

MCF51QE128 Series

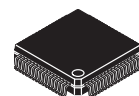
Covers: MCF51QE128, MCF51QE96, MCF51QE64, MCF51QE32

- 32-Bit Version 1 ColdFire® Central Processor Unit (CPU)
 - Up to 50.33-MHz ColdFire V1 CPU above 2.4V, 40-MHz CPU above 2.1V, and 20-MHz CPU above 1.8V, across temperature range
 - Provides 0.94 Dhrystone 2.1 MIPS per MHz performance when running from internal RAM (0.76 DMIPS/MHz from flash)
 - Implements Instruction Set Revision C (ISA_C)
 - Support for up to 30 peripheral interrupt requests and seven software interrupts
- On-Chip Memory
 - Flash read/program/erase over full operating voltage and temperature
 - Random-access memory (RAM)
 - Security circuitry to prevent unauthorized access to RAM and flash contents
- Power-Saving Modes
 - Two low power stop modes; reduced power wait mode
 - Peripheral clock enable register can disable clocks to unused modules, reducing currents; allows clocks to remain enabled to specific peripherals in stop3 mode
 - Very low power external oscillator can be used in stop3 mode to provide accurate clock to active peripherals
 - Very low power real time counter for use in run, wait, and stop modes with internal and external clock sources
 - 6 μ s typical wake up time from stop modes
- Clock Source Options
 - Oscillator (XOSC) — 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) — FLL controlled by internal or external reference; precision trimming of internal reference allows 0.2% resolution and 2% deviation; supports CPU freq. from 2 to 50.33 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 and illegal address detection with programmable reset or exception response
 - Flash block protection

MCF51QE128



80-LQFP
Case 917A
14 mm²



64-LQFP
Case 840F
10 mm²

- Development Support
 - Single-wire background debug interface
 - 4 PC plus 2 address (optional data) breakpoint registers with programmable 1- or 2-level trigger response
 - 64-entry processor status and debug data trace buffer with programmable start/stop conditions
- ADC — 24-channel, 12-bit resolution; 2.5 μ s conversion time; automatic compare function; 1.7 mV/°C temperature sensor; internal bandgap reference channel; operation in stop3; fully functional from 3.6V to 1.8V
- ACMPx — Two analog comparators with selectable interrupt on rising, falling, or either edge of comparator output; compare option to fixed internal bandgap reference voltage; outputs can be optionally routed to TPM module; operation in stop3
- SCIx — Two SCIs with full duplex non-return to zero (NRZ); LIN master extended break generation; LIN slave extended break detection; wake up on active edge
- SPIx — Two serial peripheral interfaces with Full-duplex or single-wire bidirectional; Double-buffered transmit and receive; MSB-first or LSB-first shifting
- IICx — Two IICs with; Up to 100 kbps with maximum bus loading; Multi-master operation; Programmable slave address; Interrupt driven byte-by-byte data transfer; supports broadcast mode and 10 bit addressing
- TPMx — One 6-channel and two 3-channel; Selectable input capture, output compare, or buffered edge- or center-aligned PWMs on each channel
- RTC — 8-bit modulus 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 wake-up without external components
- Input/Output
 - 70 GPIOs and 1 input-only and 1 output-only pin
 - 16 KBI interrupts with selectable polarity
 - Hysteresis and configurable pull-up device on all input pins; Configurable slew rate and drive strength on all output pins.
 - SET/CLR registers on 16 pins (PTC and PTE)
 - 16 bits of Rapid GPIO connected to the CPU's high-speed local bus with set, clear, and toggle functionality

Freescale reserves the right to change the detail specifications as may be required to permit improvements in the design of its products.

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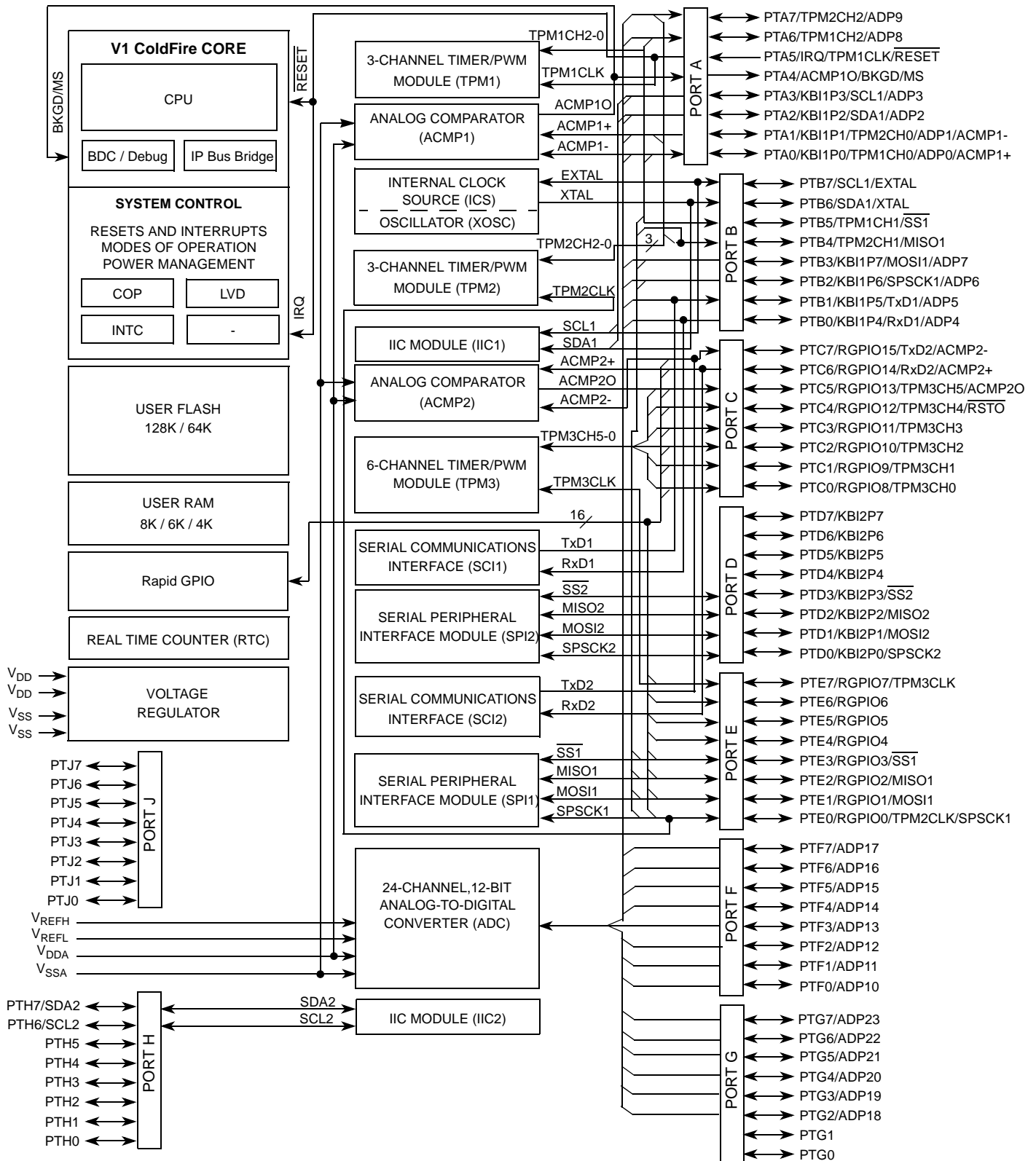


Figure 1. MCF51QE128 Series Block Diagram

1 MCF51QE128 Series Comparison

The following table compares the various device derivatives available within the MCF51QE128 series.

Table 1. MCF51QE128 Series Features by MCU and Package

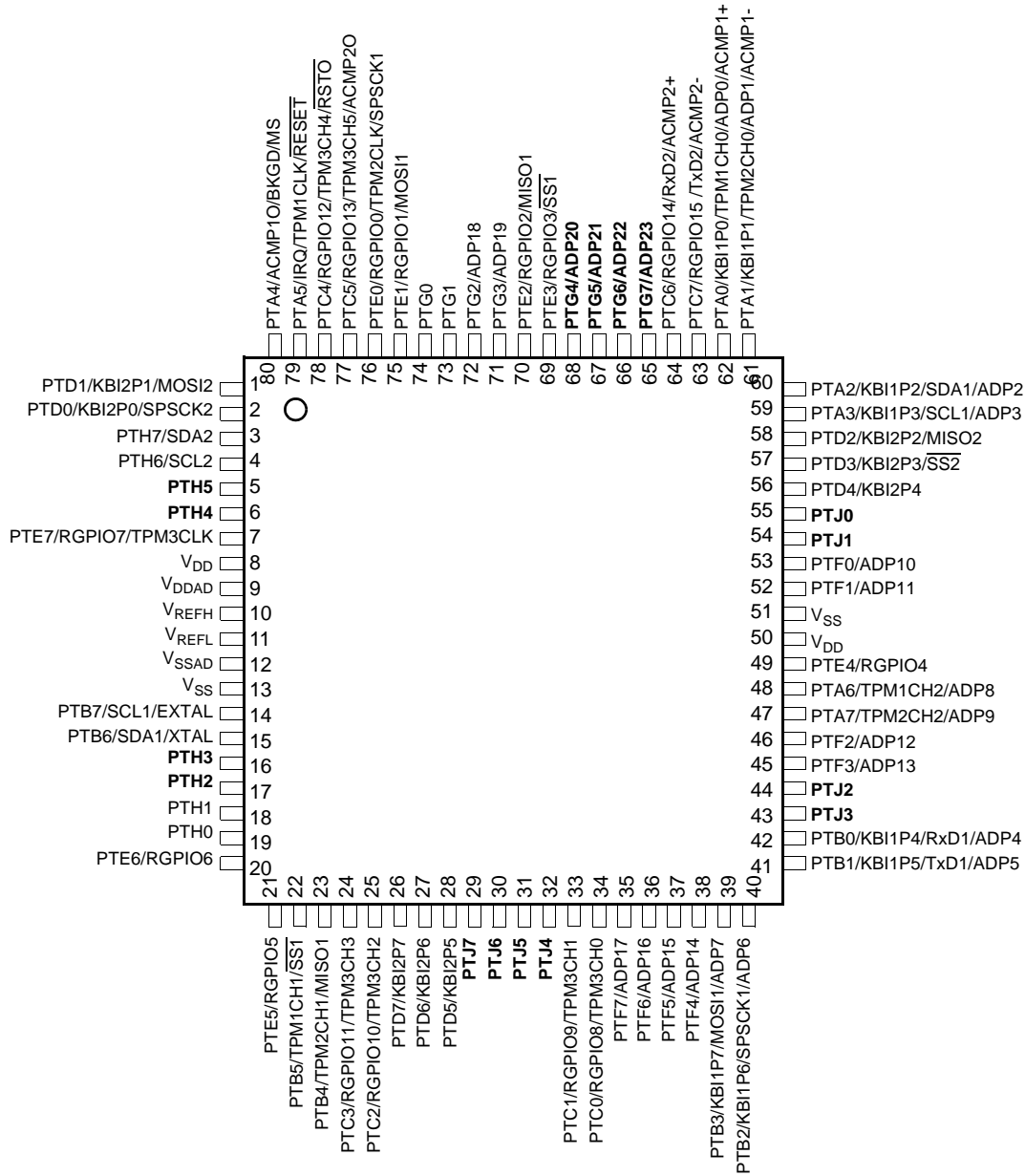
| Feature | MCF51QE128 | | MCF51QE96 | | MCF51QE64 | MCF51QE32 |
|--------------------------|------------|----|-----------|----|-----------|-----------|
| Flash size (bytes) | 131072 | | 98304 | | 65536 | 32768 |
| RAM size (bytes) | 8192 | | 8192 | | 8192 | 8192 |
| Pin quantity | 80 | 64 | 80 | 64 | 64 | 64 |
| Version 1 ColdFire core | yes | | | | | |
| ACMP1 | yes | | | | | |
| ACMP2 | yes | | | | | |
| ADC channels | 24 | 20 | 24 | 20 | 20 | 20 |
| DBG | yes | | | | | |
| ICS | yes | | | | | |
| IIC1 | yes | | | | | |
| IIC2 | yes | | | | | |
| KBI | 16 | | | | | |
| Port I/O ^{1, 2} | 70 | 54 | 70 | 54 | 54 | 54 |
| Rapid GPIO | yes | | | | | |
| RTC | yes | | | | | |
| SCI1 | yes | | | | | |
| SCI2 | yes | | | | | |
| SPI1 | yes | | | | | |
| SPI2 | yes | | | | | |
| External IRQ | yes | | | | | |
| TPM1 channels | 3 | | | | | |
| TPM2 channels | 3 | | | | | |
| TPM3 channels | 6 | | | | | |
| XOSC | yes | | | | | |

¹ Port I/O count does not include the input-only PTA5/IRQ/TPM1CLK/RESET or the output-only PTA4/ACMP1O/BKGD/MS.

² 16 bits associated with Ports C and E are shadowed with ColdFire Rapid GPIO module.

2 Pin Assignments

This section describes the pin assignments for the available packages. See [Table 1](#) for pin availability by package pin-count.



Pins in **bold** are added from the next smaller package.

Figure 2. Pin Assignments in 80-Pin LQFP

Pin Assignments

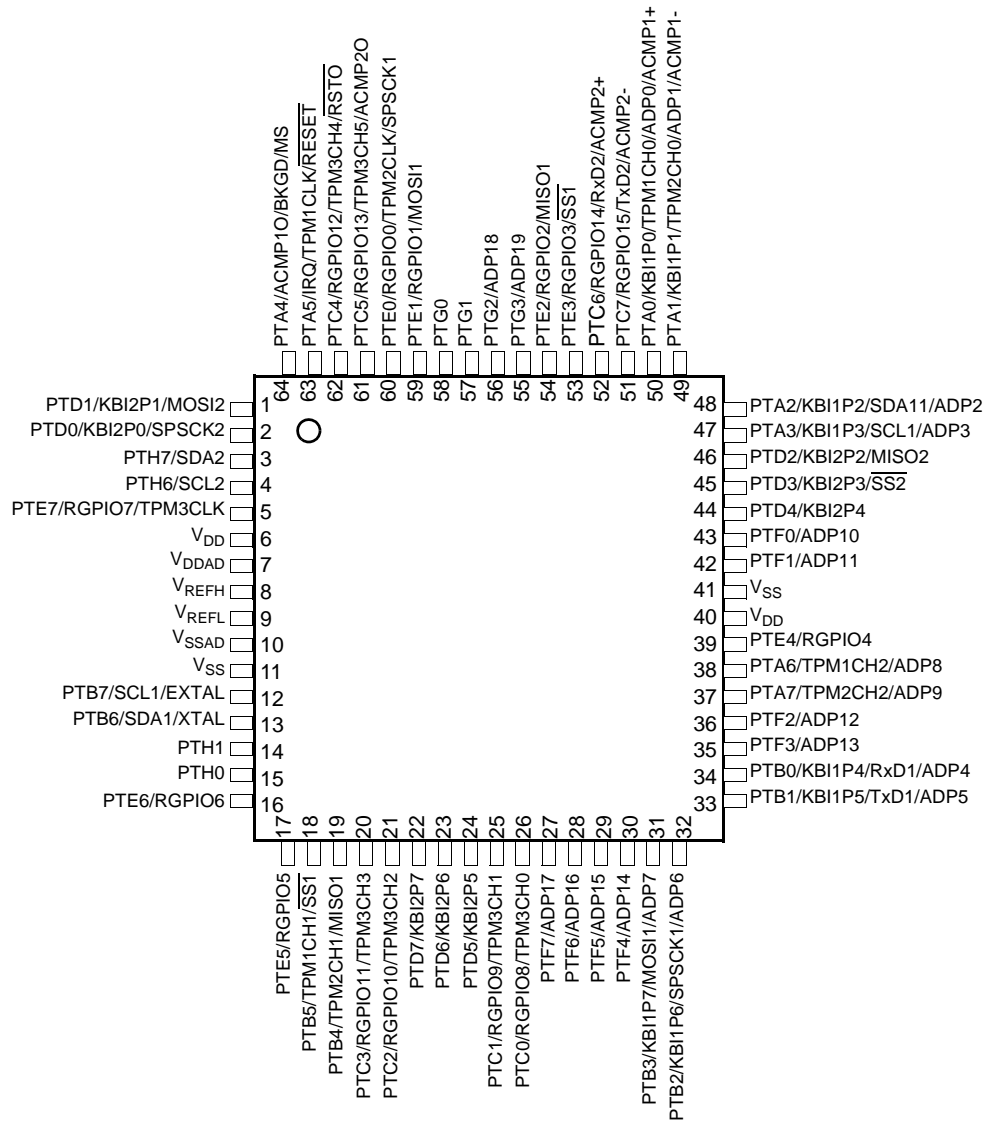


Figure 3. Pin Assignments in 64-Pin LQFP Package

Table 2. MCF51QE128 Series Pin Assignment by Package and Pin Sharing Priority

| Pin Number | | Lowest | ← | Priority | → | Highest |
|------------|----|----------|---------|--------------------|-------|-------------------|
| 80 | 64 | Port Pin | Alt 1 | Alt 2 | Alt 3 | Alt 4 |
| 1 | 1 | PTD1 | KBI2P1 | MOSI2 | | |
| 2 | 2 | PTD0 | KBI2P0 | SPSCK2 | | |
| 3 | 3 | PTH7 | SDA2 | | | |
| 4 | 4 | PTH6 | SCL2 | | | |
| 5 | — | PTH5 | | | | |
| 6 | — | PTH4 | | | | |
| 7 | 5 | PTE7 | RGPIO7 | TPM3CLK | | |
| 8 | 6 | | | | | V _{DD} |
| 9 | 7 | | | | | V _{DDAD} |
| 10 | 8 | | | | | V _{REFH} |
| 11 | 9 | | | | | V _{REFL} |
| 12 | 10 | | | | | V _{SSAD} |
| 13 | 11 | | | | | V _{SS} |
| 14 | 12 | PTB7 | SCL1 | | | EXTAL |
| 15 | 13 | PTB6 | SDA1 | | | XTAL |
| 16 | — | PTH3 | | | | |
| 17 | — | PTH2 | | | | |
| 18 | 14 | PTH1 | | | | |
| 19 | 15 | PTH0 | | | | |
| 20 | 16 | PTE6 | RGPIO6 | | | |
| 21 | 17 | PTE5 | RGPIO5 | | | |
| 22 | 18 | PTB5 | TPM1CH1 | SS1 | | |
| 23 | 19 | PTB4 | TPM2CH1 | MISO1 | | |
| 24 | 20 | PTC3 | RGPIO11 | TPM3CH3 | | |
| 25 | 21 | PTC2 | RGPIO10 | TPM3CH2 | | |
| 26 | 22 | PTD7 | KBI2P7 | | | |
| 27 | 23 | PTD6 | KBI2P6 | | | |
| 28 | 24 | PTD5 | KBI2P5 | | | |
| 29 | — | PTJ7 | | | | |
| 30 | — | PTJ6 | | | | |
| 31 | — | PTJ5 | | | | |
| 32 | — | PTJ4 | | | | |
| 33 | 25 | PTC1 | RGPIO9 | TPM3CH1 | | |
| 34 | 26 | PTC0 | RGPIO8 | TPM3CH0 | | |
| 35 | 27 | PTF7 | | | | ADP17 |
| 36 | 28 | PTF6 | | | | ADP16 |
| 37 | 29 | PTF5 | | | | ADP15 |
| 38 | 30 | PTF4 | | | | ADP14 |
| 39 | 31 | PTB3 | KBI1P7 | MOSI1 ¹ | | ADP7 |
| 40 | 32 | PTB2 | KBI1P6 | SPSCK1 | | ADP6 |

Table 2. MCF51QE128 Series Pin Assignment by Package and Pin Sharing Priority (continued)

| Pin Number | | Lowest | ← | Priority | → | Highest |
|------------|----|-------------------|---------|-------------------|--------|-----------------|
| 80 | 64 | Port Pin | Alt 1 | Alt 2 | Alt 3 | Alt 4 |
| 41 | 33 | PTB1 | KBI1P5 | TxD1 | | ADP5 |
| 42 | 34 | PTB0 | KBI1P4 | RxD1 | | ADP4 |
| 43 | — | PTJ3 | | | | |
| 44 | — | PTJ2 | | | | |
| 45 | 35 | PTF3 | | | | ADP13 |
| 46 | 36 | PTF2 | | | | ADP12 |
| 47 | 37 | PTA7 | TPM2CH2 | | | ADP9 |
| 48 | 38 | PTA6 | TPM1CH2 | | | ADP8 |
| 49 | 39 | PTE4 | RGPIO4 | | | |
| 50 | 40 | | | | | V _{DD} |
| 51 | 41 | | | | | V _{SS} |
| 52 | 42 | PTF1 | | | | ADP11 |
| 53 | 43 | PTF0 | | | | ADP10 |
| 54 | — | PTJ1 | | | | |
| 55 | — | PTJ0 | | | | |
| 56 | 44 | PTD4 | KBI2P4 | | | |
| 57 | 45 | PTD3 | KBI2P3 | SS2 | | |
| 58 | 46 | PTD2 | KBI2P2 | MISO2 | | |
| 59 | 47 | PTA3 | KBI1P3 | SCL1 ² | | ADP3 |
| 60 | 48 | PTA2 | KBI1P2 | SDA1 | | ADP2 |
| 61 | 49 | PTA1 | KBI1P1 | TPM2CH0 | ADP1 | ACMP1- |
| 62 | 50 | PTA0 | KBI1P0 | TPM1CH0 | ADP0 | ACMP1+ |
| 63 | 51 | PTC7 | RGPIO15 | TxD2 | | ACMP2- |
| 64 | 52 | PTC6 | RGPIO14 | RxD2 | | ACMP2+ |
| 65 | — | PTG7 | | | | ADP23 |
| 66 | — | PTG6 | | | | ADP22 |
| 67 | — | PTG5 | | | | ADP21 |
| 68 | — | PTG4 | | | | ADP20 |
| 69 | 53 | PTE3 | RGPIO3 | SS1 | | |
| 70 | 54 | PTE2 | RGPIO2 | MISO1 | | |
| 71 | 55 | PTG3 | | | | ADP19 |
| 72 | 56 | PTG2 | | | | ADP18 |
| 73 | 57 | PTG1 | | | | |
| 74 | 58 | PTG0 | | | | |
| 75 | 59 | PTE1 | RGPIO1 | MOSI1 | | |
| 76 | 60 | PTE0 | RGPIO0 | TPM2CLK | SPSCK1 | |
| 77 | 61 | PTC5 | RGPIO13 | TPM3CH5 | | ACMP20 |
| 78 | 62 | PTC4 | RGPIO12 | TPM3CH4 | RSTO | |
| 79 | 63 | PTA5 | IRQ | TPM1CLK | RESET | |
| 80 | 64 | PTA4 ³ | ACMP10 | BKGD | MS | |

- ¹ SPI1 pins ($\overline{SS1}$, MISO1, MOSI1, and SPCK2) can be repositioned using SPI1PS in SOPT2. Default locations are PTB5, PTB4, PTB3, and PTB2.
- ² IIC1 pins (SCL1 and SDA1) can be repositioned using IIC1PS in SOPT2. Default locations are PTA3 and PTA2, respectively.
- ³ The PTA4/ACMP10/BKGD/MS is limited to output only for the port I/O function.

3 Electrical Characteristics

3.1 Introduction

This section contains electrical and timing specifications for the MCF51QE128 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 3. Parameter Classifications

| | |
|----------|--|
| P | Those parameters are guaranteed during production testing on each individual device. |
| C | Those parameters are achieved by the design characterization by measuring a statistically relevant sample size across process variations. |
| T | 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. |
| D | 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 4](#) 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 4. 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 Single pin limit (applies to all port pins) ^{1, 2, 3} | I_D | ± 25 | mA |
| Storage temperature range | T_{stg} | -55 to 150 | °C |

¹ 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.

² All functional non-supply pins are internally clamped to V_{SS} and V_{DD} .

³ 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 5. Thermal Characteristics

| Rating | Symbol | Value | Unit |
|--|---------------|-----------|------|
| Operating temperature range (packaged): | | | |
| MCF51QE64, MCF51QE96, and MCF51QE128: | T_A | -40 to 85 | °C |
| MCF51QE32: | | 0 to 70 | |
| Maximum junction temperature | T_{JM} | 95 | °C |
| Thermal resistance Single-layer board | | | |
| 64-pin LQFP | θ_{JA} | 69 | °C/W |
| 80-pin LQFP | | 60 | |
| Thermal resistance Four-layer board | | | |
| 64-pin LQFP | θ_{JA} | 50 | °C/W |
| 80-pin LQFP | | 47 | |

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

θ_{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 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.

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 specified otherwise in the device specification.

Table 6. 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 7. ESD and Latch-Up Protection Characteristics

| No. | Rating ¹ | Symbol | Min | Max | Unit |
|-----|--|-----------|------------|-----|------|
| 1 | Human body model (HBM) | V_{HBM} | ± 2000 | — | V |
| 2 | Machine model (MM) | V_{MM} | ± 200 | — | V |
| 3 | Charge device model (CDM) | V_{CDM} | ± 500 | — | V |
| 4 | Latch-up current at $T_A = 85^\circ\text{C}$ | I_{LAT} | ± 100 | — | mA |

¹ 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 8. DC Characteristics

| Num | C | Characteristic | Symbol | Condition | Min | Typ ¹ | Max | Unit |
|-----|---|---|------------|--------------------------------------|----------------------------|------------------|----------------------|------------------|
| 1 | | Operating Voltage | | | 1.8 ² | | 3.6 | V |
| 2 | C | Output high voltage All I/O pins, low-drive strength | V_{OH} | 1.8 V, $I_{Load} = -2$ mA | $V_{DD} - 0.5$ | — | — | V |
| | P | | | All I/O pins, high-drive strength | 2.7 V, $I_{Load} = -10$ mA | $V_{DD} - 0.5$ | — | |
| | T | 2.3 V, $I_{Load} = -6$ mA | | | $V_{DD} - 0.5$ | — | — | |
| | C | 1.8 V, $I_{Load} = -3$ mA | | $V_{DD} - 0.5$ | — | — | | |
| 3 | D | Output high current Max total I_{OH} for all ports | I_{OHT} | | — | — | 100 | mA |
| 4 | C | Output low voltage All I/O pins, low-drive strength | V_{OL} | 1.8 V, $I_{Load} = 2$ mA | — | — | 0.5 | V |
| | P | | | All I/O pins, high-drive strength | 2.7 V, $I_{Load} = 10$ mA | — | — | |
| | T | 2.3 V, $I_{Load} = 6$ mA | | | — | — | 0.5 | |
| | C | 1.8 V, $I_{Load} = 3$ mA | | — | — | 0.5 | | |
| 5 | D | Output low current Max total I_{OL} for all ports | I_{OLT} | | — | — | 100 | mA |
| 6 | P | Input high voltage all digital inputs | V_{IH} | $V_{DD} > 2.7$ V | $0.70 \times V_{DD}$ | — | — | V |
| | C | | | $V_{DD} > 1.8$ V | $0.85 \times V_{DD}$ | — | — | |
| 7 | P | Input low voltage all digital inputs | V_{IL} | $V_{DD} > 2.7$ V | — | — | $0.35 \times V_{DD}$ | V |
| | C | | | $V_{DD} > 1.8$ V | — | — | $0.30 \times V_{DD}$ | |
| 8 | C | Input hysteresis all digital inputs | V_{hys} | | $0.06 \times V_{DD}$ | — | — | mV |
| 9 | P | Input leakage current all input only pins (Per pin) | $ I_{In} $ | $V_{In} = V_{DD}$ or V_{SS} | — | — | 1 | μA |
| 10 | P | Hi-Z (off-state) leakage current all input/output (per pin) | $ I_{OZ} $ | $V_{In} = V_{DD}$ or V_{SS} | — | — | 1 | μA |
| 11 | P | Pull-up resistors all digital inputs, when enabled | R_{PU} | | 17.5 | — | 52.5 | $\text{k}\Omega$ |

Table 8. DC Characteristics (continued)

| Num | C | Characteristic | Symbol | Condition | Min | Typ ¹ | Max | Unit |
|-----|---|---|-------------------------|-------------------------------------|--------------|------------------|--------------|------|
| 12 | D | DC injection current ^{3, 4, 5} Single pin limit | I_{IC} | $V_{IN} < V_{SS}, V_{IN} > V_{DD}$ | -0.2 | — | 0.2 | mA |
| | | Total MCU limit, includes sum of all stressed pins | | | -5 | — | 5 | mA |
| 13 | C | Input Capacitance, all pins | C_{In} | | — | — | 8 | pF |
| 14 | C | RAM retention voltage | V_{RAM} | | — | 0.6 | 1.0 | V |
| 15 | C | POR re-arm voltage ⁶ | V_{POR} | | 0.9 | 1.4 | 1.79 | V |
| 16 | D | POR re-arm time | t_{POR} | | 10 | — | — | μs |
| 17 | P | Low-voltage detection threshold — high range ⁷ | V_{LVDH} ⁸ | V_{DD} falling V_{DD} rising | 2.11 2.16 | 2.16 2.21 | 2.22 2.27 | V |
| 18 | P | Low-voltage detection threshold — low range ⁷ | V_{LVDL} | V_{DD} falling V_{DD} rising | 1.80 1.86 | 1.82 1.90 | 1.91 1.99 | V |
| 19 | P | Low-voltage warning threshold — high range ⁷ | V_{LVWH} | V_{DD} falling V_{DD} rising | 2.36 2.36 | 2.46 2.46 | 2.56 2.56 | V |
| 20 | P | Low-voltage warning threshold — low range ⁷ | V_{LVWL} | V_{DD} falling V_{DD} rising | 2.11 2.16 | 2.16 2.21 | 2.22 2.27 | V |
| 21 | C | Low-voltage inhibit reset/recover hysteresis ⁷ | V_{hys} | | — | 50 | — | mV |
| 22 | P | Bandgap Voltage Reference ⁹ | V_{BG} | | 1.15 | 1.17 | 1.18 | V |

¹ Typical values are measured at 25°C. Characterized, not tested

² As the supply voltage rises, the LVD circuit will hold the MCU in reset until the supply has risen above V_{LVDL} .

³ All functional non-supply pins are internally clamped to V_{SS} and V_{DD} .

⁴ 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.

⁵ 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 clock rate is very low (which would reduce overall power consumption).

⁶ Maximum is highest voltage that POR is guaranteed.

⁷ Low voltage detection and warning limits measured at 1 MHz bus frequency.

⁸ Run at 1 MHz bus frequency

⁹ Factory trimmed at $V_{DD} = 3.0$ V, Temp = 25°C

Electrical Characteristics

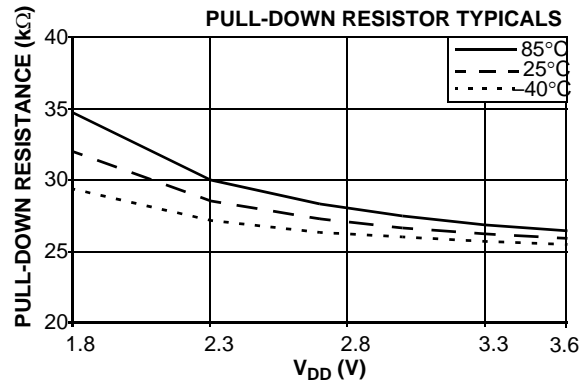
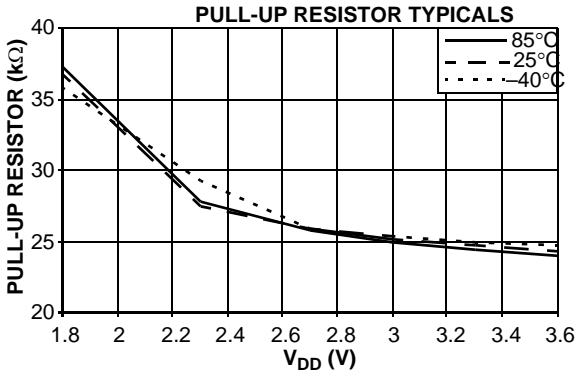


Figure 4. Pull-up and Pull-down Typical Resistor Values

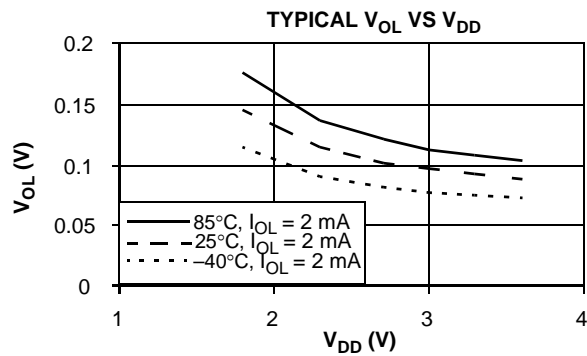
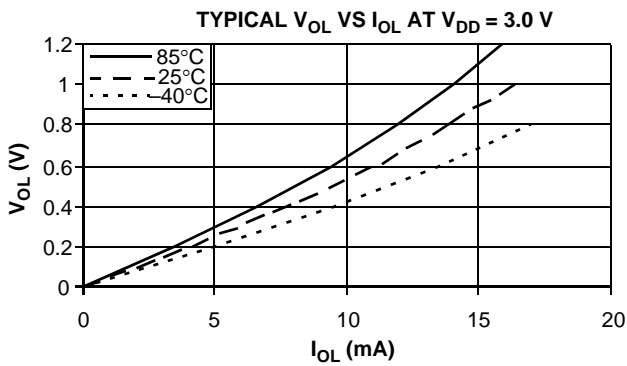


Figure 5. Typical Low-Side Driver (Sink) Characteristics — Low Drive (PTxDSn = 0)

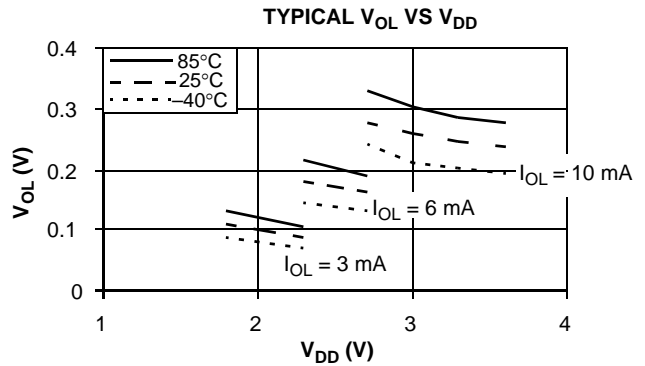
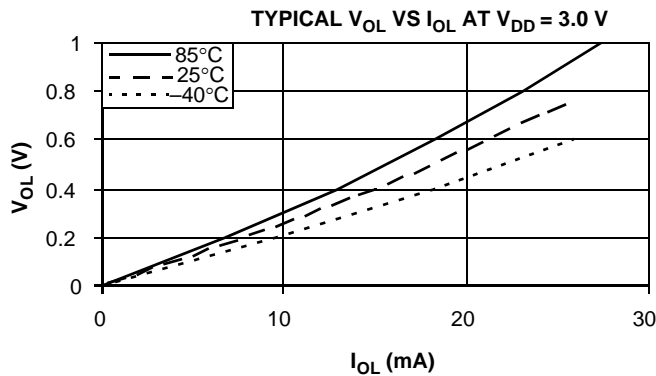


Figure 6. Typical Low-Side Driver (Sink) Characteristics — High Drive (PTxDSn = 1)

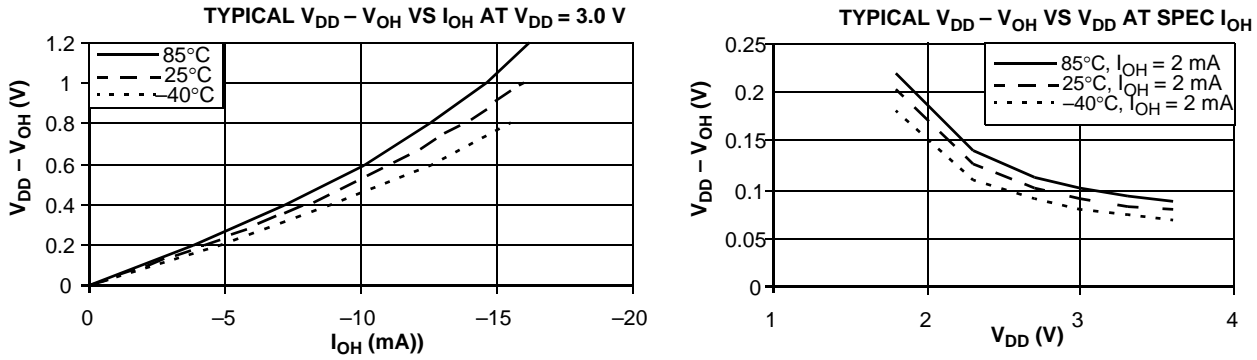


Figure 7. Typical High-Side (Source) Characteristics — Low Drive (PTxDSn = 0)

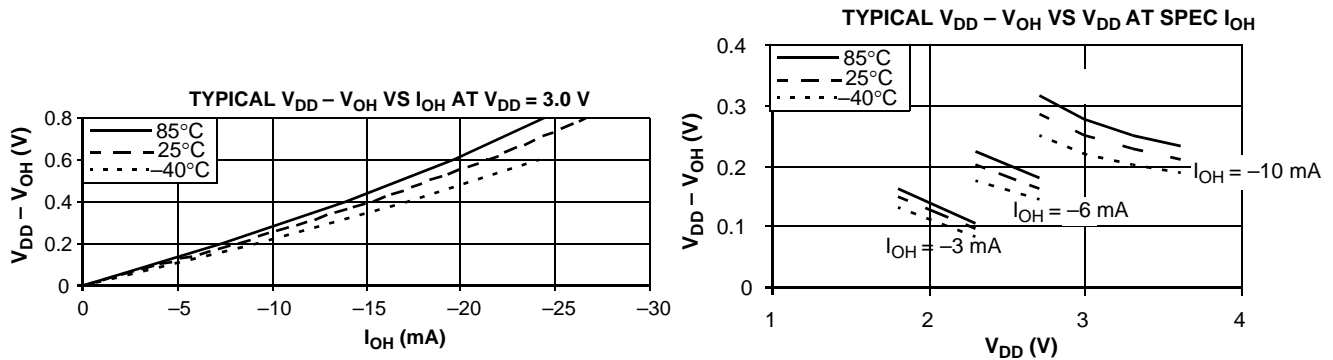


Figure 8. Typical High-Side (Source) Characteristics — High Drive (PTxDSn = 1)

3.7 Supply Current Characteristics

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

Table 9. Supply Current Characteristics

| Num | C | Parameter | Symbol | Bus Freq | V_{DD} (V) | Typ ¹ | Max | Unit | Temp (°C) | |
|-----|---|---|--------------|------------|--------------|------------------|------|------|-----------|-----------|
| 1 | P | Run supply current FEI mode, all modules on | $R_{I_{DD}}$ | 25.165 MHz | 3 | 32 | 35 | mA | -40 to 25 | |
| | P | | | | | 32 | 35 | | 85 | |
| | T | | | | | 20 MHz | 28.0 | | — | -40 to 85 |
| | T | | | | | 8 MHz | 13.2 | | — | |
| | T | | | | | 1 MHz | 2.4 | | — | |
| 2 | C | Run supply current FEI mode, all modules off | $R_{I_{DD}}$ | 25.165 MHz | 3 | 28.1 | 29.6 | mA | -40 to 85 | |
| | T | | | | | 20 MHz | 22.9 | | | — |
| | T | | | | | 8 MHz | 11.3 | | | — |
| | T | | | | | 1 MHz | 2.0 | | | — |

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Table 9. Supply Current Characteristics (continued)

| Num | C | Parameter | Symbol | Bus Freq | V _{DD} (V) | Typ ¹ | Max | Unit | Temp (°C) |
|-----|---|---|--------------------------------|-----------------|---------------------|------------------|------|------|-----------|
| 3 | T | Run supply current LPS=0, all modules off | R _I DD | 16 kHz FBILP | 3 | 203 | — | μA | -40 to 85 |
| | T | | | 16 kHz FBELP | | 154 | — | | |
| 4 | T | Run supply current LPS=1, all modules off, running from Flash | R _I DD | 16 kHz FBELP | 3 | 50 | — | μA | -40 to 85 |
| 5 | C | Wait mode supply current FEI mode, all modules off | W _I DD | 25.165 MHz | 3 | 11 | 13.7 | mA | -40 to 85 |
| | T | | | 20 MHz | | 4.57 | — | | |
| | T | | | 8 MHz | | 2 | — | | |
| | T | | | 1 MHz | | 0.73 | — | | |
| 6 | P | Stop2 mode supply current | S ₂ I _{DD} | n/a | 3 | 0.6 | 0.8 | μA | -40 to 25 |
| | C | | | | | 3.0 | 11 | | 70 |
| | P | | | | | 8.0 | 20 | | 85 |
| | C | | | | 2 | 0.6 | 0.8 | | -40 to 25 |
| | C | | | | | 2.5 | 10 | | 70 |
| | C | | | | | 6.0 | 12 | | 85 |
| 7 | P | Stop3 mode supply current No clocks active | S ₃ I _{DD} | n/a | 3 | 0.8 | 1.3 | μA | -40 to 25 |
| | C | | | | | 6.0 | 18 | | 70 |
| | P | | | | | 18.0 | 28 | | 85 |
| | C | | | | 2 | 0.8 | 1.3 | | -40 to 25 |
| | C | | | | | 5.0 | 16 | | 70 |
| | C | | | | | 12.0 | 20 | | 85 |

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

Table 10. Stop Mode Adders

| Num | C | Parameter | Condition | Temperature (°C) | | | | Units |
|-----|---|-----------------------|--|------------------|------|------|------|-------|
| | | | | -40 | 25 | 70 | 85 | |
| 1 | T | LPO | | 50 | 75 | 100 | 150 | nA |
| 2 | T | ERREFSTEN | RANGE = HGO = 0 | 1000 | 1000 | 1100 | 1500 | nA |
| 3 | T | IREFSTEN ¹ | | 63 | 70 | 77 | 81 | uA |
| 4 | T | RTC | does not include clock source current | 50 | 75 | 100 | 150 | nA |
| 5 | T | LVD ¹ | LVDSE = 1 | 90 | 100 | 110 | 115 | uA |
| 6 | T | ACMP ¹ | not using the bandgap (BGBE = 0) | 18 | 20 | 22 | 23 | uA |
| 7 | T | ADC ¹ | ADLPC = ADLSMP = 1 not using the bandgap (BGBE = 0) | 95 | 106 | 114 | 120 | uA |

¹ Not available in stop2 mode.

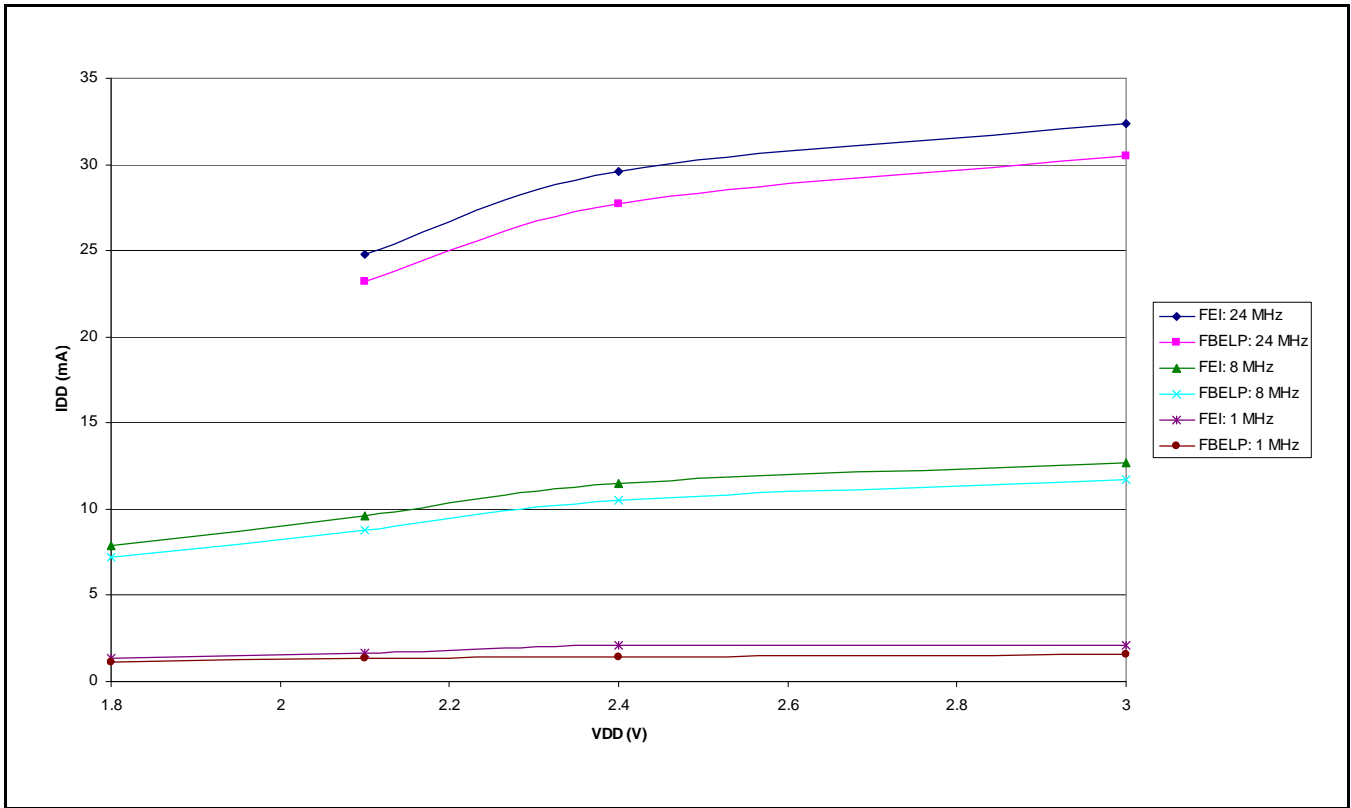


Figure 9. Typical Run I_{DD} for FBE and FEI, I_{DD} vs. V_{DD}
(ADC off, All Other Modules Enabled)

3.8 External Oscillator (XOSC) Characteristics

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

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

| Num | C | Characteristic | Symbol | Min | Typ ¹ | 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), high gain (HGO = 1) | f_{hi} | 1 | — | 16 | MHz |
| | | High range (RANGE = 1), low power (HGO = 0) | f_{hi} | 1 | — | 8 | MHz |
| 2 | D | Load capacitors Low range (RANGE=0), low power (HGO=0) Other oscillator settings | C_1, C_2 | See Note ² See Note ³ | | | |
| 3 | D | Feedback resistor | R_F | — | — | — | M Ω |
| | | Low range, low power (RANGE=0, HGO=0) ² | | — | 10 | — | |
| | | Low range, High Gain (RANGE=0, HGO=1) High range (RANGE=1, HGO=X) | | — | 1 | — | |
| 4 | D | Series resistor — | R_S | — | — | — | k Ω |
| | | Low range, low power (RANGE = 0, HGO = 0) ² | | — | 0 | — | |
| | | Low range, high gain (RANGE = 0, HGO = 1) | | — | 100 | — | |
| | | 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 ⁴ | t_{CSTL} | — | 200 | — | ms |
| | | Low range, low power | | — | 400 | — | |
| | | Low range, high power | | — | 5 | — | |
| | | High range, low power | | — | 15 | — | |
| | | High range, high power | t_{CSTH} | — | 15 | — | |
| 6 | D | Square wave input clock frequency (EREFS = 0, ERCLKEN = 1) | f_{extal} | 0.03125 | — | 40.0 | MHz |
| | | FEE or FBE mode | | 0 | — | 50.33 | MHz |
| | | FBELP mode | | | | | |

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

² Load capacitors (C_1, C_2), feedback resistor (R_F) and series resistor (R_S) are incorporated internally when RANGE=HGO=0.

³ See crystal or resonator manufacturer's recommendation.

⁴ Proper PC board layout procedures must be followed to achieve specifications.

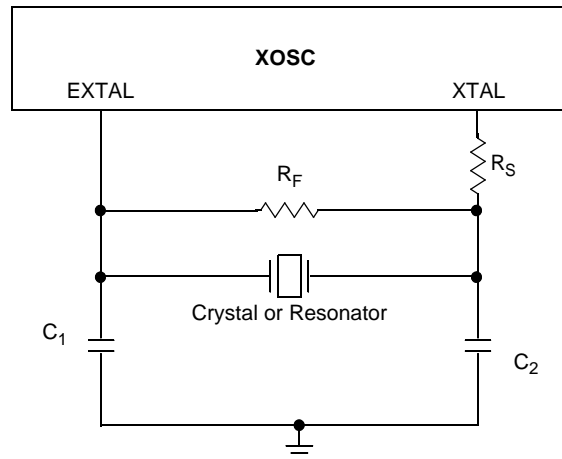


Figure 10. Typical Crystal or Resonator Circuit: High Range and Low Range/High Gain

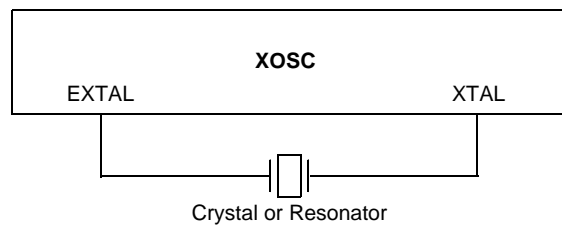


Figure 11. Typical Crystal or Resonator Circuit: Low Range/Low Gain

3.9 Internal Clock Source (ICS) Characteristics

Table 12. ICS Frequency Specifications (Temperature Range = -40 to 85°C Ambient)

| Num | C | Characteristic | Symbol | Min | Typ ¹ | Max | Unit | |
|-----|---------------------|--|--------------------------|--------------------|------------------|-------|-------------|-----|
| 1 | P | Average internal reference frequency — factory trimmed at $V_{DD} = 3.6\text{ V}$ and temperature = 25°C | f_{int_ft} | — | 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 | μs | |
| 4 | P | DCO output frequency range — trimmed ² | f_{dco_u} | Low range (DRS=00) | 16 | — | 20 | MHz |
| | Mid range (DRS=01) | | | 32 | — | 40 | | |
| | High range (DRS=10) | | | 48 | — | 60 | | |
| 5 | P | DCO output frequency ² Reference = 32768 Hz and DMX32 = 1 | f_{dco_DMX32} | Low range (DRS=00) | — | 19.92 | — | MHz |
| | Mid range (DRS=01) | | | — | 39.85 | — | | |
| | High range (DRS=10) | | | — | 59.77 | — | | |
| 6 | C | Resolution of trimmed DCO output frequency at fixed voltage and temperature (using FTRIM) | $\Delta f_{dco_res_t}$ | — | ± 0.1 | ± 0.2 | % f_{dco} | |
| 7 | C | Resolution of trimmed DCO output frequency at fixed voltage and temperature (not using FTRIM) | $\Delta f_{dco_res_t}$ | — | ± 0.2 | ± 0.4 | % f_{dco} | |

Electrical Characteristics

Table 12. ICS Frequency Specifications (Temperature Range = -40 to 85°C Ambient) (continued)

| Num | C | Characteristic | Symbol | Min | Typ ¹ | Max | Unit |
|-----|---|--|---------------------|-----|------------------|-----|-------------|
| 8 | C | Total deviation of trimmed DCO output frequency over voltage and temperature | Δf_{dco_t} | — | + 0.5 -1.0 | ± 2 | % f_{dco} |
| 9 | C | Total deviation of trimmed DCO output frequency over fixed voltage and temperature range of 0°C to 70 °C | Δf_{dco_t} | — | ± 0.5 | ± 1 | % f_{dco} |
| 10 | C | FLL acquisition time ³ | $t_{Acquire}$ | — | — | 1 | ms |
| 11 | C | Long term jitter of DCO output clock (averaged over 2-ms interval) ⁴ | C_{Jitter} | — | 0.02 | 0.2 | % f_{dco} |

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

² The resulting bus clock frequency should not exceed the maximum specified bus clock frequency of the device.

³ 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.

⁴ Jitter is the average deviation from the programmed frequency measured over the specified interval at maximum f_{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_{DD} and V_{SS} and variation in crystal oscillator frequency increase the C_{Jitter} percentage for a given interval.

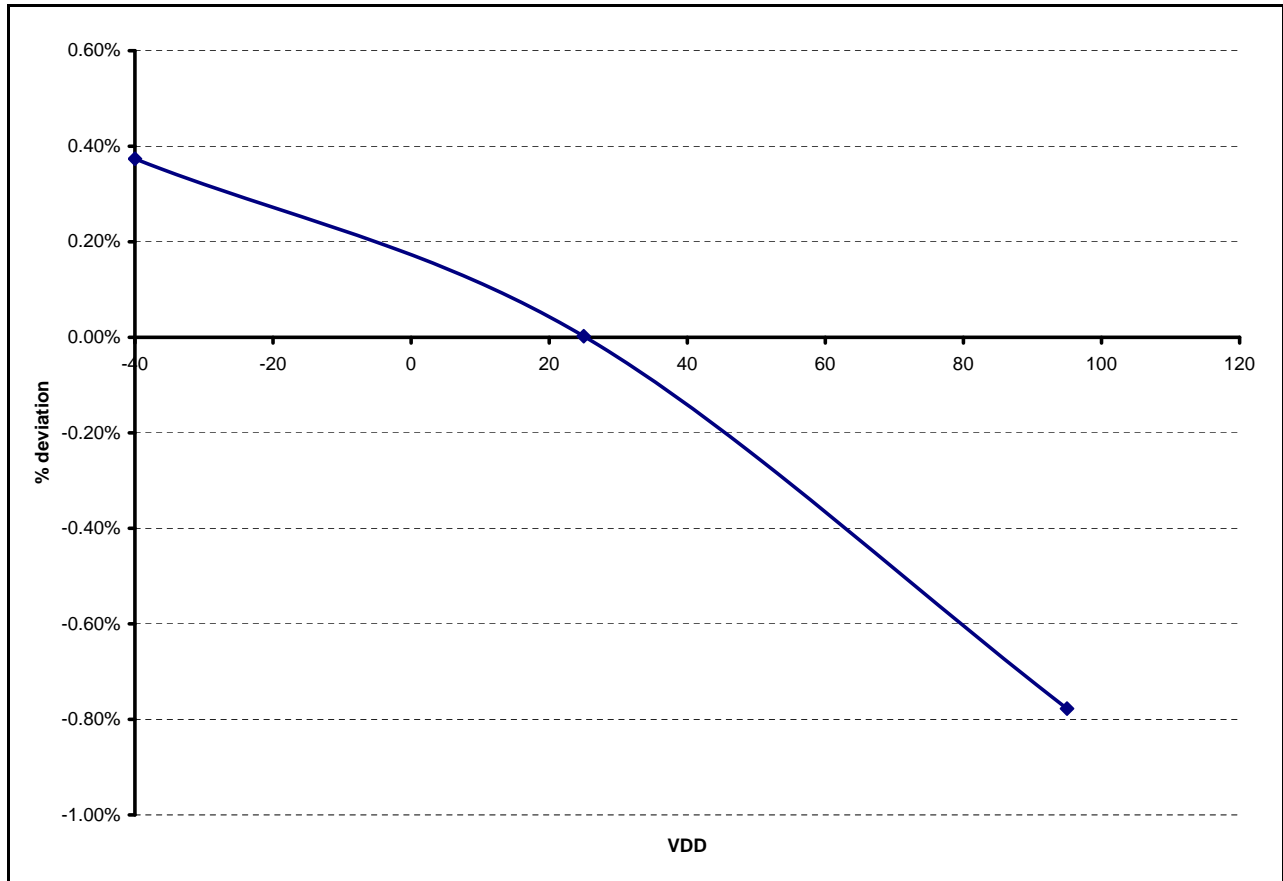
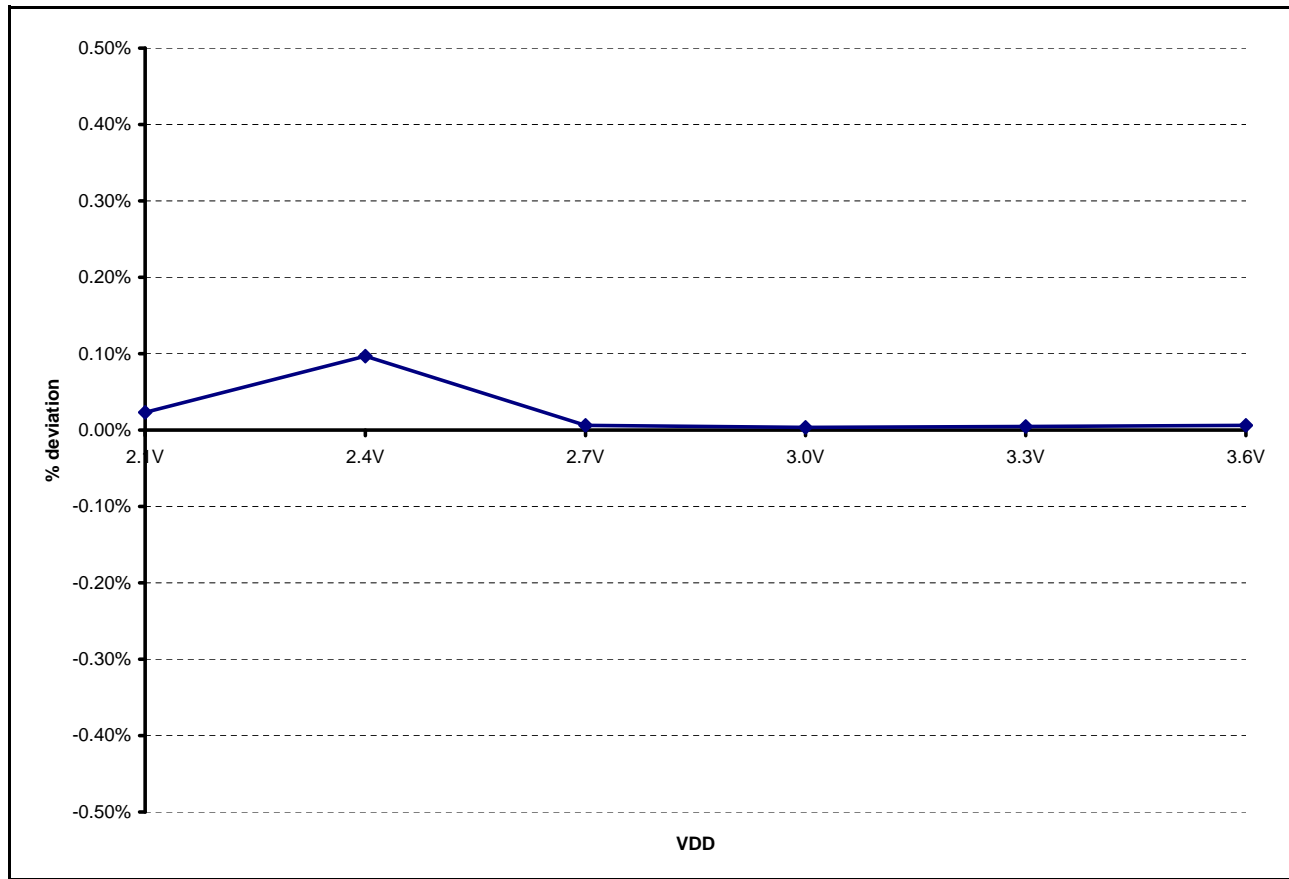


Figure 12. Deviation of DCO Output Across Temperature at $V_{DD} = 3.0\text{ V}$

Figure 13. Deviation of DCO Output Across V_{DD} at 25°C

3.10 AC Characteristics

This section describes timing characteristics for each peripheral system.

3.10.1 Control Timing

Table 13. Control Timing

| Num | C | Rating | Symbol | Min | Typ ¹ | Max | Unit |
|-----|---|---|---------------------|-----------------------|------------------|--------------------|------|
| 1 | D | Bus frequency ($t_{cyc} = 1/f_{Bus}$) V _{DD} ≥ 1.8V V _{DD} > 2.1V V _{DD} > 2.4V | f _{Bus} | dc | — — — | 10 20 25.165 | MHz |
| 2 | D | Internal low power oscillator period | t _{LPO} | 700 | — | 1300 | μs |
| 3 | D | External reset pulse width ² | t _{extrst} | 100 | — | — | ns |
| 4 | D | Reset low drive | t _{rstdrv} | 34 × 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 ³ | t _{MSH} | 100 | — | — | μs |

Table 13. Control Timing (continued)

| Num | C | Rating | Symbol | Min | Typ ¹ | Max | Unit |
|-----|---|--|----------------------|---------------------------|------------------|--------|---------|
| 7 | D | IRQ pulse width Asynchronous path ² Synchronous path ⁴ | t_{LIH}, t_{HIL} | 100 $2 \times t_{cyc}$ | — — | — — | ns |
| 8 | D | Keyboard interrupt pulse width Asynchronous path ² Synchronous path ⁴ | t_{LIH}, t_{HIL} | 100 $2 \times t_{cyc}$ | — — | — — | ns |
| 9 | C | Port rise and fall time — Low output drive (PTxDS = 0) (load = 50 pF) ⁵ Slew rate control disabled (PTxSE = 0) Slew rate control enabled (PTxSE = 1) | t_{Rise}, t_{Fall} | — — | 8 31 | — — | ns |
| | | Port rise and fall time — High output drive (PTxDS = 1) (load = 50 pF) Slew rate control disabled (PTxSE = 0) Slew rate control enabled (PTxSE = 1) | t_{Rise}, t_{Fall} | — — | 7 24 | — — | ns |
| 10 | | Voltage regulator recovery time | t_{VRR} | — | 4 | — | μ s |

¹ Typical values are based on characterization data at $V_{DD} = 3.0V$, 25°C unless otherwise stated.

² This is the shortest pulse that is guaranteed to be recognized as a reset or interrupt pin request. Shorter pulses are not guaranteed to override reset requests from internal sources.

³ 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} .

⁴ This is the minimum assertion time in which the interrupt **may** be recognized. The correct protocol is to assert the interrupt request until it is explicitly negated by the interrupt service routine.

⁵ Timing is shown with respect to 20% V_{DD} and 80% V_{DD} levels. Temperature range -40°C to 85°C.

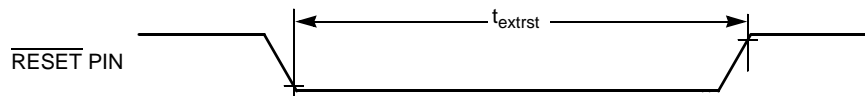


Figure 14. Reset Timing

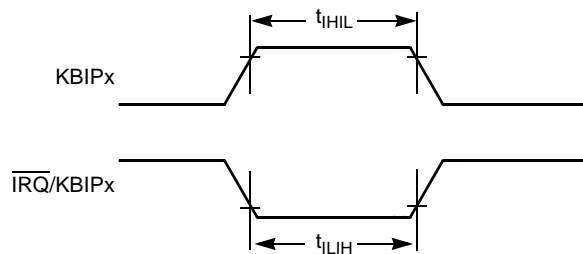


Figure 15. $\overline{IRQ/KBIPx}$ Timing

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 14. TPM Input Timing

| No. | C | Function | Symbol | Min | Max | Unit |
|-----|---|---------------------------|------------|-----|-------------|-----------|
| 1 | D | External clock frequency | f_{TCLK} | 0 | $f_{Bus}/4$ | Hz |
| 2 | D | External clock period | t_{TCLK} | 4 | — | t_{cyc} |
| 3 | D | External clock high time | t_{clkh} | 1.5 | — | t_{cyc} |
| 4 | D | External clock low time | t_{clkl} | 1.5 | — | t_{cyc} |
| 5 | D | Input capture pulse width | t_{ICPW} | 1.5 | — | t_{cyc} |

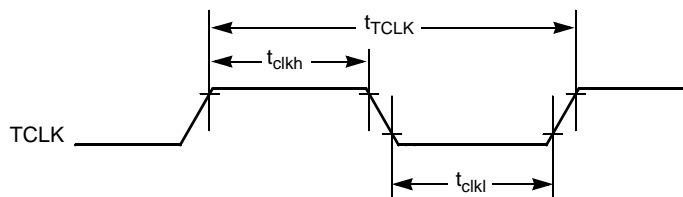


Figure 16. Timer External Clock

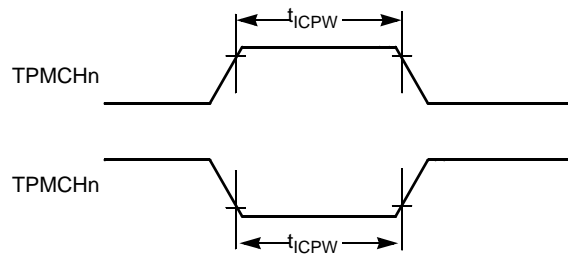


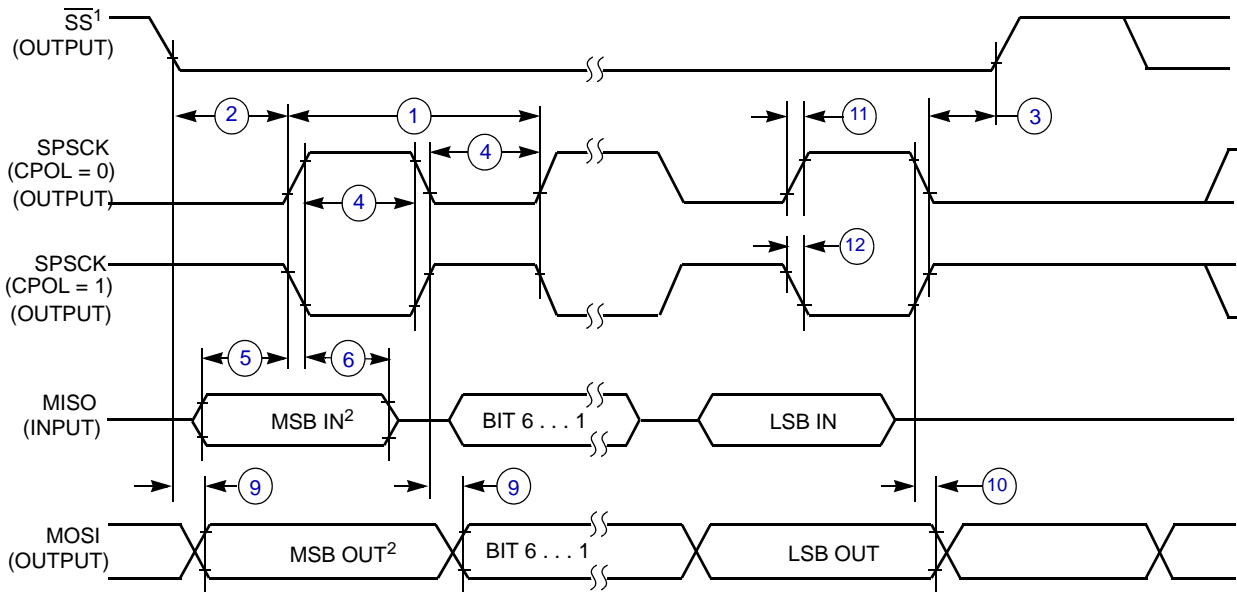
Figure 17. Timer Input Capture Pulse

3.10.3 SPI Timing

Table 15 and Figure 18 through Figure 21 describe the timing requirements for the SPI system.

Table 15. SPI Timing

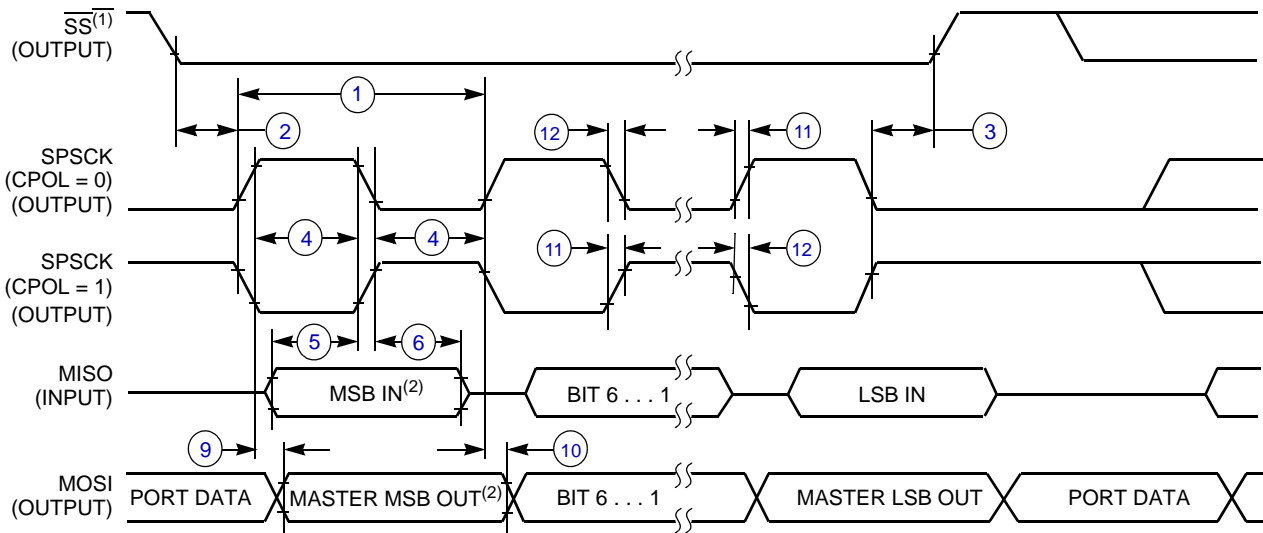
| No. | C | Function | Symbol | Min | Max | Unit |
|-----|---|---|----------------------|----------------------------------|----------------------------|--------------------------|
| — | D | Operating frequency Master Slave | f_{op} | $f_{Bus}/2048$ 0 | $f_{Bus}/2$ $f_{Bus}/4$ | Hz Hz |
| 1 | D | SPSCK period Master Slave | t_{SPSCK} | 2 4 | 2048 — | t_{cyc} t_{cyc} |
| 2 | D | Enable lead time Master Slave | t_{Lead} | 1/2 1 | — — | t_{SPSCK} t_{cyc} |
| 3 | D | Enable lag time Master Slave | t_{Lag} | 1/2 1 | — — | t_{SPSCK} t_{cyc} |
| 4 | D | Clock (SPSCK) high or low time Master Slave | t_{WSPSCK} | $t_{cyc} - 30$ $t_{cyc} - 30$ | $1024 t_{cyc}$ — | ns ns |
| 5 | D | Data setup time (inputs) Master Slave | t_{SU} | 15 15 | — — | ns ns |
| 6 | D | Data hold time (inputs) Master Slave | t_{HI} | 0 25 | — — | ns ns |
| 7 | D | Slave access time | t_a | — | 1 | t_{cyc} |
| 8 | D | Slave MISO disable time | t_{dis} | — | 1 | t_{cyc} |
| 9 | D | Data valid (after SPSCK edge) Master Slave | t_v | — — | 25 25 | ns ns |
| 10 | D | Data hold time (outputs) Master Slave | t_{HO} | 0 0 | — — | ns ns |
| 11 | D | Rise time Input Output | t_{RI} t_{RO} | — — | $t_{cyc} - 25$ 25 | ns ns |
| 12 | D | Fall time Input Output | t_{FI} t_{FO} | — — | $t_{cyc} - 25$ 25 | ns ns |



NOTES:

1. \overline{SS} output mode (DDS7 = 1, SSOE = 1).
2. LSBF = 0. For LSBF = 1, bit order is LSB, bit 1, ..., bit 6, MSB.

Figure 18. SPI Master Timing (CPHA = 0)

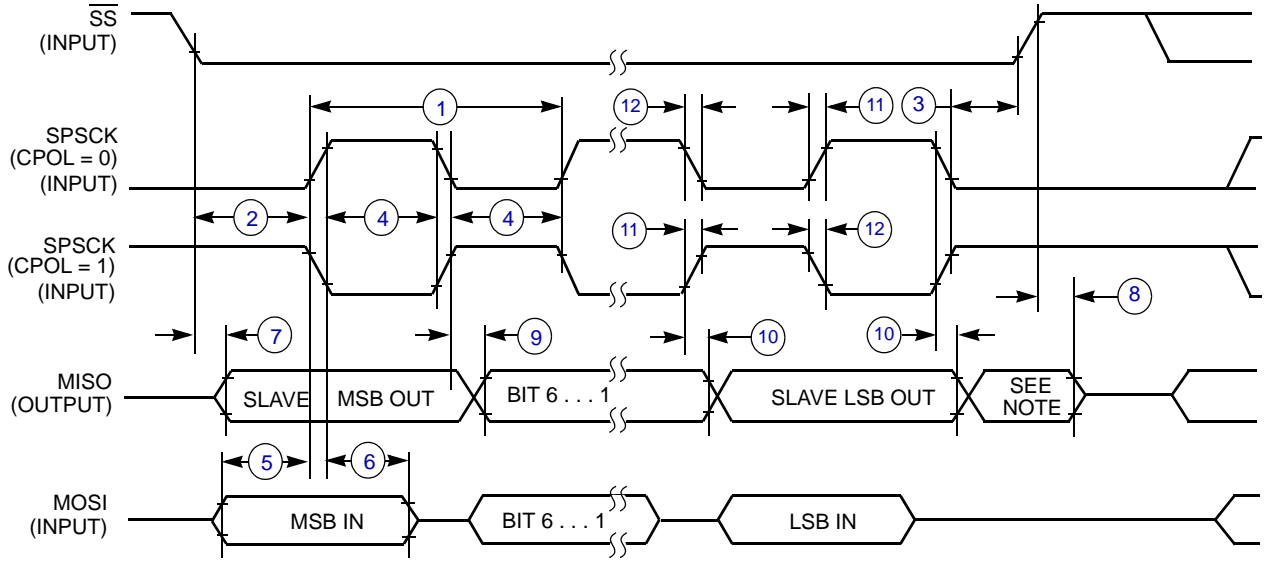


NOTES:

1. \overline{SS} output mode (DDS7 = 1, SSOE = 1).
2. LSBF = 0. For LSBF = 1, bit order is LSB, bit 1, ..., bit 6, MSB.

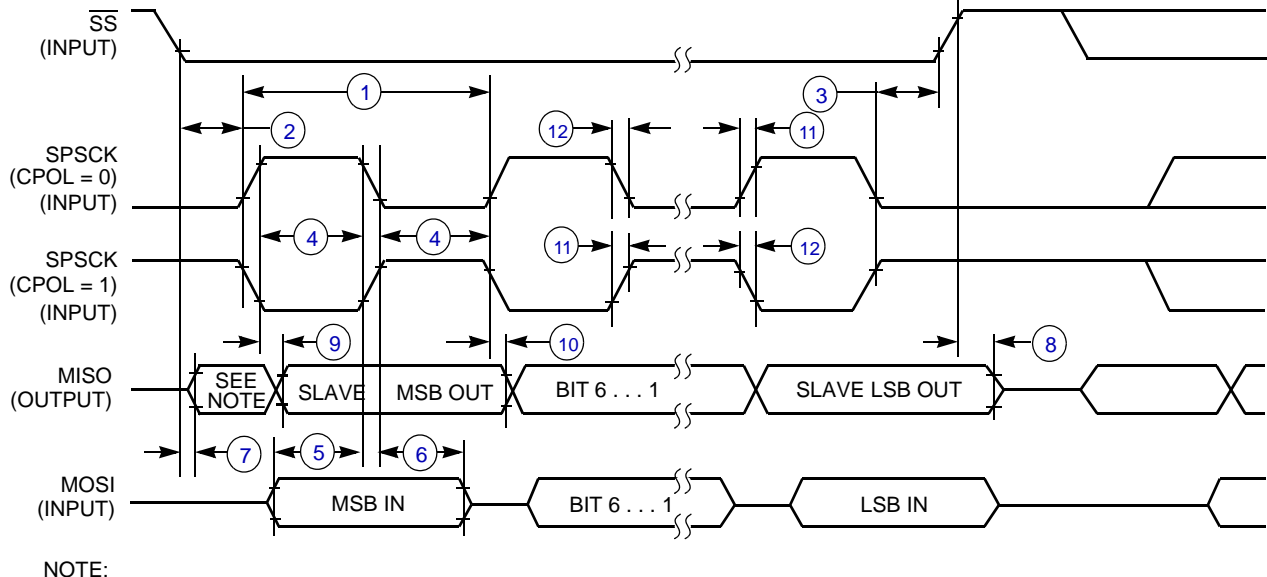
Figure 19. SPI Master Timing (CPHA = 1)

Electrical Characteristics



NOTE:
 1. Not defined but normally MSB of character just received

Figure 20. SPI Slave Timing (CPHA = 0)



NOTE:
 1. Not defined but normally LSB of character just received

Figure 21. SPI Slave Timing (CPHA = 1)

3.11 Analog Comparator (ACMP) Electricals

Table 16. Analog Comparator Electrical Specifications

| C | Characteristic | Symbol | Min | Typical | Max | Unit |
|---|--|-------------|----------------|---------|----------|---------------|
| D | Supply voltage | V_{DD} | 1.80 | — | 3.6 | V |
| C | Supply current (active) | I_{DDAC} | — | 20 | 35 | μA |
| D | Analog input voltage | V_{AIN} | $V_{SS} - 0.3$ | — | V_{DD} | V |
| C | 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 | μA |
| C | Analog comparator initialization delay | t_{AINIT} | — | — | 1.0 | μs |

3.12 ADC Characteristics

Table 17. 12-bit ADC Operating Conditions

| C | Characteristic | Conditions | Symb | Min | Typ ¹ | Max | Unit | Comment |
|---|----------------------------|---|-------------------|------------|------------------|------------|------------|-----------------|
| D | Supply voltage | Absolute | V_{DDAD} | 1.8 | — | 3.6 | V | |
| | | Delta to V_{DD} ($V_{DD} - V_{DDAD}$) ² | ΔV_{DDAD} | -100 | 0 | +100 | mV | |
| D | Ground voltage | Delta to V_{SS} ($V_{SS} - V_{SSAD}$) ² | ΔV_{SSAD} | -100 | 0 | +100 | mV | |
| D | Ref Voltage High | | V_{REFH} | 1.8 | V_{DDAD} | V_{DDAD} | V | |
| D | Ref Voltage Low | | V_{REFL} | V_{SSAD} | V_{SSAD} | V_{SSAD} | V | |
| D | Input Voltage | | V_{ADIN} | V_{REFL} | — | V_{REFH} | V | |
| C | Input Capacitance | | C_{ADIN} | — | 4.5 | 5.5 | pF | |
| C | Input Resistance | | R_{ADIN} | — | 5 | 7 | k Ω | |
| C | Analog Source Resistance | 12 bit mode $f_{ADCK} > 4\text{MHz}$ $f_{ADCK} < 4\text{MHz}$ | R_{AS} | — | — | 2 | k Ω | External to MCU |
| | | 10 bit mode $f_{ADCK} > 4\text{MHz}$ $f_{ADCK} < 4\text{MHz}$ | | — | — | 5 | | |
| | | 8 bit mode (all valid f_{ADCK}) | | — | — | 10 | | |
| D | ADC Conversion Clock Freq. | High Speed (ADLPC=0) | f_{ADCK} | 0.4 | — | 8.0 | MHz | |
| | | Low Power (ADLPC=1) | | 0.4 | — | 4.0 | | |

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

² DC potential difference.

Table 18. 12-bit ADC Characteristics ($V_{REFH} = V_{DDAD}$, $V_{REFL} = V_{SSAD}$) (continued)

| Characteristic | Conditions | C | Symb | Min | Typ ¹ | Max | Unit | Comment | |
|--|--------------------------|---|--------------|-----|------------------|-----------|------------------|---|-----------------------|
| Conversion Time (Including sample time) | Short Sample (ADLSMP=0) | P | t_{ADC} | — | 20 | — | ADCK cycles | See the ADC chapter in the <i>MCF51QE128 Reference Manual</i> for conversion time variances | |
| | Long Sample (ADLSMP=1) | C | | — | 40 | — | | | |
| Sample Time | Short Sample (ADLSMP=0) | P | t_{ADS} | — | 3.5 | — | ADCK cycles | | |
| | Long Sample (ADLSMP=1) | C | | — | 23.5 | — | | | |
| Total Unadjusted Error | 12 bit mode | T | E_{TUE} | — | ± 3.0 | — | LSB ² | | Includes Quantization |
| | 10 bit mode | P | | — | ± 1 | ± 2.5 | | | |
| | 8 bit mode | T | | — | ± 0.5 | ± 1.0 | | | |
| Differential Non-Linearity | 12 bit mode | T | DNL | — | ± 1.75 | — | LSB ² | | |
| | 10 bit mode ³ | P | | — | ± 0.5 | ± 1.0 | | | |
| | 8 bit mode ³ | T | | — | ± 0.3 | ± 0.5 | | | |
| Integral Non-Linearity | 12 bit mode | T | INL | — | ± 1.5 | — | LSB ² | | |
| | 10 bit mode | T | | — | ± 0.5 | ± 1.0 | | | |
| | 8 bit mode | T | | — | ± 0.3 | ± 0.5 | | | |
| Zero-Scale Error | 12 bit mode | T | E_{ZS} | — | ± 1.5 | — | LSB ² | $V_{ADIN} = V_{SSAD}$ | |
| | 10 bit mode | P | | — | ± 0.5 | ± 1.5 | | | |
| | 8 bit mode | T | | — | ± 0.5 | ± 0.5 | | | |
| Full-Scale Error | 12 bit mode | T | E_{FS} | — | ± 1.0 | — | LSB ² | $V_{ADIN} = V_{DDAD}$ | |
| | 10 bit mode | P | | — | ± 0.5 | ± 1 | | | |
| | 8 bit mode | T | | — | ± 0.5 | ± 0.5 | | | |
| Quantization Error | 12 bit mode | D | E_Q | — | -1 to 0 | — | LSB ² | | |
| | 10 bit mode | | | — | — | ± 0.5 | | | |
| | 8 bit mode | | | — | — | ± 0.5 | | | |
| Input Leakage Error | 12 bit mode | D | E_{IL} | — | ± 2 | — | LSB ² | Pad leakage ⁴ * R_{AS} | |
| | 10 bit mode | | | — | ± 0.2 | ± 4 | | | |
| | 8 bit mode | | | — | ± 0.1 | ± 1.2 | | | |
| Temp Sensor Slope | -40°C to 25°C | D | m | — | 1.646 | — | mV/°C | | |
| | 25°C to 85°C | | | — | 1.769 | — | | | |
| Temp Sensor Voltage | 25°C | D | V_{TEMP25} | — | 701.2 | — | mV | | |

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

² 1 LSB = $(V_{REFH} - V_{REFL})/2^N$

³ Monotonicity and No-Missing-Codes guaranteed in 10 bit and 8 bit modes

⁴ 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.

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 of the *MCF51QE128 Reference Manual*.

Table 19. Flash Characteristics

| C | Characteristic | Symbol | Min | Typical | Max | Unit |
|---|---|-------------------------|-------------|--------------|--------|-------------------|
| D | Supply voltage for program/erase -40°C to 85°C | $V_{\text{prog/erase}}$ | 1.8 | | 3.6 | V |
| D | Supply voltage for read operation | V_{Read} | 1.8 | | 3.6 | V |
| D | Internal FCLK frequency ¹ | f_{FCLK} | 150 | | 200 | kHz |
| D | Internal FCLK period (1/FCLK) | t_{FcyC} | 5 | | 6.67 | μs |
| P | Longword program time (random location) ⁽²⁾ | t_{prog} | | 9 | | t_{FcyC} |
| P | Longword program time (burst mode) ⁽²⁾ | t_{Burst} | | 4 | | t_{FcyC} |
| P | Page erase time ² | t_{Page} | | 4000 | | t_{FcyC} |
| P | Mass erase time ⁽²⁾ | t_{Mass} | | 20,000 | | t_{FcyC} |
| | Longword program current ³ | R_{IDDBP} | — | 9.7 | — | mA |
| | Page erase current ³ | R_{IDDPPE} | — | 7.6 | — | mA |
| C | Program/erase endurance ⁴ T_L to $T_H = -40^\circ\text{C}$ to $+85^\circ\text{C}$ $T = 25^\circ\text{C}$ | | 10,000 — | — 100,000 | — — | cycles |
| C | Data retention ⁵ | $t_{\text{D_ret}}$ | 15 | 100 | — | years |

¹ The frequency of this clock is controlled by a software setting.

² 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.

³ 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.

⁴ **Typical endurance for flash** was evaluated for this product family on the HC9S12Dx64. For additional information on how Freescale defines typical endurance, please refer to Engineering Bulletin EB619, *Typical Endurance for Nonvolatile Memory*.

⁵ **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*.

4 Ordering Information

This section contains ordering information for MCF51QE128MCF51QE96, and MCF51QE64 devices.

Table 20. Ordering Information

| Freescale Part Number ¹ | Memory | | Temperature range (°C) | Package ² |
|------------------------------------|--------|-----|------------------------|----------------------|
| | Flash | RAM | | |
| MCF51QE128CLK | 128K | 8K | -40 to +85 | 80 LQFP |
| MCF51QE128CLH | 128K | 8K | -40 to +85 | 64 LQFP |
| MCF51QE96CLK | 96K | 8K | -40 to +85 | 80 LQFP |
| MCF51QE96CLH | | | -40 to +85 | 64 LQFP |
| MCF51QE64CLH | 64K | 8K | -40 to +85 | 64 LQFP |
| MCF51QE32CLH | 32K | 8K | -40 to +85 | 64 LQFP |
| MCF51QE32LH | 32K | 8K | 0 to +70 | 64 LQFP |

¹ See the reference manual, *MCF51QE128RM*, for a complete description of modules included on each device.

² See [Table 21](#) for package information.

5 Package Information

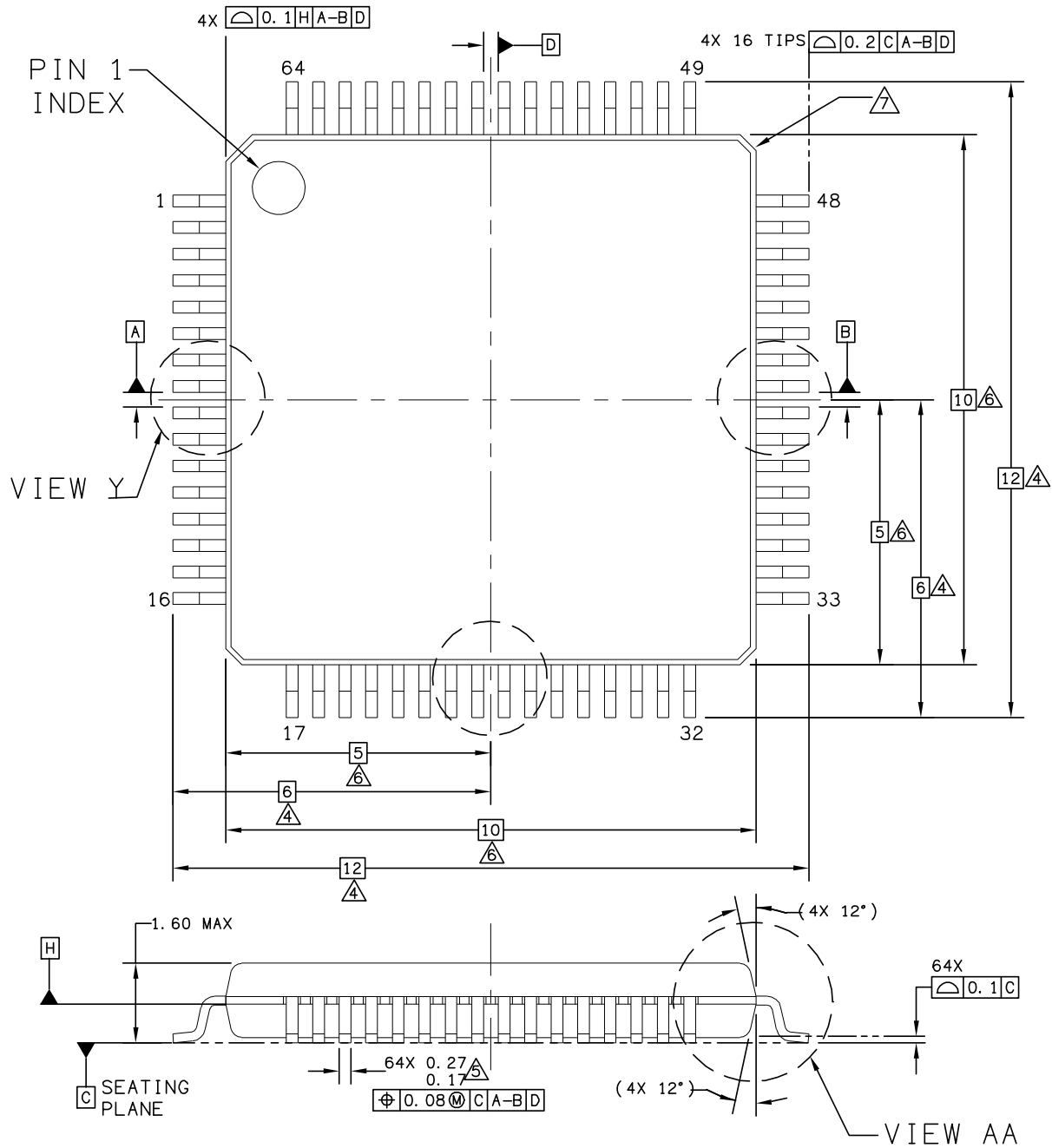
The below table details the various packages available.

Table 21. Package Descriptions

| Pin Count | Package Type | Abbreviation | Designator | Case No. | Document No. |
|-----------|-----------------------|--------------|------------|----------|--------------|
| 80 | Low Quad Flat Package | LQFP | LK | 917A | 98ASS23237W |
| 64 | Low Quad Flat Package | LQFP | LH | 840F | 98ASS23234W |

5.1 Mechanical Drawings

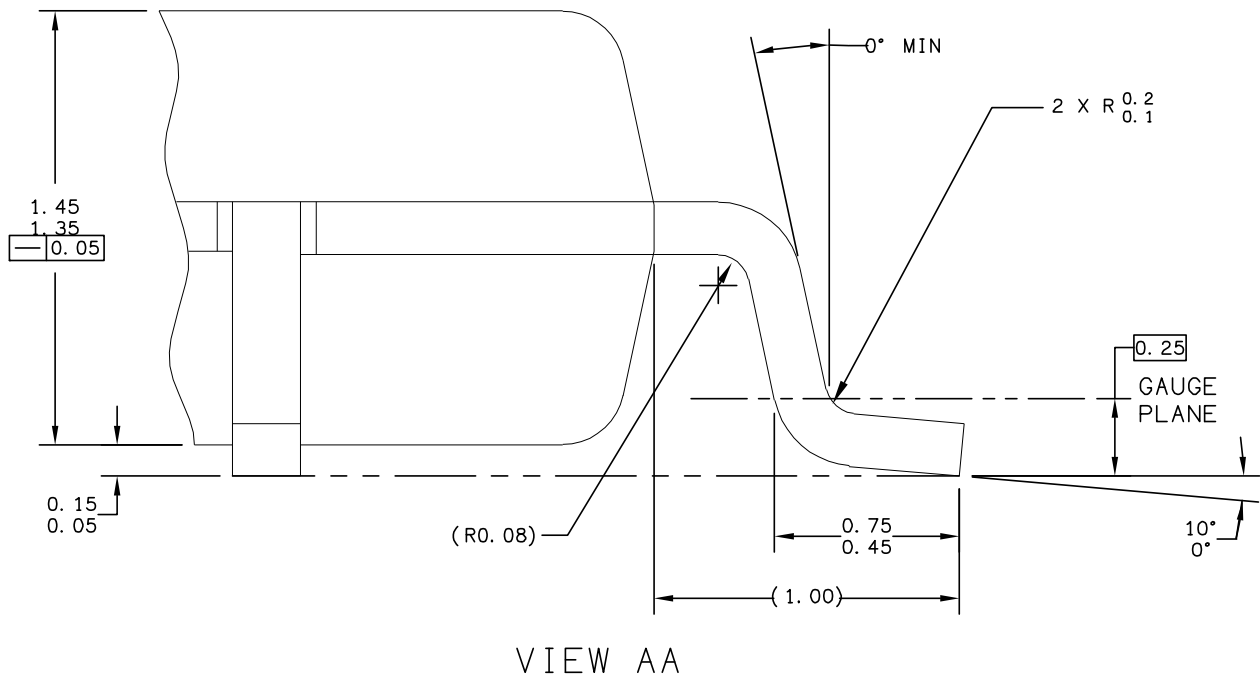
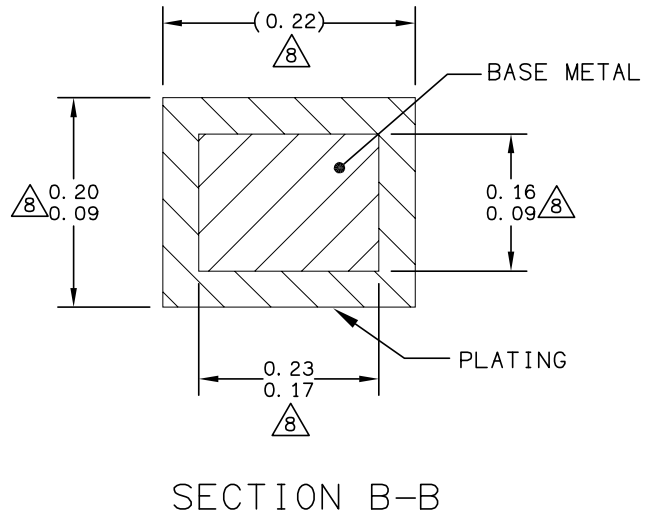
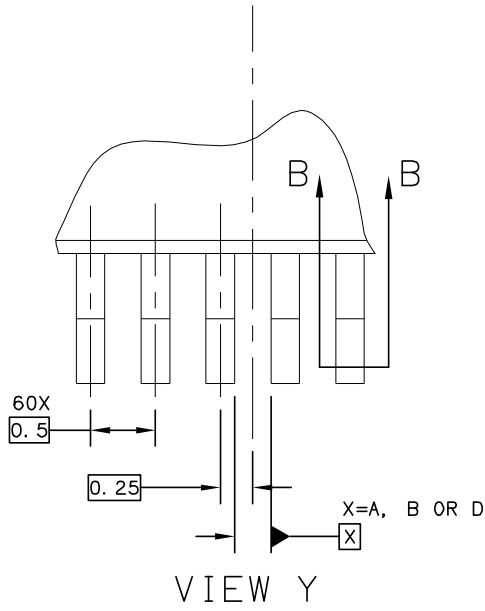
The following pages are mechanical drawings for the packages described in [Table 21](#). For the latest available drawings please visit our web site (<http://www.freescale.com>) and enter the package's document number into the keyword search box.



| | | | |
|---|----------------------------|----------------------------|--|
| © FREESCALE SEMICONDUCTOR, INC. ALL RIGHTS RESERVED. | MECHANICAL OUTLINE | PRINT VERSION NOT TO SCALE | |
| TITLE: 64LD LQFP, 10 X 10 X 1.4 PKG, 0.5 PITCH, CASE OUTLINE | DOCUMENT NO: 98ASS23234W | REV: D | |
| | CASE NUMBER: 840F-02 | 06 APR 2005 | |
| | STANDARD: JEDEC MS-026 BCD | | |

Figure 24. 64-pin LQFP Package Drawing (Case 840F, Doc #98ASS23234W), Sheet 1 of 3






Package Information



| | | | |
|--|----------------------------|----------------------------|--|
| © FREESCALE SEMICONDUCTOR, INC. ALL RIGHTS RESERVED. | MECHANICAL OUTLINE | PRINT VERSION NOT TO SCALE | |
| TITLE: 64LD LQFP, 10 X 10 X 1.4 PKG, 0.5 PITCH, CASE OUTLINE | DOCUMENT NO: 98ASS23234W | REV: D | |
| | CASE NUMBER: 840F-02 | 06 APR 2005 | |
| | STANDARD: JEDEC MS-026 BCD | | |

Figure 25. 64-pin LQFP Package Drawing (Case 840F, Doc #98ASS23234W), Sheet 2 of 3

NOTES:

1. DIMENSIONS ARE IN MILLIMETERS.
2. DIMENSIONING AND TOLERANCING PER ASME Y14.5M-1994.
3. DATUMS A, B AND D TO BE DETERMINED AT DATUM PLANE H.
4.  DIMENSIONS TO BE DETERMINED AT SEATING PLANE C.
5.  THIS DIMENSION DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL NOT CAUSE THE LEAD WIDTH TO EXCEED THE UPPER LIMIT BY MORE THAN 0.08 mm AT MAXIMUM MATERIAL CONDITION. DAMBAR CANNOT BE LOCATED ON THE LOWER RADIUS OR THE FOOT. MINIMUM SPACE BETWEEN PROTRUSION AND ADJACENT LEAD SHALL NOT BE LESS THAN 0.07 mm.
6.  THIS DIMENSION DOES NOT INCLUDE MOLD PROTRUSION. ALLOWABLE PROTRUSION IS 0.25 mm PER SIDE. THIS DIMENSION IS MAXIMUM PLASTIC BODY SIZE DIMENSION INCLUDING MOLD MISMATCH.
7.  EXACT SHAPE OF EACH CORNER IS OPTIONAL.
8.  THESE DIMENSIONS APPLY TO THE FLAT SECTION OF THE LEAD BETWEEN 0.1 mm AND 0.25 mm FROM THE LEAD TIP.

| | | | |
|--|----------------------------|----------------------------|--|
| © FREESCALE SEMICONDUCTOR, INC. ALL RIGHTS RESERVED. | MECHANICAL OUTLINE | PRINT VERSION NOT TO SCALE | |
| TITLE: 64LD LQFP, 10 X 10 X 1.4 PKG, 0.5 PITCH, CASE OUTLINE | DOCUMENT NO: 98ASS23234W | REV: D | |
| | CASE NUMBER: 840F-02 | 06 APR 2005 | |
| | STANDARD: JEDEC MS-026 BCD | | |

Figure 26. 64-pin LQFP Package Drawing (Case 840F, Doc #98ASS23234W), Sheet 3 of 3

6 Product Documentation

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

Reference Manual (MCF51QE128RM)

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

7 Revision History

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

<http://www.freescale.com>

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

Table 22. Revision History

| Revision | Date | Description of Changes |
|----------|-------------|---|
| 3 | 25 Jun 2007 | <p>Table 8: Changed Condition entires in specs #6 (V_{IH}) and #7 (V_{IL}) from $V_{DD} \geq 1.8V$ to $V_{DD} > 2.7V$ and $V_{DD} \leq 1.8V$ to $V_{DD} > 1.8V$.</p> <p>Table 8: Changed V_{DD} rising and V_{DD} falling min/typ/max specs in row #19 (Low-voltage warning threshold—high range) from 2.35, 2.40, and 2.50 to 2.36, 2.46, and 2.56 respectively.</p> |
| 4 | 17 Sep 2007 | <p>Added information about the MCF51QE32 device.</p> <p>Changed the SRAM size for the MCF51QE64 device (was 4 Kbytes, is 8 Kbytes).</p> <p>Corrected the number of ADC channels for the MCF51QE64 device (was 22, is 20).</p> <p>Corrected the number of ADC channels for the 64-pin package of the MCF51QE64 device (was 22, is 20).</p> |
| | | Changed ACMP electricals, V_{AIO} specification's test category from P to C. |
| 5 | 28 May 2008 | <p>Updated the tables Thermal Characteristics, DC Characteristics, Supply Current Characteristics, XOSC and ICS Specifications (Temperature Range = -40 to 85°C Ambient), ICS Frequency Specifications (Temperature Range = -40 to 85°C Ambient), Control Timing, and Analog Comparator Electrical Specifications, 12-bit ADC Characteristics (VREFH = VDDAD, VREFL = VSSAD)</p> <p>Updated the figures Typical Run IDD for FBE and FEI, IDD vs. VDD (ACMP and ADC off, All Other Modules Enabled), Deviation of DCO Output from Trimmed Frequency (50.33 MHz, 3.0 V), and Deviation of DCO Output from Trimmed Frequency (50.33 MHz, 25°C)</p> |
| 6 | 24 Jun 2008 | <p>Updated the table Thermal Characteristics</p> <p>Updated the row corresponding to Num 18 in the table DC Characteristics</p> <p>Updated the tables MCF51QE128 Series Features by MCU and Package, DC Characteristics, Supply Current Characteristics, Thermal Characteristics, Control Timing, and Ordering Information</p> <p>Updated the figures Typical Run IDD for FBE and FEI, IDD vs. VDD (ADC off, All Other Modules Enabled), Deviation of DCO Output Across Temperature at VDD = 3.0 V, and Deviation of DCO Output Across VDD at 25°C</p> |
| 7 | 14 Oct 2008 | <p>Updated the Stop2 and Stop3 mode supply current in the Supply Current Characteristics table.</p> <p>Replaced the stop mode adders section from the Supply Current Characteristics with its own Stop Mode Adders table with new specifications.</p> |

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Rev. 7

10/2008

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