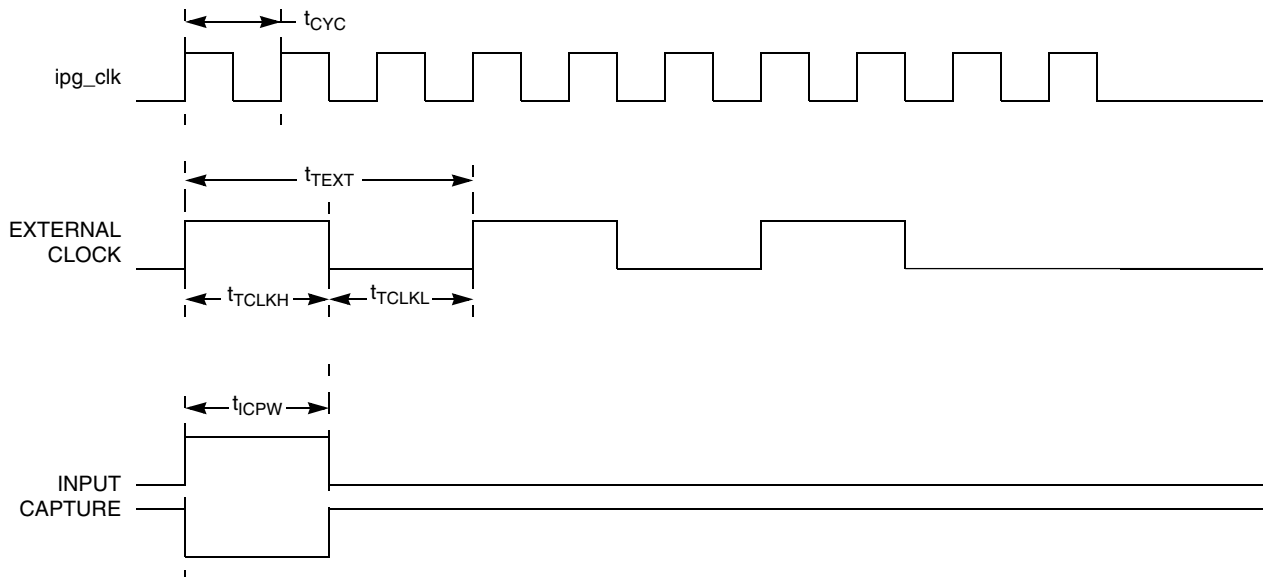


Figure 15. Timer Input Capture Pulse

### 3.11 Analog Comparator (ACMP) Electricals

Table 14. Analog Comparator Electrical Specifications

| C | Characteristic                         | Symbol      | Min            | Typical | Max      | Unit    |
|---|----------------------------------------|-------------|----------------|---------|----------|---------|
| D | Supply voltage                         | $V_{PWR}$   | 1.8            | —       | 3.6      | V       |
| D | Supply current (active)                | $I_{DDAC}$  | —              | 20      | 35       | $\mu A$ |
| D | Analog input voltage                   | $V_{AIN}$   | $V_{SS} - 0.3$ | —       | $V_{DD}$ | V       |
| P | Analog input offset voltage            | $V_{AIO}$   | —              | 20      | 40       | mV      |
| C | Analog comparator hysteresis           | $V_H$       | 3.0            | 9.0     | 15.0     | mV      |
| P | Analog input leakage current           | $I_{ALKG}$  | —              | —       | 1.0      | $\mu A$ |
| C | Analog comparator initialization delay | $t_{AINIT}$ | —              | —       | 1.0      | $\mu s$ |

### 3.12 ADC Characteristics

Table 15. 12-Bit ADC Operating Conditions

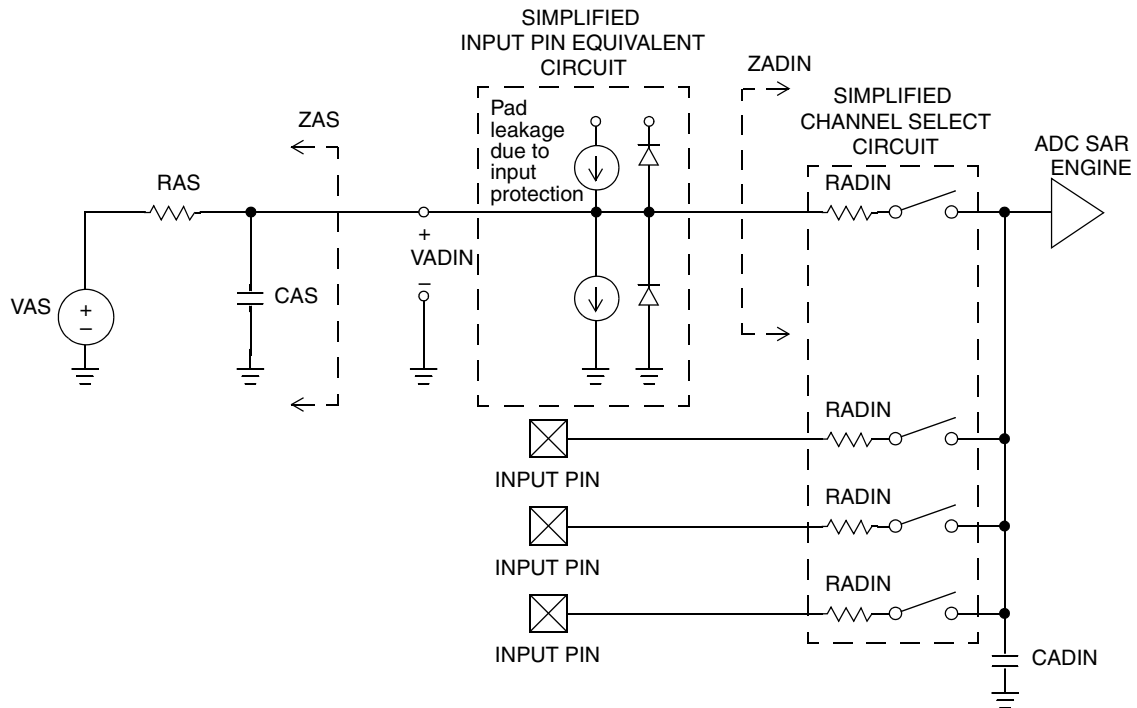
| Characteristic             | Conditions                                            | Symbol           | Min        | Typical <sup>1</sup> | Max        | Unit       | Comment         |
|----------------------------|-------------------------------------------------------|------------------|------------|----------------------|------------|------------|-----------------|
| Supply voltage             | Absolute                                              | $V_{DDA}$        | 1.8        | —                    | 3.6        | V          |                 |
|                            | Delta to $V_{DD}$ ( $V_{DD} - V_{DDA}$ ) <sup>2</sup> | $\Delta V_{DDA}$ | -100       | 0                    | 100        | mV         |                 |
| Ground voltage             | Delta to $V_{SS}$ ( $V_{SS} - V_{SSA}$ ) <sup>2</sup> | $\Delta V_{SSA}$ | -100       | 0                    | 100        | mV         |                 |
| Supply Current             | Stop, Reset, Module Off                               | $I_{DDAD}$       | —          | 0.007                | 0.8        | $\mu A$    |                 |
| Input Voltage              |                                                       | $V_{ADIN}$       | $V_{REFL}$ | —                    | $V_{REFH}$ | V          |                 |
| Input Capacitance          |                                                       | $C_{ADIN}$       | —          | 4.5                  | 5.5        | pF         |                 |
| Input Resistance           |                                                       | $R_{ADIN}$       | —          | 5                    | 7          | k $\Omega$ |                 |
| Analog Source Resistance   | 12 bit mode<br>$f_{ADCK} > 4MHz$<br>$f_{ADCK} < 4MHz$ | $R_{AS}$         | —          | —                    | 2          | k $\Omega$ | External to MCU |
|                            | 10 bit mode<br>$f_{ADCK} > 4MHz$<br>$f_{ADCK} < 4MHz$ |                  | —          | —                    | 5          |            |                 |
|                            | 8 bit mode (all valid $f_{ADCK}$ )                    |                  | —          | —                    | 10         |            |                 |
| ADC Conversion Clock Freq. | High Speed (ADLPC = 0)                                | $f_{ADCK}$       | 0.4        | —                    | 8.0        | MHz        |                 |
|                            | Low Power (ADLPC = 1)                                 |                  | 0.4        | —                    | 4.0        |            |                 |

<sup>1</sup> Typical values assume  $V_{DDA} = 3.0$  V, Temp = 25 °C,  $f_{ADCK} = 1.0$  MHz unless otherwise stated. Typical values are for reference only and are not tested in production.

<sup>2</sup> DC potential difference.

**NOTE**

$V_{DDA}/V_{SSA}$  pins do not exist in 16-pin package. The signals are derived internally by double bonding to  $V_{DD}/V_{SS}$  pair of pins.



**Figure 16. ADC Input Impedance Equivalency Diagram**

## Electrical Characteristics

**Table 16. 12-Bit ADC Characteristics ( $V_{REFH} = V_{DDA}$ ,  $V_{REFL} = V_{SSA}$ )**

| Characteristic                                  | Conditions                   | C | Symbol      | Min  | Typical <sup>1</sup> | Max | Unit             | Comment                                                                |
|-------------------------------------------------|------------------------------|---|-------------|------|----------------------|-----|------------------|------------------------------------------------------------------------|
| Supply Current<br>ADLPC=1<br>ADLSMP=1<br>ADCO=1 |                              | T | $I_{DDAD}$  | —    | 120                  | —   | $\mu\text{A}$    |                                                                        |
| Supply Current<br>ADLPC=1<br>ADLSMP=0<br>ADCO=1 |                              | T | $I_{DDAD}$  | —    | 202                  | —   | $\mu\text{A}$    |                                                                        |
| Supply Current<br>ADLPC=0<br>ADLSMP=1<br>ADCO=1 |                              | T | $I_{DDAD}$  | —    | 288                  | —   | $\mu\text{A}$    |                                                                        |
| Supply Current<br>ADLPC=0<br>ADLSMP=0<br>ADCO=1 |                              | T | $I_{DDAD}$  | —    | 0.532                | 1   | mA               |                                                                        |
| Supply Current                                  | Stop, Reset, Module Off      | T | $I_{DDAD}$  | —    | 0.007                | 0.8 | $\mu\text{A}$    |                                                                        |
| ADC<br>Asynchronous<br>Clock Source             | High Speed (ADLPC = 0)       | P | $f_{ADACK}$ | 2    | 3.3                  | 5   | MHz              | $t_{ADACK} = 1/f_{ADACK}$                                              |
|                                                 | Low Power (ADLPC = 1)        |   |             | 1.25 | 2                    | 3.3 |                  |                                                                        |
| Conversion<br>Time (Including<br>sample time)   | Short Sample<br>(ADLSMP = 0) | T | $t_{ADC}$   | —    | 20                   | —   | ADCK<br>cycles   | See reference<br>manual for<br>conversion<br>time variances            |
|                                                 | Long Sample<br>(ADLSMP = 1)  |   |             | —    | 40                   | —   |                  |                                                                        |
| Sample Time                                     | Short Sample<br>(ADLSMP = 0) | T | $t_{ADS}$   | —    | 3.5                  | —   | ADCK<br>cycles   |                                                                        |
|                                                 | Long Sample<br>(ADLSMP = 1)  |   |             | —    | 23.5                 | —   |                  |                                                                        |
| Total<br>Unadjusted<br>Error                    | 12-bit mode                  | T | $E_{TUE}$   | —    | $\pm 3.0$            | —   | LSB <sup>2</sup> | For 28-pin and<br>24-pin<br>packages only.<br>Includes<br>quantization |
|                                                 | 10-bit mode                  | P |             | —    | $\pm 1$              | —   |                  |                                                                        |
|                                                 | 8-bit mode                   | T |             | —    | $\pm 0.5$            | —   |                  |                                                                        |
| Total<br>Unadjusted<br>Error                    | 10-bit mode                  | P | $E_{TUE}$   | —    | $\pm 1.5$            | —   | LSB <sup>2</sup> | For 16-pin<br>package only.<br>Includes<br>quantization                |
|                                                 | 8-bit mode                   | T |             | —    | $\pm 0.7$            | —   |                  |                                                                        |
| Differential<br>Non-Linearity                   | 12-bit mode                  | T | DNL         | —    | $\pm 1.75$           | —   | LSB <sup>2</sup> |                                                                        |
|                                                 | 10-bit mode                  | P |             | —    | $\pm 0.5$            | —   |                  |                                                                        |
|                                                 | 8-bit mode                   | T |             | —    | $\pm 0.3$            | —   |                  |                                                                        |
| Monotonicity and No-Missing-Codes guaranteed    |                              |   |             |      |                      |     |                  |                                                                        |



Table 16. 12-Bit ADC Characteristics ( $V_{REFH} = V_{DDA}$ ,  $V_{REFL} = V_{SSA}$ ) (continued)

| Characteristic         | Conditions  | C | Symbol       | Min | Typical <sup>1</sup> | Max  | Unit             | Comment                                                      |
|------------------------|-------------|---|--------------|-----|----------------------|------|------------------|--------------------------------------------------------------|
| Integral Non-Linearity | 12-bit mode | T | INL          | —   | ±1.5                 | —    | LSB <sup>2</sup> |                                                              |
|                        | 10-bit mode | C |              | —   | ±0.5                 | —    |                  |                                                              |
|                        | 8-bit mode  | C |              | —   | ±0.3                 | —    |                  |                                                              |
| Zero-Scale Error       | 12-bit mode | C | $E_{ZS}$     | —   | ±1.5                 | —    | LSB <sup>2</sup> | For 28-pin and 24-pin packages only.<br>$V_{ADIN} = V_{SSA}$ |
|                        | 10-bit mode | P |              | —   | ±0.5                 | ±1.5 |                  |                                                              |
|                        | 8-bit mode  | T |              | —   | ±0.5                 | ±0.5 |                  |                                                              |
| Zero-Scale Error       | 10-bit mode | P | $E_{ZS}$     | —   | ±1.5                 | ±2.1 | LSB <sup>2</sup> | For 16-pin package only.<br>$V_{ADIN} = V_{SSA}$             |
|                        | 8-bit mode  | T |              | —   | ±0.5                 | ±0.7 |                  |                                                              |
| Full-Scale Error       | 12-bit mode | T | $E_{FS}$     | —   | ±1                   | —    | LSB <sup>2</sup> | For 28-pin and 24-pin packages only.<br>$V_{ADIN} = V_{DDA}$ |
|                        | 10-bit mode | P |              | —   | ±0.5                 | ±1   |                  |                                                              |
|                        | 8-bit mode  | T |              | —   | ±0.5                 | ±0.5 |                  |                                                              |
| Full-Scale Error       | 10-bit mode | T | $E_{FS}$     | —   | ±1                   | ±1.5 | LSB <sup>2</sup> | For 16-pin package only.<br>$V_{ADIN} = V_{DDA}$             |
|                        | 8-bit mode  | T |              | —   | ±0.5                 | ±0.5 |                  |                                                              |
| Quantization Error     | 12-bit mode | D | $E_Q$        | —   | -1 to 0              | —    | LSB <sup>2</sup> |                                                              |
|                        | 10-bit mode |   |              | —   | —                    | ±0.5 |                  |                                                              |
|                        | 8-bit mode  |   |              | —   | —                    | ±0.5 |                  |                                                              |
| Input Leakage Error    | 12-bit mode | D | $E_{IL}$     | —   | ±1                   | —    | LSB <sup>2</sup> | Pad leakage <sup>3</sup> *<br>$R_{AS}$                       |
|                        | 10-bit mode |   |              | 0   | ±0.2                 | ±4   |                  |                                                              |
|                        | 8-bit mode  |   |              | 0   | ±0.1                 | ±1.2 |                  |                                                              |
| Temp Sensor Slope      | -40°C– 25°C | D | m            | —   | 1.646                | —    | mV/°C            |                                                              |
|                        | 25°C– 85°C  |   |              | —   | 1.769                | —    |                  |                                                              |
| Temp Sensor Voltage    | 25°C        | D | $V_{TEMP25}$ | —   | 701.2                | —    | mV               |                                                              |

<sup>1</sup> Typical values assume  $V_{DDA} = 3.0$  V, Temp = 25 °C,  $f_{ADCK} = 1.0$  MHz unless otherwise stated. Typical values are for reference only and are not tested in production.

<sup>2</sup> 1 LSB =  $(V_{REFH} - V_{REFL})/2^N$

<sup>3</sup> Based on input pad leakage current. Refer to pad electricals.

### 3.13 Flash Specifications

This section provides details about program/erase times and program-erase endurance for the flash memory.

## Electrical Characteristics

Program and erase operations do not require any special power sources other than the normal  $V_{DD}$  supply. For more detailed information about program/erase operations, see the memory section.

**Table 17. Flash Characteristics**

| C | Characteristic                                                                                                              | Symbol                  | Min    | Typical      | Max  | Unit              |
|---|-----------------------------------------------------------------------------------------------------------------------------|-------------------------|--------|--------------|------|-------------------|
| D | Supply voltage for program/erase<br>-40°C to 85°C                                                                           | $V_{\text{prog/erase}}$ | 1.8    |              | 3.6  | V                 |
| D | Supply voltage for read operation                                                                                           | $V_{\text{Read}}$       | 1.8    |              | 3.6  | V                 |
| D | Internal FCLK frequency <sup>1</sup>                                                                                        | $f_{\text{FCLK}}$       | 150    |              | 200  | kHz               |
| D | Internal FCLK period (1/FCLK)                                                                                               | $t_{\text{Fcyc}}$       | 5      |              | 6.67 | μs                |
| D | Byte program time (random location) <sup>(2)</sup>                                                                          | $t_{\text{prog}}$       |        | 9            |      | $t_{\text{Fcyc}}$ |
| D | Byte program time (burst mode) <sup>(2)</sup>                                                                               | $t_{\text{Burst}}$      |        | 4            |      | $t_{\text{Fcyc}}$ |
| D | Page erase time <sup>2</sup>                                                                                                | $t_{\text{Page}}$       |        | 4000         |      | $t_{\text{Fcyc}}$ |
| D | Mass erase time <sup>(2)</sup>                                                                                              | $t_{\text{Mass}}$       |        | 20,000       |      | $t_{\text{Fcyc}}$ |
| D | Byte program current <sup>3</sup>                                                                                           | $RI_{\text{DDBP}}$      | —      | 4            | —    | mA                |
| D | Page erase current <sup>3</sup>                                                                                             | $RI_{\text{DDPE}}$      | —      | 6            | —    | mA                |
| C | Program/erase endurance <sup>4</sup><br>$T_L$ to $T_H = -40^\circ\text{C}$ to $+85^\circ\text{C}$<br>$T = 25^\circ\text{C}$ | —                       | 10,000 | —<br>100,000 | —    | cycles            |
| C | Data retention <sup>5</sup>                                                                                                 | $t_{\text{D\_ret}}$     | 15     | 100          | —    | years             |

<sup>1</sup> The frequency of this clock is controlled by a software setting.

<sup>2</sup> These values are hardware state machine controlled. User code does not need to count cycles. This information supplied for calculating approximate time to program and erase.

<sup>3</sup> The program and erase currents are additional to the standard run  $I_{DD}$ . These values are measured at room temperatures with  $V_{DD} = 3.0$  V, bus frequency = 4.0 MHz.

<sup>4</sup> **Typical endurance for flash** was evaluated for this product family on the 9S12Dx64. For additional information on how Freescale defines typical endurance, please refer to Engineering Bulletin EB619, *Typical Endurance for Nonvolatile Memory*.

<sup>5</sup> **Typical data retention** values are based on intrinsic capability of the technology measured at high temperature and de-rated to 25°C using the Arrhenius equation. For additional information on how Freescale defines typical data retention, please refer to Engineering Bulletin EB618, *Typical Data Retention for Nonvolatile Memory*.

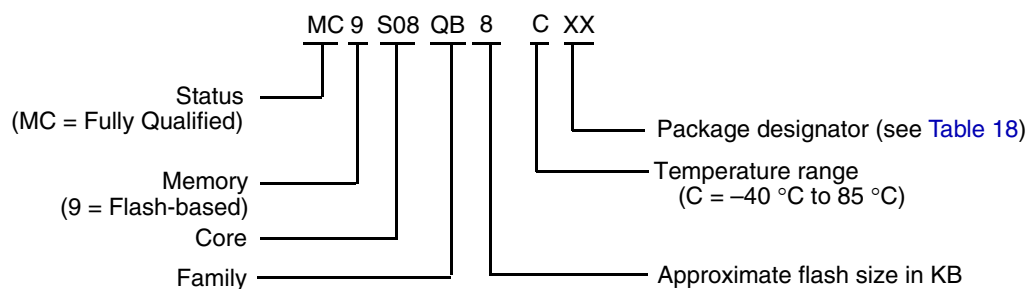
## 3.14 EMC Performance

Electromagnetic compatibility (EMC) performance is highly dependant on the environment in which the MCU resides. Board design and layout, circuit topology choices, location and characteristics of external components as well as MCU software operation all play a significant role in EMC performance. The system designer should consult Freescale applications notes such as AN2321, AN1050, AN1263, AN2764, and AN1259 for advice and guidance specifically targeted at optimizing EMC performance.

## 4 Ordering Information

This section contains ordering information for the device numbering system.

Example of the device numbering system:



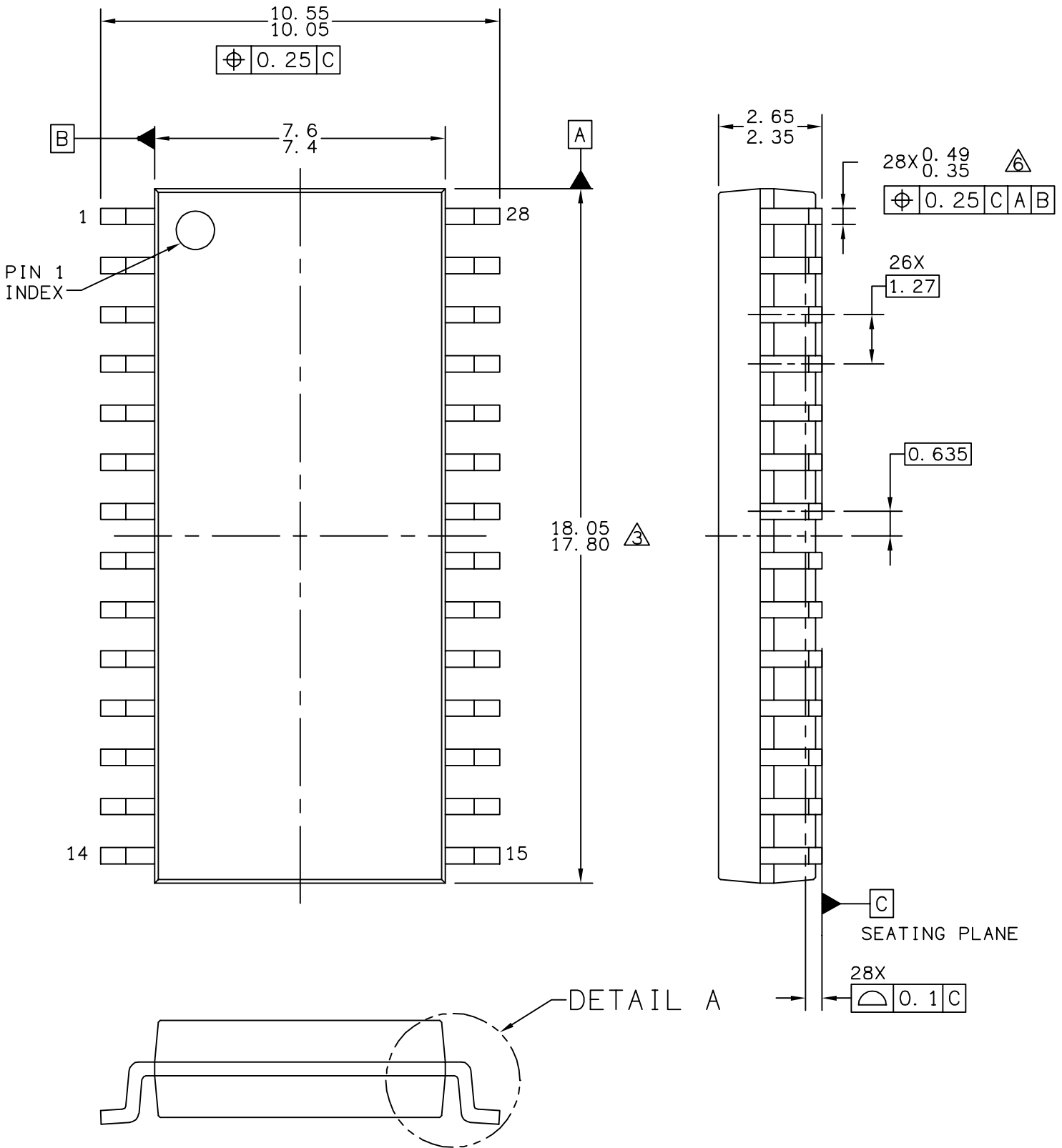
## 5 Package Information

Table 18. Package Descriptions

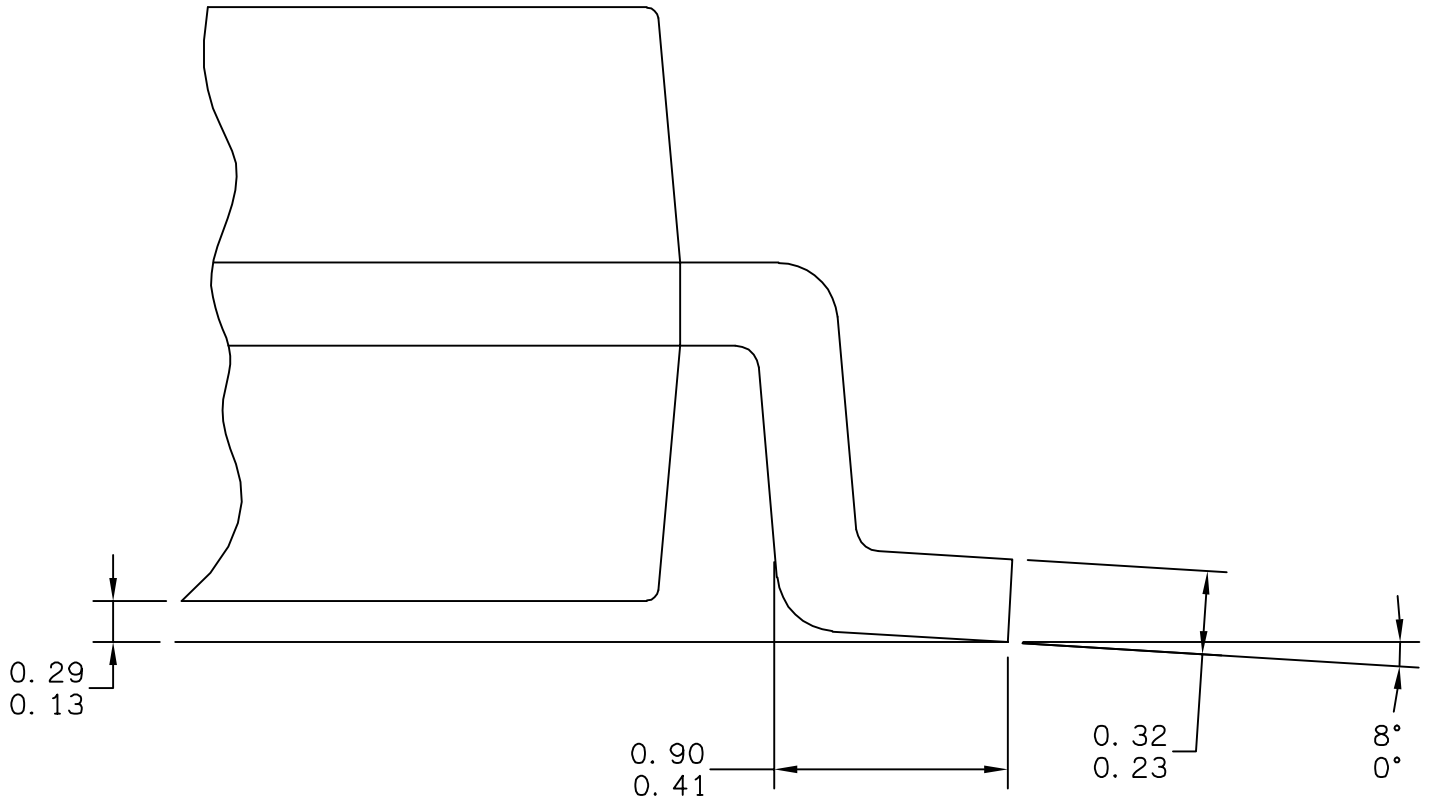
| Pin Count | Package Type                      | Abbreviation | Designator | Case No. | Document No. |
|-----------|-----------------------------------|--------------|------------|----------|--------------|
| 28        | Small Outline Integrated Circuit  | SOIC         | WL         | 751F     | 98ASB42345B  |
| 24        | Quad Flat Non-Leaded              | QFN          | GK         | 1982-01  | 98ARL10608D  |
| 16        | Thin Shrink Small Outline Package | TSSOP        | TG         | 948F     | 98ASH70247A  |

### 5.1 Mechanical Drawings

The following pages are mechanical drawings for the packages described in Table 18.



|                                                         |                           |                            |  |
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| TITLE: SOIC, WIDE BODY,<br>28 LEAD<br>CASEOUTLINE       | DOCUMENT NO: 98ASB42345B  | REV: G                     |  |
|                                                         | CASE NUMBER: 751F-05      | 10 MAR 2005                |  |
|                                                         | STANDARD: MS-013AE        |                            |  |



|                                                         |                           |                            |  |
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|                                                         | CASE NUMBER: 751F-05      | 10 MAR 2005                |  |
|                                                         | STANDARD: MS-013AE        |                            |  |

NOTES:

1. DIMENSIONS ARE IN MILLIMETERS.

2. DIMENSIONING AND TOLERANCING PER ASME Y14.5M-1994.

3. THIS DIMENSION DOES NOT INCLUDE MOLD PROTRUSION. MAXIMUM MOLD PROTRUSION 0.15 PER SIDE.

4. 751F-01 THRU -04 OBSOLETE. NEW STANDARD: 751F-05

5. THIS DIMENSION DOES NOT INCLUDE DAM BAR PROTRUSION ALLOWABLE DAM BAR PROTRUSION SHALL BE 0.13 TOTAL IN EXCESS OF THIS DIMENSION AT MAXIMUM MATERIAL CONDITION.

|                                                         |                           |                            |  |
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|                                                         | CASE NUMBER: 751F-05      | 10 MAR 2005                |  |
|                                                         | STANDARD: MS-013AE        |                            |  |



**MECHANICAL OUTLINES  
DICTIONARY**

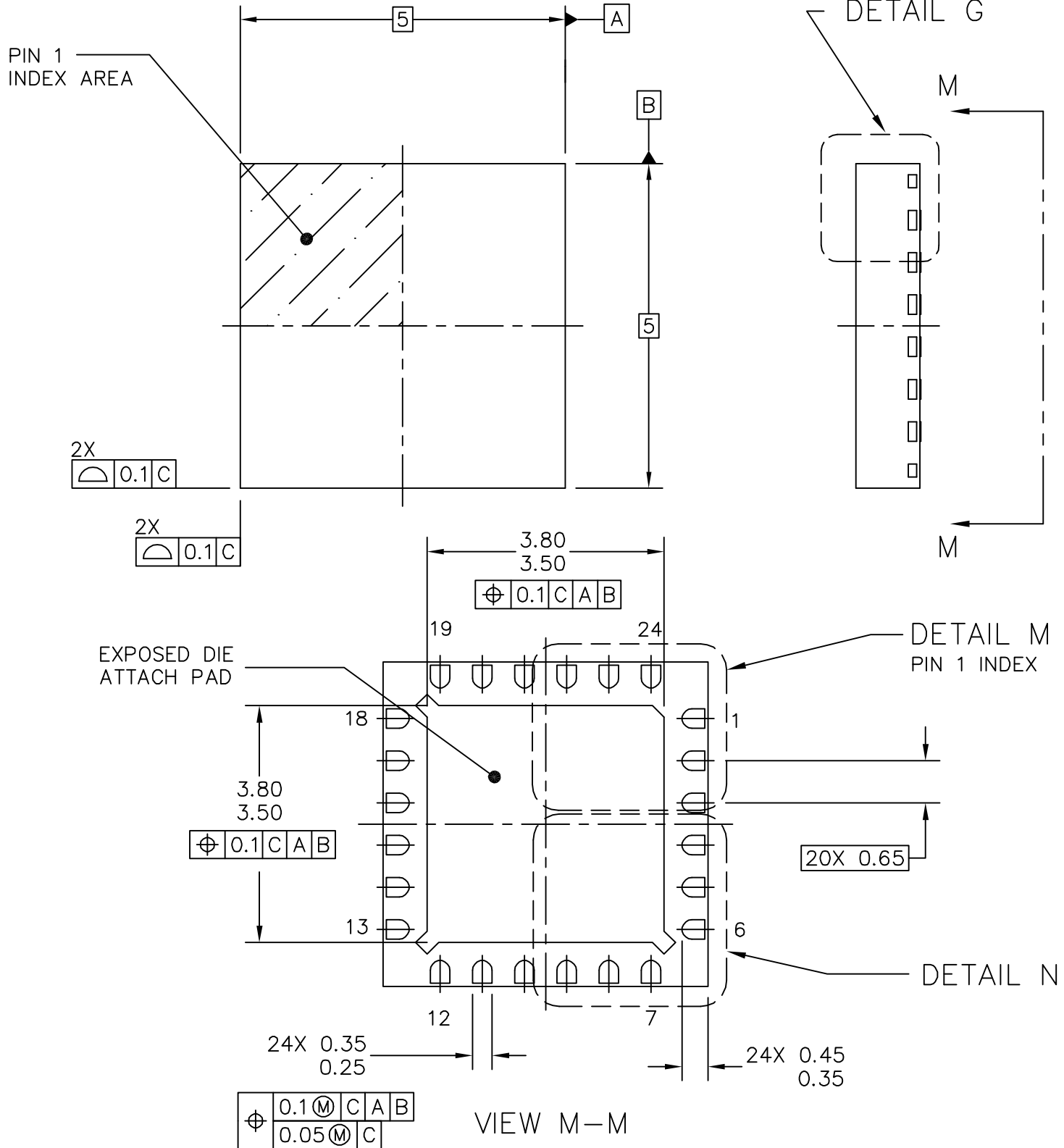
DOCUMENT NO: 98ARL10608D

PAGE: 1982

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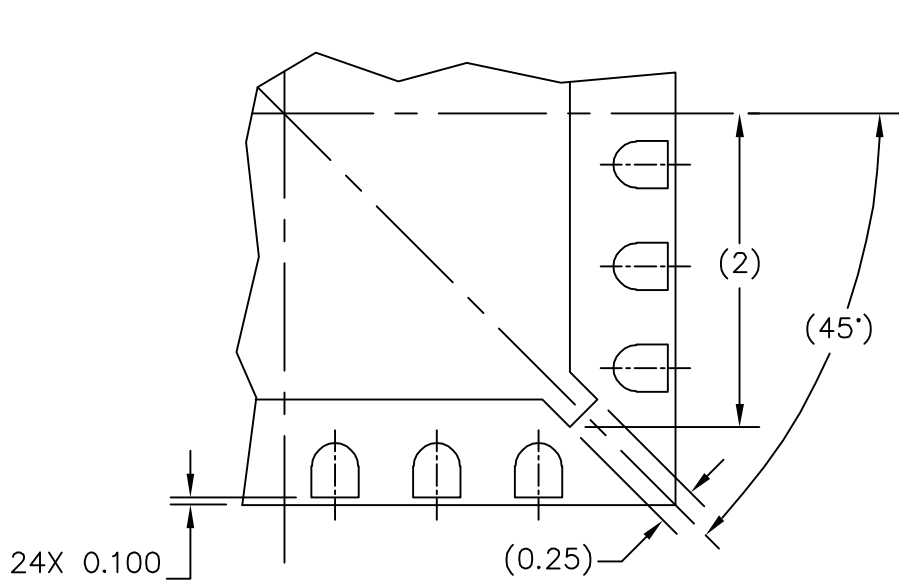
**TITLE:** THERMALLY ENHANCED QUAD  
FLAT NON-LEADED PACKAGE (QFN)  
24 TERMINAL, 0.65 PITCH (5 X 5 X 1)

**CASE NUMBER:** 1982-01

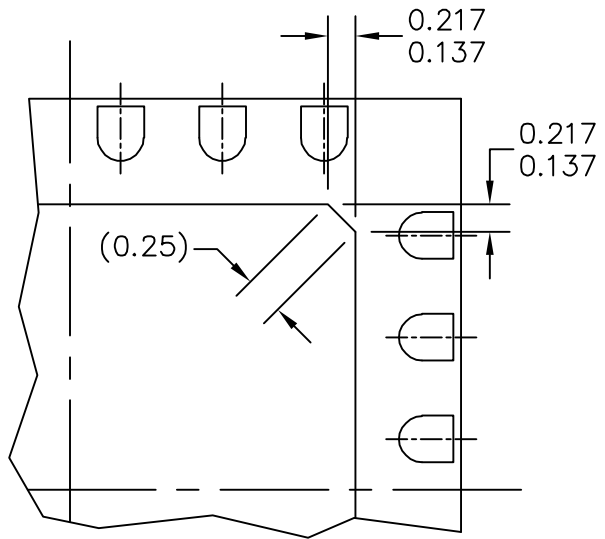
**STANDARD:** JEDEC-MO-220 VHHC-1

**PACKAGE CODE:** 6238

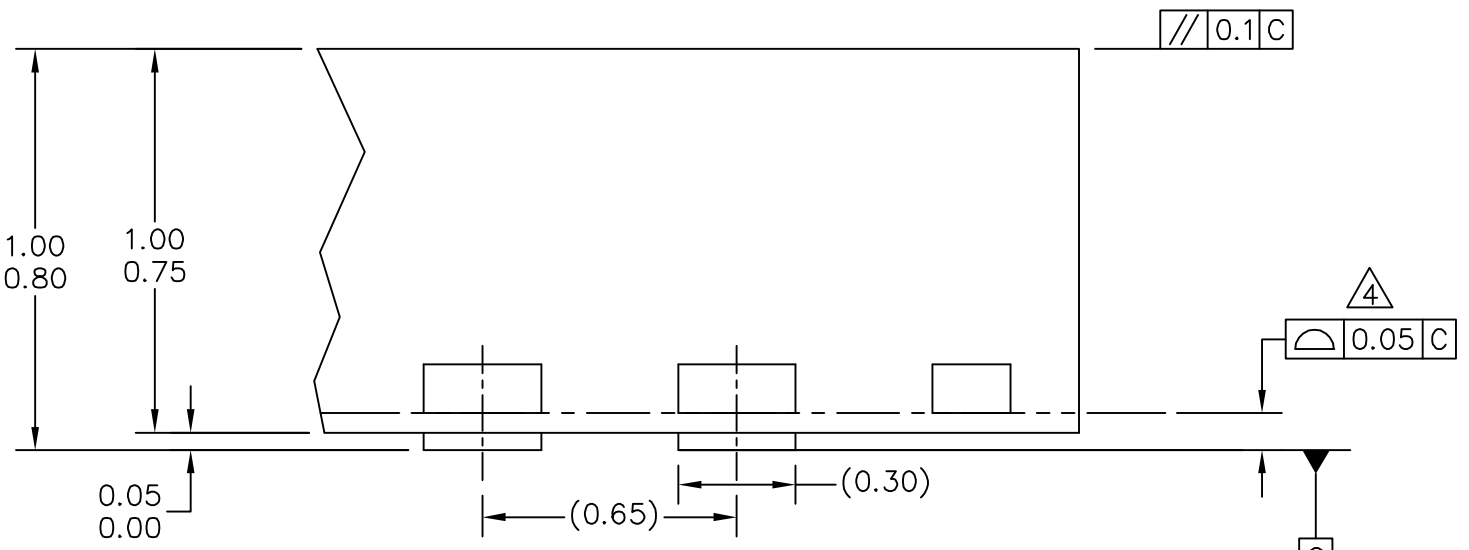
**SHEET:** 1 OF 4



**DETAIL N**  
PREFERRED CORNER CONFIGURATION



**DETAIL M**  
PREFERRED PIN 1 BACKSIDE IDENTIFIER



**DETAIL G**  
VIEW ROTATED 90° CW

SEATING PLANE

TITLE: THERMALLY ENHANCED QUAD  
FLAT NON-LEADED PACKAGE (QFN)  
24 TERMINAL, 0.65 PITCH (5 X 5 X 1)

CASE NUMBER: 1982-01

STANDARD: JEDEC-MO-220 VHHC-1

PACKAGE CODE: 6238

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NOTES:

1. DIMENSIONS ARE IN MILLIMETERS.
2. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M-1994.
3. THE COMPLETE JEDEC DESIGNATOR FOR THIS PACKAGE IS: HF-PQFN.
4.  COPLANARITY APPLIES TO LEADS, CORNER LEADS, AND DIE ATTACH PAD.
5. MIN METAL GAP SHOULD BE 0.2MM.

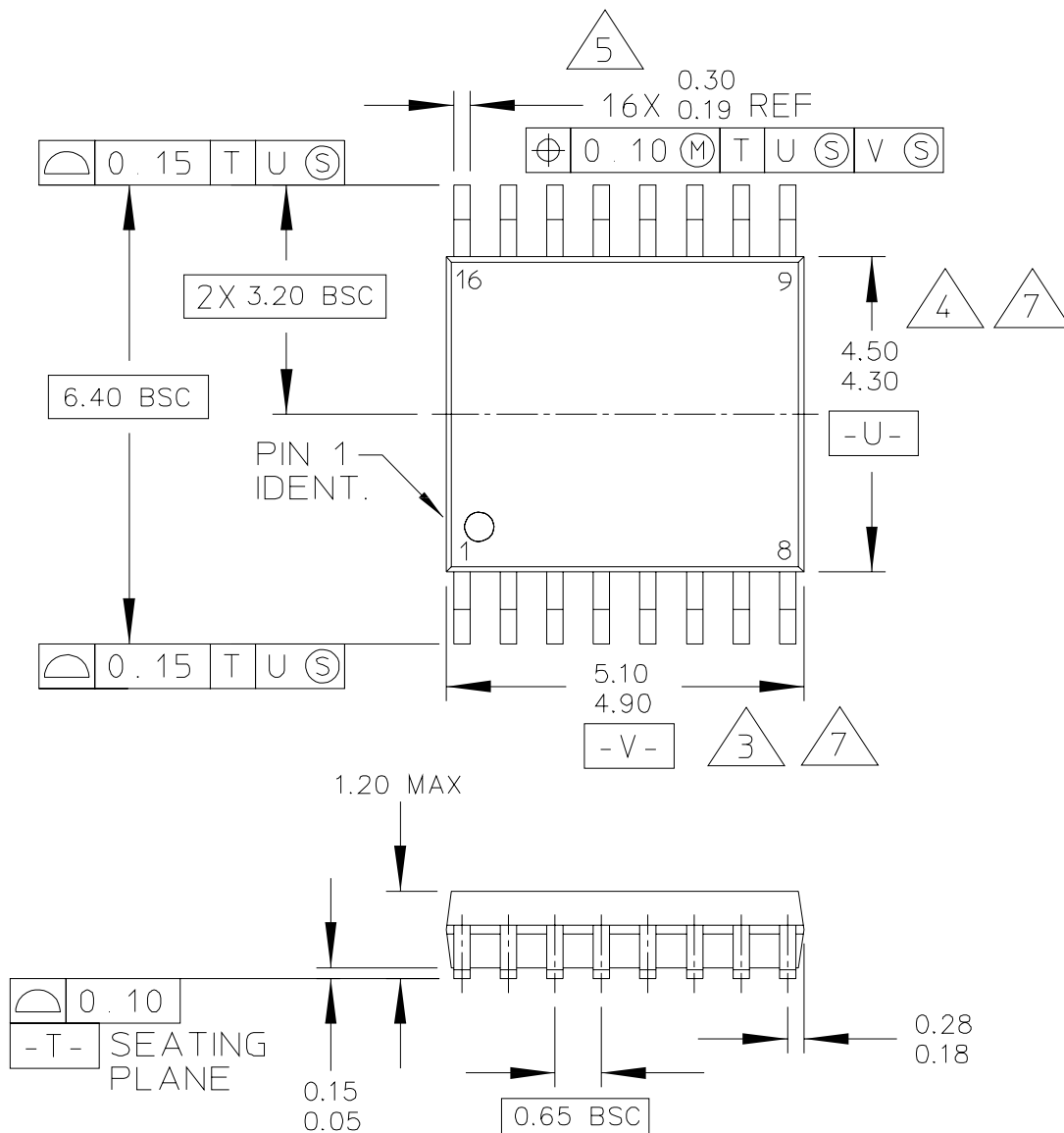
TITLE: THERMALLY ENHANCED QUAD  
FLAT NON-LEADED PACKAGE (QFN)  
24 TERMINAL, 0.65 PITCH (5 X 5 X 1)

CASE NUMBER: 1982-01

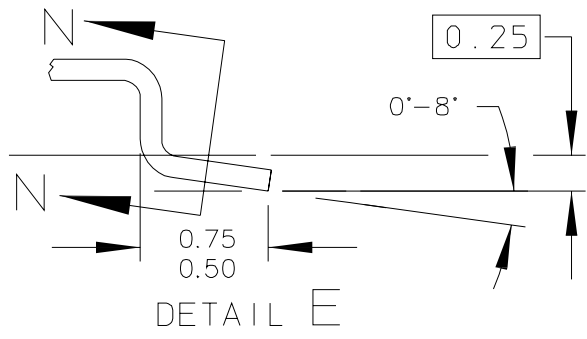
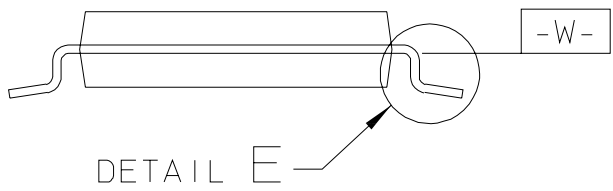
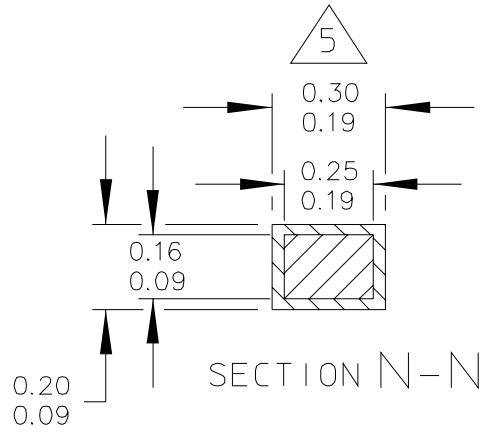
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PACKAGE CODE: 6238

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|                                                         | CASE NUMBER: 948F-01     | 19 MAY 2005                |  |
|                                                         | STANDARD: JEDEC          |                            |  |

NOTES:

1. CONTROLLING DIMENSION: MILLIMETER

2. DIMENSIONS AND TOLERANCES PER ANSI Y14.5M-1982.

3. DIMENSION DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS. MOLD FLASH OR GATE BURRS SHALL NOT EXCEED 0.15 PER SIDE.

4. DIMENSION DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSION. INTERLEAD FLASH OR PROTRUSION SHALL NOT EXCEED 0.25 PER SIDE.

5. DIMENSION DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.08 TOTAL IN EXCESS OF THE DIMENSION AT MAXIMUM MATERIAL CONDITION.

6. TERMINAL NUMBERS ARE SHOWN FOR REFERENCE ONLY.

7. DIMENSIONS ARE TO BE DETERMINED AT DATUM PLANE -W-.

|                                                         |                          |                            |  |
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