

## **MCF51AC256 Series ColdFire Microcontroller**

**Covers: MCF51AC256A  
MCF51AC256B  
MCF51AC128A  
MCF51AC128C**

The MCF51AC256 series are members of the ColdFire® family of 32-bit variable-length reduced instruction set (RISC) microcontroller. This document provides an overview of the MCF51AC256 series, focusing on its highly integrated and diverse feature set.

The MCF51AC256 series are based on the V1 ColdFire core and operates at processor core speeds up to 50.33 MHz. As part of Freescale's Controller Continuum®, it is an ideal upgrade for designs based on the MC9S08AC128 series of 8-bit microcontrollers.

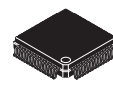
The MCF51AC256 features the following functional units:

- V1 ColdFire core with background debug module
- Up to 256 KB of flash memory
- Up to 32 KB of static RAM (SRAM)
- Up to two analog comparators (ACMP)
- Analog-to-digital converter (ADC) with up to 24 channels
- Controller-area network (CAN)
- Cyclic redundancy check (CRC)
- Inter-integrated circuit (IIC)
- Keyboard interrupt (KBI)
- Multipurpose clock generator (MCG)
- Rapid general-purpose input/output (RGPIO)

## **MCF51AC256**



80 LQFP  
14 mm × 14 mm



64 LQFP  
10 mm × 10 mm



44 LQFP  
10 mm × 10 mm



64 QFP  
14 mm × 14 mm

- Two serial communications interfaces (SCI)
- Up to two serial peripheral interfaces (SPI)
- Two flexible timer modules (FTM)
- Timer pulse-width modulator (TPM)

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# 1 MCF51AC256 Family Configurations

## 1.1 Device Comparison

The MCF51AC256 series is summarized in [Table 1](#).

**Table 1. MCF51AC256 Series Device Comparison**

| Feature                                             | MCF51AC256A |        | MCF51AC256B |        |        | MCF51AC128A           |        | MCF51AC128C |        |        |
|-----------------------------------------------------|-------------|--------|-------------|--------|--------|-----------------------|--------|-------------|--------|--------|
|                                                     | 80-pin      | 64-pin | 80-pin      | 64-pin | 44-pin | 80-pin                | 64-pin | 80-pin      | 64-pin | 44-pin |
| Flash memory size (Kbytes)                          | 256         |        |             |        |        | 128                   |        |             |        |        |
| RAM size (Kbytes)                                   | 32          |        |             |        |        | 32 or 16 <sup>1</sup> |        |             |        |        |
| V1 ColdFire core with BDM (background debug module) | Yes         |        |             |        |        |                       |        |             |        |        |
| ACMP1 (analog comparator)                           | Yes         |        |             |        |        |                       |        |             |        |        |
| ACMP2 (analog comparator)                           | Yes         |        | Yes         |        | No     | Yes                   |        |             |        | No     |
| ADC (analog-to-digital converter) channels (12-bit) | 24          | 20     | 24          | 20     | 9      | 24                    | 20     | 24          | 20     | 9      |
| CAN (controller area network)                       | Yes         |        | No          |        |        | Yes                   |        | No          |        |        |
| COP (computer operating properly)                   | Yes         |        |             |        |        |                       |        |             |        |        |
| CRC (cyclic redundancy check)                       | Yes         |        |             |        |        |                       |        |             |        |        |
| RTI                                                 | Yes         |        |             |        |        |                       |        |             |        |        |
| DBG (debug)                                         | Yes         |        |             |        |        |                       |        |             |        |        |
| IIC1 (inter-integrated circuit)                     | Yes         |        |             |        |        |                       |        |             |        |        |
| IRQ (interrupt request input)                       | Yes         |        |             |        |        |                       |        |             |        |        |
| INTC (interrupt controller)                         | Yes         |        |             |        |        |                       |        |             |        |        |
| KBI (keyboard interrupts)                           | Yes         |        |             |        |        |                       |        |             |        |        |
| LVD (low-voltage detector)                          | Yes         |        |             |        |        |                       |        |             |        |        |
| MCG (multipurpose clock generator)                  | Yes         |        |             |        |        |                       |        |             |        |        |
| OSC (crystal oscillator)                            | Yes         |        |             |        |        |                       |        |             |        |        |
| Port I/O <sup>2</sup>                               | 69          | 54     | 69          | 54     | 36     | 69                    | 54     | 69          | 54     | 36     |
| RGPIO (rapid general-purpose I/O)                   | 16          |        |             |        | 12     | 16                    |        |             |        | 12     |
| SCI1, SCI2 (serial communications interfaces)       | Yes         |        |             |        |        |                       |        |             |        |        |
| SPI1 (serial peripheral interface)                  | Yes         |        |             |        |        |                       |        |             |        |        |
| SPI2 (serial peripheral interface)                  | Yes         | No     | Yes         | No     |        | Yes                   | No     | Yes         | No     |        |
| FTM1 (flexible timer module) channels               | 6           |        |             |        | 4      | 6                     |        |             |        | 4      |
| FTM2 channels                                       | 6           | 2      | 6           | 2      | 2      | 6                     | 2      | 6           | 2      | 2      |

Table 1. MCF51AC256 Series Device Comparison (continued)

| Feature                                     | MCF51AC256A |        | MCF51AC256B |        |        | MCF51AC128A |        | MCF51AC128C |        |        |
|---------------------------------------------|-------------|--------|-------------|--------|--------|-------------|--------|-------------|--------|--------|
|                                             | 80-pin      | 64-pin | 80-pin      | 64-pin | 44-pin | 80-pin      | 64-pin | 80-pin      | 64-pin | 44-pin |
| TPM3 (timer pulse-width modulator) channels | 2           |        |             |        |        |             |        |             |        |        |
| VBUS (debug visibility bus)                 | Yes         | No     | Yes         | No     |        | Yes         | No     | Yes         | No     |        |

<sup>1</sup> The members of MCF51AC128A with CAN support have 32 KB RAM. The other members have 16 KB RAM.

<sup>2</sup> Up to 16 pins on Ports E and F are shared with the ColdFire Rapid GPIO module.

## 1.2 Block Diagram

Figure 1 shows the connections between the MCF51AC256 series pins and modules.

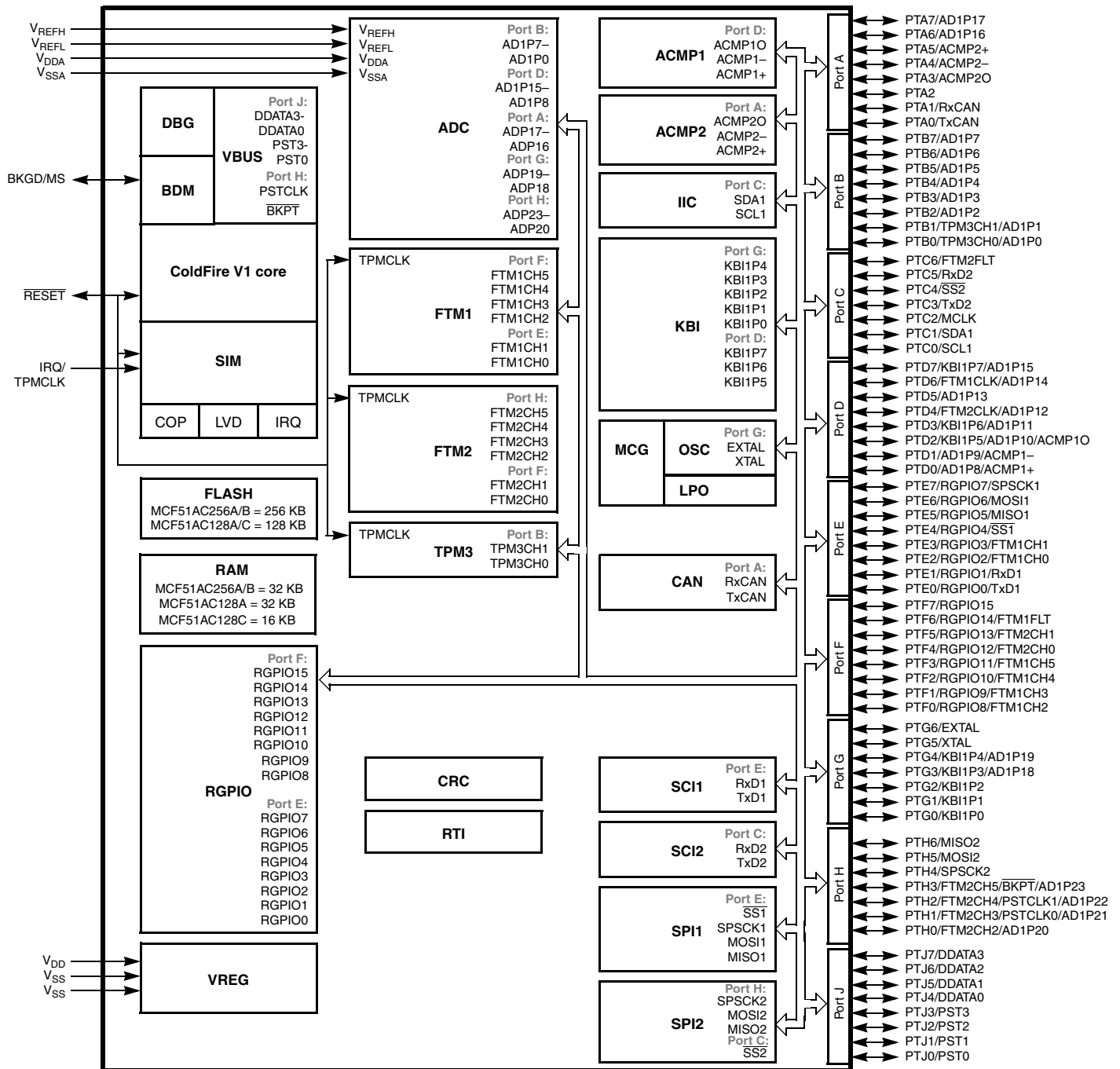


Figure 1. MCF51AC256 Series Block Diagram

## 1.3 Features

Table 2 describes the functional units of the MCF51AC256 series.

**Table 2. MCF51AC256 Series Functional Units**

| Functional Unit                                    | Function                                                                                                                                                     |
|----------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|
| CF1 Core (V1 ColdFire core)                        | Executes programs and interrupt handlers                                                                                                                     |
| BDM (background debug module)                      | Provides single pin debugging interface (part of the V1 ColdFire core)                                                                                       |
| DBG (debug)                                        | Provides debugging and emulation capabilities (part of the V1 ColdFire core)                                                                                 |
| VBUS (debug visibility bus)                        | Allows for real-time program traces (part of the V1 ColdFire core)                                                                                           |
| SIM (system integration module)                    | Controls resets and chip level interfaces between modules                                                                                                    |
| Flash (flash memory)                               | Provides storage for program code, constants and variables                                                                                                   |
| RAM (random-access memory)                         | Provides storage for program variables                                                                                                                       |
| RGPIO (rapid general-purpose input/output)         | Allows for I/O port access at CPU clock speeds                                                                                                               |
| VREG (voltage regulator)                           | Controls power management across the device                                                                                                                  |
| COP (computer operating properly)                  | Monitors a countdown timer and generates a reset if the timer is not regularly reset by the software                                                         |
| LVD (low-voltage detect)                           | Monitors internal and external supply voltage levels, and generates a reset or interrupt when the voltages are too low                                       |
| CF1_INTIC (interrupt controller)                   | Controls and prioritizes all device interrupts                                                                                                               |
| ADC (analog-to-digital converter)                  | Measures analog voltages at up to 12 bits of resolution                                                                                                      |
| FTM1, FTM2 (flexible timer/pulse-width modulators) | Provides a variety of timing-based features                                                                                                                  |
| TPM3 (timer/pulse-width modulator)                 | Provides a variety of timing-based features                                                                                                                  |
| CRC (cyclic redundancy check)                      | Accelerates computation of CRC values for ranges of memory                                                                                                   |
| ACMP1, ACMP2 (analog comparators)                  | Compares two analog inputs                                                                                                                                   |
| IIC (inter-integrated circuit)                     | Supports standard IIC communications protocol                                                                                                                |
| KBI (keyboard interrupt)                           | Provides pin interrupt capabilities                                                                                                                          |
| MCG (multipurpose clock generator)                 | Provides clocking options for the device, including a phase-locked loop (PLL) and frequency-locked loop (FLL) for multiplying slower reference clock sources |
| OSC (crystal oscillator)                           | Allows a crystal or ceramic resonator to be used as the system clock source or reference clock for the PLL or FLL                                            |
| LPO (low-power oscillator)                         | Provides a second clock source for COP and RTI.                                                                                                              |
| CAN (controller area network)                      | Supports standard CAN communications protocol                                                                                                                |
| SCI1, SCI2 (serial communications interfaces)      | Serial communications UARTs capable of supporting RS-232 and LIN protocols                                                                                   |
| SPI1 (8-bit serial peripheral interfaces)          | Provides 8-bit 4-pin synchronous serial interface                                                                                                            |
| SPI2 (16-bit serial peripheral interfaces)         | Provides 16-bit 4-pin synchronous serial interface with FIFO                                                                                                 |

### 1.3.1 Feature List

- 32-bit Version 1 ColdFire® central processor unit (CPU)
  - Up to 50.33 MHz at 2.7 V – 5.5 V
  - Provide 0.94 Dhrystone 2.1 DMIPS per MHz performance when running from internal RAM (0.76 DMIPS per MHz when running from flash)
  - Implements instruction set revision C (ISA\_C)
- On-chip memory
  - Up to 256 KB flash memory read/program/erase over full operating voltage and temperature
  - Up to 32 KB static random access memory (SRAM)
  - Security circuitry to prevent unauthorized access to SRAM and flash contents
- Power-Saving Modes
  - Three low-power stop plus wait modes
  - Peripheral clock enable register can disable clocks to unused modules, reducing currents; allows clocks to remain enabled to specific peripherals in stop3 mode
- System protection features
  - Watchdog computer operating properly (COP) reset with options to run from independent LPO clock or bus clock
  - Low-voltage detection with reset or interrupt
  - Illegal opcode and illegal address detection with programmable reset or exception response
  - Flash block protection
- Debug support
  - Single-wire background debug interface
  - Real-time debug support, with 6 hardware breakpoints (4 PC, 1 address pair and 1 data) that can be configured into a 1- or 2-level trigger
  - On-chip trace buffer provides programmable start/stop recording conditions plus support for continuous or PC-profiling modes
  - Support for real-time program (and optional partial data) trace using the debug visibility bus
- V1 ColdFire interrupt controller (CF1\_INTC)
  - Support of 40 peripheral I/O interrupt requests plus seven software (one per level) interrupt requests
  - Fixed association between interrupt request source and level plus priority, up to two requests can be remapped to the highest maskable level + priority
  - Unique vector number for each interrupt source
  - Support for service routine interrupt acknowledge (software IACK) read cycles for improved system performance
- Multipurpose clock generator (MCG)
  - 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
  - LPO clock as an optional independent clock source for COP and RTI
  - FLL/PLL controlled by internal or external reference

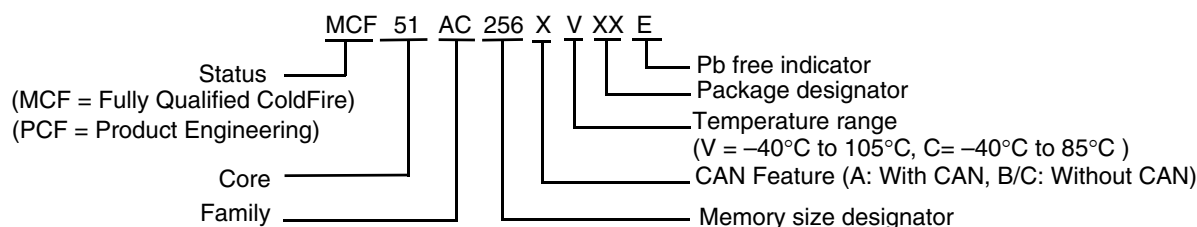
- Trimmable internal reference allows 0.2% resolution and 2% deviation
- Analog-to-digital converter (ADC)
  - 24 analog inputs with 12 bits resolution
  - Output formatted in 12-, 10- or 8-bit right-justified format
  - Single or continuous conversion (automatic return to idle after single conversion)
  - Operation in low-power modes for lower noise operation
  - Asynchronous clock source for lower noise operation
  - Automatic compare with interrupt for less-than, or greater-than or equal-to, programmable value
  - On-chip temperature sensor
- Flexible timer/pulse-width modulators (FTM)
  - 16-bit Free-running counter or a counter with initial and final value. The counting can be up and unsigned, up and signed, or up-down and unsigned
  - Up to 6 channels, and each channel can be configured for input capture, output compare or edge-aligned PWM mode, all channels can be configured for center-aligned PWM mode
    - Channels can operate as pairs with equal outputs, pairs with complimentary outputs or independent channels (with independent outputs)
    - Each pair of channels can be combined to generate a PWM signal (with independent control of both edges of PWM signal)
    - Deadtime insertion is available for each complementary pair
  - The load of the FTM registers which have write buffer can be synchronized; write protection for critical registers
  - Generation of the triggers to ADC (hardware trigger)
  - A fault input for global fault control
  - Backwards compatible with TPM
- Timer/pulse width modulator (TPM)
  - 16-bit free-running or modulo up/down count operation
  - Two channels, each channel may be input capture, output compare, or edge-aligned PWM
  - One interrupt per channel plus terminal count interrupt
- Cyclic redundancy check (CRC) generator
  - High speed hardware CRC generator circuit using 16-bit shift register
  - CRC16-CCITT compliancy with  $x^{16} + x^{12} + x^5 + 1$  polynomial
  - Error detection for all single, double, odd, and most multi-bit errors
  - Programmable initial seed value
- Analog comparators (ACMP)
  - Full rail to rail supply operation
  - Selectable interrupt on rising edge, falling edge, or either rising or falling edges of comparator output
  - Option to compare to fixed internal bandgap reference voltage
  - Option to allow comparator output to be visible on a pin, ACMPxO



- Inter-integrated circuit (IIC)
  - Compatible with IIC bus standard
  - Multi-master operation
  - Software programmable for one of 64 different serial clock frequencies
  - Interrupt driven byte-by-byte data transfer
  - Arbitration lost interrupt with automatic mode switching from master to slave
  - Calling address identification interrupt
  - Bus busy detection
  - 10-bit address extension
- Controller area network (CAN)
  - Implementation of the CAN protocol — Version 2.0A/B
    - Standard and extended data frames
    - Zero to eight bytes data length
    - Programmable bit rate up to 1 Mbps
    - Support for remote frames
  - Five receive buffers with FIFO storage scheme
  - Three transmit buffers with internal prioritization using a “local priority” concept
  - Flexible maskable identifier filter supports two full-size (32-bit) extended identifier filters, four 16-bit filters, or eight 8-bit filters
  - Programmable wakeup functionality with integrated low-pass filter
  - Programmable loopback mode supports self-test operation
  - Programmable listen-only mode for monitoring of CAN bus
  - Programmable bus-off recovery functionality
  - Separate signalling and interrupt capabilities for all CAN receiver and transmitter error states (warning, error passive, bus-off)
  - Internal timer for time-stamping of received and transmitted messages
- Serial communications interfaces (SCI)
  - Full-duplex, standard non-return-to-zero (NRZ) format
  - Double-buffered transmitter and receiver with separate enables
  - Programmable baud rates (13-bit modulo divider)
  - Interrupt-driven or polled operation
  - Hardware parity generation and checking
  - Programmable 8-bit or 9-bit character length
  - Receiver wakeup by idle-line or address-mark
  - Optional 13-bit break character generation / 11-bit break character detection
  - Selectable transmitter output polarity
- Serial peripheral interfaces (SPI)
  - Master or slave mode operation
  - Full-duplex or single-wire bidirectional option
  - Programmable transmit bit rate

- Double-buffered transmit and receive
- Serial clock phase and polarity options
- Slave select output
- Selectable MSB-first or LSB-first shifting
- 16-bit and FIFO operations in SPI2
- Input/Output
  - 69 GPIOs
  - 8 keyboard interrupt pins with selectable polarity
  - Hysteresis and configurable pull-up device on all input pins; Configurable slew rate and drive strength on all output pins
  - 16-bits Rapid GPIO pins connected to the processor's local 32-bit platform bus with set, clear, and faster toggle functionality

## 1.4 Part Numbers



**Table 3. Orderable Part Number Summary**

| Freescall Part Number | Description                                     | Flash / SRAM (Kbytes) | Package | Temperature    |
|-----------------------|-------------------------------------------------|-----------------------|---------|----------------|
| MCF51AC256AVFUE       | MCF51AC256 ColdFire Microcontroller with CAN    | 256 / 32              | 64 QFP  | -40°C to 105°C |
| MCF51AC256BVFUE       | MCF51AC256 ColdFire Microcontroller without CAN | 256 / 32              | 64 QFP  | -40°C to 105°C |
| MCF51AC256AVLKE       | MCF51AC256 ColdFire Microcontroller with CAN    | 256 / 32              | 80 LQFP | -40°C to 105°C |
| MCF51AC256BVLKE       | MCF51AC256 ColdFire Microcontroller without CAN | 256 / 32              | 80 LQFP | -40°C to 105°C |
| MCF51AC256AVPUE       | MCF51AC256 ColdFire Microcontroller with CAN    | 256 / 32              | 64 LQFP | -40°C to 105°C |
| MCF51AC256BVPUE       | MCF51AC256 ColdFire Microcontroller without CAN | 256 / 32              | 64 LQFP | -40°C to 105°C |
| MCF51AC128AVFUE       | MCF51AC128 ColdFire Microcontroller with CAN    | 128 / 32              | 64 QFP  | -40°C to 105°C |
| MCF51AC128CVFUE       | MCF51AC128 ColdFire Microcontroller without CAN | 128 / 16              | 64 QFP  | -40°C to 105°C |
| MCF51AC128AVLKE       | MCF51AC128 ColdFire Microcontroller with CAN    | 128 / 32              | 80 LQFP | -40°C to 105°C |
| MCF51AC128CVLKE       | MCF51AC128 ColdFire Microcontroller without CAN | 128 / 16              | 80 LQFP | -40°C to 105°C |
| MCF51AC128AVPUE       | MCF51AC128 ColdFire Microcontroller with CAN    | 128 / 32              | 64 LQFP | -40°C to 105°C |
| MCF51AC128CVPUE       | MCF51AC128 ColdFire Microcontroller without CAN | 128 / 16              | 64 LQFP | -40°C to 105°C |
| MCF51AC256ACFUE       | MCF51AC256 ColdFire Microcontroller with CAN    | 256 / 32              | 64 QFP  | -40°C to 85°C  |
| MCF51AC256BCFUE       | MCF51AC256 ColdFire Microcontroller without CAN | 256 / 32              | 64 QFP  | -40°C to 85°C  |
| MCF51AC256ACLKE       | MCF51AC256 ColdFire Microcontroller with CAN    | 256 / 32              | 80 LQFP | -40°C to 85°C  |
| MCF51AC256BCLKE       | MCF51AC256 ColdFire Microcontroller without CAN | 256 / 32              | 80 LQFP | -40°C to 85°C  |

Table 3. Orderable Part Number Summary

|                 |                                                 |          |         |               |
|-----------------|-------------------------------------------------|----------|---------|---------------|
| MCF51AC256ACPUE | MCF51AC256 ColdFire Microcontroller with CAN    | 256 / 32 | 64 LQFP | –40°C to 85°C |
| MCF51AC256BCPUE | MCF51AC256 ColdFire Microcontroller without CAN | 256 / 32 | 64 LQFP | –40°C to 85°C |
| MCF51AC256BCFGE | MCF51AC256 ColdFire Microcontroller without CAN | 256/32   | 44 LQFP | –40°C to 85°C |
| MCF51AC128ACFUE | MCF51AC128 ColdFire Microcontroller with CAN    | 128 / 32 | 64 QFP  | –40°C to 85°C |
| MCF51AC128CCFUE | MCF51AC128 ColdFire Microcontroller without CAN | 128 / 16 | 64 QFP  | –40°C to 85°C |
| MCF51AC128ACLKE | MCF51AC128 ColdFire Microcontroller with CAN    | 128 / 32 | 80 LQFP | –40°C to 85°C |
| MCF51AC128CCLKE | MCF51AC128 ColdFire Microcontroller without CAN | 128 / 16 | 80 LQFP | –40°C to 85°C |
| MCF51AC128ACPUE | MCF51AC128 ColdFire Microcontroller with CAN    | 128 / 32 | 64 LQFP | –40°C to 85°C |
| MCF51AC128CCPUE | MCF51AC128 ColdFire Microcontroller without CAN | 128 / 16 | 64 LQFP | –40°C to 85°C |
| MCF51AC128CCFGE | MCF51AC128 ColdFire Microcontroller without CAN | 128 / 16 | 44 LQFP | –40°C to 85°C |

## 1.5 Pinouts and Packaging

Figure 2 shows the pinout of the 80-pin LQFP.

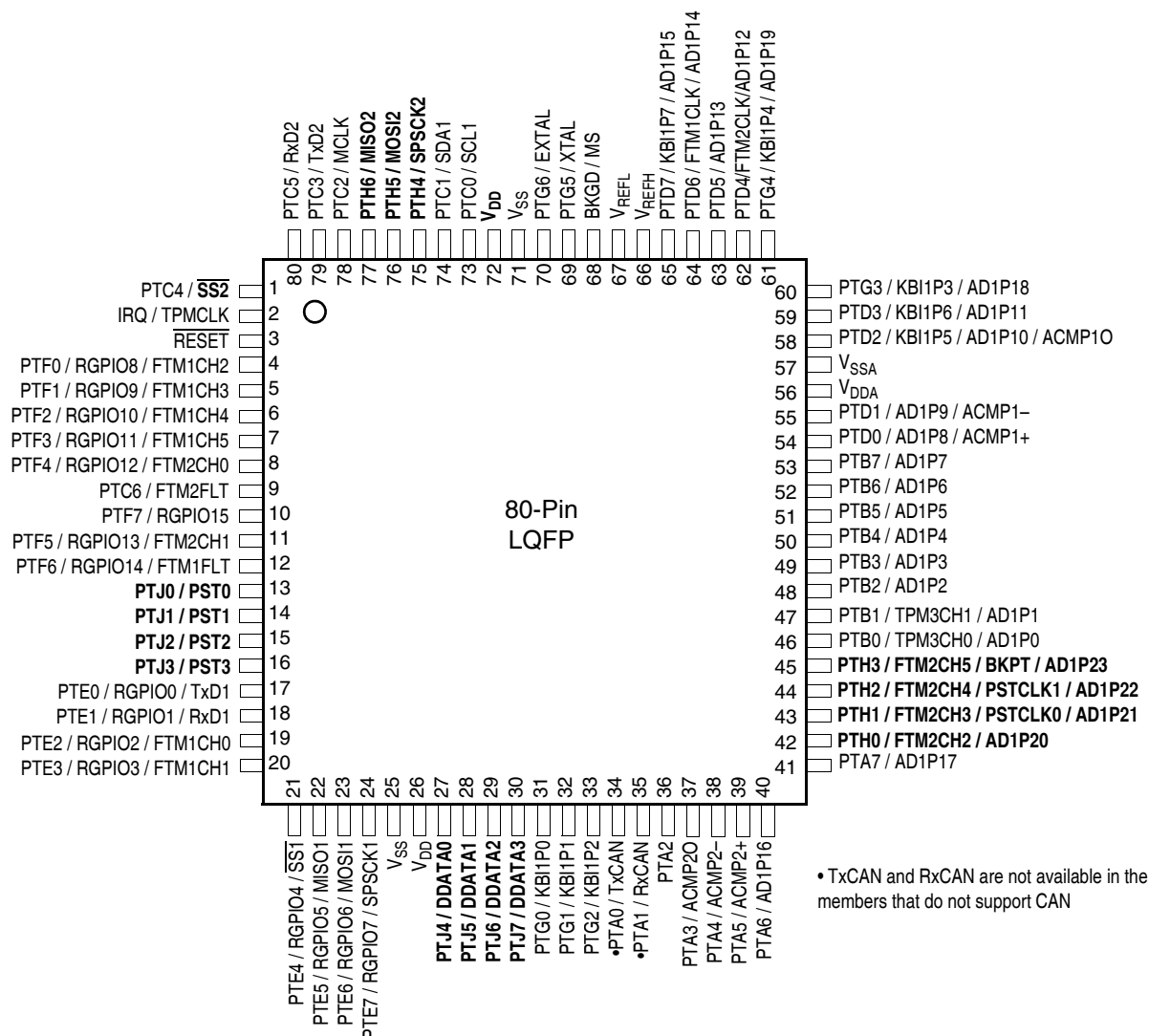
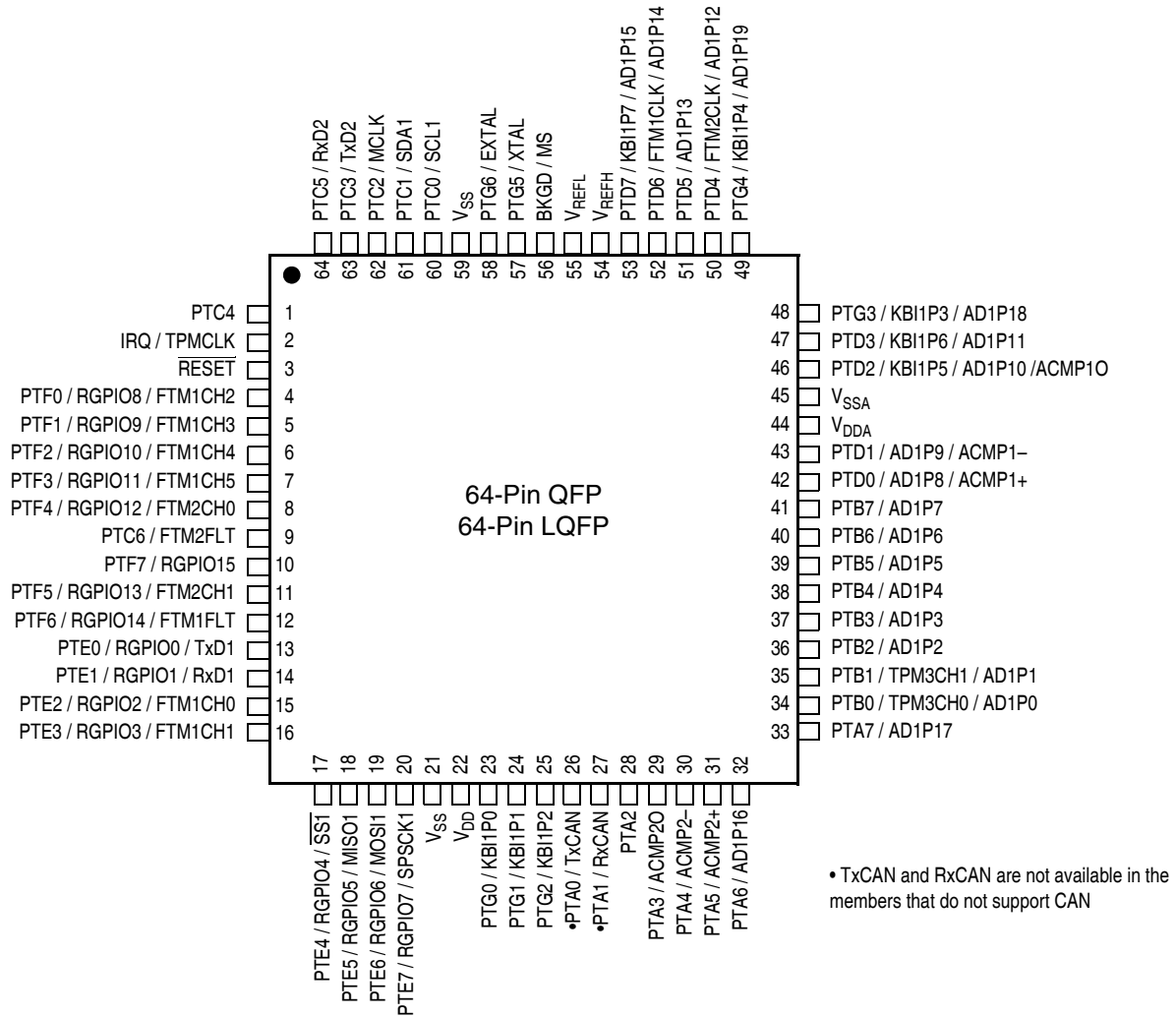


Figure 2. MCF51AC256 Series ColdFire Microcontroller 80-Pin LQFP

Figure 3 shows the pinout of the 64-pin LQFP and QFP.



**Figure 3. MCF51AC256 Series ColdFire Microcontroller 64-Pin QFP/LQFP**

Figure 4 shows the pinout of the 44-pin LQFP.

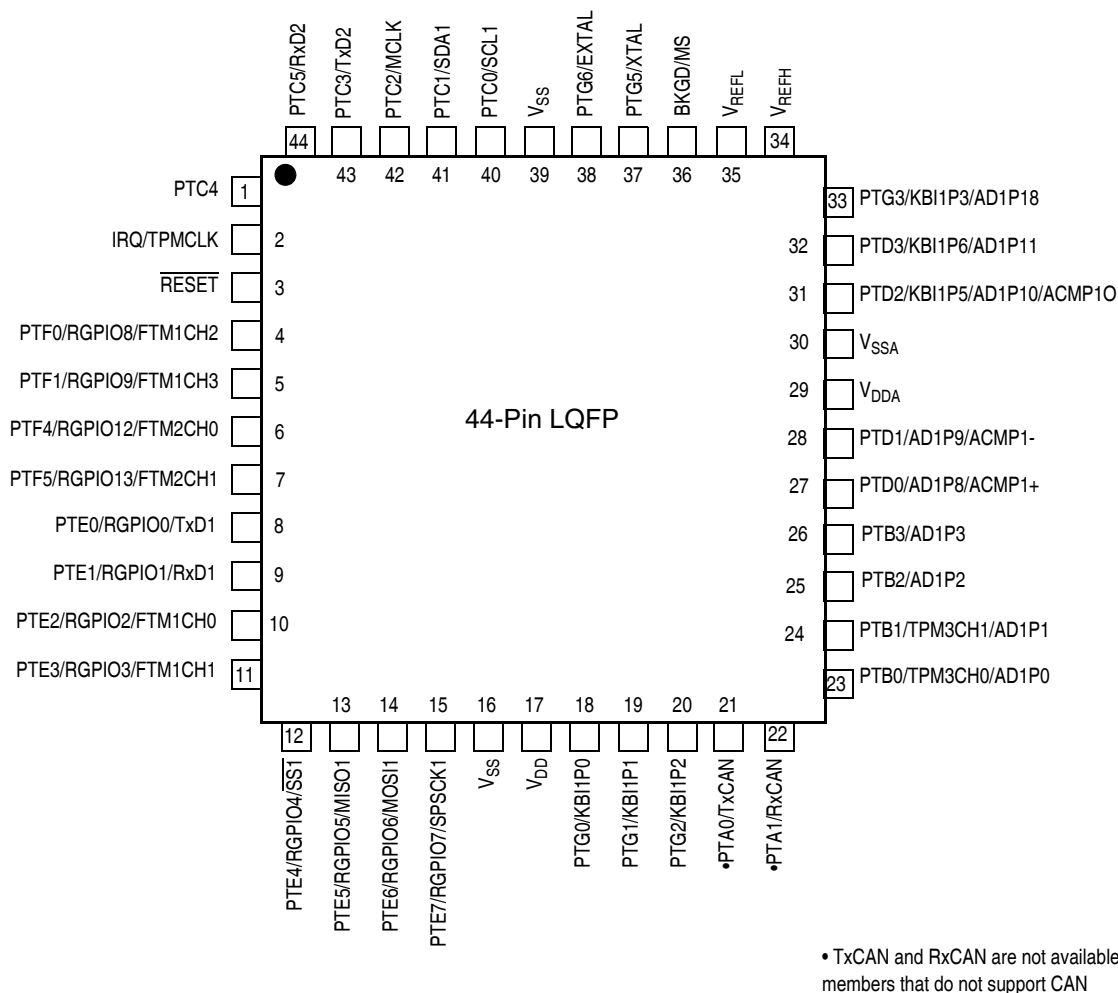


Figure 4. MCF51AC256 Series ColdFire Microcontroller 44-Pin LQFP

Table 4 shows the package pin assignments.

Table 4. Pin Availability by Package Pin-Count

| Pin Number |    |    | Lowest <-- Priority --> Highest |                     |         |       |
|------------|----|----|---------------------------------|---------------------|---------|-------|
| 80         | 64 | 44 | Port Pin                        | Alt 1               | Alt 2   | Alt 3 |
| 1          | 1  | 1  | PTC4                            | SS2                 |         |       |
| 2          | 2  | 2  | IRQ                             | TPMCLK <sup>1</sup> |         |       |
| 3          | 3  | 3  | RESET                           |                     |         |       |
| 4          | 4  | 4  | PTF0                            | RGPIO8              | FTM1CH2 |       |
| 5          | 5  | 5  | PTF1                            | RGPIO9              | FTM1CH3 |       |
| 6          | 6  | —  | PTF2                            | RGPIO10             | FTM1CH4 |       |
| 7          | 7  | —  | PTF3                            | RGPIO11             | FTM1CH5 |       |

Table 4. Pin Availability by Package Pin-Count (continued)

| Pin Number |    |    | Lowest <-- Priority --> Highest |                    |         |        |
|------------|----|----|---------------------------------|--------------------|---------|--------|
| 80         | 64 | 44 | Port Pin                        | Alt 1              | Alt 2   | Alt 3  |
| 8          | 8  | 6  | PTF4                            | RGPIO12            | FTM2CH0 |        |
| 9          | 9  | —  | PTC6                            | FTM2FLT            |         |        |
| 10         | 10 | —  | PTF7                            | RGPIO15            |         |        |
| 11         | 11 | 7  | PTF5                            | RGPIO13            | FTM2CH1 |        |
| 12         | 12 | —  | PTF6                            | RGPIO14            | FTM1FLT |        |
| 13         | —  | —  | PTJ0                            | PST0               |         |        |
| 14         | —  | —  | PTJ1                            | PST1               |         |        |
| 15         | —  | —  | PTJ2                            | PST2               |         |        |
| 16         | —  | —  | PTJ3                            | PST3               |         |        |
| 17         | 13 | 8  | PTE0                            | RGPIO0             | TxD1    |        |
| 18         | 14 | 9  | PTE1                            | RGPIO1             | RxD1    |        |
| 19         | 15 | 10 | PTE2                            | RGPIO2             | FTM1CH0 |        |
| 20         | 16 | 11 | PTE3                            | RGPIO3             | FTM1CH1 |        |
| 21         | 17 | 12 | PTE4                            | RGPIO4             | SS1     |        |
| 22         | 18 | 13 | PTE5                            | RGPIO5             | MISO1   |        |
| 23         | 19 | 14 | PTE6                            | RGPIO6             | MOSI1   |        |
| 24         | 20 | 15 | PTE7                            | RGPIO7             | SPSCK1  |        |
| 25         | 21 | 16 | V <sub>SS</sub>                 |                    |         |        |
| 26         | 22 | 17 | V <sub>DD</sub>                 |                    |         |        |
| 27         | —  | —  | PTJ4                            | DDATA0             |         |        |
| 28         | —  | —  | PTJ5                            | DDATA1             |         |        |
| 29         | —  | —  | PTJ6                            | DDATA2             |         |        |
| 30         | —  | —  | PTJ7                            | DDATA3             |         |        |
| 31         | 23 | 18 | PTG0                            | KBI1P0             |         |        |
| 32         | 24 | 19 | PTG1                            | KBI1P1             |         |        |
| 33         | 25 | 20 | PTG2                            | KBI1P2             |         |        |
| 34         | 26 | 21 | PTA0                            | TxCAN <sup>2</sup> |         |        |
| 35         | 27 | 22 | PTA1                            | RxCAN <sup>3</sup> |         |        |
| 36         | 28 | —  | PTA2                            |                    |         |        |
| 37         | 29 | —  | PTA3                            | ACMP2O             |         |        |
| 38         | 30 | —  | PTA4                            | ACMP2–             |         |        |
| 39         | 31 | —  | PTA5                            | ACMP2+             |         |        |
| 40         | 32 | —  | PTA6                            | AD1P16             |         |        |
| 41         | 33 | —  | PTA7                            | AD1P17             |         |        |
| 42         | —  | —  | PTH0                            | FTM2CH2            | AD1P20  |        |
| 43         | —  | —  | PTH1                            | FTM2CH3            | PSTCLK0 | AD1P21 |
| 44         | —  | —  | PTH2                            | FTM2CH4            | PSTCLK1 | AD1P22 |
| 45         | —  | —  | PTH3                            | FTM2CH5            | BKPT    | AD1P23 |
| 46         | 34 | 23 | PTB0                            | TPM3CH0            | AD1P0   |        |
| 47         | 35 | 24 | PTB1                            | TPM3CH1            | AD1P1   |        |
| 48         | 36 | 25 | PTB2                            | AD1P2              |         |        |

Table 4. Pin Availability by Package Pin-Count (continued)

| Pin Number |    |    | Lowest <-- Priority --> Highest |         |        |        |
|------------|----|----|---------------------------------|---------|--------|--------|
| 80         | 64 | 44 | Port Pin                        | Alt 1   | Alt 2  | Alt 3  |
| 49         | 37 | 26 | PTB3                            | AD1P3   |        |        |
| 50         | 38 | —  | PTB4                            | AD1P4   |        |        |
| 51         | 39 | —  | PTB5                            | AD1P5   |        |        |
| 52         | 40 | —  | PTB6                            | AD1P6   |        |        |
| 53         | 41 | —  | PTB7                            | AD1P7   |        |        |
| 54         | 42 | 27 | PTD0                            | AD1P8   | ACMP1+ |        |
| 55         | 43 | 28 | PTD1                            | AD1P9   | ACMP1– |        |
| 56         | 44 | 29 | V <sub>DDA</sub>                |         |        |        |
| 57         | 45 | 30 | V <sub>SSA</sub>                |         |        |        |
| 58         | 46 | 31 | PTD2                            | KBI1P5  | AD1P10 | ACMP1O |
| 59         | 47 | 32 | PTD3                            | KBI1P6  | AD1P11 |        |
| 60         | 48 | 33 | PTG3                            | KBI1P3  | AD1P18 |        |
| 61         | 49 | —  | PTG4                            | KBI1P4  | AD1P19 |        |
| 62         | 50 | —  | PTD4                            | FTM2CLK | AD1P12 |        |
| 63         | 51 | —  | PTD5                            | AD1P13  |        |        |
| 64         | 52 | —  | PTD6                            | FTM1CLK | AD1P14 |        |
| 65         | 53 | —  | PTD7                            | KBI1P7  | AD1P15 |        |
| 66         | 54 | 34 | V <sub>REFH</sub>               |         |        |        |
| 67         | 55 | 35 | V <sub>REFL</sub>               |         |        |        |
| 68         | 56 | 36 | BKGD                            | MS      |        |        |
| 69         | 57 | 37 | PTG5                            | XTAL    |        |        |
| 70         | 58 | 38 | PTG6                            | EXTAL   |        |        |
| 71         | 59 | 39 | V <sub>SS</sub>                 |         |        |        |
| 72         | —  | —  | V <sub>DD</sub>                 |         |        |        |
| 73         | 60 | 40 | PTC0                            | SCL1    |        |        |
| 74         | 61 | 41 | PTC1                            | SDA1    |        |        |
| 75         | —  | —  | PTH4                            | SPCK2   |        |        |
| 76         | —  | —  | PTH5                            | MOSI2   |        |        |
| 77         | —  | —  | PTH6                            | MISO2   |        |        |
| 78         | 62 | 42 | PTC2                            | MCLK    |        |        |
| 79         | 63 | 43 | PTC3                            | TxD2    |        |        |
| 80         | 64 | 44 | PTC5                            | RxD2    |        |        |

<sup>1</sup> TPMCLK, FTM1CLK, and FTM2CLK options are configured via software; out of reset, FTM1CLK, FTM2CLK, and TPMCLK are available to FTM1, FTM2, and TPM3 respectively.

<sup>2</sup> TxCAN is available in the member that supports CAN.

<sup>3</sup> RxCAN is available in the member that supports CAN.



## 2 Electrical Characteristics

This section contains electrical specification tables and reference timing diagrams for the MCF51AC256 microcontroller, including detailed information on power considerations, DC/AC electrical characteristics, and AC timing specifications.

The electrical specifications are preliminary and are from previous designs or design simulations. These specifications may not be fully tested or guaranteed at this early stage of the product life cycle. These specifications will, however, be met for production silicon. Finalized specifications will be published after complete characterization and device qualifications have been completed.

### NOTE

The parameters specified in this data sheet supersede any values found in the module specifications.

### 2.1 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 5. Parameter Classifications**

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

### NOTE

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

### 2.2 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 6](#) 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  $V_{DD}$ ).

**Table 6. Absolute Maximum Ratings**

| Rating                                                                                          | Symbol    | Value                  | Unit |
|-------------------------------------------------------------------------------------------------|-----------|------------------------|------|
| Supply voltage                                                                                  | $V_{DD}$  | -0.3 to 5.8            | V    |
| 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   |
| Maximum current into $V_{DD}$                                                                   | $I_{DD}$  | 120                    | mA   |
| Storage temperature                                                                             | $T_{stg}$ | -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  $V_{DD}$ .

<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.

## 2.3 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 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 7. Thermal Characteristics**

| Rating                                 | Symbol        | Value      | Unit |
|----------------------------------------|---------------|------------|------|
| Operating temperature range (packaged) | $T_A$         | -40 to 105 | °C   |
| Maximum junction temperature           | $T_J$         | 150        | °C   |
| Thermal resistance <sup>1,2,3,4</sup>  |               |            |      |
| 80-pin LQFP                            |               |            |      |
| 1s                                     |               | 51         |      |
| 2s2p                                   |               | 38         |      |
| 64-pin LQFP                            |               |            |      |
| 1s                                     |               | 59         |      |
| 2s2p                                   | $\theta_{JA}$ | 41         | °C/W |
| 64-pin QFP                             |               |            |      |
| 1s                                     |               | 50         |      |
| 2s2p                                   |               | 36         |      |
| 44-pin LQFP                            |               |            |      |
| 1s                                     |               | 67         |      |
| 2s2p                                   |               | 45         |      |

- <sup>1</sup> Junction temperature is a function of die size, on-chip power dissipation, package thermal resistance, mounting site (board) temperature, ambient temperature, air flow, power dissipation of other components on the board, and board thermal resistance
- <sup>2</sup> Junction to Ambient Natural Convection
- <sup>3</sup> 1s — Single layer board, one signal layer
- <sup>4</sup> 2s2p — Four layer board, 2 signal and 2 power layers

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  $T_A$ .

## 2.4 Electrostatic Discharge (ESD) Protection Characteristics

Although damage from static discharge 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 CDF-AEC-Q00 Stress Test Qualification for Automotive Grade Integrated Circuits. (<http://www.aecouncil.com/>) This device was qualified to AEC-Q100 Rev E.

A device is considered to have failed if, after exposure to ESD pulses, the device no longer meets the device specification requirements. Complete dc parametric and functional testing is performed per the

## Electrical Characteristics

applicable device specification at room temperature followed by hot temperature, unless specified otherwise in the device specification.

**Table 8. 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 pulse per pin     | —      | 3     |          |
| Charge device model | Series resistance           | R1     | 0     | $\Omega$ |
|                     | Storage capacitance         | C      | 0     | pF       |
|                     | Number of pulse per pin     | —      | 3     | —        |
| Latch-up            | Minimum input voltage limit | —      | -2.5  | V        |
|                     | Maximum input voltage limit | —      | 7.5   | V        |

**Table 9. ESD and Latch-Up Protection Characteristics**

| Num | Rating                                       | Symbol    | Min        | Max | Unit |
|-----|----------------------------------------------|-----------|------------|-----|------|
| 1   | Human body model (HBM)                       | $V_{HBM}$ | $\pm 2000$ | —   | V    |
| 2   | Charge device model (CDM)                    | $V_{CDM}$ | $\pm 500$  | —   | V    |
| 3   | Latch-up current at $T_A = 85^\circ\text{C}$ | $I_{LAT}$ | $\pm 100$  | —   | mA   |

## 2.5 DC Characteristics

This section includes information about power supply requirements, I/O pin characteristics, and power supply current in various operating modes.

**Table 10. DC Characteristics**

| Num | C | Parameter                                                                                                                                                  | Symbol   | Min                                                                  | Typical <sup>1</sup> | Max              | Unit |
|-----|---|------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|----------------------------------------------------------------------|----------------------|------------------|------|
| 1   | — | Operating voltage                                                                                                                                          |          | 2.7                                                                  | —                    | 5.5              | V    |
| 2   | P | Output high voltage — Low drive (PTxDSn = 0)<br>5 V, $I_{Load} = -4$ mA<br>3 V, $I_{Load} = -2$ mA<br>5 V, $I_{Load} = -2$ mA<br>3 V, $I_{Load} = -1$ mA   | $V_{OH}$ | $V_{DD} - 1.5$<br>$V_{DD} - 1.5$<br>$V_{DD} - 0.8$<br>$V_{DD} - 0.8$ | —<br>—<br>—<br>—     | —<br>—<br>—<br>— | V    |
|     |   | Output high voltage — High drive (PTxDSn = 1)<br>5 V, $I_{Load} = -15$ mA<br>3 V, $I_{Load} = -8$ mA<br>5 V, $I_{Load} = -8$ mA<br>3 V, $I_{Load} = -4$ mA |          | $V_{DD} - 1.5$<br>$V_{DD} - 1.5$<br>$V_{DD} - 0.8$<br>$V_{DD} - 0.8$ | —<br>—<br>—<br>—     | —<br>—<br>—<br>— |      |

Table 10. DC Characteristics (continued)

| Num | C | Parameter                                                                                                                                                                         | Symbol            | Min                    | Typical <sup>1</sup> | Max                      | Unit |
|-----|---|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|------------------------|----------------------|--------------------------|------|
| 3   | P | Output low voltage — Low Drive (PTxDSn = 0)<br>5 V, I <sub>Load</sub> = 4 mA<br>3 V, I <sub>Load</sub> = 2 mA<br>5 V, I <sub>Load</sub> = 2 mA<br>3 V, I <sub>Load</sub> = 1 mA   | V <sub>OL</sub>   | —                      | —                    | 1.5<br>1.5<br>0.8<br>0.8 | V    |
|     |   | Output low voltage — High Drive (PTxDSn = 1)<br>5 V, I <sub>Load</sub> = 15 mA<br>3 V, I <sub>Load</sub> = 8 mA<br>5 V, I <sub>Load</sub> = 8 mA<br>3 V, I <sub>Load</sub> = 4 mA |                   | —                      | —                    | 1.5<br>1.5<br>0.8<br>0.8 |      |
| 4   | C | Output high current — Max total I <sub>OH</sub> for all ports<br>5V<br>3V                                                                                                         | I <sub>OHT</sub>  | —                      | —                    | 100<br>60                | mA   |
| 5   | C | Output low current — Max total I <sub>OL</sub> for all ports<br>5 V<br>3 V                                                                                                        | I <sub>OLT</sub>  | —                      | —                    | 100<br>60                | mA   |
| 6   | P | Input high voltage; all digital inputs                                                                                                                                            | V <sub>IH</sub>   | 0.65 × V <sub>DD</sub> | —                    | —                        | V    |
| 7   | P | Input low voltage; all digital inputs                                                                                                                                             | V <sub>IL</sub>   | —                      | —                    | 0.35 × V <sub>DD</sub>   | V    |
| 8   | D | Input hysteresis; all digital inputs                                                                                                                                              | V <sub>hys</sub>  | 0.06 × V <sub>DD</sub> | —                    | —                        | mV   |
| 9   | P | Input leakage current; input only pins <sup>2</sup>                                                                                                                               | I <sub>in</sub>   | —                      | 0.1                  | 1                        | μA   |
| 10  | P | High impedance (off-state) leakage current <sup>2</sup>                                                                                                                           | I <sub>OZ</sub>   | —                      | 0.1                  | 1                        | μA   |
| 11  | P | Internal pullup resistors <sup>3</sup>                                                                                                                                            | R <sub>PU</sub>   | 20                     | 45                   | 65                       | kΩ   |
| 12  | P | Internal pulldown resistors <sup>4</sup>                                                                                                                                          | R <sub>PD</sub>   | 20                     | 45                   | 65                       | kΩ   |
| 13  | C | Input capacitance; all non-supply pins                                                                                                                                            | C <sub>In</sub>   | —                      | —                    | 8                        | pF   |
| 14  | P | POR rearm voltage                                                                                                                                                                 | V <sub>POR</sub>  | 0.9                    | 1.4                  | 2.0                      | V    |
| 15  | D | POR rearm time                                                                                                                                                                    | t <sub>POR</sub>  | 10                     | —                    | —                        | μs   |
| 16  | P | Low-voltage detection threshold —<br>high range<br>V <sub>DD</sub> falling<br>V <sub>DD</sub> rising                                                                              | V <sub>LVDH</sub> | 4.2<br>4.27            | 4.35<br>4.4          | 4.5<br>4.6               | V    |
| 17  | P | Low-voltage detection threshold —<br>low range<br>V <sub>DD</sub> falling<br>V <sub>DD</sub> rising                                                                               | V <sub>LVDL</sub> | 2.48<br>2.5            | 2.68<br>2.7          | 2.7<br>2.72              | V    |
| 18  | P | Low-voltage warning threshold —<br>high range<br>V <sub>DD</sub> falling<br>V <sub>DD</sub> rising                                                                                | V <sub>LVWH</sub> | 4.2<br>4.27            | 4.4<br>4.45          | 4.5<br>4.6               | V    |
| 19  | P | Low-voltage warning threshold<br>low range<br>V <sub>DD</sub> falling<br>V <sub>DD</sub> rising                                                                                   | V <sub>LVWL</sub> | 2.48<br>2.5            | 2.68<br>2.7          | 2.7<br>2.72              | V    |
| 20  | T | Low-voltage inhibit reset/recover hysteresis<br>5 V<br>3 V                                                                                                                        | V <sub>hys</sub>  | —                      | 100<br>60            | —                        | mV   |
| 21  | D | RAM retention voltage                                                                                                                                                             | V <sub>RAM</sub>  | —                      | 0.6                  | 1.0                      | V    |

Table 10. DC Characteristics (continued)

| Num | C | Parameter                                                                                                           | Symbol   | Min    | Typical <sup>1</sup> | Max       | Unit |
|-----|---|---------------------------------------------------------------------------------------------------------------------|----------|--------|----------------------|-----------|------|
| 22  | D | DC injection current <sup>5 6 7 8</sup> (single pin limit)<br>$V_{IN} > V_{DD}$<br>$V_{IN} < V_{SS}$                | $I_{IC}$ | 0<br>0 | —                    | 2<br>-0.2 | mA   |
|     |   | DC injection current (Total MCU limit, includes sum of all stressed pins)<br>$V_{IN} > V_{DD}$<br>$V_{IN} < V_{SS}$ |          | 0<br>0 | —                    | 25<br>-5  | mA   |

<sup>1</sup> Typical values are based on characterization data at 25°C unless otherwise stated.

<sup>2</sup> Measured with  $V_{IN} = V_{DD}$  or  $V_{SS}$ .

<sup>3</sup> Measured with  $V_{IN} = V_{SS}$ .

<sup>4</sup> Measured with  $V_{IN} = V_{DD}$ .

<sup>5</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 clock rate is very low (which would reduce overall power consumption).

<sup>6</sup> All functional non-supply pins are internally clamped to  $V_{SS}$  and  $V_{DD}$ .

<sup>7</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>8</sup> The **RESET** pin does not have a clamp diode to  $V_{DD}$ . Do not drive this pin above  $V_{DD}$ .

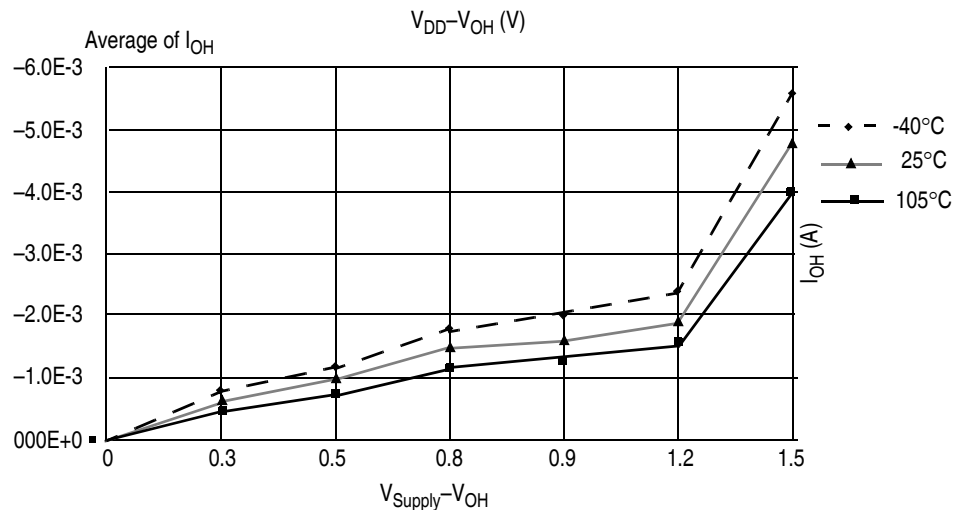


Figure 5. Typical  $I_{OH}$  vs.  $V_{DD} - V_{OH}$  at  $V_{DD} = 3$  V (Low Drive,  $PTxDSn = 0$ )

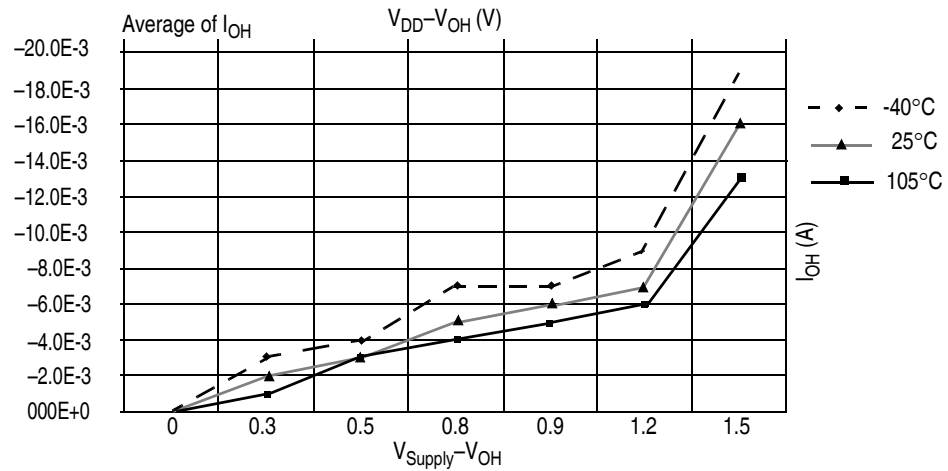


Figure 6. Typical  $I_{OH}$  vs.  $V_{DD}-V_{OH}$  at  $V_{DD} = 3$  V (High Drive, PTxDSn = 1)

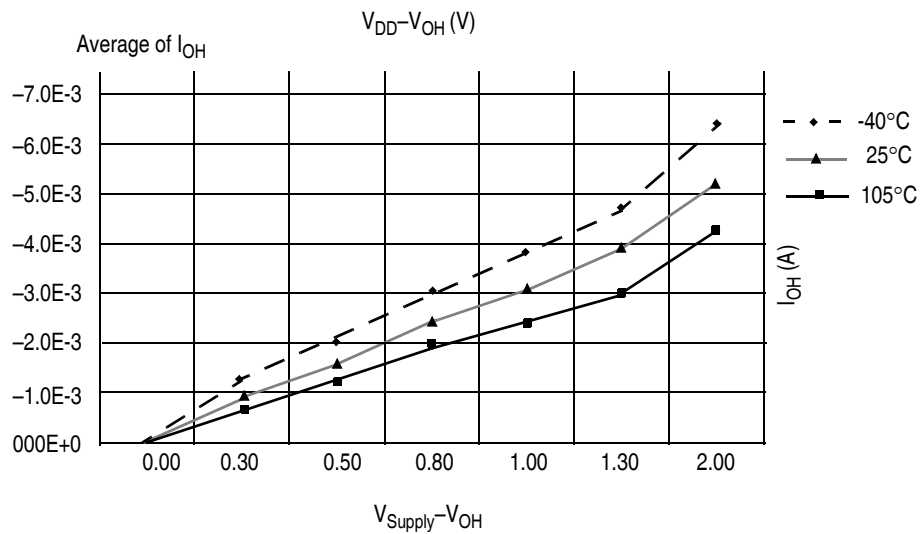


Figure 7. Typical  $I_{OH}$  vs.  $V_{DD}-V_{OH}$  at  $V_{DD} = 5$  V (Low Drive, PTxDSn = 0)

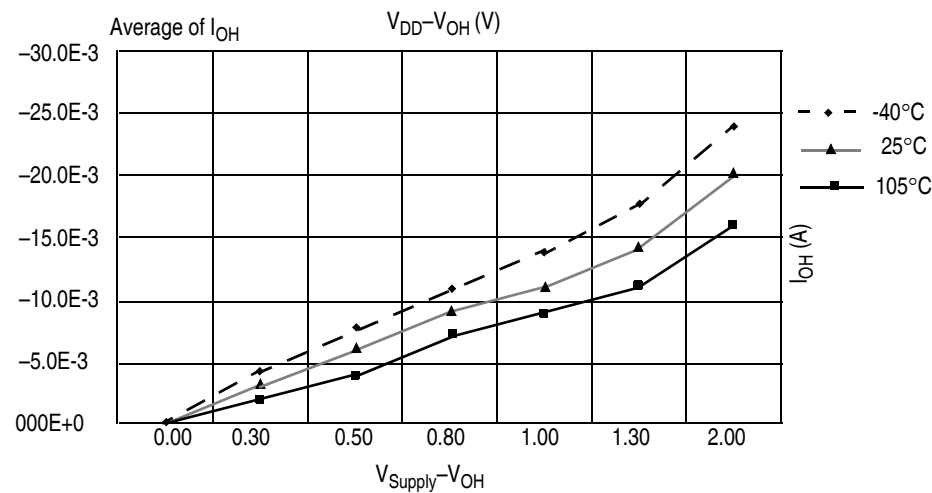


Figure 8. Typical  $I_{OH}$  vs.  $V_{DD}-V_{OH}$  at  $V_{DD} = 5$  V (High Drive, PTxDSn = 1)



## 2.6 Supply Current Characteristics

Table 11. Supply Current Characteristics

| Num | C | Parameter                                                                                       |        | Symbol                       | V <sub>DD</sub> (V) | Typical <sup>1</sup> | Max <sup>2</sup> | Unit |
|-----|---|-------------------------------------------------------------------------------------------------|--------|------------------------------|---------------------|----------------------|------------------|------|
| 1   | T | Run supply current measured at FEI mode, all modules off, system clock at:                      | 2 MHz  | R <sub>I</sub> <sub>DD</sub> | 5                   | 2.27                 | —                | mA   |
|     |   |                                                                                                 |        |                              | 3.3                 | 2.24                 | —                |      |
|     |   |                                                                                                 | 4 MHz  |                              | 5                   | 3.67                 | —                |      |
|     |   |                                                                                                 |        |                              | 3.3                 | 3.64                 | —                |      |
|     |   |                                                                                                 | 8 MHz  |                              | 5                   | 6.55                 | —                |      |
|     |   |                                                                                                 |        |                              | 3.3                 | 6.54                 | —                |      |
|     |   |                                                                                                 | 16 MHz |                              | 5                   | 11.90                | —                |      |
|     |   |                                                                                                 |        |                              | 3.3                 | 11.85                | —                |      |
| 2   | T | Run supply current measured at FEI mode, all modules on, system clock at:                       | 2 MHz  |                              | 5                   | 3.28                 | —                |      |
|     |   |                                                                                                 |        |                              | 3.3                 | 3.26                 | —                |      |
|     |   |                                                                                                 | 4 MHz  |                              | 5                   | 4.33                 | —                |      |
|     |   |                                                                                                 |        |                              | 3.3                 | 4.32                 | —                |      |
|     |   |                                                                                                 | 8 MHz  |                              | 5                   | 8.17                 | —                |      |
|     |   |                                                                                                 |        |                              | 3.3                 | 8.05                 | —                |      |
|     |   |                                                                                                 | 16 MHz |                              | 5                   | 14.8                 | —                |      |
|     |   |                                                                                                 |        |                              | 3.3                 | 14.74                | —                |      |
| 3   | T | Run supply current measured at FBE mode, all modules off (RANGE = 1, HGO = 0), system clock at: | 2 MHz  |                              | 5                   | 3.28                 | —                |      |
|     |   |                                                                                                 |        |                              | 3.3                 | 3.26                 | —                |      |
|     |   |                                                                                                 | 4 MHz  |                              | 5                   | 4.69                 | —                |      |
|     |   |                                                                                                 |        |                              | 3.3                 | 4.67                 | —                |      |
|     |   |                                                                                                 | 8 MHz  |                              | 5                   | 7.48                 | —                |      |
|     |   |                                                                                                 |        |                              | 3.3                 | 7.46                 | —                |      |
|     |   |                                                                                                 | 16 MHz |                              | 5                   | 13.10                | —                |      |
|     |   |                                                                                                 |        |                              | 3.3                 | 13.07                | —                |      |
| 4   | T | Run supply current measured at FBE mode, all modules on (RANGE = 1, HGO = 0), system clock at:  | 2 MHz  |                              | 5                   | 3.64                 | —                |      |
|     |   |                                                                                                 |        |                              | 3.3                 | 3.63                 | —                |      |
|     |   |                                                                                                 | 4 MHz  |                              | 5                   | 5.38                 | —                |      |
|     |   |                                                                                                 |        |                              | 3.3                 | 5.35                 | —                |      |
|     |   |                                                                                                 | 8 MHz  |                              | 5                   | 8.65                 | —                |      |
|     |   |                                                                                                 |        |                              | 3.3                 | 8.64                 | —                |      |
|     |   |                                                                                                 | 16 MHz |                              | 5                   | 15.55                | —                |      |
|     |   |                                                                                                 |        |                              | 3.3                 | 15.40                | —                |      |

Table 11. Supply Current Characteristics (continued)

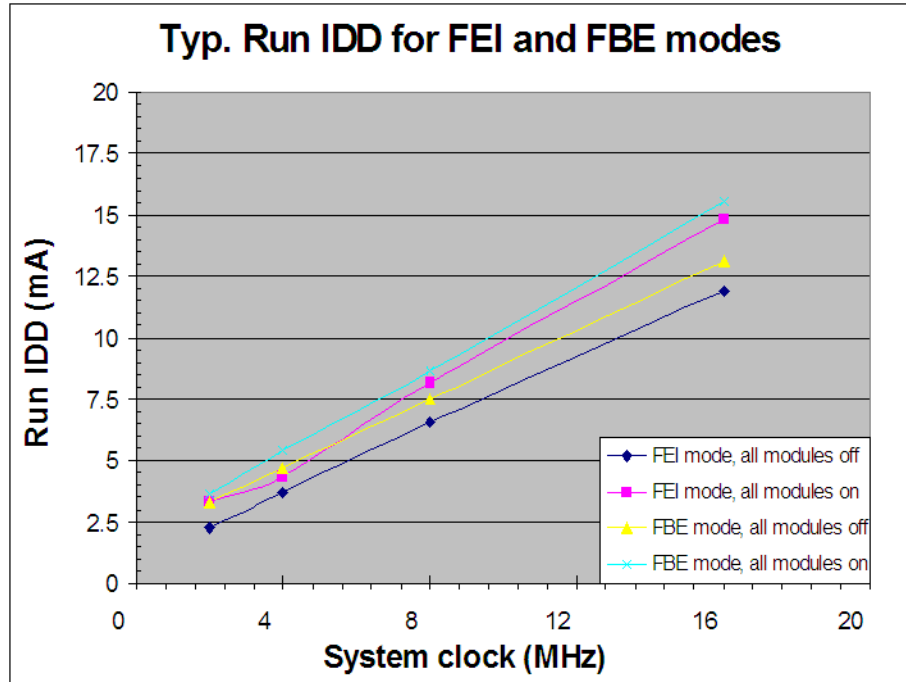
| Num | C | Parameter                                                                                         | Symbol                | V <sub>DD</sub> (V) | Typical <sup>1</sup> | Max <sup>2</sup>  | Unit |
|-----|---|---------------------------------------------------------------------------------------------------|-----------------------|---------------------|----------------------|-------------------|------|
| 5   | C | Wait mode supply <sup>3</sup> current measured at (CPU clock = 2 MHz, f <sub>BUS</sub> = 1 MHz)   | W <sub>I</sub> DD     | 5                   | 1.3                  | 2                 | mA   |
|     |   |                                                                                                   |                       | 3                   | 1.29                 | 2                 |      |
| 6   | C | Wait mode supply <sup>3</sup> current measured at (CPU clock = 16 MHz, f <sub>BUS</sub> = 8 MHz)  |                       | 5                   | 5.11                 | 8                 | mA   |
|     |   |                                                                                                   |                       | 3                   | 5.1                  | 8                 |      |
| 7   | C | Wait mode supply <sup>3</sup> current measured at (CPU clock = 50 MHz, f <sub>BUS</sub> = 25 MHz) |                       | 5                   | 15.24                | 25                | mA   |
|     |   |                                                                                                   |                       | 3                   | 15.2                 | 25                |      |
| 8   | C | Stop2 mode supply current<br>-40 °C<br>25 °C<br>120 °C                                            | S2I <sub>DD</sub>     | 5                   | 1.40                 | 2.5<br>2.5<br>200 | μA   |
|     |   |                                                                                                   |                       | 3                   | 1.16                 | 2.5<br>2.5<br>200 | μA   |
|     |   |                                                                                                   |                       | 5                   | 1.60                 | 2.5<br>2.5<br>220 | μA   |
|     |   |                                                                                                   |                       | 3                   | 1.35                 | 2.5<br>2.5<br>220 | μA   |
| 9   | C | Stop3 mode supply current<br>-40 °C<br>25 °C<br>120 °C                                            | S3I <sub>DD</sub>     | 5                   | 1.60                 | 2.5<br>2.5<br>220 | μA   |
|     |   |                                                                                                   |                       | 3                   | 1.35                 | 2.5<br>2.5<br>220 | μA   |
| 10  | C | RTI adder to stop2 or stop3 <sup>3</sup> , 25 °C                                                  | S23I <sub>DDRTI</sub> | 5                   | 300                  |                   | nA   |
|     |   |                                                                                                   |                       | 3                   | 300                  |                   | nA   |
| 11  | C | Adder to stop3 for oscillator enabled <sup>4</sup> (ERCLKEN = 1 and EREFSTEN = 1)                 | S3I <sub>DDOSC</sub>  | 5, 3                | 5                    |                   | μA   |

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

<sup>2</sup> Values given here are preliminary estimates prior to completing characterization.

<sup>3</sup> Most customers are expected to find that auto-wakeup from stop2 or stop3 can be used instead of the higher current wait mode.

<sup>4</sup> Values given under the following conditions: low range operation (RANGE = 0), low power mode (HGO = 0).

Figure 9. Typical Run  $I_{DD}$  vs. System Clock Freq. for FEI and FBE Modes

## 2.7 Analog Comparator (ACMP) Electricals

Table 12. Analog Comparator Electrical Specifications

| Num | C | Rating                                                                            | Symbol      | Min            | Typical | Max      | Unit    |
|-----|---|-----------------------------------------------------------------------------------|-------------|----------------|---------|----------|---------|
| 1   | — | Supply voltage                                                                    | $V_{DD}$    | 2.7            | —       | 5.5      | V       |
| 2   | T | Supply current (active)                                                           | $I_{DDAC}$  | —              | 20      | 35       | $\mu A$ |
| 3   | D | Analog input voltage                                                              | $V_{AIN}$   | $V_{SS} - 0.3$ | —       | $V_{DD}$ | V       |
| 4   | D | Analog input offset voltage                                                       | $V_{AIO}$   | —              | 20      | 40       | mV      |
| 5   | D | Analog comparator hysteresis                                                      | $V_H$       | 3.0            | 6.0     | 20.0     | mV      |
| 6   | D | Analog input leakage current                                                      | $I_{ALKG}$  | —              | —       | 1.0      | $\mu A$ |
| 7   | D | Analog comparator initialization delay                                            | $t_{AINIT}$ | —              | —       | 1.0      | $\mu s$ |
| 8   | P | Bandgap voltage reference<br>factory trimmed at $V_{DD} = 5.3248$ V, Temp = 25 °C | $V_{BG}$    | 1.18           | 1.20    | 1.21     | V       |

## 2.8 ADC Characteristics

Table 13. 5 Volt 12-bit ADC Operating Conditions

| Num | C | Characteristic                 | Conditions                                                          | Symb             | Min        | Typical <sup>1</sup> | Max        | Unit       | Comment         |
|-----|---|--------------------------------|---------------------------------------------------------------------|------------------|------------|----------------------|------------|------------|-----------------|
| 1   | D | Supply voltage                 | Absolute                                                            | $V_{DDA}$        | 2.7        | —                    | 5.5        | V          |                 |
|     | D |                                | Delta to $V_{DD}$<br>( $V_{DD} - V_{DDA}$ ) <sup>2</sup>            | $\Delta V_{DDA}$ | −100       | 0                    | 100        | mV         |                 |
| 2   | D | Ground voltage                 | Delta to $V_{SS}$<br>( $V_{SS} - V_{SSA}$ ) <sup>2</sup>            | $\Delta V_{SSA}$ | −100       | 0                    | 100        | mV         |                 |
| 3   | D | Reference voltage high         |                                                                     | $V_{REFH}$       | 2.7        | $V_{DDA}$            | $V_{DDA}$  | V          |                 |
| 4   | D | Reference voltage low          |                                                                     | $V_{REFL}$       | $V_{SSA}$  | $V_{SSA}$            | $V_{SSA}$  | V          |                 |
| 5   | D | Input voltage                  |                                                                     | $V_{ADIN}$       | $V_{REFL}$ | —                    | $V_{REFH}$ | V          |                 |
| 6   | C | Input capacitance              |                                                                     | $C_{ADIN}$       | —          | 4.5                  | 5.5        | pF         |                 |
| 7   | C | Input resistance               |                                                                     | $R_{ADIN}$       | —          | 3                    | 5          | k $\Omega$ |                 |
| 8   | C | Analog source resistance       | 12-bit mode<br>$f_{ADCK} > 4\text{MHz}$<br>$f_{ADCK} < 4\text{MHz}$ | $R_{AS}$         | —<br>—     | —<br>—               | 2<br>5     | k $\Omega$ | External to MCU |
|     | C |                                | 10-bit mode<br>$f_{ADCK} > 4\text{MHz}$<br>$f_{ADCK} < 4\text{MHz}$ |                  | —<br>—     | —<br>—               | 5<br>10    |            |                 |
|     | C |                                | 8-bit mode (all valid $f_{ADCK}$ )                                  |                  | —          | —                    | 10         |            |                 |
| 9   | D | ADC conversion clock frequency | High speed (ADLPC = 0)                                              | $f_{ADCK}$       | 0.4        | —                    | 8.0        | MHz        |                 |
|     | D |                                | Low power (ADLPC = 1)                                               |                  | 0.4        | —                    | 4.0        |            |                 |

<sup>1</sup> Typical values assume  $V_{DDA} = 5.0\text{ V}$ , 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> DC potential difference.

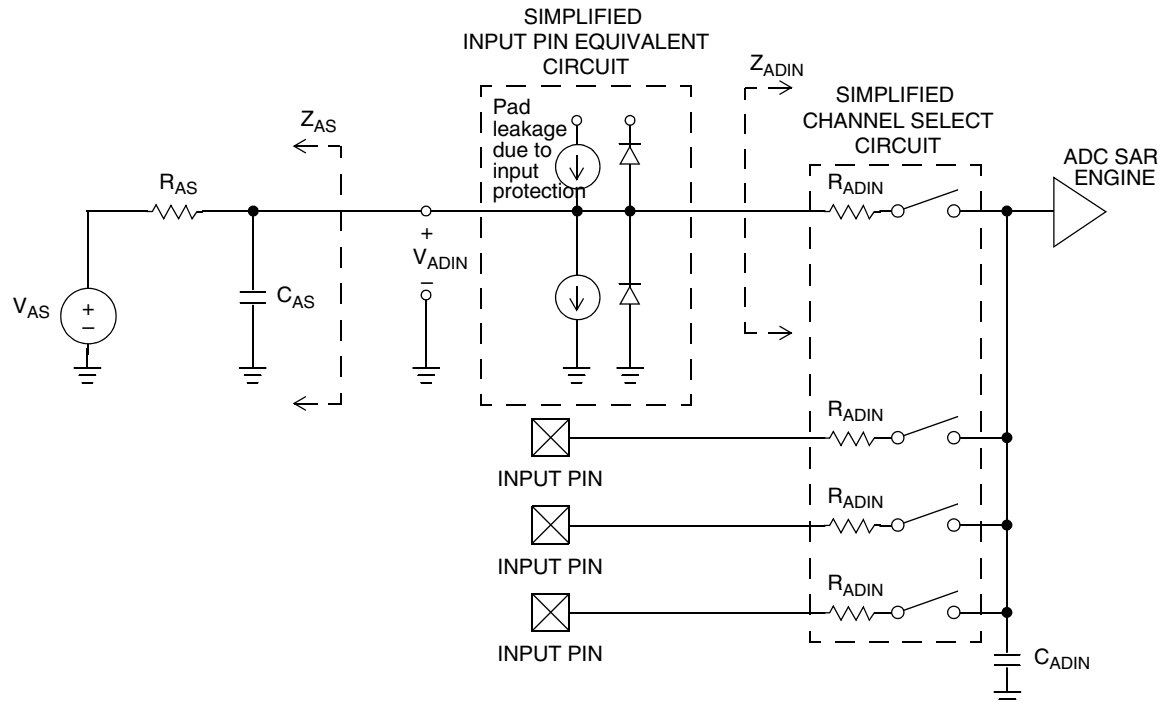


Figure 10. ADC Input Impedance Equivalency Diagram

Table 14. 5 Volt 12-bit ADC Characteristics ( $V_{REFH} = V_{DDA}$ ,  $V_{REFL} = V_{SSA}$ )

| Num | C | Characteristic                                        | Conditions              | Symb        | Min  | Typical <sup>1</sup> | Max | Unit    | Comment                   |
|-----|---|-------------------------------------------------------|-------------------------|-------------|------|----------------------|-----|---------|---------------------------|
| 1   | T | Supply current<br>ADLPC = 1<br>ADLSMP = 1<br>ADCO = 1 |                         | $I_{DDA}$   | —    | 133                  | —   | $\mu A$ |                           |
| 2   | T | Supply current<br>ADLPC = 1<br>ADLSM = 0<br>ADCO = 1  |                         | $I_{DDA}$   | —    | 218                  | —   | $\mu A$ |                           |
| 3   | T | Supply current<br>ADLPC = 0<br>ADLSMP = 1<br>ADCO = 1 |                         | $I_{DDA}$   | —    | 327                  | —   | $\mu A$ |                           |
| 4   | D | Supply current<br>ADLPC = 0<br>ADLSMP = 0<br>ADCO = 1 |                         | $I_{DDA}$   | —    | 0.582                | 1   | mA      |                           |
| 5   | T | Supply current                                        | Stop, reset, module off | $I_{DDA}$   | —    | 0.011                | 1   | $\mu A$ |                           |
| 6   | P | ADC asynchronous clock source                         | High speed (ADLPC = 0)  | $f_{ADACK}$ | 2    | 3.3                  | 5   | MHz     | $t_{ADACK} = 1/f_{ADACK}$ |
|     |   |                                                       | Low power (ADLPC = 1)   |             | 1.25 | 2                    | 3.3 |         |                           |

Table 14. 5 Volt 12-bit ADC Characteristics ( $V_{REFH} = V_{DDA}$ ,  $V_{REFL} = V_{SSA}$ ) (continued)

| Num | C | Characteristic                          | Conditions                | Symb         | Min | Typical <sup>1</sup> | Max  | Unit             | Comment                                    |
|-----|---|-----------------------------------------|---------------------------|--------------|-----|----------------------|------|------------------|--------------------------------------------|
| 7   | P | Conversion time (including sample time) | Short sample (ADLSMP = 0) | $t_{ADC}$    | —   | 20                   | —    | ADCK cycles      | See Table 10 for conversion time variances |
|     |   |                                         | Long sample (ADLSMP = 1)  |              | —   | 40                   | —    |                  |                                            |
| 8   | T | Sample time                             | Short sample (ADLSMP = 0) | $t_{ADS}$    | —   | 3.5                  | —    | ADCK cycles      |                                            |
|     |   |                                         | Long sample (ADLSMP = 1)  |              | —   | 23.5                 | —    |                  |                                            |
| 9   | T | Total unadjusted error                  | 12-bit mode               | $E_{TUE}$    | —   | ±3.0                 | —    | LSB <sup>2</sup> | Includes quantization                      |
|     | P |                                         | 10-bit mode               |              | —   | ±1                   | ±2.5 |                  |                                            |
|     | T |                                         | 8-bit mode                |              | —   | ±0.5                 | ±1.0 |                  |                                            |
| 10  | T | Differential non-linearity              | 12-bit mode               | DNL          | —   | ±1.75                | —    | LSB <sup>2</sup> |                                            |
|     | P |                                         | 10-bit mode <sup>3</sup>  |              | —   | ±0.5                 | ±1.0 |                  |                                            |
|     | T |                                         | 8-bit mode <sup>3</sup>   |              | —   | ±0.3                 | ±0.5 |                  |                                            |
| 11  | T | Integral non-linearity                  | 12-bit mode               | INL          | —   | ±1.5                 | —    | LSB <sup>2</sup> |                                            |
|     | T |                                         | 10-bit mode               |              | —   | ±0.5                 | ±1.0 |                  |                                            |
|     | T |                                         | 8-bit mode                |              | —   | ±0.3                 | ±0.5 |                  |                                            |
| 12  | T | Zero-scale error                        | 12-bit mode               | $E_{ZS}$     | —   | ±1.5                 | —    | LSB <sup>2</sup> | $V_{ADIN} = V_{SSA}$                       |
|     | P |                                         | 10-bit mode               |              | —   | ±0.5                 | ±1.5 |                  |                                            |
|     | T |                                         | 8-bit mode                |              | —   | ±0.5                 | ±0.5 |                  |                                            |
| 13  | T | Full-scale error                        | 12-bit mode               | $E_{FS}$     | —   | ±1                   | —    | LSB <sup>2</sup> | $V_{ADIN} = V_{DDA}$                       |
|     | P |                                         | 10-bit mode               |              | —   | ±0.5                 | ±1   |                  |                                            |
|     | T |                                         | 8-bit mode                |              | —   | ±0.5                 | ±0.5 |                  |                                            |
| 14  | D | Quantization error                      | 12-bit mode               | $E_Q$        | —   | −1 to 0              | —    | LSB <sup>2</sup> |                                            |
|     |   |                                         | 10-bit mode               |              | —   | —                    | ±0.5 |                  |                                            |
|     |   |                                         | 8-bit mode                |              | —   | —                    | ±0.5 |                  |                                            |
| 15  | D | Input leakage error                     | 12-bit mode               | $E_{IL}$     | —   | ±1                   | —    | LSB <sup>2</sup> | Pad leakage <sup>4*</sup><br>$R_{AS}$      |
|     |   |                                         | 10-bit mode               |              | —   | ±0.2                 | ±2.5 |                  |                                            |
|     |   |                                         | 8-bit mode                |              | —   | ±0.1                 | ±1   |                  |                                            |
| 16  | D | Temp sensor voltage                     | 25°C                      | $V_{TEMP25}$ | —   | 1.396                | —    | V                |                                            |
| 17  | D | Temp sensor slope                       | −40 °C–25 °C              | m            | —   | 3.266                | —    | mV/°C            |                                            |
|     |   |                                         | 25 °C–85 °C               |              | —   | 3.638                | —    |                  |                                            |

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

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

<sup>3</sup> Monotonicity and No-Missing-Codes guaranteed in 10-bit and 8-bit modes

<sup>4</sup> Based on input pad leakage current. Refer to pad electricals.

## 2.9 External Oscillator (XOSC) Characteristics

**Table 15. Oscillator Electrical Specifications (Temperature Range = –40 to 105 °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>            | $f_{hi-ll}$    | 1                                                       | —                    | 5    | MHz  |
|     |   | High range (RANGE = 1) PEE or PBE mode <sup>3</sup>            | $f_{hi-pll}$   | 1                                                       | —                    | 16   | MHz  |
|     |   | High range (RANGE = 1, HGO = 1) BLPE mode                      | $f_{hi-hgo}$   | 1                                                       | —                    | 16   | MHz  |
|     |   | High range (RANGE = 1, HGO = 0) BLPE mode                      | $f_{hi-lp}$    | 1                                                       | —                    | 8    | MHz  |
| 2   | — | Load capacitors                                                | $C_1$<br>$C_2$ | See crystal or resonator manufacturer's recommendation. |                      |      |      |
| 3   | — | Feedback resistor                                              | $R_F$          |                                                         | 10                   |      | MΩ   |
|     |   | Low range (32 kHz to 38.4 kHz)<br>High range (1 MHz to 16 MHz) |                |                                                         | 1                    |      |      |
| 4   | — | Series resistor                                                | $R_S$          |                                                         |                      |      | kΩ   |
|     |   | Low range, low gain (RANGE = 0, HGO = 0)                       |                | —                                                       | 0                    | —    |      |
|     |   | Low range, high gain (RANGE = 0, HGO = 1)                      |                | —                                                       | 100                  | —    |      |
|     |   | High range, low gain (RANGE = 1, HGO = 0)                      |                | —                                                       | 0                    | —    |      |
|     |   | High range, high gain (RANGE = 1, HGO = 1)                     |                | —                                                       | 0                    | 0    |      |
|     |   | ≥ 8 MHz                                                        |                | —                                                       | 0                    | 0    |      |
| 5   | T | Crystal start-up time <sup>4</sup>                             |                |                                                         |                      |      | ms   |
|     |   | Low range, low gain (RANGE = 0, HGO = 0)                       | $t_{CSTL-LP}$  | —                                                       | 200                  | —    |      |
|     |   | Low range, high gain (RANGE = 0, HGO = 1)                      | $t_{CSTL-HGO}$ | —                                                       | 400                  | —    |      |
|     |   | High range, low gain (RANGE = 1, HGO = 0) <sup>5</sup>         | $t_{CSTH-LP}$  | —                                                       | 5                    | —    |      |
|     |   | High range, high gain (RANGE = 1, HGO = 1) <sup>5</sup>        | $t_{CSTH-HGO}$ | —                                                       | 15                   | —    |      |
|     |   |                                                                |                |                                                         |                      |      |      |
| 6   | T | Square wave input clock frequency (EREFS = 0, ERCLKEN = 1)     |                |                                                         |                      |      | MHz  |
|     |   | FEE or FBE mode <sup>2</sup>                                   | $f_{extal}$    | 0.03125                                                 | —                    | 5    |      |
|     |   | PEE or PBE mode <sup>3</sup>                                   |                | 1                                                       | —                    | 16   |      |
|     |   | BLPE mode                                                      |                | 0                                                       | —                    | 40   |      |

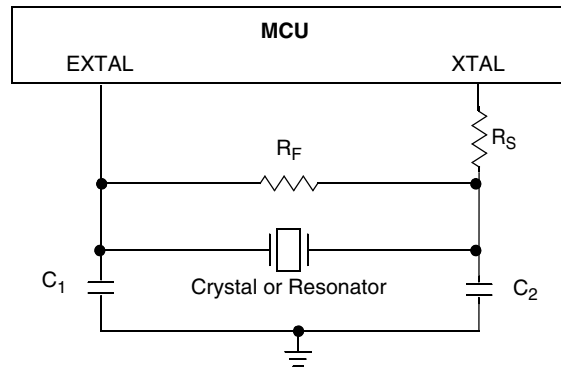
<sup>1</sup> Data in Typical column was characterized at 5.0 V, 25 °C or is typical recommended value.

<sup>2</sup> When MCG is configured for FEE or FBE mode, input clock source must be divisible using RDIV to within the range of 31.25 kHz to 39.0625 kHz.

<sup>3</sup> When MCG is configured for PEE or PBE mode, input clock source must be divisible using RDIV to within the range of 1 MHz to 2 MHz.

<sup>4</sup> This parameter is characterized and not tested on each device. Proper PC board layout procedures must be followed to achieve specifications.

<sup>5</sup> 4 MHz crystal



## 2.10 MCG Specifications

Table 16. MCG Frequency Specifications (Temperature Range =  $-40$  to  $105$  °C Ambient)

| Num | C | Rating                                                                                                    | Symbol                   | Min        | Typical <sup>1</sup> | Max        | Unit        |
|-----|---|-----------------------------------------------------------------------------------------------------------|--------------------------|------------|----------------------|------------|-------------|
| 1   | C | Internal reference frequency — factory trimmed at $V_{DD} = 5$ V and temperature = $25$ °C                | $f_{int\_ft}$            | —          | 32.768               | —          | kHz         |
| 2   | C | Average internal reference frequency — untrimmed                                                          | $f_{int\_ut}$            | 31.25      | —                    | 39.0625    | kHz         |
| 3   | T | Internal reference startup time                                                                           | $t_{irefst}$             | —          | 60                   | 100        | μs          |
| 4   | C | DCO output frequency range — untrimmed <sup>2</sup>                                                       | $f_{dco\_ut}$            | 16         | —                    | 20         | MHz         |
|     | C |                                                                                                           |                          | 32         | —                    | 40         |             |
|     | C |                                                                                                           |                          | 48         | —                    | 60         |             |
| 5   | P | DCO output frequency <sup>2</sup> reference = 32768Hz and DMX32 = 1                                       | $f_{dco\_DMX32}$         | —          | 16.82                | —          | MHz         |
|     | P |                                                                                                           |                          | —          | 33.69                | —          |             |
|     | P |                                                                                                           |                          | —          | 50.48                | —          |             |
| 6   | D | Resolution of trimmed DCO output frequency at fixed voltage and temperature (using FTRIM)                 | $\Delta f_{dco\_res\_t}$ | —          | $\pm 0.1$            | $\pm 0.2$  | % $f_{dco}$ |
| 7   | D | Resolution of trimmed DCO output frequency at fixed voltage and temperature (not using FTRIM)             | $\Delta f_{dco\_res\_t}$ | —          | $\pm 0.2$            | $\pm 0.4$  | % $f_{dco}$ |
| 8   | D | Total deviation of trimmed DCO output frequency over voltage and temperature                              | $\Delta f_{dco\_t}$      | —          | 0.5<br>–1.0          | $\pm 2$    | % $f_{dco}$ |
| 9   | D | Total deviation of trimmed DCO output frequency over fixed voltage and temperature range of $0$ – $70$ °C | $\Delta f_{dco\_t}$      | —          | $\pm 0.5$            | $\pm 1$    | % $f_{dco}$ |
| 10  | D | FLL acquisition time <sup>3</sup>                                                                         | $t_{fll\_acquire}$       | —          | —                    | 1          | ms          |
| 11  | D | PLL acquisition time <sup>4</sup>                                                                         | $t_{pll\_acquire}$       | —          | —                    | 1          | ms          |
| 12  | D | Long term jitter of DCO output clock (averaged over 2ms interval) <sup>5</sup>                            | $C_{jitter}$             | —          | 0.02                 | 0.2        | % $f_{dco}$ |
| 13  | D | VCO operating frequency                                                                                   | $f_{vco}$                | 7.0        | —                    | 55.0       | MHz         |
| 16  | D | Jitter of PLL output clock measured over 625 ns <sup>6</sup>                                              | $f_{pll\_jitter\_625ns}$ | —          | 0.566 <sup>6</sup>   | —          | % $f_{pll}$ |
| 17  | D | Lock entry frequency tolerance <sup>7</sup>                                                               | $D_{lock}$               | $\pm 1.49$ | —                    | $\pm 2.98$ | %           |



**Table 16. MCG Frequency Specifications (continued)(Temperature Range = –40 to 105 °C Ambient)**

| Num | C | Rating                                                  | Symbol                | Min                      | Typical <sup>1</sup> | Max                                                         | Unit |
|-----|---|---------------------------------------------------------|-----------------------|--------------------------|----------------------|-------------------------------------------------------------|------|
| 18  | D | Lock exit frequency tolerance <sup>8</sup>              | D <sub>unl</sub>      | ±4.47                    | —                    | ±5.97                                                       | %    |
| 19  | D | Lock time — FLL                                         | t <sub>fil_lock</sub> | —                        | —                    | t <sub>fil_acquire</sub> +<br>1075(1/f <sub>int_t</sub> )   | s    |
| 20  | D | Lock time — PLL                                         | t <sub>pll_lock</sub> | —                        | —                    | t <sub>pll_acquire</sub> +<br>1075(1/f <sub>pll_ref</sub> ) | s    |
| 21  | D | Loss of external clock minimum frequency —<br>RANGE = 0 | f <sub>loc_low</sub>  | (3/5) × f <sub>int</sub> | —                    | —                                                           | kHz  |

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

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

<sup>3</sup> This specification applies when the FLL reference source or reference divider is changed, trim value changed or changing from FLL disabled (BLPE, BLPI) to FLL enabled (FEI, FEE, FBE, FBI). If a crystal/resonator is being used as the reference, this specification assumes it is already running.

<sup>4</sup> This specification applies when the PLL VCO divider or reference divider is changed, or changing from PLL disabled (BLPE, BLPI) to PLL enabled (PBE, PEE). If a crystal/resonator is being used as the reference, this specification assumes it is already running.

<sup>5</sup> Jitter is the average deviation from the programmed frequency measured over the specified interval at maximum f<sub>BUS</sub>. 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<sub>DD</sub> and V<sub>SS</sub> and variation in crystal oscillator frequency increase the C<sub>Jitter</sub> percentage for a given interval.

<sup>6</sup> 625 ns represents 5 time quanta for CAN applications, under worst case conditions of 8 MHz CAN bus clock, 1 Mbps CAN bus speed, and 8 time quanta per bit for bit time settings. 5 time quanta is the minimum time between a synchronization edge and the sample point of a bit using 8 time quanta per bit.

<sup>7</sup> Below D<sub>lock</sub> minimum, the MCG enters lock. Above D<sub>lock</sub> maximum, the MCG will not enter lock. But if the MCG is already in lock, then the MCG may stay in lock.

<sup>8</sup> Below D<sub>unl</sub> minimum, the MCG will not exit lock if already in lock. Above D<sub>unl</sub> maximum, the MCG is guaranteed to exit lock.

## 2.11 AC Characteristics

This section describes ac timing characteristics for each peripheral system.

## 2.11.1 Control Timing

Table 17. Control Timing

| Num | C | Parameter                                                                                                                                                                                                                                                             | Symbol               | Min                         | Typical <sup>1</sup> | Max  | Unit    |
|-----|---|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|-----------------------------|----------------------|------|---------|
| 1   | D | Bus frequency ( $t_{cyc} = 1/f_{Bus}$ )                                                                                                                                                                                                                               | $f_{Bus}$            | dc                          | —                    | 24   | MHz     |
| 2   | D | Internal low-power oscillator period                                                                                                                                                                                                                                  | $t_{LPO}$            | 800                         | —                    | 1500 | $\mu s$ |
| 3   | D | External reset pulse width <sup>2</sup><br>( $t_{cyc} = 1/f_{Self\_reset}$ )                                                                                                                                                                                          | $t_{extrst}$         | 100                         | —                    | —    | ns      |
| 4   | D | Reset low drive                                                                                                                                                                                                                                                       | $t_{rstdrv}$         | $66 \times t_{cyc}$         | —                    | —    | ns      |
| 5   | D | Active background debug mode latch setup time                                                                                                                                                                                                                         | $t_{MSSU}$           | 500                         | —                    | —    | ns      |
| 6   | D | Active background debug mode latch hold time                                                                                                                                                                                                                          | $t_{MSH}$            | 100                         | —                    | —    | ns      |
| 7   | D | IRQ pulse width<br>Asynchronous path <sup>2</sup><br>Synchronous path <sup>3</sup>                                                                                                                                                                                    | $t_{ILIH}, t_{IHIL}$ | 100<br>$1.5 \times t_{cyc}$ | —                    | —    | ns      |
| 8   | D | KBIPx pulse width<br>Asynchronous path <sup>2</sup><br>Synchronous path <sup>3</sup>                                                                                                                                                                                  | $t_{ILIH}, t_{IHIL}$ | 100<br>$1.5 \times t_{cyc}$ | —                    | —    | ns      |
| 9   | D | Port rise and fall time (load = 50 pF) <sup>4</sup><br>Slew rate control disabled (PTxSE = 0), Low Drive<br>Slew rate control enabled (PTxSE = 1), Low Drive<br>Slew rate control disabled (PTxSE = 0), Low Drive<br>Slew rate control enabled (PTxSE = 1), Low Drive | $t_{Rise}, t_{Fall}$ | —<br>—<br>—<br>—            | 11<br>35<br>40<br>75 | —    | ns      |

<sup>1</sup> Typical values are based on characterization data at  $V_{DD} = 5.0 V$ , 25 °C unless otherwise stated.

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

<sup>3</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>4</sup> Timing is shown with respect to 20%  $V_{DD}$  and 80%  $V_{DD}$  levels. Temperature range –40 °C to 105 °C.

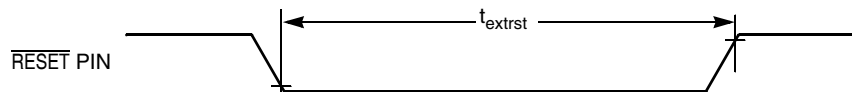


Figure 11. Reset Timing

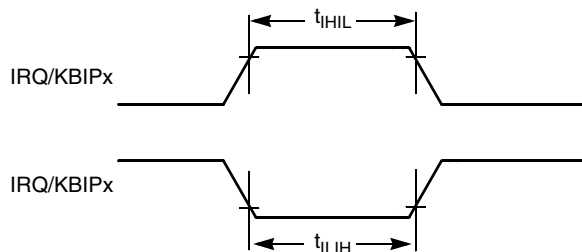


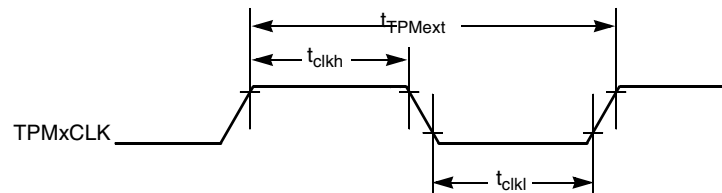
Figure 12. IRQ/KBIPx Timing

## 2.11.2 Timer (TPM/FTM) Module Timing

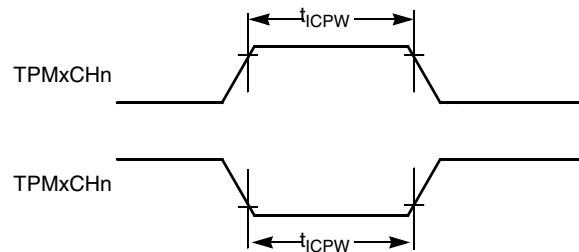
Synchronizer circuits determine the shortest input pulses that can be recognized or the fastest clock that can be used as the optional external source to the timer counter. These synchronizers operate from the current bus rate clock.

**Table 18. TPM/FTM Input Timing**

| NUM | C | Function                  | Symbol              | Min | Max                | Unit             |
|-----|---|---------------------------|---------------------|-----|--------------------|------------------|
| 1   | — | External clock frequency  | $f_{\text{TPMext}}$ | DC  | $f_{\text{Bus}}/4$ | MHz              |
| 2   | — | 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 13. Timer External Clock**



**Figure 14. Timer Input Capture Pulse**

## 2.11.3 MSCAN

**Table 19. MSCAN Wake-Up Pulse Characteristics**

| Num | C | Parameter                             | Symbol           | Min | Typical <sup>1</sup> | Max | Unit          |
|-----|---|---------------------------------------|------------------|-----|----------------------|-----|---------------|
| 1   | D | MSCAN wake-up dominant pulse filtered | $t_{\text{WUP}}$ | —   | —                    | 2   | $\mu\text{s}$ |
| 2   | D | MSCAN wake-up dominant pulse pass     | $t_{\text{WUP}}$ | 5   | —                    | 5   | $\mu\text{s}$ |

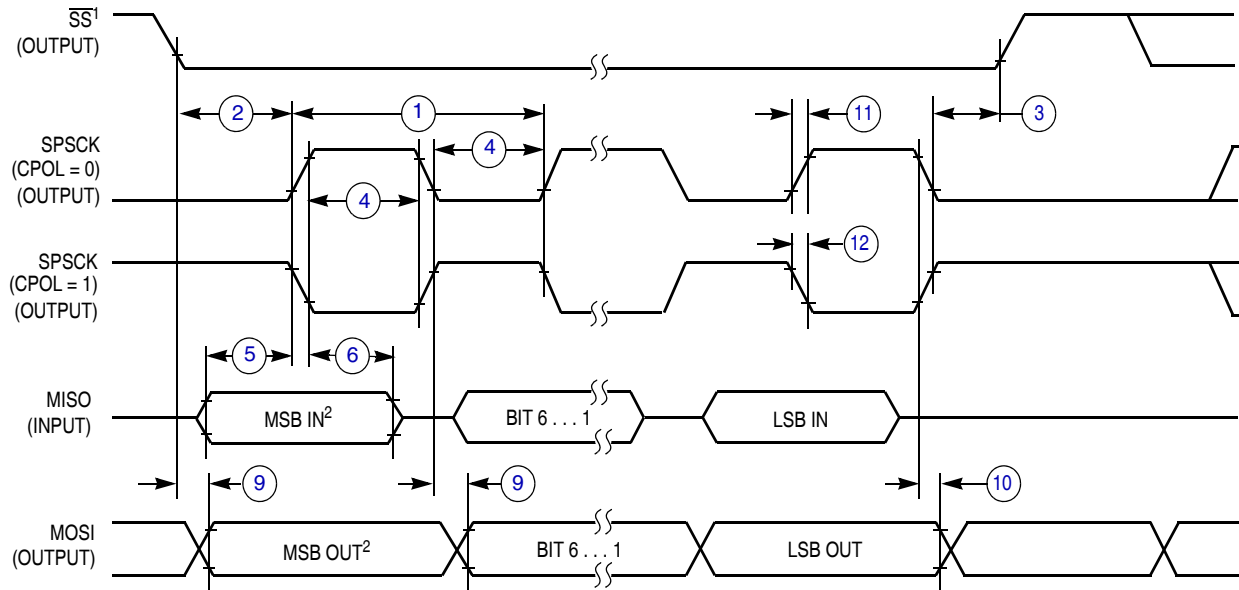
<sup>1</sup> Typical values are based on characterization data at  $V_{\text{DD}} = 5.0 \text{ V}$ ,  $25^\circ\text{C}$  unless otherwise stated.

## 2.12 SPI Characteristics

Table 20 and Figure 15 through Figure 18 describe the timing requirements for the SPI system.

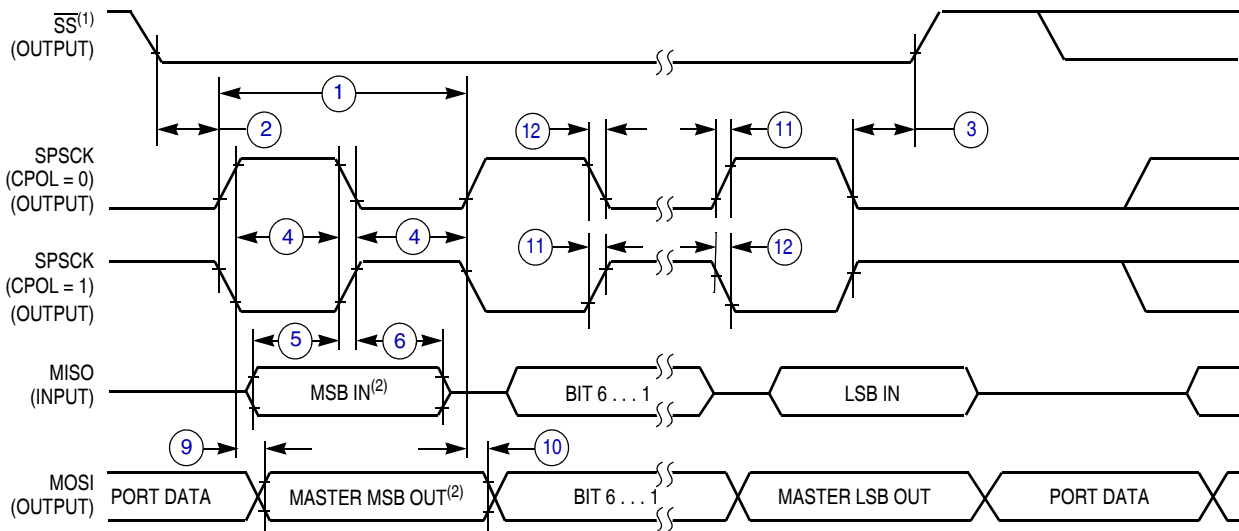
**Table 20. SPI Timing**

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



## NOTES:

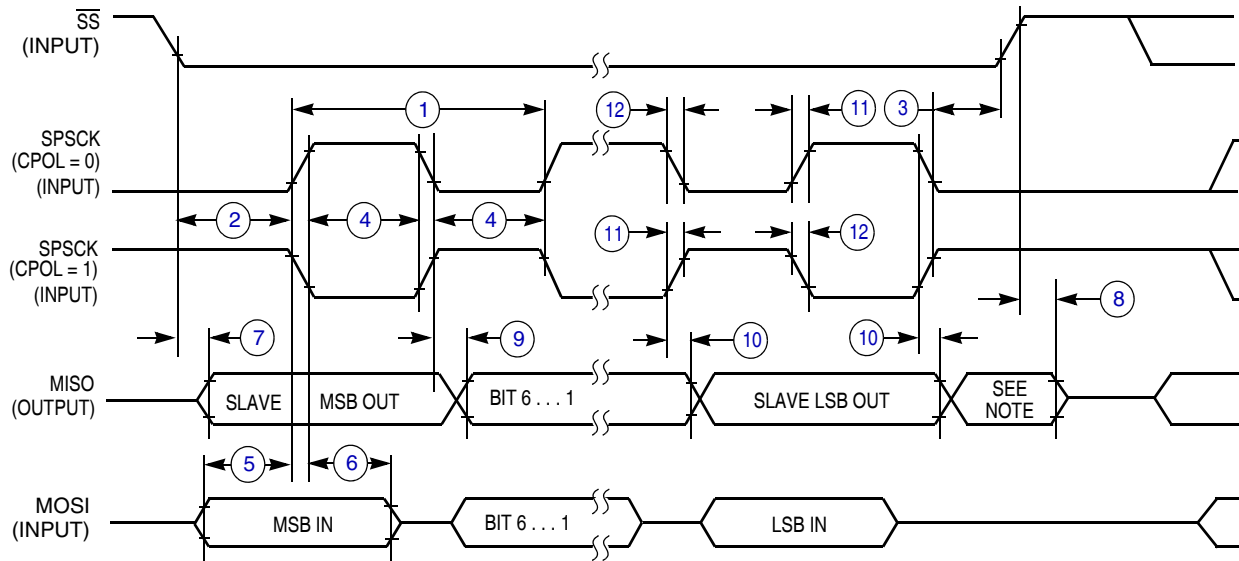
1.  $\overline{SS}$  output mode (DDS7 = 1, SSOE = 1).
2. LSBF = 0. For LSBF = 1, bit order is LSB, bit 1, ..., bit 6, MSB.

**Figure 15. 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.

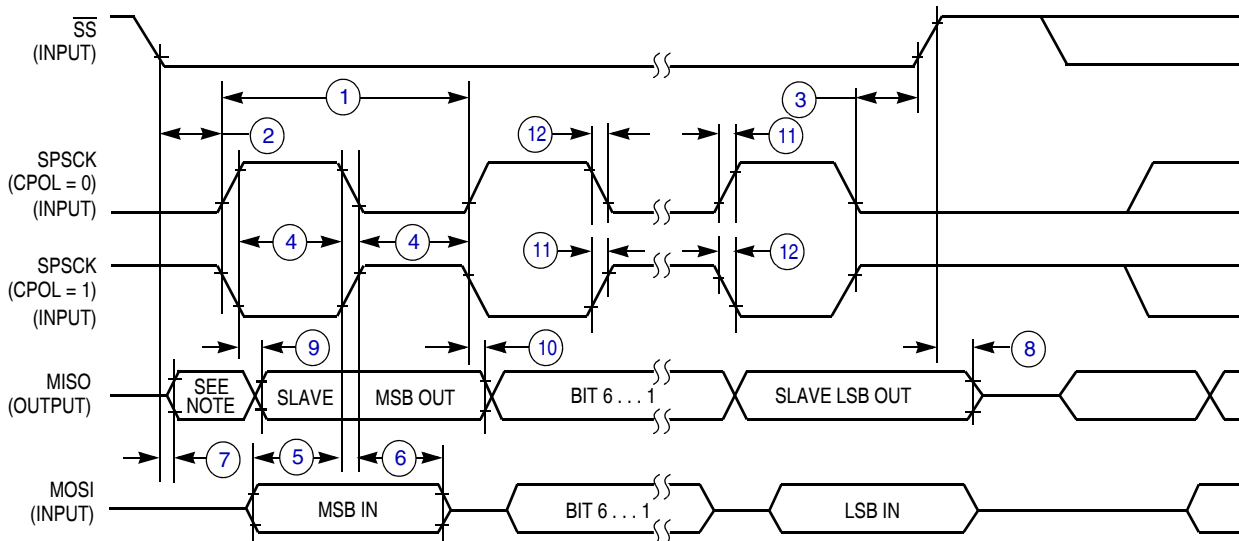
**Figure 16. SPI Master Timing (CPHA = 1)**



NOTE:

1. Not defined but normally MSB of character just received

Figure 17. SPI Slave Timing (CPHA = 0)



NOTE:

1. Not defined but normally LSB of character just received

Figure 18. SPI Slave Timing (CPHA = 1)

## 2.13 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 [Chapter 4, “Memory.”](#)

Table 21. Flash Characteristics

| Num | C | Characteristic                                                                                                                                            | Symbol                  | Min         | Typical <sup>1</sup> | Max    | Unit              |
|-----|---|-----------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|-------------|----------------------|--------|-------------------|
| 1   | — | Supply voltage for program/erase                                                                                                                          | $V_{\text{prog/erase}}$ | 2.7         | —                    | 5.5    | V                 |
| 2   | — | Supply voltage for read operation                                                                                                                         | $V_{\text{Read}}$       | 2.7         | —                    | 5.5    | V                 |
| 3   | — | Internal FCLK frequency <sup>2</sup>                                                                                                                      | $f_{\text{FCLK}}$       | 150         | —                    | 200    | kHz               |
| 4   | — | Internal FCLK period (1/FCLK)                                                                                                                             | $t_{\text{Fcyc}}$       | 5           | —                    | 6.67   | $\mu\text{s}$     |
| 5   | — | Byte program time (random location) <sup>2</sup>                                                                                                          | $t_{\text{prog}}$       | 9           |                      |        | $t_{\text{Fcyc}}$ |
| 6   | — | Byte program time (burst mode) <sup>2</sup>                                                                                                               | $t_{\text{Burst}}$      | 4           |                      |        | $t_{\text{Fcyc}}$ |
| 7   | — | Page erase time <sup>3</sup>                                                                                                                              | $t_{\text{Page}}$       | 4000        |                      |        | $t_{\text{Fcyc}}$ |
| 8   | — | Mass erase time <sup>2</sup>                                                                                                                              | $t_{\text{Mass}}$       | 20,000      |                      |        | $t_{\text{Fcyc}}$ |
| 9   | C | Program/erase endurance <sup>4</sup><br>$T_L$ to $T_H = -40\text{ }^{\circ}\text{C}$ to $105\text{ }^{\circ}\text{C}$<br>$T = 25\text{ }^{\circ}\text{C}$ | —                       | 10,000<br>— | —<br>100,000         | —<br>— | cycles            |
| 10  | C | Data retention <sup>5</sup>                                                                                                                               | $t_{\text{D\_ret}}$     | 15          | 100                  | —      | years             |

<sup>1</sup> Typical values are based on characterization data at  $V_{\text{DD}} = 5.0\text{ V}$ ,  $25\text{ }^{\circ}\text{C}$  unless otherwise stated.

<sup>2</sup> The frequency of this clock is controlled by a software setting.

<sup>3</sup> These values are hardware state machine controlled. User code does not need to count cycles. This information supplied for calculating approximate time to program and erase.

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

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

## 2.14 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.

### 2.14.1 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). For more detailed information concerning the evaluation results, conditions and setup, please refer to the EMC Evaluation Report for this device.

### 3 Mechanical Outline Drawings

Table 22 provides the available package types and their document numbers. The latest package outline/mechanical drawings are available on the MCF51AC256 Series Product Summary pages at <http://www.freescale.com>.

To view the latest drawing, either:

- Click on the appropriate link in Table 22, or
- Open a browser to the Freescale website (<http://www.freescale.com>), and enter the appropriate document number (from Table 22) in the “Enter Keyword” search box at the top of the page.

**Table 22. Package Information**

| Pin Count | Type | Document No.                |
|-----------|------|-----------------------------|
| 80        | LQFP | <a href="#">98ARL10530D</a> |
| 64        | LQFP | <a href="#">98ASS23234W</a> |
| 64        | QFP  | <a href="#">98ASB42844B</a> |
| 44        | LQFP | <a href="#">98ASS23225W</a> |



## 4 Revision History

**Table 23. Revision History**

| Revision | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1        | Initial published                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| 2        | Updated ADC channels, Item 1, 4-5 on Table 2.10                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| 3        | Completed all the TBDs.<br>Changed RTC to RTI in <a href="#">Figure 1</a> .<br>Corrected the block diagram.<br>Changed $V_{DDAD}$ to $V_{DDA}$ , $V_{SSAD}$ to $V_{SSA}$ .<br>Added charge device model data and removed machine data in <a href="#">Table 8</a> .<br>Updated the specifications of $V_{LVDH}$ , $V_{LVDL}$ , $V_{LVWH}$ and $V_{LVWL}$ in <a href="#">Table 10</a> .<br>Updated $S2I_{DD}$ , $S3I_{DD}$ in <a href="#">Table 11</a> .<br>Added C column in <a href="#">Table 14</a> .<br>Updated $f_{dco\_DMX32}$ in <a href="#">Table 16</a> . |
| 4        | Corrected the expansion of SPI to serial peripheral interface.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| 5        | Updated $V_{LVDL}$ in the <a href="#">Table 10</a> .<br>Updated $RI_{DD}$ in the <a href="#">Table 11</a> .                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| 6        | Updated $V_{LVDH}$ , $V_{LVDL}$ , $V_{LVWH}$ and $V_{LVWL}$ in the <a href="#">Table 10</a> .<br>Added LPO on the <a href="#">Figure 1</a> and LPO features in the <a href="#">Section 1.3, "Features."</a>                                                                                                                                                                                                                                                                                                                                                      |
| 7        | Added 44-pin LQFP package information for AC256 and AC128.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |

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