

# 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                                      |



## MC9RS08KB12

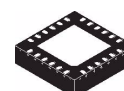
### MC9RS08KB12 Series

**Covers: MC9RS08KB12**  
**MC9RS08KB8**  
**MC9RS08KB4**  
**MC9RS08KB2**

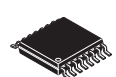
- 8-Bit RS08 Central Processor Unit (CPU)
  - Up to 20 MHz CPU at 1.8 V to 5.5 V across temperature range of –40 °C to 85 °C
  - Subset of HC08 instruction set with added BGND instruction
  - Single Global interrupt vector
- On-Chip Memory
  - Up to 12 KB flash read/program/erase over full operating voltage and temperature, 12 KB/8 KB/4 KB/2 KB flash are optional
  - Up to 254-byte random-access memory (RAM), 254-byte/126-byte RAM are optional
  - Security circuitry to prevent unauthorized access to flash contents
- Power-Saving Modes
  - Wait mode — CPU shuts down; system clocks continue to run; full voltage regulation
  - Stop mode — CPU shuts down; system clocks are stopped; voltage regulator in standby
  - Wakeup from power-saving modes using RTI, KBI, ADC, ACMP, SCI and LVD
- Clock Source Options
  - Oscillator (XOSC) — Loop-control Pierce oscillator; crystal or ceramic resonator range of 31.25 kHz to 39.0625 kHz or 1 MHz to 16 MHz
  - Internal Clock Source (ICS) — Internal clock source module containing a frequency-locked-loop (FLL) controlled by internal or external reference; precision trimming of internal reference allows 0.2% resolution and 2% deviation over temperature and voltage; supporting bus frequencies up to 10 MHz
- System Protection
  - Watchdog computer operating properly (COP) reset with option to run from dedicated 1 kHz internal low power oscillator
  - Low-voltage detection with reset or interrupt
  - Illegal opcode detection with reset
  - Illegal address detection with reset
  - Flash-block protection



20-Pin SOIC  
Case 751D



24-Pin QFN  
Case 1982-01



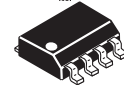
16-Pin TSSOP  
Case 948F



16-Pin SOIC N/B  
Case 751B



8-Pin DFN  
Case 1452-02



8-Pin SOIC  
Case 751

- Development Support
  - Single-wire background debug interface
  - Breakpoint capability to allow single breakpoint setting during in-circuit debugging
- Peripherals
  - **ADC** — 12-channel, 10-bit resolution; 2.5  $\mu$ s conversion time; automatic compare function; 1.7 mV/°C temperature sensor; internal bandgap reference channel; operation in stop; hardware trigger
  - **ACMP** — Analog comparator; full rail-to-rail supply operation; option to compare to fixed internal bandgap reference voltage; can operate in stop mode
  - **TPM** — One 2-channel timer/pulse-width modulator module; selectable input capture, output compare, or buffered edge- or center-aligned PWM on each channel
  - **IIC** — Inter-integrated circuit bus module capable of operation up to 100 kbps with maximum bus loading; capable of higher baud rates with reduced loading
  - **SCI** — One serial communications interface module with optional 13-bit break; LIN extensions
  - **MTIM** — Two 8-bit modulo timers; optional clock sources
  - **RTI** — One real-time clock with optional clock sources
  - **KBI** — Keyboard interrupts; up to 8 ports
- Input/Output
  - 18 GPIOs in 24- and 20-pin packages; 14 GPIOs in 16-pin package; 6 GPIOs in 8-pin package; including one output-only pin and one input-only pin
  - Hysteresis and configurable pullup device on all input pins; configurable slew rate and drive strength on all output pins
- Package Options
  - MC9RS08KB12/MC9RS08KB8/MC9RS08KB4
    - 24-pin QFN, 20-pin SOIC, 16-pin SOIC NB or TSSOP
  - MC9RS08KB2
    - 8-pin SOIC or DFN

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

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## 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.

| Revision | Date      | Description of Changes                                                                                                                                                                                                                                           |
|----------|-----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1        | 4/13/2009 | Updated on shared review comments, added package information.                                                                                                                                                                                                    |
| 2        | 5/22/2009 | Completed most of the TBDs, corrected the block diagram.                                                                                                                                                                                                         |
| 3        | 8/31/2009 | Completed all the TBDs.<br>Changed $V_{LVD}$ and added $R_{PD}$ in the <a href="#">Table 7</a> .<br>Changed $SI_{DD}$ , ADC adder from stop, RTI adder from stop with 1 kHz clock source enabled and LVI adder from stop at 5 V in the <a href="#">Table 8</a> . |
| 4        | 6/23/2011 | Split the 10-Bit ADC Characteristics to <a href="#">Table 15</a> and <a href="#">Table 16</a> for the $V_{DDAD}$ ranges.<br>Corrected the note 4 in the <a href="#">Table 8</a> .                                                                                |
| 5        | 1/30/2012 | Added 24-pin QFN package.                                                                                                                                                                                                                                        |

## Related Documentation

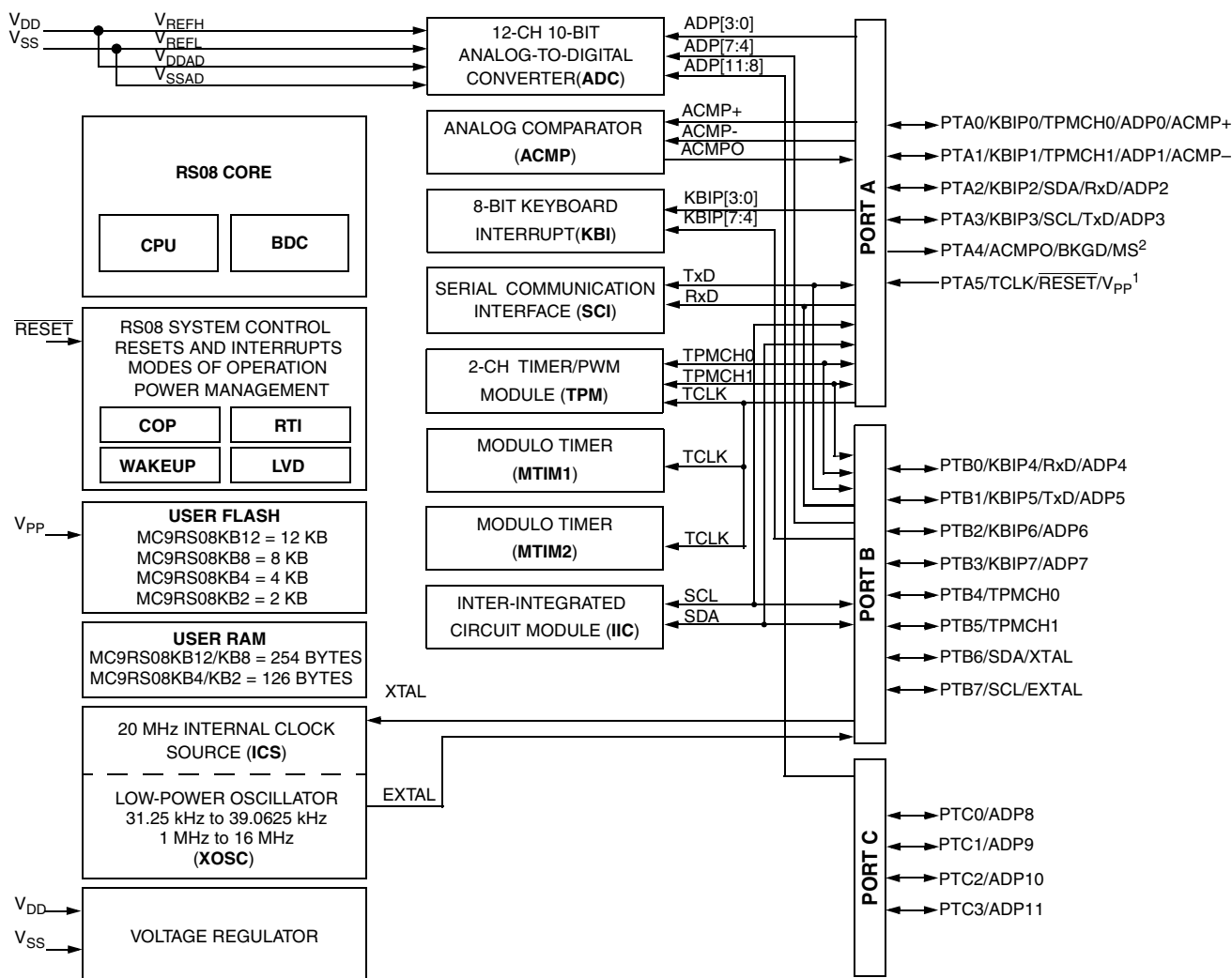
Find the most current versions of all documents at: <http://www.freescale.com>

### Reference Manual (MC9RS08KB12RM)

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, [Figure 1](#), shows the structure of the MC9RS08KB12 MCU.



## NOTES:

1. PTA5/TCLK/RESET/V<sub>PP</sub> is an input-only pin when used as port pin
2. PTA4/ACMPO/BKGD/MS is an output-only pin when used as port pin

Figure 1. MC9RS08KB12 Series Block Diagram

## 2 Pin Assignments

This section shows the pin assignments in the packages available for the MC9RS08KB12 series.

Table 1. Pin Availability by Package Pin-Count

| Pin Number |    |    |   | <-- Lowest Priority --> Highest |                     |                     |                  |                 |
|------------|----|----|---|---------------------------------|---------------------|---------------------|------------------|-----------------|
| 24         | 20 | 16 | 8 | Port Pin                        | Alt 1               | Alt 2               | Alt 3            | Alt 4           |
| 1          | 3  | 3  | 3 |                                 |                     |                     |                  | V <sub>DD</sub> |
| 2          | —  | —  | — | NC                              |                     |                     |                  |                 |
| 3          | 4  | 4  | 4 |                                 |                     |                     |                  | V <sub>SS</sub> |
| 4          | 5  | 5  | — | PTB7                            | SCL <sup>1</sup>    |                     |                  | EXTAL           |
| 5          | 6  | 6  | — | PTB6                            | SDA <sup>1</sup>    |                     |                  | XTAL            |
| 6          | 7  | 7  | — | PTB5                            | TPMCH1 <sup>2</sup> |                     |                  |                 |
| 7          | 8  | 8  | — | PTB4                            | TPMCH0 <sup>2</sup> |                     |                  |                 |
| 8          | 9  | —  | — | PTC3                            |                     |                     | ADP11            |                 |
| 9          | 10 | —  | — | PTC2                            |                     |                     | ADP10            |                 |
| 10         | 11 | —  | — | PTC1                            |                     |                     | ADP9             |                 |
| 11         | 12 | —  | — | PTC0                            |                     |                     | ADP8             |                 |
| 12         | 13 | 9  | — | PTB3                            | KBIP7               |                     | ADP7             |                 |
| 13         | 14 | 10 | — | PTB2                            | KBIP6               |                     | ADP6             |                 |
| 14         | 15 | 11 | — | PTB1                            | KBIP5               | TxD <sup>3</sup>    | ADP5             |                 |
| 15         | 16 | 12 | — | PTB0                            | KBIP4               | RxD <sup>3</sup>    | ADP4             |                 |
| 16         | 17 | 13 | 5 | PTA3                            | KBIP3               | SCL <sup>1</sup>    | TxD <sup>3</sup> | ADP3            |
| 17         | 18 | 14 | 6 | PTA2                            | KBIP2               | SDA <sup>1</sup>    | RxD <sup>3</sup> | ADP2            |
| 18         | 19 | 15 | 7 | PTA1                            | KBIP1               | TPMCH1 <sup>2</sup> | ADP1             | ACMP–           |
| 19         | 20 | 16 | 8 | PTA0                            | KBIP0               | TPMCH0 <sup>2</sup> | ADP0             | ACMP+           |
| 20         | —  | —  | — | NC                              |                     |                     |                  |                 |
| 21         | —  | —  | — | NC                              |                     |                     |                  |                 |
| 22         | —  | —  | — | NC                              |                     |                     |                  |                 |
| 23         | 1  | 1  | 1 | PTA5                            |                     | TCLK                | RESET            | V <sub>PP</sub> |
| 24         | 2  | 2  | 2 | PTA4                            | ACMPO               | BKGD                | MS               |                 |

<sup>1</sup> IIC pins can be remapped to PTB6 and PTB7, default reset location is PTA2 and PTA3. It can be configured only once.

<sup>2</sup> TPM pins can be remapped to PTB4 and PTB5, default reset location is PTA0 and PTA1.

<sup>3</sup> SCI pins can be remapped to PTA2 and PTA3, default reset location is PTB0 and PTB1. It can be configured only once.

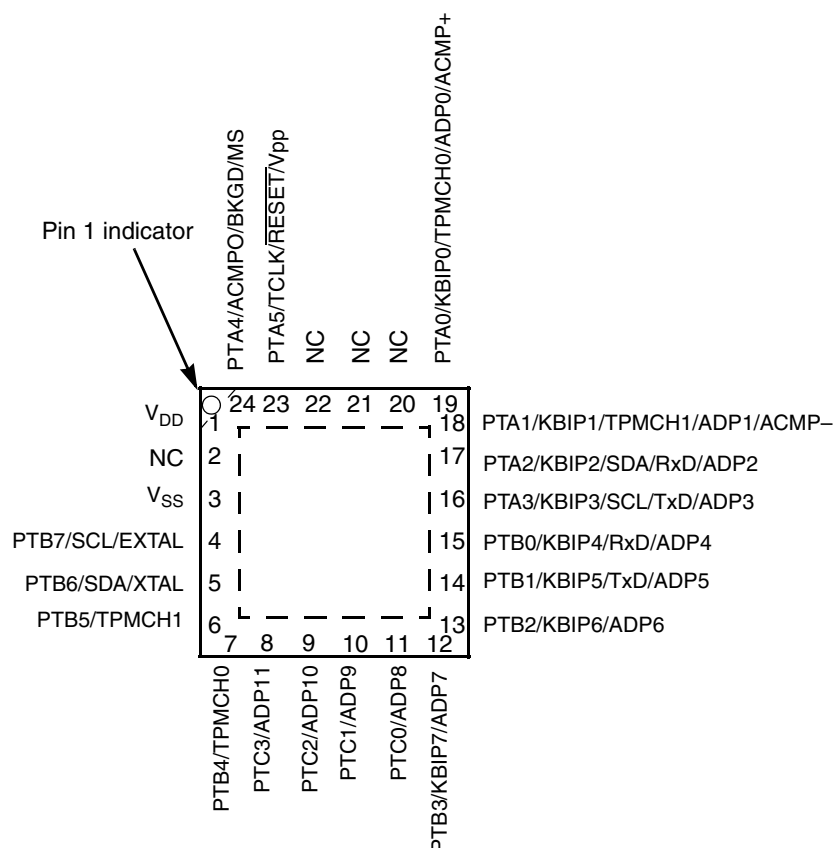


Figure 2. MC9RS08KB12 Series 24-Pin QFN Package

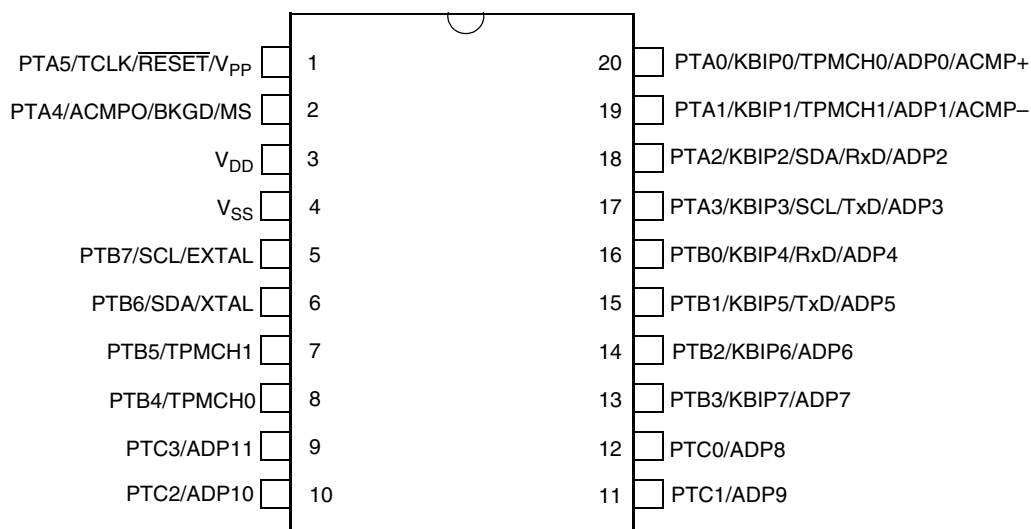


Figure 3. MC9RS08KB12 Series 20-Pin SOIC Package

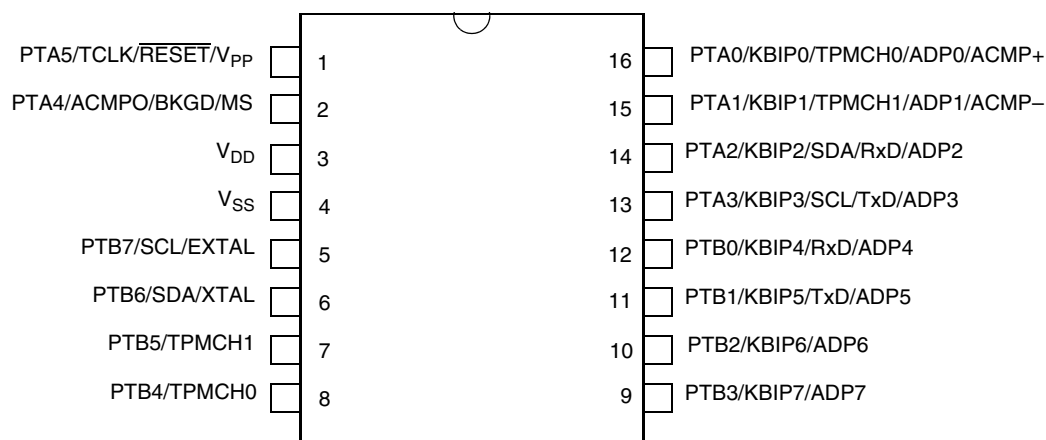


Figure 4. MC9RS08KB12 Series 16-Pin SOIC NB/TSSOP Package

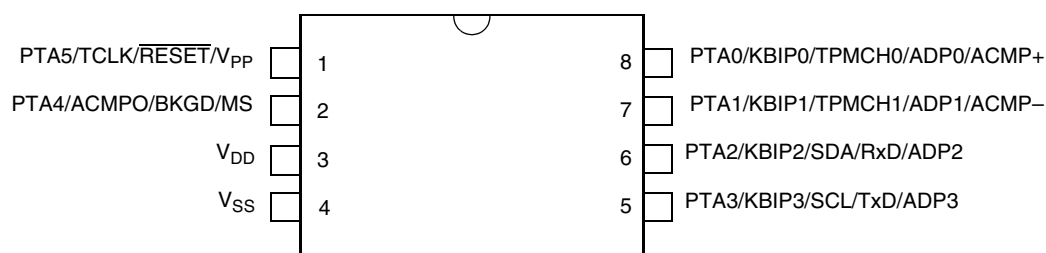


Figure 5. MC9RS08KB12 Series 8-Pin SOIC/DFN Package

## 3 Electrical Characteristics

### 3.1 Introduction

This chapter contains electrical and timing specifications for the MC9RS08KB12 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. |



Table 2. Parameter Classifications

|          |                                                       |
|----------|-------------------------------------------------------|
| <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 chapter.

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,  $V_{SS}$  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 5.8            | 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 are internally clamped to  $V_{SS}$  and  $V_{DD}$  except the  $\overline{RESET}/V_{PP}$  pin which is internally clamped to  $V_{SS}$  only.

<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. In order 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           | $T_{JMAX}$    | 150                         | °C   |
| Thermal resistance 24-pin QFN          | $\theta_{JA}$ | 113                         | °C/W |
| Thermal resistance 20-pin SOIC         | $\theta_{JA}$ | 83                          | °C/W |
| Thermal resistance 16-pin SOIC NB      | $\theta_{JA}$ | 103                         | °C/W |
| Thermal resistance 16-pin TSSOP        | $\theta_{JA}$ | 29                          | °C/W |
| Thermal resistance 8-pin SOIC          | $\theta_{JA}$ | 150                         | °C/W |
| Thermal resistance 8-pin DFN           | $\theta_{JA}$ | 110                         | °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 must be used 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.

During the device qualification ESD stresses were performed for the human body model (HBM) 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 specified otherwise in the device specification.

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

| Model      | Description                 | Symbol | Value | Unit     |
|------------|-----------------------------|--------|-------|----------|
| Human body | Series resistance           | R1     | 1500  | $\Omega$ |
|            | Storage capacitance         | C      | 100   | pF       |
|            | Number of pulses per pin    | —      | 1     | —        |
| 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)                       | $V_{\text{HBM}}$ | $\pm 2000$ | —   | V    |
| 2   | Charge device model (CDM)                    | $V_{\text{CDM}}$ | $\pm 500$  | —   | V    |
| 3   | Latch-up current at $T_A = 85^\circ\text{C}$ | $I_{\text{LAT}}$ | $\pm 100$  | —   | 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, I/O pin characteristics, and power supply current in various operating modes.

Table 7. DC Characteristics (Temperature Range =  $-40$  to  $85^\circ\text{C}$  Ambient)

| No. | C | Parameter                                                                                                                                                                              | Symbol             | Min                         | Typical      | Max                         | Unit             |
|-----|---|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------|-----------------------------|--------------|-----------------------------|------------------|
| 1   | — | Supply voltage (run, wait and stop modes.)<br>$0 < f_{\text{BUS}} < 10 \text{ MHz}$                                                                                                    | $V_{\text{DD}}$    | 1.8                         | —            | 5.5                         | V                |
| 2   | C | Minimum RAM retention supply voltage applied to $V_{\text{DD}}$                                                                                                                        | $V_{\text{RAM}}$   | 0.8 <sup>1</sup>            | —            | —                           | V                |
| 3   | P | Low-voltage detection threshold<br>( $V_{\text{DD}}$ falling)<br>( $V_{\text{DD}}$ rising)                                                                                             | $V_{\text{LVD}}$   | 1.80<br>1.88                | 1.86<br>1.94 | 1.95<br>2.05                | V                |
| 4   | C | Power on RESET (POR) voltage                                                                                                                                                           | $V_{\text{POR}}^1$ | 0.9                         | —            | 1.7                         | V                |
| 5   | C | Input high voltage ( $V_{\text{DD}} > 2.3\text{V}$ ) (all digital inputs)                                                                                                              | $V_{\text{IH}}$    | $0.70 \times V_{\text{DD}}$ | —            | —                           | V                |
| 6   | C | Input high voltage ( $1.8 \text{ V} \leq V_{\text{DD}} \leq 2.3 \text{ V}$ ) (all digital inputs)                                                                                      | $V_{\text{IH}}$    | $0.85 \times V_{\text{DD}}$ | —            | —                           | V                |
| 7   | C | Input low voltage ( $V_{\text{DD}} > 2.3 \text{ V}$ ) (all digital inputs)                                                                                                             | $V_{\text{IL}}$    | —                           | —            | $0.30 \times V_{\text{DD}}$ | V                |
| 8   | C | Input low voltage ( $1.8 \text{ V} \leq V_{\text{DD}} \leq 2.3 \text{ V}$ ) (all digital inputs)                                                                                       | $V_{\text{IL}}$    | —                           | —            | $0.30 \times V_{\text{DD}}$ | V                |
| 9   | C | Input hysteresis (all digital inputs)                                                                                                                                                  | $V_{\text{hys}}^1$ | $0.06 \times V_{\text{DD}}$ | —            | —                           | V                |
| 10  | P | Input leakage current (per pin)<br>$V_{\text{In}} = V_{\text{DD}}$ or $V_{\text{SS}}$ , all input only pins                                                                            | $I_{\text{InI}}$   | —                           | 0.025        | 1.0                         | $\mu\text{A}$    |
| 11  | P | High impedance (off-state) leakage current (per pin)<br>$V_{\text{In}} = V_{\text{DD}}$ or $V_{\text{SS}}$ , all input/output                                                          | $I_{\text{IOZ}}$   | —                           | 0.025        | 1.0                         | $\mu\text{A}$    |
| 12  | P | Internal pullup resistors <sup>2</sup> (all port pins)                                                                                                                                 | $R_{\text{PU}}$    | 20                          | 45           | 65                          | $\text{k}\Omega$ |
| 13  | P | Internal pulldown resistors <sup>2</sup> (all port pins)                                                                                                                               | $R_{\text{PD}}$    | 20                          | 45           | 65                          | $\text{k}\Omega$ |
| 14  | C | Output high voltage — Low drive ( $\text{PTxDSn} = 0$ )<br>5 V, $I_{\text{Load}} = 2 \text{ mA}$<br>3 V, $I_{\text{Load}} = 1 \text{ mA}$<br>1.8 V, $I_{\text{Load}} = 0.5 \text{ mA}$ | $V_{\text{OH}}$    | $V_{\text{DD}} - 0.8$       | —<br>—<br>—  | —<br>—<br>—                 | V                |
|     |   | Output high voltage — High drive ( $\text{PTxDSn} = 1$ )<br>5 V, $I_{\text{Load}} = 5 \text{ mA}$<br>3 V, $I_{\text{Load}} = 3 \text{ mA}$<br>1.8 V, $I_{\text{Load}} = 2 \text{ mA}$  |                    | $V_{\text{DD}} - 0.8$       | —<br>—<br>—  | —<br>—<br>—                 |                  |
| 15  | C | Maximum total IOH for all port pins                                                                                                                                                    | $ I_{\text{OHT}} $ | —                           | —            | 40                          | mA               |

**Table 7. DC Characteristics (Temperature Range = -40 to 85°C Ambient) (continued)**

| No. | C | Parameter                                                                                                                     | Symbol    | Min | Typical | Max | Unit |
|-----|---|-------------------------------------------------------------------------------------------------------------------------------|-----------|-----|---------|-----|------|
| 16  | C | Output low voltage — Low drive (PTxDSn = 0)<br>5 V, $I_{Load} = 2$ mA<br>3 V, $I_{Load} = 1$ mA<br>1.8 V, $I_{Load} = 0.5$ mA | $V_{OL}$  | —   | —       | 0.8 | V    |
|     |   | Output low voltage — High drive (PTxDSn = 1)<br>5 V, $I_{Load} = 5$ mA<br>3 V, $I_{Load} = 3$ mA<br>1.8 V, $I_{Load} = 2$ mA  |           | —   | —       | 0.8 |      |
| 17  | C | Maximum total IOL for all port pins                                                                                           | $I_{OLT}$ | —   | —       | 40  | mA   |
| 18  | C | DC injection current <sup>3, 4, 5, 6</sup><br>$V_{In} < V_{SS}$ , $V_{In} > V_{DD}$<br>Single pin limit                       |           | —   | —       | 0.2 | mA   |
|     |   | Total MCU limit, includes sum of all stressed pins                                                                            |           | —   | —       | 0.8 |      |
| 19  | C | Input capacitance (all non-supply pins)                                                                                       | $C_{In}$  | —   | —       | 7   | pF   |

<sup>1</sup> This parameter is characterized and not tested on each device.

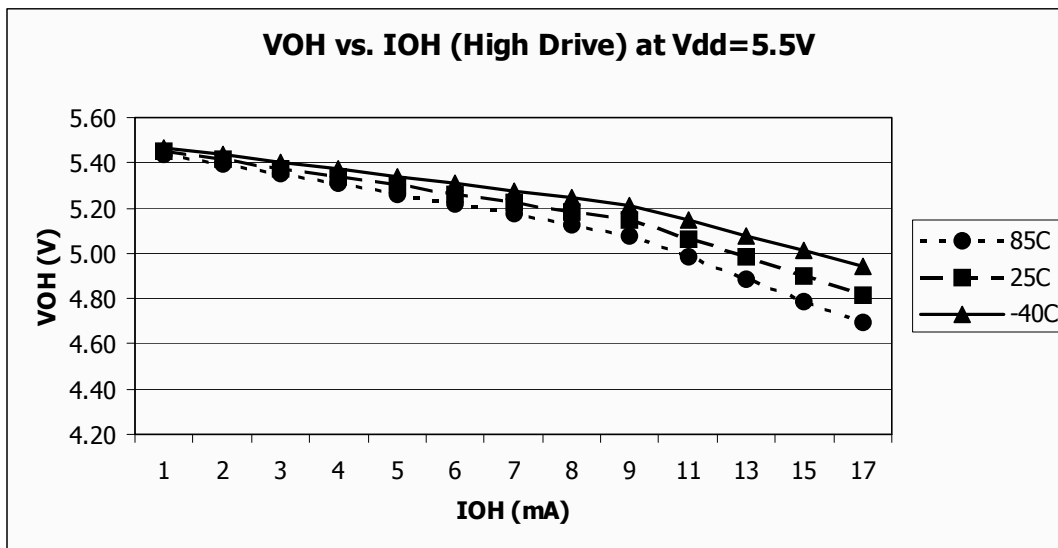
<sup>2</sup> Measurement condition for pull resistors:  $V_{In} = V_{SS}$  for pullup and  $V_{In} = V_{DD}$  for pulldown.

<sup>3</sup> All functional non-supply pins are internally clamped to  $V_{SS}$  and  $V_{DD}$  except the  $\overline{RESET}/V_{PP}$  which is internally clamped to  $V_{SS}$  only.

<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> 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>6</sup> This parameter is characterized and not tested on each device.



**Figure 6. Typical  $V_{OH}$  vs.  $I_{OH}$   
 $V_{DD} = 5.5$  V (High Drive)**

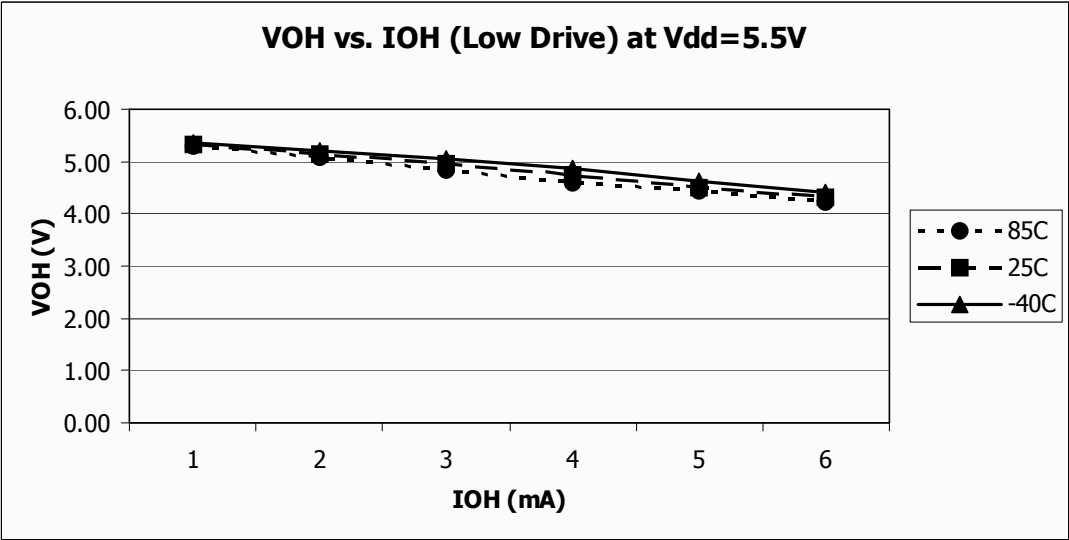


Figure 7. Typical  $V_{OH}$  vs.  $I_{OH}$   
 $V_{DD} = 5.5\text{ V}$  (Low Drive)

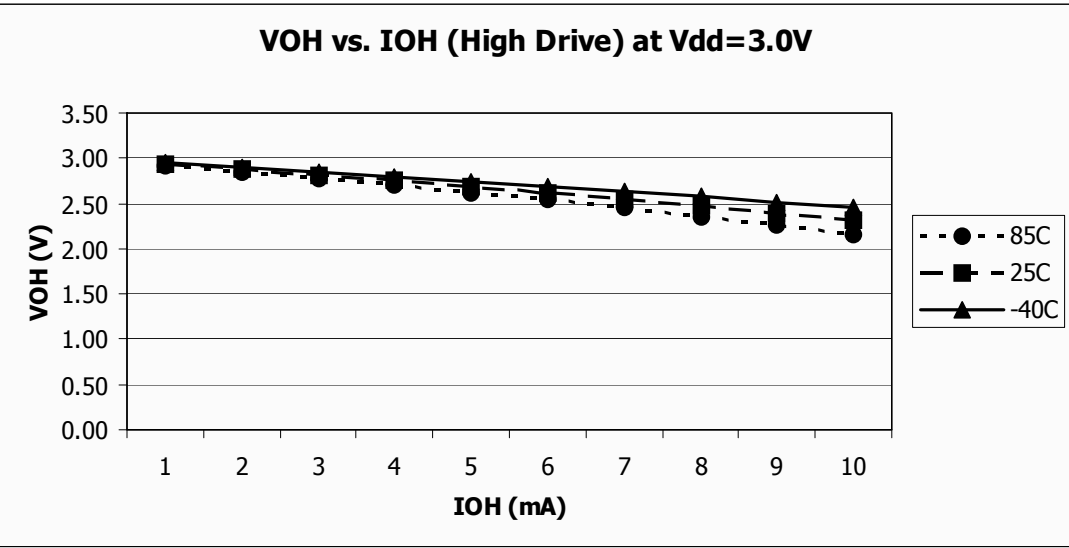


Figure 8. Typical  $V_{OH}$  vs.  $I_{OH}$   
 $V_{DD} = 3.0\text{ V}$  (High Drive)

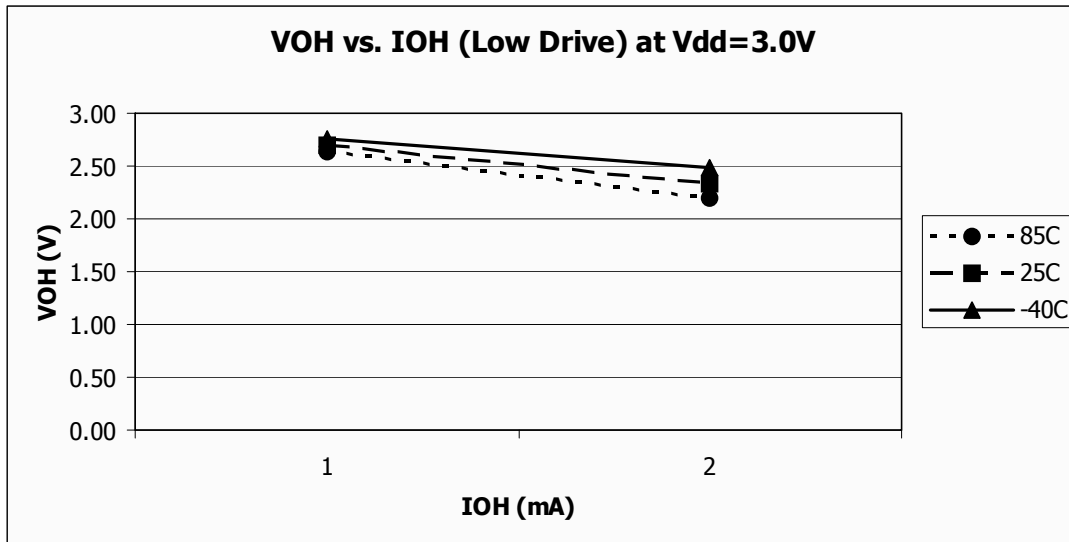


Figure 9. Typical  $V_{OH}$  vs.  $I_{OH}$   
 $V_{DD} = 3.0\text{ V}$  (Low Drive)

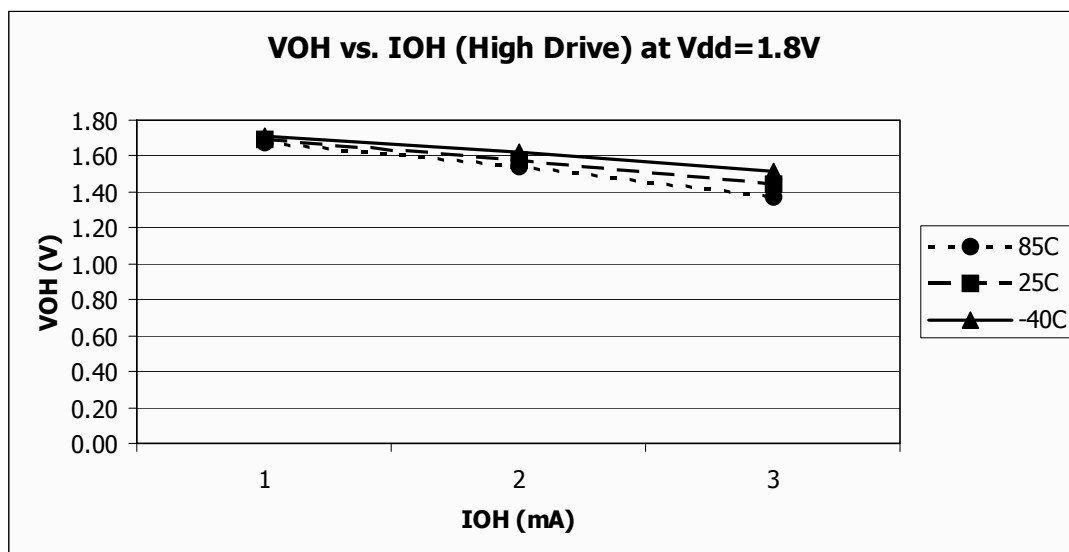


Figure 10. Typical  $V_{OH}$  vs.  $I_{OH}$   
 $V_{DD} = 1.8\text{ V}$  (High Drive)

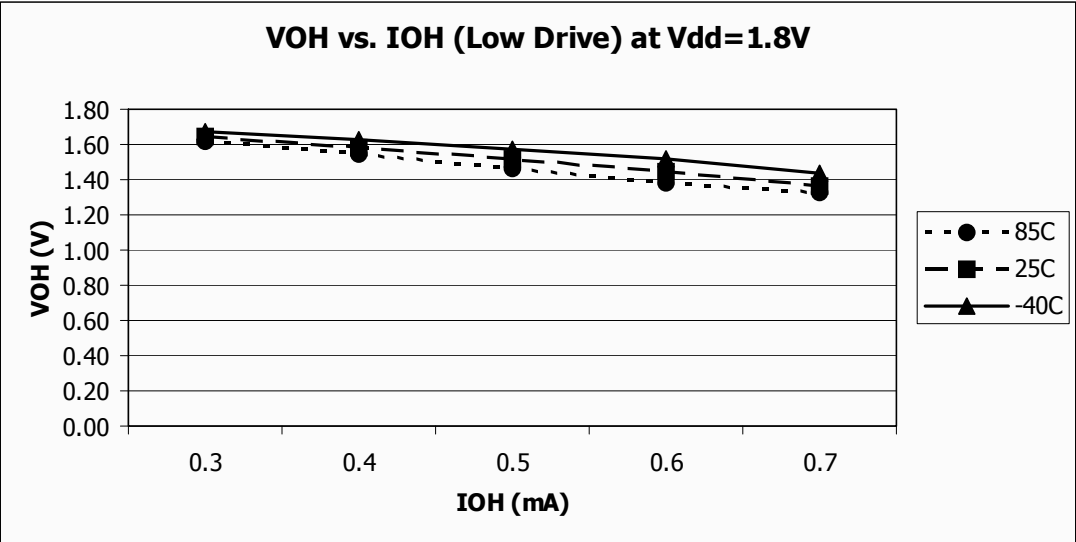


Figure 11. Typical  $V_{OH}$  vs.  $I_{OH}$   
 $V_{DD} = 1.8\text{ V}$  (Low Drive)

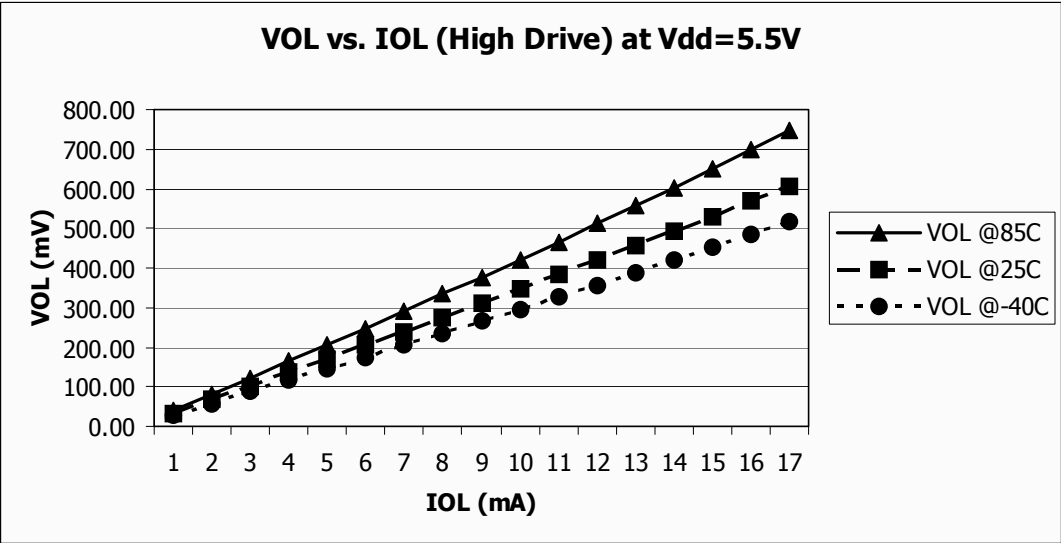


Figure 12. Typical  $V_{OL}$  vs.  $I_{OL}$   
 $V_{DD} = 5.5\text{ V}$  (High Drive)



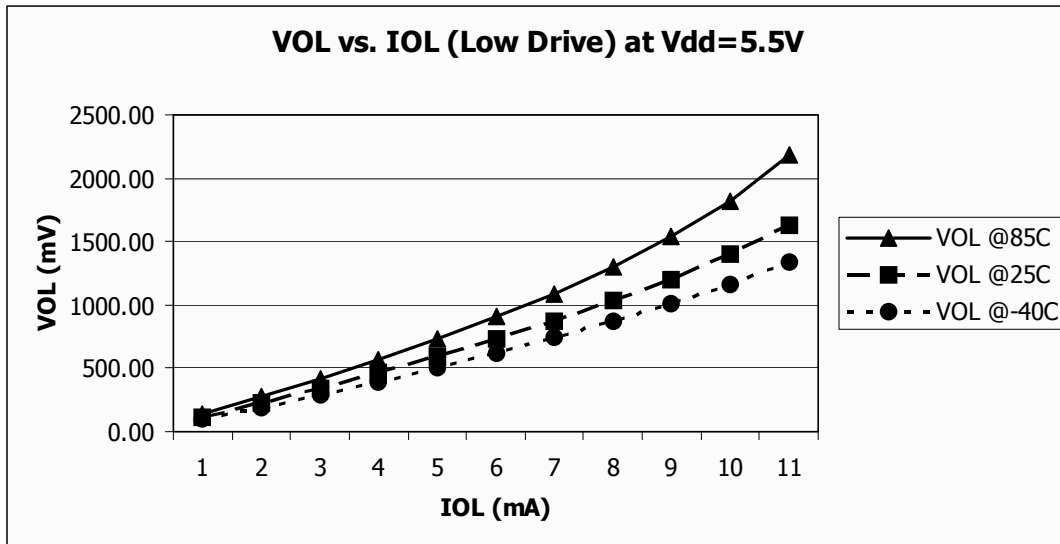


Figure 13. Typical V<sub>OL</sub> vs. I<sub>OL</sub>  
V<sub>DD</sub> = 5.5 V (Low Drive)

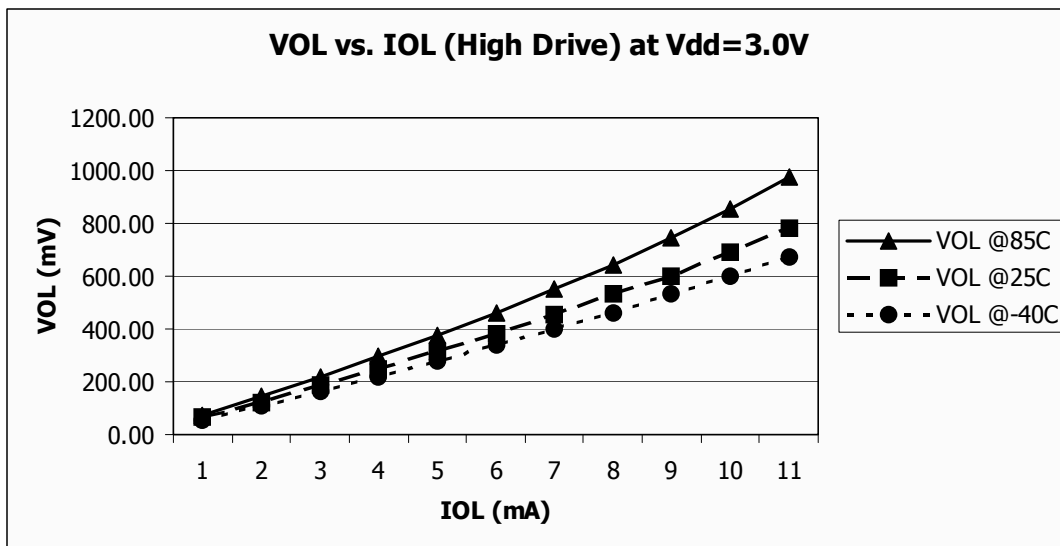


Figure 14. Typical V<sub>OL</sub> vs. I<sub>OL</sub>  
V<sub>DD</sub> = 3.0 V (High Drive)

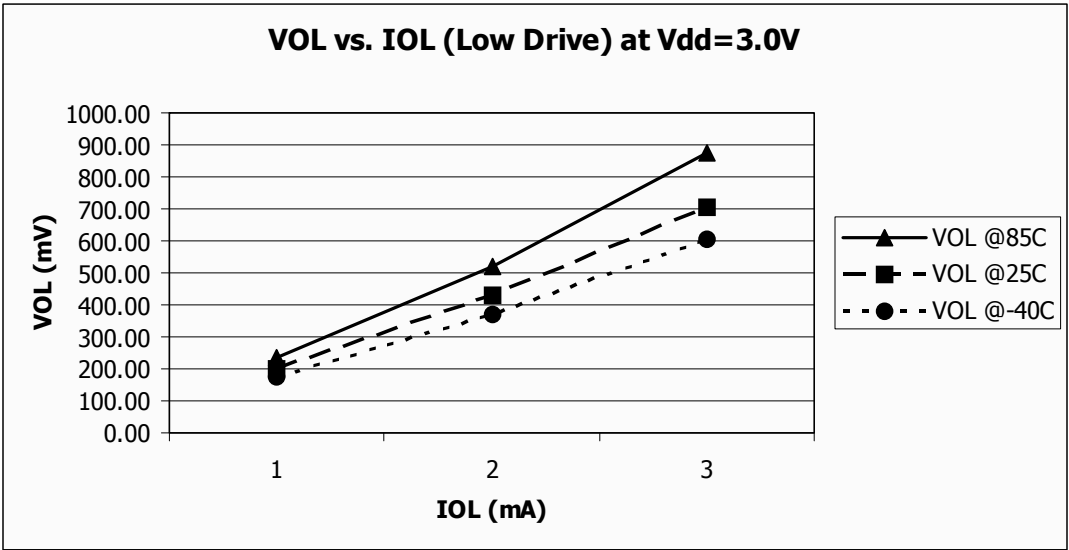


Figure 15. Typical VOL vs. IOL  
VDD = 3.0 V (Low Drive)

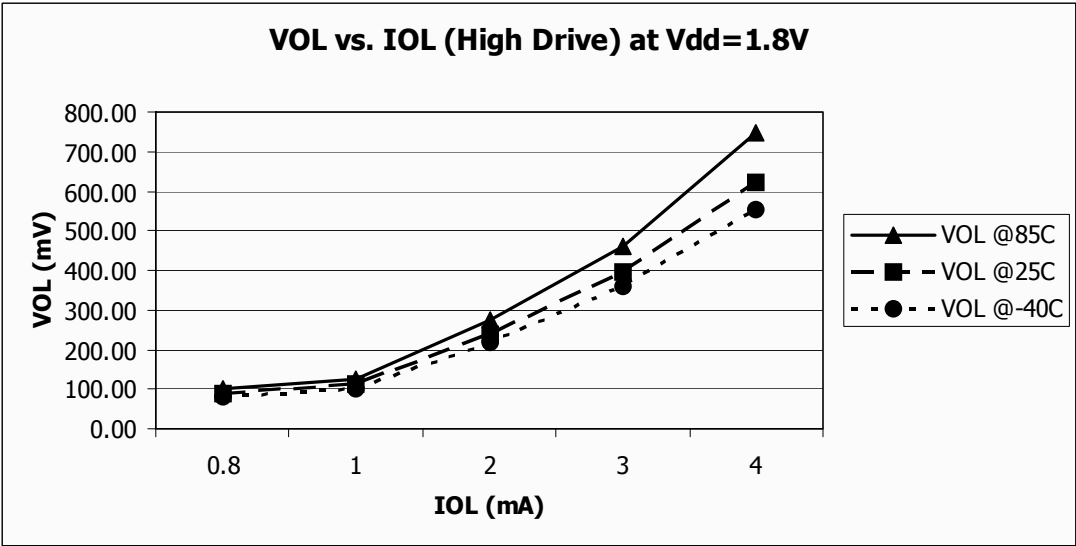


Figure 16. Typical VOL vs. IOL  
VDD = 1.8 V (High Drive)

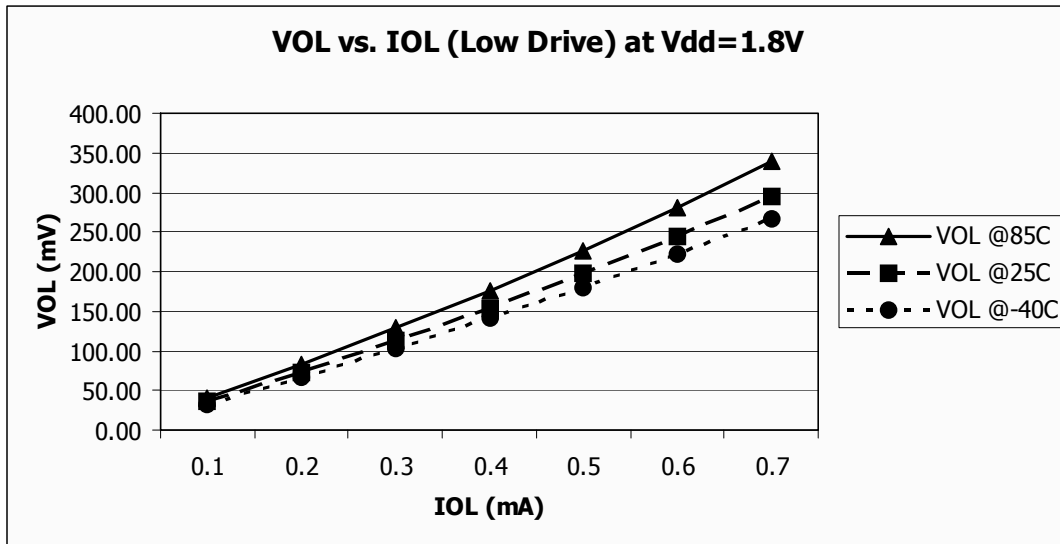


Figure 17. Typical  $V_{OL}$  vs.  $I_{OL}$   
 $V_{DD} = 1.8\text{ V}$  (Low Drive)

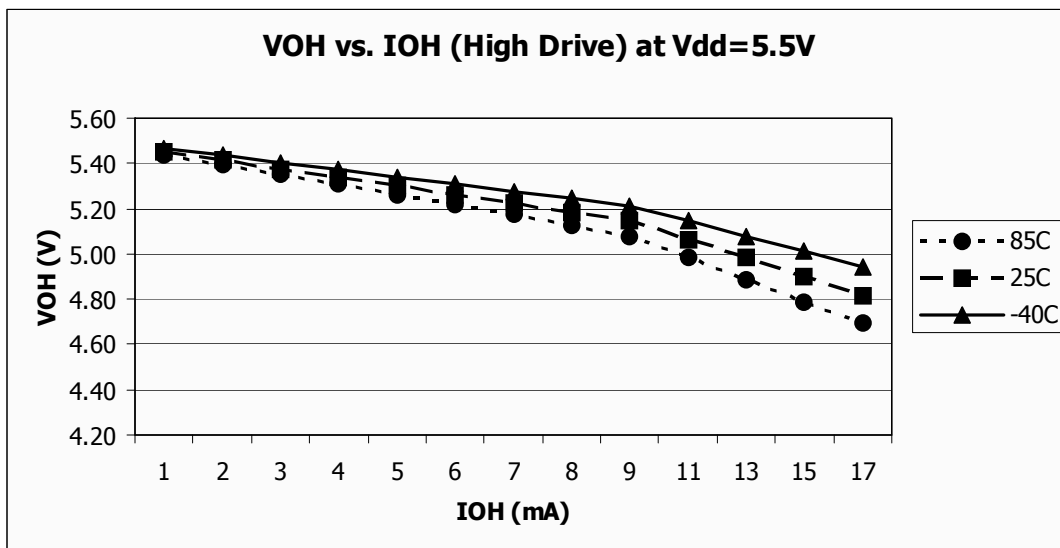


Figure 18. Typical  $I_{OH}$  vs.  $V_{DD} - V_{OH}$   
 $V_{DD} = 5.5\text{ V}$  (High Drive)

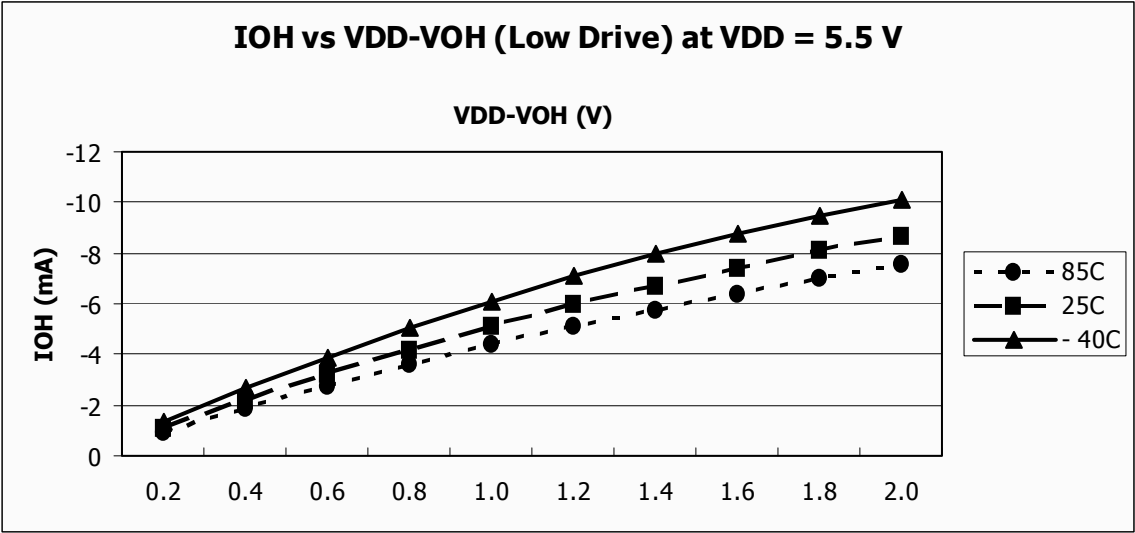


Figure 19. Typical IOH vs. VDD-VOH  
VDD = 5.5 V (Low Drive)

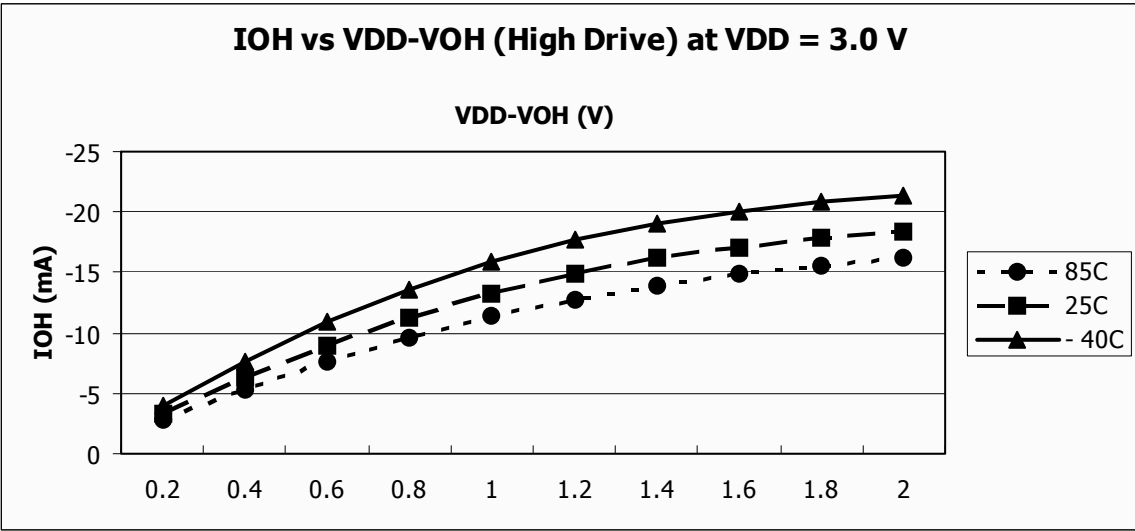


Figure 20. Typical IOH vs. VDD-VOH  
VDD = 3 V (High Drive)

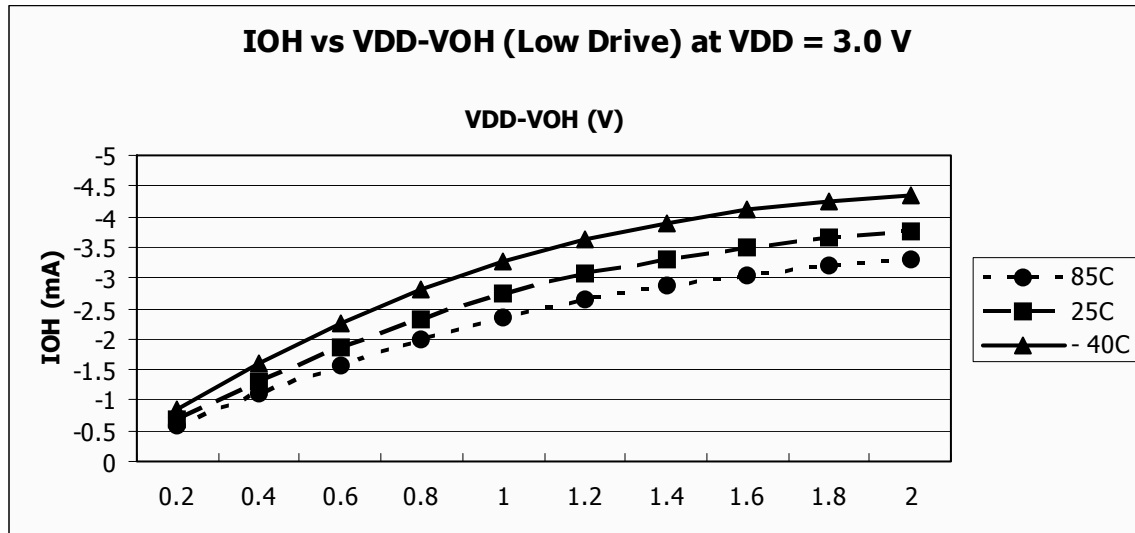


Figure 21. Typical  $I_{OH}$  vs.  $V_{DD}-V_{OH}$   
 $V_{DD} = 3\text{ V}$  (Low Drive)

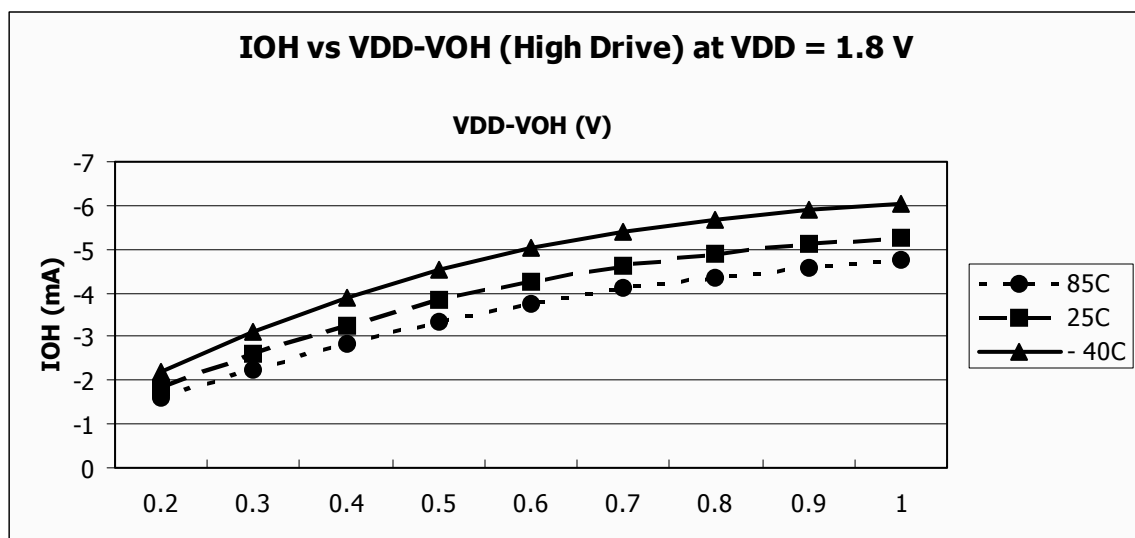


Figure 22. Typical  $I_{OH}$  vs.  $V_{DD}-V_{OH}$   
 $V_{DD} = 1.8\text{ V}$  (High Drive)

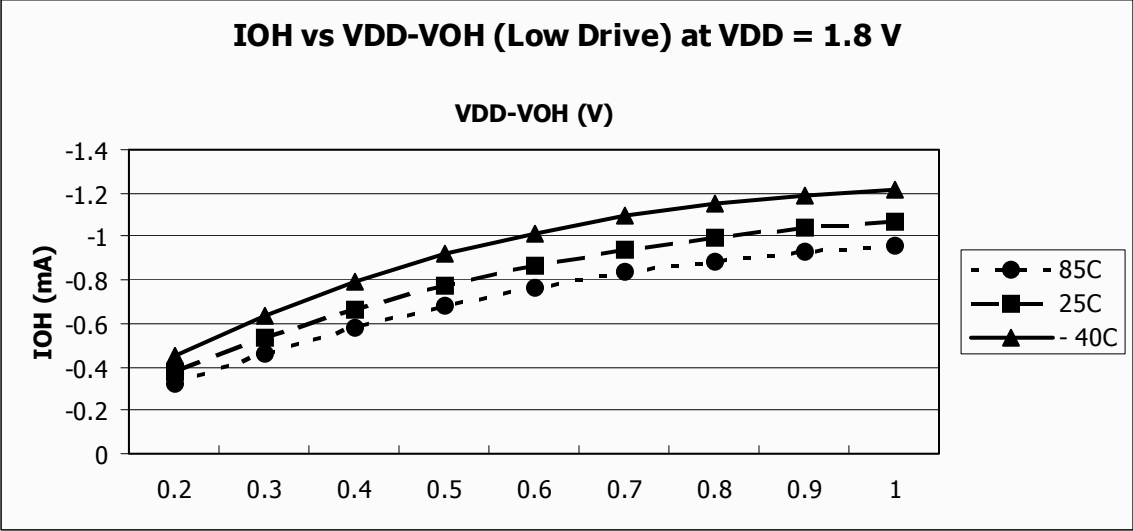


Figure 23. Typical  $I_{OH}$  vs.  $V_{DD}-V_{OH}$   
 $V_{DD} = 1.8\text{ V}$  (Low Drive)

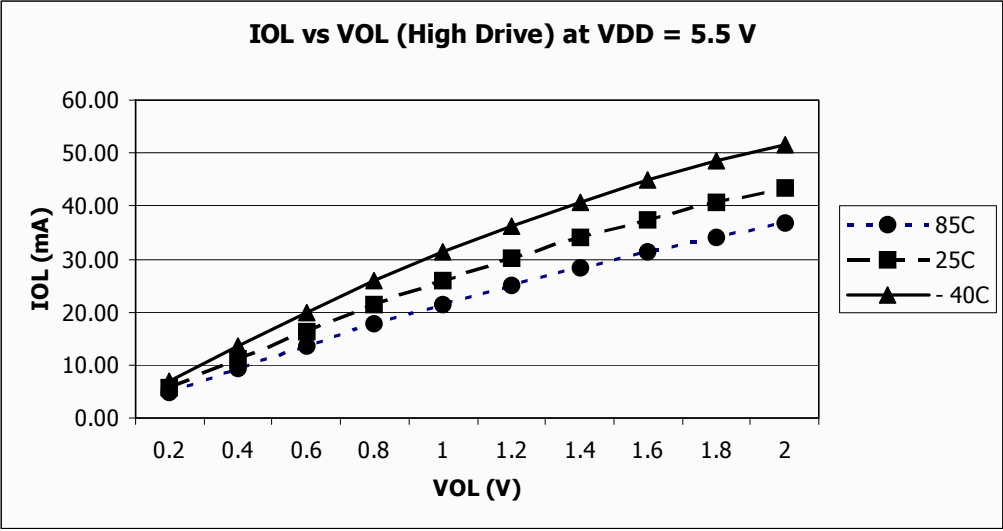


Figure 24. Typical  $I_{OL}$  vs.  $V_{OL}$   
 $V_{DD} = 5.5\text{ V}$  (High Drive)

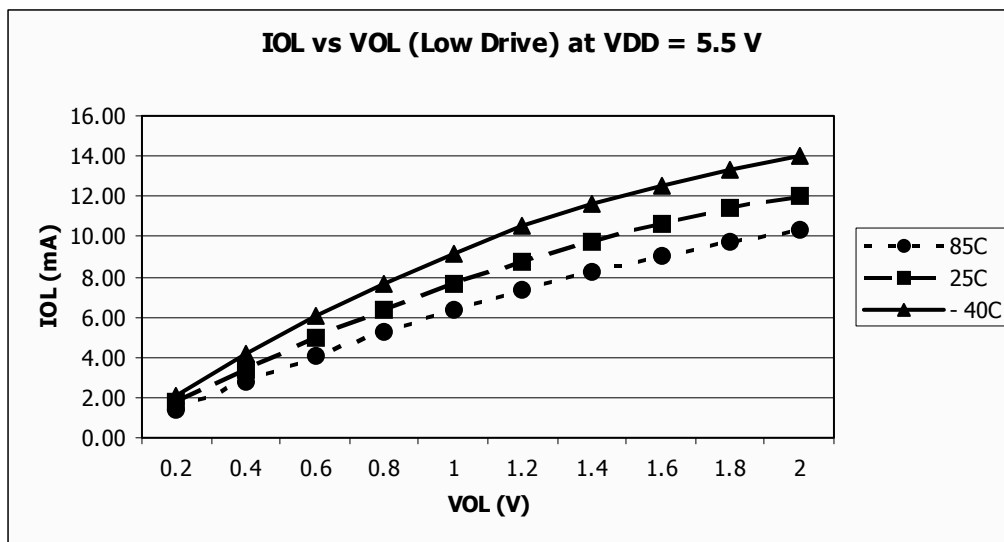


Figure 25. Typical  $I_{OL}$  vs.  $V_{OL}$   
 $V_{DD} = 5.5$  V (Low Drive)

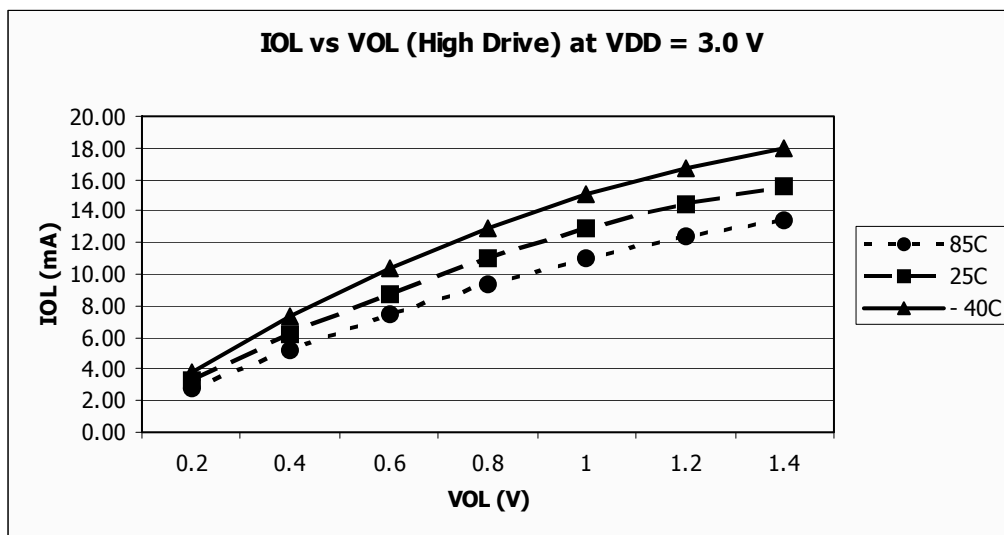


Figure 26. Typical  $I_{OL}$  vs.  $V_{OL}$   
 $V_{DD} = 3$  V (High Drive)

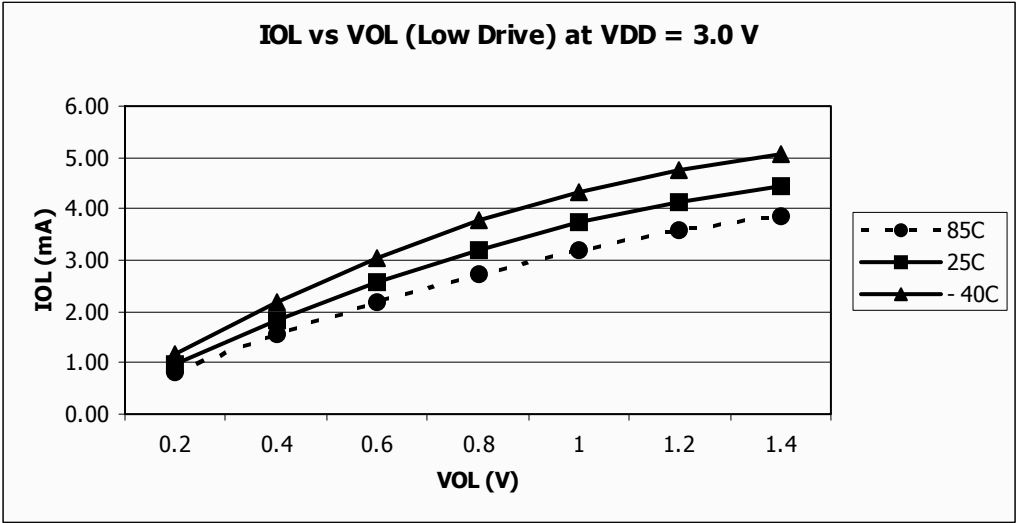


Figure 27. Typical I<sub>OL</sub> vs. V<sub>OL</sub>  
V<sub>DD</sub> = 3 V (Low Drive)

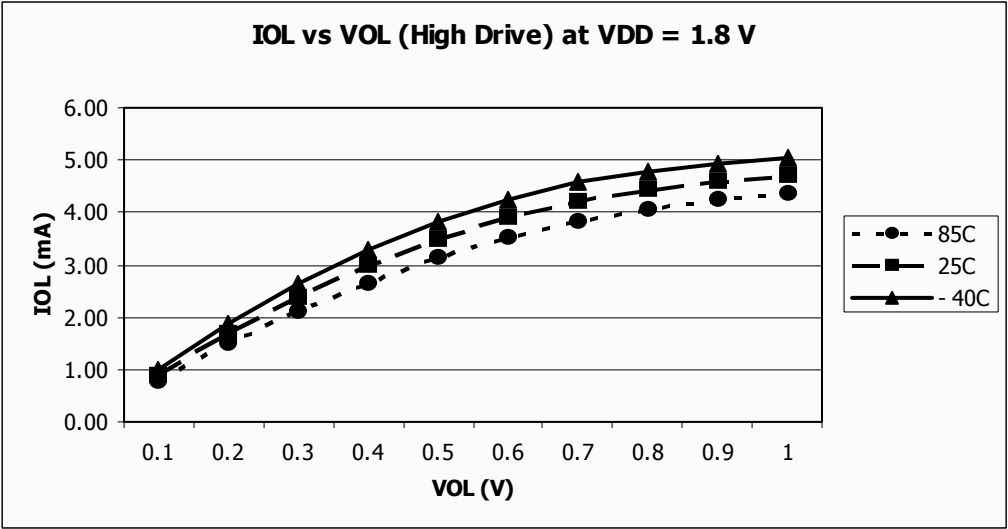


Figure 28. Typical I<sub>OL</sub> vs. V<sub>OL</sub>  
V<sub>DD</sub> = 1.8 V (High Drive)



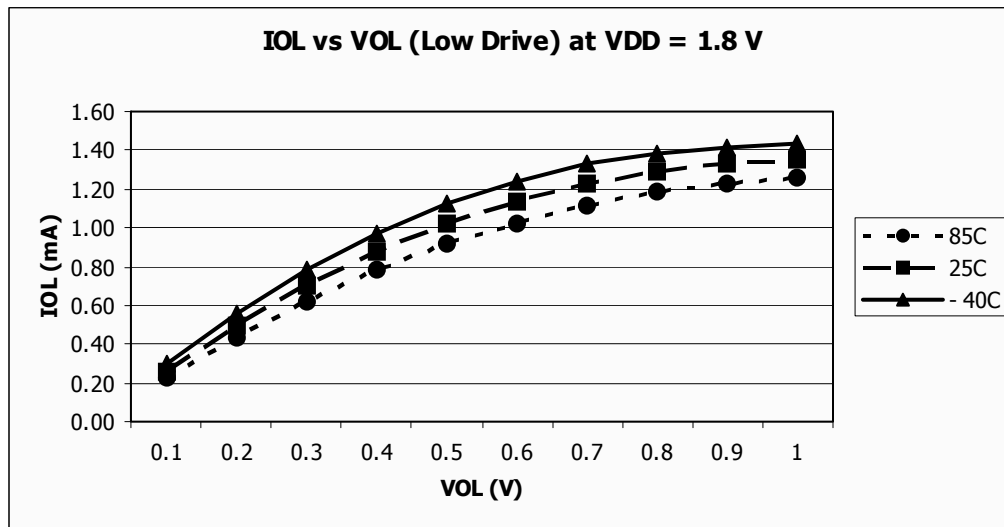


Figure 29. Typical  $I_{OL}$  vs.  $V_{OL}$   
 $V_{DD} = 1.8\text{ V}$  (Low Drive)

### 3.7 Supply Current Characteristics

Table 8. Supply Current Characteristics

| N | C | Parameter                                                                      | Symbol      | $V_{DD}$ (V) | Typical              | Max <sup>1</sup> | Temp. (°C)      | Unit |
|---|---|--------------------------------------------------------------------------------|-------------|--------------|----------------------|------------------|-----------------|------|
| 1 | P | Run supply current <sup>2</sup> measured at<br>( $f_{Bus} = 10\text{ MHz}$ )   | $RI_{DD10}$ | 5            | 3.45<br>3.48<br>3.53 | 7                | -40<br>25<br>85 | mA   |
| 2 | C |                                                                                |             | 3            | 3.39<br>3.42<br>3.49 | —                | -40<br>25<br>85 |      |
| 3 | C |                                                                                |             | 1.80         | 2.40<br>2.42<br>2.44 | —                | -40<br>25<br>85 |      |
| 4 | C | Run supply current <sup>3</sup> measured at<br>( $f_{Bus} = 1.25\text{ MHz}$ ) | $RI_{DD1}$  | 5            | 0.93<br>0.96<br>0.99 | —                | -40<br>25<br>85 | mA   |
| 5 | T |                                                                                |             | 3            | 0.91<br>0.92<br>0.92 | —                | -40<br>25<br>85 |      |
| 6 | T |                                                                                |             | 1.80         | 0.66<br>0.67<br>0.68 | —                | -40<br>25<br>85 |      |

Table 8. Supply Current Characteristics (continued)

| N  | C | Parameter                                                                             | Symbol             | V <sub>DD</sub> (V) | Typical                    | Max <sup>1</sup> | Temp. (°C)      | Unit |
|----|---|---------------------------------------------------------------------------------------|--------------------|---------------------|----------------------------|------------------|-----------------|------|
| 7  | C | Wait mode supply current <sup>3</sup><br>measured at<br>(f <sub>Bus</sub> = 2.00 MHz) | W <sub>I</sub> DD2 | 5                   | 841.13<br>859.98<br>873.69 | —                | –40<br>25<br>85 | μA   |
| 8  | T |                                                                                       |                    | 3                   | 840.21<br>850.60<br>846.67 | —                | –40<br>25<br>85 |      |
| 9  | T |                                                                                       |                    | 1.80                | 630.64<br>635.10<br>643.67 | —                | –40<br>25<br>85 |      |
| 10 | C | Wait mode supply current <sup>3</sup><br>measured at<br>(f <sub>Bus</sub> = 1.00 MHz) | W <sub>I</sub> DD1 | 5                   | 667.86<br>683.38<br>688.02 | —                | –40<br>25<br>85 | μA   |
| 11 | T |                                                                                       |                    | 3                   | 666.34<br>672.79<br>669.15 | —                | –40<br>25<br>85 |      |
| 12 | T |                                                                                       |                    | 1.80                | 505.39<br>509.28<br>502.52 | —                | –40<br>25<br>85 |      |
| 13 | P | Stop mode supply current                                                              | S <sub>I</sub> DD  | 5                   | 1.15<br>1.40<br>7.67       | 11               | –40<br>25<br>85 | μA   |
| 14 | C |                                                                                       |                    | 3                   | 1.05<br>1.26<br>4.52       | —                | –40<br>25<br>85 |      |
| 15 | C |                                                                                       |                    | 1.80                | 0.39<br>0.56<br>4.21       | —                | –40<br>25<br>85 |      |
| 16 | C | ADC adder from stop <sup>3</sup>                                                      | —                  | 5                   | 128.86<br>140.44<br>154.97 | —                | –40<br>25<br>85 | μA   |
| 17 | T |                                                                                       |                    | 3                   | 102.98<br>111.71<br>118.33 | —                | –40<br>25<br>85 |      |
| 18 | T |                                                                                       |                    | 1.80                | 54.77<br>66.33<br>74.42    | —                | –40<br>25<br>85 |      |
| 19 | C | ACMP adder from stop (ACME = 1)                                                       | —                  | 5                   | 14.43<br>15.96<br>16.77    | —                | –40<br>25<br>85 | μA   |
| 20 | T |                                                                                       |                    | 3                   | 14.37<br>14.72<br>14.45    | —                | –40<br>25<br>85 |      |
| 21 | T |                                                                                       |                    | 1.80                | 13.05<br>14.02<br>12.92    | —                | –40<br>25<br>85 |      |

Table 8. Supply Current Characteristics (continued)

| N  | C | Parameter                                                                  | Symbol | V <sub>DD</sub> (V) | Typical                 | Max <sup>1</sup> | Temp. (°C)      | Unit |
|----|---|----------------------------------------------------------------------------|--------|---------------------|-------------------------|------------------|-----------------|------|
| 22 | C | RTI adder from stop with 1 kHz clock source enabled <sup>4</sup>           | —      | 5                   | 0.10<br>0.10<br>0.17    | —                | –40<br>25<br>85 | μA   |
| 23 | T |                                                                            |        | 3                   | 0.02<br>0.06<br>0.02    | —                | –40<br>25<br>85 |      |
| 24 | T |                                                                            |        | 1.80                | 0.40<br>0.45<br>0.20    | —                | –40<br>25<br>85 |      |
| 25 | T | RTI adder from stop with 32.768KHz external clock source reference enabled | —      | 5                   | 0.70<br>1.08<br>1.94    | —                | –40<br>25<br>85 | μA   |
| 26 | T |                                                                            |        | 3                   | 0.56<br>0.56<br>0.62    | —                | –40<br>25<br>85 |      |
| 27 | T |                                                                            |        | 1.80                | 0.70<br>0.86<br>0.50    | —                | –40<br>25<br>85 |      |
| 28 | C | LVI adder from stop (LVDE = 1 and LVDSE = 1)                               | —      | 5                   | 58.93<br>68.27<br>76.60 | —                | –40<br>25<br>85 | μA   |
| 29 | T |                                                                            |        | 3                   | 58.89<br>61.98<br>63.45 | —                | –40<br>25<br>85 |      |
| 30 | T |                                                                            |        | 1.80                | 52.84<br>54.52<br>52.49 | —                | –40<br>25<br>85 |      |

<sup>1</sup> Maximum value is measured at the nominal V<sub>DD</sub> voltage times 10% tolerance. Values given here are preliminary estimates prior to completing characterization.

<sup>2</sup> Not include any DC loads on port pins.

<sup>3</sup> Required asynchronous ADC clock and LVD to be enabled.

<sup>4</sup> Most customers are expected to find that auto-wakeup from stop can be used instead of the higher current wait mode. Wait mode typical is 672.79 μA at 3 V and 509.28 μA at 1.8 V with f<sub>BUS</sub> = 1 MHz.

### 3.8 External Oscillator (XOSC) Characteristics

Table 9. Oscillator Electrical Specifications (Temperature Range = –40 to 85°C Ambient)

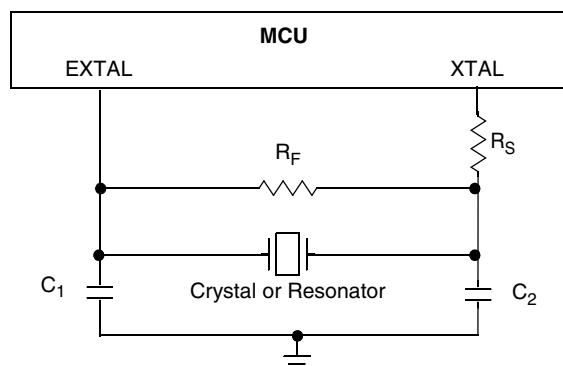
| Num | C | Rating                                                                                                   | Symbol         | Min                                                     | Typical <sup>1</sup> | Max     | Unit       |
|-----|---|----------------------------------------------------------------------------------------------------------|----------------|---------------------------------------------------------|----------------------|---------|------------|
| 1   | C | Oscillator crystal or resonator (EREFS = 1, ERCLKEN = 1)                                                 |                |                                                         |                      |         |            |
|     |   | Low range (RANGE = 0)                                                                                    | $f_{lo}$       | 32                                                      | —                    | 38.4    | kHz        |
|     |   | High range (RANGE = 1) FEE or FBE mode <sup>2</sup>                                                      | $f_{hi}$       | 1                                                       | —                    | 5       | MHz        |
|     |   | High range (RANGE = 1, HGO = 1) FBELP mode                                                               | $f_{hi-hgo}$   | 1                                                       | —                    | 16      | MHz        |
|     |   | High range (RANGE = 1, HGO = 0) FBELP mode                                                               | $f_{hi-lp}$    | 1                                                       | —                    | 8       | MHz        |
| 2   | D | Load capacitors                                                                                          | $C_1, C_2$     | See crystal or resonator manufacturer's recommendation. |                      |         |            |
| 3   | D | Feedback resistor                                                                                        | $R_F$          | —                                                       | 10                   | —       | M $\Omega$ |
|     |   | Low range (32 kHz to 100 kHz)<br>High range (1 MHz to 16 MHz)                                            |                | —                                                       | 1                    | —       |            |
| 4   | D | Series resistor                                                                                          | $R_S$          | —                                                       | 0                    | —       | k $\Omega$ |
|     |   | Low range, low gain (RANGE = 0, HGO = 0)                                                                 |                | —                                                       | 100                  | —       |            |
|     |   | Low range, high gain (RANGE = 0, HGO = 1)                                                                |                | —                                                       | 0                    | —       |            |
|     |   | High range, low gain (RANGE = 1, HGO = 0)                                                                |                | —                                                       | 0                    | —       |            |
|     |   | High range, high gain (RANGE = 1, HGO = 1)                                                               |                | —                                                       | 0                    | 0       |            |
|     |   | ≥ 8 MHz                                                                                                  |                | —                                                       | 0                    | 10      |            |
| 5   | C | Crystal start-up time <sup>3</sup>                                                                       |                |                                                         |                      |         |            |
|     |   | Low range, low gain (RANGE = 0, HGO = 0)                                                                 | $t_{CSTL-LP}$  | —                                                       | 200                  | —       | ms         |
|     |   | Low range, high gain (RANGE = 0, HGO = 1)                                                                | $t_{CSTL-HGO}$ | —                                                       | 400                  | —       |            |
|     |   | High range, low gain (RANGE = 1, HGO = 0) <sup>4</sup>                                                   | $t_{CSTH-LP}$  | —                                                       | 5                    | —       |            |
|     |   | High range, high gain (RANGE = 1, HGO = 1) <sup>4</sup>                                                  | $t_{CSTH-HGO}$ | —                                                       | 20                   | —       |            |
| 6   | D | Square wave input clock frequency (EREFS = 0, ERCLKEN = 1)<br>FEE or FBE mode <sup>2</sup><br>FBELP mode | $f_{extal}$    | 0.03125<br>0                                            | —<br>—               | 5<br>40 | MHz        |

<sup>1</sup> Typical data was characterized at 5.0 V, 25 °C or is recommended value.

<sup>2</sup> The input clock source must be divided using RDIV to within the range of 31.25 kHz to 39.0625 kHz.

<sup>3</sup> This parameter is characterized and not tested on each device. Proper PC board layout procedures must be followed to achieve specifications.

<sup>4</sup> 4 MHz crystal.



### 3.9 AC Characteristics

This section describes AC timing characteristics for each peripheral system.

### 3.9.1 Control Timing

Table 10. Control Timing

| Num | C | Parameter                                                                       | Symbol               | Min           | Typical | Max  | Unit    |
|-----|---|---------------------------------------------------------------------------------|----------------------|---------------|---------|------|---------|
| 1   | D | Bus frequency ( $t_{cyc} = 1/f_{Bus}$ )                                         | $f_{Bus}$            | 0             | —       | 10   | MHz     |
| 2   | D | Real time interrupt internal oscillator period                                  | $t_{RTI}$            | 700           | 1000    | 1300 | $\mu s$ |
| 3   | D | External $\overline{RESET}$ pulse width <sup>1</sup>                            | $t_{extrst}$         | 150           | —       | —    | ns      |
| 4   | D | KBI pulse width <sup>2</sup>                                                    | $t_{KBIPW}$          | $1.5 t_{cyc}$ | —       | —    | ns      |
| 5   | D | KBI pulse width in stop <sup>1</sup>                                            | $t_{KBIPWS}$         | 100           | —       | —    | ns      |
| 6   | D | Port rise and fall time (load = 50 pF) <sup>3</sup>                             | $t_{Rise}, t_{Fall}$ | —             | 11      | —    | ns      |
|     |   | Slew rate control disabled (PTxSE = 0)<br>Slew rate control enabled (PTxSE = 1) |                      |               | 35      | —    |         |

<sup>1</sup> This is the shortest pulse guaranteed to pass through the pin input filter circuitry. Shorter pulses may or may not be recognized.

<sup>2</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 in that case.

<sup>3</sup> Timing is shown with respect to 20%  $V_{DD}$  and 80%  $V_{DD}$  levels. Temperature range  $-40^{\circ}C$  to  $85^{\circ}C$ .

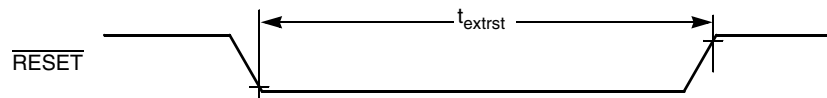


Figure 30. Reset Timing

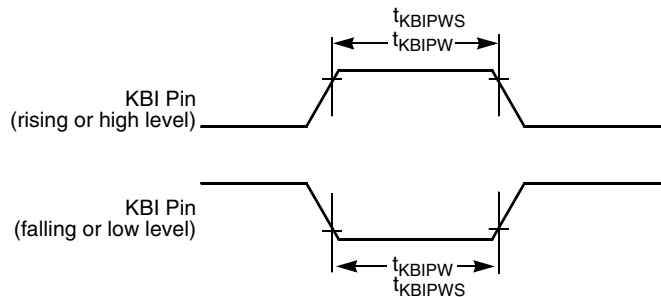


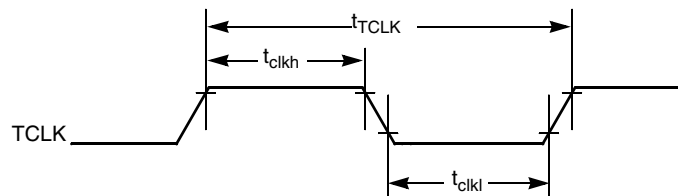
Figure 31. KBI Pulse Width

### 3.9.2 TPM/MTIM Module Timing

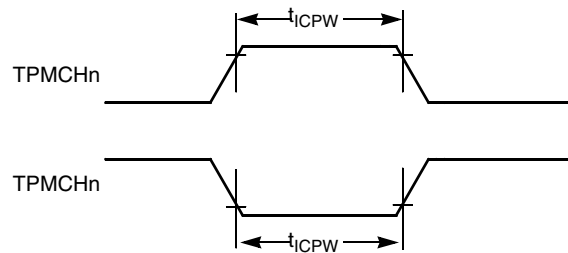
Synchronizer circuits determine the shortest input pulses that can be recognized or the fastest clock that can be used as the optional external source to the timer counter. These synchronizers operate from the current bus rate clock.

**Table 11. TPM Input Timing**

| Num | C | Rating                    | Symbol              | Min | Max                | Unit             |
|-----|---|---------------------------|---------------------|-----|--------------------|------------------|
| 1   | D | External clock frequency  | $f_{\text{TPMext}}$ | DC  | $f_{\text{Bus}}/4$ | MHz              |
| 2   | D | External clock period     | $t_{\text{TPMext}}$ | 4   | —                  | $t_{\text{cyc}}$ |
| 3   | D | External clock high time  | $t_{\text{clkh}}$   | 1.5 | —                  | $t_{\text{cyc}}$ |
| 4   | D | External clock low time   | $t_{\text{clkl}}$   | 1.5 | —                  | $t_{\text{cyc}}$ |
| 5   | D | Input capture pulse width | $t_{\text{ICPW}}$   | 1.5 | —                  | $t_{\text{cyc}}$ |



**Figure 32. Timer External Clock**



**Figure 33. Timer Input Capture Pulse**

## 3.10 Analog Comparator (ACMP) Electrical

**Table 12. Analog Comparator Electrical Specifications**

| Num | C | Characteristic                            | Symbol             | Min                   | Typical | Max             | Unit             |
|-----|---|-------------------------------------------|--------------------|-----------------------|---------|-----------------|------------------|
| 1   | D | Supply voltage                            | $V_{\text{DD}}$    | 1.80                  | —       | 5.5             | V                |
| 2   | P | Supply current (active)                   | $I_{\text{DDAC}}$  | —                     | 20      | 35              | $\mu\text{A}$    |
| 3   | D | Analog input voltage <sup>1</sup>         | $V_{\text{AIN}}$   | $V_{\text{SS}} - 0.3$ | —       | $V_{\text{DD}}$ | V                |
| 4   | C | Analog input offset voltage <sup>1</sup>  | $V_{\text{AIO}}$   | —                     | 20      | 40              | mV               |
| 5   | C | Analog Comparator hysteresis <sup>1</sup> | $V_{\text{H}}$     | 3.0                   | 9.0     | 15.0            | mV               |
| 6   | C | Analog source impedance <sup>1</sup>      | $R_{\text{AS}}$    | —                     | —       | 10              | $\text{k}\Omega$ |
| 7   | P | Analog input leakage current              | $I_{\text{ALKG}}$  | —                     | —       | 1.0             | $\mu\text{A}$    |
| 8   | C | Analog Comparator initialization delay    | $t_{\text{AINIT}}$ | —                     | —       | 1.0             | $\mu\text{s}$    |

Table 12. Analog Comparator Electrical Specifications (continued)

| Num | C | Characteristic                              | Symbol   | Min | Typical | Max | Unit |
|-----|---|---------------------------------------------|----------|-----|---------|-----|------|
| 9   | P | Analog Comparator bandgap reference voltage | $V_{BG}$ | 1.1 | 1.208   | 1.3 | V    |

<sup>1</sup> These data are characterized but not production tested.

### 3.11 Internal Clock Source Characteristics

Table 13. Internal Clock Source Specifications

| Num | C | Characteristic                                                                                 | Symbol                   | Min   | Typical <sup>1</sup> | Max     | Unit              |
|-----|---|------------------------------------------------------------------------------------------------|--------------------------|-------|----------------------|---------|-------------------|
| 1   | C | Average internal reference frequency — untrimmed                                               | $f_{int\_ut}$            | 25    | 31.25                | 41.66   | kHz               |
| 2   | P | Average internal reference frequency — trimmed                                                 | $f_{int\_t}$             | 31.25 | 32.768               | 39.0625 | kHz               |
| 3   | C | DCO output frequency range — untrimmed                                                         | $f_{dco\_ut}$            | 12.8  | 16                   | 21.33   | MHz               |
| 4   | P | DCO output frequency range — trimmed                                                           | $f_{dco\_t}$             | 16    | 16.77                | 20      | MHz               |
| 5   | C | Resolution of trimmed DCO output frequency at fixed voltage and temperature                    | $\Delta f_{dco\_res\_t}$ | —     | —                    | 0.2     | %f <sub>dco</sub> |
| 6   | C | Total deviation of trimmed DCO output frequency over voltage and temperature                   | $\Delta f_{dco\_t}$      | —     | —                    | 2       | %f <sub>dco</sub> |
| 7   | C | FLL acquisition time <sup>2,3</sup>                                                            | $t_{acquire}$            | —     | —                    | 1       | ms                |
| 8   | C | Stop recovery time (FLL wakeup to previous acquired frequency)<br>IREFSTEN = 0<br>IREFSTEN = 1 | $t_{wakeup}$             | —     | 100<br>86            | —       | μs                |

<sup>1</sup> Data in typical column was characterized at 3.0 V and 5.0 V, 25 °C or is typical recommended value.

<sup>2</sup> This parameter is characterized and not tested on each device.

<sup>3</sup> This specification applies to any time the FLL reference source or reference divider is changed, trim value changed or changing from FLL disabled (FBILP) to FLL enabled (FEI, FBI).

### 3.12 ADC Characteristics

Table 14. 10-Bit ADC Operating Conditions

| Characteristic           | Conditions                                                          | Symb       | Min        | Typ <sup>1</sup> | Max        | Unit | Comment         |
|--------------------------|---------------------------------------------------------------------|------------|------------|------------------|------------|------|-----------------|
| Supply voltage           | Absolute                                                            | $V_{DDAD}$ | 1.8        | —                | 5.5        | V    |                 |
| Input voltage            |                                                                     | $V_{ADIN}$ | $V_{REFL}$ | —                | $V_{REFH}$ | V    |                 |
| Input capacitance        |                                                                     | $C_{ADIN}$ | —          | 4.5              | 5.5        | pF   |                 |
| Input resistance         |                                                                     | $R_{ADIN}$ | —          | 3                | 5          | kΩ   |                 |
| Analog source resistance | 10-bit mode<br>$f_{ADCK} > 4\text{MHz}$<br>$f_{ADCK} < 4\text{MHz}$ | $R_{AS}$   | —          | —                | 5<br>10    | kΩ   | External to MCU |
|                          | 8-bit mode (all valid $f_{ADCK}$ )                                  |            | —          | —                | 10         |      |                 |

Table 14. 10-Bit ADC Operating Conditions (continued)

| Characteristic             | Conditions           | Symb       | Min | Typ <sup>1</sup> | Max | Unit | Comment |
|----------------------------|----------------------|------------|-----|------------------|-----|------|---------|
| 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  $V_{DDAD} = 5.0$  V, Temp = 25 °C,  $f_{ADCK} = 1.0$  MHz unless otherwise stated. Typical values are for reference only and are not tested in production.

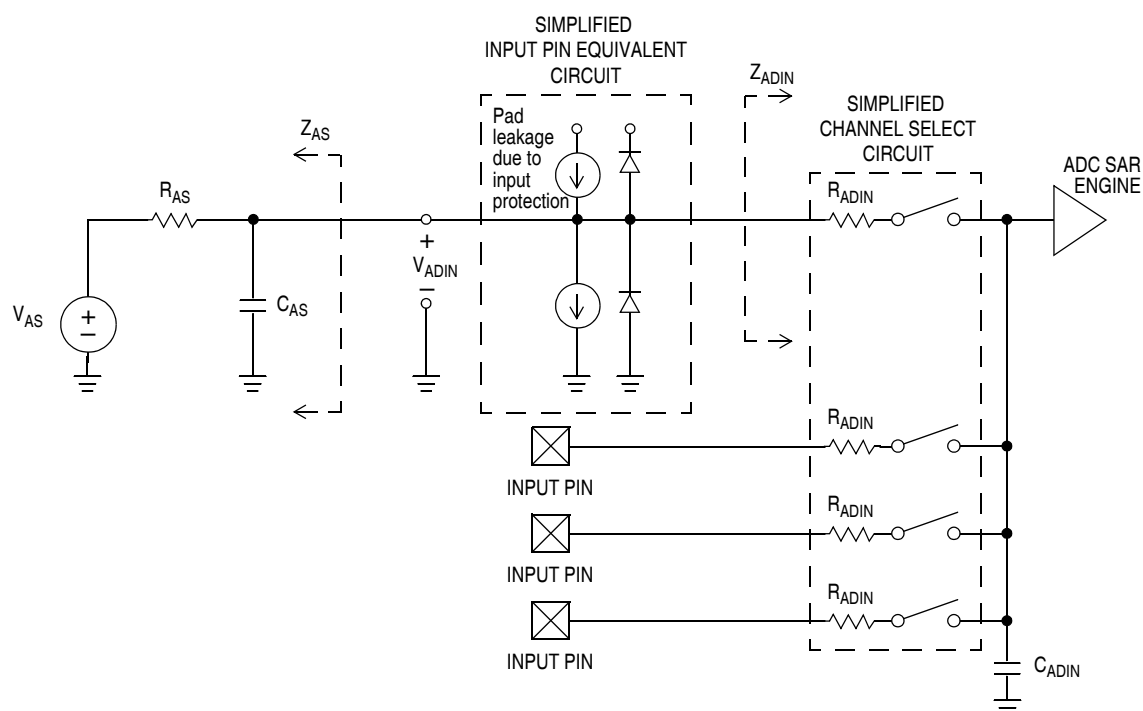


Figure 34. ADC Input Impedance Equivalency Diagram

Table 15. 10-Bit ADC Characteristics ( $V_{REFH} = V_{DDAD}$ ,  $V_{REFL} = V_{SSAD}$ ,  $2.7$  V <  $V_{DDAD} < 5.5$  V)

| C | Characteristic                                        | Conditions | Symb       | Min | Typ <sup>1</sup> | Max | Unit | Comment |
|---|-------------------------------------------------------|------------|------------|-----|------------------|-----|------|---------|
| T | Supply Current<br>ADLPC = 1<br>ADLSMP = 1<br>ADCO = 1 |            | $I_{DDAD}$ | —   | 133              | —   | μA   |         |
| T | Supply Current<br>ADLPC = 1<br>ADLSMP = 0<br>ADCO = 1 |            | $I_{DDAD}$ | —   | 218              | —   | μA   |         |
| T | Supply Current<br>ADLPC = 0<br>ADLSMP = 1<br>ADCO = 1 |            | $I_{DDAD}$ | —   | 327              | —   | μA   |         |



**Table 15. 10-Bit ADC Characteristics ( $V_{REFH} = V_{DDAD}$ ,  $V_{REFL} = V_{SSAD}$ ,  $2.7\text{ V} < V_{DDAD} < 5.5\text{ V}$ )**

| C | Characteristic                                        | Conditions                                   | Symb               | Min  | Typ <sup>1</sup> | Max  | Unit             | Comment                                            |
|---|-------------------------------------------------------|----------------------------------------------|--------------------|------|------------------|------|------------------|----------------------------------------------------|
| C | Supply Current<br>ADLPC = 0<br>ADLSMP = 0<br>ADCO = 1 |                                              | I <sub>DDAD</sub>  | —    | 0.582            | 1    | mA               |                                                    |
| C | ADC Asynchronous Clock Source                         | High Speed (ADLPC = 0)                       | f <sub>ADACK</sub> | 2    | 3.3              | 5    | MHz              | t <sub>ADACK</sub> = 1/f <sub>ADACK</sub>          |
|   |                                                       | Low Power (ADLPC = 1)                        |                    | 1.25 | 2                | 3.3  |                  |                                                    |
| D | Conversion Time (Including sample time)               | Short Sample (ADLSMP = 0)                    | t <sub>ADC</sub>   | —    | 20               | —    | ADCK cycles      | See reference manual for conversion time variances |
|   |                                                       | Long Sample (ADLSMP = 1)                     |                    | —    | 40               | —    |                  |                                                    |
| D | Sample Time                                           | Short Sample (ADLSMP = 0)                    | t <sub>ADS</sub>   | —    | 3.5              | —    | ADCK cycles      |                                                    |
|   |                                                       | Long Sample (ADLSMP = 1)                     |                    | —    | 23.5             | —    |                  |                                                    |
| C | Total Unadjusted Error                                | 10-bit mode                                  | E <sub>TUE</sub>   | —    | ±1.5             | ±3.5 | LSB <sup>2</sup> | Includes quantization                              |
|   |                                                       | 8-bit mode                                   |                    | —    | ±0.7             | ±1.5 |                  |                                                    |
| T | Differential Non-Linearity                            | 10-bit mode                                  | DNL                | —    | ±0.5             | ±1.0 | LSB <sup>2</sup> |                                                    |
|   |                                                       | 8-bit mode                                   |                    | —    | ±0.3             | ±0.5 |                  |                                                    |
|   |                                                       | Monotonicity and No-Missing-Codes guaranteed |                    |      |                  |      |                  |                                                    |
| C | Integral Non-Linearity                                | 10-bit mode                                  | INL                | —    | ±0.5             | ±1.0 | LSB <sup>2</sup> |                                                    |
|   |                                                       | 8-bit mode                                   |                    | —    | ±0.3             | ±0.5 |                  |                                                    |
| P | Zero-Scale Error                                      | 10-bit mode                                  | E <sub>ZS</sub>    | —    | ±1.5             | ±2.5 | LSB <sup>2</sup> | V <sub>ADIN</sub> = V <sub>SSA</sub>               |
|   |                                                       | 8-bit mode                                   |                    | —    | ±0.5             | ±0.7 |                  |                                                    |
| P | Full-Scale Error                                      | 10-bit mode                                  | E <sub>FS</sub>    | —    | ±1               | ±1.5 | LSB <sup>2</sup> | V <sub>ADIN</sub> = V <sub>DDA</sub>               |
|   |                                                       | 8-bit mode                                   |                    | —    | ±0.5             | ±0.5 |                  |                                                    |
| D | Quantization Error                                    | 10-bit mode                                  | E <sub>Q</sub>     | —    | —                | ±0.5 | LSB <sup>2</sup> |                                                    |
|   |                                                       | 8-bit mode                                   |                    | —    | —                | ±0.5 |                  |                                                    |
| D | Input Leakage Error                                   | 10-bit mode                                  | E <sub>IL</sub>    | —    | ±0.2             | ±2.5 | LSB <sup>2</sup> | Pad leakage <sup>2*</sup><br>R <sub>AS</sub>       |
|   |                                                       | 8-bit mode                                   |                    | —    | ±0.1             | ±1   |                  |                                                    |

<sup>1</sup> Typical values assume  $V_{DDAD} = 5.0\text{ V}$ , Temp = 25 °C,  $f_{ADCK} = 1.0\text{ MHz}$  unless otherwise stated. Typical values are for reference only and are not tested in production.

<sup>2</sup> Based on input pad leakage current. Refer to pad electricals.

Table 16. 10-Bit ADC Characteristics ( $V_{REFH} = V_{DDAD}$ ,  $V_{REFL} = V_{SSAD}$ ,  $1.8\text{ V} < V_{DDAD} < 2.7\text{ V}$ )

| C | Characteristic                                        | Conditions                                   | Symb               | Min  | Typ <sup>1</sup> | Max  | Unit             | Comment                                                     |
|---|-------------------------------------------------------|----------------------------------------------|--------------------|------|------------------|------|------------------|-------------------------------------------------------------|
| T | Supply Current<br>ADLPC = 1<br>ADLSMP = 1<br>ADCO = 1 | 8-bit mode                                   | I <sub>DDAD</sub>  | —    | 88               | —    | μA               |                                                             |
| T | Supply Current<br>ADLPC = 1<br>ADLSMP = 0<br>ADCO = 1 | 8-bit mode                                   | I <sub>DDAD</sub>  | —    | 152              | —    | μA               |                                                             |
| T | Supply Current<br>ADLPC = 0<br>ADLSMP = 1<br>ADCO = 1 | 8-bit mode                                   | I <sub>DDAD</sub>  | —    | 214              | —    | μA               |                                                             |
| T | Supply Current<br>ADLPC = 0<br>ADLSMP = 0<br>ADCO = 1 | 8-bit mode                                   | I <sub>DDAD</sub>  | —    | 390              | —    | μA               |                                                             |
| C | ADC<br>Asynchronous<br>Clock Source                   | High Speed (ADLPC = 0)                       | f <sub>ADACK</sub> | 2    | 3.3              | 5    | MHz              | t <sub>ADACK</sub> =<br>1/f <sub>ADACK</sub>                |
|   |                                                       | Low Power (ADLPC = 1)                        |                    | 1.25 | 2                | 3.3  |                  |                                                             |
| D | Conversion<br>Time (Including<br>sample time)         | Short Sample (ADLSMP = 0)                    | t <sub>ADC</sub>   | —    | 20               | —    | ADCK<br>cycles   | See reference<br>manual for<br>conversion<br>time variances |
|   |                                                       | Long Sample (ADLSMP = 1)                     |                    | —    | 40               | —    |                  |                                                             |
| D | Sample Time                                           | Short Sample (ADLSMP = 0)                    | t <sub>ADS</sub>   | —    | 3.5              | —    | ADCK<br>cycles   |                                                             |
|   |                                                       | Long Sample (ADLSMP = 1)                     |                    | —    | 23.5             | —    |                  |                                                             |
| C | Total<br>Unadjusted<br>Error                          | 10-bit mode                                  | E <sub>TUE</sub>   | —    | —                | —    | LSB <sup>2</sup> | Includes<br>quantization                                    |
|   |                                                       | 8-bit mode                                   |                    | —    | ±3.5             | —    |                  |                                                             |
| T | Differential<br>Non-Linearity                         | 10-bit mode                                  | DNL                | —    | —                | —    | LSB <sup>2</sup> |                                                             |
|   |                                                       | 8-bit mode                                   |                    | —    | ±1.0             | —    |                  |                                                             |
|   |                                                       | Monotonicity and No-Missing-Codes guaranteed |                    |      |                  |      |                  |                                                             |
| C | Integral<br>Non-Linearity                             | 10-bit mode                                  | INL                | —    | —                | —    | LSB <sup>2</sup> |                                                             |
|   |                                                       | 8-bit mode                                   |                    | —    | ±1.5             | —    |                  |                                                             |
| C | Zero-Scale<br>Error                                   | 10-bit mode                                  | E <sub>ZS</sub>    | —    | —                | —    | LSB <sup>2</sup> | V <sub>ADIN</sub> = V <sub>SSA</sub>                        |
|   |                                                       | 8-bit mode                                   |                    | —    | ±1.5             | —    |                  |                                                             |
| C | Full-Scale Error                                      | 10-bit mode                                  | E <sub>FS</sub>    | —    | —                | —    | LSB <sup>2</sup> | V <sub>ADIN</sub> = V <sub>DDA</sub>                        |
|   |                                                       | 8-bit mode                                   |                    | —    | ±1.0             | —    |                  |                                                             |
| D | Quantization<br>Error                                 | 10-bit mode                                  | E <sub>Q</sub>     | —    | —                | —    | LSB <sup>2</sup> |                                                             |
|   |                                                       | 8-bit mode                                   |                    | —    | —                | ±0.5 |                  |                                                             |

**Table 16. 10-Bit ADC Characteristics ( $V_{REFH} = V_{DDAD}$ ,  $V_{REFL} = V_{SSAD}$ ,  $1.8\text{ V} < V_{DDAD} < 2.7\text{ V}$ )**

| C | Characteristic      | Conditions  | Symb     | Min | Typ <sup>1</sup> | Max | Unit             | Comment                               |
|---|---------------------|-------------|----------|-----|------------------|-----|------------------|---------------------------------------|
| D | Input Leakage Error | 10-bit mode | $E_{IL}$ | —   | —                | —   | LSB <sup>2</sup> | Pad leakage <sup>2*</sup><br>$R_{AS}$ |
|   |                     | 8-bit mode  |          | —   | ±0.1             | ±1  |                  |                                       |

<sup>1</sup> Typical values assume  $V_{DDAD} = 1.8\text{ V}$ , Temp = 25 °C,  $f_{ADCK} = 1.0\text{ MHz}$  unless otherwise stated. Typical values are for reference only and are not tested in production.

<sup>2</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. For detailed information about program/erase operations, see the reference manual.

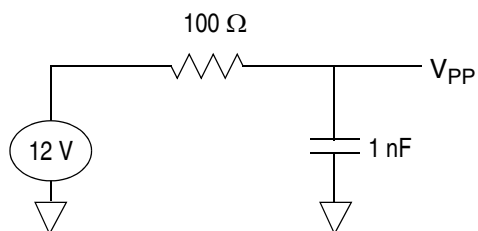
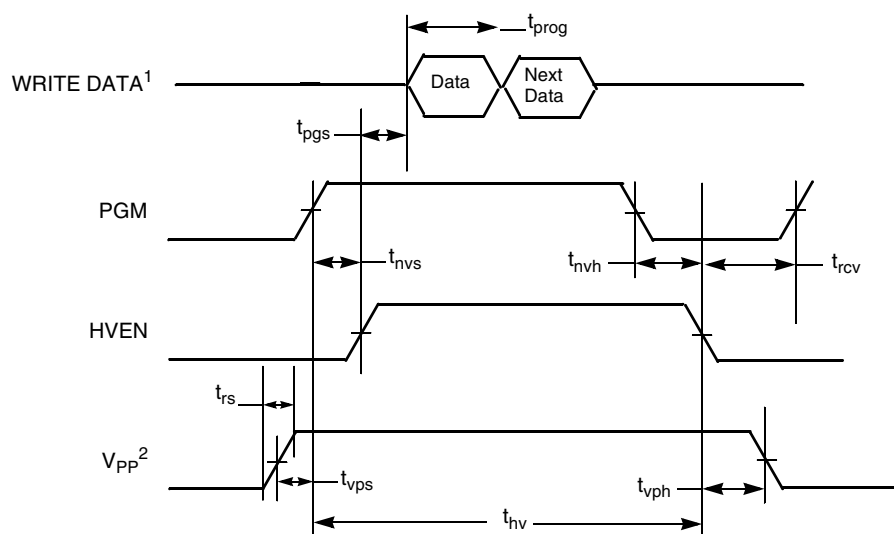
**Table 17. Flash Characteristics**

| No. | C | Characteristic                                                               | Symbol                              | Min  | Typical <sup>1</sup> | Max  | Unit   |
|-----|---|------------------------------------------------------------------------------|-------------------------------------|------|----------------------|------|--------|
| 1   | D | Supply voltage for program/erase                                             | $V_{DD}$                            | 2.7  | —                    | 5.5  | V      |
| 2   | D | Program/Erase voltage                                                        | $V_{PP}$                            | 11.8 | 12                   | 12.2 | V      |
| 3   | C | VPP current                                                                  | $I_{VPP\_prog}$<br>$I_{VPP\_erase}$ | —    | —                    | 200  | μA     |
|     |   | Program<br>Mass erase                                                        |                                     | —    | —                    | 100  | μA     |
| 4   | D | Supply voltage for read operation<br>$0 < f_{Bus} < 10\text{ MHz}$           | $V_{Read}$                          | 1.8  | —                    | 5.5  | V      |
| 5   | P | Byte program time                                                            | $t_{prog}$                          | 20   | —                    | 40   | μs     |
| 6   | P | Mass erase time                                                              | $t_{me}$                            | 500  | —                    | —    | ms     |
| 7   | C | Cumulative program HV time <sup>2</sup>                                      | $t_{hv}$                            | —    | —                    | 8    | ms     |
| 8   | C | Total cumulative HV time<br>(total of $t_{me}$ & $t_{hv}$ applied to device) | $t_{hv\_total}$                     | —    | —                    | 2    | hours  |
| 9   | D | HVEN to program setup time                                                   | $t_{pgs}$                           | 10   | —                    | —    | μs     |
| 10  | D | PGM/MASS to HVEN setup time                                                  | $t_{nvs}$                           | 5    | —                    | —    | μs     |
| 11  | D | HVEN hold time for PGM                                                       | $t_{nvh}$                           | 5    | —                    | —    | μs     |
| 12  | D | HVEN hold time for MASS                                                      | $t_{nvh1}$                          | 100  | —                    | —    | μs     |
| 13  | D | $V_{PP}$ to PGM/MASS setup time                                              | $t_{vps}$                           | 20   | —                    | —    | ns     |
| 14  | D | HVEN to $V_{PP}$ hold time                                                   | $t_{vph}$                           | 20   | —                    | —    | ns     |
| 15  | D | $V_{PP}$ rise time <sup>3</sup>                                              | $t_{vrs}$                           | 200  | —                    | —    | ns     |
| 16  | D | Recovery time                                                                | $t_{rcv}$                           | 1    | —                    | —    | μs     |
| 17  | D | Program/erase endurance<br>$T_L$ to $T_H = -40\text{ °C}$ to $85\text{ °C}$  | —                                   | 1000 | —                    | —    | cycles |
| 18  | C | Data retention                                                               | $t_{D\_ret}$                        | 15   | —                    | —    | years  |

<sup>1</sup> Typicals are measured at 25 °C.

<sup>2</sup>  $t_{hv}$  is the cumulative high voltage programming time to the same row before next erase. Same address can not be programmed more than twice before next erase.

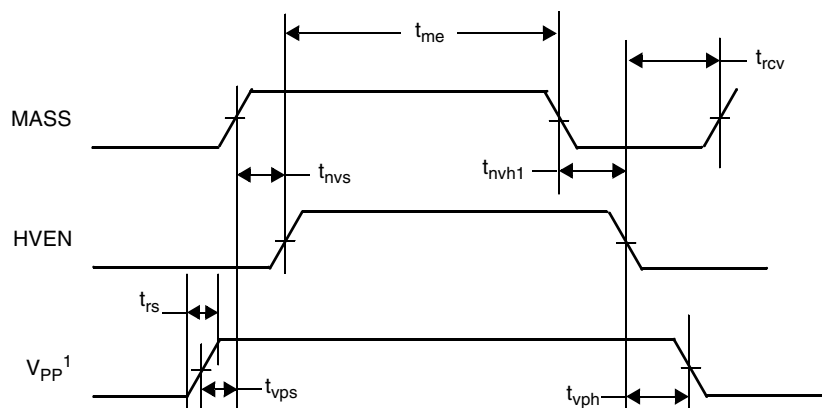
<sup>3</sup> Fast  $V_{PP}$  rise time may potentially trigger the ESD protection structure, which may result in over current flowing into the pad and cause permanent damage to the pad. External filtering for the  $V_{PP}$  power source is recommended. An example  $V_{PP}$  filter is shown in [Figure 35](#).

Figure 35. Example  $V_{PP}$  Filtering

<sup>1</sup> Next Data applies if programming multiple bytes in a single row, refer to *MC9RS08KB12 Series Reference Manual*.

<sup>2</sup>  $V_{DD}$  must be at a valid operating voltage before voltage is applied or removed from the  $V_{PP}$  pin.

Figure 36. Flash Program Timing



<sup>1</sup>  $V_{DD}$  must be at a valid operating voltage before voltage is applied or removed from the  $V_{PP}$  pin.

Figure 37. Flash Mass Erase Timing

## **3.14 EMC Performance**

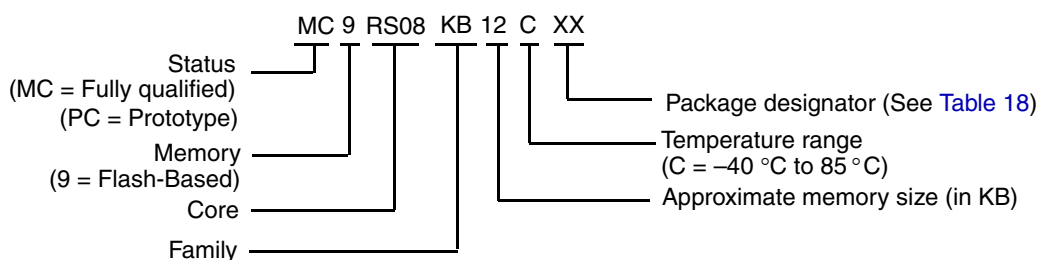
Electromagnetic compatibility (EMC) performance is highly dependant on the environment in which the MCU resides. Board design and layout, circuit topology choices, location and characteristics of external components as well as MCU software operation all play a significant role in EMC performance. The 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.

### **3.14.1 Radiated Emissions**

Microcontroller radiated RF emissions are measured from 150 kHz to 1 GHz using the TEM/GTEM Cell method in accordance with the IEC 61967-2 and SAE J1752/3 standards. The measurement is performed with the microcontroller installed on a custom EMC evaluation board while running specialized EMC test software. The radiated emissions from the microcontroller are measured in a TEM cell in two package orientations (North and East).

## 4 Ordering Information

This section contains ordering numbers for MC9RS08KB12 series devices. See below for an example of the device numbering system.



## 5 Package Information and Mechanical Drawings

Table 18 provides the available package types and their document numbers. The latest package outline/mechanical drawings are available on the MC9RS08KB12 Series Product Summary pages at <http://www.freescale.com>.

To view the latest drawing, either:

- Click on the appropriate link in Table 18, or
- Open a browser to the Freescale® website (<http://www.freescale.com>), and enter the appropriate document number (from Table 18) in the “Enter Keyword” search box at the top of the page.

**Table 18. Device Numbering System**

| Device Number                           | Memory |           | Package    |            |                             |
|-----------------------------------------|--------|-----------|------------|------------|-----------------------------|
|                                         | Flash  | RAM       | Type       | Designator | Document No.                |
| MC9RS08KB12<br>MC9RS08KB8<br>MC9RS08KB4 | 12 KB  | 254 bytes | 24 QFN     | FK         | <a href="#">98ASA00087D</a> |
|                                         | 8 KB   | 254 bytes | 20 SOIC WB | WJ         | <a href="#">98ASB42343B</a> |
|                                         | 4 KB   | 126 bytes | 16 SOIC NB | SG         | <a href="#">98ASB42566B</a> |
|                                         |        |           | 16 TSSOP   | TG         | <a href="#">98ASH70247A</a> |
| MC9RS08KB2                              | 2 KB   | 126 bytes | 8 SOIC NB  | SC         | <a href="#">98ASB42564B</a> |
|                                         |        |           | 8 DFN      | DC         | <a href="#">98ARL10557D</a> |

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Document Number: MC9RS08KB12

Rev. 5

1/2012

