



### An Energy-Efficient Solution from Freescale

## MCF51MM256/128

The MCF51MM256 series devices are members of the low-cost, low-power, high-performance ColdFire V1 family of 32-bit microcontrollers (MCUs) designed for handheld metering devices.

Not all features are available in all devices or packages; see [Table 1](#) for a comparison of features by device.



80-LQFP  
12mm x 12mm



81-BGA  
10mm x 10mm



100-LQFP  
14mm x 14mm



104-BGA  
10mm x 10mm

### 32-Bit ColdFire V1 Central Processor Unit (CPU)

- Up to 50.33 MHz ColdFire CPU above 2.4 V and 40 MHz CPU above 2.1V and 20 MHz CPU above 1.8 V across temperature range of -40°C to 105°C.
- ColdFire Instruction Set Revision C (ISA\_C).
- 32-bit multiply and accumulate (MAC) supports signed or unsigned integer or signed fractional inputs.

### On-Chip Memory

- 256 K Flash comprised of two independent 128 K flash arrays; read/program/erase over full operating voltage and temperature; allows interrupt processing while programming.
- 32 KB System Random-access memory (RAM).
- Security circuitry to prevent unauthorized access to RAM and Flash contents.

### Power-Saving Modes

- Two ultra-low power stop modes. Peripheral clock enable register can disable clocks to unused modules to reduce currents.
- Time of Day (TOD) — Ultra low-power 1/4 sec counter with up to 64 sec timeout.
- Ultra-low power external oscillator that can be used in stop modes to provide accurate clock source to the TOD. 6  $\mu$ s typical wake up time from stop3 mode.

### Clock Source Options

- Oscillator (XOSC1) — Loop-control Pierce oscillator; 32.768 kHz crystal or ceramic resonator dedicated for TOD operation.
- Oscillator (XOSC2) for high frequency crystal input for MCG reference to be used for system clock and USB operations.
- Multipurpose Clock Generator (MCG) — PLL and FLL; precision trimming of internal reference allows 0.2% resolution and typical +0.5% to -1% deviation over temperature and voltage; supports CPU frequencies from 4 kHz to 50 MHz.

### System Protection

- Watchdog computer operating properly (COP) reset with option to run from dedicated 1 kHz internal clock source or bus clock.
- Low-voltage detection with reset or interrupt; selectable trip points; separate low voltage warning with optional interrupt; selectable trip points.
- Illegal opcode and illegal address detection with reset.
- Flash block protection for each array to prevent accidental write / erasure.
- Hardware CRC to support fast cyclic redundancy checks.

### Development Support

- Integrated ColdFire DEBUG\_Rev\_B+ interface with single wire BDM connection supports same electrical interface used by the S08 family debug modules.
- Real-time debug with 6 hardware breakpoints (4 PC, 1 address and 1 data).
- On-chip trace buffer provides programmable start/stop recording conditions.

### Peripherals

- **USB** — Dual-role USB On-The-Go (OTG) device, supports USB in either device, host or OTG configuration. On-chip transceiver and 3.3V regulator help save system cost, fully compliant with USB Specification

- 2.0. Allows control, bulk, interrupt and isochronous transfers.
- **SC1x** — Two serial communications interfaces with optional 13-bit break; option to connect Rx input to PRACMP output on SCI1 and SCI2; High current drive on Tx on SCI1 and SCI2; wake-up from stop3 on Rx edge.
- **SPI1** — Serial peripheral interface with 32-bit FIFO buffer; 16-bit or 8-bit data transfers; full-duplex or single-wire bidirectional; double-buffered transmit and receive; master or slave mode; MSB-first or LSB-first shifting.
- **SPI2** — Serial peripheral interface with full-duplex or single-wire bidirectional; Double-buffered transmit and receive; Master or Slave mode; MSB-first or LSB-first shifting.
- **IIC** — Up to 100 kbps with maximum bus loading; Multi-master operation; Programmable slave address; Interrupt driven byte-by-byte data transfer; supports broadcast mode and 11-bit addressing.
- **CMT** — Carrier Modulator timer for remote control communications. Carrier generator, modulator and driver for dedicated infrared out (IRO). Can be used as an output compare timer.
- **TPMx** — Two 4-channel Timer/PWM Module; Selectable input capture, output compare, or buffered edge- or center-aligned PWM on each channel; external clock input/pulse accumulator.
- **Mini-FlexBus** — Multi-function external bus interface with user programmable chip selects and the option to multiplex address and data lines.
- **PRACMP** — Analog comparator with selectable interrupt; compare option to programmable internal reference voltage; operation in stop3.

### Measurement Engine

- **ADC16** — 16-bit successive approximation ADC with up to 4 dedicated differential channels and 8 single-ended channels; range compare function; 1.7 mV/ $\times$ C temperature sensor; internal bandgap reference channel; operation in stop3; fully functional from 3.6 V to 1.8 V. Configurable hardware trigger for 8 Channel select and result registers.
- **PDB** — Programmable delay block with 16-bit counter and modulus and prescale to set reference clock to bus divided by 1 to bus divided by 2048; 8 trigger outputs for ADC module provides periodic coordination of ADC sampling sequence with sequence completion interrupt; Back-to-Back mode and Timed mode.
- **DAC** — 12-bit resolution DAC; configurable settling time.
- **OPAMPx** — 2 flexible operational amplifiers configurable for general operations; Low offset and temperature drift.
- **TRIAMPx** — 2 trans-impedance amplifiers dedicated for converting current inputs into voltages.

### Input/Output

- Up to 68 GPIOs and 1 output-only pin.
- Voltage Reference output (VREFO).
- Dedicated infrared output pin (IRO) with high current sink capability.
- Up to 16 KBI pins with selectable polarity.
- Up to 16 pins of rapid general purpose I/O (RGPIO).



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# 1 Features

The following table provides a cross-comparison of the features of the MCF51MM256/128 according to package.

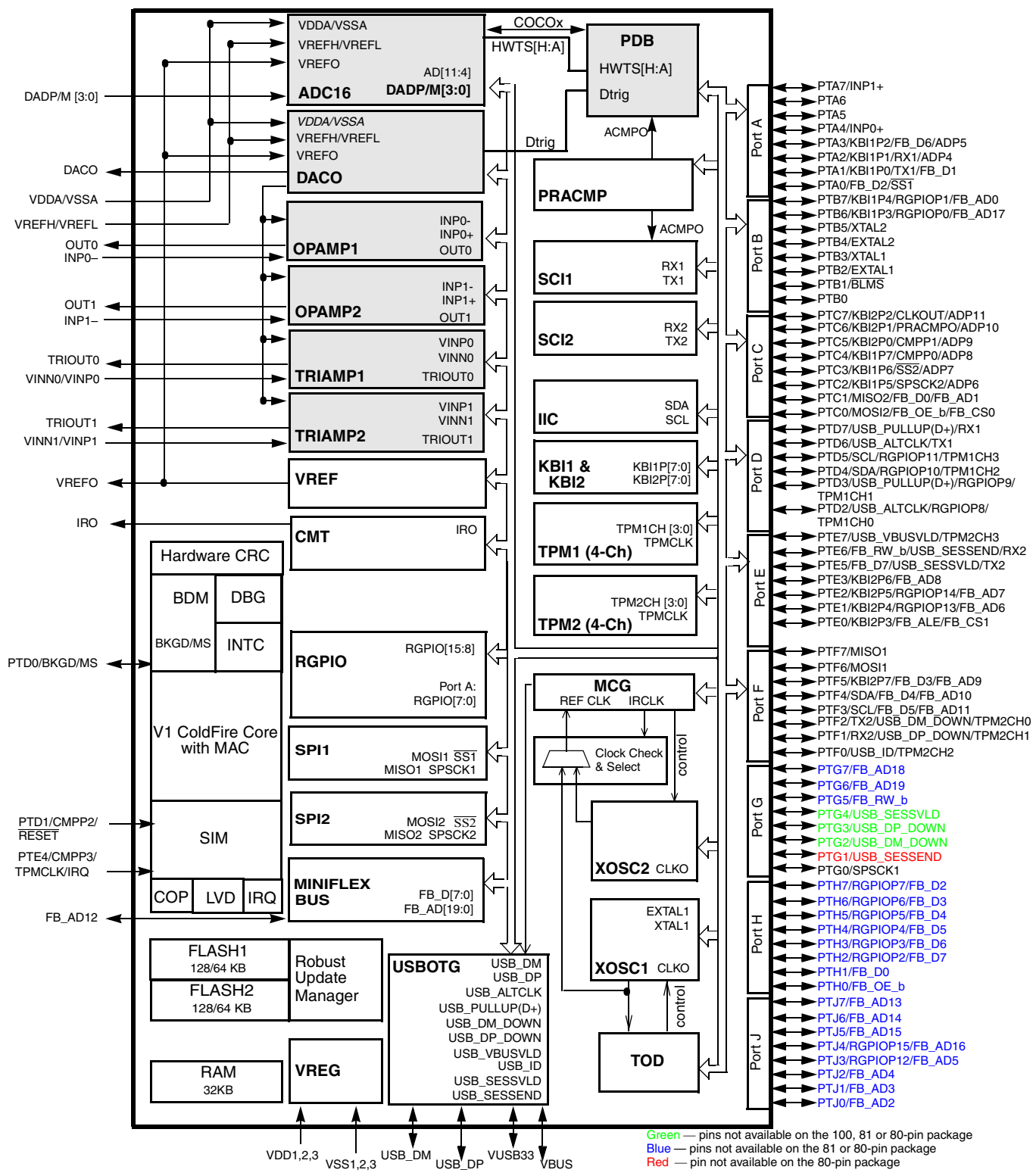
**Table 1. MCF51MM256/128 Features by MCU and Package**

| Feature   | MCF51MM256 |     |                   |                   | MCF51MM128        |                   |
|---|------------|-----|-------------------|-------------------|-------------------|-------------------|
|   |            |     |                   |                   |                   |                   |
| FLASH Size (bytes)                                | 262144     |     |                   |                   | 131072            |                   |
| RAM Size (bytes)                                  | 32K        |     |                   |                   | 32K               |                   |
| Pin Quantity                                      | 104        | 100 | 81                | 80                | 81                | 80                |
| Programmable Analog Comparator (PRACMP)           | yes        | yes | yes               | yes               | yes               | yes               |
| Debug Module (DBG)                                | yes        | yes | yes               | yes               | yes               | yes               |
| Multipurpose Clock Generator (MCG)                | yes        | yes | yes               | yes               | yes               | yes               |
| Inter-Integrated Communication (IIC)              | yes        | yes | yes               | yes               | yes               | yes               |
| Interrupt Request Pin (IRQ)                       | yes        | yes | yes               | yes               | yes               | yes               |
| Keyboard Interrupt (KBI)                          | 16         | 16  | 16                | 16                | 16                | 16                |
| Digital General Purpose I/O <sup>1</sup>          | 69         | 65  | 48                | 47                | 48                | 47                |
| Dedicated Analog Input Pins                       | 14         | 14  | 14                | 14                | 14                | 14                |
| Power and Ground Pins                             | 8          | 8   | 8                 | 8                 | 8                 | 8                 |
| Time Of Day (TOD)                                 | yes        | yes | yes               | yes               | yes               | yes               |
| Serial Communications (SCI1)                      | yes        | yes | yes               | yes               | yes               | yes               |
| Serial Communications (SCI2)                      | yes        | yes | yes               | yes               | yes               | yes               |
| Serial Peripheral Interface (SPI1(FIFO))          | yes        | yes | yes               | yes               | yes               | yes               |
| Serial Peripheral Interface(SPI2)                 | yes        | yes | yes               | yes               | yes               | yes               |
| Carrier Modulator Timer Pin (IRO)                 | yes        | yes | yes               | yes               | yes               | yes               |
| TPM Input Clock Pin (TPMCLK)                      | yes        | yes | yes               | yes               | yes               | yes               |
| TPM1 Channels                                     | 4          | 4   | 4                 | 4                 | 4                 | 4                 |
| TPM2 Channels                                     | 4          | 4   | 4                 | 4                 | 4                 | 4                 |
| XOSC1   | yes        | yes | yes               | yes               | yes               | yes               |
| XOSC2   | yes        | yes | yes               | yes               | yes               | yes               |
| USB On-the-Go                                     | yes        | yes | yes               | yes               | yes               | yes               |
| Mini-FlexBus                                      | yes        | yes | DATA <sup>2</sup> | DATA <sup>2</sup> | DATA <sup>2</sup> | DATA <sup>2</sup> |
| Rapid GPIO  | 16         | 16  | 9                 | 9                 | 9                 | 9                 |
| <b>MEASUREMENT ENGINE</b>                         |            |     |                   |                   |                   |                   |
| Programmable Delay Block (PDB)                    | yes        | yes | yes               | yes               | yes               | yes               |
| 16-Bit SAR ADC Differential Channels <sup>3</sup> | 4          | 4   | 4                 | 4                 | 4                 | 4                 |
| 16-Bit SAR ADC Single-Ended Channels              | 8          | 8   | 8                 | 8                 | 8                 | 8                 |
| DAC Output Pin (DACO)                             | yes        | yes | yes               | yes               | yes               | yes               |
| Voltage Reference Output Pin (VREFO)              | yes        | yes | yes               | yes               | yes               | yes               |
| General Purpose Operational Amplifier (OPAMP)     | yes        | yes | yes               | yes               | yes               | yes               |
| Trans-Impedance Amplifier (TRIAMP)                | yes        | yes | yes               | yes               | yes               | yes               |

<sup>1</sup> Port I/O count does not include BLMS, BKGD and IRQ. BLMS and BKGD are Output only, IRQ is input only.

<sup>2</sup> The 80/81 pin packages contain the Mini-FlexBus data pins to support an 8-bit data bus interface to external peripherals.

<sup>3</sup> Each differential channel is comprised of 2 pin inputs.



**Figure 1. MCF51MM256 Series Block Diagram**

The following table describes the functional units of the MCF51MM256/128.

**Table 2. MCF51MM256/128 Functional Units**

| Unit                                       | Function  |
|--|---|
| Measurement Engine                         | DAC (digital to analog converter) — Used to output voltage levels.  |
|  | 16-BIT SAR ADC (analog-to-digital converter) — Measures analog voltages at up to 16 bits of resolution. The ADC has up to four differential and 8 single-ended inputs.                        |
|  | OPAMP — General purpose op amp used for signal filtering or amplification.  |
|  | TRIAMP — Transimpedance amplifier optimized for converting small currents into voltages.  |
|  | Measurement Engine PDB — The measurement engine PDB is used to precisely trigger the DAC and the ADC modules to complete sensor biasing and measuring.  |
| Mini-FlexBus                               | Provides expansion capability for off-chip memory and peripherals.  |
| USB On-the-Go                              | Supports the USB On-the-Go dual-role controller.  |
| CMT (Carrier Modulator Timer)              | Infrared output used for the Remote Controller operation.   |
| 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.                                 |
| BDM (Background Debug Module)              | Provides single pin debugging interface (part of the V1 ColdFire core).   |
| CF1 CORE (V1 ColdFire Core)                | Executes programs and interrupt handlers.   |
| PRACMP                                     | Analog comparators for comparing external analog signals against each other, or a variety of reference levels.  |
| COP (Computer Operating Properly)          | Software Watchdog.  |
| IRQ (Interrupt Request)                    | Single-pin high-priority interrupt (part of the V1 ColdFire core).  |
| CRC (Cyclic Redundancy Check)              | High-speed CRC calculation.   |
| DBG (Debug)                                | Provides debugging and emulation capabilities (part of the V1 ColdFire core)  |
| FLASH (Flash Memory)                       | Provides storage for program code, constants, and variables.  |
| IIC (Inter-integrated Circuits)            | Supports standard IIC communications protocol and SMBus.  |
| INTC (Interrupt Controller)                | Controls and prioritizes all device interrupts.   |
| KBI1 & KBI2                                | Keyboard Interfaces 1 and 2.  |
| LVD (Low-voltage Detect)                   | Provides an interrupt to the ColdFire V1 CORE in the event that the supply voltage drops below a critical value. The LVD can also be programmed to reset the device upon a low voltage event. |
| VREF (Voltage Reference)                   | The Voltage Reference output is available for both on- and off-chip use.  |
| RAM (Random-Access Memory)                 | Provides stack and variable storage.  |
| RGPIO (Rapid General-purpose Input/output) | Allows for I/O port access at CPU clock speeds. RGPIO is used to implement GPIO functionality.  |

**Table 2. MCF51MM256/128 Functional Units (continued)**

| Unit   | Function   |
|--|--|
| SCI1, SCI2 (Serial Communications Interfaces)    | Serial communications UARTs capable of supporting RS-232 and LIN protocols.  |
| SIM (system integration unit)                    |  |
| SPI1 (FIFO), SPI2 (Serial Peripheral Interfaces) | SPI1 and SPI2 provide standard master/slave capability. SPI contains a FIFO buffer in order to increase the throughput for this peripheral.            |
| TPM1, TPM2 (Timer/PWM Module)                    | Timer/PWM module can be used for a variety of generic timer operations as well as pulse-width modulation.  |
| VREG (Voltage Regulator)                         | Controls power management across the device.   |
| XOSC1 and XOSC2 (Crystal Oscillators)            | These devices incorporate redundant crystal oscillators. One is intended primarily for use by the TOD, and the other by the CPU and other peripherals. |

## 2 Pinouts and Pin Assignments

### 2.1 104-Pin MAPBGA

The following figure shows the 104-pin MAPBGA pinout configuration.

|   | 1       | 2     | 3      | 4      | 5      | 6    | 7    | 8       | 9    | 10   | 11   |   |
|---|---------|-------|--------|--------|--------|------|------|---------|------|------|------|---|
| A | PTF6    | PTF7  | USB_DP | USB_DM | VUSB33 | PTF4 | PTF3 | FB_AD12 | PTJ7 | PTJ5 | PTJ4 | A |
| B | PTG0    | PTA0  | PTG3   | VBUS   | PTF5   | PTJ6 | PTH0 | PTE5    | PTF0 | PTF1 | PTF2 | B |
| C | IRO     | PTG4  | PTA6   | PTG2   | PTG6   | PTG5 | PTG7 | PTH1    | PTE4 | PTE6 | PTE7 | C |
| D | PTA5    | PTA4  | PTB1   | VDD1   |        | VDD2 |      | VDD3    | PTA1 | PTE3 | PTE2 | D |
| E | VSSA    | PTA7  | PTB0   |        |        |      |      |         | PTA2 | PTJ3 | PTE1 | E |
| F | VREFL   | INP1- | INP2-  | PTG1   |        |      |      | PTC7    | PTJ2 | PTJ0 | PTJ1 | F |
| G | TRIOUT1 | OUT1  | OUT2   |        |        |      |      |         | PTD5 | PTD7 | PTE0 | G |
| H | VINP1   | VINN1 | PTA3   | VSS1   |        | VSS2 |      | VSS3    | PTD4 | PTD3 | PTD2 | H |
| J | DADP0   | DADM0 | PTH7   | PTH6   | PTH4   | PTH3 | PTH2 | PTD6    | PTC2 | PTC0 | PTC1 | J |
| K | VINP2   | VINN2 | DADP1  | PTH5   | PTB6   | PTB7 | PTC3 | PTD1    | PTC4 | PTC5 | PTC6 | K |
| L | TRIOUT2 | DACO  | DADM1  | VREFO  | VREFH  | VDDA | PTB3 | PTB2    | PTD0 | PTB5 | PTB4 | L |
|   | 1       | 2     | 3      | 4      | 5      | 6    | 7    | 8       | 9    | 10   | 11   |   |

Figure 2. 104-Pin MAPBGA

## 2.2 100-Pin LQFP

The following figure shows the 100-pin LQFP pinout configuration.

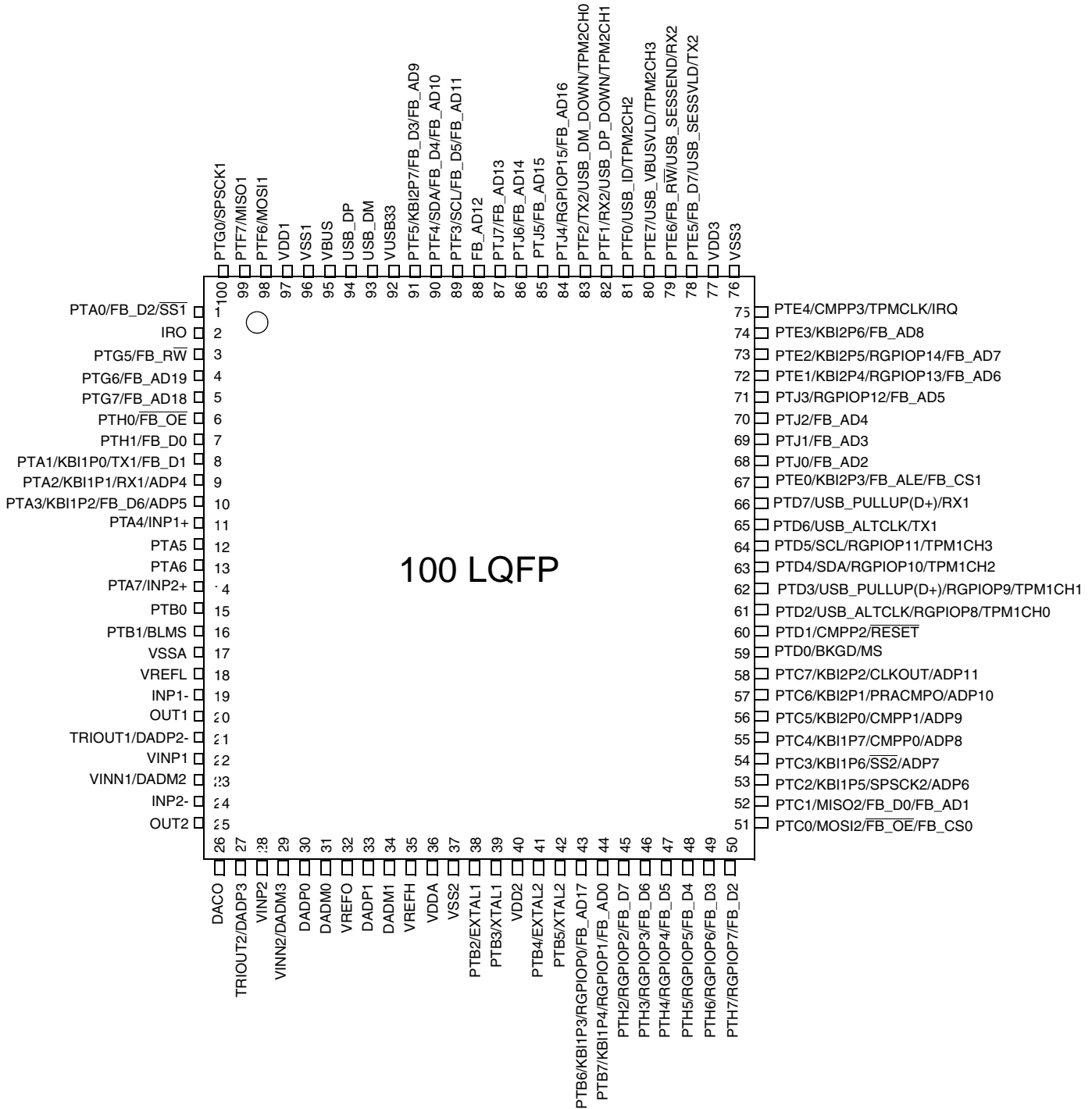


Figure 3. 100-Pin LQFP



## 2.3 81-Pin MAPBGA

The following figure shows the 81-pin MAPBGA pinout configuration.

|   | 1     | 2       | 3       | 4      | 5     | 6      | 7    | 8    | 9    |   |
|---|-------|---------|---------|--------|-------|--------|------|------|------|---|
| A | IRO   | PTG0    | PTF6    | USB_DP | VBUS  | VUSB33 | PTF4 | PTF3 | PTE4 | A |
| B | PTF7  | PTA0    | PTG1    | USB_DM | PTF5  | PTE7   | PTF1 | PTF0 | PTE3 | B |
| C | PTA4  | PTA5    | PTA6    | PTA1   | PTF2  | PTE6   | PTE5 | PTE2 | PTE1 | C |
| D | INP1- | PTA7    | PTB0    | PTB1   | PTA2  | PTA3   | PTD5 | PTD7 | PTE0 | D |
| E | OUT1  | VINN1   | OUT2    | VDD2   | VDD3  | VDD1   | PTD2 | PTD3 | PTD6 | E |
| F | VINP1 | TRIOUT1 | INP2-   | VSS2   | VSS3  | VSS1   | PTB7 | PTC7 | PTD4 | F |
| G | DADP0 | DACO    | TRIOUT2 | VINN2  | VREFO | PTB6   | PTC0 | PTC1 | PTC2 | G |
| H | DADM0 | DADM1   | DADP1   | VINP2  | PTC3  | PTC4   | PTD0 | PTC5 | PTC6 | H |
| J | VSSA  | VREFL   | VREFH   | VDDA   | PTB2  | PTB3   | PTD1 | PTB4 | PTB5 | J |
|   | 1     | 2       | 3       | 4      | 5     | 6      | 7    | 8    | 9    |   |

Figure 4. 81-Pin MAPBGA

## 2.4 80-Pin LQFP

The following figure shows the 80-pin LQFP pinout configuration.

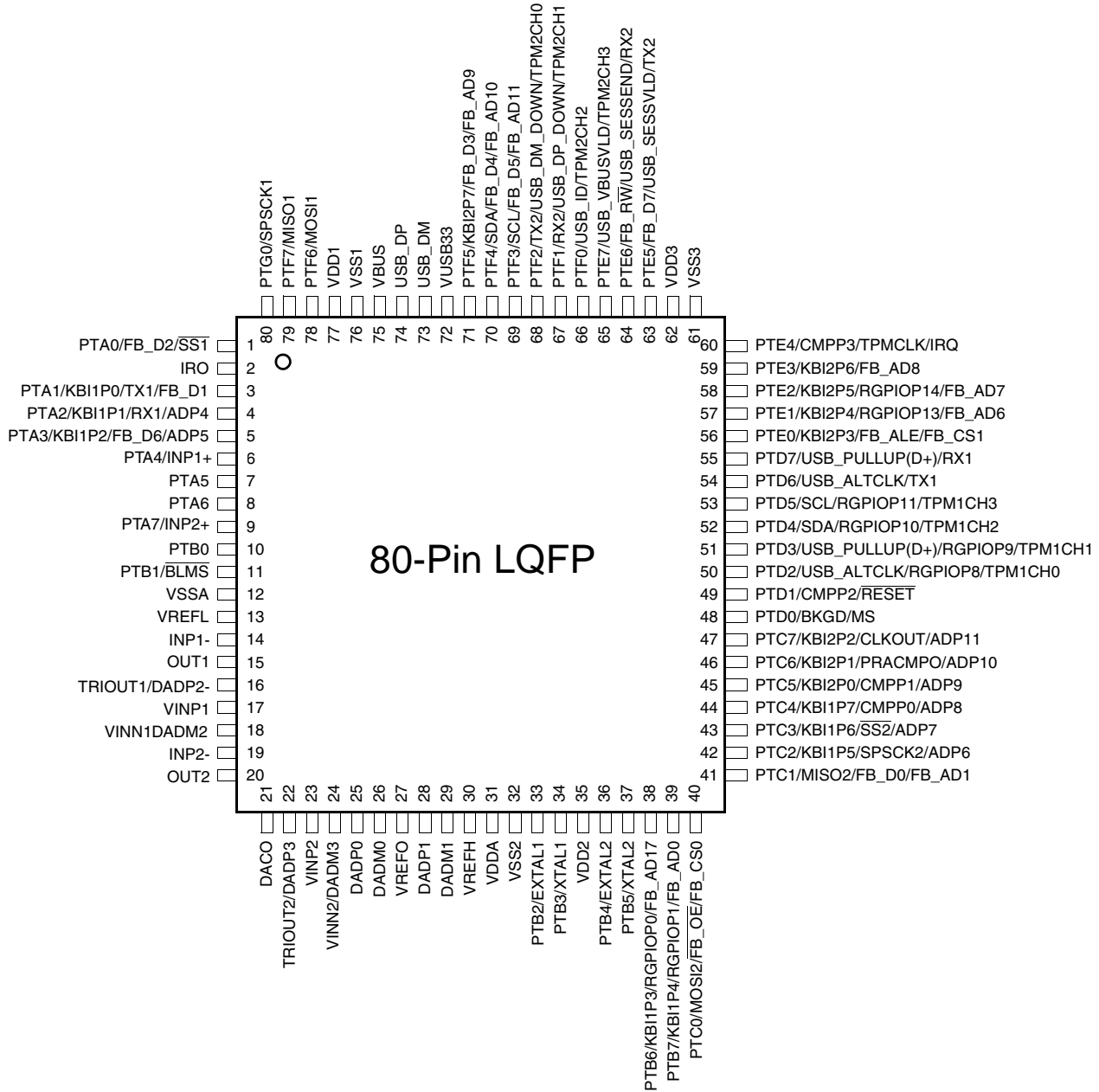


Figure 5. 80-Pin LQFP

## 2.5 Pin Assignments

Table 3. Package Pin Assignments

| Package    |          |           |         | Default Function | Alternate 1         | Alternate 2      | Alternate 3 | Composite Pin Name           |
|------------|----------|-----------|---------|------------------|---------------------|------------------|-------------|------------------------------|
| 104 MAPBGA | 100 LQFP | 81 MAPBGA | 80 LQFP |                  |                     |                  |             |                              |
| B2         | 1        | B2        | 1       | PTA0             | FB_D2               | $\overline{SS1}$ | —           | PTA0/FB_D2/ $\overline{SS1}$ |
| C1         | 2        | A1        | 2       | IRO              | —                   | —                | —           | IRO                          |
| C6         | 3        | —         | —       | PTG5             | FB_R $\overline{W}$ | —                | —           | PTG5/FB_R $\overline{W}$     |
| C5         | 4        | —         | —       | PTG6             | FB_AD19             | —                | —           | PTG6/FB_AD19                 |
| C7         | 5        | —         | —       | PTG7             | FB_AD18             | —                | —           | PTG7/FB_AD18                 |
| B7         | 6        | —         | —       | PTH0             | $\overline{FB\_OE}$ | —                | —           | PTH0/ $\overline{FB\_OE}$    |
| C8         | 7        | —         | —       | PTH1             | FB_D0               | —                | —           | PTH1/FB_D0                   |
| D9         | 8        | C4        | 3       | PTA1             | KBI1P0              | TX1              | FB_D1       | PTA1/KBI1P0/TX1/FB_D1        |
| E9         | 9        | D5        | 4       | PTA2             | KBI1P1              | RX1              | ADP4        | PTA2/KBI1P1/RX1/ADP4         |
| H3         | 10       | D6        | 5       | PTA3             | KBI1P2              | FB_D6            | ADP5        | PTA3/KBI1P2/FB_D6/ADP5       |
| D2         | 11       | C1        | 6       | PTA4             | INP1+               | —                | —           | PTA4/INP1+                   |
| D1         | 12       | C2        | 7       | PTA5             | —                   | —                | —           | PTA5                         |
| C3         | 13       | C3        | 8       | PTA6             | —                   | —                | —           | PTA6                         |
| E2         | 14       | D2        | 9       | PTA7             | INP2+               | —                | —           | PTA7/INP2+                   |
| E3         | 15       | D3        | 10      | PTB0             | —                   | —                | —           | PTB0                         |
| D3         | 16       | D4        | 11      | PTB1             | $\overline{BLMS}$   | —                | —           | PTB1/ $\overline{BLMS}$      |
| E1         | 17       | J1        | 12      | VSSA             | —                   | —                | —           | VSSA                         |
| F1         | 18       | J2        | 13      | VREFL            | —                   | —                | —           | VREFL                        |
| F2         | 19       | D1        | 14      | INP1-            | —                   | —                | —           | INP1-                        |
| G2         | 20       | E1        | 15      | OUT1             | —                   | —                | —           | OUT1                         |
| G1         | 21       | F2        | 16      | DADP2            | TRIOUT1             | —                | —           | DADP2/TRIOUT1                |
| H1         | 22       | F1        | 17      | VINP1            | —                   | —                | —           | VINP1                        |
| H2         | 23       | E2        | 18      | DADM2            | VINN1               | —                | —           | DADM2/VINN1                  |
| F3         | 24       | F3        | 19      | INP2-            | —                   | —                | —           | INP2-                        |
| G3         | 25       | E3        | 20      | OUT2             | —                   | —                | —           | OUT2                         |
| L2         | 26       | G2        | 21      | DACO             | —                   | —                | —           | DACO                         |
| L1         | 27       | G3        | 22      | DADP3            | TRIOUT2             | —                | —           | DADP3/TRIOUT2                |
| K1         | 28       | H4        | 23      | VINP2            | —                   | —                | —           | VINP2                        |
| K2         | 29       | G4        | 24      | DADM3            | VINN2               | —                | —           | DADM3/VINN2                  |

Table 3. Package Pin Assignments (continued)

| Package    |          |           |         | Default Function | Alternate 1 | Alternate 2                | Alternate 3 | Composite Pin Name                             |
|------------|----------|-----------|---------|------------------|-------------|----------------------------|-------------|--|
| 104 MAPBGA | 100 LQFP | 81 MAPBGA | 80 LQFP |                  |             |                            |             |  |
| J1         | 30       | G1        | 25      | DADP0            | —           | —                          | —           | DADP0  |
| J2         | 31       | H1        | 26      | DADM0            | —           | —                          | —           | DADM0  |
| L4         | 32       | G5        | 27      | VREFO            | —           | —                          | —           | VREFO  |
| K3         | 33       | H3        | 28      | DADP1            | —           | —                          | —           | DADP1  |
| L3         | 34       | H2        | 29      | DADM1            | —           | —                          | —           | DADM1  |
| L5         | 35       | J3        | 30      | VREFH            | —           | —                          | —           | VREFH  |
| L6         | 36       | J4        | 31      | VDDA             | —           | —                          | —           | VDDA   |
| H6         | 37       | F4        | 32      | VSS2             | —           | —                          | —           | VSS2   |
| L8         | 38       | J5        | 33      | PTB2             | EXTAL1      | —                          | —           | PTB2/EXTAL1                                    |
| L7         | 39       | J6        | 34      | PTB3             | XTAL1       | —                          | —           | PTB3/XTAL1                                     |
| D6         | 40       | E4        | 35      | VDD2             | —           | —                          | —           | VDD2   |
| L11        | 41       | J8        | 36      | PTB4             | EXTAL2      | —                          | —           | PTB4/EXTAL2                                    |
| L10        | 42       | J9        | 37      | PTB5             | XTAL2       | —                          | —           | PTB5/XTAL2                                     |
| K5         | 43       | G6        | 38      | PTB6             | KBI1P3      | RGPIOP0                    | FB_AD17     | PTB6/KBI1P3/RGPIOP0/FB_AD17                    |
| K6         | 44       | F7        | 39      | PTB7             | KBI1P4      | RGPIOP1                    | FB_AD0      | PTB7/KBI1P4/RGPIOP1/FB_AD0                     |
| J7         | 45       | —         | —       | PTH2             | RGPIOP2     | FB_D7                      | —           | PTH2/RGPIOP2/FB_D7                             |
| J6         | 46       | —         | —       | PTH3             | RGPIOP3     | FB_D6                      | —           | PTH3/RGPIOP3/FB_D6                             |
| J5         | 47       | —         | —       | PTH4             | RGPIOP4     | FB_D5                      | —           | PTH4/RGPIOP4/FB_D5                             |
| K4         | 48       | —         | —       | PTH5             | RGPIOP5     | FB_D4                      | —           | PTH5/RGPIOP5/FB_D4                             |
| J4         | 49       | —         | —       | PTH6             | RGPIOP6     | FB_D3                      | —           | PTH6/RGPIOP6/FB_D3                             |
| J3         | 50       | —         | —       | PTH7             | RGPIOP7     | FB_D2                      | —           | PTH7/RGPIOP7/FB_D2                             |
| J10        | 51       | G7        | 40      | PTC0             | MOSI2       | $\overline{\text{FB\_OE}}$ | FB_CS0      | PTC0/MOSI2/ $\overline{\text{FB\_OE}}$ /FB_CS0 |
| J11        | 52       | G8        | 41      | PTC1             | MISO2       | FB_D0                      | FB_AD1      | PTC1/MISO2/FB_D0/FB_AD1                        |
| J9         | 53       | G9        | 42      | PTC2             | KBI1P5      | SPSCK2                     | ADP6        | PTC2/KBI1P5/SPSCK2/ADP6                        |
| K7         | 54       | H5        | 43      | PTC3             | KBI1P6      | $\overline{\text{SS2}}$    | ADP7        | PTC3/KBI1P6/ $\overline{\text{SS2}}$ /ADP7     |
| K9         | 55       | H6        | 44      | PTC4             | KBI1P7      | CMPP0                      | ADP8        | PTC4/KBI1P7/CMPP0/ADP8                         |
| K10        | 56       | H8        | 45      | PTC5             | KBI2P0      | CMPP1                      | ADP9        | PTC5/KBI2P0/CMPP1/ADP9                         |
| K11        | 57       | H9        | 46      | PTC6             | KBI2P1      | PRACMPO                    | ADP10       | PTC6/KBI2P1/PRACMPO/ADP10                      |
| F8         | 58       | F8        | 47      | PTC7             | KBI2P2      | CLKOUT                     | ADP11       | PTC7/KBI2P2/CLKOUT/ADP11                       |
| L9         | 59       | H7        | 48      | PTD0             | BKGD        | MS                         | —           | PTD0/BKGD/MS                                   |
| K8         | 60       | J7        | 49      | PTD1             | CMPP2       | $\overline{\text{RESET}}$  | —           | PTD1/CMPP2/ $\overline{\text{RESET}}$          |

Table 3. Package Pin Assignments (continued)

| Package    |          |           |         | Default Function | Alternate 1     | Alternate 2     | Alternate 3 | Composite Pin Name                  |
|------------|----------|-----------|---------|------------------|-----------------|-----------------|-------------|-------------------------------------|
| 104 MAPBGA | 100 LQFP | 81 MAPBGA | 80 LQFP |                  |                 |                 |             |                                     |
| H11        | 61       | E7        | 50      | PTD2             | USB_ALTCLK      | RGPIOP8         | TPM1CH0     | PTD2/USB_ALTCLK/RGPIOP8/TPM1CH0     |
| H10        | 62       | E8        | 51      | PTD3             | USB_PULLUP (D+) | RGPIOP9         | TPM1CH1     | PTD3/USB_PULLUP(D+)/RGPIOP9/TPM1CH1 |
| H9         | 63       | F9        | 52      | PTD4             | SDA             | RGPIOP10        | TPM1CH2     | PTD4/SDA/RGPIOP10/TPM1CH2           |
| G9         | 64       | D7        | 53      | PTD5             | SCL             | RGPIOP11        | TPM1CH3     | PTD5/SCL/RGPIOP11/TPM1CH3           |
| J8         | 65       | E9        | 54      | PTD6             | USB_ALTCLK      | TX1             | —           | PTD6/USB_ALTCLK/TX1                 |
| G10        | 66       | D8        | 55      | PTD7             | USB_PULLUP (D+) | RX1             | —           | PTD7/USB_PULLUP(D+) /RX1            |
| G11        | 67       | D9        | 56      | PTE0             | KBI2P3          | FB_ALE          | FB_CS1      | PTE0/KBI2P3/FB_ALE/FB_CS1           |
| F10        | 68       | —         | —       | PTJ0             | FB_AD2          | —               | —           | PTJ0/FB_AD2                         |
| F11        | 69       | —         | —       | PTJ1             | FB_AD3          | —               | —           | PTJ1/FB_AD3                         |
| F9         | 70       | —         | —       | PTJ2             | FB_AD4          | —               | —           | PTJ2/FB_AD4                         |
| E10        | 71       | —         | —       | PTJ3             | RGPIOP12        | FB_AD5          | —           | PTJ3/RGPIOP12/FB_AD5                |
| E11        | 72       | C9        | 57      | PTE1             | KBI2P4          | RGPIOP13        | FB_AD6      | PTE1/KBI2P4/RGPIOP13/FB_AD6         |
| D11        | 73       | C8        | 58      | PTE2             | KBI2P5          | RGPIOP14        | FB_AD7      | PTE2/KBI2P5/RGPIOP14/FB_AD7         |
| D10        | 74       | B9        | 59      | PTE3             | KBI2P6          | FB_AD8          | —           | PTE3/KBI2P6/FB_AD8                  |
| C9         | 75       | A9        | 60      | PTE4             | CMPP3           | TPMCLK          | IRQ         | PTE4/CMPP3/TPMCLK/IRQ               |
| H8         | 76       | F5        | 61      | VSS3             | —               | —               | —           | VSS3                                |
| D8         | 77       | E5        | 62      | VDD3             | —               | —               | —           | VDD3                                |
| B8         | 78       | C7        | 63      | PTE5             | FB_D7           | USB_SESSVLD     | TX2         | PTE5/FB_D7/USB_SESSVLD/TX2          |
| C10        | 79       | C6        | 64      | PTE6             | FB_R $\bar{W}$  | USB_SESEND      | RX2         | PTE6/FB_R $\bar{W}$ /USB_SESEND/RX2 |
| C11        | 80       | B6        | 65      | PTE7             | USB_VBUSVLD     | TPM2CH3         | —           | PTE7/USB_VBUSVLD/TPM2CH3            |
| B9         | 81       | B8        | 66      | PTF0             | USB_ID          | TPM2CH2         | —           | PTF0/USB_ID/TPM2CH2                 |
| B10        | 82       | B7        | 67      | PTF1             | RX2             | USB_DP_D<br>OWN | TPM2CH1     | PTF1/RX2/USB_DP_DOWN/TPM2CH1        |
| B11        | 83       | C5        | 68      | PTF2             | TX2             | USB_DM_<br>DOWN | TPM2CH0     | PTF2/TX2/USB_DM_DOWN/TPM2CH0        |
| A11        | 84       | —         | —       | PTJ4             | RGPIOP15        | FB_AD16         | —           | PTJ4/RGPIOP15/FB_AD16               |
| A10        | 85       | —         | —       | PTJ5             | FB_AD15         | —               | —           | PTJ5/FB_AD15                        |
| B6         | 86       | —         | —       | PTJ6             | FB_AD14         | —               | —           | PTJ6/FB_AD14                        |
| A9         | 87       | —         | —       | PTJ7             | FB_AD13         | —               | —           | PTJ7/FB_AD13                        |

**Table 3. Package Pin Assignments (continued)**

| Package    |          |           |         | Default Function | Alternate 1 | Alternate 2 | Alternate 3 | Composite Pin Name       |
|------------|----------|-----------|---------|------------------|-------------|-------------|-------------|--------------------------|
| 104 MAPBGA | 100 LQFP | 81 MAPBGA | 80 LQFP |                  |             |             |             |                          |
| A8         | 88       | —         | —       | FB_AD12          | —           | —           | —           | FB_AD12                  |
| A7         | 89       | A8        | 69      | PTF3             | SCL         | FB_D5       | FB_AD11     | PTF3/SCL/FB_D5/FB_AD11   |
| A6         | 90       | A7        | 70      | PTF4             | SDA         | FB_D4       | FB_AD10     | PTF4/SDA/FB_D4/FB_AD10   |
| B5         | 91       | B5        | 71      | PTF5             | KBI2P7      | FB_D3       | FB_AD9      | PTF5/KBI2P7/FB_D3/FB_AD9 |
| A5         | 92       | A6        | 72      | VUSB33           | —           | —           | —           | VUSB33                   |
| A4         | 93       | B4        | 73      | USB_DM           | —           | —           | —           | USB_DM                   |
| A3         | 94       | A4        | 74      | USB_DP           | —           | —           | —           | USB_DP                   |
| B4         | 95       | A5        | 75      | VBUS             | —           | —           | —           | VBUS                     |
| H4         | 96       | F6        | 76      | VSS1             | —           | —           | —           | VSS1                     |
| D4         | 97       | E6        | 77      | VDD1             | —           | —           | —           | VDD1                     |
| A1         | 98       | A3        | 78      | PTF6             | MOSI1       | —           | —           | PTF6/MOSI1               |
| A2         | 99       | B1        | 79      | PTF7             | MISO1       | —           | —           | PTF7/MISO1               |
| B1         | 100      | A2        | 80      | PTG0             | SPSCK1      | —           | —           | PTG0/SPSCK1              |
| F4         | —        | A1        | —       | PTG1             | USB_SESEND  | —           | —           | PTG1/USB_SESEND          |
| C4         | —        | —         | —       | PTG2             | USB_DM_DOWN | —           | —           | PTG2/USB_DM_DOWN         |
| B3         | —        | —         | —       | PTG3             | USB_DP_DOWN | —           | —           | PTG3/USB_DP_DOWN         |
| C2         | —        | —         | —       | PTG4             | USB_SESSVLD | —           | —           | PTG4/USB_SESSVLD         |

## 3 Electrical Characteristics

This section contains electrical specification tables and reference timing diagrams for the MCF51MM256/128 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.

### 3.1 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 4. Parameter Classifications**

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

### NOTE

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

## 3.2 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 the following table may affect device reliability or cause permanent damage to the device. For functional operating conditions, refer to the remaining tables in this section.

**Table 5. Absolute Maximum Ratings**

| # | Rating  | Symbol    | Value                  | Unit |
|---|---|-----------|------------------------|------|
| 1 | Supply voltage  | $V_{DD}$  | -0.3 to +3.8           | V    |
| 2 | Maximum current into $V_{DD}$   | $I_{DD}$  | 120                    | mA   |
| 3 | Digital input voltage   | $V_{In}$  | -0.3 to $V_{DD} + 0.3$ | V    |
| 4 | Instantaneous maximum current<br>Single pin limit (applies to all port pins) <sup>1, 2, 3</sup> | $I_D$     | ± 25                   | mA   |
| 5 | Storage temperature range   | $T_{stg}$ | -55 to 150             | °C   |

<sup>1</sup> Input must be current limited to the value specified. To determine the value of the required current-limiting resistor, calculate resistance values for positive ( $V_{DD}$ ) and negative ( $V_{SS}$ ) clamp voltages, then use the larger of the two resistance values.

<sup>2</sup> All functional non-supply pins are internally clamped to  $V_{SS}$  and  $V_{DD}$ .

<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).

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  $V_{DD}$ ).



### 3.3 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 6. Thermal Characteristics**

| # | Symbol        | Rating   | Value      | Unit |
|---|---------------|--|------------|------|
| 1 | $T_A$         | Operating temperature range (packaged):                          |            | °C   |
|   |               | MCF51MM256   | –40 to 105 |      |
|   |               | MCF51MM128   | –40 to 105 |      |
| 2 | $T_{JMAX}$    | Maximum junction temperature                                     | 135        | °C   |
| 3 | $\theta_{JA}$ | Thermal resistance <sup>1,2,3,4</sup> Single-layer board — 1s    |            | °C/W |
|   |               | 104-pin MBGA   | 67         |      |
|   |               | 100-pin LQFP   | 53         |      |
|   |               | 81-pin MBGA  | 67         |      |
|   |               | 80-pin LQFP  | 53         |      |
| 4 | $\theta_{JA}$ | Thermal resistance <sup>1, 2, 3, 4</sup> Four-layer board — 2s2p |            | °C/W |
|   |               | 104-pin MBGA   | 39         |      |
|   |               | 100-pin LQFP   | 41         |      |
|   |               | 81-pin MBGA  | 39         |      |
|   |               | 80-pin LQFP  | 39         |      |

<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

## Electrical Characteristics

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

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

Solving Equation 1 and Equation 2 for K gives:

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

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

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

**Table 7. 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     | —        |
| Machine    | Series Resistance           | R1     | 0     | $\Omega$ |
|            | Storage Capacitance         | C      | 200   | pF       |
|            | Number of Pulse per pin     | —      | 3     | —        |
| Latch-up   | Minimum input voltage limit | —      | -2.5  | V        |
|            | Maximum input voltage limit | —      | 7.5   | V        |

**Table 8. ESD and Latch-Up Protection Characteristics**

| # | Rating                 | Symbol    | Min        | Max | Unit | C |
|---|------------------------|-----------|------------|-----|------|---|
| 1 | Human Body Model (HBM) | $V_{HBM}$ | $\pm 2000$ | —   | V    | T |
| 2 | Machine Model (MM)     | $V_{MM}$  | $\pm 200$  | —   | V    | T |

**Table 8. ESD and Latch-Up Protection Characteristics (continued)**

|   |   |           |           |   |    |   |
|---|---|-----------|-----------|---|----|---|
| 3 | Charge Device Model (CDM)                     | $V_{CDM}$ | $\pm 500$ | — | V  | T |
| 4 | Latch-up Current at $T_A = 125^\circ\text{C}$ | $I_{LAT}$ | $\pm 100$ | — | mA | T |

### 3.5 DC Characteristics

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

**Table 9. DC Characteristics**

| Num | Symbol           | Characteristic   | Condition   | Min                     | Typ <sup>1</sup>     | Max | Unit | C  |   |
|-----|------------------|--|---|-------------------------|----------------------|-----|------|----|---|
| 1   | —                | Operating Voltage  | —   | 1.8 <sup>2</sup>        | —                    | 3.6 | V    | —  |   |
| 2   | V <sub>OH</sub>  | Output high voltage                                      | All I/O pins, low-drive strength                              |                         |                      |     |      |    |   |
|     |                  |  | $V_{DD} \geq 1.8\text{ V},$<br>$I_{Load} = -600\ \mu\text{A}$ | $V_{DD} - 0.5$          | —                    | —   | V    | C  |   |
|     |                  |  | All I/O pins, high-drive strength                             |                         |                      |     |      |    |   |
|     |                  |  | $V_{DD} \geq 2.7\text{ V},$<br>$I_{Load} = -10\text{ mA}$     | $V_{DD} - 0.5$          | —                    | —   | V    | P  |   |
|     |                  |  | $V_{DD} \geq 2.3\text{ V},$<br>$I_{Load} = -6\text{ mA}$      | $V_{DD} - 0.5$          | —                    | —   | V    | T  |   |
|     |                  | $V_{DD} \geq 1.8\text{ V},$<br>$I_{Load} = -3\text{ mA}$ | $V_{DD} - 0.5$  | —                       | —                    | V   | C    |    |   |
| 3   | I <sub>OHT</sub> | Output high current                                      | Max total I <sub>OH</sub> for all ports                       | —                       | —                    | —   | 100  | mA | D |
|     |                  |  |   | —                       | —                    | —   | 100  | mA | D |
| 4   | V <sub>OL</sub>  | Output low voltage                                       | All I/O pins, low-drive strength                              |                         |                      |     |      |    |   |
|     |                  |  | $V_{DD} \geq 1.8\text{ V},$<br>$I_{Load} = 600\ \mu\text{A}$  | —                       | —                    | 0.5 | V    | C  |   |
|     |                  |  | All I/O pins, high-drive strength                             |                         |                      |     |      |    |   |
|     |                  |  | $V_{DD} \geq 2.7\text{ V},$<br>$I_{Load} = 10\text{ mA}$      | —                       | —                    | 0.5 | V    | P  |   |
|     |                  |  | $V_{DD} \geq 2.3\text{ V},$<br>$I_{Load} = 6\text{ mA}$       | —                       | —                    | 0.5 | V    | T  |   |
|     |                  | $V_{DD} \geq 1.8\text{ V},$<br>$I_{Load} = 3\text{ mA}$  | —   | —                       | 0.5                  | V   | C    |    |   |
| 5   | I <sub>OLT</sub> | Output low current                                       | Max total I <sub>OL</sub> for all ports                       | —                       | —                    | —   | 100  | mA | D |
| 6   | V <sub>IH</sub>  | Input high voltage                                       | all digital inputs  | $V_{DD} > 2.7\text{ V}$ | $0.70 \times V_{DD}$ | —   | —    | V  | P |
|     |                  |  |   | $V_{DD} > 1.8\text{ V}$ | $0.85 \times V_{DD}$ | —   | —    | V  | C |
|     |                  |  |   |                         |                      |     |      |    |   |

Table 9. DC Characteristics (continued)

| Num | Symbol                         | Characteristic   | Condition  | Min                    | Typ <sup>1</sup> | Max                    | Unit | C |   |
|-----|--------------------------------|--|--|------------------------|------------------|------------------------|------|---|---|
| 7   | V <sub>IL</sub>                | Input low voltage all digital inputs   | V <sub>DD</sub> > 2.7 V                              | —                      | —                | 0.35 x V <sub>DD</sub> | V    | P |   |
|     |                                |  | V <sub>DD</sub> > 1.8 V                              | —                      | —                | 0.30 x V <sub>DD</sub> | V    | C |   |
|     |                                |  |  |                        |                  |                        |      |   |   |
| 8   | V <sub>hys</sub>               | Input hysteresis all digital inputs  | —  | 0.06 x V <sub>DD</sub> | —                | —                      | mV   | C |   |
| 9   | I <sub>IInI</sub>              | Input leakage current all input only pins (Per pin)                              | V <sub>In</sub> = V <sub>DD</sub> or V <sub>SS</sub> | —                      | —                | 0.5                    | μA   | P |   |
| 10  | I <sub>IOnI</sub>              | Hi-Z (off-state) leakage current <sup>3</sup> all digital input/output (per pin) | V <sub>In</sub> = V <sub>DD</sub> or V <sub>SS</sub> | —                      | 0.003            | 0.5                    | μA   | P |   |
| 11  | R <sub>PU</sub>                | Pull-up resistors all digital inputs, when enabled                               | —  | 17.5                   | —                | 52.5                   | kΩ   | P |   |
| 12  | R <sub>PD</sub>                | Internal pull-down resistors <sup>4</sup>  | —  | 17.5                   | —                | 52.5                   | kΩ   | P |   |
| 13  | I <sub>IC</sub>                | DC injection current <sup>5, 6, 7</sup> Single pin limit                         | V <sub>SS</sub> > V <sub>IN</sub> > V <sub>DD</sub>  | -0.2                   | —                | 0.2                    | mA   | D |   |
|     |                                |  | Total MCU limit, includes sum of all stressed pins   |                        |                  |                        |      |   |   |
|     |                                |  | V <sub>SS</sub> > V <sub>IN</sub> > V <sub>DD</sub>  | -5                     | —                | 5                      | mA   | D |   |
| 14  | C <sub>In</sub>                | Input Capacitance, all pins  | —  | —                      | —                | 8                      | pF   | C |   |
| 15  | V <sub>RAM</sub>               | RAM retention voltage  | —  | —                      | 0.6              | 1.0                    | V    | C |   |
| 16  | V <sub>POR</sub>               | POR re-arm voltage <sup>8</sup>  | —  | 0.9                    | 1.4              | 1.79                   | V    | C |   |
| 17  | t <sub>POR</sub>               | POR re-arm time  | —  | 10                     | —                | —                      | μs   | D |   |
| 18  | V <sub>LVdH</sub> <sup>9</sup> | Low-voltage detection threshold — high range                                     | V <sub>DD</sub> falling                              | —                      | 2.11             | 2.16                   | 2.22 | V | P |
|     |                                |  | V <sub>DD</sub> rising                               | —                      | 2.16             | 2.21                   | 2.27 | V | P |
| 19  | V <sub>LVdL</sub>              | Low-voltage detection threshold — low range <sup>9</sup>                         | V <sub>DD</sub> falling                              | —                      | 1.80             | 1.82                   | 1.91 | V | P |
|     |                                |  | V <sub>DD</sub> rising                               | —                      | 1.86             | 1.90                   | 1.99 | V | P |

Table 9. DC Characteristics (continued)

| Num | Symbol            | Characteristic  | Condition               | Min   | Typ <sup>1</sup> | Max   | Unit | C |   |
|-----|-------------------|---|-------------------------|-------|------------------|-------|------|---|---|
| 20  | V <sub>LVWH</sub> | Low-voltage warning threshold — high range <sup>9</sup>   | V <sub>DD</sub> falling | —     | 2.36             | 2.46  | 2.56 | V | P |
|     |                   |   | V <sub>DD</sub> rising  | —     | 2.36             | 2.46  | 2.56 | V | P |
| 21  | V <sub>LVWL</sub> | Low-voltage warning threshold — low range <sup>9</sup>    | V <sub>DD</sub> falling | —     | 2.11             | 2.16  | 2.22 | V | P |
|     |                   |   | V <sub>DD</sub> rising  | —     | 2.16             | 2.21  | 2.27 | V | P |
| 22  | V <sub>hys</sub>  | Low-voltage inhibit reset/recoverhysteresis <sup>10</sup> | —                       | —     | 50               | —     | mV   | C |   |
| 23  | V <sub>BG</sub>   | Bandgap Voltage Reference <sup>11</sup>                   | —                       | 1.110 | 1.17             | 1.230 | V    | P |   |

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

<sup>2</sup> As the supply voltage rises, the LVD circuit will hold the MCU in reset until the supply has risen above V<sub>LVDL</sub>.

<sup>3</sup> Does not include analog module pins. Dedicated analog pins should not be pulled to V<sub>DD</sub> or V<sub>SS</sub> and should be left floating when not used to reduce current leakage.

<sup>4</sup> Measured with V<sub>in</sub> = V<sub>DD</sub>.

<sup>5</sup> All functional non-supply pins are internally clamped to V<sub>SS</sub> and V<sub>DD</sub> except PTD1.

<sup>6</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>7</sup> Power supply must maintain regulation within operating V<sub>DD</sub> range during instantaneous and operating maximum current conditions. If positive injection current (V<sub>in</sub> > V<sub>DD</sub>) is greater than I<sub>DD</sub>, the injection current may flow out of V<sub>DD</sub> and could result in external power supply going out of regulation. Ensure external V<sub>DD</sub> 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>8</sup> Maximum is highest voltage that POR is guaranteed.

<sup>9</sup> Run at 1 MHz bus frequency

<sup>10</sup> Low voltage detection and warning limits measured at 1 MHz bus frequency.

<sup>11</sup> Factory trimmed at V<sub>DD</sub> = 3.0 V, Temp = 25°C

### 3.6 Supply Current Characteristics

Table 10. Supply Current Characteristics

| # | Symbol            | Parameter  | Bus Freq    | V <sub>DD</sub> (V) | Typ <sup>1</sup> | Max  | Unit | Temp (°C)  | C |
|---|-------------------|--|-------------|---------------------|------------------|------|------|------------|---|
| 1 | R <sub>I</sub> DD | Run supply current<br>FEI mode; all modules ON <sup>2</sup>  | 25.165 MHz  | 3                   | 44               | 48   | mA   | -40 to 25  | P |
|   |                   |  | 25.165 MHz  | 3                   | 44               | 48   | mA   | 105        | P |
|   |                   |  | 20 MHz      | 3                   | 32.3             | —    | mA   | -40 to 105 | T |
|   |                   |  | 8 MHz       | 3                   | 16.4             | —    | mA   | -40 to 105 | T |
|   |                   |  | 1 MHz       | 3                   | 2.9              | —    | mA   | -40 to 105 | T |
| 2 | R <sub>I</sub> DD | Run supply current<br>FEI mode; all modules OFF <sup>3</sup> | 25.165 MHz  | 3                   | 29               | 29.6 | mA   | -40 to 105 | C |
|   |                   |  | 20 MHz      | 3                   | 25.4             | —    | mA   | -40 to 105 | T |
|   |                   |  | 8 MHz       | 3                   | 12.7             | —    | mA   | -40 to 105 | T |
|   |                   |  | 1 MHz       | 3                   | 2.4              | —    | mA   | -40 to 105 | T |
|   |                   |  | 16 kHz FBI  | 3                   | 232              | 280  | μA   | -40 to 105 | T |
| 3 | R <sub>I</sub> DD | Run supply current<br>LPR=0; all modules OFF <sup>3</sup>    | 16 kHz FBE  | 3                   | 231              | 296  | μA   | -40 to 105 | T |
|   |                   |  | 16 kHz BLPE | 3                   | 74               | 75   | μA   | 0 to 70    | T |
| 4 | R <sub>I</sub> DD | Run supply current<br>LPR=1, all modules OFF <sup>3</sup>    | 16 kHz BLPE | 3                   | 74               | 120  | μA   | -40 to 105 | T |
|   |                   |  | 16 kHz BLPE | 3                   | 74               | 120  | μA   | -40 to 105 | T |

Table 10. Supply Current Characteristics (continued)

| # | Symbol              | Parameter  | Bus Freq   | V <sub>DD</sub> (V) | Typ <sup>1</sup> | Max   | Unit | Temp (°C)  | C |
|---|---------------------|--|------------|---------------------|------------------|-------|------|------------|---|
| 5 | W <sub>I</sub> DD   | Wait mode supply current<br>FEI mode, all modules OFF <sup>3</sup> | 25.165 MHz | 3                   | 16.5             | —     | mA   | –40 to 105 | C |
|   |                     |  | 20 MHz     | 3                   | 10.3             | —     | mA   | –40 to 105 | T |
|   |                     |  | 8 MHz      | 3                   | 6.6              | —     | mA   | –40 to 105 | T |
|   |                     |  | 1 MHz      | 3                   | 1.7              | —     | mA   | –40 to 105 | T |
| 6 | LPW <sub>I</sub> DD | Low-Power Wait mode supply current                                 | 16 KHz     | 3                   | 28               | 62    | µA   | –40 to 105 | T |
|   |                     |  |            |                     |                  |       |      |            |   |
| 7 | S2 <sub>I</sub> DD  | Stop2 mode supply current <sup>4</sup>                             | N/A        | 3                   | 0.410            | 1.00  | µA   | –40 to 25  | P |
|   |                     |  | N/A        | 3                   | 3.7              | 10    | µA   | 70         | C |
|   |                     |  | N/A        | 3                   | 10               | 20    | µA   | 85         | C |
|   |                     |  | N/A        | 3                   | 21               | 31.5  | µA   | 105        | P |
|   |                     |  | N/A        | 2                   | 0.410            | 0.640 | µA   | –40 to 25  | C |
|   |                     |  | N/A        | 2                   | 3.4              | 9     | µA   | 70         | C |
|   |                     |  | N/A        | 2                   | 9.5              | 18    | µA   | 85         | C |
|   |                     |  | N/A        | 2                   | 20               | 30    | µA   | 105        | C |



Table 10. Supply Current Characteristics (continued)

| # | Symbol            | Parameter  | Bus Freq | V <sub>DD</sub> (V) | Typ <sup>1</sup> | Max   | Unit | Temp (°C) | C |
|---|-------------------|--|----------|---------------------|------------------|-------|------|-----------|---|
| 8 | S3I <sub>DD</sub> | Stop3 mode supply current <sup>4</sup><br>No clocks active | n/a      | 3                   | 0.750            | 1.3   | μA   | -40 to 25 | P |
|   |                   |  |          |                     | 8.5              | 18    |      | 70        | C |
|   |                   |  |          |                     | 20               | 28    |      | 85        | C |
|   |                   |  |          |                     | 53               | 63    |      | 105       | P |
|   |                   |  |          | 2                   | 0.400            | 0.900 |      | -40 to 25 | C |
|   |                   |  |          |                     | 8.2              | 16    |      | 70        | C |
|   |                   |  |          |                     | 18               | 26    |      | 85        | C |
|   |                   |  |          |                     | 47               | 59    |      | 105       | C |

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

<sup>2</sup> ON = System Clock Gating Control registers turn on system clock to the corresponding modules.

<sup>3</sup> OFF = System Clock Gating Control registers turn off system Clock to the corresponding modules.

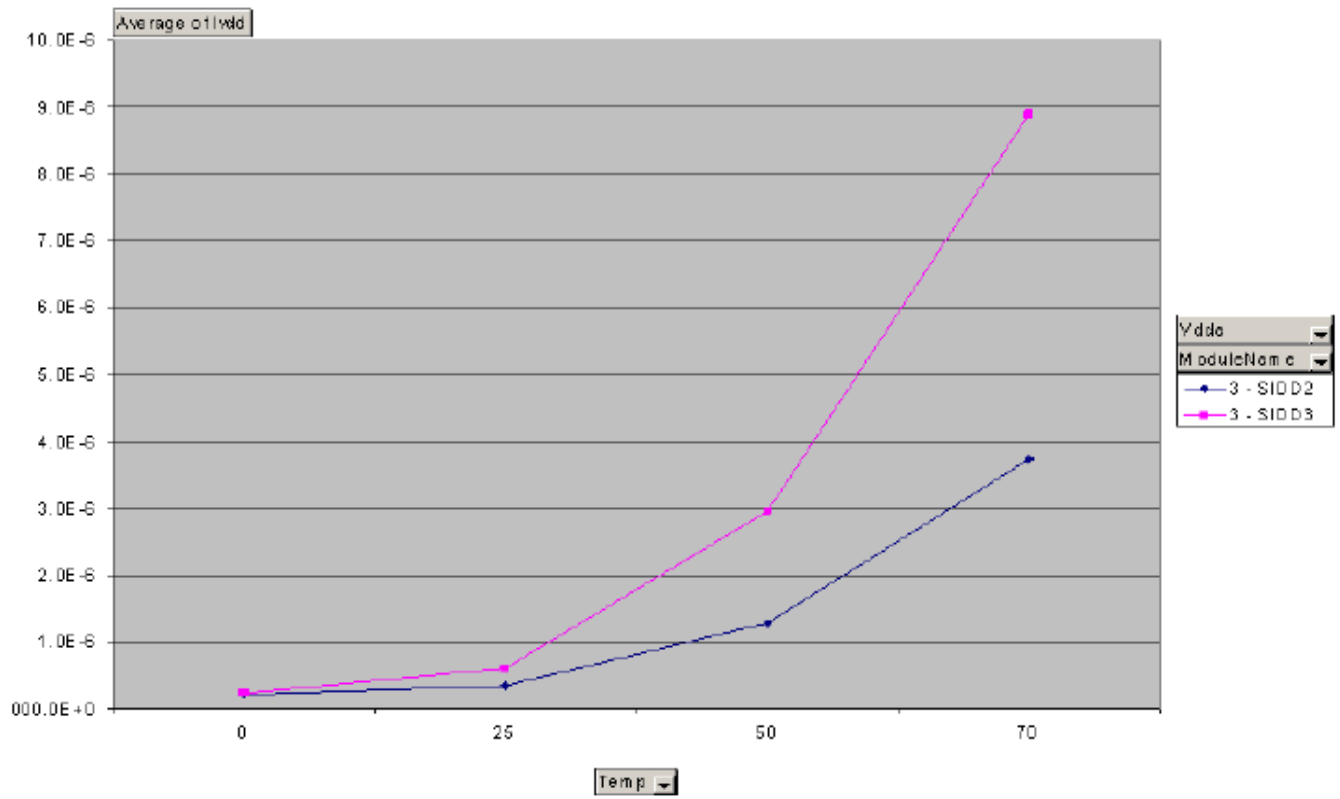
<sup>4</sup> All digital pins must be configured to a known state to prevent floating pins from adding current. Smaller packages may have some pins that are not bonded out; however, software must still be configured to the largest pin package available so that all pins are in a known state. Otherwise, floating pins that are not bonded in the smaller packages may result in a higher current draw. NOTE: I/O pins are configured to output low; input-only pins are configured to pullup-enabled. IRO pin connects to ground. FB\_AD12 pin is pullup-enabled. TRIAMPx, OPAMPx, DACO, and VREF0 pins are at reset state and unconnected.

Table 11. Typical Stop Mode Adders

| #  | Parameter             | Condition  | Temperature (°C) |     |     |     |      | Units | C |
|----|-----------------------|--|------------------|-----|-----|-----|------|-------|---|
|    |                       |  | -40              | 25  | 70  | 85  | 105  |       |   |
| 1  | LPO                   | —  | 50               | 75  | 100 | 150 | 250  | nA    | D |
| 2  | EREFSTEN              | RANGE = HGO = 0  | 600              | 650 | 750 | 850 | 1000 | nA    | D |
| 3  | IREFSTEN <sup>1</sup> | —  | —                | 73  | 80  | 93  | 125  | μA    | T |
| 4  | TOD                   | Does not include clock source current                  | 50               | 75  | 100 | 150 | 250  | nA    | D |
| 5  | LVD <sup>1</sup>      | LVDSE = 1  | 116              | 117 | 126 | 132 | 172  | μA    | T |
| 6  | PRACMP <sup>1</sup>   | Not using the bandgap (BGBE = 0)                       | 17               | 18  | 24  | 35  | 74   | μA    | T |
| 7  | ADC <sup>1</sup>      | ADLPC = ADLSMP = 1<br>Not using the bandgap (BGBE = 0) | 190              | 195 | 210 | 220 | 260  | μA    | T |
| 8  | DAC <sup>1</sup>      | High-Power mode; no load on DACO                       | 339              | 345 | 346 | 346 | 360  | μA    | T |
|    |                       | Low-Power mode   | 41               | 43  | 43  | 44  | 50   | μA    | T |
| 9  | OPAMP <sup>1</sup>    | High-Power mode  | 276              | 350 | 370 | 376 | 390  | μA    | T |
|    |                       | Low-Power mode   | 42               | 49  | 57  | 58  | 68   | μA    | T |
| 10 | TRIAMP <sup>1</sup>   | High-Power mode  | 420              | 432 | 433 | 438 | 478  | μA    | T |
|    |                       | Low-Power mode   | 52               | 52  | 52  | 55  | 60   | μA    | T |

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

## Electrical Characteristics



**Figure 7. Stop IDD versus Temperature**

### 3.7 PRACMP Electricals

**Table 12. PRACMP Electrical Specifications**

| #  | Characteristic                                 | Symbol               | Min            | Typical | Max      | Unit    | C |
|----|--|----------------------|----------------|---------|----------|---------|---|
| 1  | Supply voltage                                 | $V_{PWR}$            | 1.8            | —       | 3.6      | V       | P |
| 2  | Supply current (active) (PRG enabled)          | $I_{DDACT1}$         | —              | —       | 80       | $\mu A$ | D |
| 3  | Supply current (active) (PRG disabled)         | $I_{DDACT2}$         | —              | —       | 40       | $\mu A$ | D |
| 4  | Supply current (ACMP and PRG all disabled)     | $I_{DDDIS}$          | —              | —       | 2        | nA      | D |
| 5  | Analog input voltage                           | $V_{AIN}$            | $V_{SS} - 0.3$ | —       | $V_{DD}$ | V       | D |
| 6  | Analog input offset voltage                    | $V_{AIO}$            | —              | 5       | 40       | mV      | D |
| 7  | Analog comparator hysteresis                   | $V_H$                | 3.0            | —       | 20.0     | mV      | D |
| 8  | Analog input leakage current                   | $I_{ALKG}$           | —              | —       | 1        | nA      | D |
| 9  | Analog comparator initialization delay         | $t_{AINIT}$          | —              | —       | 1.0      | $\mu s$ | D |
| 10 | Programmable reference generator inputs        | $V_{In2} (V_{DD25})$ | 1.8            | —       | 2.75     | V       | D |
| 11 | Programmable reference generator setup delay   | $t_{PRGST}$          | —              | 1       | —        | $\mu s$ | D |
| 12 | Programmable reference generator step size     | $V_{step}$           | 0.75           | 1       | 1.25     | LSB     | D |
| 13 | Programmable reference generator voltage range | $V_{prgout}$         | $V_{In}/32$    | —       | $V_{in}$ | V       | P |

### 3.8 12-Bit DAC Electricals

**Table 13. DAC 12LV Operating Requirements**

| # | Characteristic          | Symbol     | Min  | Max | Unit        | C | Notes  |
|---|-------------------------|------------|------|-----|-------------|---|--|
| 1 | Supply voltage          | $V_{DDA}$  | 1.8  | 3.6 | V           | P |  |
| 2 | Reference voltage       | $V_{DACR}$ | 1.15 | 3.6 | V           | C |  |
| 3 | Temperature             | $T_A$      | -40  | 105 | $^{\circ}C$ | C |  |
| 4 | Output load capacitance | $C_L$      | —    | 100 | pF          | C | A small load capacitance (47 pF) can improve the bandwidth performance of the DAC. |
| 5 | Output load current     | $I_L$      | —    | 1   | mA          | C |  |

**Table 14. DAC 12-Bit Operating Behaviors**

| # | Characteristic | Symbol | Min | Typ | Max | Unit | C | Notes |
|---|----------------|--------|-----|-----|-----|------|---|-------|
| 1 | Resolution     | N      | 12  | —   | 12  | bit  | T |       |

Table 14. DAC 12-Bit Operating Behaviors (continued)

| #  | Characteristic   | Symbol           | Min              | Typ       | Max       | Unit    | C | Notes   |
|----|--|------------------|------------------|-----------|-----------|---------|---|---|
| 2  | Supply current low-power mode  | $I_{DDA\_DACLP}$ | —                | 50        | 100       | $\mu A$ | T |   |
| 3  | Supply current high-power mode   | $I_{DDA\_DACHP}$ | —                | 345       | 500       | $\mu A$ | T |   |
| 4  | Full-scale Settling time ( $\pm 1$ LSB) (0x080 to 0xF7F or 0xF7F to 0x080) low-power mode                              | $T_{s_{FS}LP}$   | —                | —         | 200       | $\mu s$ | T | <ul style="list-style-type: none"> <li><math>V_{DDA} = 3 V</math> or <math>2.2 V</math></li> <li><math>V_{REFSEL} = 1</math></li> <li>Temperature = <math>25^{\circ}C</math></li> </ul> |
| 5  | Full-scale Settling time ( $\pm 1$ LSB) (0x080 to 0xF7F or 0xF7F to 0x080) high-power mode                             | $T_{s_{FS}HP}$   | —                | —         | 30        | $\mu s$ | T | <ul style="list-style-type: none"> <li><math>V_{DDA} = 3 V</math> or <math>2.2 V</math></li> <li><math>V_{REFSEL} = 1</math></li> <li>Temperature = <math>25^{\circ}C</math></li> </ul> |
| 6  | Code-to-code Settling time ( $\pm 1$ LSB) (0xBF8 to 0xC08 or 0xC08 to 0xBF8) low-power mode                            | $T_{s_{C-C}LP}$  | —                | —         | 5         | $\mu s$ | T | <ul style="list-style-type: none"> <li><math>V_{DDA} = 3 V</math> or <math>2.2 V</math></li> <li><math>V_{REFSEL} = 1</math></li> <li>Temperature = <math>25^{\circ}C</math></li> </ul> |
| 7  | Code-to-code Settling time ( $\pm 1$ LSB) (0xBF8 to 0xC08 or 0xC08 to 0xBF8) high-power mode (3 V at Room Temperature) | $T_{s_{C-C}HP}$  | —                | 1         | —         | $\mu s$ | T | <ul style="list-style-type: none"> <li><math>V_{DDA} = 3 V</math> or <math>2.2 V</math></li> <li><math>V_{REFSEL} = 1</math></li> <li>Temperature = <math>25^{\circ}C</math></li> </ul> |
| 8  | DAC output voltage range low (high-power mode, no load, DAC set to 0) (3 V at Room Temperature)                        | $V_{dacoutl}$    | —                | —         | 100       | mV      | T |   |
| 9  | DAC output voltage range high (high-power mode, no load, DAC set to 0xFFF)   | $V_{dacouth}$    | $V_{DACR} - 100$ | —         | —         | mV      | T |   |
| 10 | Integral non-linearity error   | INL              | —                | —         | $\pm 8$   | LSB     | T |   |
| 11 | Differential non-linearity error $V_{DACR}$ is $> 2.4 V$   | DNL              | —                | —         | $\pm 1$   | LSB     | T |   |
| 12 | Offset error   | $E_O$            | —                | $\pm 0.4$ | $\pm 3$   | %FSR    | T | Calculated by a best fit curve from $V_{SS} + 100mV$ to $V_{REFH} - 100mV$  |
| 13 | Gain error, $V_{REFH} = V_{ext} = V_{DD}$  | $E_G$            | —                | $\pm 0.1$ | $\pm 0.5$ | %FSR    | T | Calculated by a best fit curve from $V_{SS} + 100mV$ to $V_{REFH} - 100mV$  |

Table 14. DAC 12-Bit Operating Behaviors (continued)

| #  | Characteristic   | Symbol   | Min | Typ | Max | Unit       | C | Notes                                  |
|----|--|----------|-----|-----|-----|------------|---|--|
| 14 | Power supply rejection ratio<br>$V_{DD} \geq 2.4$ V        | PSRR     | 60  | —   | —   | dB         | T |  |
| 15 | Temperature drift of offset voltage<br>(DAC set to 0x0800) | $T_{CO}$ | —   | —   | 2   | mV         | T | See Typical Drift figure that follows. |
| 16 | Offset aging coefficient                                   | $A_C$    | —   | —   | 8   | $\mu$ V/yr | T |  |

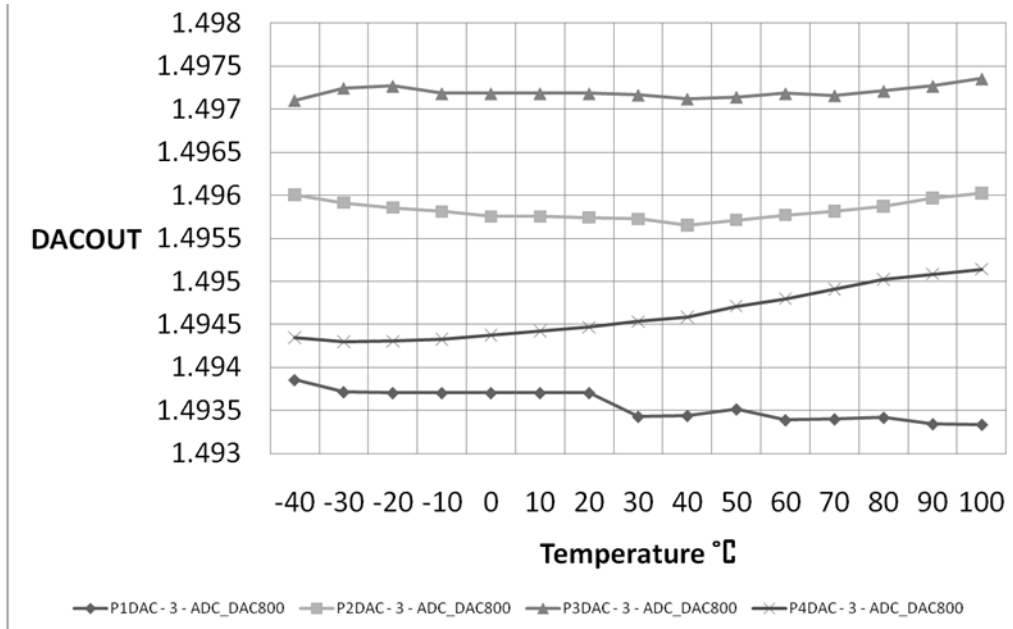


Figure 7. Offset at Half Scale vs Temperature

### 3.9 ADC Characteristics

Table 15. 16-Bit ADC Operating Conditions

| # | Symb             | Characteristic   | Conditions                                  | Min  | Typ <sup>1</sup> | Max       | Unit | C | Comment |
|---|------------------|------------------|---|------|------------------|-----------|------|---|---------|
| 1 | $V_{DDA}$        | Supply voltage   | Absolute                                    | 1.8  | —                | 3.6       | V    | D |         |
| 2 | $\Delta V_{DDA}$ |                  | Delta to $V_{DD}$<br>$(V_{DD} - V_{DDA})^2$ | -100 | 0                | +100      | mV   | D |         |
| 3 | $\Delta V_{SSA}$ | Ground voltage   | Delta to $V_{SS}$<br>$(V_{SS} - V_{SSA})^2$ | -100 | 0                | +100      | mV   | D |         |
| 4 | $V_{REFH}$       | Ref Voltage High |   | 1.15 | $V_{DDA}$        | $V_{DDA}$ | V    | D |         |

**Table 15. 16-Bit ADC Operating Conditions (continued)**

| #            | Symb                      | Characteristic                 | Conditions                        | Min               | Typ <sup>1</sup> | Max               | Unit | C | Comment                          |                  |                                   |   |     |     |    |   |
|--------------|---------------------------|--------------------------------|-----------------------------------|-------------------|------------------|-------------------|------|---|----------------------------------|------------------|-----------------------------------|---|-----|-----|----|---|
| 5            | V <sub>REFL</sub>         | Ref Voltage Low                |                                   | V <sub>SSA</sub>  | V <sub>SSA</sub> | V <sub>SSA</sub>  | V    | D |                                  |                  |                                   |   |     |     |    |   |
| 6            | V <sub>ADIN</sub>         | Input Voltage                  |                                   | V <sub>REFL</sub> | —                | V <sub>REFH</sub> | V    | D |                                  |                  |                                   |   |     |     |    |   |
| 7            | C <sub>ADIN</sub>         | Input Capacitance              | 16-bit modes<br>8/10/12-bit modes | —                 | 8<br>4           | 10<br>5           | pF   | T |                                  |                  |                                   |   |     |     |    |   |
| 8            | R <sub>ADIN</sub>         | Input Resistance               |                                   | —                 | 2                | 5                 | kΩ   | T |                                  |                  |                                   |   |     |     |    |   |
| 9            | R <sub>AS</sub>           | Analog Source Resistance       |                                   |                   |                  |                   |      |   | External to MCU Assumes ADLSMP=0 |                  |                                   |   |     |     |    |   |
|              |                           |                                |                                   |                   |                  |                   |      |   |                                  | 16-bit mode      | f <sub>ADCK</sub> > 8 MHz         | — | —   | 0.5 | kΩ | T |
|              |                           |                                |                                   |                   |                  |                   |      |   |                                  |                  | 4 MHz < f <sub>ADCK</sub> < 8 MHz | — | —   | 1   | kΩ | T |
|              |                           |                                |                                   |                   |                  |                   |      |   |                                  |                  | f <sub>ADCK</sub> < 4 MHz         | — | —   | 2   | kΩ | T |
|              |                           |                                |                                   |                   |                  |                   |      |   |                                  | 13/12-bit mode   | f <sub>ADCK</sub> > 8 MHz         | — | —   | 1   | kΩ | T |
|              |                           |                                |                                   |                   |                  |                   |      |   |                                  |                  | 4 MHz < f <sub>ADCK</sub> < 8 MHz | — | —   | 2   | kΩ | T |
|              |                           |                                |                                   |                   |                  |                   |      |   |                                  |                  | f <sub>ADCK</sub> < 4 MHz         | — | —   | 5   | kΩ | T |
|              |                           |                                |                                   |                   |                  |                   |      |   |                                  | 11/10-bit mode   | f <sub>ADCK</sub> > 8 MHz         | — | —   | 2   | kΩ | T |
|              |                           |                                |                                   |                   |                  |                   |      |   |                                  |                  | 4 MHz < f <sub>ADCK</sub> < 8 MHz | — | —   | 5   | kΩ | T |
|              |                           |                                |                                   |                   |                  |                   |      |   |                                  |                  | f <sub>ADCK</sub> < 4 MHz         | — | —   | 10  | kΩ | T |
| 9/8-bit mode | f <sub>ADCK</sub> > 8 MHz | —                              | —                                 | 5                 | kΩ               | T                 |      |   |                                  |                  |                                   |   |     |     |    |   |
|              | f <sub>ADCK</sub> < 8 MHz | —                              | —                                 | 10                | kΩ               | T                 |      |   |                                  |                  |                                   |   |     |     |    |   |
| 10           | f <sub>ADCK</sub>         | ADC Conversion Clock Frequency |                                   |                   |                  |                   |      |   |                                  |                  |                                   |   |     |     |    |   |
|              |                           |                                |                                   |                   |                  |                   |      |   |                                  | ADLPC=0, ADHSC=1 | 1.0                               | — | 8.0 | MHz | D  |   |
|              |                           |                                |                                   |                   |                  |                   |      |   |                                  | ADLPC=0, ADHSC=0 | 1.0                               | — | 5.0 | MHz | D  |   |
|              |                           |                                |                                   |                   |                  |                   |      |   |                                  | ADLPC=1, ADHSC=0 | 1.0                               | — | 2.5 | MHz | D  |   |

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

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

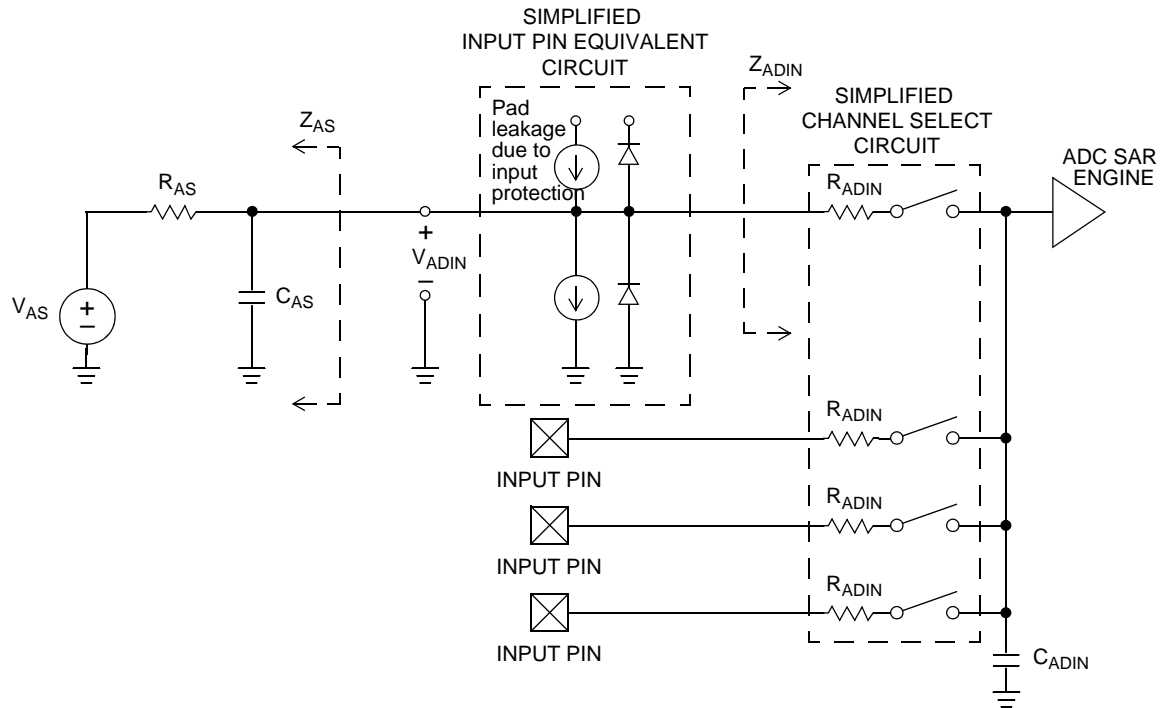


Figure 8. ADC Input Impedance Equivalency Diagram

**Table 16. 16-Bit SAR ADC Characteristics full operating range**  
**( $V_{REFH} = V_{DDA}, > 1.8, V_{REFL} = V_{SSA} \leq 8 \text{ MHz}, -40 \text{ to } 85 \text{ }^\circ\text{C}$ )**

| # | Characteristic                | Conditions <sup>1</sup>                              | Symb        | Min    | Typ <sup>2</sup>        | Max                      | Unit             | C | Comment   |
|---|-------------------------------|--|-------------|--------|-------------------------|--------------------------|------------------|---|---|
| 1 | Supply Current                | ADLPC=1, ADHSC=0                                     | $I_{DDAD}$  | —      | 215                     | —                        | $\mu\text{A}$    | T | ADLSMP=0<br>ADCO=1  |
|   |                               | ADLPC=0, ADHSC=0                                     |             | —      | 470                     | —                        |                  |   |   |
|   |                               | ADLPC=0, ADHSC=1                                     |             | —      | 610                     | —                        |                  |   |   |
| 2 | Supply Current                | Stop, Reset, Module Off                              | $I_{DDAD}$  | —      | 0.01                    | —                        | $\mu\text{A}$    | T |   |
| 3 | ADC Asynchronous Clock Source | ADLPC=1, ADHSC=0                                     | $f_{ADACK}$ | —      | 2.4                     | —                        | MHz              | C | $t_{ADACK} = 1/f_{ADACK}$                                 |
|   |                               | ADLPC=0, ADHSC=0                                     |             | —      | 5.2                     | —                        |                  |   |   |
|   |                               | ADLPC=0, ADHSC=1                                     |             | —      | 6.2                     | —                        |                  |   |   |
| 4 | Sample Time                   | See Reference Manual for sample times                |             |        |                         |                          |                  |   |   |
| 5 | Conversion Time               | See Reference Manual for conversion times            |             |        |                         |                          |                  |   |   |
| 6 | Total Unadjusted Error        | 16-bit differential mode<br>16-bit single-ended mode | TUE         | —<br>— | $\pm 16$<br>$\pm 20$    | $+48/-40$<br>$+56/-28$   | LSB <sup>3</sup> | T | 32x<br>Hardware<br>Averaging<br>(AVGE = %1<br>AVGS = %11) |
|   |                               | 13-bit differential mode<br>12-bit single-ended mode |             | —<br>— | $\pm 1.5$<br>$\pm 1.75$ | $\pm 3.0$<br>$\pm 3.5$   |                  | T |   |
|   |                               | 11-bit differential mode<br>10-bit single-ended mode |             | —<br>— | $\pm 0.7$<br>$\pm 0.8$  | $\pm 1.5$<br>$\pm 1.5$   |                  | T |   |
|   |                               | 9-bit differential mode<br>8-bit single-ended mode   |             | —<br>— | $\pm 0.5$<br>$\pm 0.5$  | $\pm 1.0$<br>$\pm 1.0$   |                  | T |   |
| 7 | Differential Non-Linearity    | 16-bit differential mode<br>16-bit single-ended mode | DNL         | —<br>— | $\pm 2.5$<br>$\pm 2.5$  | $+5/-3$<br>$+5/-3$       | LSB <sup>2</sup> | T |   |
|   |                               | 13-bit differential mode<br>12-bit single-ended mode |             | —<br>— | $\pm 0.7$<br>$\pm 0.7$  | $\pm 1$<br>$\pm 1$       |                  | T |   |
|   |                               | 11-bit differential mode<br>10-bit single-ended mode |             | —<br>— | $\pm 0.5$<br>$\pm 0.5$  | $\pm 0.75$<br>$\pm 0.75$ |                  | T |   |
|   |                               | 9-bit differential mode<br>8-bit single-ended mode   |             | —<br>— | $\pm 0.2$<br>$\pm 0.2$  | $\pm 0.5$<br>$\pm 0.5$   |                  | T |   |



**Table 16. 16-Bit SAR ADC Characteristics full operating range**  
 ( $V_{REFH} = V_{DDA}, > 1.8, V_{REFL} = V_{SSA} \leq 8 \text{ MHz}, -40 \text{ to } 85 \text{ }^\circ\text{C}$ ) (continued)

| #  | Characteristic                  | Conditions <sup>1</sup>   | Symb            | Min                                  | Typ <sup>2</sup>                     | Max                   | Unit             | C | Comment  |
|----|---------------------------------|---|-----------------|--------------------------------------|--------------------------------------|-----------------------|------------------|---|--|
| 8  | Integral Non-Linearity          | 16-bit differential mode  | INL             | —                                    | ±6.0                                 | ±16.0                 | LSB <sup>2</sup> | T |  |
|    |                                 | 16-bit single-ended mode  |                 | —                                    | ±10.0                                | ±20.0                 |                  | T |  |
|    |                                 | 13-bit differential mode  |                 | —                                    | ±1.0                                 | ±2.5                  |                  | T |  |
|    |                                 | 12-bit single-ended mode  |                 | —                                    | ±1.0                                 | ±2.5                  |                  | T |  |
| 9  | Zero-Scale Error                | 16-bit differential mode  | E <sub>ZS</sub> | —                                    | ±4.0                                 | +32/-24               | LSB <sup>2</sup> | T | V <sub>ADIN</sub> = V <sub>SSA</sub>           |
|    |                                 | 16-bit single-ended mode  |                 | —                                    | ±4.0                                 | +24/-16               |                  | T |  |
|    |                                 | 13-bit differential mode  |                 | —                                    | ±0.7                                 | ±2.5                  |                  | T |  |
|    |                                 | 12-bit single-ended mode  |                 | —                                    | ±0.7                                 | ±2.0                  |                  | T |  |
| 10 | Full-Scale Error                | 16-bit differential mode  | E <sub>FS</sub> | —                                    | +10/0                                | +42/-2                | LSB <sup>2</sup> | T | V <sub>ADIN</sub> = V <sub>DDA</sub>           |
|    |                                 | 16-bit single-ended mode  |                 | —                                    | +14/0                                | +46/-2                |                  | T |  |
|    |                                 | 13-bit differential mode  |                 | —                                    | ±1.0                                 | ±3.5                  |                  | T |  |
|    |                                 | 12-bit single-ended mode  |                 | —                                    | ±1.0                                 | ±3.5                  |                  | T |  |
| 11 | Quantization Error              | 16-bit modes  | E <sub>Q</sub>  | —                                    | -1 to 0                              | —                     | LSB <sup>2</sup> | D |  |
|    |                                 | ≤13-bit modes   |                 | —                                    | —                                    | ±0.5                  |                  | D |  |
| 12 | Effective Number of Bits        | 16-bit differential mode<br>Avg=32<br>Avg=16<br>Avg=8<br>Avg=4<br>Avg=1 | ENOB            | 12.8<br>12.7<br>12.6<br>12.5<br>11.9 | 14.2<br>13.8<br>13.6<br>13.3<br>12.5 | —<br>—<br>—<br>—<br>— | Bits             | C | F <sub>in</sub> = F <sub>sample</sub> /10<br>0 |
| 13 | Signal to Noise plus Distortion | See ENOB  | SINAD           | $SINAD = 6.02 \cdot ENOB + 1.76$     |                                      |                       | dB               |   |  |

**Table 16. 16-Bit SAR ADC Characteristics full operating range**  
**( $V_{REFH} = V_{DDA}, > 1.8, V_{REFL} = V_{SSA} \leq 8 \text{ MHz}, -40 \text{ to } 85 \text{ }^\circ\text{C}$ ) (continued)**

| #  | Characteristic              | Conditions <sup>1</sup>            | Symb             | Min               | Typ <sup>2</sup> | Max   | Unit      | C | Comment   |
|----|-----------------------------|------------------------------------|------------------|-------------------|------------------|-------|-----------|---|---|
| 14 | Total Harmonic Distortion   | 16-bit differential mode<br>Avg=32 | THD              | —                 | -91.5            | -74.3 | dB        | C | $F_{in} = F_{sample}/10$<br>0   |
|    |                             | 16-bit single-ended mode<br>Avg=32 |                  | —                 | -85.5            | —     |           | D |   |
| 15 | Spurious Free Dynamic Range | 16-bit differential mode<br>Avg=32 | SFDR             | 75.0              | 92.2             | —     | dB        | C | $F_{in} = F_{sample}/10$<br>0   |
|    |                             | 16-bit single-ended mode<br>Avg=32 |                  | —                 | 86.2             | —     |           | D |   |
| 16 | Input Leakage Error         | all modes                          | $E_{IL}$         | $I_{in} * R_{AS}$ |                  |       | mV        | D | $I_{in} =$<br>leakage<br>current<br>(refer to<br>DC<br>characteri<br>stics) |
| 17 | Temp Sensor Slope           | -40°C – 25°C                       | m                | —                 | 1.646            | —     | mV/x<br>C | C |   |
|    |                             | 25°C – 125°C                       |                  | —                 | 1.769            | —     |           |   |   |
| 18 | Temp Sensor Voltage         | 25°C                               | $V_{TEMP2}$<br>5 | —                 | 718.2            | —     | mV        | C |   |

<sup>1</sup> All accuracy numbers assume the ADC is calibrated with  $V_{REFH}=V_{DDA}$

<sup>2</sup> Typical values assume  $V_{DDA} = 3.0V$ , Temp = 25°C,  $f_{ADCK}=2.0MHz$  unless otherwise stated. Typical values are for reference only and are not tested in production.

<sup>3</sup>  $1 \text{ LSB} = (V_{REFH} - V_{REFL})/2^N$

**Table 17. 16-bit SAR ADC Characteristics full operating range**  
 ( $V_{REFH} = V_{DDA} \geq 2.7\text{ V}$ ,  $V_{REFL} = V_{SSA}$ ,  $f_{ADACK} \leq 4\text{ MHz}$ ,  $ADHSC = 1$ )

| # | Characteristic             | Conditions <sup>1</sup>                              | Symb            | Min    | Typ <sup>2</sup>        | Max                      | Unit             | C | Comment                                       |
|---|----------------------------|--|-----------------|--------|-------------------------|--------------------------|------------------|---|---|
| 1 | Total Unadjusted Error     | 16-bit differential mode<br>16-bit single-ended mode | TUE             | —<br>— | $\pm 16$<br>$\pm 20$    | $+24/-24$<br>$+32/-20$   | LSB <sup>3</sup> | T | 32x Hardware Averaging (AVGE = %1 AVGS = %11) |
|   |                            | 13-bit differential mode<br>12-bit single-ended mode |                 | —<br>— | $\pm 1.5$<br>$\pm 1.75$ | $\pm 2.0$<br>$\pm 2.5$   |                  | T |   |
|   |                            | 11-bit differential mode<br>10-bit single-ended mode |                 | —<br>— | $\pm 0.7$<br>$\pm 0.8$  | $\pm 1.0$<br>$\pm 1.25$  |                  | T |   |
|   |                            | 9-bit differential mode<br>8-bit single-ended mode   |                 | —<br>— | $\pm 0.5$<br>$\pm 0.5$  | $\pm 1.0$<br>$\pm 1.0$   |                  | T |   |
| 2 | Differential Non-Linearity | 16-bit differential mode<br>16-bit single-ended mode | DNL             | —<br>— | $\pm 2.5$<br>$\pm 2.5$  | $\pm 3$<br>$\pm 3$       | LSB <sup>2</sup> | T |   |
|   |                            | 13-bit differential mode<br>12-bit single-ended mode |                 | —<br>— | $\pm 0.7$<br>$\pm 0.7$  | $\pm 1$<br>$\pm 1$       |                  | T |   |
|   |                            | 11-bit differential mode<br>10-bit single-ended mode |                 | —<br>— | $\pm 0.5$<br>$\pm 0.5$  | $\pm 0.75$<br>$\pm 0.75$ |                  | T |   |
|   |                            | 9-bit differential mode<br>8-bit single-ended mode   |                 | —<br>— | $\pm 0.2$<br>$\pm 0.2$  | $\pm 0.5$<br>$\pm 0.5$   |                  | T |   |
| 3 | Integral Non-Linearity     | 16-bit differential mode<br>16-bit single-ended mode | INL             | —<br>— | $\pm 6.0$<br>$\pm 10.0$ | $\pm 12.0$<br>$\pm 16.0$ | LSB <sup>2</sup> | T |   |
|   |                            | 13-bit differential mode<br>12-bit single-ended mode |                 | —<br>— | $\pm 1.0$<br>$\pm 1.0$  | $\pm 2.0$<br>$\pm 2.0$   |                  | T |   |
|   |                            | 11-bit differential mode<br>10-bit single-ended mode |                 | —<br>— | $\pm 0.5$<br>$\pm 0.5$  | $\pm 1.0$<br>$\pm 1.0$   |                  | T |   |
|   |                            | 9-bit differential mode<br>8-bit single-ended mode   |                 | —<br>— | $\pm 0.3$<br>$\pm 0.3$  | $\pm 0.5$<br>$\pm 0.5$   |                  | T |   |
| 4 | Zero-Scale Error           | 16-bit differential mode<br>16-bit single-ended mode | E <sub>ZS</sub> | —<br>— | $\pm 4.0$<br>$\pm 4.0$  | $+16/0$<br>$+16/-8$      | LSB <sup>2</sup> | T | $V_{ADIN} = V_{SSA}$                          |
|   |                            | 13-bit differential mode<br>12-bit single-ended mode |                 | —<br>— | $\pm 0.7$<br>$\pm 0.7$  | $\pm 2.0 \pm 2.0$        |                  | T |   |
|   |                            | 11-bit differential mode<br>10-bit single-ended mode |                 | —<br>— | $\pm 0.4$<br>$\pm 0.4$  | $\pm 1.0$<br>$\pm 1.0$   |                  | T |   |
|   |                            | 9-bit differential mode<br>8-bit single-ended mode   |                 | —<br>— | $\pm 0.2$<br>$\pm 0.2$  | $\pm 0.5$<br>$\pm 0.5$   |                  | T |   |

**Table 17. 16-bit SAR ADC Characteristics full operating range**  
**( $V_{REFH} = V_{DDA} \geq 2.7$  V,  $V_{REFL} = V_{SSA}$ ,  $f_{ADACK} \leq 4$  MHz,  $ADHSC = 1$ ) (continued)**

| #  | Characteristic                  | Conditions <sup>1</sup>   | Symb           | Min                                  | Typ <sup>2</sup>                     | Max                   | Unit             | C | Comment  |
|----|---------------------------------|---|----------------|--------------------------------------|--------------------------------------|-----------------------|------------------|---|--|
| 5  | Full-Scale Error                | 16-bit differential mode<br>16-bit single-ended mode                    | $E_{FS}$       | —                                    | +8/0                                 | +24/0                 | LSB <sup>2</sup> | T | $V_{ADIN} = V_{DDA}$                                     |
|    |                                 | 13-bit differential mode<br>12-bit single-ended mode                    |                | —                                    | ±0.7                                 | ±2.0                  |                  | T |  |
|    |                                 | 11-bit differential mode<br>10-bit single-ended mode                    |                | —                                    | ±0.4                                 | ±1.0                  |                  | T |  |
|    |                                 | 9-bit differential mode<br>8-bit single-ended mode                      |                | —                                    | ±0.2                                 | ±0.5                  |                  | T |  |
| 6  | Quantization Error              | 16-bit modes  | $E_Q$          | —                                    | -1 to 0                              | —                     | LSB <sup>2</sup> | D |  |
|    |                                 | ≤13-bit modes   |                | —                                    | —                                    | ±0.5                  |                  |   |  |
| 7  | Effective Number of Bits        | 16-bit differential mode<br>Avg=32<br>Avg=16<br>Avg=8<br>Avg=4<br>Avg=1 | $ENO$<br>$B$   | 14.3<br>13.8<br>13.4<br>13.1<br>12.4 | 14.5<br>14.0<br>13.7<br>13.4<br>12.6 | —<br>—<br>—<br>—<br>— | Bits             | C | $F_{in} = F_{sample}/10$<br>0                            |
| 8  | Signal to Noise plus Distortion | See ENOB  | $SINAD$<br>$D$ | $SINAD = 6.02 \cdot ENOB + 1.76$     |                                      |                       | dB               |   |  |
| 9  | Total Harmonic Distortion       | 16-bit differential mode<br>Avg=32                                      | THD            | —                                    | -95.8                                | -90.4                 | dB               | C | $F_{in} = F_{sample}/10$<br>0                            |
|    |                                 | 16-bit single-ended mode<br>Avg=32                                      |                | —                                    | —                                    | —                     |                  | D |  |
| 10 | Spurious Free Dynamic Range     | 16-bit differential mode<br>Avg=32                                      | SFDR           | 91.0                                 | 96.5                                 | —                     | dB               | C | $F_{in} = F_{sample}/10$<br>0                            |
|    |                                 | 16-bit single-ended mode<br>Avg=32                                      |                | —                                    | —                                    | —                     |                  | D |  |
| 11 | Input Leakage Error             | all modes   | $E_{IL}$       | $I_{in} \cdot R_{AS}$                |                                      |                       | mV               | D | $I_{in} =$ leakage current (refer to DC characteristics) |

<sup>1</sup> All accuracy numbers assume the ADC is calibrated with  $V_{REFH} = V_{DDA}$

<sup>2</sup> Typical values assume  $V_{DDA} = 3.0$ V, Temp = 25°C,  $f_{ADCK} = 2.0$ MHz unless otherwise stated. Typical values are for reference only and are not tested in production.

<sup>3</sup> 1 LSB =  $(V_{REFH} - V_{REFL})/2^N$

### 3.10 MCG and External Oscillator (XOSC) Characteristics

Table 18. MCG (Temperature Range = -40 to 105°C Ambient)

| #  | Rating   | Symbol                   | Min                        | Typical  | Max                | Unit                                      | C           |         |   |
|----|--|--------------------------|----------------------------|--|--------------------|---|-------------|---------|---|
| 1  | Internal reference startup time  | $t_{irefst}$             | —                          | 55   | 100                | $\mu\text{s}$                             | D           |         |   |
| 2  | Average internal reference frequency   | $f_{int\_ft}$            | —                          | factory trimmed at VDD=3.0 V and temp=25°C     | 31.25              | —   | kHz         | C       |   |
|    |  |                          |                            | user trimmed                                   | 31.25              | —   |             | 39.0625 | C |
| 3  | DCO output frequency range — trimmed   | $f_{dco\_t}$             | —                          | Low range (DRS=00)                             | —                  | 20  | MHz         | C       |   |
|    |  |                          |                            | Mid range (DRS=01)                             | 32                 | —   |             | 40      | C |
|    |  |                          |                            | High range <sup>1</sup> (DRS=10)               | 40                 | —   |             | 60      | C |
| 4  | Resolution of trimmed DCO output frequency at fixed voltage and temperature    | $\Delta f_{dco\_res\_t}$ | —                          | with FTRIM                                     | $\pm 0.1$          | $\pm 0.2$                                 | % $f_{dco}$ | C       |   |
|    |  |                          |                            | without FTRIM                                  | $\pm 0.2$          | $\pm 0.4$                                 |             | C       |   |
| 5  | Total deviation of trimmed DCO output frequency over voltage and temperature   | $\Delta f_{dco\_t}$      | —                          | over voltage and temperature                   | $\pm 1.0$          | $\pm 2$                                   | % $f_{dco}$ | P       |   |
|    |  |                          |                            | over fixed voltage and temp range of 0 – 70 °C | $\pm 0.5$          | $\pm 1$                                   |             | C       |   |
| 6  | Acquisition time   | FLL <sup>2</sup>         | $t_{fll\_acquire}$         | —  | —                  | 1   | ms          | C       |   |
|    |  | PLL <sup>3</sup>         | $t_{pll\_acquire}$         | —  | —                  | 1   |             | D       |   |
| 7  | Long term Jitter of DCO output clock (averaged over 2mS interval) <sup>4</sup> | $C_{jitter}$             | —                          | 0.02   | 0.2                | % $f_{dco}$                               | C           |         |   |
| 8  | VCO operating frequency  | $f_{vco}$                | 7.0                        | —  | 55.0               | MHz                                       | D           |         |   |
| 9  | PLL reference frequency range  | $f_{pll\_ref}$           | 1.0                        | —  | 2.0                | MHz                                       | D           |         |   |
| 10 | Jitter of PLL output clock measured over 625ns <sup>5</sup>                    | Long term                | $f_{pll\_jitter\_625ns}$   | —  | 0.566 <sup>4</sup> | —   | % $f_{pll}$ | D       |   |
| 11 | Lock frequency tolerance   | Entry <sup>6</sup>       | $D_{lock}$                 | $\pm 1.49$                                     | —                  | $\pm 2.98$                                | %           | D       |   |
|    |  | Exit <sup>7</sup>        | $D_{unl}$                  | $\pm 4.47$                                     | —                  | $\pm 5.97$                                |             | D       |   |
| 12 | Lock time  | FLL                      | $t_{fll\_lock}$            | —  | —                  | $t_{fll\_acquire} + 1075(1/f_{int\_t})$   | s           | D       |   |
|    |  | PLL                      | $t_{pll\_lock}$            | —  | —                  | $t_{pll\_acquire} + 1075(1/f_{pll\_ref})$ |             | D       |   |
| 13 | Loss of external clock minimum frequency - RANGE = 0                           | $f_{loc\_low}$           | $(3/5) \times f_{int\_t}$  | —  | —                  | kHz                                       | D           |         |   |
| 14 | Loss of external clock minimum frequency - RANGE = 1                           | $f_{loc\_high}$          | $(16/5) \times f_{int\_t}$ | —  | —                  | kHz                                       | D           |         |   |

<sup>1</sup> This should not exceed the maximum CPU frequency for this device which is 50.33 MHz.

## Electrical Characteristics

- <sup>2</sup> This specification applies to any time the FLL reference source or reference divider is changed, trim value is changed, DMX32 bit is changed, DRS bit is 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>3</sup> This specification applies to any time 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>4</sup> Jitter is the average deviation from the programmed frequency measured over the specified interval at maximum  $f_{BUS}$ . Measurements are made with the device powered by filtered supplies and clocked by a stable external clock signal. Noise injected into the FLL circuitry via  $V_{DD}$  and  $V_{SS}$  and variation in crystal oscillator frequency increase the  $C_{Jitter}$  percentage for a given interval.
- <sup>5</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>6</sup> Below  $D_{lock}$  minimum, the MCG is guaranteed to enter lock. Above  $D_{lock}$  maximum, the MCG will not enter lock. But if the MCG is already in lock, then the MCG may stay in lock.
- <sup>7</sup> Below  $D_{unl}$  minimum, the MCG will not exit lock if already in lock. Above  $D_{unl}$  maximum, the MCG is guaranteed to exit lock.

**Table 19. XOSC (Temperature Range = -40 to 105°C Ambient)**

| # | Characteristic   | Symbol   | Min   | Typ <sup>1</sup> | Max | Unit | C   |   |
|---|--|--|---|------------------|-----|------|-----|---|
| 1 | Oscillator crystal or resonator (EREFS = 1, ERCLKEN = 1) | • Low range (RANGE = 0)  | $f_{lo}$  | 32               | —   | 38.4 | kHz | D |
|   |  | • High range (RANGE = 1),<br>• FEE or FBE mode <sup>2</sup>        | $f_{hi-fll}$  | 1                | —   | 5    | MHz | D |
|   |  | • High range (RANGE = 1),<br>• PEE or PBE mode <sup>3</sup>        | $f_{hi-pll}$  | 1                | —   | 16   | MHz | D |
|   |  | • High range (RANGE = 1),<br>• High gain (HGO = 1),<br>• BLPE mode | $f_{hi-hgo}$  | 1                | —   | 16   | MHz | D |
|   |  | • High range (RANGE = 1),<br>• Low power (HGO = 0),<br>• BLPE mode | $f_{hi-lp}$   | 1                | —   | 8    | MHz | D |
| 2 | Load capacitors  | $C_1$<br>$C_2$   | See crystal or resonator manufacturer's recommendation. |                  |     |      |     | D |
| 3 | Feedback resistor  | • Low range (32 kHz to 38.4 kHz)                                   | $R_F$   | —                | 10  | —    | MΩ  | D |
|   |  | • High range (1 MHz to 16 MHz)                                     | —   | —                | 1   | —    |     | D |
| 4 | Series resistor — Low range                              | • Low Gain (HGO = 0)   | $R_S$   | —                | 0   | —    | kΩ  | D |
|   |  | • High Gain (HGO = 1)  |   | —                | 100 | —    |     | D |
| 5 | Series resistor — High range                             | • Low Gain (HGO = 0)   | $R_S$   | —                | 0   | —    | kΩ  | D |
|   |  | • High Gain (HGO = 1)  |   | —                | 0   | —    |     | D |
|   |  | ≥ 8 MHz  |   | —                | 0   | 0    |     | D |
|   |  | 4 MHz  |   | —                | 0   | 10   |     | D |
|   |  | 1 MHz  | —   | 0                | 20  |      | D   |   |

**Table 19. XOSC (Temperature Range = -40 to 105°C Ambient) (continued)**

| # | Characteristic  | Symbol                 | Min | Typ <sup>1</sup> | Max | Unit | C |
|---|---|------------------------|-----|------------------|-----|------|---|
| 6 | • Low range, low gain (RANGE = 0, HGO = 0)                | $t_{\text{CSTL-LP}}$   | —   | 200              | —   | ms   | D |
|   | • Low range, high gain (RANGE = 0, HGO = 1)               | $t_{\text{CSTL-HG}_O}$ | —   | 400              | —   |      | D |
|   | • High range, low gain (RANGE = 1, HGO = 0) <sup>5</sup>  | $t_{\text{CSTH-LP}}$   | —   | 5                | —   |      | D |
|   | • High range, high gain (RANGE = 1, HGO = 1) <sup>5</sup> | $t_{\text{CSTH-HG}_O}$ | —   | 15               | —   |      | D |

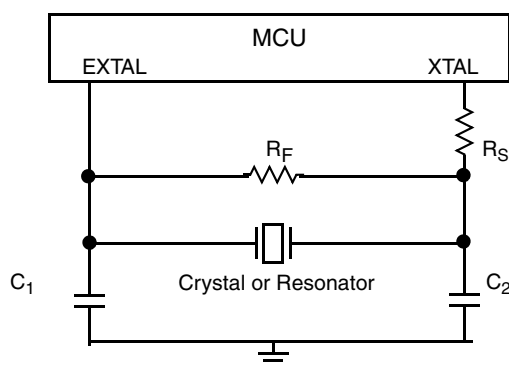
<sup>1</sup> Data in Typical column was characterized at 3.0 V, 25°C or is typical recommended value.

<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.



### 3.11 Mini-FlexBus Timing Specifications

A multi-function external bus interface called Mini-FlexBus is provided with basic functionality to interface to slave-only devices up to a maximum bus frequency of 25.1666 MHz. It can be directly connected to asynchronous or synchronous devices such as external boot ROMs, flash memories, gate-array logic, or other simple target (slave) devices with little or no additional circuitry. For asynchronous devices a simple chip-select based interface can be used.

All processor bus timings are synchronous; that is, input setup/hold and output delay are given in respect to the rising edge of a reference clock, MB\_CLK. The MB\_CLK frequency is half the internal system bus frequency.

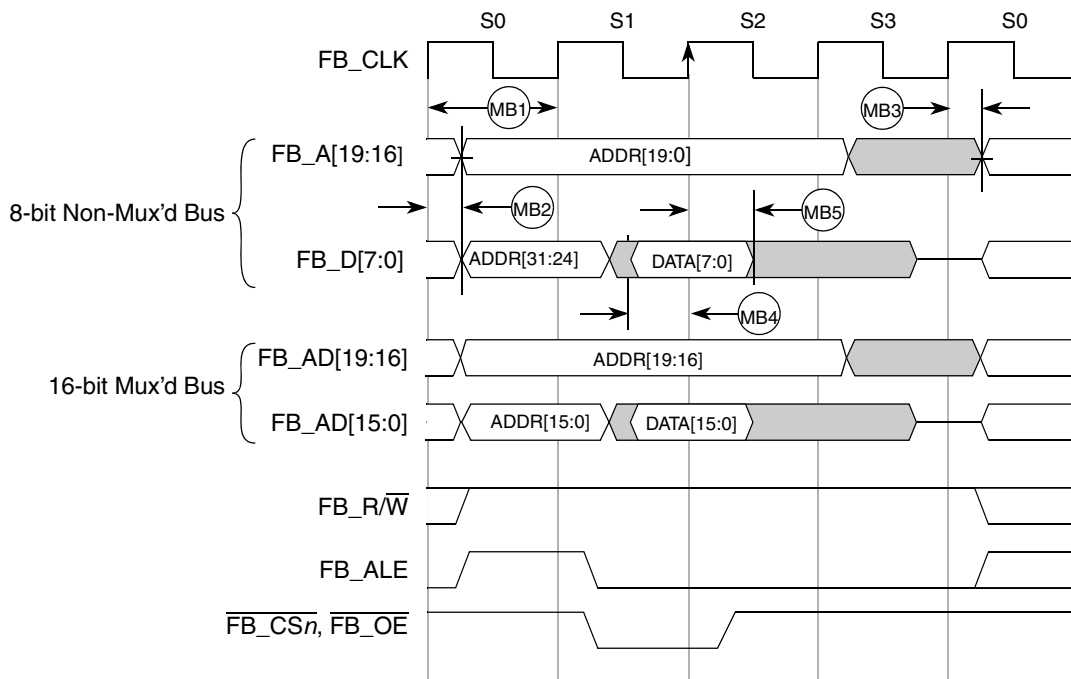
The following timing numbers indicate when data is latched or driven onto the external bus, relative to the Mini-FlexBus output clock (MB\_CLK). All other timing relationships can be derived from these values.

**Table 20. Mini-FlexBus AC Timing Specifications**

| Num | C | Characteristic         | Min   | Max     | Unit | Notes |
|-----|---|------------------------|-------|---------|------|-------|
| —   | — | Frequency of Operation | —     | 25.1666 | MHz  | —     |
| MB1 | D | Clock Period           | 39.73 | —       | ns   | —     |
| MB2 | D | Output Valid           | —     | 20      | ns   | 1     |
| MB3 | D | Output Hold            | 1.0   | —       | ns   | 1     |
| MB4 | D | Input Setup            | 22    | —       | ns   | 2     |
| MB5 | D | Input Hold             | 10    | —       | ns   | 2     |

<sup>1</sup> Specification is valid for all MB\_A[19:0], MB\_D[7:0],  $\overline{\text{MB\_CS}}[1:0]$ ,  $\overline{\text{MB\_OE}}$ , MB\_R/W, and MB\_ALE.

<sup>2</sup> Specification is valid for all MB\_D[7:0].



**Figure 9. Mini-FlexBus Read Timing**



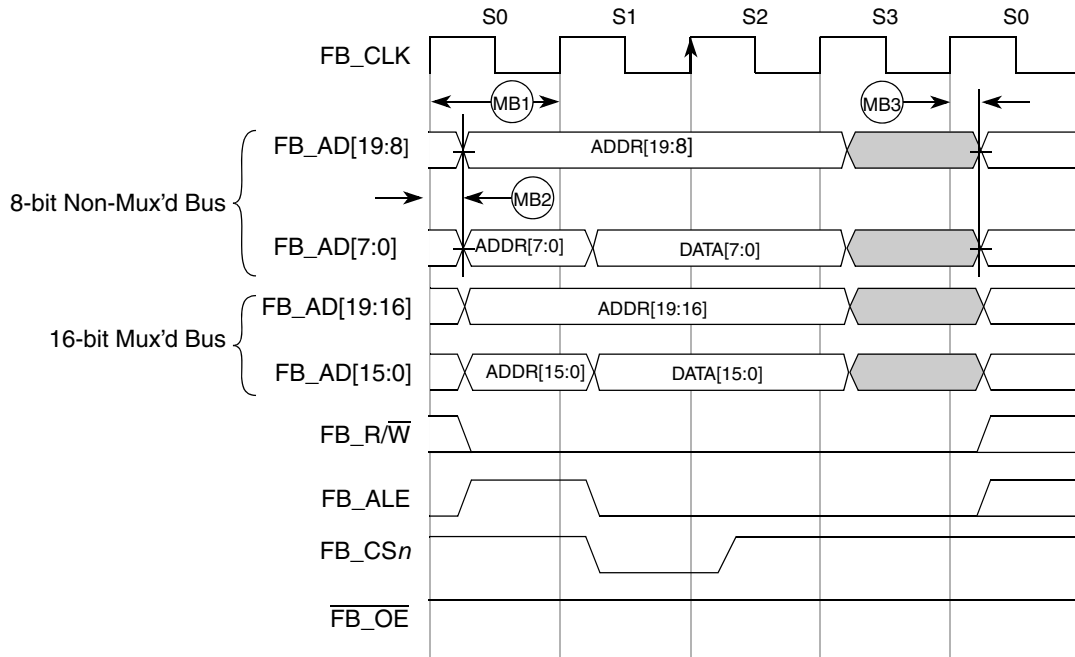


Figure 10. Mini-FlexBus Write Timing

### 3.12 AC Characteristics

This section describes ac timing characteristics for each peripheral system.

#### 3.12.1 Control Timing

Table 21. Control Timing

| # | Symbol               | Parameter  | Min                         | Typical <sup>1</sup> | Max    | C | Unit          |
|---|----------------------|--|-----------------------------|----------------------|--------|---|---------------|
| 1 | $f_{Bus}$            | Bus frequency ( $t_{cyc} = 1/f_{Bus}$ )  |                             |                      |        |   | MHz           |
|   |                      | $V_{DD} \geq 1.8\text{ V}$   | dc                          | —                    | 10     | D |               |
|   |                      | $V_{DD} > 2.1\text{ V}$  | dc                          | —                    | 20     | D |               |
|   |                      | $V_{DD} > 2.4\text{ V}$  | dc                          | —                    | 25.165 | D |               |
| 2 | $t_{LPO}$            | Internal low-power oscillator period   | 700                         | 1000                 | 1300   | P | $\mu\text{s}$ |
| 3 | $t_{extrst}$         | External reset pulse width <sup>2</sup><br>( $t_{cyc} = 1/f_{Self\_reset}$ )             | 100                         | —                    | —      | D | ns            |
| 4 | $t_{rstdrv}$         | Reset low drive  | $66 \times t_{cyc}$         | —                    | —      | D | ns            |
| 5 | $t_{MSSU}$           | Active background debug mode latch setup time  | 500                         | —                    | —      | D | ns            |
| 6 | $t_{MSH}$            | Active background debug mode latch hold time   | 100                         | —                    | —      | D | ns            |
| 7 | $t_{ILIH}, t_{IHIL}$ | IRQ pulse width<br>• Asynchronous path <sup>2</sup><br>• Synchronous path <sup>3</sup>   | 100<br>$1.5 \times t_{cyc}$ | —                    | —      | D | ns            |
| 8 | $t_{ILIH}, t_{IHIL}$ | KBIPx pulse width<br>• Asynchronous path <sup>2</sup><br>• Synchronous path <sup>3</sup> | 100<br>$1.5 \times t_{cyc}$ | —                    | —      | D | ns            |

**Table 21. Control Timing (continued)**

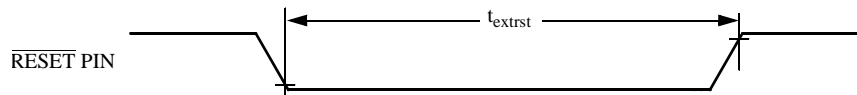
| # | Symbol               | Parameter   | Min | Typical <sup>1</sup> | Max | C | Unit |
|---|----------------------|---|-----|----------------------|-----|---|------|
| 9 | $t_{Rise}, t_{Fall}$ | Port rise and fall time (load = 50 pF) <sup>4</sup> , Low Drive |     |                      |     |   | ns   |
|   |                      | Slew rate control disabled (PTxSE = 0)                          | —   | 11                   | —   | D |      |
|   |                      | Slew rate control enabled (PTxSE = 1)                           | —   | 35                   | —   | D |      |
|   |                      | Slew rate control disabled (PTxSE = 0)                          | —   | 40                   | —   | D |      |
|   |                      | Slew rate control enabled (PTxSE = 1)                           | —   | 75                   | —   | D |      |

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

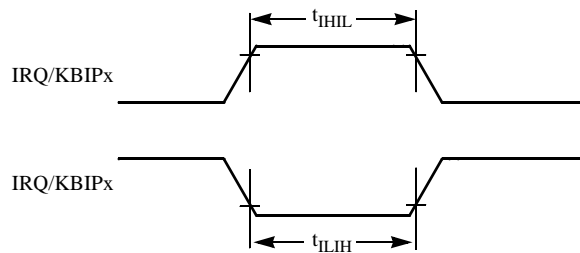
<sup>2</sup> This is the shortest pulse that is guaranteed to be recognized as a reset pin request. Shorter pulses are not guaranteed to override reset requests from internal sources.

<sup>3</sup> This is the minimum pulse width that is guaranteed to pass through the pinsynchronization 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  $-40\text{ }^\circ\text{C}$  to  $105\text{ }^\circ\text{C}$ .



**Figure 11. Reset Timing**



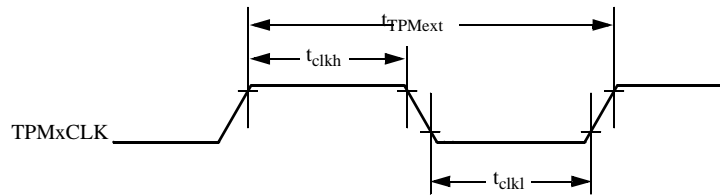
**Figure 12. IRQ/KBIPx Timing**

### 3.12.2 TPM Timing

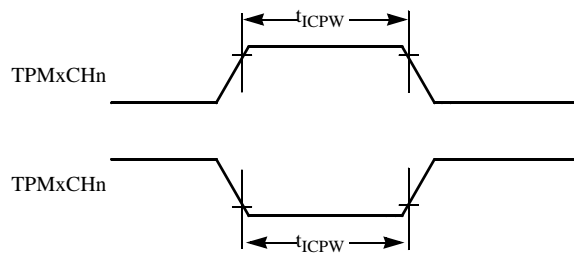
Synchronizer circuits determine the shortest input pulses that can be recognized or the fastest clock that can be used as the optional external source to the timer counter. These synchronizers operate from the current bus rate clock.

**Table 22. TPM Input Timing**

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



**Figure 13. Timer External Clock**



**Figure 14. Timer Input Capture Pulse**

### 3.13 SPI Characteristics

Table 23 and Figure 15 through Figure 18 describe the timing requirements for the SPI system.

Table 23. SPI Timing

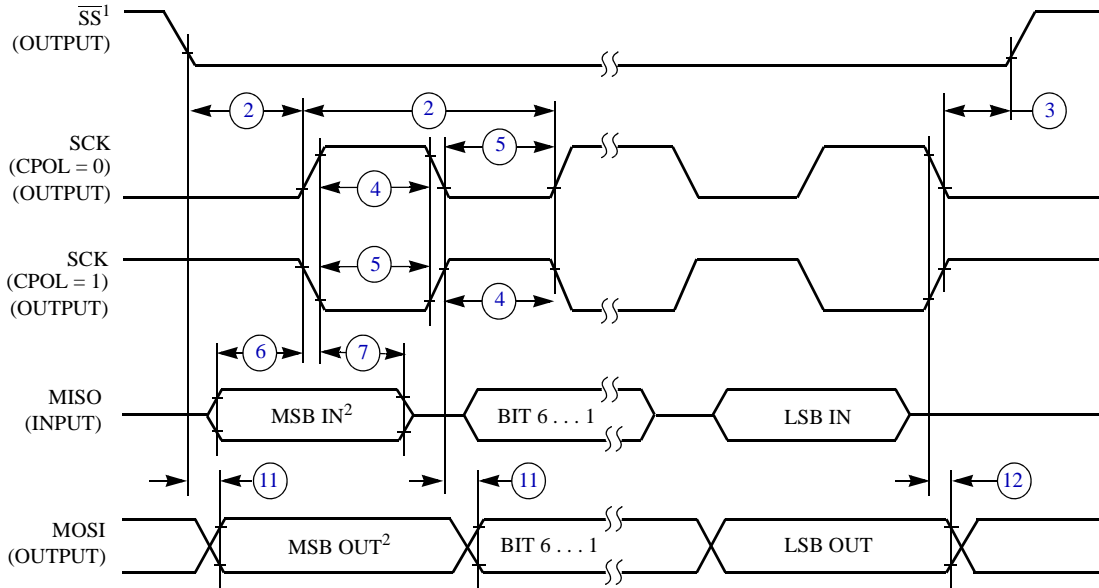
| No. <sup>1</sup> | Characteristic <sup>2</sup>                       | Symbol               | Min                              | Max                        | Unit                     | C |
|------------------|---|----------------------|----------------------------------|----------------------------|--------------------------|---|
| 1                | Operating frequency<br>Master<br>Slave            | $f_{op}$             | $f_{BUS}/2048$<br>0              | $f_{BUS}/2$<br>$f_{BUS}/4$ | Hz<br>Hz                 | D |
| 2                | SPSCK period<br>Master<br>Slave                   | $t_{SPSCK}$          | 2<br>4                           | 2048<br>—                  | $t_{cyc}$<br>$t_{cyc}$   | D |
| 3                | Enable lead time<br>Master<br>Slave               | $t_{Lead}$           | 1/2<br>1                         | —<br>—                     | $t_{SPSCK}$<br>$t_{cyc}$ | D |
| 4                | Enable lag time<br>Master<br>Slave                | $t_{Lag}$            | 1/2<br>1                         | —<br>—                     | $t_{SPSCK}$<br>$t_{cyc}$ | D |
| 5                | 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                 | D |
| 6                | Data setup time (inputs)<br>Master<br>Slave       | $t_{SU}$<br>$t_{SU}$ | 15<br>15                         | —<br>—                     | ns<br>ns                 | D |
| 7                | Data hold time (inputs)<br>Master<br>Slave        | $t_{HI}$<br>$t_{HI}$ | 0<br>25                          | —<br>—                     | ns<br>ns                 | D |
| 8                | Slave access time <sup>3</sup>                    | $t_a$                | —                                | 1                          | $t_{cyc}$                | D |
| 9                | Slave MISO disable time <sup>4</sup>              | $t_{dis}$            | —                                | 1                          | $t_{cyc}$                | D |
| 10               | Data valid (after SPSCK edge)<br>Master<br>Slave  | $t_v$                | —<br>—                           | 25<br>25                   | ns<br>ns                 | D |
| 11               | Data hold time (outputs)<br>Master<br>Slave       | $t_{HO}$             | 0<br>0                           | —<br>—                     | ns<br>ns                 | D |
| 12               | Rise time<br>Input<br>Output                      | $t_{RI}$<br>$t_{RO}$ | —<br>—                           | $t_{cyc} - 25$<br>25       | ns<br>ns                 | D |
| 13               | Fall time<br>Input<br>Output                      | $t_{FI}$<br>$t_{FO}$ | —<br>—                           | $t_{cyc} - 25$<br>25       | ns<br>ns                 | D |

<sup>1</sup> Numbers in this column identify elements in Figure 15 through Figure 18.

<sup>2</sup> All timing is shown with respect to 20%  $V_{DD}$  and 70%  $V_{DD}$ , unless noted; 100 pF load on all SPI pins. All timing assumes slew rate control disabled and high drive strength enabled for SPI output pins.

<sup>3</sup> Time to data active from high-impedance state.

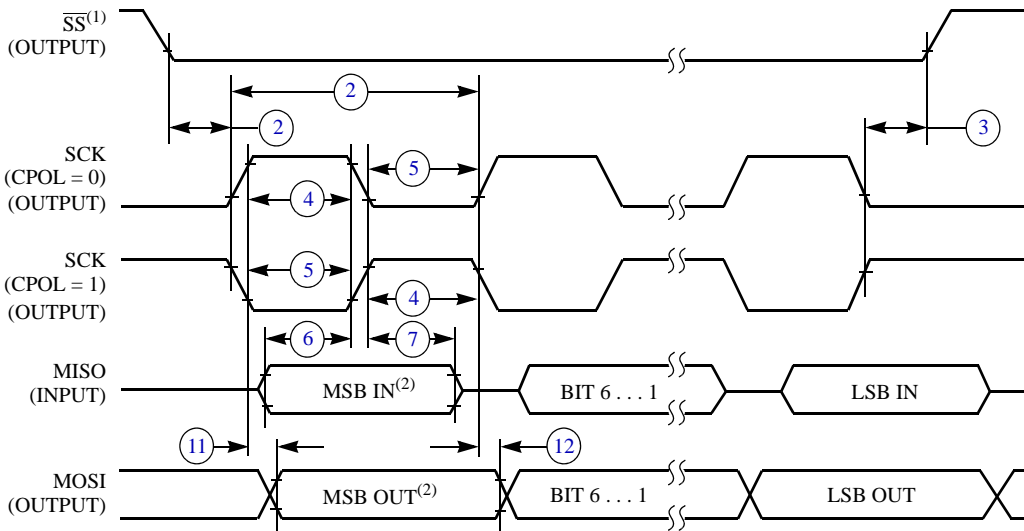
<sup>4</sup> Hold time to high-impedance state.



NOTES:

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

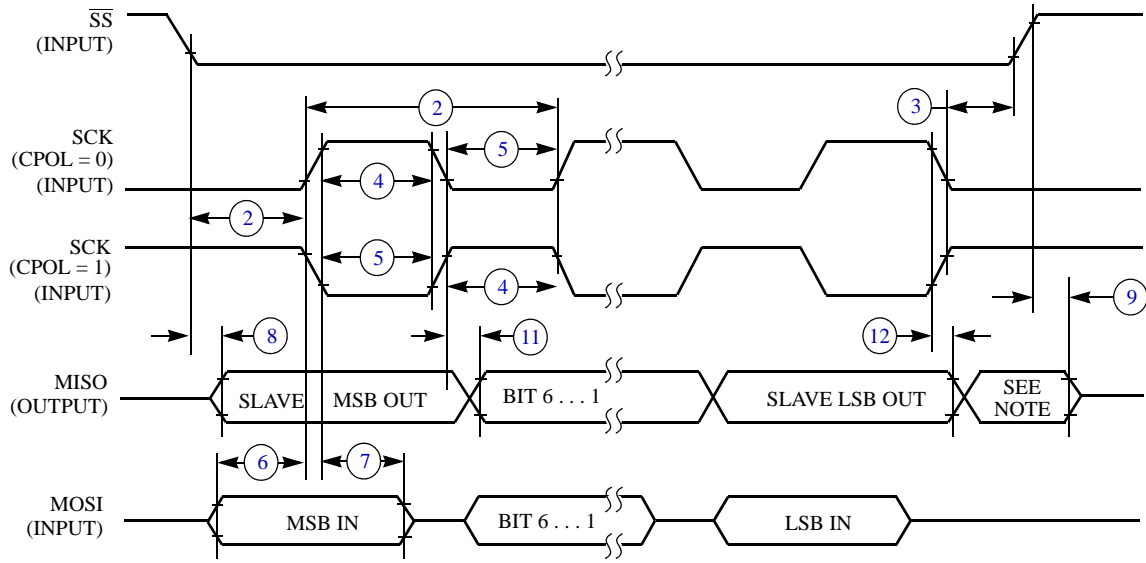
**Figure 15. SPI Master Timing (CPHA = 0)**



NOTES:

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

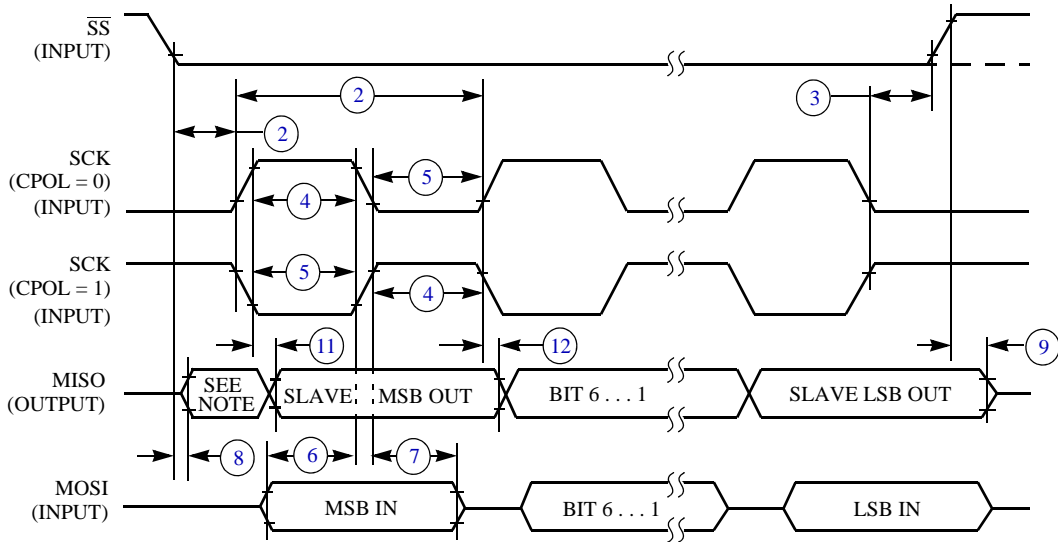
**Figure 16. SPI Master Timing (CPHA = 1)**



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)**

### 3.14 Flash Specifications

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

Program and erase operations do not require any special power sources other than the normal  $V_{DD}$  supply. For more detailed information about program/erase operations, see the Memory chapter in the Reference Manual for this device (MCF51MM256RM).

**Table 24. Flash Characteristics**

| #  | Characteristic   | Symbol                  | Min         | Typical      | Max    | Unit              | C |
|----|--|-------------------------|-------------|--------------|--------|-------------------|---|
| 1  | Supply voltage for program/erase<br>-40°C to 105°C   | $V_{\text{prog/erase}}$ | 1.8         | —            | 3.6    | V                 | D |
| 2  | Supply voltage for read operation  | $V_{\text{Read}}$       | 1.8         | —            | 3.6    | V                 | D |
| 3  | Internal FCLK frequency <sup>1</sup>   | $f_{\text{FCLK}}$       | 150         | —            | 200    | kHz               | D |
| 4  | Internal FCLK period (1/FCLK)  | $t_{\text{FcyC}}$       | 5           | —            | 6.67   | μs                | D |
| 5  | Byte program time (random location) <sup>2</sup>   | $t_{\text{prog}}$       | 9           |              |        | $t_{\text{FcyC}}$ | P |
| 6  | Byte program time (burst mode) <sup>2</sup>  | $t_{\text{Burst}}$      | 4           |              |        | $t_{\text{FcyC}}$ | P |
| 7  | Page erase time <sup>2</sup>   | $t_{\text{Page}}$       | 4000        |              |        | $t_{\text{FcyC}}$ | P |
| 8  | Mass erase time <sup>2</sup>   | $t_{\text{Mass}}$       | 20,000      |              |        | $t_{\text{FcyC}}$ | P |
| 9  | Program/erase endurance <sup>3</sup><br>$T_L$ to $T_H = -40^\circ\text{C}$ to $+105^\circ\text{C}$<br>$T = 25^\circ\text{C}$ |                         | 10,000<br>— | —<br>100,000 | —<br>— | cycles            | C |
| 10 | Data retention <sup>4</sup>  | $t_{\text{D\_ret}}$     | 15          | 100          | —      | years             | C |

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

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

<sup>3</sup> **Typical endurance for flash** was evaluated for this product family on the HC9S12Dx64. For additional information on how Freescale defines typical endurance, please refer to Engineering Bulletin EB619, *Typical Endurance for Nonvolatile Memory*.

<sup>4</sup> **Typical data retention** values are based on intrinsic capability of the technology measured at high temperature and de-rated to 25°C using the Arrhenius equation. For additional information on how Freescale defines typical data retention, please refer to Engineering Bulletin EB618, *Typical Data Retention for Nonvolatile Memory*.



### 3.15 USB Electricals

The USB electricals for the USB On-the-Go module conform to the standards documented by the Universal Serial Bus Implementers Forum. For the most up-to-date standards, visit <http://www.usb.org>.

If the Freescale USB On-the-Go implementation has electrical characteristics that deviate from the standard or require additional information, this space would be used to communicate that information.

**Table 25. Internal USB 3.3 V Voltage Regulator Characteristics**

| # | Characteristic                                       | Symbol               | Min | Typ | Max  | Unit | C |
|---|--|----------------------|-----|-----|------|------|---|
| 1 | Regulator operating voltage                          | $V_{\text{regin}}$   | 3.9 | —   | 5.5  | V    | C |
| 2 | VREG output  | $V_{\text{regout}}$  | 3   | 3.3 | 3.75 | V    | P |
| 3 | $V_{\text{USB33}}$ input with internal VREG disabled | $V_{\text{usb33in}}$ | 3   | 3.3 | 3.6  | V    | C |
| 4 | VREG Quiescent Current                               | $I_{\text{VRQ}}$     | —   | 0.5 | —    | mA   | C |

### 3.16 VREF Electrical Specifications

**Table 26. VREF Electrical Specifications**

| #  | Characteristic   | Symbol      | Min   | Max   | Unit         | C |
|----|--|-------------|-------|-------|--------------|---|
| 1  | Supply voltage   | $V_{DDA}$   | 1.80  | 3.6   | V            | C |
| 2  | Operating temperature range  | $T_A$       | -40   | 105   | °C           | C |
| 3  | Output Load Capacitance  | $C_L$       | —     | 100   | nF           | D |
| 4  | Maximum Load   | —           | —     | 10    | mA           | — |
| 5  | Voltage Reference Output with Factory Trim. $V_{DD} = 3$ V at 25 °C  | $V_{out}$   | 1.145 | 1.153 | V            | P |
| 6  | Temperature Drift ( $V_{min} - V_{max}$ across the full temperature range)   | $T_{drift}$ | —     | 25    | $mV^1$       | T |
| 7  | Aging Coefficient <sup>2</sup>   | $A_C$       | —     | 60    | $\mu V/year$ | C |
| 8  | Powered down Current (Off Mode, VREFEN=0, VRSTEN=0)  | I           | —     | 0.10  | $\mu A$      | C |
| 9  | Bandgap only (Mode_LV[1:0] = 00)   | I           | —     | 75    | $\mu A$      | T |
| 10 | Low-Power buffer (MODE_LV[1:0] = 01)   | I           | —     | 125   | $\mu A$      | T |
| 11 | Tight-Regulation buffer (MODE_LV[1:0] = 10)  | I           | —     | 1.1   | mA           | T |
| 12 | Load Regulation MODE_LV = 10   | —           | —     | 100   | $\mu V/mA$   | C |
| 13 | Line Regulation MODE = 1:0, Tight Regulation $V_{DD} < 2.3$ V, Delta $V_{DDA} = 100$ mV, VREFH = 1.2 V driven externally with VREFO disabled. (Power Supply Rejection) | DC          | 70    | —     | dB           | C |

<sup>1</sup> See typical chart that follows (Figure 20).

<sup>2</sup> Linear reliability model (1008 hours stress at 125°C = 10 years operating life) used to calculate Aging  $\mu V/year$ . VREFO data recorded per month.

**Table 27. VREF Limited Range Operating Behaviors**

| # | Characteristic   | Symbol      | Min   | Max   | Unit   | C |
|---|--|-------------|-------|-------|--------|---|
| 1 | Voltage Reference Output with Factory Trim (Temperature range from 0°C to 50 °C) | $V_{out}$   | 1.149 | 1.152 | mV     | T |
| 2 | Temperature Drive ( $V_{min} - V_{max}$ Temperature range from 0 °C to 50 °C)    | $T_{drift}$ | —     | 3     | $mV^1$ | T |

<sup>1</sup> See typical chart that follows (Figure 20).

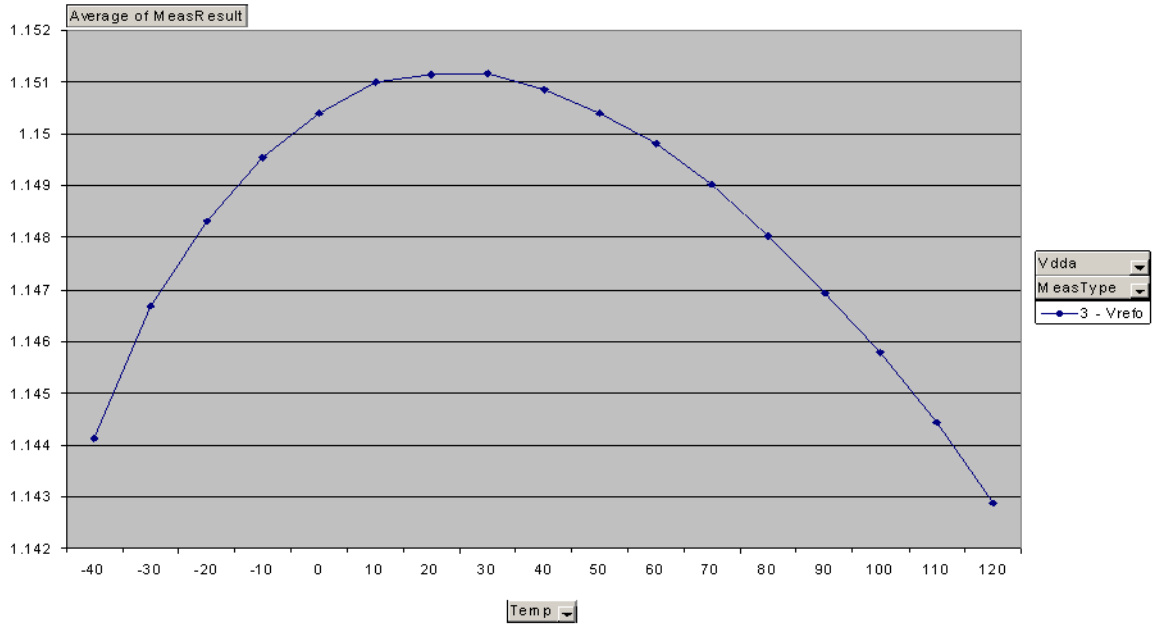


Figure 19. Typical VREF Output vs. Temperature

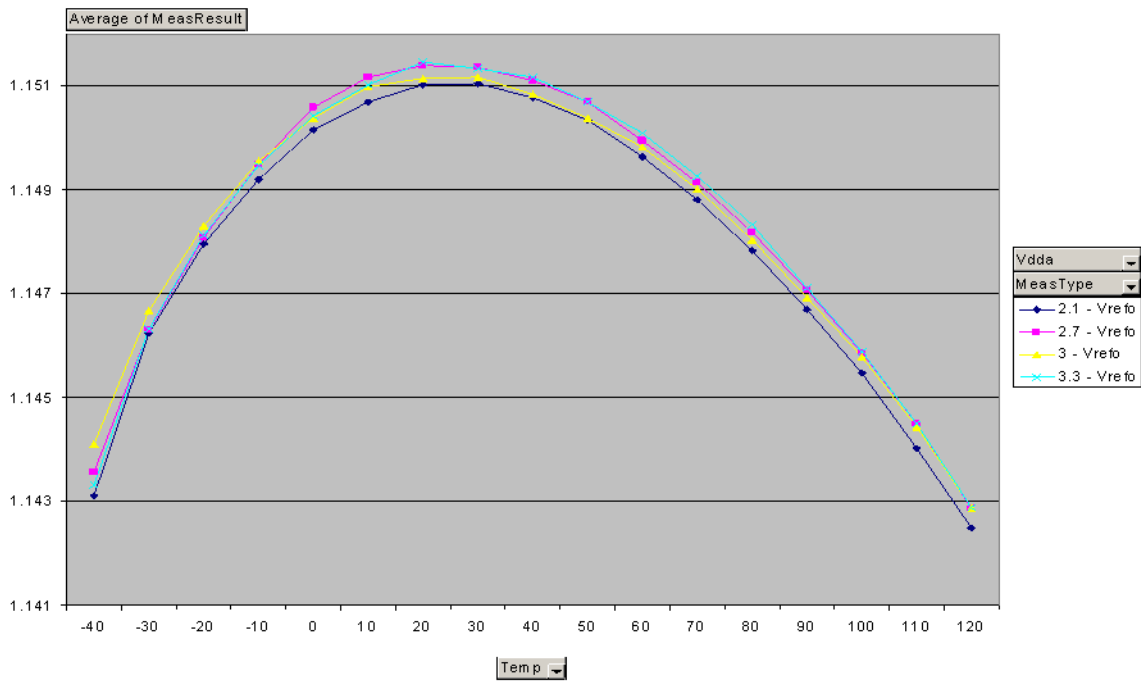


Figure 20. Typical VREF Output vs. VDD

### 3.17 TRIAMP Electrical Parameters

Table 28. TRIAMP Characteristics 1.8–3.6 V, –40°C~105°C

| #  | Characteristic <sup>1</sup>                                     | Symbol              | Min  | Typ <sup>2</sup> | Max                   | Unit | C |
|----|---|---------------------|------|------------------|-----------------------|------|---|
| 1  | Operating Voltage   | V <sub>DD</sub>     | 1.8  | —                | 3.6                   | V    | C |
| 2  | Supply Current (I <sub>OUT</sub> =0mA, CL=0)<br>Low-power mode  | I <sub>SUPPLY</sub> | —    | 52               | 60                    | μA   | T |
| 3  | Supply Current (I <sub>OUT</sub> =0mA, CL=0)<br>High-speed mode | I <sub>SUPPLY</sub> | —    | 432              | 480                   | μA   | T |
| 4  | Input Offset Voltage  | V <sub>OS</sub>     | —    | ± 1              | ± 5                   | mV   | T |
| 5  | Input Offset Voltage Temperature Drift                          | α <sub>VOS</sub>    | —    | 600              | —                     | μV   | T |
| 6  | Input Offset Current  | I <sub>OS</sub>     | —    | ±120             | 500                   | pA   | T |
| 7  | Input Bias Current (0 ~ 50°C)                                   | I <sub>BIAS</sub>   | —    | < 350            | < ±500                | pA   | T |
| 8  | Input Bias Current (–40 ~ 105°C)                                | I <sub>BIAS</sub>   | —    | 3                | 6.55                  | nA   | T |
| 9  | Input Common Mode Voltage Low                                   | V <sub>CM L</sub>   | 0    | —                | —                     | V    | T |
| 10 | Input Common Mode Voltage High                                  | V <sub>CM H</sub>   | —    | —                | V <sub>DD</sub> –1.4  | V    | T |
| 11 | Input Resistance  | R <sub>IN</sub>     | 500  | —                | —                     | MΩ   | T |
| 12 | Input Capacitances  | C <sub>IN</sub>     | —    | —                | 5                     | pF   | D |
| 13 | AC Input Impedance (f <sub>IN</sub> =100kHz)                    | X <sub>IN</sub>     | —    | 1                | —                     | MΩ   | D |
| 14 | Input Common Mode Rejection Ratio                               | CMRR                | 60   | 70               | —                     | dB   | T |
| 15 | Power Supply Rejection Ration                                   | PSRR                | 60   | 70               | —                     | dB   | T |
| 16 | Slew Rate (ΔV <sub>IN</sub> =100mV) Low-power mode              | SR                  | —    | 0.1              | —                     | V/μs | T |
| 17 | Slew Rate (ΔV <sub>IN</sub> =100mV) High-speed mode             | SR                  | —    | 1                | —                     | V/μs | T |
| 18 | Unity Gain Bandwidth (Low-power mode)<br>50pF                   | GBW                 | 0.15 | 0.25             | —                     | MHz  | T |
| 19 | Unity Gain Bandwidth (High-speed mode)<br>50pF                  | GBW                 | —    | 1.6              | —                     | MHz  | T |
| 20 | DC Open Loop Voltage Gain                                       | A <sub>V</sub>      | —    | 80               | —                     | dB   | T |
| 21 | Load Capacitance Driving Capability                             | CL(max)             | —    | —                | 100                   | pF   | T |
| 22 | Output Impedance AC Open Loop<br>(@ 100 kHz Low-power mode)     | R <sub>OUT</sub>    | —    | 1.4              | —                     | kΩ   | D |
| 23 | Output Impedance AC Open Loop<br>(@ 100 kHz High-speed mode)    | R <sub>OUT</sub>    | —    | 184              | —                     | Ω    | D |
| 24 | Output Voltage Range  | tr <sub>OUT</sub>   | 0.15 | —                | V <sub>DD</sub> –0.15 | V    | T |
| 25 | Output Drive Capability   | I <sub>OUT</sub>    | —    | ± 1.0            | —                     | mA   | T |
| 26 | Gain Margin   | GM                  | 20   | —                | —                     | dB   | D |
| 27 | Phase Margin  | PM                  | 45   | 55               | —                     | deg  | T |

**Table 28. TRIAMP Characteristics 1.8–3.6 V, –40°C~105°C (continued)**

| #  | Characteristic <sup>1</sup> | Symbol              | Min | Typ <sup>2</sup> | Max | Unit                   | C |
|----|-----------------------------|---------------------|-----|------------------|-----|------------------------|---|
| 28 | Input Voltage Noise Density | $f = 1 \text{ kHz}$ | —   | 160              | —   | nV/ $\sqrt{\text{Hz}}$ | T |

<sup>1</sup> All parameters are measured at 3.0 V,  $C_L = 47 \text{ pF}$  across temperature –40 to + 105 °C unless specified.

<sup>2</sup> Data in Typical column was characterized at 3.0 V, 25°C or is typical recommended value.

### 3.18 OPAMP Electrical Parameters

**Table 29. OPAMP Characteristics 1.8–3.6 V**

| #  | Characteristics <sup>1</sup>   | Symbol         | Min | Typ <sup>2</sup> | Max       | Unit                   | C |
|----|--|----------------|-----|------------------|-----------|------------------------|---|
| 1  | Operating Voltage  | $V_{DD}$       | 1.8 | —                | 3.6       | V                      | C |
| 2  | Supply Current ( $I_{OUT} = 0 \text{ mA}$ , $C_L = 0$ Low-Power mode)  | $I_{SUPPLY}$   | —   | 48               | 80        | $\mu\text{A}$          | T |
| 3  | Supply Current ( $I_{OUT} = 0 \text{ mA}$ , $C_L = 0$ High-Speed mode) | $I_{SUPPLY}$   | —   | 350              | 500       | $\mu\text{A}$          | T |
| 4  | Input Offset Voltage   | $V_{OS}$       | —   | $\pm 2$          | $\pm 6$   | mV                     | T |
| 5  | Input Offset Voltage Temperature Coefficient                           | $\alpha_{VOS}$ | —   | 10               | —         | $\mu\text{V}/\text{C}$ | T |
| 6  | Input Offset Current (–40°C to 105°C)                                  | $I_{OS}$       | —   | $\pm 2.5$        | $\pm 250$ | nA                     | T |
| 7  | Input Offset Current (–40°C to 50°C)                                   | $I_{OS}$       | —   | —                | 45        | nA                     | T |
| 8  | Positive Input Bias Current (–40°C to 105°C)                           | $I_{BIAS}$     | —   | 0.8              | 3.5       | nA                     | T |
| 9  | Positive Input Bias Current (–40°C to 50°C)                            | $I_{BIAS}$     | —   | —                | $\pm 2$   | nA                     | T |
| 10 | Negative Input Bias Current (–40°C to 105°C)                           | $I_{BIAS}$     | —   | 2.5              | 250       | nA                     | T |
| 11 | Negative Input Bias Current (–40°C to 50°C)                            | $I_{BIAS}$     | —   | —                | 45        | nA                     | T |
| 12 | Input Common Mode Voltage Low  | $V_{CML}$      | 0.1 | —                | —         | V                      | T |
| 13 | Input Common Mode Voltage High   | $V_{CMH}$      | —   | —                | $V_{DD}$  | V                      | T |
| 14 | Input Resistance   | $R_{IN}$       | —   | 500              | —         | $\text{M}\Omega$       | T |
| 15 | Input Capacitances   | $C_{IN}$       | —   | —                | 10        | pF                     | D |
| 16 | AC Input Impedance ( $f_{IN} = 100 \text{ kHz}$ Negative Channel)      | $ X_{IN} $     | —   | 52               | —         | $\text{k}\Omega$       | D |
| 17 | AC Input Impedance ( $f_{IN} = 100 \text{ kHz}$ Positive Channel)      | $ X_{IN} $     | —   | 132              | —         | $\text{k}\Omega$       | D |
| 18 | Input Common Mode Rejection Ratio                                      | CMRR           | 55  | 65               | —         | dB                     | T |
| 19 | Power Supply Rejection Ratio   | PSRR           | 60  | 65               | —         | dB                     | T |
| 20 | Slew Rate ( $\Delta V_{IN} = 100 \text{ mV}$ Low-Power mode)           | SR             | 0.1 | —                | —         | $\text{V}/\mu\text{s}$ | T |
| 21 | Slew Rate ( $\Delta V_{IN} = 100 \text{ mV}$ High-Speed mode)          | SR             | 1   | —                | —         | $\text{V}/\mu\text{s}$ | T |
| 22 | Unity Gain Bandwidth (Low-Power mode)                                  | GBW            | 0.2 | —                | —         | MHz                    | T |
| 23 | Unity Gain Bandwidth (High-Speed mode)                                 | GBW            | 1   | —                | —         | MHz                    | T |
| 24 | DC Open Loop Voltage Gain  | $A_V$          | 80  | 90               | —         | dB                     | T |
| 25 | Load Capacitance Driving Capability                                    | CL(max)        | —   | —                | 100       | pF                     | T |
| 26 | Output Impedance AC Open Loop (@ 100 kHz Low-Power mode)               | $R_{OUT}$      | —   | 4k               | —         | $\Omega$               | D |

Table 29. OPAMP Characteristics 1.8–3.6 V (continued)

| #  | Characteristics <sup>1</sup>  | Symbol               | Min  | Typ <sup>2</sup> | Max             | Unit   | C |
|----|---|----------------------|------|------------------|-----------------|--------|---|
| 27 | Output Impedance AC Open Loop (@100 kHz High-Speed mode)  | R <sub>OUT</sub>     | —    | 220              | —               | Ω      | D |
| 28 | Output Voltage Range  | V <sub>OUT</sub>     | 0.15 | —                | $V_{DD} - 0.15$ | V      | T |
| 29 | Output Drive Capability   | I <sub>OUT</sub>     | ±0.5 | ±1.0             | —               | mA     | T |
| 30 | Gain Margin   | GM                   | 20   | —                | —               | dB     | D |
| 31 | Phase Margin  | PM                   | 45   | 55               | —               | deg    | T |
| 32 | GPAMP startup time (Low-Power mode)<br>(Tolerance < 1%, V <sub>in</sub> = 0.5 V <sub>p-p</sub> , CL = 25 pF, RL = 100k) | T <sub>startup</sub> | —    | 4                | —               | μs     | T |
| 33 | GPAMP startup time (Low-Power mode)<br>(Tolerance < 1%, V <sub>in</sub> = 0.5 V <sub>p-p</sub> , CL = 25 pF, RL = 100k) | T <sub>startup</sub> | —    | 1                | —               | μs     | T |
| 34 | Input Voltage Noise Density   | f=1 kHz              | —    | 250              | —               | nV/√Hz | T |

<sup>1</sup> All parameters are measured at 3.3 V, CL = 4 7 pF across temperature –40 to + 105°C unless specified.

<sup>2</sup> Data in Typical column was characterized at 3.0 V, 25°C or is typical recommended value.

## 4 Ordering Information

This section contains ordering information for the device numbering system. See [Table 1](#) for feature summary by package information.

### 4.1 Part Numbers

**Table 30. Orderable Part Number Summary**

| Freescale Part Number | Description                         | Flash / SRAM (Kbytes) | Package    | Temperature   |
|-----------------------|-------------------------------------|-----------------------|------------|---------------|
| MCF51MM256VML         | MCF51MM256 ColdFire Microcontroller | 256K/32K              | 104 MAPBGA | -40 to 105 °C |
| MCF51MM256VLL         | MCF51MM256 ColdFire Microcontroller | 256K/32K              | 100 LQFP   | -40 to 105 °C |
| MCF51MM256VMB         | MCF51MM256 ColdFire Microcontroller | 256K/32K              | 81 MAPBGA  | -40 to 105 °C |
| MCF51MM256VLK         | MCF51MM256 ColdFire Microcontroller | 256K/32K              | 80 LQFP    | -40 to 105 °C |
| MCF51MM128VMB         | MCF51MM128 ColdFire Microcontroller | 128K/32K              | 81 MAPBGA  | -40 to 105 °C |
| MCF51MM128VLK         | MCF51MM128 ColdFire Microcontroller | 128K/32K              | 80 LQFP    | -40 to 105 °C |

### 4.2 Package Information

**Table 31. Package Descriptions**

| Pin Count | Package Type          | Abbreviation | Designator | Case No. | Document No.                |
|-----------|-----------------------|--------------|------------|----------|-----------------------------|
| 100       | Low Quad Flat Package | LQFP         | LL         | 983-03   | <a href="#">98ASS23308W</a> |
| 80        | Low Quad Flat Package | LQFP         | LK         | 1418     | <a href="#">98ASS23174W</a> |
| 104       | MAP BGA Package       | MAPBGA       | ML         | 1285-02  | <a href="#">98ARH98267A</a> |
| 81        | MAP BGA Package       | MAPBGA       | MB         | 1662-01  | <a href="#">98ASA10670D</a> |

### 4.3 Mechanical Drawings

[Table 31](#) provides the available package types and their document numbers. The latest package outline/mechanical drawings are available on the MCF51MM256/128 Product Summary pages at <http://www.freescale.com>.

To view the latest drawing, either:

- Click on the appropriate link in [Table 31](#), or
- Open a browser to the Freescale website (<http://www.freescale.com>), and enter the appropriate document number (from [Table 31](#)) in the “Enter Keyword” search box at the top of the page.

## 5 Revision History

This section lists major changes between versions of the MCF51MM256 Data Sheet.

**Table 32. Revision History**

| Revision | Date             | Description  |
|----------|------------------|--|
| 0        | March/April 2009 | Initial Draft  |
| 1        | July 2009        | <ul style="list-style-type: none"> <li>Revised to follow standard template.</li> <li>Removed extraneous headings from the TOC.</li> <li>Corrected units for Monotonicity to be blank in for the DAC specification.</li> <li>Updated ADC characteristic tables to include 16-Bit SAR in headings.</li> </ul>  |
| 2        | July 2009        | <ul style="list-style-type: none"> <li>Changed MCG (XOSC) Electricals Table - Row 2, Average Internal Reference Frequency typical value from 32.768 to 31.25.</li> </ul>   |
| 3        | April 2010       | <ul style="list-style-type: none"> <li>Updated Thermal Characteristics table. Reinserted the 81 and 104 MapBGA devices.</li> <li>Revised the ESD and Latch-Up Protection Characteristic description to read: Latch-up Current at <math>T_A = 125^\circ\text{C}</math>.</li> <li>Changed <a href="#">Table 9</a>. DC Characteristics rows 2 and 4, to 1.8 V, <math>I_{\text{Load}} = -600\text{ mA}</math> conditions to 1.8 V, <math>I_{\text{Load}} = 600\mu\text{A}</math> respectively.</li> <li>Corrected the 16-bit SAR ADC Operating Condition table Ref Voltage High Min value to be 1.13 instead of 1.15.</li> <li>Updated the ADC electricals.</li> <li>Inserted the Mini-FlexBus Timing Specifications.</li> <li>Added a Temp Drift parameter to the VREF Electrical Specifications.</li> <li>Removed the S08 Naming Convention diagram.</li> <li>Updated the Orderable Part Number Summary to include the Freescale Part Number suffixes.</li> <li>Completed the Package Description table values.</li> <li>Changed the 80LQFP package drawing from 98ARL10530D to 98ASS23174W.</li> <li>Updated electrical characteristic data.</li> </ul> |
| 4        | October 2010     | <ul style="list-style-type: none"> <li>Updated with the latest characteristic data. Added several figures. Added the ADC Typical Operation table.</li> </ul>   |
| 5        | July 2012        | <p>In "Supply current characteristics" table,</p> <ul style="list-style-type: none"> <li>For <math>S3I_{DD}</math>, the maximum value for the first row at <math>1\mu\text{A}</math> is changed to <math>1.3\mu\text{A}</math> and the typical value <math>0.65\mu\text{A}</math> is changed to <math>0.75\mu\text{A}</math>.</li> <li>For parameter 3, changed "LPS" to "LPR", "FBILP" to "FBI" and "FBELP" to "FBE".</li> <li>For parameter 4, changed "LPS" to "LPR", and "FBELP" to "BLPE" in both instances.</li> </ul>   |



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