

# MSP430FR267x Capacitive Touch Sensing Mixed-Signal Microcontrollers

## 1 Features

- **CapTIvate™ technology** – capacitive touch
  - Performance
    - Fast electrode scanning with four simultaneous scans
    - Support for high-resolution sliders with up to 1024 points
    - Proximity sensing
  - Reliability
    - Increased immunity to power line, RF, and other environmental noise
    - Built-in spread spectrum, automatic tuning, noise filtering, and debouncing algorithms
    - Enable [reliable touch solutions](#) with 10-V RMS common-mode noise, 4-kV electrical fast transients, and 15-kV electrostatic discharge, allowing for IEC-61000-4-6, IEC-61000-4-4, and IEC-61000-4-2 compliance
    - Reduced RF emissions to simplify electrical designs
    - Support for metal touch and water rejection designs
  - Flexibility
    - Up to 16 self-capacitance and 64 mutual-capacitance electrodes
    - Mix and match [self- and mutual-capacitive electrodes in the same design](#)
    - Support multi-touch functionality
    - Wide range of capacitance detection, wide electrode range of 0 to 300 pF
  - Low power
    - <0.9  $\mu$ A/button in wake-on-touch mode, where capacitive measurement and touch detection is done by hardware state machine while CPU is asleep
    - Wake-on-touch state machine allows electrode scanning while CPU sleeps
    - Hardware acceleration for environmental compensation, filtering, and threshold detection
  - Ease of use
    - [CapTIvate Design Center](#) PC GUI lets engineers design and tune capacitive buttons in real time without having to write code
    - CapTIvate software library in ROM provides ample FRAM for customer application
- Embedded microcontroller
  - 16-bit RISC architecture
  - Clock supports frequencies up to 16 MHz
  - Wide supply voltage range from 3.6 V down to 1.8 V (minimum supply voltage is restricted by SVS levels, see the [SVS specifications](#))
- Optimized ultra-low-power modes
  - Active mode: 135  $\mu$ A/MHz (typical)
  - Standby: <5  $\mu$ A wake-on-touch with four sensors
  - Shutdown (LPM4.5): 37 nA without SVS
- Low-power ferroelectric RAM (FRAM)
  - Up to 64KB of nonvolatile memory
  - Built-in error correction code (ECC)
  - Configurable write protection
  - Unified memory of program, constants, and storage
  - $10^{15}$  write cycle endurance
  - Radiation resistant and nonmagnetic
- Intelligent digital peripherals
  - Four 16-bit timers with three capture/compare registers each (Timer\_A3)
  - One 16-bit timer with seven capture/compare registers (Timer\_B7)
  - One 16-bit timer associated with CapTIvate technology
  - One 16-bit counter-only RTC
  - 16-bit cyclic redundancy check (CRC)
- Enhanced serial communications with support for pin remap feature
  - Two eUSCI\_A supports UART, IrDA, and SPI
  - Two eUSCI\_B supports SPI and I<sup>2</sup>C
- High-performance analog
  - One 12-bit analog-to-digital converter (ADC) with up to 12 channels
    - Internal shared reference (1.5, 2.0, or 2.5 V)
    - Sample-and-hold 200 ksp/s
  - One enhanced comparator (eCOMP)
    - Integrated 6-bit DAC as reference voltage
    - Programmable hysteresis
    - Configurable high-power and low-power modes
- Clock system (CS)
  - On-chip 32-kHz RC oscillator (REFO) with 1  $\mu$ A support
  - On-chip 16-MHz digitally controlled oscillator (DCO) with frequency-locked loop (FLL)
    - $\pm 1\%$  accuracy with on-chip reference at room temperature
  - On-chip very low-frequency 10-kHz oscillator (VLO)
  - On-chip high-frequency modulation oscillator (MODOSC)



- External 32-kHz crystal oscillator (LFXT)
- Programmable MCLK prescaler of 1 to 128
- SMCLK derived from MCLK with programmable prescaler of 1, 2, 4, or 8
- General input/output and pin functionality
  - 43 I/Os on LQFP-48 package
  - 43 interrupt pins on all GPIOs can wake MCU from low-power modes
- Development tools and software
  - Development tools
    - MSP CapTivate™ MCU development kit evaluation: use with [CAPTIVATE-PGMR](#) programmer and capacitive touch MSP430FR2676 MCU board [CAPTIVATE-FR2676](#)
    - Target development board [MSP-TS430PT48A](#)
  - Ease-of-use ecosystem
    - [CapTivate Design Center](#) – code generation, customizable GUI, real-time tuning
- 16KB ROM library includes CapTivate touch libraries and driver libraries
- Family members (also see [Device Comparison](#))
  - MSP430FR2676: 64KB of program FRAM, 512B of information FRAM, 8KB of RAM supports up to 16 self-capacitive and 64 mutual-capacitive sensors
  - MSP430FR2675: 32KB of program FRAM, 512B of information FRAM, 6KB of RAM supports up to 16 self-capacitive and 64 mutual-capacitive sensors
  - MSP430FR2673: 16KB of program FRAM, 512B of information FRAM, 4KB of RAM supports up to 16 self-capacitive and 64 mutual-capacitive sensors
  - MSP430FR2672: 8KB of program FRAM, 512B of information FRAM, 2KB of RAM supports up to 16 self-capacitive and 24 mutual-capacitive sensors
- Package options
  - 48-pin: LQFP (PT)
  - 40-pin: VQFN (RHA)
  - 32-pin: VQFN (RHB)

## 2 Applications

- Major appliances
- Intrusion HMI keypads and control panels
- Electronic smart locks, door keypads, and readers
- Garage door systems
- Motorized window blinds
- Remote controls
- Personal electronics
- Wireless speakers and headsets
- Handheld video game controllers
- A/V receivers
- White goods
- Garden and power tools

## 3 Description

The MSP430FR267x is an ultra-low-power MSP430™ microcontroller for capacitive touch sensing that feature [CapTivate touch technology](#) for buttons, slides, wheel and proximity applications. MSP430 MCUs with CapTivate technology provide the most integrated and autonomous capacitive-touch solution in the market with high reliability and noise immunity at the lowest power. TI's capacitive touch technology supports concurrent self-capacitance and mutual-capacitance electrodes on the same design for maximum flexibility. MSP430 MCUs with CapTivate technology operate through thick glass, plastic enclosures, metal, and wood with operation in harsh environments including wet, greasy, and dirty environments.

TI capacitive touch sensing MSP430 MCUs are supported by an extensive hardware and software ecosystem with reference designs and code examples to get your design started quickly. Development kits include the [MSP-CAPT-FR2633 CapTivate Technology Development Kit](#). TI also provides free software including the [CapTivate Design Center](#), where engineers can quickly develop applications with an easy-to-use GUI and [MSP430Ware™ software](#), and comprehensive documentation with the [CapTivate Technology Guide](#). MSP430 MCUs are also supported by extensive online collateral, such as our [housekeeping example series](#), [MSP Academy training](#), and online support through the [TI E2E™ support forums](#).

The TI MSP430 family of low-power microcontrollers consists of devices with different sets of peripherals targeted for various applications. The architecture, combined with extensive low-power modes, is optimized to achieve extended battery life in portable measurement applications. The MCU features a powerful 16-bit RISC CPU, 16-bit registers, and constant generators that contribute to maximum code efficiency. The digitally controlled oscillator (DCO) allows the MCU to wake up from low-power modes to active mode in less than 10 µs (typical).

For complete module descriptions, see the [MSP430FR4xx and MSP430FR2xx Family User's Guide](#).

### Device Information

| PART NUMBER <sup>(1)</sup> | PACKAGE   | BODY SIZE <sup>(2)</sup> |
|----------------------------|-----------|--------------------------|
| MSP430FR2676TPT            | LQFP (48) | 7 mm × 7 mm              |
| MSP430FR2675TPT            | LQFP (48) | 7 mm × 7 mm              |
| MSP430FR2676TRHA           | VQFN (40) | 6 mm × 6 mm              |
| MSP430FR2675TRHA           | VQFN (40) | 6 mm × 6 mm              |
| MSP430FR2676TRHB           | VQFN (32) | 5 mm × 5 mm              |
| MSP430FR2675TRHB           | VQFN (32) | 5 mm × 5 mm              |
| MSP430FR2673TRHB           | VQFN (32) | 5 mm × 5 mm              |
| MSP430FR2672TRHB           | VQFN (32) | 5 mm × 5 mm              |

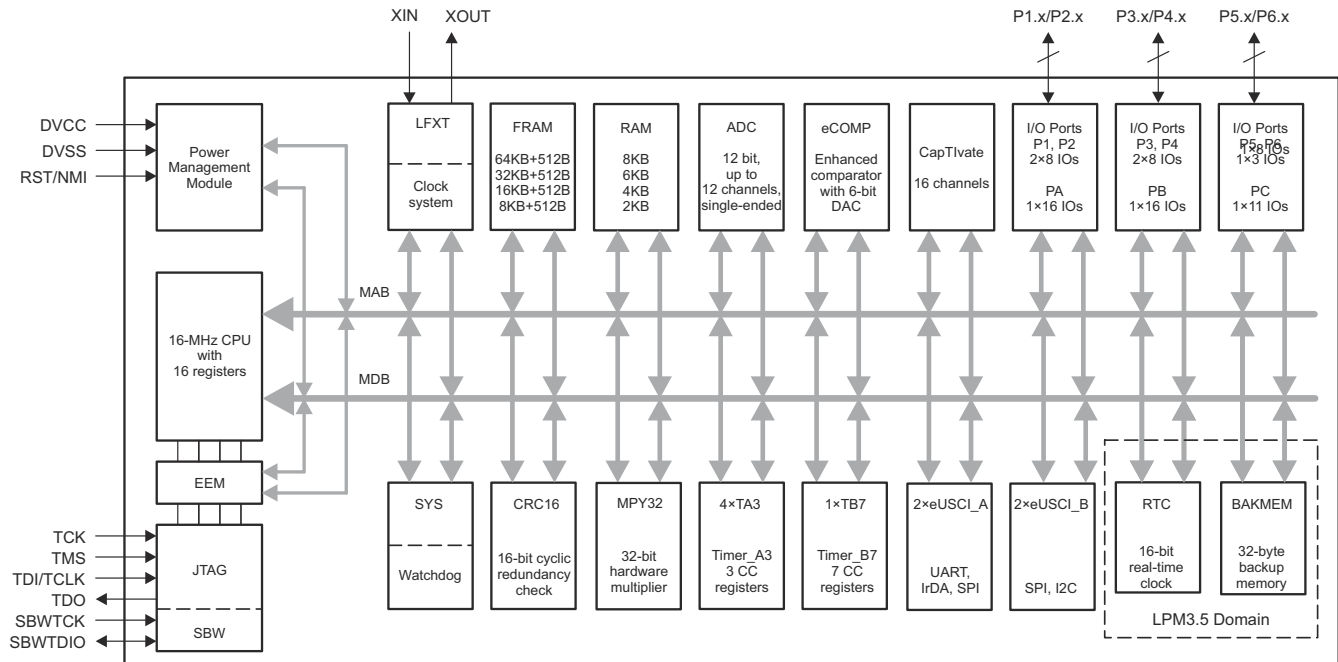
- (1) For the most current part, package, and ordering information, see the *Package Option Addendum* in [Section 12](#), or see the TI website at [www.ti.com](http://www.ti.com).
- (2) The sizes shown here are approximations. For the package dimensions with tolerances, see the *Mechanical Data* in [Section 12](#).

### CAUTION

System-level ESD protection must be applied in compliance with the device-level ESD specification to prevent electrical overstress or disturbing of data or code memory. See [MSP430 System-Level ESD Considerations](#) for more information.

## 4 Functional Block Diagram

Figure 4-1 shows the functional block diagram.



**Figure 4-1. Functional Block Diagram**

- The MCU has one main power pair of DVCC and DVSS that supplies digital and analog modules. Recommended bypass and decoupling capacitors are 4.7  $\mu$ F to 10  $\mu$ F and 0.1  $\mu$ F, respectively, with  $\pm 5\%$  accuracy.
- VREG is the decoupling capacitor of the CapTIvate regulator. The recommended value for the required decoupling capacitor is 1  $\mu$ F, with a maximum ESR of  $\leq 200$  m $\Omega$ .
- All GPIOs feature the pin interrupt function and can wake the MCU from all LPMs.
- In LPM3 or LPM4 mode, the CapTIvate module can be functional while the rest of the peripherals are off.

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## 5 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from revision C to revision D

| Changes from February 20, 2020 to September 14, 2021                                                                                                              | Page |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| • Updated the numbering format for tables, figures, and cross references throughout the document.....                                                             | 1    |
| • Added links to online collateral in <a href="#">Section 3 Description</a> .....                                                                                 | 2    |
| • Corrected the pin numbers for the Verif+ and Verif- signals in <a href="#">Table 7-2, Signal Descriptions</a> .....                                             | 18   |
| • Corrected the TAxRMP, USCIA0RMP, USCIB0RMP, and USCIB1RMP bit names in the notes for <a href="#">Table 7-2, Signal Descriptions</a> .....                       | 18   |
| • Corrected the USCIA0RMP and USCIBxRMP bit names in <a href="#">Section 9.10.7, Enhanced Universal Serial Communication Interface (eUSCI_A0, eUSCI_B0)</a> ..... | 60   |
| • Corrected the TAxRMP bit name in the notes for <a href="#">Table 9-16, TA2 and TA3 Pin Configurations of Remap Functionality</a> .....                          | 61   |
| • Added an inverter to the Schmitt-trigger enable in <a href="#">Figure 9-4, Port Input/Output With Schmitt Trigger</a> .....                                     | 70   |
| • Corrected the value of the P5SEL.x column for P5.3 and P5.4 in <a href="#">Table 9-27, Port P5 (P5.0 to P5.7) Pin Functions</a> .....                           | 77   |
| • Added the SYSCFG3 register to <a href="#">Table 9-35, SYS Registers (Base Address: 0140h)</a> .....                                                             | 82   |

Changes from revision B to revision C

| Changes from December 11, 2019 to February 19, 2020                                                               | Page |
|-------------------------------------------------------------------------------------------------------------------|------|
| • Added MSP430FR2673 and MSP430FR2672 to <a href="#">Section 1, Features</a> .....                                | 1    |
| • Added MSP430FR2673 and MSP430FR2672 to this data sheet.....                                                     | 1    |
| • Added MSP430FR2673 and MSP430FR2672 to <i>Device Information</i> in <a href="#">Section 3 Description</a> ..... | 2    |
| • Added MSP430FR2673TRHB and MSP430FR2672TRHB to <a href="#">Table 6-1, Device Comparison</a> .....               | 8    |
| • Added MSP430FR2673TRHB and MSP430FR2672TRHB to <a href="#">Figure 7-3, 32-Pin RHB Package (Top View)</a> ....   | 10   |
| • Added MSP430FR2673 and MSP430FR2672 to <a href="#">Table 9-29, Device IDs</a> .....                             | 79   |
| • Added MSP430FR2673 and MSP430FR2672 to <a href="#">Table 9-31, Memory Organization</a> .....                    | 81   |
| • Added MSP430FR2673 and MSP430FR2672 in <a href="#">Figure 11-1, Device Nomenclature</a> .....                   | 98   |

Changes from revision A to revision B

| Changes from April 26, 2019 to December 10, 2019                                                                                                                                                               | Page |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| • Updated <a href="#">Section 1, Features</a> .....                                                                                                                                                            | 1    |
| • Changed the note that begins "Supply voltage changes faster than 0.2 V/μs can trigger a BOR reset..." in <a href="#">Section 8.3, Recommended Operating Conditions</a> .....                                 | 24   |
| • Added the note that begins "TI recommends that power to the DVCC pin must not exceed the limits..." in <a href="#">Section 8.3, Recommended Operating Conditions</a> .....                                   | 24   |
| • Changed the note that begins "A capacitor tolerance of ±20% or better is required..." in <a href="#">Section 8.3, Recommended Operating Conditions</a> .....                                                 | 24   |
| • Added the note "See <a href="#">MSP430 32-kHz Crystal Oscillators</a> for details on crystal section, layout, and testing" to <a href="#">Section 8.12.3.1, XT1 Crystal Oscillator (Low Frequency)</a> ..... | 32   |
| • Changed the note that begins "Requires external capacitors at both terminals..." in <a href="#">Section 8.12.3.1, XT1 Crystal Oscillator (Low Frequency)</a> .....                                           | 32   |
| • Added the t <sub>TA,cap</sub> parameter in <a href="#">Section 8.12.6.1, Timer_A</a> .....                                                                                                                   | 39   |
| • Added the t <sub>TB,cap</sub> parameter in <a href="#">Section 8.12.6.2, Timer_B</a> .....                                                                                                                   | 39   |
| • Corrected the test conditions for the R <sub>I</sub> parameter in <a href="#">Section 8.12.8.1, ADC, Power Supply and Input Range Conditions</a> .....                                                       | 45   |
| • Removed ADCDIV from the equations for t <sub>CONVERT</sub> because ADCCLK is after division in <a href="#">Section 8.12.8.2, ADC, Timing Parameters</a> .....                                                | 45   |
| • Added the note that begins "t <sub>Sample</sub> = ln(2 <sup>n+1</sup> ) × T ..." in <a href="#">Section 8.12.8.2, ADC, Timing Parameters</a> .....                                                           | 45   |

- Changed the symbol and description of the  $DC_{CAPCLK}$  parameter in [Section 8.12.10.1](#), *CapTlvate Electrical Characteristics* .....48
- Changed CRC covered end address to 0x1AF7 in table note (1) in [Table 9-30](#), *Device Descriptors* .....79

Changes from initial release to revision A

| <b>Changes from March 12, 2019 to April 25, 2019</b>                                                                                                                        | <b>Page</b> |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|
| • Changed document status to Production Data.....                                                                                                                           | 1           |
| • Added memory sizes for MSP430FR2673 and MSP430FR2672 in <a href="#">Figure 4-1</a> , <i>Functional Block Diagram</i> .....                                                | 4           |
| • Updated <a href="#">Section 8.7</a> <i>Low-Power Mode (LPM3, LPM4) Supply Currents (Into <math>V_{CC}</math>) Excluding External Current</i> with production values ..... | 26          |
| • Updated <a href="#">Section 8.12.3.2</a> <i>DCO FLL, Frequency</i> with production values.....                                                                            | 33          |

## 6 Device Comparison

Table 6-1 summarizes the features of the available family members.

**Table 6-1. Device Comparison**

| DEVICE <sup>(1) (2)</sup> | PROGRAM FRAM<br>+ INFORMATION<br>FRAM (KB) | SRAM<br>(KB) | TA0, TA1,<br>TA2, TA3     | TB0                       | eUSCI_A0<br>eUSCI_A1 | eUSCI_B0<br>eUSCI_B1 | 12-BIT ADC<br>CHANNELS | eCOMP | CapTIvate<br>TECHNOLOGY<br>CHANNELS | GPIOs | PACKAGE          |
|---------------------------|--------------------------------------------|--------------|---------------------------|---------------------------|----------------------|----------------------|------------------------|-------|-------------------------------------|-------|------------------|
| MSP430FR2676TPT           | 64 + 0.5                                   | 8            | 4, 3 × CCR <sup>(3)</sup> | 1, 7 × CCR <sup>(4)</sup> | 2                    | 2                    | 12                     | 1     | 16                                  | 43    | 48 LQFP (PT)     |
| MSP430FR2675TPT           | 32 + 0.5                                   | 6            | 4, 3 × CCR <sup>(3)</sup> | 1, 7 × CCR <sup>(4)</sup> | 2                    | 2                    | 12                     | 1     | 16                                  | 43    | 48 LQFP (PT)     |
| MSP430FR2676TRHA          | 64 + 0.5                                   | 8            | 4, 3 × CCR <sup>(3)</sup> | 1, 7 × CCR <sup>(4)</sup> | 2                    | 2                    | 10                     | 1     | 16                                  | 35    | 40 VQFN<br>(RHA) |
| MSP430FR2675TRHA          | 32 + 0.5                                   | 6            | 4, 3 × CCR <sup>(3)</sup> | 1, 7 × CCR <sup>(4)</sup> | 2                    | 2                    | 10                     | 1     | 16                                  | 35    | 40 VQFN<br>(RHA) |
| MSP430FR2676TRHB          | 64 + 0.5                                   | 8            | 4, 3 × CCR <sup>(3)</sup> | 1, 7 × CCR <sup>(5)</sup> | 2                    | 2                    | 8                      | 1     | 16                                  | 27    | 32 VQFN<br>(RHB) |
| MSP430FR2675TRHB          | 32 + 0.5                                   | 6            | 4, 3 × CCR <sup>(3)</sup> | 1, 7 × CCR <sup>(5)</sup> | 2                    | 2                    | 8                      | 1     | 16                                  | 27    | 32 VQFN<br>(RHB) |
| MSP430FR2673TRHB          | 16 + 0.5                                   | 4            | 4, 3 × CCR <sup>(3)</sup> | 1, 7 × CCR <sup>(5)</sup> | 2                    | 2                    | 8                      | 1     | 16                                  | 27    | 32 VQFN<br>(RHB) |
| MSP430FR2672TRHB          | 8 + 0.5                                    | 2            | 4, 3 × CCR <sup>(3)</sup> | 1, 7 × CCR <sup>(5)</sup> | 2                    | 2                    | 8                      | 1     | 16                                  | 27    | 32 VQFN<br>(RHB) |

(1) For the most current package and ordering information, see the *Package Option Addendum* in [Section 12](#), or see the TI website at [www.ti.com](http://www.ti.com)

(2) Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at [www.ti.com/packaging](http://www.ti.com/packaging)

(3) A CCR register is a configurable register that provides internal and external capture or compare inputs, or internal and external PWM outputs. TA0 and TA1 are externally connected on CCR1, CCR2. TA2 and TA3 are externally connected on CCR0 to CCR2.

(4) A CCR register is a configurable register that provides internal and external capture or compare inputs, or internal and external PWM outputs. TB0 is externally connected on CCR0 to CCR6.

(5) A CCR register is a configurable register that provides internal capture only, CCR0 to CCR6 registers can only be used for period timing and interrupt generation, NO PWM outputs functionality.

## 6.1 Related Products

For information about other devices in this family of products or related products, see the following links.

### [Products for microcontrollers](#)

Our diverse portfolio of 16- and 32-bit microcontrollers (MCUs) with real-time control capabilities and high-precision analog integration are optimized for industrial and automotive applications. Backed by decades of expertise and innovative hardware and software solutions, our MCUs can meet the needs of any design and budget.

### [Products for MSP430 microcontrollers](#)

Our 16-bit MSP430™ microcontrollers (MCUs) provide affordable solutions for all applications. Our leadership in integrated precision analog enables designers to enhance system performance and lower system costs. Designers can find a cost-effective MCU within the broad MSP430 portfolio of over 2000 devices for virtually any need. Get started quickly and reduce time to market with our simplified tools, software, and best-in-class support.

### [Reference designs for MSP430FR2676](#)

Find reference designs leveraging the best in TI technology – from analog and power management to embedded processors

## 7 Terminal Configuration and Functions

### 7.1 Pin Diagrams

Figure 7-1 shows the pinout for the 48-pin PT package.

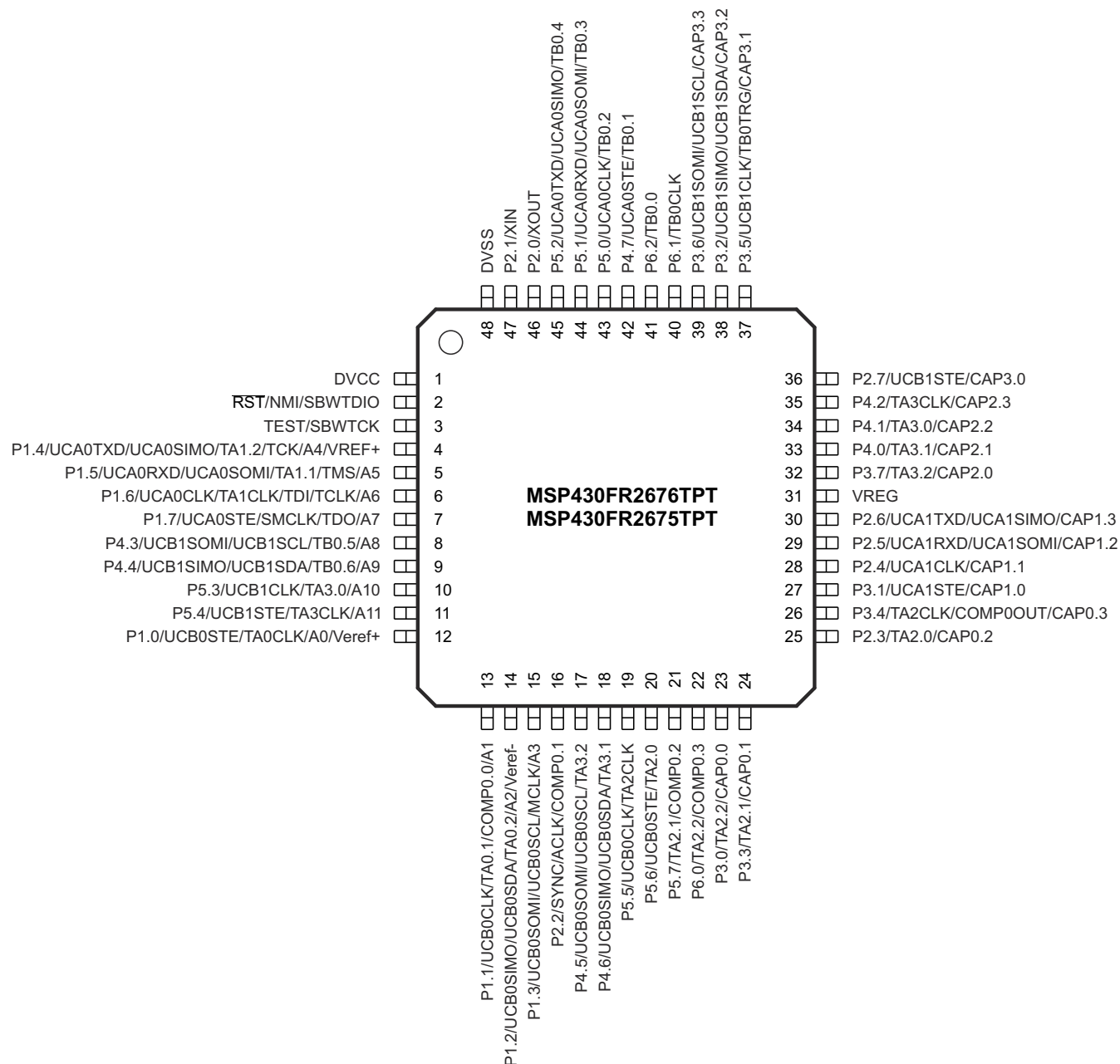
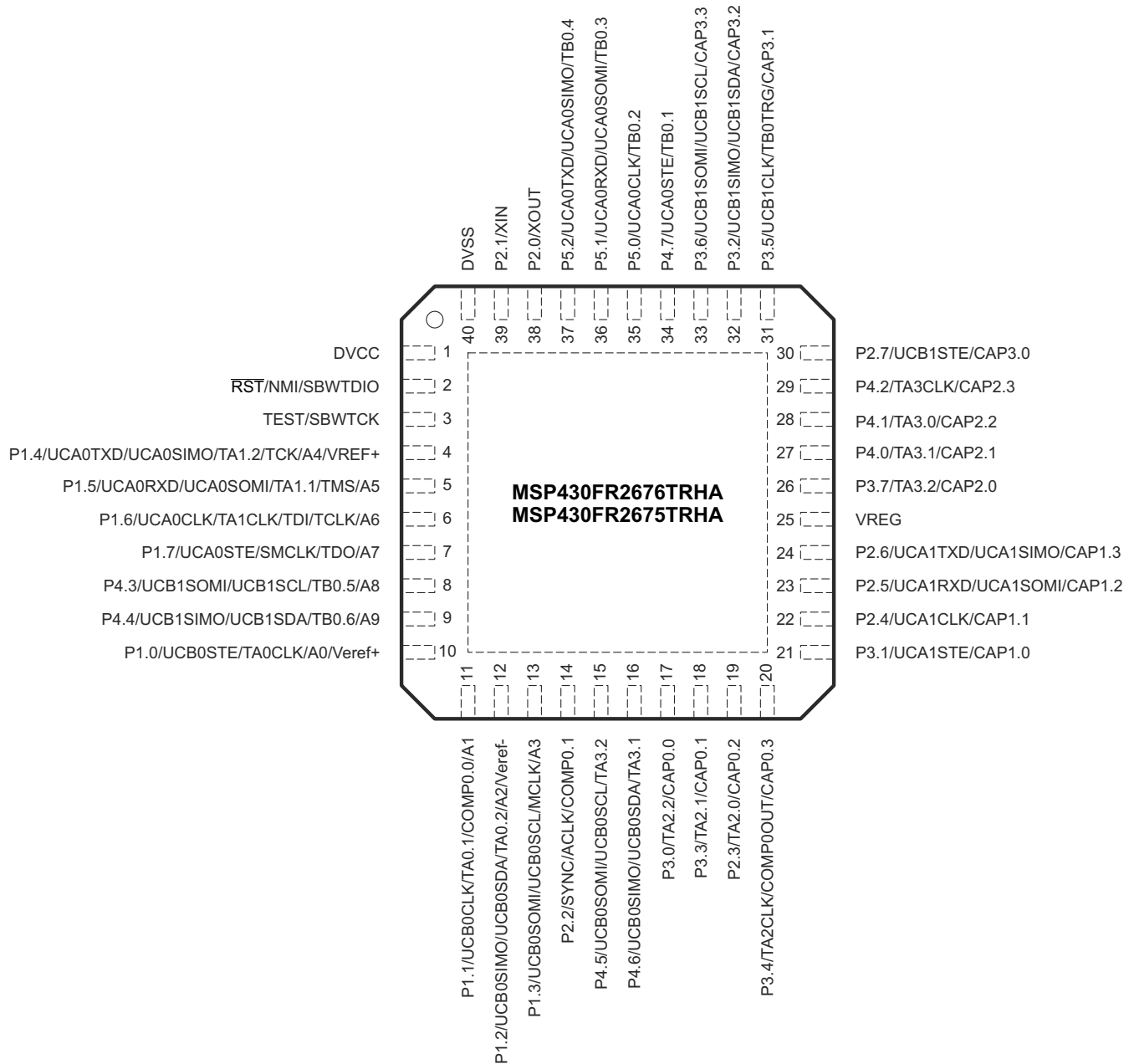


Figure 7-1. 48-Pin PT Package (Top View)

Figure 7-2 shows the pinout for the 40-pin RHA package.



**Figure 7-2. 40-Pin RHA Package (Top View)**

Figure 7-3 shows the pinout for the 32-pin RHB package.

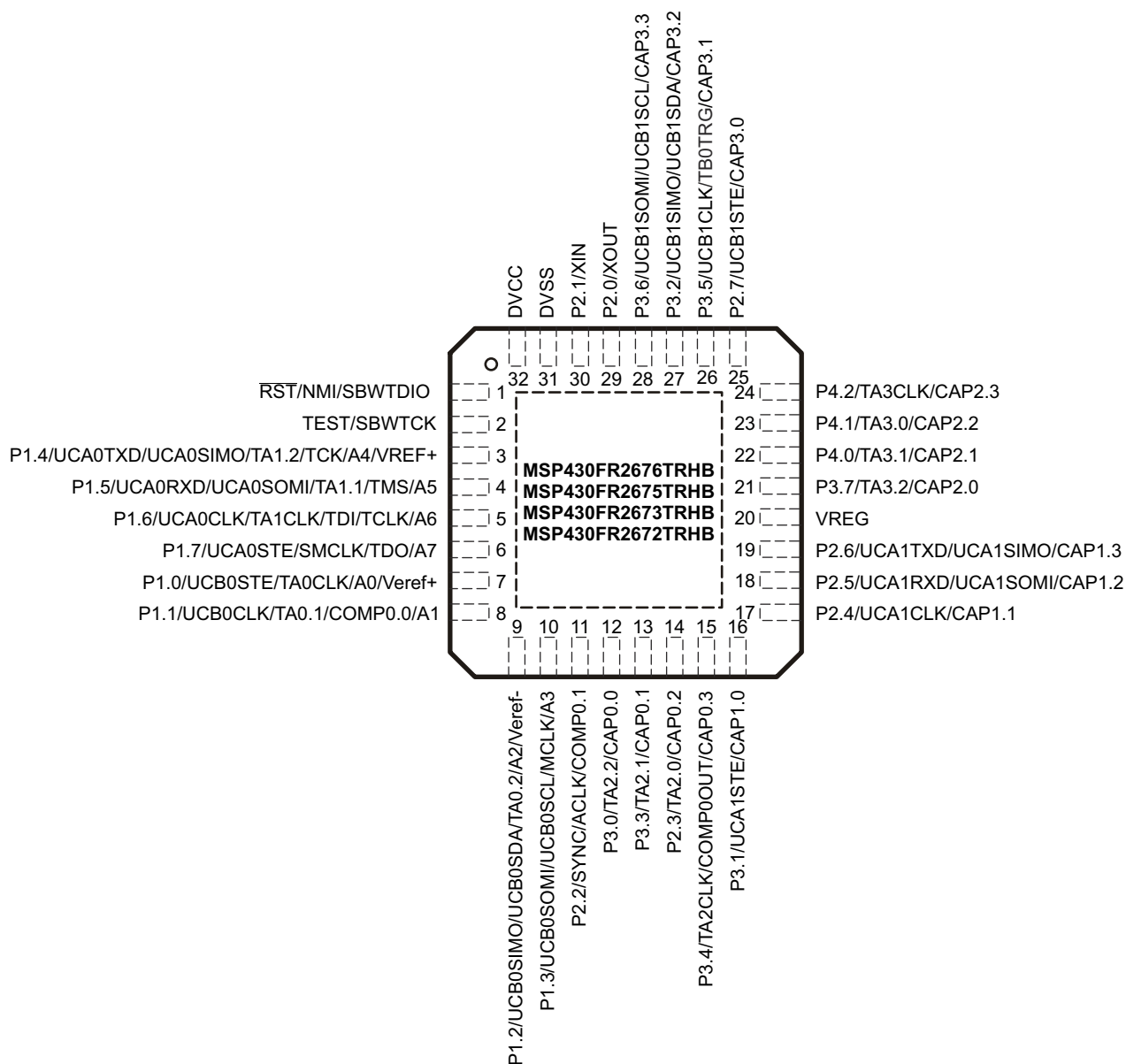


Figure 7-3. 32-Pin RHB Package (Top View)

## 7.2 Pin Attributes

Table 7-1 lists the attributes of all pins.

**Table 7-1. Pin Attributes**

| PIN NUMBER |     |     | SIGNAL NAME <sup>(1) (2)</sup> | SIGNAL TYPE <sup>(3)</sup> | BUFFER TYPE <sup>(4)</sup> | POWER SOURCE <sup>(5)</sup> | RESET STATE AFTER BOR <sup>(6)</sup> |
|------------|-----|-----|--------------------------------|----------------------------|----------------------------|-----------------------------|--------------------------------------|
| PT         | RHA | RHB |                                |                            |                            |                             |                                      |
| 1          | 1   | 32  | DVCC                           | P                          | Power                      | DVCC                        | N/A                                  |
| 2          | 2   | 1   | RST (RD)                       | I                          | LVC MOS                    | DVCC                        | PU                                   |
|            |     |     | NMI                            | I                          | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | SBWTDIO                        | I/O                        | LVC MOS                    | DVCC                        | –                                    |
| 3          | 3   | 2   | TEST (RD)                      | I                          | LVC MOS                    | DVCC                        | PD                                   |
|            |     |     | SBWTCK                         | I                          | LVC MOS                    | DVCC                        | –                                    |
| 4          | 4   | 3   | P1.4 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | UCA0TXD                        | O                          | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | UCA0SIMO                       | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | TA1.2                          | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | TCK                            | I                          | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | A4                             | I                          | Analog                     | DVCC                        | –                                    |
|            |     |     | VREF+                          | O                          | Power                      | DVCC                        | –                                    |
| 5          | 5   | 4   | P1.5 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | UCA0RXD                        | I                          | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | UCA0SOMI                       | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | TA1.1                          | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | TMS                            | I                          | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | A5                             | I                          | Analog                     | DVCC                        | –                                    |
| 6          | 6   | 5   | P1.6 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | UCA0CLK                        | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | TA1CLK                         | I                          | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | TDI                            | I                          | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | TCLK                           | I                          | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | A6                             | I                          | Analog                     | DVCC                        | –                                    |
| 7          | 7   | 6   | P1.7 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | UCA0STE                        | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | SMCLK                          | O                          | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | TDO                            | O                          | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | A7                             | I                          | Analog                     | DVCC                        | –                                    |
| 8          | 8   | –   | P4.3 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | UCB1SOMI                       | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | UCB1SCL                        | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | TB0.5                          | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | A8                             | I                          | Analog                     | DVCC                        | –                                    |
| 9          | 9   | –   | P4.4 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | UCB1SIMO                       | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | UCB1SDA                        | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | TB0.6                          | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | A9                             | I                          | Analog                     | DVCC                        | –                                    |

Table 7-1. Pin Attributes (continued)

| PIN NUMBER |     |     | SIGNAL NAME <sup>(1) (2)</sup> | SIGNAL TYPE <sup>(3)</sup> | BUFFER TYPE <sup>(4)</sup> | POWER SOURCE <sup>(5)</sup> | RESET STATE AFTER BOR <sup>(6)</sup> |
|------------|-----|-----|--------------------------------|----------------------------|----------------------------|-----------------------------|--------------------------------------|
| PT         | RHA | RHB |                                |                            |                            |                             |                                      |
| 10         | –   | –   | P5.3 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | UCB1CLK                        | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | TA3.0                          | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | A10                            | I                          | Analog                     | DVCC                        | –                                    |
| 11         | –   | –   | P5.4 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | UCB1STE                        | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | TA3CLK                         | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | A11                            | I                          | Analog                     | DVCC                        | –                                    |
| 12         | 10  | 7   | P1.0 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | UCB0STE                        | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | TA0CLK                         | I                          | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | A0                             | I                          | Analog                     | DVCC                        | –                                    |
|            |     |     | Veref+                         | I                          | Power                      | DVCC                        | –                                    |
| 13         | 11  | 8   | P1.1 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | UCB0CLK                        | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | TA0.1                          | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | A1                             | I                          | Analog                     | DVCC                        | –                                    |
|            |     |     | COMP0.0                        | I                          | Analog                     | DVCC                        | –                                    |
| 14         | 12  | 9   | P1.2 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | UCB0SIMO                       | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | UCB0SDA                        | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | TA0.2                          | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | A2                             | I                          | Analog                     | DVCC                        | –                                    |
|            |     |     | Veref-                         | I                          | Power                      | DVCC                        | –                                    |
| 15         | 13  | 10  | P1.3 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | UCB0SOMI                       | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | UCB0SCL                        | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | MCLK                           | O                          | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | A3                             | I                          | Analog                     | DVCC                        | –                                    |
| 16         | 14  | 11  | P2.2 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | SYNC                           | I                          | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | ACLK                           | O                          | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | COMP0.1                        | I                          | Analog                     | DVCC                        | –                                    |
| 17         | 15  | –   | P4.5 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | UCB0SOMI                       | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | UCB0SCL                        | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | TA3.2                          | I/O                        | LVC MOS                    | DVCC                        | –                                    |
| 18         | 16  | –   | P4.6 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | UCB0SIMO                       | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | UCB0SDA                        | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | TA3.1                          | I/O                        | LVC MOS                    | DVCC                        | –                                    |
| 19         | –   | –   | P5.5 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | UCB0CLK                        | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | TA2CLK                         | I/O                        | LVC MOS                    | DVCC                        | –                                    |

**Table 7-1. Pin Attributes (continued)**

| PIN NUMBER |     |     | SIGNAL NAME <sup>(1) (2)</sup> | SIGNAL TYPE <sup>(3)</sup> | BUFFER TYPE <sup>(4)</sup> | POWER SOURCE <sup>(5)</sup> | RESET STATE AFTER BOR <sup>(6)</sup> |
|------------|-----|-----|--------------------------------|----------------------------|----------------------------|-----------------------------|--------------------------------------|
| PT         | RHA | RHB |                                |                            |                            |                             |                                      |
| 20         | –   | –   | P5.6 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | UCB0STE                        | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | TA2.0                          | I/O                        | LVC MOS                    | DVCC                        | –                                    |
| 21         | –   | –   | P5.7 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | TA2.1                          | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | COMP0.2                        | I                          | Analog                     | DVCC                        | –                                    |
| 22         | –   | –   | P6.0 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | TA2.2                          | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | COMP0.3                        | I                          | Analog                     | DVCC                        | –                                    |
| 23         | 17  | 12  | P3.0 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | TA2.2                          | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | CAP0.0                         | I/O                        | Analog                     | V <sub>REG</sub>            | –                                    |
| 24         | 18  | 13  | P3.3 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | TA2.1                          | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | CAP0.1                         | I/O                        | Analog                     | V <sub>REG</sub>            | OFF                                  |
| 25         | 19  | 14  | P2.3 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | TA2.0                          | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | CAP0.2                         | I/O                        | Analog                     | V <sub>REG</sub>            | –                                    |
| 26         | 20  | 15  | P3.4 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | TA2CLK                         | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | COMP0OUT                       | O                          | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | CAP0.3                         | I/O                        | Analog                     | V <sub>REG</sub>            | OFF                                  |
| 27         | 21  | 16  | P3.1 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | UCA1STE                        | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | CAP1.0                         | I/O                        | Analog                     | V <sub>REG</sub>            | –                                    |
| 28         | 22  | 17  | P2.4 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | UCA1CLK                        | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | CAP1.1                         | I/O                        | Analog                     | V <sub>REG</sub>            | –                                    |
| 29         | 23  | 18  | P2.5 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | UCA1RXD                        | I                          | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | UCA1SOMI                       | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | CAP1.2                         | I/O                        | Analog                     | V <sub>REG</sub>            | –                                    |
| 30         | 24  | 19  | P2.6 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | UCA1TXD                        | O                          | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | UCA1SIMO                       | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | CAP1.3                         | I/O                        | Analog                     | V <sub>REG</sub>            | –                                    |
| 31         | 25  | 20  | VREG                           | P                          | Power                      | V <sub>REG</sub>            | N/A                                  |
| 32         | 26  | 21  | P3.7 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | TA3.2                          | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | CAP2.0                         | I/O                        | Analog                     | V <sub>REG</sub>            | OFF                                  |
| 33         | 27  | 22  | P4.0 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | TA3.1                          | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | CAP2.1                         | I/O                        | Analog                     | V <sub>REG</sub>            | OFF                                  |

Table 7-1. Pin Attributes (continued)

| PIN NUMBER |     |     | SIGNAL NAME <sup>(1) (2)</sup> | SIGNAL TYPE <sup>(3)</sup> | BUFFER TYPE <sup>(4)</sup> | POWER SOURCE <sup>(5)</sup> | RESET STATE AFTER BOR <sup>(6)</sup> |
|------------|-----|-----|--------------------------------|----------------------------|----------------------------|-----------------------------|--------------------------------------|
| PT         | RHA | RHB |                                |                            |                            |                             |                                      |
| 34         | 28  | 23  | P4.1 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | TA3.0                          | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | CAP2.2                         | I/O                        | Analog                     | V <sub>REG</sub>            | OFF                                  |
| 35         | 29  | 24  | P4.2 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | TA3CLK                         | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | CAP2.3                         | I/O                        | Analog                     | V <sub>REG</sub>            | OFF                                  |
| 36         | 30  | 25  | P2.7 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | UCB1STE                        | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | CAP3.0                         | I/O                        | Analog                     | V <sub>REG</sub>            | –                                    |
| 37         | 31  | 26  | P3.5 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | UCB1CLK                        | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | TB0TRG                         | I                          | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | CAP3.1                         | I/O                        | Analog                     | V <sub>REG</sub>            | OFF                                  |
| 38         | 32  | 27  | P3.2 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | UCB1SIMO                       | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | UCB1SDA                        | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | CAP3.2                         | I/O                        | Analog                     | V <sub>REG</sub>            | –                                    |
| 39         | 33  | 28  | P3.6(RD)                       | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | UCB1SOMI                       | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | UCB1SCL                        | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | CAP3.3                         | I/O                        | Analog                     | V <sub>REG</sub>            | OFF                                  |
| 40         | –   | –   | P6.1 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | TB0CLK                         | I/O                        | LVC MOS                    | DVCC                        | –                                    |
| 41         | –   | –   | P6.2 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | TB0.0                          | I/O                        | LVC MOS                    | DVCC                        | –                                    |
| 42         | 34  | –   | P4.7 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | UCA0STE                        | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | TB0.1                          | I/O                        | LVC MOS                    | DVCC                        | –                                    |
| 43         | 35  | –   | P5.0 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | UCA0CLK                        | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | TB0.2                          | I                          | LVC MOS                    | DVCC                        | –                                    |
| 44         | 36  | –   | P5.1 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | UCA0RXD                        | I                          | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | UCA0SOMI                       | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | TB0.3                          | I/O                        | LVC MOS                    | DVCC                        | –                                    |
| 45         | 37  | –   | P5.2 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | UCA0TXD                        | O                          | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | UCA0SIMO                       | I/O                        | LVC MOS                    | DVCC                        | –                                    |
|            |     |     | TB0.4                          | I/O                        | LVC MOS                    | DVCC                        | –                                    |
| 46         | 38  | 29  | P2.0 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | XOUT                           | O                          | LVC MOS                    | DVCC                        | –                                    |
| 47         | 39  | 30  | P2.1 (RD)                      | I/O                        | LVC MOS                    | DVCC                        | OFF                                  |
|            |     |     | XIN                            | I                          | LVC MOS                    | DVCC                        | –                                    |

**Table 7-1. Pin Attributes (continued)**

| PIN NUMBER |     |     | SIGNAL NAME <sup>(1) (2)</sup> | SIGNAL TYPE <sup>(3)</sup> | BUFFER TYPE <sup>(4)</sup> | POWER SOURCE <sup>(5)</sup> | RESET STATE AFTER BOR <sup>(6)</sup> |
|------------|-----|-----|--------------------------------|----------------------------|----------------------------|-----------------------------|--------------------------------------|
| PT         | RHA | RHB |                                |                            |                            |                             |                                      |
| 48         | 40  | 31  | DVSS                           | P                          | Power                      | DVCC                        | N/A                                  |

- (1) Signals names with (RD) denote the reset default pin name.
- (2) To determine the pin mux encodings for each pin, see [Section 9.11](#).
- (3) Signal types: I = input, O = output, I/O = input or output
- (4) Buffer types: LVCMOS, Analog, or Power (see [Table 7-3](#))
- (5) The power source shown in this table is the I/O power source, which may differ from the module power source.
- (6) Reset States:  
 OFF = High impedance with Schmitt trigger and pullup or pulldown (if available) disabled  
 PU = Pullup is enabled  
 PD = Pulldown is enabled  
 N/A = Not applicable

## 7.3 Signal Descriptions

Table 7-2 describes the signals for all device variants and package options.

**Table 7-2. Signal Descriptions**

| FUNCTION  | SIGNAL NAME | PIN NUMBER |     |     | PIN TYPE <sup>(1)</sup> | DESCRIPTION                                                       |
|-----------|-------------|------------|-----|-----|-------------------------|-------------------------------------------------------------------|
|           |             | PT         | RHA | RHB |                         |                                                                   |
| ADC       | A0          | 12         | 10  | 7   | I                       | Analog input A0                                                   |
|           | A1          | 13         | 11  | 8   | I                       | Analog input A1                                                   |
|           | A2          | 14         | 12  | 9   | I                       | Analog input A2                                                   |
|           | A3          | 15         | 13  | 10  | I                       | Analog input A3                                                   |
|           | A4          | 4          | 4   | 3   | I                       | Analog input A4                                                   |
|           | A5          | 5          | 5   | 4   | I                       | Analog input A5                                                   |
|           | A6          | 6          | 6   | 5   | I                       | Analog input A6                                                   |
|           | A7          | 7          | 7   | 6   | I                       | Analog input A7                                                   |
|           | A8          | 8          | 8   | –   | I                       | Analog input A8                                                   |
|           | A9          | 9          | 9   | –   | I                       | Analog input A9                                                   |
|           | A10         | 10         | –   | –   | I                       | Analog input A10                                                  |
|           | A11         | 11         | –   | –   | I                       | Analog input A11                                                  |
|           | Veref+      | 12         | 10  | 7   | I                       | ADC positive reference                                            |
|           | Veref-      | 14         | 12  | 9   | I                       | ADC negative reference                                            |
| eCOMP0    | COMP0.0     | 13         | 11  | 8   | I                       | Enhanced comparator input channel C0                              |
|           | COMP0.1     | 16         | 14  | 11  | I                       | Enhanced comparator input channel C1                              |
|           | COMP0.2     | 21         | –   | –   | I                       | Enhanced comparator input channel C2                              |
|           | COMP0.3     | 22         | –   | –   | I                       | Enhanced comparator input channel C3                              |
|           | COMP0OUT    | 26         | 20  | 15  | O                       | Enhanced comparator output channel COUT                           |
| CapTlvate | CAP0.0      | 23         | 17  | 12  | I/O                     | CapTlvate channel                                                 |
|           | CAP0.1      | 24         | 18  | 13  | I/O                     | CapTlvate channel                                                 |
|           | CAP0.2      | 25         | 19  | 14  | I/O                     | CapTlvate channel                                                 |
|           | CAP0.3      | 26         | 20  | 15  | I/O                     | CapTlvate channel                                                 |
|           | CAP1.0      | 27         | 21  | 16  | I/O                     | CapTlvate channel                                                 |
|           | CAP1.1      | 28         | 22  | 17  | I/O                     | CapTlvate channel                                                 |
|           | CAP1.2      | 29         | 23  | 18  | I/O                     | CapTlvate channel                                                 |
|           | CAP1.3      | 30         | 24  | 19  | I/O                     | CapTlvate channel                                                 |
|           | CAP2.0      | 32         | 26  | 21  | I/O                     | CapTlvate channel                                                 |
|           | CAP2.1      | 33         | 27  | 22  | I/O                     | CapTlvate channel                                                 |
|           | CAP2.2      | 34         | 28  | 23  | I/O                     | CapTlvate channel                                                 |
|           | CAP2.3      | 35         | 29  | 24  | I/O                     | CapTlvate channel                                                 |
|           | CAP3.0      | 36         | 30  | 25  | I/O                     | CapTlvate channel                                                 |
|           | CAP3.1      | 37         | 31  | 26  | I/O                     | CapTlvate channel                                                 |
|           | CAP3.2      | 38         | 32  | 27  | I/O                     | CapTlvate channel                                                 |
|           | CAP3.3      | 39         | 33  | 28  | I/O                     | CapTlvate channel                                                 |
|           | SYNC        | 16         | 14  | 11  | I                       | CapTlvate synchronous trigger input for processing and conversion |
| Clock     | ACLK        | 16         | 14  | 11  | I/O                     | ACLK output                                                       |
|           | MCLK        | 15         | 13  | 10  | O                       | MCLK output                                                       |
|           | SMCLK       | 7          | 7   | 6   | O                       | SMCLK output                                                      |
|           | XIN         | 47         | 39  | 30  | I                       | Input terminal for crystal oscillator                             |
|           | XOUT        | 46         | 38  | 29  | O                       | Output terminal for crystal oscillator                            |

**Table 7-2. Signal Descriptions (continued)**

| FUNCTION     | SIGNAL NAME | PIN NUMBER |     |     | PIN TYPE <sup>(1)</sup> | DESCRIPTION                                                                 |
|--------------|-------------|------------|-----|-----|-------------------------|-----------------------------------------------------------------------------|
|              |             | PT         | RHA | RHB |                         |                                                                             |
| Debug        | SBWTCK      | 3          | 3   | 2   | I                       | Spy-Bi-Wire input clock                                                     |
|              | SBWTDIO     | 2          | 2   | 1   | I/O                     | Spy-Bi-Wire data input/output                                               |
|              | TCK         | 4          | 4   | 3   | I                       | Test clock                                                                  |
|              | TCLK        | 6          | 6   | 5   | I                       | Test clock input                                                            |
|              | TDI         | 6          | 6   | 5   | I                       | Test data input                                                             |
|              | TDO         | 7          | 7   | 6   | O                       | Test data output                                                            |
|              | TEST        | 3          | 3   | 2   | I                       | Test Mode pin – selected digital I/O on JTAG pins                           |
|              | TMS         | 5          | 5   | 4   | I                       | Test mode select                                                            |
| GPIO, Port 1 | P1.0        | 12         | 10  | 7   | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5                |
|              | P1.1        | 13         | 11  | 8   | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5                |
|              | P1.2        | 14         | 12  | 9   | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5                |
|              | P1.3        | 15         | 13  | 10  | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5                |
|              | P1.4        | 4          | 4   | 3   | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5 <sup>(2)</sup> |
|              | P1.5        | 5          | 5   | 4   | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5 <sup>(2)</sup> |
|              | P1.6        | 6          | 6   | 5   | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5 <sup>(2)</sup> |
|              | P1.7        | 7          | 7   | 6   | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5 <sup>(2)</sup> |
| GPIO, Port 2 | P2.0        | 46         | 38  | 29  | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5                |
|              | P2.1        | 47         | 39  | 30  | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5                |
|              | P2.2        | 16         | 14  | 11  | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5                |
|              | P2.3        | 25         | 19  | 14  | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5                |
|              | P2.4        | 28         | 22  | 17  | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5                |
|              | P2.5        | 29         | 23  | 18  | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5                |
|              | P2.6        | 30         | 24  | 19  | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5                |
|              | P2.7        | 36         | 30  | 25  | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5                |
| GPIO, Port 3 | P3.0        | 23         | 17  | 12  | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5                |
|              | P3.1        | 27         | 21  | 16  | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5                |
|              | P3.2        | 38         | 32  | 27  | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5                |
|              | P3.3        | 24         | 18  | 13  | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5                |
|              | P3.4        | 26         | 20  | 15  | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5                |
|              | P3.5        | 37         | 31  | 26  | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5                |
|              | P3.6        | 39         | 33  | 28  | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5                |
|              | P3.7        | 32         | 26  | 21  | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5                |
| GPIO, Port 4 | P4.0        | 33         | 27  | 22  | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5                |
|              | P4.1        | 34         | 28  | 23  | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5                |
|              | P4.2        | 35         | 29  | 24  | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5                |
|              | P4.3        | 8          | 8   | –   | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5                |
|              | P4.4        | 9          | 9   | –   | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5                |
|              | P4.5        | 17         | 15  | –   | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5                |
|              | P4.6        | 18         | 16  | –   | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5                |
|              | P4.7        | 42         | 34  | –   | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5                |

Table 7-2. Signal Descriptions (continued)

| FUNCTION         | SIGNAL NAME            | PIN NUMBER |     |     | PIN TYPE <sup>(1)</sup> | DESCRIPTION                                                   |
|------------------|------------------------|------------|-----|-----|-------------------------|---------------------------------------------------------------|
|                  |                        | PT         | RHA | RHB |                         |                                                               |
| GPIO, Port 5     | P5.0                   | 43         | 35  | –   | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5  |
|                  | P5.1                   | 44         | 36  | –   | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5  |
|                  | P5.2                   | 45         | 37  | –   | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5  |
|                  | P5.3                   | 10         | –   | –   | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5  |
|                  | P5.4                   | 11         | –   | –   | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5  |
|                  | P5.5                   | 19         | –   | –   | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5  |
|                  | P5.6                   | 20         | –   | –   | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5  |
|                  | P5.7                   | 21         | –   | –   | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5  |
| GPIO, Port 6     | P6.0                   | 22         | –   | –   | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5  |
|                  | P6.1                   | 40         | –   | –   | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5  |
|                  | P6.2                   | 41         | –   | –   | I/O                     | General-purpose I/O with port interrupt and wake from LPMx.5  |
| I <sup>2</sup> C | UCB0SCL <sup>(3)</sup> | 15         | 13  | 10  | I/O                     | eUSCI_B0 I <sup>2</sup> C clock                               |
|                  | UCB0SDA <sup>(3)</sup> | 14         | 12  | 9   | I/O                     | eUSCI_B0 I <sup>2</sup> C data                                |
|                  | UCB0SCL <sup>(4)</sup> | 17         | 15  | –   | I/O                     | eUSCI_B0 I <sup>2</sup> C clock                               |
|                  | UCB0SDA <sup>(4)</sup> | 18         | 16  | –   | I/O                     | eUSCI_B0 I <sup>2</sup> C data                                |
|                  | UCB1SCL <sup>(3)</sup> | 39         | 33  | 28  | I/O                     | eUSCI_B1 I <sup>2</sup> C clock                               |
|                  | UCB1SDA <sup>(3)</sup> | 38         | 32  | 27  | I/O                     | eUSCI_B1 I <sup>2</sup> C data                                |
|                  | UCB1SCL <sup>(4)</sup> | 8          | 8   | –   | I/O                     | eUSCI_B1 I <sup>2</sup> C clock                               |
|                  | UCB1SDA <sup>(4)</sup> | 9          | 9   | –   | I/O                     | eUSCI_B1 I <sup>2</sup> C data                                |
| Power            | DVCC                   | 1          | 1   | 32  | P                       | Power supply                                                  |
|                  | DVSS                   | 48         | 40  | 31  | P                       | Power ground                                                  |
|                  | VREF+                  | 4          | 4   | 3   | P                       | Output of positive reference voltage with ground as reference |
|                  | VREG                   | 31         | 25  | 20  | O                       | CapTIvate regulator external decoupling capacitor             |

**Table 7-2. Signal Descriptions (continued)**

| FUNCTION | SIGNAL NAME             | PIN NUMBER |     |     | PIN TYPE <sup>(1)</sup> | DESCRIPTION                        |
|----------|-------------------------|------------|-----|-----|-------------------------|------------------------------------|
|          |                         | PT         | RHA | RHB |                         |                                    |
| SPI      | UCA0STE <sup>(3)</sup>  | 7          | 7   | 6   | I/O                     | eUSCI_A0 SPI slave transmit enable |
|          | UCA0CLK <sup>(3)</sup>  | 6          | 6   | 5   | I/O                     | eUSCI_A0 SPI clock input/output    |
|          | UCA0SOMI <sup>(3)</sup> | 5          | 5   | 4   | I/O                     | eUSCI_A0 SPI slave out/master in   |
|          | UCA0SIMO <sup>(3)</sup> | 4          | 4   | 3   | I/O                     | eUSCI_A0 SPI slave in/master out   |
|          | UCA0STE <sup>(4)</sup>  | 42         | 34  | –   | I/O                     | eUSCI_A0 SPI slave transmit enable |
|          | UCA0CLK <sup>(4)</sup>  | 43         | 35  | –   | I/O                     | eUSCI_A0 SPI clock input/output    |
|          | UCA0SOMI <sup>(4)</sup> | 44         | 36  | –   | I/O                     | eUSCI_A0 SPI slave out/master in   |
|          | UCA0SIMO <sup>(4)</sup> | 45         | 37  | –   | I/O                     | eUSCI_A0 SPI slave in/master out   |
|          | UCA1STE                 | 27         | 21  | 16  | I/O                     | eUSCI_A1 SPI slave transmit enable |
|          | UCA1CLK                 | 28         | 22  | 17  | I/O                     | eUSCI_A1 SPI clock input/output    |
|          | UCA1SOMI                | 29         | 23  | 18  | I/O                     | eUSCI_A1 SPI slave out/master in   |
|          | UCA1SIMO                | 30         | 24  | 19  | I/O                     | eUSCI_A1 SPI slave in/master out   |
|          | UCB0STE <sup>(3)</sup>  | 12         | 10  | 7   | I/O                     | eUSCI_B0 slave transmit enable     |
|          | UCB0CLK <sup>(3)</sup>  | 13         | 11  | 8   | I/O                     | eUSCI_B0 clock input/output        |
|          | UCB0SOMI <sup>(3)</sup> | 15         | 13  | 10  | I/O                     | eUSCI_B0 SPI slave out/master in   |
|          | UCB0SIMO <sup>(3)</sup> | 14         | 12  | 9   | I/O                     | eUSCI_B0 SPI slave in/master out   |
|          | UCB0STE <sup>(4)</sup>  | 20         | –   | –   | I/O                     | eUSCI_B0 slave transmit enable     |
|          | UCB0CLK <sup>(4)</sup>  | 19         | –   | –   | I/O                     | eUSCI_B0 clock input/output        |
|          | UCB0SOMI <sup>(4)</sup> | 17         | –   | –   | I/O                     | eUSCI_B0 SPI slave out/master in   |
|          | UCB0SIMO <sup>(4)</sup> | 18         | –   | –   | I/O                     | eUSCI_B0 SPI slave in/master out   |
|          | UCB1STE <sup>(3)</sup>  | 36         | 30  | 25  | I/O                     | eUSCI_B1 slave transmit enable     |
|          | UCB1CLK <sup>(3)</sup>  | 37         | 31  | 26  | I/O                     | eUSCI_B1 clock input/output        |
|          | UCB1SOMI <sup>(3)</sup> | 39         | 33  | 28  | I/O                     | eUSCI_B1 SPI slave out/master in   |
|          | UCB1SIMO <sup>(3)</sup> | 38         | 32  | 27  | I/O                     | eUSCI_B1 SPI slave in/master out   |
|          | UCB1STE <sup>(4)</sup>  | 11         | –   | –   | I/O                     | eUSCI_B1 slave transmit enable     |
|          | UCB1CLK <sup>(4)</sup>  | 10         | –   | –   | I/O                     | eUSCI_B1 clock input/output        |
|          | UCB1SOMI <sup>(4)</sup> | 8          | –   | –   | I/O                     | eUSCI_B1 SPI slave out/master in   |
|          | UCB1SIMO <sup>(4)</sup> | 9          | –   | –   | I/O                     | eUSCI_B1 SPI slave in/master out   |
| System   | NMI                     | 2          | 2   | 1   | I                       | Nonmaskable interrupt input        |
|          | RST                     | 2          | 2   | 1   | I                       | Active-low reset input             |

Table 7-2. Signal Descriptions (continued)

| FUNCTION | SIGNAL NAME            | PIN NUMBER |     |     | PIN TYPE <sup>(1)</sup> | DESCRIPTION                                                                   |
|----------|------------------------|------------|-----|-----|-------------------------|-------------------------------------------------------------------------------|
|          |                        | PT         | RHA | RHB |                         |                                                                               |
| Timer_A  | TA0.1                  | 13         | 11  | 8   | I/O                     | Timer TA0 CCR1 capture: CCI1A input, compare: Out1 outputs                    |
|          | TA0.2                  | 14         | 12  | 9   | I/O                     | Timer TA0 CCR2 capture: CCI2A input, compare: Out2 outputs                    |
|          | TA0CLK                 | 12         | 10  | 7   | I                       | Timer clock input TACLK for TA0                                               |
|          | TA1.1                  | 5          | 5   | 4   | I/O                     | Timer TA1 CCR1 capture: CCI1A input, compare: Out1 outputs                    |
|          | TA1.2                  | 4          | 4   | 3   | I/O                     | Timer TA1 CCR2 capture: CCI2A input, compare: Out2 outputs                    |
|          | TA1CLK                 | 6          | 6   | 5   | I                       | Timer clock input TACLK for TA1                                               |
|          | TA2.0 <sup>(5)</sup>   | 25         | 19  | 14  | I/O                     | Timer TA2 CCR0 capture: CCI0A input, compare: Out0 outputs                    |
|          | TA2.1 <sup>(5)</sup>   | 24         | 18  | 13  | I/O                     | Timer TA2 CCR1 capture: CCI1A input, compare: Out1 outputs                    |
|          | TA2.2 <sup>(5)</sup>   | 23         | 17  | 12  | I/O                     | Timer TA2 CCR2 capture: CCI2A input, compare: Out2 outputs                    |
|          | TA2CLK <sup>(5)</sup>  | 26         | 20  | 15  | I                       | Timer clock input TACLK for TA2                                               |
|          | TA2.0 <sup>(6)</sup>   | 20         | –   | –   | I/O                     | Timer TA2 CCR0 capture: CCI0A input, compare: Out0 outputs                    |
|          | TA2.1 <sup>(6)</sup>   | 21         | –   | –   | I/O                     | Timer TA2 CCR1 capture: CCI1A input, compare: Out1 outputs                    |
|          | TA2.2 <sup>(6)</sup>   | 22         | –   | –   | I/O                     | Timer TA2 CCR2 capture: CCI2A input, compare: Out2 outputs                    |
|          | TA2CLK <sup>(6)</sup>  | 19         | –   | –   | I                       | Timer clock input TACLK for TA2                                               |
|          | TA3.0 <sup>(5)</sup>   | 34         | 28  | 23  | I/O                     | Timer TA3 CCR0 capture: CCI0A input, compare: Out0 outputs                    |
|          | TA3.1 <sup>(5)</sup>   | 33         | 27  | 22  | I/O                     | Timer TA3 CCR1 capture: CCI1A input, compare: Out1 outputs                    |
|          | TA3.2 <sup>(5)</sup>   | 32         | 26  | 21  | I/O                     | Timer TA3 CCR2 capture: CCI2A input, compare: Out2 outputs                    |
|          | TA3CLK <sup>(5)</sup>  | 35         | 29  | 24  | I                       | Timer clock input TACLK for TA3                                               |
|          | TA3.0 <sup>(6)</sup>   | 10         | –   | –   | I/O                     | Timer TA3 CCR0 capture: CCI0A input, compare: Out0 outputs                    |
|          | TA3.1 <sup>(6)</sup>   | 18         | 16  | –   | I/O                     | Timer TA3 CCR1 capture: CCI1A input, compare: Out1 outputs                    |
|          | TA3.2 <sup>(6)</sup>   | 17         | 15  | –   | I/O                     | Timer TA3 CCR2 capture: CCI2A input, compare: Out2 outputs                    |
|          | TA3CLK <sup>(6)</sup>  | 11         | –   | –   | I                       | Timer clock input TACLK for TA3                                               |
| Timer_B  | TB0.0                  | 41         | –   | –   | I/O                     | Timer TB0 CCR0 capture: CCI0A input, compare: Out0 outputs                    |
|          | TB0.1                  | 42         | 34  | –   | I/O                     | Timer TB0 CCR1 capture: CCI1A input, compare: Out1 outputs                    |
|          | TB0.2                  | 43         | 35  | –   | I/O                     | Timer TB0 CCR2 capture: CCI2A input, compare: Out2 outputs                    |
|          | TB0.3                  | 44         | 36  | –   | I/O                     | Timer TB0 CCR3 capture: CCI3A input, compare: Out3 outputs                    |
|          | TB0.4                  | 45         | 37  | –   | I/O                     | Timer TB0 CCR4 capture: CCI4A input, compare: Out4 outputs                    |
|          | TB0.5                  | 8          | 8   | –   | I/O                     | Timer TB0 CCR5 capture: CCI5A input, compare: Out5 outputs                    |
|          | TB0.6                  | 9          | 9   | –   | I/O                     | Timer TB0 CCR6 capture: CCI6A input, compare: Out6 outputs                    |
|          | TB0CLK                 | 40         | –   | –   | I                       | Timer clock input TBCLK for TB0                                               |
|          | TB0TRG                 | 37         | 31  | 26  |                         | Timer TB0 external trigger input for TB0OUTH                                  |
| UART     | UCA0RXD                | 5          | 5   | 4   | I                       | eUSCI_A0 UART receive data                                                    |
|          | UCA0TXD                | 4          | 4   | 3   | O                       | eUSCI_A0 UART transmit data                                                   |
|          | UCA0RXD <sup>(3)</sup> | 44         | 36  | –   | I                       | eUSCI_A0 UART receive data                                                    |
|          | UCA0TXD <sup>(3)</sup> | 45         | 37  | –   | O                       | eUSCI_A0 UART transmit data                                                   |
|          | UCA1RXD <sup>(4)</sup> | 29         | 23  | 18  | I                       | eUSCI_A1 UART receive data                                                    |
|          | UCA1TXD <sup>(4)</sup> | 30         | 24  | 19  | O                       | eUSCI_A1 UART transmit data                                                   |
| VQFN pad | VQFN thermal pad       | –          | PAD | PAD | –                       | VQFN package exposed thermal pad. TI recommends connecting to V <sub>SS</sub> |

(1) Pin Types: I = Input, O = Output, I/O = Input or Output, P = Power

(2) Because this pin is multiplexed with the JTAG function, TI recommends disabling the pin interrupt function while in JTAG debug to prevent collisions.

(3) This is the default functionality that can be remapped by the USCIBxRMP or USCIA0RMP bit of the SYSCFG2 or SYSCFG3 register. Only one selected port is valid at any time.

- (4) This is the remapped functionality controlled by the USCIBxRMP or USCIA0RMP bit of the SYSCFG2 or SYSCFG3 register. Only one selected port is valid at any time.
- (5) This is the default functionality that can be remapped by the TAxRMP bit of the SYSCFG3 register. Only one selected port is valid at any time.
- (6) This is the remapped functionality controlled by the TAxRMP bit of the SYSCFG3 register. Only one selected port is valid at any time.

## 7.4 Pin Multiplexing

Pin multiplexing for this MCU is controlled by both register settings and operating modes (for example, if the MCU is in test mode). For details of the settings for each pin and diagrams of the multiplexed ports, see [Section 9.11](#).

## 7.5 Buffer Types

[Table 7-3](#) defines the pin buffer types that are listed in [Table 7-1](#)

**Table 7-3. Buffer Types**

| BUFFER TYPE (STANDARD) | NOMINAL VOLTAGE | HYSTERESIS       | PU OR PD     | NOMINAL PU OR PD STRENGTH ( $\mu$ A) | OUTPUT DRIVE STRENGTH (mA)         | OTHER CHARACTERISTICS                                        |
|------------------------|-----------------|------------------|--------------|--------------------------------------|------------------------------------|--------------------------------------------------------------|
| LVC MOS                | 3.0 V           | Y <sup>(1)</sup> | Programmable | See <a href="#">Section 8.12.4</a>   | See <a href="#">Section 8.12.4</a> |                                                              |
| Analog                 | 3.0 V           | N                | N/A          | N/A                                  | N/A                                | See analog modules in <a href="#">Section 8</a> for details. |
| Power (DVCC)           | 3.0 V           | N                | N/A          | N/A                                  | N/A                                | SVS enables hysteresis on DVCC.                              |
| Power (AVCC)           | 3.0 V           | N                | N/A          | N/A                                  | N/A                                |                                                              |

- (1) Only for input pins.

## 7.6 Connection of Unused Pins

[Table 7-4](#) lists the correct termination of unused pins.

**Table 7-4. Connection of Unused Pins**

| PIN <sup>(1)</sup> | POTENTIAL        | COMMENT                                                                                         |
|--------------------|------------------|-------------------------------------------------------------------------------------------------|
| Px.0 to Px.7       | Open             | Switched to port function, output direction (PxDIR.n = 1)                                       |
| RST/NMI            | DV <sub>CC</sub> | 47-k $\Omega$ pullup or internal pullup selected with 10-nF (or 1.1-nF) pulldown <sup>(2)</sup> |
| TEST               | Open             | This pin always has an internal pulldown enabled.                                               |

- (1) Any unused pin with a secondary function that is shared with general-purpose I/O should follow the Px.0 to Px.7 unused pin connection guidelines.
- (2) The pulldown capacitor should not exceed 1.1 nF when using MCUs with Spy-Bi-Wire interface in Spy-Bi-Wire mode with TI tools like FET interfaces or GANG programmers.

## 8 Specifications

### 8.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)<sup>(1)</sup>

|                                                             | MIN  | MAX                                  | UNIT |
|-------------------------------------------------------------|------|--------------------------------------|------|
| Voltage applied at DVCC pin to V <sub>SS</sub>              | −0.3 | 4.1                                  | V    |
| Voltage applied to any pin in CapTivate mode <sup>(2)</sup> | −0.3 | V <sub>REG</sub>                     | V    |
| Voltage applied to any other pin <sup>(3)</sup>             | −0.3 | V <sub>CC</sub> + 0.3<br>(4.1 V Max) | V    |
| Diode current at any device pin                             |      | ±2                                   | mA   |
| Junction temperature, T <sub>J</sub>                        |      | 115                                  | °C   |
| Storage temperature, T <sub>stg</sub> <sup>(4)</sup>        | −40  | 125                                  | °C   |

- (1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) This applies I/Os worked in CapTivate mode.
- (3) All voltages referenced to V<sub>SS</sub>.
- (4) Higher temperature may be applied during board soldering according to the current JEDEC J-STD-020 specification with peak reflow temperatures not higher than classified on the device label on the shipping boxes or reels.

### 8.2 ESD Ratings

|                                            | VALUE                                                                          | UNIT  |
|--------------------------------------------|--------------------------------------------------------------------------------|-------|
| V <sub>(ESD)</sub> Electrostatic discharge | Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>              | ±1000 |
|                                            | Charged-device model (CDM), per JEDEC specification JESD22-C101 <sup>(2)</sup> | ±250  |
|                                            |                                                                                | V     |

- (1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process. Pins listed as ±1000 V may actually have higher performance.
- (2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process. Pins listed as ±250 V may actually have higher performance.

### 8.3 Recommended Operating Conditions

|                                                                             | MIN                                                                  | NOM | MAX               | UNIT |
|-----------------------------------------------------------------------------|----------------------------------------------------------------------|-----|-------------------|------|
| V <sub>CC</sub> Supply voltage applied at DVCC pin <sup>(1) (2)</sup>       | 1.8 <sup>(5)</sup>                                                   |     | 3.6               | V    |
|                                                                             | CapTivate in VREG electrode charge mode (default) <sup>(3) (4)</sup> |     | 3.6               |      |
|                                                                             | CapTivate in DVCC electrode charge mode <sup>(4)</sup>               | 2.7 |                   |      |
| V <sub>SS</sub> Supply voltage applied at DVSS pin                          |                                                                      | 0   |                   | V    |
| T <sub>A</sub> Operating free-air temperature                               | −40                                                                  |     | 105               | °C   |
| T <sub>J</sub> Operating junction temperature                               | −40                                                                  |     | 115               | °C   |
| C <sub>DVCC</sub> Recommended capacitor at DVCC <sup>(6)</sup>              | 4.7                                                                  | 10  |                   | μF   |
| f <sub>SYSTEM</sub> Processor frequency (MCLK frequency) <sup>(5) (7)</sup> | No FRAM wait states (NWAITSx = 0)                                    | 0   | 8                 | MHz  |
|                                                                             | With FRAM wait states (NWAITSx = 1) <sup>(8)</sup>                   | 0   | 16 <sup>(9)</sup> |      |
| f <sub>ACLK</sub> ACLK frequency                                            |                                                                      |     | 40                | kHz  |
| f <sub>SMCLK</sub> SMCLK frequency                                          |                                                                      |     | 16 <sup>(9)</sup> | MHz  |

- (1) Supply voltage changes faster than 0.2 V/μs can trigger a BOR reset even within the recommended supply voltage range. Following the data sheet recommendation for capacitor C<sub>DVCC</sub> limits the slopes accordingly.
- (2) TI recommends that power to the DVCC pin must not exceed the limits specified in *Recommended Operating Conditions*. Exceeding the specified limits can cause malfunction of the device including erroneous writes to RAM and FRAM.
- (3) Modules may have a different supply voltage range specification. See the specification of the respective module in this data sheet.
- (4) CapTivate electrode charge mode is selectable from within the CapTivate Design Center GUI and the CapTivate Software Library. The default operating mode is VREG..
- (5) The minimum supply voltage is defined by the SVS levels. Refer to the SVS threshold parameters in [Section 8.12.1.1](#).
- (6) A capacitor tolerance of ±20% or better is required. A low-ESR ceramic capacitor of 100 nF (minimum) should be placed as close as possible (within a few millimeters) to the respective pin pair.
- (7) Modules may have a different maximum input clock specification. See the specification of the respective module in this data sheet.
- (8) Wait states only occur on actual FRAM accesses (that is, on FRAM cache misses). RAM and peripheral accesses are always executed without wait states.

- (9) If clock sources such as HF crystals or the DCO with frequencies >16 MHz are used, the clock must be divided in the clock system to comply with this operating condition.

## 8.4 Active Mode Supply Current Into $V_{CC}$ Excluding External Current

See (1)

| PARAMETER                           | EXECUTION MEMORY             | TEST CONDITION | FREQUENCY (f <sub>MCLK</sub> = f <sub>SMCLK</sub> ) |     |                                         |     |                                         |     | UNIT |
|-------------------------------------|------------------------------|----------------|-----------------------------------------------------|-----|-----------------------------------------|-----|-----------------------------------------|-----|------|
|                                     |                              |                | 1 MHz<br>0 WAIT STATES<br>(NWAITSx = 0)             |     | 8 MHz<br>0 WAIT STATES<br>(NWAITSx = 0) |     | 16 MHz<br>1 WAIT STATE<br>(NWAITSx = 1) |     |      |
|                                     |                              |                | TYP                                                 | MAX | TYP                                     | MAX | TYP                                     | MAX |      |
| I <sub>AM, FRAM</sub> (0%)          | FRAM<br>0% cache hit ratio   | 3 V, 25°C      | 567                                                 |     | 3208                                    |     | 3472                                    |     | μA   |
|                                     |                              | 3 V, 85°C      | 578                                                 |     | 3226                                    |     | 3471                                    |     |      |
|                                     |                              | 3 V, 105°C     | 593                                                 |     | 3249                                    |     | 3496    3750                            |     |      |
| I <sub>AM, FRAM</sub> (75%)         | FRAM<br>75% cache hit ratio  | 3 V, 25°C      | 324                                                 |     | 1272                                    |     | 2022                                    |     | μA   |
|                                     |                              | 3 V, 85°C      | 340                                                 |     | 1304                                    |     | 2065                                    |     |      |
|                                     |                              | 3 V, 105°C     | 354                                                 |     | 1321                                    |     | 2085                                    |     |      |
| I <sub>AM, FRAM</sub> (100%)        | FRAM<br>100% cache hit ratio | 3 V, 25°C      | 241                                                 |     | 604                                     |     | 1016                                    |     | μA   |
|                                     |                              | 3 V, 85°C      | 255                                                 |     | 624                                     |     | 1041                                    |     |      |
|                                     |                              | 3 V, 105°C     | 270                                                 |     | 641                                     |     | 1060    1150                            |     |      |
| I <sub>AM, RAM</sub> <sup>(2)</sup> | RAM                          | 3 V, 25°C      | 268                                                 |     | 821                                     |     | 1446                                    |     | μA   |

- (1) All inputs are tied to 0 V or to  $V_{CC}$ . Outputs do not source or sink any current. Characterized with program executing typical data processing.  
 $f_{ACLK} = 32768$  Hz,  $f_{MCLK} = f_{SMCLK} = f_{DCO}$  at specified frequency  
 Program and data entirely reside in FRAM. All execution is from FRAM.
- (2) Program and data reside entirely in RAM. All execution is from RAM. No access to FRAM.

## 8.5 Active Mode Supply Current Per MHz

$V_{CC} = 3$  V,  $T_A = 25^\circ C$  (unless otherwise noted)

| PARAMETER          | TEST CONDITIONS                                                                                                                                                                                                                   | TYP | UNIT        |
|--------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|-------------|
| $dI_{AM, FRAM}/df$ | Active mode current consumption per MHz, execution from FRAM, no wait states<br>$[I_{AM}(75\% \text{ cache hit rate}) \text{ at } 8 \text{ MHz} - I_{AM}(75\% \text{ cache hit rate}) \text{ at } 1 \text{ MHz}] / 7 \text{ MHz}$ | 135 | $\mu A/MHz$ |

## 8.6 Low-Power Mode LPM0 Supply Currents Into $V_{CC}$ Excluding External Current

$V_{CC} = 3$  V,  $T_A = 25^\circ C$  (unless otherwise noted) (1) (2)

| PARAMETER         | V <sub>CC</sub> | FREQUENCY (f <sub>SMCLK</sub> ) |     |       |     |        |     | UNIT |
|-------------------|-----------------|---------------------------------|-----|-------|-----|--------|-----|------|
|                   |                 | 1 MHz                           |     | 8 MHz |     | 16 MHz |     |      |
|                   |                 | TYP                             | MAX | TYP   | MAX | TYP    | MAX |      |
| I <sub>LPM0</sub> | 2 V             | 204                             |     | 312   |     | 437    |     | μA   |
|                   | 3 V             | 215                             |     | 325   |     | 450    |     |      |

- (1) All inputs are tied to 0 V or to  $V_{CC}$ . Outputs do not source or sink any current.
- (2) Current for watchdog timer clocked by SMCLK included.  
 $f_{ACLK} = 32768$  Hz,  $f_{MCLK} = 0$  MHz,  $f_{SMCLK}$  at specified frequency.

## 8.7 Low-Power Mode (LPM3, LPM4) Supply Currents (Into $V_{CC}$ ) Excluding External Current

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted) <sup>(1)</sup>

| PARAMETER                                               |                                                                        | $V_{CC}$ | –40°C |     | 25°C  |     | 85°C |     | 105°C |      | UNIT    |
|---------------------------------------------------------|------------------------------------------------------------------------|----------|-------|-----|-------|-----|------|-----|-------|------|---------|
|                                                         |                                                                        |          | TYP   | MAX | TYP   | MAX | TYP  | MAX | TYP   | MAX  |         |
| $I_{LPM3,XT1}$                                          | Low-power mode 3, 12.5-pF crystal, includes SVS <sup>(2) (3) (4)</sup> | 3 V      | 1.2   |     | 1.48  |     | 7.82 |     | 17.12 | 46   | $\mu A$ |
|                                                         |                                                                        | 2 V      | 1.17  |     | 1.46  |     | 7.75 |     | 16.99 |      |         |
| $I_{LPM3, REFO}$                                        | Low-power mode 3, RTC, excludes SVS <sup>(10)</sup>                    | 3 V      | 1.87  |     | 2.20  |     | 8.53 |     | 17.76 |      | $\mu A$ |
|                                                         |                                                                        | 2 V      | 1.85  |     | 2.18  |     | 8.47 |     | 17.65 |      |         |
| $I_{LPM3,VLO}$                                          | Low-power mode 3, VLO, excludes SVS <sup>(5)</sup>                     | 3 V      | 0.92  |     | 1.20  |     | 7.54 |     | 16.83 | 45.8 | $\mu A$ |
|                                                         |                                                                        | 2 V      | 0.90  |     | 1.17  |     | 7.47 |     | 16.70 |      |         |
| $I_{LPM3, RTC}$                                         | Low-power mode 3, RTC, excludes SVS <sup>(9)</sup>                     | 3 V      | 0.99  |     | 1.27  |     | 7.6  |     | 16.9  |      | $\mu A$ |
|                                                         |                                                                        | 2 V      | 0.97  |     | 1.24  |     | 7.53 |     | 16.77 |      |         |
| $I_{LPM3, CapTivate, 1 proximity, wake on touch, XT1}$  | Low-power mode 3, CapTivate, excludes SVS <sup>(11)</sup>              | 3 V      |       |     | 6.1   |     |      |     |       |      | $\mu A$ |
| $I_{LPM3, CapTivate, 1 proximity, wake on touch, REFO}$ | Low-power mode 3, CapTivate, excludes SVS <sup>(11)</sup>              | 3 V      |       |     | 6.9   |     |      |     |       |      | $\mu A$ |
| $I_{LPM3, CapTivate, 1 button, wake on touch, XT1}$     | Low-power mode 3, CapTivate, excludes SVS <sup>(12)</sup>              | 3 V      |       |     | 4.0   |     |      |     |       |      | $\mu A$ |
| $I_{LPM3, CapTivate, 1 button, wake on touch, REFO}$    | Low-power mode 3, CapTivate, excludes SVS <sup>(12)</sup>              | 3 V      |       |     | 4.8   |     |      |     |       |      | $\mu A$ |
| $I_{LPM3, CapTivate, 4 buttons, wake on touch, XT1}$    | Low-power mode 3, CapTivate, excludes SVS <sup>(13)</sup>              | 3 V      |       |     | 4.6   |     |      |     |       |      | $\mu A$ |
| $I_{LPM3, CapTivate, 4 buttons, wake on touch, REFO}$   | Low-power mode 3, CapTivate, excludes SVS <sup>(13)</sup>              | 3 V      |       |     | 5.4   |     |      |     |       |      | $\mu A$ |
| $I_{LPM3, CapTivate, 16 buttons, XT1}$                  | Low-power mode 3, CapTivate, excludes SVS <sup>(14)</sup>              | 3 V      |       |     | 33.8  |     |      |     |       |      | $\mu A$ |
| $I_{LPM3, CapTivate, 16 buttons, REFO}$                 | Low-power mode 3, CapTivate, excludes SVS <sup>(14)</sup>              | 3 V      |       |     | 34.2  |     |      |     |       |      | $\mu A$ |
| $I_{LPM3, CapTivate, 64 buttons, XT1}$                  | Low-power mode 3, CapTivate, excludes SVS <sup>(15)</sup>              | 3 V      |       |     | 145.2 |     |      |     |       |      | $\mu A$ |
| $I_{LPM3, CapTivate, 64 buttons, REFO}$                 | Low-power mode 3, CapTivate, excludes SVS <sup>(15)</sup>              | 3 V      |       |     | 144.7 |     |      |     |       |      | $\mu A$ |
| $I_{LPM4, SVS}$                                         | Low-power mode 4, includes SVS <sup>(6)</sup>                          | 3 V      | 0.65  |     | 0.90  |     | 7.19 |     | 16.41 |      | $\mu A$ |
|                                                         |                                                                        | 2 V      | 0.64  |     | 0.89  |     | 7.13 |     | 16.30 |      |         |
| $I_{LPM4}$                                              | Low-power mode 4, excludes SVS <sup>(6)</sup>                          | 3 V      | 0.50  |     | 0.74  |     | 7.02 |     | 16.24 |      | $\mu A$ |
|                                                         |                                                                        | 2 V      | 0.49  |     | 0.73  |     | 6.96 |     | 16.13 |      |         |
| $I_{LPM4,VLO}$                                          | Low-power mode 4, RTC is sourced from VLO, excludes SVS <sup>(7)</sup> | 3 V      | 0.59  |     | 0.83  |     | 7.12 |     | 16.35 |      | $\mu A$ |
|                                                         |                                                                        | 2 V      | 0.58  |     | 0.82  |     | 7.06 |     | 16.24 |      |         |
| $I_{LPM4,XT1}$                                          | Low-power mode 4, RTC is sourced from XT1, excludes SVS <sup>(8)</sup> | 3 V      | 0.92  |     | 1.2   |     | 7.54 |     | 16.84 |      | $\mu A$ |
|                                                         |                                                                        | 2 V      | 0.90  |     | 1.18  |     | 7.47 |     | 16.70 |      |         |
| $I_{LPM4, CapTivate, 1 proximity, wake on touch}$       | Low-power mode 4, CapTivate, excludes SVS <sup>(16)</sup>              | 3 V      |       |     | 5.5   |     |      |     |       |      | $\mu A$ |
| $I_{LPM4, CapTivate, 1 button, wake on touch}$          | Low-power mode 4, CapTivate, excludes SVS <sup>(16)</sup>              | 3 V      |       |     | 3.4   |     |      |     |       |      | $\mu A$ |

## 8.7 Low-Power Mode (LPM3, LPM4) Supply Currents (Into $V_{CC}$ ) Excluding External Current (continued)

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted) <sup>(1)</sup>

| PARAMETER                                                                                                     | $V_{CC}$ | -40°C |     | 25°C |     | 85°C |     | 105°C |     | UNIT    |
|---------------------------------------------------------------------------------------------------------------|----------|-------|-----|------|-----|------|-----|-------|-----|---------|
|                                                                                                               |          | TYP   | MAX | TYP  | MAX | TYP  | MAX | TYP   | MAX |         |
| $I_{LPM4}$ , CapTIvate, 4 buttons, wake on touch<br>Low-power mode 4, CapTIvate, excludes SVS <sup>(17)</sup> | 3 V      |       |     | 3.8  |     |      |     |       |     | $\mu A$ |

- (1) All inputs are tied to 0 V or to  $V_{CC}$ . Outputs do not source or sink any current.
- (2) Not applicable for MCUs with HF crystal oscillator only.
- (3) Characterized with a Seiko Crystal SC-32S MS1V-T1K crystal with a load capacitance of 12.5 pF. The internal and external load capacitance are chosen to closely match the required 12.5-pF load.
- (4) Low-power mode 3, 12.5-pF crystal, includes SVS test conditions:  
Current for watchdog timer clocked by ACLK and RTC clocked by XT1 included. Current for brownout and SVS included (SVSHE = 1).  
CPUOFF = 1, SCG0 = 1 SCG1 = 1, OSCOFF = 0 (LPM3),  
 $f_{XT1} = 32768$  Hz,  $f_{ACLK} = f_{XT1}$ ,  $f_{MCLK} = f_{SMCLK} = 0$  MHz
- (5) Low-power mode 3, VLO, excludes SVS test conditions:  
Current for watchdog timer clocked by VLO included. RTC disabled. Current for brownout included. SVS disabled (SVSHE = 0).  
CPUOFF = 1, SCG0 = 1 SCG1 = 1, OSCOFF = 0 (LPM3)  
 $f_{XT1} = 32768$  Hz,  $f_{ACLK} = f_{MCLK} = f_{SMCLK} = 0$  MHz
- (6) Low-power mode 4, CPUOFF = 1, SCG0 = 1 SCG1 = 1, OSCOFF = 1 (LPM4), CPU and all clocks are disabled, WDT and RTC disabled
- (7) Low-power mode 4, VLO, excludes SVS test conditions:  
Current for RTC clocked by VLO included. Current for brownout included. SVS disabled (SVSHE = 0).  
CPUOFF = 1, SCG0 = 1 SCG1 = 1, OSCOFF = 1 (LPM4)  
 $f_{XT1} = 0$  Hz,  $f_{MCLK} = f_{SMCLK} = 0$  MHz
- (8) Low-power mode 4, XT1, excludes SVS test conditions:  
Current for RTC clocked by XT1 included. Current for brownout included. SVS disabled (SVSHE = 0).  
CPUOFF = 1, SCG0 = 1 SCG1 = 1, OSCOFF = 1 (LPM4)  
 $f_{XT1} = 32768$  Hz,  $f_{MCLK} = f_{SMCLK} = 0$  MHz
- (9) RTC periodically wakes up every second with external 32768-Hz input as source.
- (10) RTC periodically wakes up every second with internal REFO 32768-Hz input as source.
- (11) CapTIvate technology works in LPM3 with one proximity sensor for wake on touch. CapTIvate BSWP demo panel with 1.5-mm overlay. Current for brownout included. SVS disabled (SVSHE = 0),  
 $f_{SCAN} = 8$  Hz,  $f_{CONVER} = 2$  MHz, COUNTS = 800, see the specified clock source (XT1 or REFO) condition on each test item.
- (12) CapTIvate technology works in LPM3 with one button, wake on touch. CapTIvate BSWP demo panel with 1.5-mm overlay, Current for brownout included. SVS disabled (SVSHE = 0).  
 $f_{SCAN} = 8$  Hz,  $f_{CONVER} = 2$  MHz, COUNTS = 250, see the specified clock source (XT1 or REFO) condition on each test item.
- (13) CapTIvate technology works in LPM3 with four self-capacitance buttons, wake on touch. CapTIvate BSWP demo panel with 1.5-mm overlay. Current for brownout included. SVS disabled (SVSHE = 0).  
 $f_{SCAN} = 8$  Hz,  $f_{CONVER} = 2$  MHz, COUNTS = 250, see the specified clock source (XT1 or REFO) condition on each test item.
- (14) CapTIvate technology works in LPM3 with 16 self-capacitance buttons. The CPU enters active mode in between time cycles to configure the conversions and read the results. CapTIvate BSWP demo panel with 1.5-mm overlay. Current for brownout included. SVS disabled (SVSHE = 0).  
 $f_{SCAN} = 8$  Hz,  $f_{CONVER} = 2$  MHz, COUNTS = 250, see the specified clock source (XT1 or REFO) condition on each test item.
- (15) CapTIvate technology works in LPM3 with 64 mutual-capacitance buttons. The CPU enters active mode in between time cycles to configure the conversions and read the results. CapTIvate BSWP demo panel with 1.5-mm overlay. Current for brownout included. SVS disabled (SVSHE = 0).  
 $f_{SCAN} = 8$  Hz,  $f_{CONVER} = 4$  MHz, COUNTS = 250, see the specified clock source (XT1 or REFO) condition on each test item.
- (16) CapTIvate technology works in LPM4 with one button, wake on touch. CapTIvate BSWP demo panel with 1.5-mm overlay, Current for brownout included. SVS disabled (SVSHE = 0). VLO (10 kHz) sources to CapTIvate timer, no external crystal.  
 $f_{SCAN} = 8$  Hz,  $f_{CONVER} = 2$  MHz, COUNTS = 250
- (17) CapTIvate technology works in LPM4 with four self-capacitance buttons, wake on touch. CapTIvate BSWP demo panel with 1.5-mm overlay. Current for brownout included. SVS disabled (SVSHE = 0). VLO (10 kHz) sources to CapTIvate timer, no external crystal.  
 $f_{SCAN} = 8$  Hz,  $f_{CONVER} = 2$  MHz, COUNTS = 250

## 8.8 Low-Power Mode LPMx.5 Supply Currents (Into $V_{CC}$ ) Excluding External Current

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)

| PARAMETER         |                                                                                                                 | $V_{CC}$ | –40°C |     | 25°C  |     | 85°C  |     | 105°C |      | UNIT    |
|-------------------|-----------------------------------------------------------------------------------------------------------------|----------|-------|-----|-------|-----|-------|-----|-------|------|---------|
|                   |                                                                                                                 |          | TYP   | MAX | TYP   | MAX | TYP   | MAX | TYP   | MAX  |         |
| $I_{LPM3.5, XT1}$ | Low-power mode 3.5, 12.5-pF crystal, includes SVS <sup>(1) (2) (3)</sup> (also see <a href="#">Figure 8-3</a> ) | 3 V      | 0.60  |     | 0.66  |     | 0.96  |     | 1.41  | 2.95 | $\mu A$ |
|                   |                                                                                                                 | 2 V      | 0.58  |     | 0.65  |     | 0.92  |     | 1.33  |      |         |
| $I_{LPM4.5, SVS}$ | Low-power mode 4.5, includes SVS <sup>(4)</sup>                                                                 | 3 V      | 0.24  |     | 0.26  |     | 0.40  |     | 0.61  | 1.10 | $\mu A$ |
|                   |                                                                                                                 | 2 V      | 0.23  |     | 0.25  |     | 0.37  |     | 0.56  |      |         |
| $I_{LPM4.5}$      | Low-power mode 4.5, excludes SVS <sup>(5)</sup>                                                                 | 3 V      | 0.029 |     | 0.041 |     | 0.161 |     | 0.361 | 0.80 | $\mu A$ |
|                   |                                                                                                                 | 2 V      | 0.027 |     | 0.037 |     | 0.137 |     | 0.31  |      |         |

(1) Not applicable for MCUs with HF crystal oscillator only.

(2) Characterized with a Seiko Crystal SC-32S MS1V-T1K crystal with a load capacitance of 12.5 pF. The internal and external load capacitance are chosen to closely match the required 12.5-pF load.

(3) Low-power mode 3.5, 12.5-pF crystal, includes SVS test conditions:

Current for RTC clocked by XT1 included. Current for brownout and SVS included (SVSHE = 1). Core regulator disabled.

PMMREGOFF = 1, CPUOFF = 1, SCG0 = 1 SCG1 = 1, OSCOFF = 1 (LPMx.5),

$f_{XT1}$  = 32768 Hz,  $f_{ACLK}$  = 0,  $f_{MCLK}$  =  $f_{SMCLK}$  = 0 MHz

(4) Low-power mode 4.5, includes SVS test conditions:

Current for brownout and SVS included (SVSHE = 1). Core regulator disabled.

PMMREGOFF = 1, CPUOFF = 1, SCG0 = 1 SCG1 = 1, OSCOFF = 1 (LPMx.5)

$f_{XT1}$  = 0 Hz,  $f_{ACLK}$  =  $f_{MCLK}$  =  $f_{SMCLK}$  = 0 MHz

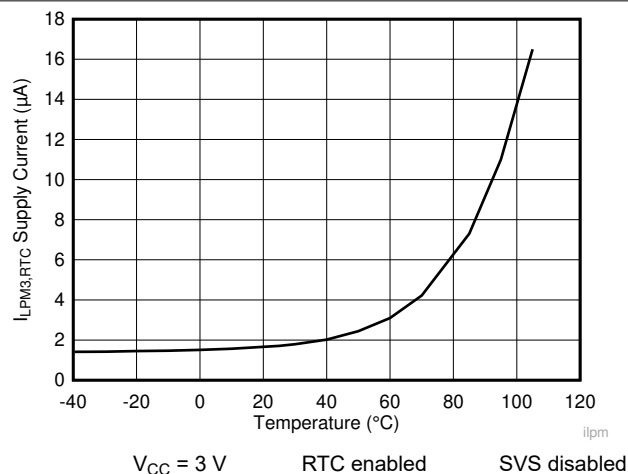
(5) Low-power mode 4.5, excludes SVS test conditions:

Current for brownout included. SVS disabled (SVSHE = 0). Core regulator disabled.

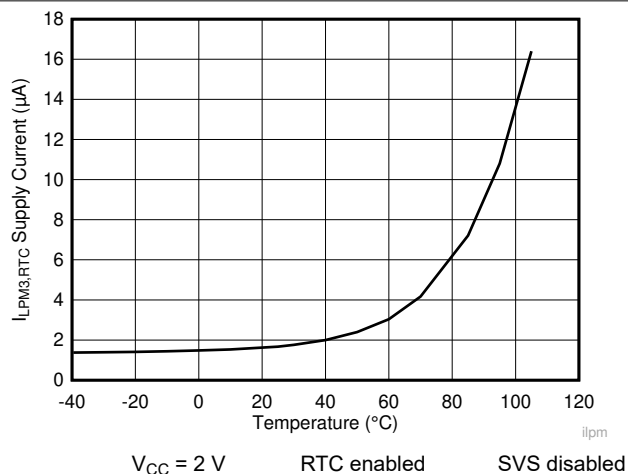
PMMREGOFF = 1, CPUOFF = 1, SCG0 = 1 SCG1 = 1, OSCOFF = 1 (LPMx.5)

$f_{XT1}$  = 0 Hz,  $f_{ACLK}$  =  $f_{MCLK}$  =  $f_{SMCLK}$  = 0 MHz

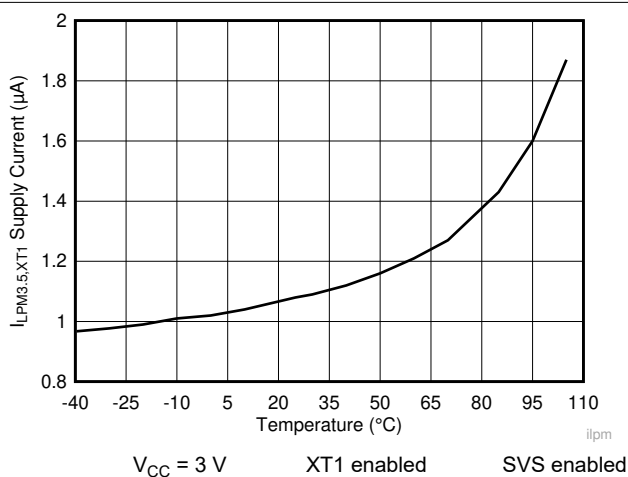
## 8.9 Typical Characteristics – Low-Power Mode Supply Currents



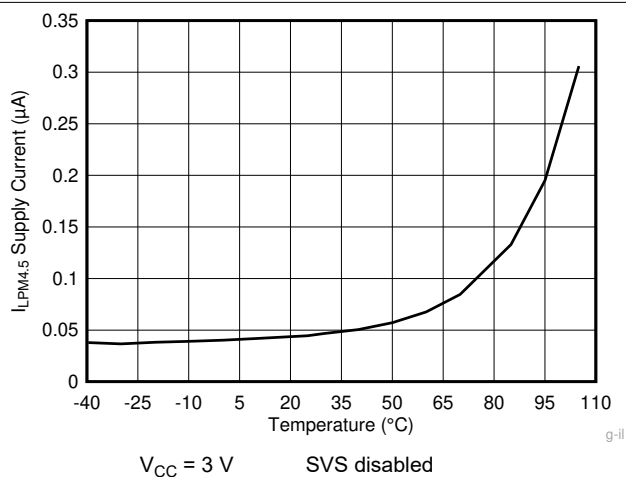
**Figure 8-1. LPM3 Supply Current vs Temperature**



**Figure 8-2. LPM3 Supply Current vs Temperature**



**Figure 8-3. LPM3.5 Supply Current vs Temperature**



**Figure 8-4. LPM4.5 Supply Current vs Temperature**

## 8.10 Current Consumption Per Module

| MODULE  | TEST CONDITIONS                  | REFERENCE CLOCK    | MIN | TYP | MAX | UNIT   |
|---------|----------------------------------|--------------------|-----|-----|-----|--------|
| Timer_A |                                  | Module input clock |     | 5   |     | µA/MHz |
| eUSCI_A | UART mode                        | Module input clock |     | 7   |     | µA/MHz |
| eUSCI_A | SPI mode                         | Module input clock |     | 5   |     | µA/MHz |
| eUSCI_B | SPI mode                         | Module input clock |     | 5   |     | µA/MHz |
| eUSCI_B | I <sup>2</sup> C mode, 100 kbaud | Module input clock |     | 5   |     | µA/MHz |
| RTC     |                                  | 32 kHz             |     | 85  |     | nA     |
| CRC     | From start to end of operation   | MCLK               |     | 8.5 |     | µA/MHz |

## 8.11 Thermal Resistance Characteristics

| THERMAL METRIC <sup>(1)</sup>                                     |                   | VALUE <sup>(2)</sup> | UNIT |
|-------------------------------------------------------------------|-------------------|----------------------|------|
| R $\theta_{JA}$ Junction-to-ambient thermal resistance, still air | LQFP 48 pin (PT)  | 62.4                 | °C/W |
|                                                                   | VQFN 40 pin (RHA) | 31.0                 |      |
|                                                                   | VQFN 32 pin (RHB) | 30.8                 |      |
| R $\theta_{JC}$ Junction-to-case (top) thermal resistance         | LQFP 48 pin (PT)  | 22.1                 | °C/W |
|                                                                   | VQFN 40 pin (RHA) | 22.3                 |      |
|                                                                   | VQFN 32 pin (RHB) | 20.8                 |      |
| R $\theta_{JB}$ Junction-to-board thermal resistance              | LQFP 48 pin (PT)  | 26.3                 | °C/W |
|                                                                   | VQFN 40 pin (RHA) | 12.3                 |      |
|                                                                   | VQFN 32 pin (RHB) | 11.6                 |      |

- (1) For more information about traditional and new thermal metrics, see [Semiconductor and IC Package Thermal Metrics](#).
- (2) These values are based on a JEDEC-defined 2S2P system (with the exception of the Theta JC (R $\theta_{JC}$ ) value, which is based on a JEDEC-defined 1S0P system) and will change based on environment and application. For more information, see these EIA/JEDEC standards:
- JESD51-2, *Integrated Circuits Thermal Test Method Environmental Conditions - Natural Convection (Still Air)*
  - JESD51-3, *Low Effective Thermal Conductivity Test Board for Leaded Surface Mount Packages*
  - JESD51-7, *High Effective Thermal Conductivity Test Board for Leaded Surface Mount Packages*
  - JESD51-9, *Test Boards for Area Array Surface Mount Package Thermal Measurements*

## 8.12 Timing and Switching Characteristics

### 8.12.1 Power Supply Sequencing

#### 8.12.1.1 PMM, SVS and BOR

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)

| PARAMETER                                                                      | TEST CONDITIONS         | MIN  | TYP  | MAX  | UNIT |
|--------------------------------------------------------------------------------|-------------------------|------|------|------|------|
| V <sub>BOR, safe</sub> Safe BOR power-down level <sup>(1)</sup>                |                         | 0.1  |      |      | V    |
| t <sub>BOR, safe</sub> Safe BOR reset delay <sup>(2)</sup>                     |                         | 10   |      |      | ms   |
| I <sub>SVSH, AM</sub> SVS <sub>H</sub> current consumption, active mode        | V <sub>CC</sub> = 3.6 V |      |      | 1.5  | μA   |
| I <sub>SVSH, LPM</sub> SVS <sub>H</sub> current consumption, low-power modes   | V <sub>CC</sub> = 3.6 V |      | 240  |      | nA   |
| V <sub>SVSH-</sub> SVS <sub>H</sub> power-down level <sup>(4)</sup>            |                         | 1.71 | 1.80 | 1.87 | V    |
| V <sub>SVSH+</sub> SVS <sub>H</sub> power-up level <sup>(4)</sup>              |                         | 1.76 | 1.88 | 1.99 | V    |
| V <sub>SVSH_hys</sub> SVS <sub>H</sub> hysteresis                              |                         |      | 100  |      | mV   |
| t <sub>PD, SVSH, AM</sub> SVS <sub>H</sub> propagation delay, active mode      |                         |      |      | 10   | μs   |
| t <sub>PD, SVSH, LPM</sub> SVS <sub>H</sub> propagation delay, low-power modes |                         |      |      | 100  | μs   |

- (1) A safe BOR can be correctly generated only if DVCC drops below this voltage before it rises.
- (2) When an BOR occurs, a safe BOR can be correctly generated only if DVCC is kept low longer than this period before it reaches V<sub>SVSH+</sub>.
- (3) This is a characterized result with external 1-mA load to ground from –40°C to 85°C.
- (4) For additional information, see the [Dynamic Voltage Scaling Power Solution for MSP430 Devices With Single-Channel LDO Reference Design](#).

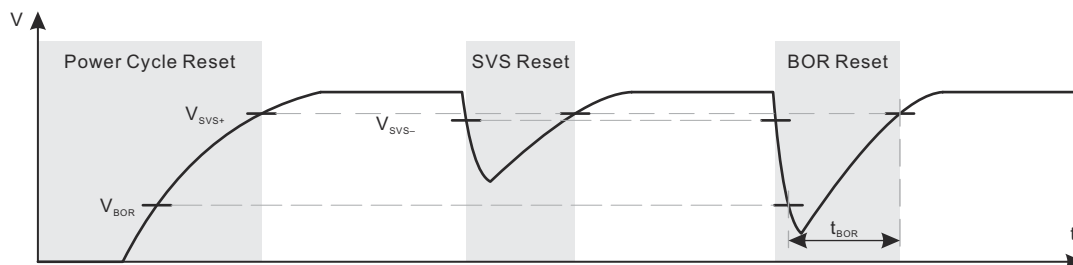


Figure 8-5. Power Cycle, SVS, and BOR Reset Conditions

## 8.12.2 Reset Timing

### 8.12.2.1 Wake-up Times From Low-Power Modes and Reset

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)

| PARAMETER                   | TEST CONDITIONS                                                                                                                                                              | V <sub>CC</sub> | MIN | TYP                             | MAX | UNIT |
|-----------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|-----|---------------------------------|-----|------|
| t <sub>WAKE-UP FRAM</sub>   | Additional wake-up time to activate the FRAM in AM if previously disabled by the FRAM controller or from a LPM if immediate activation is selected for wakeup <sup>(1)</sup> | 3 V             |     | 10                              |     | μs   |
| t <sub>WAKE-UP LPM0</sub>   | Wake-up time from LPM0 to active mode <sup>(1)</sup>                                                                                                                         | 3 V             |     | 200 +<br>2.5 / f <sub>DCO</sub> |     | ns   |
| t <sub>WAKE-UP LPM3</sub>   | Wake-up time from LPM3 to active mode <sup>(2)</sup>                                                                                                                         | 3 V             |     | 10                              |     | μs   |
| t <sub>WAKE-UP LPM4</sub>   | Wake-up time from LPM4 to active mode                                                                                                                                        | 3 V             |     | 10                              |     | μs   |
| t <sub>WAKE-UP LPM3.5</sub> | Wake-up time from LPM3.5 to active mode <sup>(2)</sup>                                                                                                                       | 3 V             |     | 350                             |     | μs   |
| t <sub>WAKE-UP LPM4.5</sub> | Wake-up time from LPM4.5 to active mode <sup>(2)</sup>                                                                                                                       | SVSHE = 1       |     | 350                             |     | μs   |
|                             |                                                                                                                                                                              | SVSHE = 0       |     | 1                               |     | ms   |
| t <sub>WAKE-UP-RESET</sub>  | Wake-up time from $\overline{\text{RST}}$ or BOR event to active mode <sup>(2)</sup>                                                                                         | 3 V             |     | 1                               |     | ms   |
| t <sub>RESET</sub>          | Pulse duration required at $\overline{\text{RST}}$ /NMI pin to accept a reset                                                                                                | 3 V             |     | 2                               |     | μs   |

- (1) The wake-up time is measured from the edge of an external wake-up signal (for example, port interrupt or wake-up event) to the first externally observable MCLK clock edge.
- (2) The wake-up time is measured from the edge of an external wake-up signal (for example, port interrupt or wake-up event) until the first instruction of the user program is executed.

## 8.12.3 Clock Specifications

### 8.12.3.1 XT1 Crystal Oscillator (Low Frequency)

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)<sup>(1) (2)</sup>

| PARAMETER                |                                                          | TEST CONDITIONS                                                                                                         | V <sub>CC</sub> | MIN | TYP    | MAX  | UNIT |
|--------------------------|----------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|-----------------|-----|--------|------|------|
| f <sub>XT1, LF</sub>     | XT1 oscillator crystal, low frequency                    | LFXTBYPASS = 0                                                                                                          |                 |     | 32768  |      | Hz   |
| DC <sub>XT1, LF</sub>    | XT1 oscillator LF duty cycle                             | Measured at MCLK,<br>f <sub>LFXT</sub> = 32768 Hz                                                                       |                 | 30% |        | 70%  |      |
| f <sub>XT1, SW</sub>     | XT1 oscillator logic-level square-wave input frequency   | LFXTBYPASS = 1 <sup>(3) (4)</sup>                                                                                       |                 |     | 32.768 |      | kHz  |
| DC <sub>XT1, SW</sub>    | LFXT oscillator logic-level square-wave input duty cycle | LFXTBYPASS = 1                                                                                                          |                 | 40% |        | 60%  |      |
| OA <sub>LFXT</sub>       | Oscillation allowance for LF crystals <sup>(5)</sup>     | LFXTBYPASS = 0, LFXTDRIVE = {3},<br>f <sub>LFXT</sub> = 32768 Hz, C <sub>L,eff</sub> = 12.5 pF                          |                 |     | 200    |      | kΩ   |
| C <sub>L,eff</sub>       | Integrated effective load capacitance <sup>(6)</sup>     | See <sup>(7)</sup>                                                                                                      |                 |     | 1      |      | pF   |
| t <sub>START, LFXT</sub> | Start-up time <sup>(9)</sup>                             | f <sub>OSC</sub> = 32768 Hz,<br>LFXTBYPASS = 0, LFXTDRIVE = {3},<br>T <sub>A</sub> = 25°C, C <sub>L,eff</sub> = 12.5 pF |                 |     | 1000   |      | ms   |
| f <sub>Fault, LFXT</sub> | Oscillator fault frequency <sup>(10)</sup>               | XTS = 0 <sup>(8)</sup>                                                                                                  |                 | 0   |        | 3500 | Hz   |

- (1) To improve EMI on the LFXT oscillator, observe the following guidelines:
  - Keep the trace between the device and the crystal as short as possible.
  - Design a good ground plane around the oscillator pins.
  - Prevent crosstalk from other clock or data lines into oscillator pins XIN and XOUT.
  - Avoid running PCB traces underneath or adjacent to the XIN and XOUT pins.
  - Use assembly materials and processes that avoid any parasitic load on the oscillator XIN and XOUT pins.
  - If conformal coating is used, make sure that it does not induce capacitive or resistive leakage between the oscillator pins.
- (2) See the [MSP430 32-kHz Crystal Oscillators](#) application note for details on crystal section, layout, and testing.
- (3) When LFXTBYPASS is set, LFXT circuits are automatically powered down. Input signal is a digital square wave with parametrics defined in the Schmitt-trigger inputs section of this data sheet. Duty cycle requirements are defined by DC<sub>LFXT, SW</sub>.
- (4) Maximum frequency of operation of the entire device cannot be exceeded.
- (5) Oscillation allowance is based on a safety factor of 5 for recommended crystals. The oscillation allowance is a function of the LFXTDRIVE settings and the effective load. In general, comparable oscillator allowance can be achieved based on the following guidelines, but should be evaluated based on the actual crystal selected for the application:
  - For LFXTDRIVE = {0}, C<sub>L,eff</sub> = 3.7 pF
  - For LFXTDRIVE = {1}, 6 pF ≤ C<sub>L,eff</sub> ≤ 9 pF
  - For LFXTDRIVE = {2}, 6 pF ≤ C<sub>L,eff</sub> ≤ 10 pF
  - For LFXTDRIVE = {3}, 6 pF ≤ C<sub>L,eff</sub> ≤ 12 pF
- (6) Includes parasitic bond and package capacitance (approximately 2 pF per pin).
- (7) Requires external capacitors at both terminals to meet the effective load capacitance specified by crystal manufacturers. Recommended effective load capacitance values supported are 3.7 pF, 6 pF, 9 pF, and 12.5 pF. Maximum shunt capacitance of 1.6 pF. The PCB adds additional capacitance, so it must also be considered in the overall capacitance. Verify that the recommended effective load capacitance of the selected crystal is met.
- (8) Measured with logic-level input frequency but also applies to operation with crystals.
- (9) Includes start-up counter of 1024 clock cycles.
- (10) Frequencies above the MAX specification do not set the fault flag. Frequencies between the MIN and MAX specifications might set the flag. A static condition or stuck at fault condition sets the flag.

### 8.12.3.2 DCO FLL, Frequency

over recommended operating free-air temperature (unless otherwise noted)

| PARAMETER              |                                            | TEST CONDITIONS                                      | V <sub>CC</sub> | MIN   | TYP    | MAX  | UNIT |
|------------------------|--------------------------------------------|------------------------------------------------------|-----------------|-------|--------|------|------|
| f <sub>DCO, FLL</sub>  | FLL lock frequency, 16 MHz, 25°C           | Measured at MCLK, Internal trimmed REFO as reference | 3 V             | –1.0% |        | 1.0% |      |
|                        | FLL lock frequency, 16 MHz, –40°C to 105°C |                                                      | 3 V             | –3.0% |        | 3.0% |      |
|                        | FLL lock frequency, 16 MHz, –40°C to 105°C | Measured at MCLK, XT1 crystal as reference           | 3 V             | –0.5% |        | 0.5% |      |
| f <sub>DUTY</sub>      | Duty cycle                                 | Measured at MCLK, XT1 crystal as reference           | 3 V             | 40%   | 50%    | 60%  |      |
| Jitter <sub>cc</sub>   | Cycle-to-cycle jitter, 16 MHz              |                                                      | 3 V             |       | 0.25%  |      |      |
| Jitter <sub>long</sub> | Long term jitter, 16 MHz                   |                                                      | 3 V             |       | 0.022% |      |      |
| t <sub>FLL, lock</sub> | FLL lock time, 16MHz                       |                                                      | 3 V             |       | 200    |      | ms   |

### 8.12.3.3 DCO Frequency

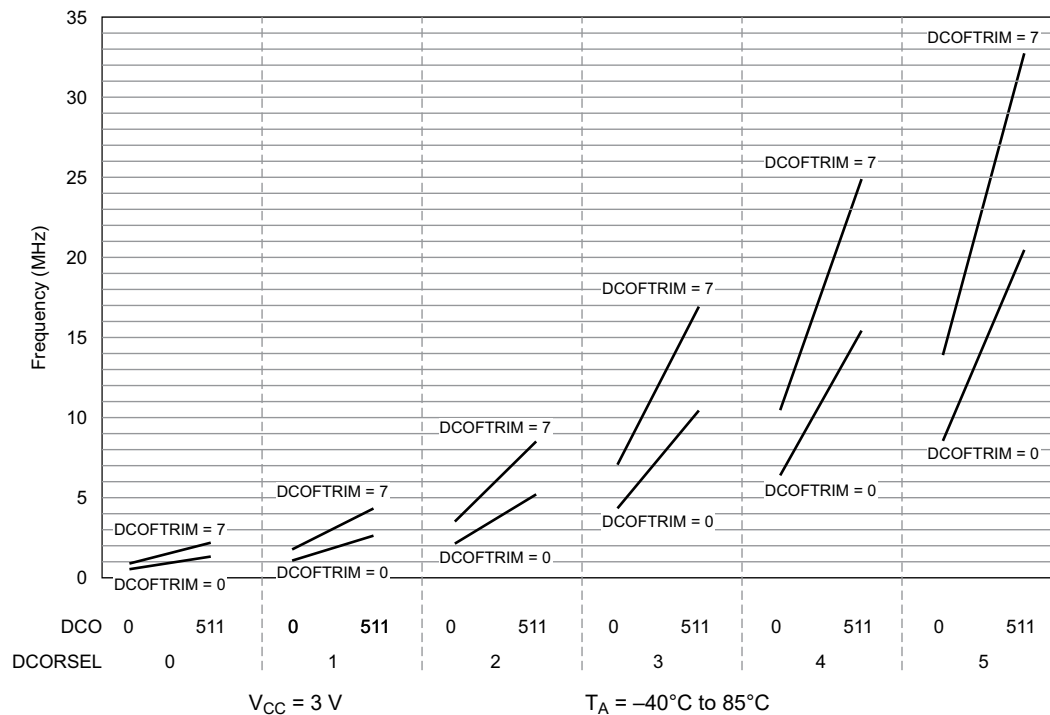
over recommended operating free-air temperature (unless otherwise noted) (see [Figure 8-6](#))

| PARAMETER               |                       | TEST CONDITIONS                                                          | V <sub>CC</sub> | TYP  | UNIT |
|-------------------------|-----------------------|--------------------------------------------------------------------------|-----------------|------|------|
| f <sub>DCO, 16MHz</sub> | DCO frequency, 16 MHz | DCORSEL = 101b, DISMOD = 1b, DCOFTRIMEN = 1b, DCOFTRIM = 000b, DCO = 0   | 3 V             | 8.5  | MHz  |
|                         |                       | DCORSEL = 101b, DISMOD = 1b, DCOFTRIMEN = 1b, DCOFTRIM = 000b, DCO = 511 |                 | 13.9 |      |
|                         |                       | DCORSEL = 101b, DISMOD = 1b, DCOFTRIMEN = 1b, DCOFTRIM = 111b, DCO = 0   |                 | 20   |      |
|                         |                       | DCORSEL = 101b, DISMOD = 1b, DCOFTRIMEN = 1b, DCOFTRIM = 111b, DCO = 511 |                 | 32.7 |      |
| f <sub>DCO, 12MHz</sub> | DCO frequency, 12 MHz | DCORSEL = 100b, DISMOD = 1b, DCOFTRIMEN = 1b, DCOFTRIM = 000b, DCO = 0   | 3 V             | 6.4  | MHz  |
|                         |                       | DCORSEL = 100b, DISMOD = 1b, DCOFTRIMEN = 1b, DCOFTRIM = 000b, DCO = 511 |                 | 10.5 |      |
|                         |                       | DCORSEL = 100b, DISMOD = 1b, DCOFTRIMEN = 1b, DCOFTRIM = 111b, DCO = 0   |                 | 15.4 |      |
|                         |                       | DCORSEL = 100b, DISMOD = 1b, DCOFTRIMEN = 1b, DCOFTRIM = 111b, DCO = 511 |                 | 24.8 |      |
| f <sub>DCO, 8MHz</sub>  | DCO frequency, 8 MHz  | DCORSEL = 011b, DISMOD = 1b, DCOFTRIMEN = 1b, DCOFTRIM = 000b, DCO = 0   | 3 V             | 4.3  | MHz  |
|                         |                       | DCORSEL = 011b, DISMOD = 1b, DCOFTRIMEN = 1b, DCOFTRIM = 000b, DCO = 511 |                 | 7.1  |      |
|                         |                       | DCORSEL = 011b, DISMOD = 1b, DCOFTRIMEN = 1b, DCOFTRIM = 111b, DCO = 0   |                 | 10.4 |      |
|                         |                       | DCORSEL = 011b, DISMOD = 1b, DCOFTRIMEN = 1b, DCOFTRIM = 111b, DCO = 511 |                 | 16.9 |      |
| f <sub>DCO, 4MHz</sub>  | DCO frequency, 4 MHz  | DCORSEL = 010b, DISMOD = 1b, DCOFTRIMEN = 1b, DCOFTRIM = 000b, DCO = 0   | 3 V             | 2.1  | MHz  |
|                         |                       | DCORSEL = 010b, DISMOD = 1b, DCOFTRIMEN = 1b, DCOFTRIM = 000b, DCO = 511 |                 | 3.5  |      |
|                         |                       | DCORSEL = 010b, DISMOD = 1b, DCOFTRIMEN = 1b, DCOFTRIM = 111b, DCO = 0   |                 | 5.2  |      |
|                         |                       | DCORSEL = 010b, DISMOD = 1b, DCOFTRIMEN = 1b, DCOFTRIM = 111b, DCO = 511 |                 | 8.5  |      |

### 8.12.3.3 DCO Frequency (continued)

over recommended operating free-air temperature (unless otherwise noted) (see [Figure 8-6](#))

| PARAMETER                                   | TEST CONDITIONS                                                          | V <sub>CC</sub> | TYP | UNIT |
|---------------------------------------------|--------------------------------------------------------------------------|-----------------|-----|------|
| f <sub>DCO, 2MHz</sub> DCO frequency, 2 MHz | DCORSEL = 001b, DISMOD = 1b, DCOFTRIMEN = 1b, DCOFTRIM = 000b, DCO = 0   | 3 V             | 1.1 | MHz  |
|                                             | DCORSEL = 001b, DISMOD = 1b, DCOFTRIMEN = 1b, DCOFTRIM = 000b, DCO = 511 |                 | 1.8 |      |
|                                             | DCORSEL = 001b, DISMOD = 1b, DCOFTRIMEN = 1b, DCOFTRIM = 111b, DCO = 0   |                 | 2.6 |      |
|                                             | DCORSEL = 001b, DISMOD = 1b, DCOFTRIMEN = 1b, DCOFTRIM = 111b, DCO = 511 |                 | 4.3 |      |
| f <sub>DCO, 1MHz</sub> DCO frequency, 1 MHz | DCORSEL = 000b, DISMOD = 1b, DCOFTRIMEN = 1b, DCOFTRIM = 000b, DCO = 0   | 3 V             | 0.5 | MHz  |
|                                             | DCORSEL = 000b, DISMOD = 1b, DCOFTRIMEN = 1b, DCOFTRIM = 000b, DCO = 511 |                 | 0.9 |      |
|                                             | DCORSEL = 000b, DISMOD = 1b, DCOFTRIMEN = 1b, DCOFTRIM = 111b, DCO = 0   |                 | 1.3 |      |
|                                             | DCORSEL = 000b, DISMOD = 1b, DCOFTRIMEN = 1b, DCOFTRIM = 111b, DCO = 511 |                 | 2.2 |      |



**Figure 8-6. Typical DCO Frequency**

### 8.12.3.4 REFO

over recommended operating free-air temperature (unless otherwise noted)

| PARAMETER                            |                                     | TEST CONDITIONS                         | V <sub>CC</sub> | MIN   | TYP   | MAX   | UNIT |
|--------------------------------------|-------------------------------------|-----------------------------------------|-----------------|-------|-------|-------|------|
| I <sub>REFO</sub>                    | REFO oscillator current consumption | T <sub>A</sub> = 25°C                   | 3 V             |       | 1     |       | μA   |
| f <sub>REFO</sub>                    | REFO calibrated frequency           | Measured at MCLK                        | 3 V             |       | 32768 |       | Hz   |
|                                      | REFO absolute calibrated tolerance  | –40°C to 105°C                          | 1.8 V to 3.6 V  | –3.5% |       | +3.5% |      |
| df <sub>REFO</sub> /dT               | REFO frequency temperature drift    | Measured at MCLK <sup>(1)</sup>         | 3 V             |       | 0.01  |       | %/°C |
| df <sub>REFO</sub> /dV <sub>CC</sub> | REFO frequency supply voltage drift | Measured at MCLK at 25°C <sup>(2)</sup> | 1.8 V to 3.6 V  |       | 1     |       | %/V  |
| f <sub>DC</sub>                      | REFO duty cycle                     | Measured at MCLK                        | 1.8 V to 3.6 V  | 40%   | 50%   | 60%   |      |
| t <sub>START</sub>                   | REFO start-up time                  | 40% to 60% duty cycle                   |                 |       | 50    |       | μs   |

(1) Calculated using the box method: (MAX(–40°C to 105°C) – MIN(–40°C to 105°C)) / MIN(–40°C to 105°C) / (105°C – (–40°C))

(2) Calculated using the box method: (MAX(1.8 V to 3.6 V) – MIN(1.8 V to 3.6 V)) / MIN(1.8 V to 3.6 V) / (3.6 V – 1.8 V)

### 8.12.3.5 Internal Very-Low-Power Low-Frequency Oscillator (VLO)

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)

| PARAMETER                           |                                    | TEST CONDITIONS                 | V <sub>CC</sub> | TYP | UNIT |
|-------------------------------------|------------------------------------|---------------------------------|-----------------|-----|------|
| f <sub>VLO</sub>                    | VLO frequency                      | Measured at MCLK                | 3 V             | 10  | kHz  |
| df <sub>VLO</sub> /dT               | VLO frequency temperature drift    | Measured at MCLK <sup>(1)</sup> | 3 V             | 0.5 | %/°C |
| df <sub>VLO</sub> /dV <sub>CC</sub> | VLO frequency supply voltage drift | Measured at MCLK <sup>(2)</sup> | 1.8 V to 3.6 V  | 4   | %/V  |
| f <sub>VLO,DC</sub>                 | Duty cycle                         | Measured at MCLK                | 3 V             | 50% |      |

(1) Calculated using the box method: (MAX(–40°C to 105°C) – MIN(–40°C to 105°C)) / MIN(–40°C to 105°C) / (105°C – (–40°C))

(2) Calculated using the box method: (MAX(1.8 V to 3.6 V) – MIN(1.8 V to 3.6 V)) / MIN(1.8 V to 3.6 V) / (3.6 V – 1.8 V)

#### Note

The VLO clock frequency is reduced by 15% (typical) when the device switches from active mode to LPM3 or LPM4, because the reference changes. This lower frequency is not a violation of the VLO specifications (see [Section 8.12.3.5](#)).

### 8.12.3.6 Module Oscillator (MODOSC)

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)

| PARAMETER                             |                                       | TEST CONDITIONS | V <sub>CC</sub> | MIN | TYP   | MAX | UNIT |
|---------------------------------------|---------------------------------------|-----------------|-----------------|-----|-------|-----|------|
| f <sub>MODOSC</sub>                   | MODOSC frequency                      |                 | 3 V             | 3.0 | 3.8   | 4.6 | MHz  |
| f <sub>MODOSC</sub> /dT               | MODOSC frequency temperature drift    |                 | 3 V             |     | 0.102 |     | %/°C |
| f <sub>MODOSC</sub> /dV <sub>CC</sub> | MODOSC frequency supply voltage drift |                 | 1.8 V to 3.6 V  |     | 1.17  |     | %/V  |
| f <sub>MODOSC,DC</sub>                | Duty cycle                            |                 | 3 V             | 40% | 50%   | 60% |      |

## 8.12.4 Digital I/Os

### 8.12.4.1 Digital Inputs

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)

| PARAMETER                                                                                                           | TEST CONDITIONS                                                                                  | V <sub>CC</sub> | MIN  | TYP | MAX  | UNIT |
|---------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|-----------------|------|-----|------|------|
| V <sub>IT+</sub> Positive-going input threshold voltage                                                             |                                                                                                  | 2 V             | 0.90 |     | 1.50 | V    |
|                                                                                                                     |                                                                                                  | 3 V             | 1.35 |     | 2.25 |      |
| V <sub>IT-</sub> Negative-going input threshold voltage                                                             |                                                                                                  | 2 V             | 0.50 |     | 1.10 | V    |
|                                                                                                                     |                                                                                                  | 3 V             | 0.75 |     | 1.65 |      |
| V <sub>hys</sub> Input voltage hysteresis (V <sub>IT+</sub> – V <sub>IT-</sub> )                                    |                                                                                                  | 2 V             | 0.3  |     | 0.8  | V    |
|                                                                                                                     |                                                                                                  | 3 V             | 0.4  |     | 1.2  |      |
| R <sub>Pull</sub> Pullup or pulldown resistor                                                                       | For pullup: V <sub>IN</sub> = V <sub>SS</sub><br>For pulldown: V <sub>IN</sub> = V <sub>CC</sub> |                 | 20   | 35  | 50   | kΩ   |
| C <sub>I,dig</sub> Input capacitance, digital only port pins                                                        | V <sub>IN</sub> = V <sub>SS</sub> or V <sub>CC</sub>                                             |                 |      | 3   |      | pF   |
| C <sub>I,ana</sub> Input capacitance, port pins with shared analog functions                                        | V <sub>IN</sub> = V <sub>SS</sub> or V <sub>CC</sub>                                             |                 |      | 5   |      | pF   |
| I <sub>kg(Px.y)</sub> High-impedance leakage current of GPIO Pins                                                   | See (1) (2)                                                                                      | 2 V, 3 V        | -20  |     | 20   | nA   |
| I <sub>kg(Px.y)</sub> High-impedance leakage current of GPIO pins shared with CapTIvate functionality               | See (1) (2) (3)                                                                                  | 2 V, 3 V        | -70  |     | -70  | nA   |
| t <sub>(int)</sub> External interrupt timing (external trigger pulse duration to set interrupt flag) <sup>(4)</sup> | Ports with interrupt capability (see block diagram and terminal function descriptions)           | 2 V, 3 V        | 50   |     |      | ns   |

(1) The leakage current is measured with V<sub>SS</sub> or V<sub>CC</sub> applied to the corresponding pins, unless otherwise noted.

(2) The leakage of the digital port pins is measured individually. The port pin is selected for input and the pullup or pulldown resistor is disabled.

(3) This leakage applies to only GPIOs that are shared with CapTIvate technology pins.

(4) An external signal sets the interrupt flag every time the minimum interrupt pulse duration t<sub>(int)</sub> is met. It may be set by trigger signals shorter than t<sub>(int)</sub>.

### 8.12.4.2 Digital Outputs

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)

| PARAMETER                                                           | TEST CONDITIONS                             | V <sub>CC</sub> | MIN | TYP | MAX  | UNIT |
|---------------------------------------------------------------------|---------------------------------------------|-----------------|-----|-----|------|------|
| V <sub>OH</sub> High-level output voltage                           | I <sub>(OHmax)</sub> = -3 mA <sup>(1)</sup> | 2 V             | 1.4 |     | 2.0  | V    |
|                                                                     | I <sub>(OHmax)</sub> = -5 mA <sup>(1)</sup> | 3 V             | 2.4 |     | 3.0  |      |
| V <sub>OL</sub> Low-level output voltage                            | I <sub>(OLmax)</sub> = 3 mA <sup>(1)</sup>  | 2 V             | 0.0 |     | 0.60 | V    |
|                                                                     | I <sub>(OHmax)</sub> = 5 mA <sup>(1)</sup>  | 3 V             | 0.0 |     | 0.60 |      |
| f <sub>Port_CLK</sub> Clock output frequency                        | C <sub>L</sub> = 20 pF <sup>(2)</sup>       | 2 V             | 16  |     |      | MHz  |
|                                                                     |                                             | 3 V             | 16  |     |      |      |
| t <sub>rise,dig</sub> Port output rise time, digital only port pins | C <sub>L</sub> = 20 pF                      | 2 V             |     | 10  |      | ns   |
|                                                                     |                                             | 3 V             |     | 7   |      |      |
| t <sub>fall,dig</sub> Port output fall time, digital only port pins | C <sub>L</sub> = 20 pF                      | 2 V             |     | 10  |      | ns   |
|                                                                     |                                             | 3 V             |     | 5   |      |      |

(1) The maximum total current, I<sub>(OHmax)</sub> and I<sub>(OLmax)</sub>, for all outputs combined should not exceed ±48 mA to hold the maximum voltage drop specified.

(2) The port can output frequencies at least up to the specified limit and might support higher frequencies.

### 8.12.4.3 Typical Characteristics – Outputs at 3 V and 2 V

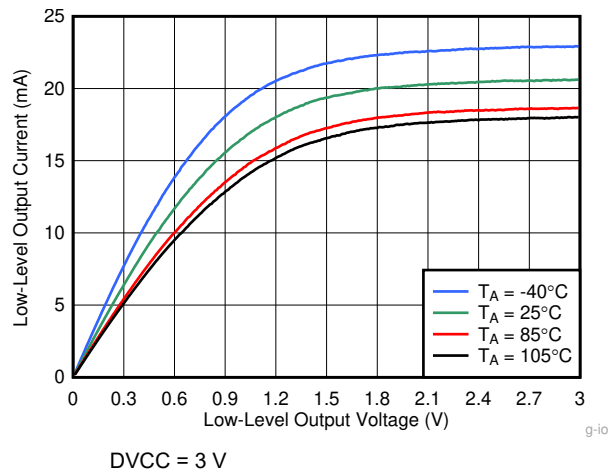


Figure 8-7. Typical Low-Level Output Current vs Low-Level Output Voltage

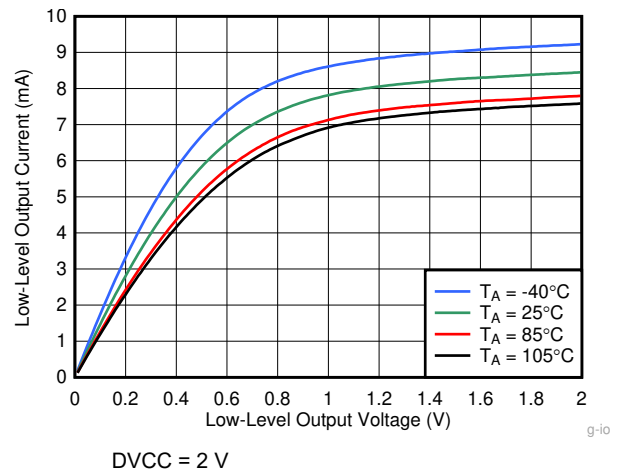


Figure 8-8. Typical Low-Level Output Current vs Low-Level Output Voltage

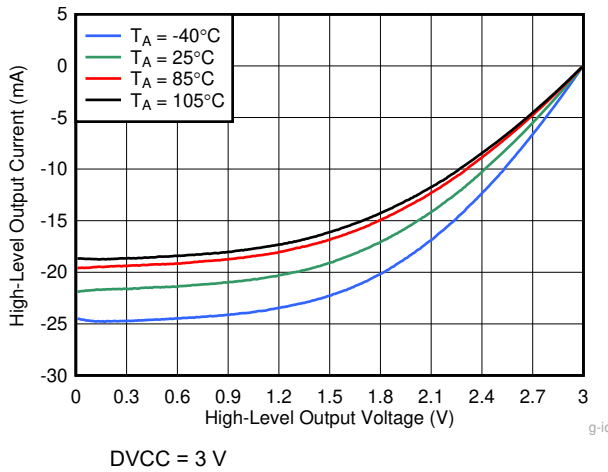


Figure 8-9. Typical High-Level Output Current vs High-Level Output Voltage

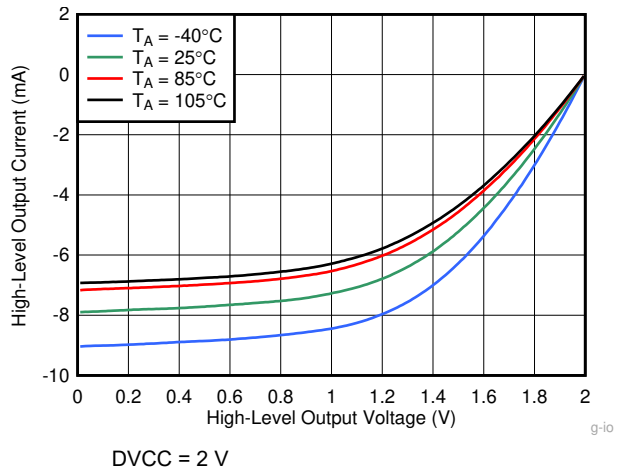


Figure 8-10. Typical High-Level Output Current vs High-Level Output Voltage

## 8.12.5 Internal Shared Reference

### 8.12.5.1 Internal Reference Characteristics

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)

| PARAMETER                                                                                                                   |                                                                                  | TEST CONDITIONS                                                                                                               | V <sub>CC</sub> | MIN   | TYP  | MAX   | UNIT  |
|-----------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------|-----------------|-------|------|-------|-------|
| V <sub>SENSOR</sub>                                                                                                         | Temperature sensor voltage                                                       | T <sub>J</sub> = 30°C                                                                                                         | 2.0 V, 3.0 V    | 788   |      |       | mV    |
| TC <sub>SENSOR</sub>                                                                                                        | Temperature sensor coefficient                                                   | T <sub>J</sub> = 30°C                                                                                                         |                 | 2.5   |      |       | mV/°C |
| V <sub>eCOMP, LP</sub>                                                                                                      | Low-power threshold for eCOMP                                                    | T <sub>J</sub> = 30°C                                                                                                         | 2.0 V, 3.0 V    | 1.20  |      |       | V     |
| V <sub>REF+</sub> , 1.2V Output                                                                                             | Positive built-in reference output at VREF+ pin with 1-mA load current to ground | EXTREFEN = 1 with 1-mA load current                                                                                           | 2.0 V, 3.0 V    | 1.16  | 1.20 | 1.24  | V     |
| TC <sub>REF+, 1.2V</sub>                                                                                                    | Temperature coefficient of VREF+ = 1.2 V built-in reference                      | EXTREFEN = 1 with 1-mA load current                                                                                           | 3.0 V           | 30    |      |       | μV/°C |
| The following parameters are for the 1.5-V, 2.0-V, and 2.5-V internal reference only and cannot be output to the VREF+ pin. |                                                                                  |                                                                                                                               |                 |       |      |       |       |
| V <sub>REF+</sub> , 1.5V, 2.0V, 2.5V                                                                                        | Positive built-in reference voltage as internal reference                        | REFVSEL = {2} for 2.5 V, INTREFEN = 1                                                                                         | 3.0 V           | 2.5   |      | ±1.5% | V     |
|                                                                                                                             |                                                                                  | REFVSEL = {1} for 2.0 V, INTREFEN = 1                                                                                         | 2.5 V           | 2.0   |      | ±1.5% |       |
|                                                                                                                             |                                                                                  | REFVSEL = {0} for 1.5 V, INTREFEN = 1                                                                                         | 2.0 V           | 1.5   |      | ±1.8% |       |
| Noise                                                                                                                       | RMS noise at VREF <sup>(3)</sup>                                                 | From 0.1 Hz to 10 Hz, REFVSEL = {0}                                                                                           |                 | 30    |      | 130   | μV    |
| DV <sub>CC(min)</sub>                                                                                                       | DVCC minimum voltage, Positive built-in reference active                         | REFVSEL = {0} for 1.5 V                                                                                                       |                 | 1.8   |      |       | V     |
|                                                                                                                             |                                                                                  | REFVSEL = {1} for 2.0 V                                                                                                       |                 | 2.2   |      |       |       |
|                                                                                                                             |                                                                                  | REFVSEL = {2} for 2.5 V                                                                                                       |                 | 2.7   |      |       |       |
| I <sub>REF+</sub>                                                                                                           | Operating supply current into DVCC terminal <sup>(1)</sup>                       | INTREFEN = 1                                                                                                                  | 3 V             | 19    |      | 26    | μA    |
| I <sub>REF+ ,ADC_BUF</sub>                                                                                                  | Operating supply current into AVCC terminal <sup>(1)</sup>                       | ADC ON, REFVSEL = {0, 1, 2}                                                                                                   | 3 V             | 247   |      | 400   | μA    |
| I <sub>O(VREF+)</sub>                                                                                                       | VREF (1.5 V, 2.0 V, 2.5 V) maximum load current, VREF+ terminal                  | REFVSEL = {0, 1, 2}, AVCC = AVCC(min) for each reference level, INTREFEN = 1                                                  | 3 V             | -1000 |      | +10   | μA    |
| ΔV <sub>out</sub> / ΔI <sub>o</sub> (VREF+)                                                                                 | Load-current regulation, VREF+ terminal                                          | REFVSEL = {0, 1, 2}, I <sub>O(VREF+)</sub> = +10 μA or -1000 μA AVCC = AVCC(min) for each reference level, INTREFEN = 1       | 3 V             |       |      | 1500  | μV/mA |
| C <sub>VREF+/-</sub>                                                                                                        | Capacitance at VREF+ and VREF- terminals                                         | INTREFEN = 1                                                                                                                  | 3 V             | 0     |      | 100   | pF    |
| TC <sub>REF+</sub>                                                                                                          | Temperature coefficient of built-in reference                                    | REFVSEL = {0, 1, 2}, INTREFEN = 1, T <sub>A</sub> = −40°C to 105°C <sup>(4)</sup>                                             | 3 V             | 24    |      | 50    | ppm/K |
| PSRR_DC                                                                                                                     | Power supply rejection ratio (DC)                                                | AV <sub>CC</sub> = AV <sub>CC (min)</sub> to AV <sub>CC(max)</sub> , T <sub>A</sub> = 25°C, REFVSEL = {0, 1, 2}, INTREFEN = 1 | 3 V             | 100   |      | 420   | μV/V  |
| PSRR_AC                                                                                                                     | Power supply rejection ratio (AC)                                                | ΔAV <sub>CC</sub> = 0.1 V at 1 kHz                                                                                            | 3 V             | 3.0   |      |       | mV/V  |
| t <sub>SETTLE</sub>                                                                                                         | Settling time of reference voltage <sup>(2)</sup>                                | AV <sub>CC</sub> = AV <sub>CC (min)</sub> to AV <sub>CC(max)</sub> , REFVSEL = {0, 1, 2}, INTREFEN = 0 → 1                    | 3 V             | 75    |      | 100   | μs    |

- (1) The internal reference current is supplied through the AVCC terminal.
- (2) The condition is that the error in a conversion started after t<sub>REFON</sub> is less than ±0.5 LSB.
- (3) The internal reference noise affects ADC performance when the ADC uses the internal reference.
- (4) Calculated using the box method: (MAX(-40°C to 105°C) – MIN(-40°C to 105°C)) / (105°C – (-40°C))

## 8.12.6 Timer\_A and Timer\_B

### 8.12.6.1 Timer\_A

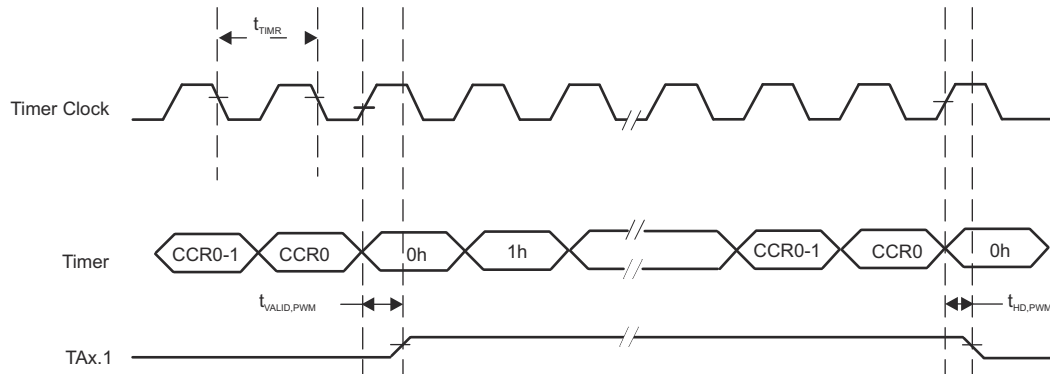
over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)

| PARAMETER                                     | TEST CONDITIONS                                                   | V <sub>CC</sub> | MIN | MAX | UNIT |
|-----------------------------------------------|-------------------------------------------------------------------|-----------------|-----|-----|------|
| f <sub>TA</sub> Timer_A input clock frequency | Internal: SMCLK, ACLK<br>External: TACLK<br>Duty cycle = 50% ±10% | 2 V, 3 V        |     | 16  | MHz  |
| t <sub>TA,cap</sub> Timer_A capture timing    | All capture inputs, minimum pulse duration required for capture   | 2 V, 3 V        | 20  |     | ns   |

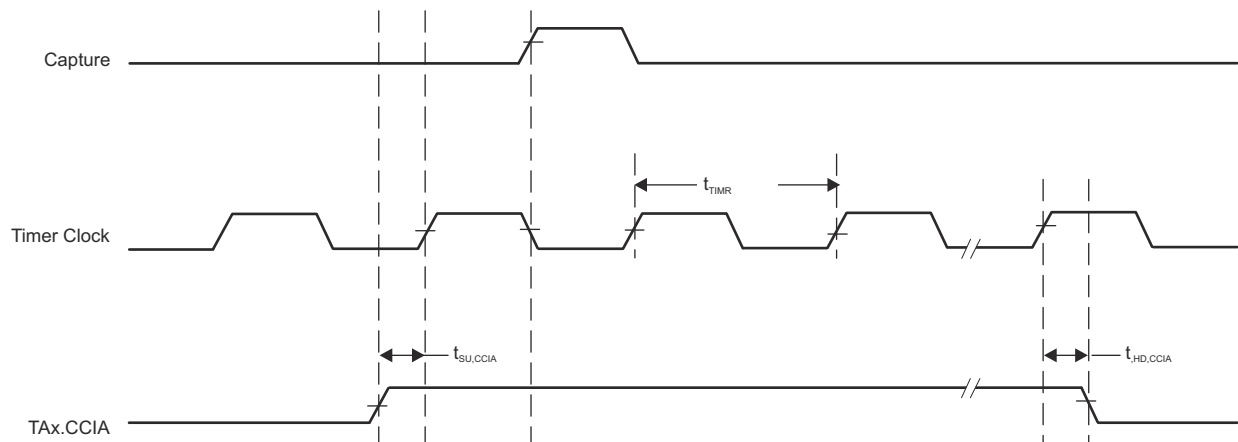
### 8.12.6.2 Timer\_B

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)

| PARAMETER                                     | TEST CONDITIONS                                                   | V <sub>CC</sub> | MIN | MAX | UNIT |
|-----------------------------------------------|-------------------------------------------------------------------|-----------------|-----|-----|------|
| f <sub>TB</sub> Timer_B input clock frequency | Internal: SMCLK, ACLK<br>External: TBCLK<br>Duty cycle = 50% ±10% | 2 V, 3 V        |     | 16  | MHz  |
| t <sub>TB,cap</sub> Timer_B capture timing    | All capture inputs, minimum pulse duration required for capture   | 2 V, 3 V        | 20  |     | ns   |



**Figure 8-11. Timer PWM Mode**



**Figure 8-12. Timer Capture Mode**

## 8.12.7 eUSCI

### 8.12.7.1 eUSCI (UART Mode) Clock Frequency

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)

| PARAMETER                                                              | TEST CONDITIONS                                                    | V <sub>CC</sub> | MIN | MAX | UNIT |
|------------------------------------------------------------------------|--------------------------------------------------------------------|-----------------|-----|-----|------|
| f <sub>eUSCI</sub> eUSCI input clock frequency                         | Internal: SMCLK, MODCLK<br>External: UCLK<br>Duty cycle = 50% ±10% | 2 V, 3 V        |     | 16  | MHz  |
| f <sub>BITCLK</sub> BITCLK clock frequency (equals baud rate in Mbaud) |                                                                    | 2 V, 3 V        |     | 5   | MHz  |

### 8.12.7.2 eUSCI (UART Mode) Timing Characteristics

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)

| PARAMETER                                                | TEST CONDITIONS | V <sub>CC</sub> | TYP | UNIT |
|----------------------------------------------------------|-----------------|-----------------|-----|------|
| t <sub>t</sub> UART receive deglitch time <sup>(1)</sup> | UCGLITx = 0     | 2 V, 3 V        | 12  | ns   |
|                                                          | UCGLITx = 1     |                 | 40  |      |
|                                                          | UCGLITx = 2     |                 | 68  |      |
|                                                          | UCGLITx = 3     |                 | 110 |      |

- (1) Pulses on the UART receive input (UCxRX) shorter than the UART receive deglitch time are suppressed. To ensure that pulses are correctly recognized, their duration should exceed the maximum specification of the deglitch time.

### 8.12.7.3 eUSCI (SPI Master Mode) Clock Frequency

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)

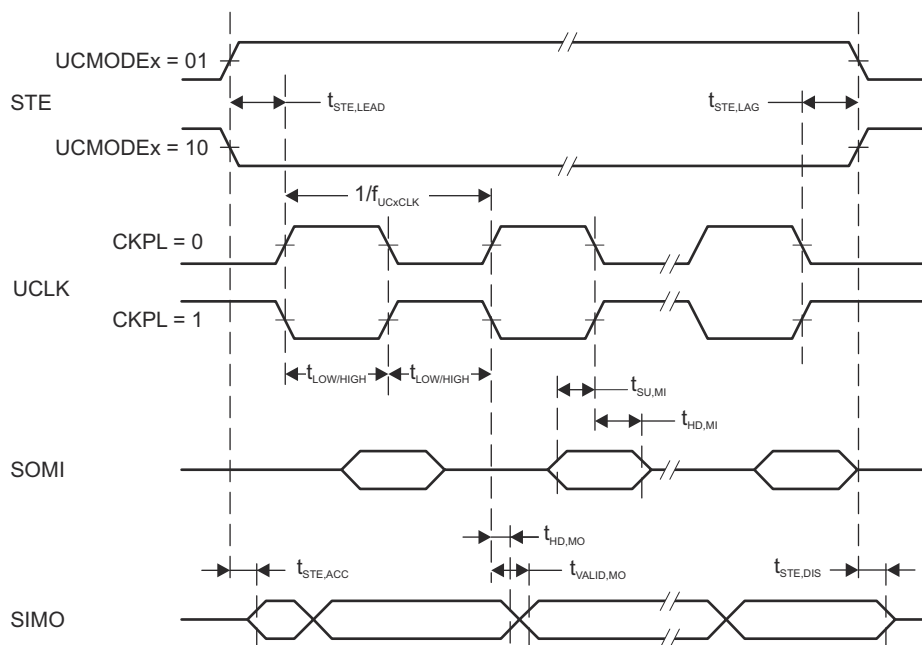
| PARAMETER                                      | TEST CONDITIONS                                  | MIN | MAX | UNIT |
|------------------------------------------------|--------------------------------------------------|-----|-----|------|
| f <sub>eUSCI</sub> eUSCI input clock frequency | Internal: SMCLK, MODCLK<br>Duty cycle = 50% ±10% |     | 8   | MHz  |

### 8.12.7.4 eUSCI (SPI Master Mode)

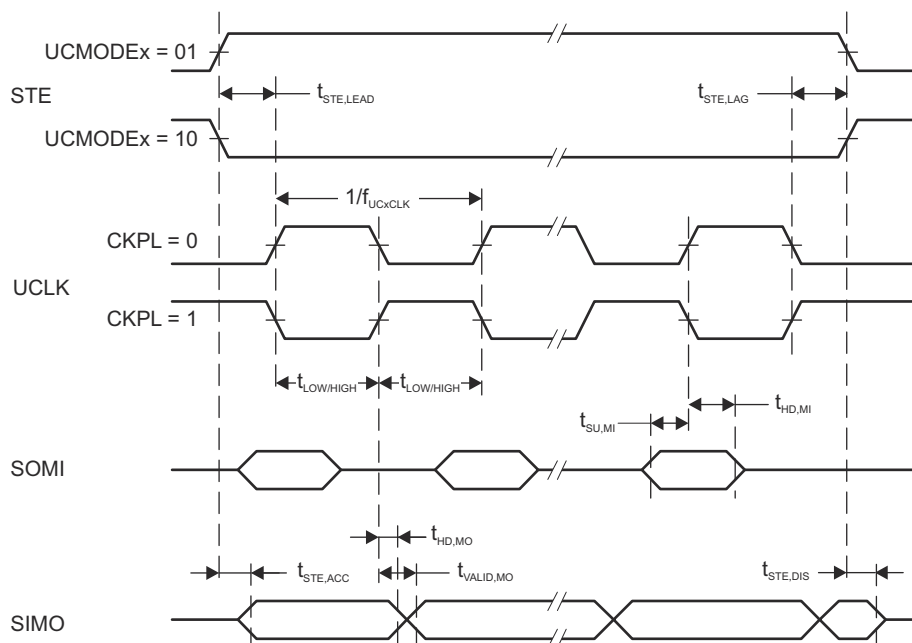
over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)<sup>(1)</sup>

| PARAMETER                                                        | TEST CONDITIONS                                 | V <sub>CC</sub> | MIN | MAX | UNIT          |
|------------------------------------------------------------------|-------------------------------------------------|-----------------|-----|-----|---------------|
| t <sub>STE,LEAD</sub> STE lead time, STE active to clock         | UCSTEM = 0, UCMODEx = 01 or 10                  |                 | 1   |     | UCxCLK cycles |
|                                                                  | UCSTEM = 1, UCMODEx = 01 or 10                  |                 |     |     |               |
| t <sub>STE,LAG</sub> STE lag time, last clock to STE inactive    | UCSTEM = 0, UCMODEx = 01 or 10                  |                 | 1   |     | UCxCLK cycles |
|                                                                  | UCSTEM = 1, UCMODEx = 01 or 10                  |                 |     |     |               |
| t <sub>SU,MI</sub> SOMI input data setup time                    |                                                 | 2 V             | 58  |     | ns            |
|                                                                  |                                                 | 3 V             | 40  |     |               |
| t <sub>HD,MI</sub> SOMI input data hold time                     |                                                 | 2 V             | 0   |     | ns            |
|                                                                  |                                                 | 3 V             | 0   |     |               |
| t <sub>VALID,MO</sub> SIMO output data valid time <sup>(2)</sup> | UCLK edge to SIMO valid, C <sub>L</sub> = 20 pF | 2 V             |     | 20  | ns            |
|                                                                  |                                                 | 3 V             |     | 20  |               |
| t <sub>HD,MO</sub> SIMO output data hold time <sup>(3)</sup>     | C <sub>L</sub> = 20 pF                          | 2 V             | -3  |     | ns            |
|                                                                  |                                                 | 3 V             | -3  |     |               |

- (1) f<sub>UCxCLK</sub> = 1/2t<sub>LO/HI</sub> with t<sub>LO/HI</sub> = max(t<sub>VALID,MO</sub>(eUSCI) + t<sub>SU,SI</sub>(Slave), t<sub>SU,MI</sub>(eUSCI) + t<sub>VALID,SO</sub>(Slave)). For the slave parameters t<sub>SU,SI</sub>(Slave) and t<sub>VALID,SO</sub>(Slave), see the SPI parameters of the attached slave.
- (2) Specifies the time to drive the next valid data to the SIMO output after the output changing UCLK clock edge. See the timing diagrams in [Figure 8-13](#) and [Figure 8-14](#).
- (3) Specifies how long data on the SIMO output is valid after the output changing UCLK clock edge. Negative values indicate that the data on the SIMO output can become invalid before the output changing clock edge observed on UCLK. Refer to the timing diagrams in [Figure 8-13](#) and [Figure 8-14](#).



**Figure 8-13. SPI Master Mode, CKPH = 0**



**Figure 8-14. SPI Master Mode, CKPH = 1**

### 8.12.7.5 eUSCI (SPI Slave Mode)

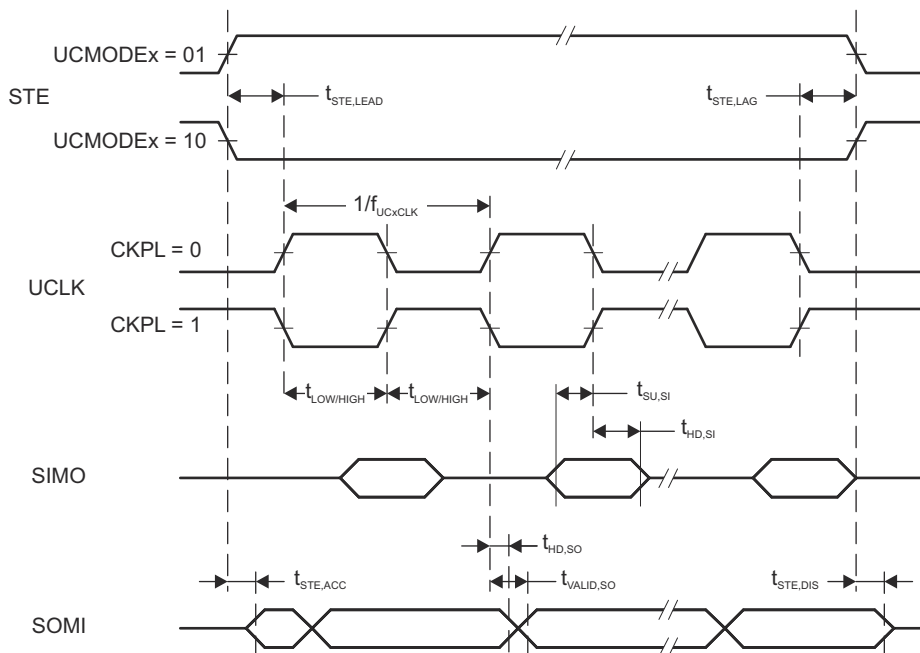
over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)<sup>(1)</sup>

| PARAMETER                                                                  | TEST CONDITIONS                                    | V <sub>CC</sub> | MIN | MAX | UNIT |
|----------------------------------------------------------------------------|----------------------------------------------------|-----------------|-----|-----|------|
| t <sub>STE,LEAD</sub> STE lead time, STE active to clock                   |                                                    | 2 V             | 55  |     | ns   |
|                                                                            |                                                    | 3 V             | 45  |     |      |
| t <sub>STE,LAG</sub> STE lag time, Last clock to STE inactive              |                                                    | 2 V             | 20  |     | ns   |
|                                                                            |                                                    | 3 V             | 20  |     |      |
| t <sub>STE,ACC</sub> STE access time, STE active to SOMI data out          |                                                    | 2 V             |     | 65  | ns   |
|                                                                            |                                                    | 3 V             |     | 40  |      |
| t <sub>STE,DIS</sub> STE disable time, STE inactive to SOMI high impedance |                                                    | 2 V             |     | 40  | ns   |
|                                                                            |                                                    | 3 V             |     | 35  |      |
| t <sub>SU,SI</sub> SIMO input data setup time                              |                                                    | 2 V             | 15  |     | ns   |
|                                                                            |                                                    | 3 V             | 6   |     |      |
| t <sub>HD,SI</sub> SIMO input data hold time                               |                                                    | 2 V             | 12  |     | ns   |
|                                                                            |                                                    | 3 V             | 12  |     |      |
| t <sub>VALID,SO</sub> SOMI output data valid time <sup>(2)</sup>           | UCLK edge to SOMI valid,<br>C <sub>L</sub> = 20 pF | 2 V             |     | 71  | ns   |
|                                                                            |                                                    | 3 V             |     | 42  |      |
| t <sub>HD,SO</sub> SOMI output data hold time <sup>(3)</sup>               | C <sub>L</sub> = 20 pF                             | 2 V             | 5   |     | ns   |
|                                                                            |                                                    | 3 V             | 5   |     |      |

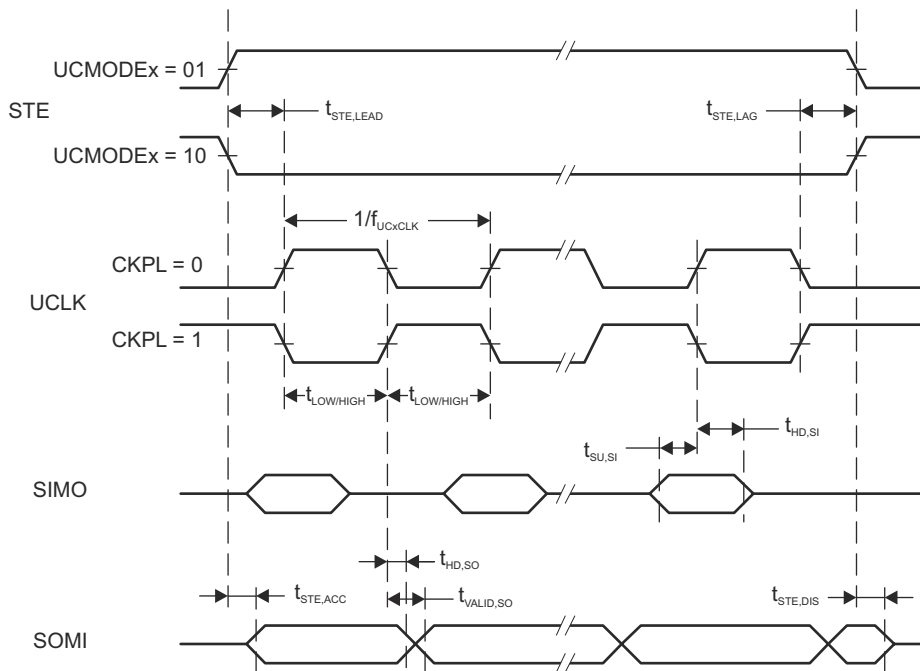
(1)  $f_{UCLK} = 1/2t_{LO/HI}$  with  $t_{LO/HI} \geq \max(t_{VALID,MO(Master)} + t_{SU,SI(eUSCI)}, t_{SU,MI(Master)} + t_{VALID,SO(eUSCI)})$ .

For the master parameters  $t_{SU,MI(Master)}$  and  $t_{VALID,MO(Master)}$ , see the SPI parameters of the attached master.

- (2) Specifies the time to drive the next valid data to the SOMI output after the output changing UCLK clock edge. See the timing diagrams in [Figure 8-15](#) and [Figure 8-16](#).
- (3) Specifies how long data on the SOMI output is valid after the output changing UCLK clock edge. Refer to the timing diagrams in [Figure 8-15](#) and [Figure 8-16](#).



**Figure 8-15. SPI Slave Mode, CKPH = 0**

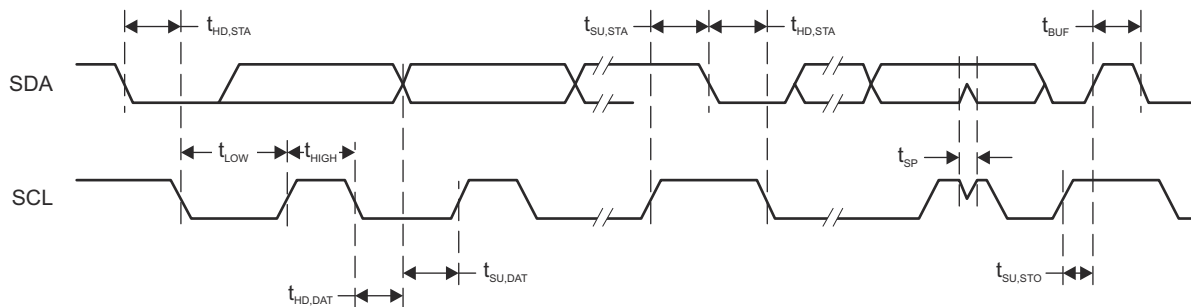


**Figure 8-16. SPI Slave Mode, CKPH = 1**

### 8.12.7.6 eUSCI (I<sup>2</sup>C Mode)

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted) (see [Figure 8-17](#))

| PARAMETER                                                           | TEST CONDITIONS                                                    | V <sub>CC</sub> | MIN        | TYP | MAX | UNIT |
|---------------------------------------------------------------------|--------------------------------------------------------------------|-----------------|------------|-----|-----|------|
| f <sub>eUSCI</sub> eUSCI input clock frequency                      | Internal: SMCLK, MODCLK<br>External: UCLK<br>Duty cycle = 50% ±10% |                 |            |     | 16  | MHz  |
| f <sub>SCL</sub> SCL clock frequency                                |                                                                    | 2 V, 3 V        | 0          |     | 400 | kHz  |
| t <sub>HD,STA</sub> Hold time (repeated) START                      | f <sub>SCL</sub> = 100 kHz<br>f <sub>SCL</sub> > 100 kHz           | 2 V, 3 V        | 4.0<br>0.6 |     |     | μs   |
| t <sub>SU,STA</sub> Setup time for a repeated START                 | f <sub>SCL</sub> = 100 kHz<br>f <sub>SCL</sub> > 100 kHz           | 2 V, 3 V        | 4.7<br>0.6 |     |     | μs   |
| t <sub>HD,DAT</sub> Data hold time                                  |                                                                    | 2 V, 3 V        | 0          |     |     | ns   |
| t <sub>SU,DAT</sub> Data setup time                                 |                                                                    | 2 V, 3 V        | 250        |     |     | ns   |
| t <sub>SU,STO</sub> Setup time for STOP                             | f <sub>SCL</sub> = 100 kHz<br>f <sub>SCL</sub> > 100 kHz           | 2 V, 3 V        | 4.0<br>0.6 |     |     | μs   |
| t <sub>SP</sub> Pulse duration of spikes suppressed by input filter | UCGLITx = 0                                                        | 2 V, 3 V        | 50         |     | 600 | ns   |
|                                                                     | UCGLITx = 1                                                        |                 | 25         |     | 300 |      |
|                                                                     | UCGLITx = 2                                                        |                 | 12.5       |     | 150 |      |
|                                                                     | UCGLITx = 3                                                        |                 | 6.3        |     | 75  |      |
| t <sub>TIMEOUT</sub> Clock low time-out                             | UCCLTOx = 1                                                        | 2 V, 3 V        |            | 27  |     | ms   |
|                                                                     | UCCLTOx = 2                                                        |                 |            | 30  |     |      |
|                                                                     | UCCLTOx = 3                                                        |                 |            | 33  |     |      |



**Figure 8-17. I<sup>2</sup>C Mode Timing**

## 8.12.8 ADC

### 8.12.8.1 ADC, Power Supply and Input Range Conditions

over operating free-air temperature range (unless otherwise noted)

| PARAMETER                                                                                                                | TEST CONDITIONS                                                                                                    | V <sub>CC</sub> | MIN | TYP | MAX              | UNIT |
|--------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------|-----------------|-----|-----|------------------|------|
| DV <sub>CC</sub> ADC supply voltage                                                                                      |                                                                                                                    |                 | 2.0 |     | 3.6              | V    |
| V <sub>(Ax)</sub> Analog input voltage range                                                                             | All ADC pins                                                                                                       |                 | 0   |     | DV <sub>CC</sub> | V    |
| I <sub>ADC</sub> Operating supply current into DVCC terminal, reference current not included, repeat-single-channel mode | f <sub>ADCCLK</sub> = 5 MHz, ADCON = 1, REFON = 0, SHT0 = 0, SHT1 = 0, ADCDIV = 0, ADCCONSEQx = 10b                | 2.0 V           |     | 220 |                  | μA   |
|                                                                                                                          |                                                                                                                    | 3.0 V           |     | 277 |                  |      |
| C <sub>I</sub> Input capacitance                                                                                         | Only one terminal Ax can be selected at one time from the pad to the ADC capacitor array, including wiring and pad | 2.2 V           |     | 4.5 | 5.5              | pF   |
| R <sub>I</sub> Input MUX ON resistance                                                                                   | DV <sub>CC</sub> = 2 V, 0 V ≤ V <sub>Ax</sub> ≤ DV <sub>CC</sub>                                                   |                 |     |     | 2                | kΩ   |

### 8.12.8.2 ADC, Timing Parameters

over operating free-air temperature range (unless otherwise noted)

| PARAMETER                                           | TEST CONDITIONS                                                                                                                                                                                  | V <sub>CC</sub> | MIN  | TYP | MAX | UNIT |
|-----------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|------|-----|-----|------|
| f <sub>ADCCLK</sub>                                 | For specified performance of ADC linearity parameters, 10-bit mode                                                                                                                               | 2.4 V to 3.6 V  |      | 6   |     | MHz  |
|                                                     | For specified performance of ADC linearity parameters, 12-bit mode                                                                                                                               | 2.4 V to 3.6 V  |      | 4.4 |     |      |
| t <sub>CONVERT</sub> Conversion time                | External f <sub>ADCCLK</sub> from ACLK, MCLK, or SMCLK, ADCSSEL ≠ 0                                                                                                                              | 2.4 V to 3.6 V  |      | (2) |     | μs   |
| t <sub>ADCON</sub> Turn-on settling time of the ADC | The error in a conversion started after t <sub>ADCON</sub> is less than ±0.5 LSB, Reference and input signal already settled                                                                     |                 |      |     | 100 | ns   |
| t <sub>Sample</sub> Sampling time                   | R <sub>S</sub> = 1000 Ω, R <sub>I</sub> = 20000 Ω, C <sub>I</sub> = 5.5 pF, C <sub>EXT</sub> = 8 pF, Approximately 7.62 Tau (t) are required for an error of less than ±0.5 LSB, 10-bit mode.(3) | 2.4 V to 3.6 V  | 0.52 |     |     | μs   |
|                                                     | R <sub>S</sub> = 1000 Ω, R <sub>I</sub> = 40000 Ω, C <sub>I</sub> = 5.5 pF, C <sub>EXT</sub> = 8 pF, Approximately 9.01 Tau (t) are required for an error of less than ±0.5 LSB, 12-bit mode.(3) | 2.4 V to 3.6 V  | 0.61 |     |     |      |

(1)  $12 \times 1/f_{ADCCLK}$

(2)  $(n + 2) \times 1/f_{ADCCLK}$ , n = ADC resolution (8, 10, 12)

(3)  $t_{Sample} = \ln(2^{n+1}) \times \tau$ , where n = ADC resolution,  $\tau = (R_I + R_S) \times C_I$

### 8.12.8.3 ADC, Linearity Parameters

over operating free-air temperature range (unless otherwise noted)

| PARAMETER      |                                            | TEST CONDITIONS                                                                                          | V <sub>CC</sub> | MIN  | TYP | MAX | UNIT |
|----------------|--------------------------------------------|----------------------------------------------------------------------------------------------------------|-----------------|------|-----|-----|------|
| E <sub>I</sub> | Integral linearity error (12-bit mode)     | V <sub>ref+</sub> reference                                                                              | 2.4 V to 3.6 V  | –2.5 |     | 2.5 | LSB  |
|                | Integral linearity error (10-bit mode)     | V <sub>ref+</sub> reference                                                                              | 2.4 V to 3.6 V  | –2   |     | 2   |      |
| E <sub>D</sub> | Differential linearity error (12-bit mode) | V <sub>ref+</sub> reference                                                                              | 2.4 V to 3.6 V  | –1   |     | 1.5 | LSB  |
|                | Differential linearity error (10-bit mode) | V <sub>ref+</sub> reference                                                                              | 2.4 V to 3.6 V  | –1   |     | 1.5 |      |
| E <sub>O</sub> | Offset error (12-bit mode)                 | V <sub>ref+</sub> reference, TLV calibration data can be used to improve the parameter <sup>(2)</sup>    | 2.4 V to 3.6 V  | –4.0 |     | 4.0 | mV   |
|                | Offset error (10-bit mode)                 | V <sub>ref+</sub> reference, TLV calibration data can be used to improve the parameter <sup>(2)</sup>    | 2.4 V to 3.6 V  | –4.0 |     | 4.0 |      |
| E <sub>G</sub> | Gain error (12-bit mode)                   | V <sub>ref+</sub> as reference, TLV calibration data can be used to improve the parameter <sup>(2)</sup> | 2.4 V to 3.6 V  | –9.0 |     | 9.0 | LSB  |
|                | Gain error (10-bit mode)                   | V <sub>ref+</sub> as reference, TLV calibration data can be used to improve the parameter <sup>(2)</sup> | 2.4 V to 3.6 V  | –3.0 |     | 3.0 | LSB  |
| E <sub>T</sub> | Total unadjusted error (12-bit mode)       | V <sub>ref+</sub> as reference, TLV calibration data can be used to improve the parameter <sup>(2)</sup> | 2.4 V to 3.6 V  | –5.0 |     | 5.0 | LSB  |
|                | Total unadjusted error (10-bit mode)       | V <sub>ref+</sub> as reference, TLV calibration data can be used to improve the parameter <sup>(2)</sup> | 2.4 V to 3.6 V  | –2.0 |     | 2.0 | LSB  |

(1) The typical equivalent impedance of the sensor is 700 kΩ. The sample time required includes the sensor on time,  $t_{\text{SENSOR(on)}}$ .

(2) For details, see the device descriptor in the [MP430FR4xx and MP430FR2xx Family User's Guide](#), and see [Designing With the MP430FR4xx and MP430FR2xx ADC](#) application note for details on optimizing ADC performance for your application with the choice of internal or external reference.



## 8.12.10 CapTIvate

### 8.12.10.1 CapTIvate Electrical Characteristics

over operating free-air temperature range, unless otherwise noted.

| PARAMETER                                 |                                                                                                                  | TEST CONDITIONS                                         | MIN  | TYP  | MAX              | UNIT  |
|-------------------------------------------|------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------|------|------|------------------|-------|
| V <sub>REG</sub>                          | Reference voltage output                                                                                         | I <sub>LOAD</sub> = 1.5 µA to 2 mA, after trim          | 1.5  | 1.55 | 1.6              | V     |
| C <sub>REG</sub>                          | External buffer capacitor                                                                                        | ESR ≤ 200 mΩ                                            | 0.8  | 1    | 1.2              | µF    |
| C <sub>ELECTRODE</sub>                    | Total capacitance of all external electrodes on all CapTIvate blocks                                             | Running a conversion at 4 MHz                           |      |      | 300              | pF    |
| t <sub>WAKEUP,COLD</sub>                  | Voltage regulator wake-up time                                                                                   | LDO off and then turned on                              |      | 700  |                  | µs    |
| t <sub>WAKEUP,WARM</sub>                  | Voltage regulator wake-up time                                                                                   | LDO in low-power mode and then turned on                |      | 260  |                  | µs    |
| f <sub>CAPCLK</sub>                       | CapTIvate oscillator frequency, nominal                                                                          | T <sub>A</sub> = 25°C, CAPCLK0.FREQSHFT = 00b           |      | 16   |                  | MHz   |
| DC <sub>CAPCLK</sub>                      | CapTIvate oscillator duty cycle                                                                                  | Excluding first clock cycle, DC = t <sub>high</sub> × f | 40%  | 50%  | 60%              |       |
| CapTIvate I/O voltage range allowed       |                                                                                                                  | Use internal regulator for sensing (VREGSEL = 00b)      | -0.3 |      | V <sub>REG</sub> | V     |
|                                           |                                                                                                                  | Use DVCC for sensing (VREGSEL = 01b)                    | -0.3 |      | DVCC             |       |
| DVCC range allowed                        |                                                                                                                  | Capacitive sensing using internal LDO (VREGSEL = 00b)   | 1.8  |      | 3.6              | V     |
|                                           |                                                                                                                  | Capacitive sensing using DVCC (VREGSEL = 01b)           | 2.7  |      | 3.6              |       |
| DVCC C <sub>p</sub> :C <sub>m</sub> ratio | Ratio of RX parasitic capacitance (C <sub>p</sub> ) to RX-TX mutual capacitance (C <sub>m</sub> ) <sup>(1)</sup> | CapTIvate module in mutual capacitance measurement mode | 10:1 |      | 100:1            | ratio |

- (1) The ratio of the parasitic RX-GND capacitance C<sub>p</sub> to the mutual RX-TX capacitance C<sub>m</sub> must be larger than the minimum specified value to prevent an over voltage condition on the RX pin. This parameter only applied in mutual capacitance mode.

### 8.12.10.2 CapTIvate Signal-to-Noise Ratio Characteristics

over operating free-air temperature range from -40°C to 105°C ambient (T<sub>A</sub>), unless otherwise noted.

| PARAMETER |                                      | TEST CONDITIONS                                                                                      | MIN  | TYP  | MAX | UNIT |
|-----------|--------------------------------------|------------------------------------------------------------------------------------------------------|------|------|-----|------|
| SNR       | Signal-to-noise ratio <sup>(1)</sup> | T <sub>A</sub> = 25°C, C <sub>t</sub> > 0.5 pF, C <sub>p</sub> < 20 pF, >2.5% change in capacitance  | 13:1 | 42:1 |     |      |
|           |                                      | T <sub>A</sub> = -40°C, C <sub>t</sub> > 0.5 pF, C <sub>p</sub> < 20 pF, >2.5% change in capacitance |      | 28:1 |     |      |

- (1) SNR is defined as the ratio of the measured change in electrode capacitance due to a touch compared with measured change in capacitance due to the device noise floor. For additional detail on SNR in capacitive sensing applications and how to measure it in your system, see [Sensitivity, SNR, and Design Margin in Capacitive Touch Applications](#).

## 8.12.11 FRAM

### 8.12.11.1 FRAM Characteristics

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)

| PARAMETER                                      | TEST CONDITIONS        | MIN              | TYP                                    | MAX | UNIT   |
|------------------------------------------------|------------------------|------------------|----------------------------------------|-----|--------|
| Read and write endurance                       |                        | 10 <sup>15</sup> |                                        |     | cycles |
| t <sub>Retention</sub> Data retention duration | T <sub>J</sub> = 25°C  | 100              |                                        |     | years  |
|                                                | T <sub>J</sub> = 70°C  | 40               |                                        |     |        |
|                                                | T <sub>J</sub> = 95°C  | 10               |                                        |     |        |
|                                                | T <sub>J</sub> = 115°C | 10               |                                        |     |        |
| I <sub>WRITE</sub> Current to write into FRAM  |                        |                  | I <sub>READ</sub> <sup>(1)</sup>       |     | nA     |
| I <sub>ERASE</sub> Erase current               |                        |                  | N/A <sup>(2)</sup>                     |     | nA     |
| t <sub>WRITE</sub> Write time                  |                        |                  | t <sub>READ</sub> <sup>(3)</sup>       |     | ns     |
| t <sub>READ</sub> Read time                    | NWAITSx = 0            |                  | 1 / f <sub>SYSTEM</sub> <sup>(4)</sup> |     | ns     |
|                                                | NWAITSx = 1            |                  | 2 / f <sub>SYSTEM</sub> <sup>(4)</sup> |     |        |

- (1) Writing to FRAM does not require a setup sequence or additional power when compared to reading from FRAM. The FRAM read current I<sub>READ</sub> is included in the active mode current consumption parameter I<sub>AM,FRAM</sub>.
- (2) FRAM does not require a special erase sequence.
- (3) Writing into FRAM is as fast as reading.
- (4) The maximum read (and write) speed is specified by f<sub>SYSTEM</sub> using the appropriate wait state settings (NWAITSx).

## 8.12.12 Debug and Emulation

### 8.12.12.1 JTAG, 4-Wire and Spy-Bi-Wire Interface

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)

| PARAMETER                                                                                                                                      | V <sub>CC</sub> | MIN  | TYP | MAX | UNIT |
|------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|------|-----|-----|------|
| f <sub>SBW</sub> Spy-Bi-Wire input frequency                                                                                                   | 2.2 V, 3.0 V    | 0    |     | 8   | MHz  |
| t <sub>SBW,Low</sub> Spy-Bi-Wire low clock pulse duration                                                                                      | 2.2 V, 3.0 V    | 0.04 |     | 15  | μs   |
| t <sub>SBW,En</sub> Spy-Bi-Wire enable time (TEST high to acceptance of first clock edge) <sup>(1)</sup>                                       | 2.2 V, 3.0 V    |      |     | 100 | μs   |
| t <sub>SBW,Rst</sub> Spy-Bi-Wire return to normal operation time                                                                               |                 | 15   |     | 100 | μs   |
| f <sub>TCK</sub> TCK input frequency, 4-wire JTAG <sup>(2)</sup>                                                                               | 2.2 V           | 0    |     | 10  | MHz  |
|                                                                                                                                                | 3.0 V           | 0    |     | 10  | MHz  |
| R <sub>internal</sub> Internal pulldown resistance on TEST                                                                                     | 2.2 V, 3.0 V    | 20   | 35  | 50  | kΩ   |
| f <sub>TCLK</sub> TCLK/MCLK frequency during JTAG access, no FRAM access (limited by f <sub>SYSTEM</sub> )                                     |                 |      |     | 16  | MHz  |
| t <sub>TCLK,Low/High</sub> TCLK low or high clock pulse duration, no FRAM access                                                               |                 |      |     | 25  | ns   |
| f <sub>TCLK,FRAM</sub> TCLK/MCLK frequency during JTAG access, including FRAM access (limited by f <sub>SYSTEM</sub> with no FRAM wait states) |                 |      |     | 4   | MHz  |
| t <sub>TCLK,FRAM,Low/High</sub> TCLK low or high clock pulse duration, including FRAM accesses                                                 |                 |      |     | 100 | ns   |

- (1) Tools that access the Spy-Bi-Wire and BSL interfaces must wait for the t<sub>SBW,En</sub> time after the first transition of the TEST/SBW<sub>TCK</sub> pin (low to high), before the second transition of the pin (high to low) during the entry sequence.
- (2) f<sub>TCK</sub> may be restricted to meet the timing requirements of the module selected.

## 9 Detailed Description

### 9.1 Overview

The MSP430FR267x ultra-low-power MCUs are FRAM-based MCUs with integrated high-performance charge-transfer CapTivate technology in ultra-low-power high-reliability high-flexibility MCUs. The MSP430FR267x MCU features up to 16 self-capacitance or 64 mutual-capacitance electrodes, proximity sensing, and high accuracy up to 1-ff detection. The MCUs also include five 16-bit timers, four eUSCs that support UART, SPI, and I<sup>2</sup>C, a hardware multiplier, an RTC module, and a high-performance 12-bit ADC, an enhanced comparator with built in 6-bit DAC for internal voltage reference ..

### 9.2 CPU

The MSP430™ CPU has a 16-bit RISC architecture that is highly transparent to the application. All operations, other than program-flow instructions, are performed as register operations in conjunction with seven addressing modes for source operand and four addressing modes for destination operand.

The CPU is integrated with 16 registers that provide reduced instruction execution time. The register-to-register operation execution time is one cycle of the CPU clock.

Four of the registers, R0 to R3, are dedicated as program counter (PC), stack pointer (SP), status register (SR), and constant generator (CG), respectively. The remaining registers are general-purpose registers.

Peripherals are connected to the CPU using data, address, and control buses. Peripherals can be handled with all instructions.

### 9.3 Operating Modes

The MSP430 has one active mode and several software-selectable low-power modes of operation (see [Table 9-1](#)). An interrupt event can wake the MCU from low-power mode LPM0, LPM3 or LPM4, service the request, and restore the MCU back to the low-power mode on return from the interrupt program. Low-power modes LPM3.5 and LPM4.5 disable the core supply to minimize power consumption.

---

#### Note

XT1CLK and VLOCLK can be active during LPM4 mode if requested by low-frequency peripherals, such as RTC, WDT, and CapTivate .

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**Table 9-1. Operating Modes**

| MODE                           |                              | AM                    | LPM0            | LPM3                                  | LPM4                | LPM3.5                                | LPM4.5            |
|--------------------------------|------------------------------|-----------------------|-----------------|---------------------------------------|---------------------|---------------------------------------|-------------------|
|                                |                              | ACTIVE MODE (FRAM ON) | CPU OFF         | STANDBY                               | OFF                 | ONLY RTC                              | SHUTDOWN          |
| Maximum system clock           |                              | 16 MHz                | 16 MHz          | 40 kHz                                | 0                   | 40 kHz                                | 0                 |
| Power consumption at 25°C, 3 V |                              | 135 µA/MHz            | 40 µA/MHz       | < 5 µA wake-on-touch with two sensors | 0.74 µA without SVS | 0.66 µA with RTC counter only in LFXT | 41 nA without SVS |
| Wake-up time                   |                              | N/A                   | Instant         | 10 µs                                 | 10 µs               | 350 µs                                | 350 µs            |
| Wake-up events                 |                              | N/A                   | All             | All                                   | CapTlvate or I/O    | RTC or I/O                            | I/O               |
| Power                          | Regulator                    | Full regulation       | Full regulation | Partial power down                    | Partial power down  | Partial power down                    | Power down        |
|                                | SVS                          | On                    | On              | Optional                              | Optional            | Optional                              | Optional          |
|                                | Brownout                     | On                    | On              | On                                    | On                  | On                                    | On                |
| Clock <sup>(2)</sup>           | MCLK                         | Active                | Off             | Off                                   | Off                 | Off                                   | Off               |
|                                | SMCLK                        | Optional              | Optional        | Off                                   | Off                 | Off                                   | Off               |
|                                | FLL                          | Optional              | Optional        | Off                                   | Off                 | Off                                   | Off               |
|                                | DCO                          | Optional              | Optional        | Off                                   | Off                 | Off                                   | Off               |
|                                | MODCLK                       | Optional              | Optional        | Off                                   | Off                 | Off                                   | Off               |
|                                | REFO                         | Optional              | Optional        | Optional                              | Off                 | Off                                   | Off               |
|                                | ACLK                         | Optional              | Optional        | Optional                              | Off                 | Off                                   | Off               |
|                                | XT1CLK                       | Optional              | Optional        | Optional                              | Off                 | Optional                              | Off               |
|                                | VLOCLK                       | Optional              | Optional        | Optional                              | Off                 | Optional                              | Off               |
|                                | CapTlvate MODCLK             | Optional              | Optional        | Optional                              | Off                 | Off                                   | Off               |
| Core                           | CPU                          | On                    | Off             | Off                                   | Off                 | Off                                   | Off               |
|                                | FRAM                         | On                    | On              | Off                                   | Off                 | Off                                   | Off               |
|                                | RAM                          | On                    | On              | On                                    | On                  | Off                                   | Off               |
|                                | Backup memory <sup>(1)</sup> | On                    | On              | On                                    | On                  | On                                    | Off               |
| Peripherals                    | Timer0_A3                    | Optional              | Optional        | Optional                              | Off                 | Off                                   | Off               |
|                                | Timer1_A3                    | Optional              | Optional        | Optional                              | Off                 | Off                                   | Off               |
|                                | Timer2_A3                    | Optional              | Optional        | Optional                              | Off                 | Off                                   | Off               |
|                                | Timer3_A3                    | Optional              | Optional        | Optional                              | Off                 | Off                                   | Off               |
|                                | Timer0_B7                    | Optional              | Optional        | Optional                              | Off                 | Off                                   | Off               |
|                                | WDT                          | Optional              | Optional        | Optional                              | Off                 | Off                                   | Off               |
|                                | eUSCI_A0                     | Optional              | Optional        | Optional                              | Off                 | Off                                   | Off               |
|                                | eUSCI_A1                     | Optional              | Optional        | Optional                              | Off                 | Off                                   | Off               |
|                                | eUSCI_B0                     | Optional              | Optional        | Optional                              | Off                 | Off                                   | Off               |
|                                | eUSCI_B1                     | Optional              | Optional        | Optional                              | Off                 | Off                                   | Off               |
|                                | CRC                          | Optional              | Optional        | Off                                   | Off                 | Off                                   | Off               |
|                                | ADC                          | Optional              | Optional        | Optional                              | Off                 | Off                                   | Off               |
|                                | RTC                          | Optional              | Optional        | Optional                              | Off                 | Optional                              | Off               |
|                                | CapTlvate                    | Optional              | Optional        | Optional                              | Off                 | Off                                   | Off               |
| I/O                            | GPIO                         | On                    | Optional        | State held                            | State held          | State held                            | State held        |

(1) Backup memory contains 32 bytes of register space in peripheral memory. See [Table 9-32](#) and [Table 9-54](#) for its memory allocation.

(2) The status shown for LPM4 applies to internal clocks only.

## 9.4 Interrupt Vector Addresses

The interrupt vectors and the power-up start address are in the address range 0FFFFh to 0FF80h (see [Table 9-2](#)). The vector contains the 16-bit address of the appropriate interrupt-handler instruction sequence.

**Table 9-2. Interrupt Sources, Flags, and Vectors**

| INTERRUPT SOURCE                                                                                                                                                                                                       | INTERRUPT FLAG                                                                                                                                                                                                  | SYSTEM INTERRUPT | WORD ADDRESS | PRIORITY    |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|--------------|-------------|
| <b>System Reset</b><br>Power up, Brownout, Supply supervisor<br>External reset $\overline{RST}$<br>Watchdog time-out, key violation<br>FRAM uncorrectable bit error detection<br>Software POR, BOR<br>FLL unlock error | SVSHIFG<br>PMMRSTIFG<br>WDTIFG<br>PMMPORIFG, PMMBORIFG<br>SYSRSTIV<br>FLLUNLOCKIFG                                                                                                                              | Reset            | FFFEh        | 63, Highest |
| <b>System NMI</b><br>Vacant memory access<br>JTAG mailbox<br>FRAM access time error<br>FRAM bit error detection                                                                                                        | VMAIFG<br>JMBINIFG, JMBOUTIFG<br>CBDIFG, UBDIFG                                                                                                                                                                 | Nonmaskable      | FFFCh        | 62          |
| <b>User NMI</b><br>External NMI<br>Oscillator fault                                                                                                                                                                    | NMIFG<br>OFIFG                                                                                                                                                                                                  | Nonmaskable      | FFFAh        | 61          |
| Timer0_A3                                                                                                                                                                                                              | TA0CCR0 CCIFG0                                                                                                                                                                                                  | Maskable         | FFF8h        | 60          |
| Timer0_A3                                                                                                                                                                                                              | TA0CCR1 CCIFG1, TA0CCR2 CCIFG2, TA0IFG (TA0IV)                                                                                                                                                                  | Maskable         | FFF6h        | 59          |
| Timer1_A3                                                                                                                                                                                                              | TA1CCR0 CCIFG0                                                                                                                                                                                                  | Maskable         | FFF4h        | 58          |
| Timer1_A3                                                                                                                                                                                                              | TA1CCR1 CCIFG1, TA1CCR2 CCIFG2, TA1IFG (TA1IV)                                                                                                                                                                  | Maskable         | FFF2h        | 57          |
| Time2_A3                                                                                                                                                                                                               | TA2CCR0 CCIFG0                                                                                                                                                                                                  | Maskable         | FFF0h        | 56          |
| Timer2_A3                                                                                                                                                                                                              | TA2CCR1 CCIFG1, TA2CCR2 CCIFG2, TA2IFG (TA2IV)                                                                                                                                                                  | Maskable         | FFEEh        | 55          |
| Timer3_A3                                                                                                                                                                                                              | TA3CCR0 CCIFG0                                                                                                                                                                                                  | Maskable         | FFECh        | 54          |
| Timer3_A3                                                                                                                                                                                                              | TA3CCR1 CCIFG1, TA3CCR2 CCIFG2, TA3IFG (TA3IV)                                                                                                                                                                  | Maskable         | FFEAh        | 53          |
| Timer0_B7                                                                                                                                                                                                              | TB0CCR0 CCIFG0                                                                                                                                                                                                  | Maskable         | FFE8h        | 52          |
| Timer0_B7                                                                                                                                                                                                              | TB0CCR1 CCIFG1, TB0CCR2 CCIFG2, TB0CCR3 CCIFG3, TB0CCR4 CCIFG4, TB0CCR5 CCIFG5, TB0CCR6 CCIFG6, TB0IFG (TB0IV)                                                                                                  | Maskable         | FFE6h        | 51          |
| RTC                                                                                                                                                                                                                    | RTCIFG                                                                                                                                                                                                          | Maskable         | FFE4h        | 50          |
| Watchdog timer interval mode                                                                                                                                                                                           | WDTIFG                                                                                                                                                                                                          | Maskable         | FFE2h        | 49          |
| eUSCI_A0 receive or transmit                                                                                                                                                                                           | UCTXCPTIFG, UCSTTIFG, UCRXIFG, UCTXIFG (UART mode)<br>UCRXIFG, UCTXIFG (SPI mode) (UCA0IV)                                                                                                                      | Maskable         | FFE0h        | 48          |
| eUSCI_A1 receive or transmit                                                                                                                                                                                           | UCTXCPTIFG, UCSTTIFG, UCRXIFG, UCTXIFG (UART mode)<br>UCRXIFG, UCTXIFG (SPI mode) (UCA0IV)                                                                                                                      | Maskable         | FFDEh        | 47          |
| eUSCI_B0 receive or transmit                                                                                                                                                                                           | UCB0RXIFG, UCB0TXIFG (SPI mode)<br>UCALIFG, UCNACKIFG, UCSTTIFG, UCSTPIFG, UCRXIFG0, UCTXIFG0, UCRXIFG1, UCTXIFG1, UCRXIFG2, UCTXIFG2, UCRXIFG3, UCTXIFG3, UCCNTIFG, UCBIT9IFG (I <sup>2</sup> C mode) (UCB0IV) | Maskable         | FFDCh        | 46          |

**Table 9-2. Interrupt Sources, Flags, and Vectors (continued)**

| INTERRUPT SOURCE             | INTERRUPT FLAG                                                                                                                                                                                                                 | SYSTEM INTERRUPT | WORD ADDRESS | PRIORITY   |
|------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|--------------|------------|
| eUSCI_B1 receive or transmit | UCB1RXIFG, UCB1TXIFG (SPI mode)<br>UCALIFG, UCNACKIFG, UCSTTIFG,<br>UCSTPIFG, UCRXIFG0, UCTXIFG0,<br>UCRXIFG1, UCTXIFG1, UCRXIFG2,<br>UCTXIFG2, UCRXIFG3, UCTXIFG3,<br>UCCNTIFG, UCBIT9IFG (I <sup>2</sup> C mode)<br>(UCB0IV) | Maskable         | FFDAh        | 45         |
| ADC                          | ADCIFG0, ADCINIFG, ADCLOIFG,<br>ADCHIFG, ADCTOVIFG, ADCOVIFG<br>(ADCIV)                                                                                                                                                        | Maskable         | FFD8h        | 44         |
| P1                           | P1IFG.0 to P1IFG.7 (P1IV)                                                                                                                                                                                                      | Maskable         | FFD6h        | 43         |
| P2                           | P2IFG.0 to P2IFG.7 (P2IV)                                                                                                                                                                                                      | Maskable         | FFD4h        | 42         |
| P3                           | P3IFG.0 to P2IFG.7 (P3IV)                                                                                                                                                                                                      | Maskable         | FFD2h        | 41         |
| P4                           | P4IFG.0 to P4IFG.7 (P4IV)                                                                                                                                                                                                      | Maskable         | FFD0h        | 40         |
| P5                           | P5IFG.0 to P5IFG.7 (P5IV)                                                                                                                                                                                                      | Maskable         | FFCEh        | 39         |
| P6                           | P6IFG.0 to P6IFG.2 (P6IV)                                                                                                                                                                                                      | Maskable         | FFCCh        | 38         |
| eCOMP0                       | CPIIFG, CPIFG (CP0IV)                                                                                                                                                                                                          | Maskable         | FFCAh        | 37         |
| CapTivate                    | (see <a href="#">CapTivate Design Center</a> for<br>details)                                                                                                                                                                   | Maskable         | FFC8h        | 36, Lowest |
| Reserved                     | Reserved                                                                                                                                                                                                                       | Maskable         | FFC6h–FF88h  |            |

**Table 9-3. Signatures**

| SIGNATURE                      | WORD ADDRESS |
|--------------------------------|--------------|
| BSL I2C Address <sup>(1)</sup> | 0FFA0h       |
| BSL Config                     | 0FF8Ah       |
| BSL Config Signature           | 0FF88h       |
| BSL Signature2                 | 0FF86h       |
| BSL Signature1                 | 0FF84h       |
| JTAG Signature2                | 0FF82h       |
| JTAG Signature1                | 0FF80h       |

(1) 7-bit address BSL I<sup>2</sup>C interface

## 9.5 Bootloader (BSL)

The BSL lets users program the FRAM or RAM using either the UART serial interface or the I<sup>2</sup>C interface. Access to the MCU memory through the BSL is protected by an user-defined password. Use of the BSL requires four pins (see [Table 9-4](#) and [Table 9-5](#)). The BSL entry requires a specific entry sequence on the RST/NMI/SBWTIO and TEST/SBWTCK pins. This device can support the blank device detection automatically to invoke the BSL with bypass this special entry sequence for saving time and on board programmable. For the complete description of the feature of the BSL, see the [MSP430™ FRAM Devices Bootloader \(BSL\) User's Guide](#).

**Table 9-4. UART BSL Pin Requirements and Functions**

| DEVICE SIGNAL  | BSL FUNCTION          |
|----------------|-----------------------|
| RST/NMI/SBWTIO | Entry sequence signal |
| TEST/SBWTCK    | Entry sequence signal |
| P1.4           | Data transmit         |
| P1.5           | Data receive          |
| VCC            | Power supply          |
| VSS            | Ground supply         |

**Table 9-5. I<sup>2</sup>C BSL Pin Requirements and Functions**

| DEVICE SIGNAL                                     | BSL FUNCTION              |
|---------------------------------------------------|---------------------------|
| $\overline{\text{RST}}/\text{NMI}/\text{SBWTDIO}$ | Entry sequence signal     |
| TEST/SBWTCCK                                      | Entry sequence signal     |
| P1.2                                              | Data transmit and receive |
| P1.3                                              | Clock                     |
| VCC                                               | Power supply              |
| VSS                                               | Ground supply             |

## 9.6 JTAG Standard Interface

The MSP low-power microcontrollers support the standard JTAG interface, which requires four signals for sending and receiving data. The JTAG signals are shared with general-purpose I/O. The TEST/SBWTCCK pin enables the JTAG signals. In addition to these signals, the  $\overline{\text{RST}}/\text{NMI}/\text{SBWTDIO}$  is required to interface with MSP430 development tools and device programmers. [Table 9-6](#) lists the JTAG pin requirements. For further details on interfacing to development tools and device programmers, see the [MSP430 Hardware Tools User's Guide](#). For details on using the JTAG interface, see [MSP430 Programming With the JTAG Interface User's Guide](#).

**Table 9-6. JTAG Pin Requirements and Function**

| DEVICE SIGNAL                                     | DIRECTION | JTAG FUNCTION               |
|---------------------------------------------------|-----------|-----------------------------|
| P1.4/.../TCK                                      | IN        | JTAG clock input            |
| P1.5/.../TMS                                      | IN        | JTAG state control          |
| P1.6/.../TDI/TCLK                                 | IN        | JTAG data input, TCLK input |
| P1.7/.../TDO                                      | OUT       | JTAG data output            |
| TEST/SBWTCCK                                      | IN        | Enable JTAG pins            |
| $\overline{\text{RST}}/\text{NMI}/\text{SBWTDIO}$ | IN        | External reset              |
| DVCC                                              | –         | Power supply                |
| DVSS                                              | –         | Ground supply               |

## 9.7 Spy-Bi-Wire Interface (SBW)

The MSP low-power microcontrollers support the 2-wire SBW interface. SBW can be used to interface with MSP development tools and device programmers. [Table 9-7](#) lists the SBW interface pin requirements. For further details on interfacing to development tools and device programmers, see the [MSP430 Hardware Tools User's Guide](#). For details on using the SBW interface, see the [MSP430 Programming With the JTAG Interface User's Guide](#).

**Table 9-7. Spy-Bi-Wire Pin Requirements and Functions**

| DEVICE SIGNAL                                     | DIRECTION | SBW FUNCTION                      |
|---------------------------------------------------|-----------|-----------------------------------|
| TEST/SBWTCCK                                      | IN        | Spy-Bi-Wire clock input           |
| $\overline{\text{RST}}/\text{NMI}/\text{SBWTDIO}$ | IN, OUT   | Spy-Bi-Wire data input and output |
| DVCC                                              | –         | Power supply                      |
| DVSS                                              | –         | Ground supply                     |

## 9.8 FRAM

The FRAM can be programmed using the JTAG port, SBW, the BSL, or in-system by the CPU. Features of the FRAM include:

- Byte and word access capability
- Programmable wait state generation
- Error correction coding (ECC)

## 9.9 Memory Protection

The device features memory protection for user access authority and write protection, including options to:

- Secure the whole memory map to prevent unauthorized access from JTAG port or BSL, by writing JTAG and BSL signatures using the JTAG port, SBW, the BSL, or in-system by the CPU.
- Enable write protection to prevent unwanted write operation to FRAM contents by setting the control bits in the System Configuration 0 register. For detailed information, see the SYS chapter in the [MP430FR4xx and MP430FR2xx Family User's Guide](#).

## 9.10 Peripherals

Peripherals are connected to the CPU through data, address, and control buses. All peripherals can be handled by using all instructions in the memory map. For complete module description, see the [MP430FR4xx and MP430FR2xx Family User's Guide](#).

### 9.10.1 Power-Management Module (PMM)

The PMM includes an integrated voltage regulator that supplies the core voltage to the device. The PMM also includes supply voltage supervisor (SVS) and brownout protection. The brownout reset circuit (BOR) is implemented to provide the proper internal reset signal to the device during power on and power off. The SVS circuitry detects if the supply voltage drops below a user-selectable safe level. SVS circuitry is available on the primary supply.

The device contains two on-chip reference: 1.5 V for internal reference and 1.2 V for external reference.

The 1.5-V reference is internally connected to ADC channel 13. DVCC is internally connected to ADC channel 15. When DVCC is set as the reference voltage for ADC conversion, the DVCC can be easily represent as [Equation 1](#) by using ADC sampling 1.5-V reference without any external components support.

$$DVCC = (1023 \times 1.5 \text{ V}) \div 1.5\text{-V reference ADC result} \quad (1)$$

A 1.2-V reference voltage can be buffered, when EXTREFEN = 1 on PMMCTL2 register, and it can be output to P1.4/..A1/VREF+ , meanwhile the ADC channel 1 can also be selected to monitor this voltage. For more detailed information, see the [MSP430FR4xx and MSP430FR2xx Family User's Guide](#).

### 9.10.2 Clock System (CS) and Clock Distribution

The clock system includes a 32-kHz crystal oscillator (XT1), an internal very-low-power low-frequency oscillator (VLO), an integrated 32-kHz RC oscillator (REFO), an integrated internal digitally controlled oscillator (DCO) that may use frequency-locked loop (FLL) locking with internal or external 32-kHz reference clock, and an on-chip asynchronous high-speed clock (MODOSC). The clock system is designed for cost-effective designs with minimal external components. A fail-safe mechanism is included for XT1. The clock system module offers the following clock signals.

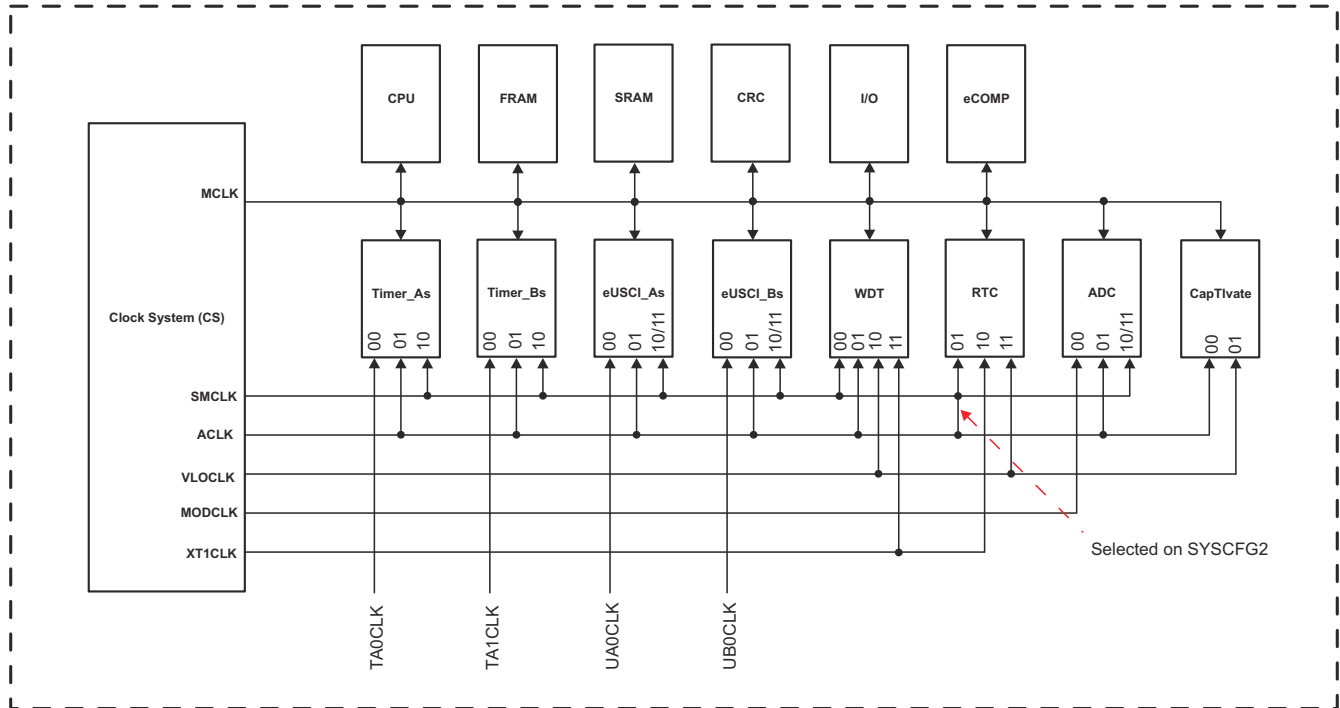
- Main Clock (MCLK): The system clock used by the CPU and all relevant peripherals accessed by the bus. All clock sources except MODOSC can be selected as the source with a predivider of 1, 2, 4, 8, 16, 32, 64, or 128.
- Sub-Main Clock (SMCLK): The subsystem clock used by the peripheral modules. SMCLK derives from the MCLK with a predivider of 1, 2, 4, or 8. This means SMCLK is always equal to or less than MCLK.
- Auxiliary Clock (ACLK): This clock is derived from the external XT1 clock, internal VLO or internal REFO clock up to 40 kHz.

All peripherals may have one or several clock sources depending on specific functionality. [Table 9-8](#) lists the clock distribution used in this device.

**Table 9-8. Clock Distribution**

|                 | CLOCK<br>SOURCE<br>SELECT<br>BITS | MCLK         | SMCLK              | ACLK               | MODCLK          | XT1CLK       | VLOCLK           | EXTERNAL PIN      |
|-----------------|-----------------------------------|--------------|--------------------|--------------------|-----------------|--------------|------------------|-------------------|
| Frequency range |                                   | DC to 16 MHz | DC to 16 MHz       | DC to 40 kHz       | 5 MHz $\pm$ 10% | DC to 40 kHz | 10 kHz $\pm$ 50% | –                 |
| CPU             | N/A                               | Default      | –                  | –                  | –               | –            | –                | –                 |
| FRAM            | N/A                               | Default      | –                  | –                  | –               | –            | –                | –                 |
| RAM             | N/A                               | Default      | –                  | –                  | –               | –            | –                | –                 |
| CRC             | N/A                               | Default      | –                  | –                  | –               | –            | –                | –                 |
| MPY32           | N/A                               | Default      | –                  | –                  | –               | –            | –                | –                 |
| I/O             | N/A                               | Default      | –                  | –                  | –               | –            | –                | –                 |
| TA0             | TASSEL                            | –            | 10b                | 01b                | –               | –            | 11b              | 00b (TA0CLK pin)  |
| TA1             | TASSEL                            | –            | 10b                | 01b                | –               | –            | –                | 00b (TA1CLK pin)  |
| TA2             | TASSEL                            | –            | 10b                | 01b                | –               | –            | 11b              | 00b (TA2CLK pin)  |
| TA3             | TASSEL                            | –            | 10b                | 01b                | –               | –            | –                | 00b (TA3CLK pin)  |
| TB0             | TBSSEL                            | –            | 10b                | 01b                | –               | –            | –                | 00b (TB0CLK pin)  |
| eUSCI_A0        | UCSSEL                            | –            | 10b or 11b         | 01b                | –               | –            | –                | 00b (UCA0CLK pin) |
| eUSCI_A1        | UCSSEL                            | –            | 10b or 11b         | 01b                | –               | –            | –                | 00b (UCA1CLK pin) |
| eUSCI_B0        | UCSSEL                            | –            | 10b or 11b         | 01b                | –               | –            | –                | 00b (UCB0CLK pin) |
| eUSCI_B1        | UCSSEL                            | –            | 10b or 11b         | 01b                | –               | –            | –                | 00b (UCB1CLK pin) |
| WDT             | WDTSEL                            | –            | 00b                | 01b                | –               | –            | 10b              | –                 |
| ADC             | ADCSSEL                           | –            | 10b or 11b         | 01b                | 00b             | –            | –                | –                 |
| CapTlvate       | CAPTSSEL                          | –            | –                  | 00b                | –               | –            | 01b              | –                 |
| RTC             | RTCSS                             | –            | 01b <sup>(1)</sup> | 01b <sup>(1)</sup> | –               | 10b          | 11b              | –                 |

(1) Controlled by the RTCKSEL bit in the SYSCFG2 register.



**Figure 9-1. Clock Distribution Block Diagram**

### 9.10.3 General-Purpose Input/Output Port (I/O)

Up to 43 I/O ports are implemented.

- P1, P3, P4, and P5 implement 8 bits each. P2 implements 6 bits excluding the I/Os multiplexed with XIN and XOUT. P6 implements 3 bits.
- All individual I/O bits are independently programmable.
- Any combination of input, output, and interrupt conditions is possible.
- Programmable pullup or pulldown on all ports.
- Edge-selectable interrupt and LPMx.5 wake-up input capability are available for all GPIOs (up to 43)
- Read and write access to port-control registers is supported by all instructions.
- Ports can be accessed byte-wise or word-wise as a pair.
- CapTIvate functionality is supported on all CAPx.y pins.

#### Note

##### Configuration of digital I/Os after BOR reset

To prevent any cross currents during start-up of the device, all port pins are high-impedance with Schmitt triggers and module functions disabled. To enable the I/O functions after a BOR reset, the ports must be configured first and then the LOCKLPM5 bit must be cleared. For details, see the *Configuration After Reset* section in the Digital I/O chapter of the [MP430FR4xx and MP430FR2xx Family User's Guide](#).

### 9.10.4 Watchdog Timer (WDT)

The primary function of the WDT module is to perform a controlled system restart after a software problem occurs. If the selected time interval expires, a system reset is generated. If the watchdog function is not needed in an application, the module can be configured as an interval timer and can generate interrupts at selected time intervals. [Table 9-9](#) lists the system clocks that can be used to source the WDT.

**Table 9-9. WDT Clocks**

| WDTSEL | NORMAL OPERATION<br>(WATCHDOG AND INTERVAL TIMER<br>MODE) |
|--------|-----------------------------------------------------------|
| 00     | SMCLK                                                     |
| 01     | ACLK                                                      |
| 10     | VLOCLK                                                    |
| 11     | Reserved                                                  |

### 9.10.5 System (SYS) Module

The SYS module handles many of the system functions within the device. These features include power-on reset (POR) and power-up clear (PUC) handling, NMI source selection and management, reset interrupt vector generators, bootloader entry mechanisms, and configuration management (device descriptors). The SYS module also includes a data exchange mechanism through SBW called a JTAG mailbox mail box that can be used in the application. [Table 9-10](#) summarizes the interrupts that are managed by the SYS module.

**Table 9-10. System Module Interrupt Vector Registers**

| INTERRUPT VECTOR REGISTER | ADDRESS | INTERRUPT EVENT                        | VALUE           | PRIORITY |
|---------------------------|---------|----------------------------------------|-----------------|----------|
| SYSRSTIV, System Reset    | 015Eh   | No interrupt pending                   | 00h             |          |
|                           |         | Brownout (BOR)                         | 02h             | Highest  |
|                           |         | RSTIFG RST/NMI (BOR)                   | 04h             |          |
|                           |         | PMMSWBOR software BOR (BOR)            | 06h             |          |
|                           |         | LPMx.5 wakeup (BOR)                    | 08h             |          |
|                           |         | Security violation (BOR)               | 0Ah             |          |
|                           |         | Reserved                               | 0Ch             |          |
|                           |         | SVSHIFG SVSH event (BOR)               | 0Eh             |          |
|                           |         | Reserved                               | 10h             |          |
|                           |         | Reserved                               | 12h             |          |
|                           |         | PMMSWPOR software POR (POR)            | 14h             |          |
|                           |         | WDTIFG watchdog time-out (PUC)         | 16h             |          |
|                           |         | WDTPW password violation (PUC)         | 18h             |          |
|                           |         | FRCTLPW password violation (PUC)       | 1Ah             |          |
|                           |         | Uncorrectable FRAM bit error detection | 1Ch             |          |
|                           |         | Peripheral area fetch (PUC)            | 1Eh             |          |
|                           |         | PMMPW PMM password violation (PUC)     | 20h             |          |
|                           |         | FLL unlock (PUC)                       | 24h             |          |
|                           |         | Reserved                               | 22h, 26h to 3Eh | Lowest   |

**Table 9-10. System Module Interrupt Vector Registers (continued)**

| INTERRUPT VECTOR REGISTER | ADDRESS | INTERRUPT EVENT                          | VALUE      | PRIORITY |
|---------------------------|---------|------------------------------------------|------------|----------|
| SYSSNIV, System NMI       | 015Ch   | No interrupt pending                     | 00h        |          |
|                           |         | SVS low-power reset entry                | 02h        | Highest  |
|                           |         | Uncorrectable FRAM bit error detection   | 04h        |          |
|                           |         | Reserved                                 | 06h        |          |
|                           |         | Reserved                                 | 08h        |          |
|                           |         | Reserved                                 | 0Ah        |          |
|                           |         | Reserved                                 | 0Ch        |          |
|                           |         | Reserved                                 | 0Eh        |          |
|                           |         | Reserved                                 | 10h        |          |
|                           |         | VMAIFG vacant memory access              | 12h        |          |
|                           |         | JMBINIFG JTAG mailbox input              | 14h        |          |
|                           |         | JMBOUTIFG JTAG mailbox output            | 16h        |          |
|                           |         | Correctable FRAM bit error detection     | 18h        |          |
|                           |         | Reserved                                 | 1Ah to 1Eh | Lowest   |
| SYSUNIV, User NMI         | 015Ah   | No interrupt pending                     | 00h        |          |
|                           |         | NMIIFG NMI pin or SVS <sub>H</sub> event | 02h        | Highest  |
|                           |         | OFIFG oscillator fault                   | 04h        |          |
|                           |         | Reserved                                 | 06h to 1Eh | Lowest   |

### 9.10.6 Cyclic Redundancy Check (CRC)

The 16-bit cyclic redundancy check (CRC) module produces a signature based on a sequence of data values and can be used for data checking purposes. The CRC generation polynomial is compliant with CRC-16-CCITT standard of  $x^{16} + x^{12} + x^5 + 1$ .

### 9.10.7 Enhanced Universal Serial Communication Interface (eUSCI\_A0, eUSCI\_B0)

The eUSCI modules are used for serial data communications. The eUSCI\_A module supports either UART or SPI communications. The eUSCI\_B module supports either SPI or I<sup>2</sup>C communications. Additionally, eUSCI\_A supports automatic baud-rate detection and IrDA. The eUSCI\_A and eUSCI\_B are connected either from P1 port or P2 port, it can be selected from the USCIA0RMP or USCIBxRMP bits of SYSCFG2 and SYSCFG3. [Table 9-11](#) lists the pin configurations that are required for each eUSCI mode.

**Table 9-11. eUSCI Pin Configurations**

|          | PIN (PxSEL Selection) | UART             | SPI  |
|----------|-----------------------|------------------|------|
|          |                       |                  |      |
| eUSCI_A0 | P1.4 <sup>(1)</sup>   | TXD              | SIMO |
|          | P1.5 <sup>(1)</sup>   | RXD              | SOMI |
|          | P1.6 <sup>(1)</sup>   | –                | SCLK |
|          | P1.7 <sup>(1)</sup>   | –                | STE  |
|          | PIN (PxSEL Selection) | UART             | SPI  |
|          | P5.2 <sup>(2)</sup>   | TXD              | SIMO |
|          | P5.1 <sup>(2)</sup>   | RXD              | SOMI |
|          | P5.0 <sup>(2)</sup>   | –                | SCLK |
|          | P4.7 <sup>(2)</sup>   | –                | STE  |
|          | PIN (PxSEL Selection) | UART             | SPI  |
| eUSCI_A1 | P2.6                  | TXD              | SIMO |
|          | P2.5                  | RXD              | SOMI |
|          | P2.4                  | –                | SCLK |
|          | P3.1                  | –                | STE  |
|          | PIN (PxSEL Selection) | I <sup>2</sup> C | SPI  |
| eUSCI_B0 | P1.0 <sup>(1)</sup>   | –                | STE  |
|          | P1.1 <sup>(1)</sup>   | –                | SCLK |
|          | P1.2 <sup>(1)</sup>   | SDA              | SIMO |
|          | P1.3 <sup>(1)</sup>   | SCL              | SOMI |
|          | PIN (PxSEL Selection) | I <sup>2</sup> C | SPI  |
|          | P5.6 <sup>(2)</sup>   | –                | STE  |
|          | P5.5 <sup>(2)</sup>   | –                | SCLK |
|          | P4.6 <sup>(2)</sup>   | SDA              | SIMO |
|          | P4.5 <sup>(2)</sup>   | SCL              | SOMI |
|          | PIN (PxSEL Selection) | I <sup>2</sup> C | SPI  |
| eUSCI_B1 | P2.7 <sup>(1)</sup>   | –                | STE  |
|          | P3.5 <sup>(1)</sup>   | –                | SCLK |
|          | P3.2 <sup>(1)</sup>   | SDA              | SIMO |
|          | P3.6 <sup>(1)</sup>   | SCL              | SOMI |
|          | PIN (PxSEL Selection) | I <sup>2</sup> C | SPI  |
|          | P5.4 <sup>(2)</sup>   | –                | STE  |
|          | P5.3 <sup>(2)</sup>   | –                | SCLK |
|          | P4.4 <sup>(2)</sup>   | SDA              | SIMO |
|          | P4.3 <sup>(2)</sup>   | SCL              | SOMI |
|          | PIN (PxSEL Selection) | I <sup>2</sup> C | SPI  |

(1) This is the default functionality that can be remapped by the USCIBxRMP or USCIA0RMP bit of the SYSCFG2 or SYSCFG3 register. Only one selected port is valid at any time.

(2) This is the remapped functionality controlled by the USCIBxRMP or USCIA0RMP bit of the SYSCFG2 or SYSCFG3 register. Only one selected port is valid at any time.

### 9.10.8 Timers (TA0, TA1, TA2, TA3 and TB0)

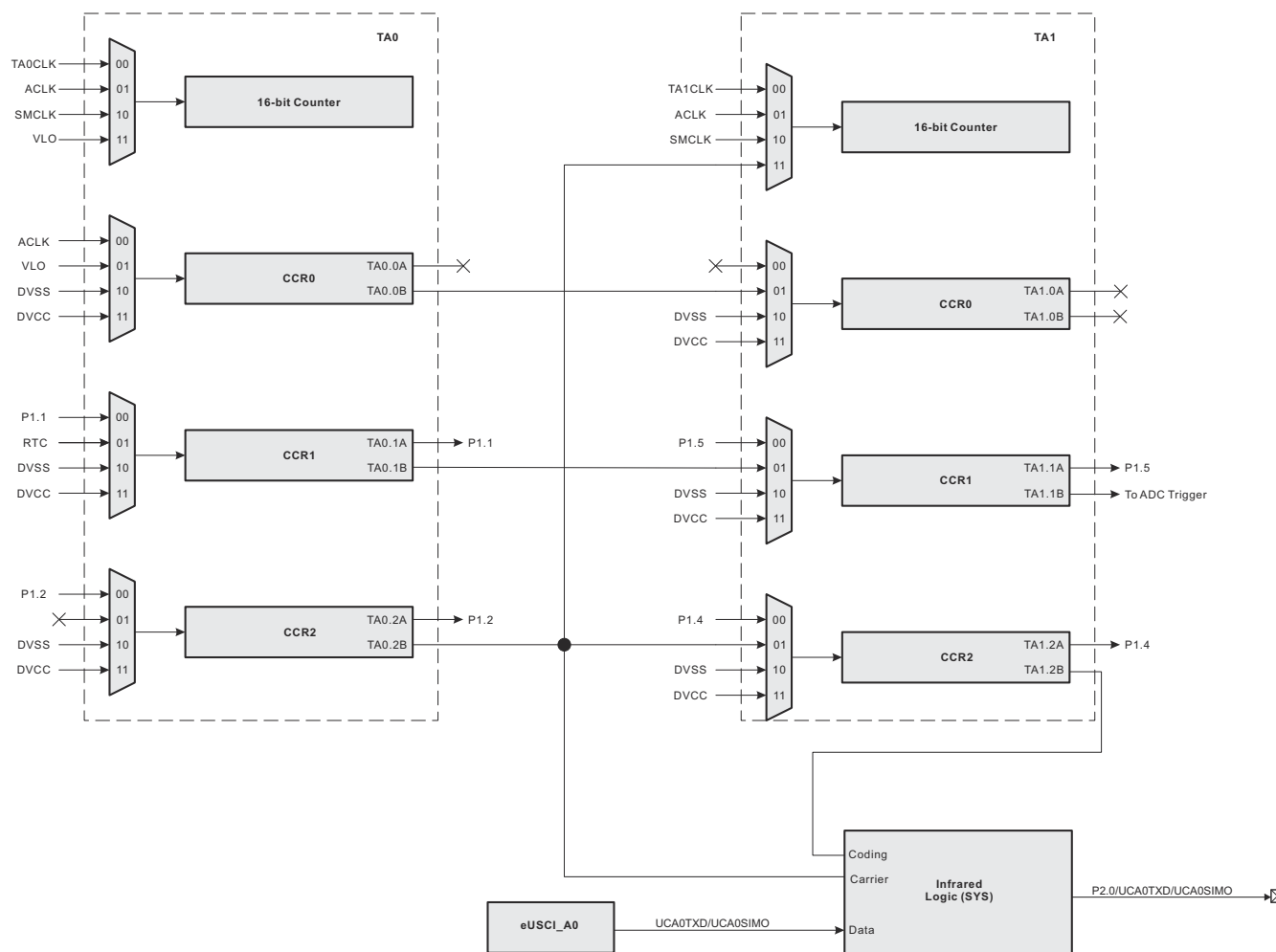
The TA0, TA1, TA2 and TA3 modules are 16-bit timers and counters with three capture/compare registers each. Each timer supports multiple captures or compares, PWM outputs, and interval timing (see [Table 9-12](#) and [Table 9-13](#)). Each timer has extensive interrupt capabilities. Interrupts may be generated from the counter on overflow conditions and from each of the capture/compare registers. The CCR0 registers on both TA0 and TA2 are not externally connected and can only be used for hardware period timing and interrupt generation. In Up mode, they can be used to set the overflow value of the counter.

**Table 9-12. Timer0\_A0 Signal Connections**

| PORT PIN | DEVICE INPUT SIGNAL | MODULE INPUT NAME | MODULE BLOCK | MODULE OUTPUT SIGNAL | DEVICE OUTPUT SIGNAL                                          |
|----------|---------------------|-------------------|--------------|----------------------|---------------------------------------------------------------|
| P1.0     | TA0CLK              | TACLK             | Timer        | N/A                  |                                                               |
|          | ACLK (internal)     | ACLK              |              |                      |                                                               |
|          | SMCLK (internal)    | SMCLK             |              |                      |                                                               |
|          | VLO (internal)      | INCLK             |              |                      |                                                               |
|          | ACLK (internal)     | CCI0A             | CCR0         | TA0                  | Not used                                                      |
|          | VLO (internal)      | CCI0B             |              |                      | Timer1_A1 CCI0B input                                         |
|          | DVSS                | GND               |              |                      |                                                               |
|          | DVCC                | V <sub>CC</sub>   |              |                      |                                                               |
| P1.1     | TA0.1               | CCI1A             | CCR1         | TA1                  | TA0.1                                                         |
|          | RTC (internal)      | CCI1B             |              |                      | Timer1_A1 CCI1B input                                         |
|          | DVSS                | GND               |              |                      |                                                               |
|          | DVCC                | V <sub>CC</sub>   |              |                      |                                                               |
| P1.2     | TA0.2               | CCI2A             | CCR2         | TA2                  | TA0.2                                                         |
|          | N/A                 | CCI2B             |              |                      | Timer1_A1 INCLK<br>Timer1_A1 CCI2B input,<br>IR carrier input |
|          | DVSS                | GND               |              |                      |                                                               |
|          | DVCC                | V <sub>CC</sub>   |              |                      |                                                               |

**Table 9-13. Timer0\_A1 Signal Connections**

| PORT PIN | DEVICE INPUT SIGNAL               | MODULE INPUT NAME | MODULE BLOCK | MODULE OUTPUT SIGNAL | DEVICE OUTPUT SIGNAL |
|----------|-----------------------------------|-------------------|--------------|----------------------|----------------------|
| P1.6     | TA1CLK                            | TACLK             | Timer        | N/A                  |                      |
|          | ACLK (internal)                   | ACLK              |              |                      |                      |
|          | SMCLK (internal)                  | SMCLK             |              |                      |                      |
|          | Timer0_A3 CCR2B output (internal) | INCLK             |              |                      |                      |
|          | N/A                               | CCI0A             | CCR0         | TA0                  | Not used             |
|          | Timer0_A3 CCR0B output (internal) | CCI0B             |              |                      | Not used             |
|          | DVSS                              | GND               |              |                      |                      |
|          | DVCC                              | V <sub>CC</sub>   |              |                      |                      |
| P1.5     | TA1.1                             | CCI1A             | CCR1         | TA1                  | TA1.1                |
|          | Timer0_A3 CCR1B output (internal) | CCI1B             |              |                      | To ADC trigger       |
|          | DVSS                              | GND               |              |                      |                      |
|          | DVCC                              | V <sub>CC</sub>   |              |                      |                      |
| P1.4     | TA1.2                             | CCI2A             | CCR2         | TA2                  | TA1.2                |
|          | Timer0_A3 CCR2B output (internal) | CCI2B             |              |                      | IR coding input      |
|          | DVSS                              | GND               |              |                      |                      |
|          | DVCC                              | V <sub>CC</sub>   |              |                      |                      |



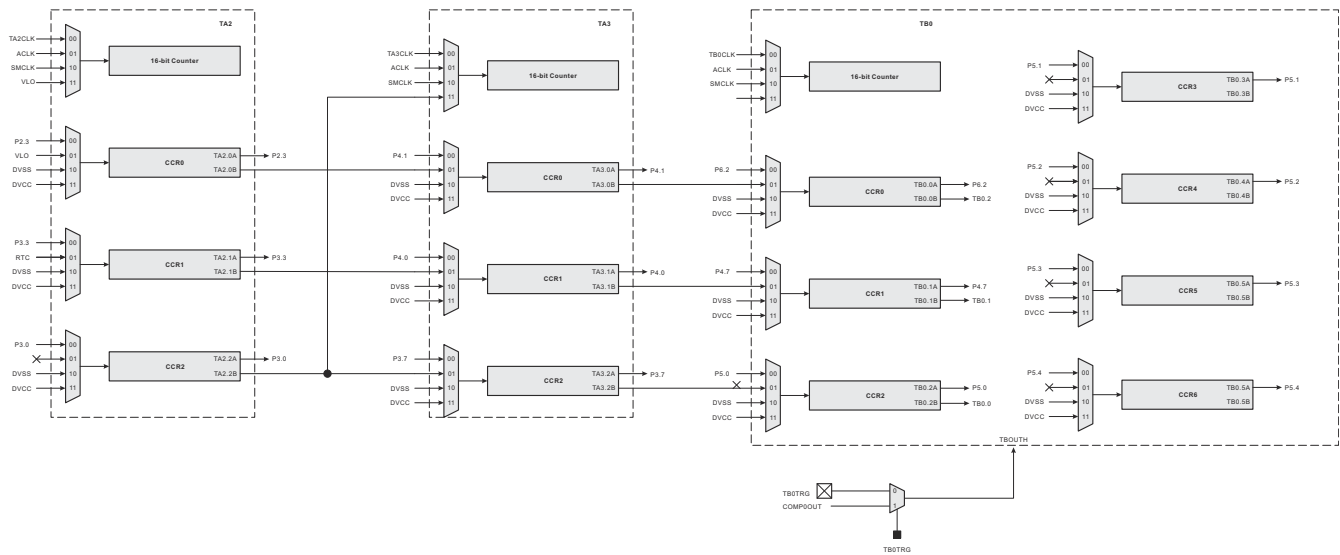
**Figure 9-2. TA0 and TA1 Signal Connections**

**Table 9-14. Timer2\_A3 and Timer3\_A3 Signal Connections**

| PORT PIN | DEVICE INPUT SIGNAL               | MODULE INPUT NAME | MODULE BLOCK | MODULE OUTPUT SIGNAL | DEVICE OUTPUT SIGNAL  |
|----------|-----------------------------------|-------------------|--------------|----------------------|-----------------------|
| P3.4     | TA2CLK                            | TACLK             | Timer        | N/A                  |                       |
|          | ACLK (internal)                   | ACLK              |              |                      |                       |
|          | SMCLK (internal)                  | SMCLK             |              |                      |                       |
|          | VLO (internal)                    | INCLK             |              |                      |                       |
| P2.3     | TA2.0                             | CCI0A             | CCR0         | TA0                  | TA2.0                 |
|          | VLO (internal)                    | CCI0B             |              |                      | Timer3_A3 CCI0B input |
|          | DVSS                              | GND               |              |                      |                       |
|          | DVCC                              | V <sub>CC</sub>   |              |                      |                       |
| P3.3     | TA2.1                             | CCI1A             | CCR1         | TA1                  | TA2.1                 |
|          | RTC (internal)                    | CCI1B             |              |                      | Timer3_A3 CCI1B input |
|          | DVSS                              | GND               |              |                      |                       |
|          | DVCC                              | V <sub>CC</sub>   |              |                      |                       |
| P3.0     | TA2.2                             | CCI2A             | CCR2         | TA2                  | TA2.2                 |
|          | N/A                               | CCI2B             |              |                      | Timer3_A3 CCI2B input |
|          | DVSS                              | GND               |              |                      |                       |
|          | DVCC                              | V <sub>CC</sub>   |              |                      |                       |
| P4.2     | TA3CLK                            | TACLK             | Timer        | N/A                  |                       |
|          | ACLK (internal)                   | ACLK              |              |                      |                       |
|          | SMCLK (internal)                  | SMCLK             |              |                      |                       |
|          | Timer2_A3 CCR2B output (internal) | INCLK             |              |                      |                       |
| P4.1     | TA3.0                             | CCI0A             | CCR0         | TA0                  | TA3.0                 |
|          | Timer2_A3 CCR0B output (internal) | CCI0B             |              |                      | Timer3_B0 CCI0B input |
|          | DVSS                              | GND               |              |                      |                       |
|          | DVCC                              | V <sub>CC</sub>   |              |                      |                       |
| P4.0     | TA3.1                             | CCI1A             | CCR1         | TA1                  | TA3.1                 |
|          | Timer2_A3 CCR1B output (internal) | CCI1B             |              |                      | Timer3_B0 CCI1B input |
|          | DVSS                              | GND               |              |                      |                       |
|          | DVCC                              | V <sub>CC</sub>   |              |                      |                       |
| P3.7     | TA3.2                             | CCI2A             | CCR2         | TA2                  | TA3.2                 |
|          | Timer2_A3 CCR2B output (internal) | CCI2B             |              |                      | Timer3_B0 CCI2B input |
|          | DVSS                              | GND               |              |                      |                       |
|          | DVCC                              | V <sub>CC</sub>   |              |                      |                       |

**Table 9-15. Timer0\_B7 Signal Connections**

| PORT PIN | DEVICE INPUT SIGNAL              | MODULE INPUT NAME | MODULE BLOCK | MODULE OUTPUT SIGNAL | DEVICE OUTPUT SIGNAL |
|----------|----------------------------------|-------------------|--------------|----------------------|----------------------|
| P6.1     | TB0CLK                           | TBCLK             | Timer        | N/A                  |                      |
|          | ACLK (internal)                  | ACLK              |              |                      |                      |
|          | SMCLK (internal)                 | SMCLK             |              |                      |                      |
|          | N/A                              | INCLK             |              |                      |                      |
| P6.2     | TB0.0                            | CCI0A             | CCR0         | TB0                  | TB0.0                |
|          | Timer3_A3 CCI0B input (internal) | CCI0B             |              |                      |                      |
|          | DVSS                             | GND               |              |                      |                      |
|          | DVCC                             | V <sub>CC</sub>   |              |                      |                      |
| P4.7     | TB0.1                            | CCI1A             | CCR1         | TB1                  | TB0.1                |
|          | Timer3_A3 CCI1B input (internal) | CCI1B             |              |                      |                      |
|          | DVSS                             | GND               |              |                      |                      |
|          | DVCC                             | V <sub>CC</sub>   |              |                      |                      |
| P5.0     | TB0.2                            | CCI2A             | CCR2         | TB2                  | TB0.2                |
|          | Timer3_A3 CCI2B input (internal) | CCI2B             |              |                      |                      |
|          | DVSS                             | GND               |              |                      |                      |
|          | DVCC                             | V <sub>CC</sub>   |              |                      |                      |
| P5.1     | TB0.3                            | CCI1A             | CCR3         | TB3                  | TB0.3                |
|          | N/A                              | CCI1B             |              |                      |                      |
|          | DVSS                             | GND               |              |                      |                      |
|          | DVCC                             | V <sub>CC</sub>   |              |                      |                      |
| P5.2     | TB0.4                            | CCI1A             | CCR4         | TB4                  | TB0.4                |
|          | N/A                              | CCI1B             |              |                      |                      |
|          | DVSS                             | GND               |              |                      |                      |
|          | DVCC                             | V <sub>CC</sub>   |              |                      |                      |
| P4.3     | TB0.5                            | CCI1A             | CCR5         | TB5                  | TB0.5                |
|          | N/A                              | CCI1B             |              |                      |                      |
|          | DVSS                             | GND               |              |                      |                      |
|          | DVCC                             | V <sub>CC</sub>   |              |                      |                      |
| P4.4     | TB0.6                            | CCI1A             | CCR6         | TB6                  | TB0.6                |
|          | N/A                              | CCI1B             |              |                      |                      |
|          | DVSS                             | GND               |              |                      |                      |
|          | DVCC                             | V <sub>CC</sub>   |              |                      |                      |



### Figure 9-3. TA2, TA3 and TB0 Signal Connections

### Table 9-16. TA2 and TA3 Pin Configurations of Remap Functionality

|     |                              |                                   |
|-----|------------------------------|-----------------------------------|
| TA2 | <b>PIN (PxSEL Selection)</b> | <b>DEVICE INPUT/OUTPUT SIGNAL</b> |
|     | P3.4 <sup>(1)</sup>          | TA2CLK                            |
|     | P2.3 <sup>(1)</sup>          | TA2.0                             |
|     | P3.3 <sup>(1)</sup>          | TA2.1                             |
|     | P3.0 <sup>(1)</sup>          | TA2.2                             |
|     | <b>PIN (PxSEL Selection)</b> | <b>DEVICE INPUT/OUTPUT SIGNAL</b> |
|     | P5.5 <sup>(2)</sup>          | TA2CLK                            |
|     | P5.6 <sup>(2)</sup>          | TA2.0                             |
|     | P5.7 <sup>(2)</sup>          | TA2.1                             |
|     | P6.0 <sup>(2)</sup>          | TA2.2                             |
| TA3 | <b>PIN (PxSEL Selection)</b> | <b>DEVICE INPUT/OUTPUT SIGNAL</b> |
|     | P4.2 <sup>(1)</sup>          | TA3CLK                            |
|     | P4.1 <sup>(1)</sup>          | TA3.0                             |
|     | P4.0 <sup>(1)</sup>          | TA3.1                             |
|     | P3.7 <sup>(1)</sup>          | TA3.2                             |
|     | <b>PIN (PxSEL Selection)</b> | <b>DEVICE INPUT/OUTPUT SIGNAL</b> |
|     | P5.4 <sup>(2)</sup>          | TA3CLK                            |
|     | P5.3 <sup>(2)</sup>          | TA3.0                             |
|     | P4.6 <sup>(2)</sup>          | TA3.1                             |
|     | P4.5 <sup>(2)</sup>          | TA3.2                             |

- (1) This is the default functionality that can be remapped by the TAxRMP bit of the SYSCFG3 register. Only one selected port is valid at any time.
- (2) This is the remapped functionality controlled by the TAxRMP bit of the SYSCFG3 register. Only one selected port is valid at any time.

The interconnection of Timer0\_A3 and Timer1\_A3 can be used to modulate the eUSCI\_A pin of UCA0TXD/ UCA0SIMO in either ASK or FSK mode, with which a user can easily acquire a modulated infrared command for directly driving an external IR diode. The IR functions are fully controlled by SYS configuration register 1 including IREN (enable), IRPSEL (polarity select), IRMSSEL (mode select), IRDSSEL (data select), and IRDATA

(data) bits. For more information, see the SYS chapter in the [MP430FR4xx and MP430FR2xx Family User's Guide](#).

The Timer\_B module feature the function to put Timer\_B all outputs into a high impedance state when the selected source is triggered. The source can be selected from external pin or internal of the device, it is controlled by TBxTRG in SYS. For more information, see the SYS chapter in the [MP430FR4xx and MP430FR2xx Family User's Guide](#).

Table 9-17 lists the Timer\_B high-impedance trigger source selections.

**Table 9-17. TB0OUTH Selection**

| TB0TRGSEL     | TB0OUTH TRIGGER SOURCE SELECTION | Timer_B PAD OUTPUT HIGH IMPEDANCE        |
|---------------|----------------------------------|------------------------------------------|
| TB0TRGSEL = 0 | eCOMP0 output (internal)         | P6.2, P4.7, P5.0, P5.1, P5.2, P4.3, P4.4 |
| TB0TRGSEL = 1 | P3.5                             |                                          |

### 9.10.9 Hardware Multiplier (MPY)

The multiplication operation is supported by a dedicated peripheral module. The module performs operations with 32-, 24-, 16-, and 8-bit operands. The MPY module supports signed multiplication, unsigned multiplication, signed multiply-and-accumulate, and unsigned multiply-and-accumulate operations.

### 9.10.10 Backup Memory (BAKMEM)

The BAKMEM supports data retention during LPM3.5. This device provides up to 32 bytes that are retained during LPM3.5.

### 9.10.11 Real-Time Clock (RTC)

The RTC is a 16-bit modulo counter that is functional in AM, LPM0, LPM3, and LPM3.5. This module may periodically wake up the CPU from LPM0, LPM3 and LPM3.5 based on timing from a low-power clock source such as the XT1 and VLO clocks. RTC also can be sourced from ACLK controlled by RTCCSEL in SYSCFG2. In AM, RTC can be driven by SMCLK to generate high-frequency timing events and interrupts. The RTC overflow events trigger:

- Timer0\_B3 CCI1B
- ADC conversion trigger when ADCSHSx bits are set as 01b

**Table 9-18. RTC Clock Source**

| RTCSS | CLOCK SOURCE                              |
|-------|-------------------------------------------|
| 00    | Reserved                                  |
| 01    | SMCLK, or ACLK is selected <sup>(1)</sup> |
| 10    | XT1CLK                                    |
| 11    | VLOCLK                                    |

(1) Controlled by RTCCLK bit of SYSCFG2 register.

### 9.10.12 12-Bit Analog-to-Digital Converter (ADC)

The 12-bit ADC module supports fast 12-bit analog-to-digital conversions with single-ended input. The module implements a 12-bit SAR core, sample select control, reference generator and a conversion result buffer. A window comparator with a lower and upper limits allows CPU-independent result monitoring with three window comparator interrupt flags.

The ADC supports 12 external inputs and four internal inputs (see [Table 9-19](#)).

**Table 9-19. ADC Channel Connections**

| ADCINCHx | ADC CHANNELS                                           | EXTERNAL PIN OUTPUT |
|----------|--------------------------------------------------------|---------------------|
| 0        | A0/Vref+                                               | P1.0                |
| 1        | A1/                                                    | P1.1                |
| 2        | A2/Vref-                                               | P1.2                |
| 3        | A3                                                     | P1.3                |
| 4        | A4 <sup>(1)</sup>                                      | P1.4                |
| 5        | A5                                                     | P1.5                |
| 6        | A6                                                     | P1.6                |
| 7        | A7                                                     | P1.7                |
| 8        | A8                                                     | P4.3                |
| 9        | A9                                                     | P4.4                |
| 10       | A10                                                    | P5.3                |
| 11       | A11                                                    | P5.4                |
| 12       | On-chip temperature sensor                             | N/A                 |
| 13       | Internal shared reference voltage (1.5, 2.0, or 2.5-V) | N/A                 |
| 14       | DVSS                                                   | N/A                 |
| 15       | DVCC                                                   | N/A                 |

- (1) When A4 is used, the PMM 1.2-V reference voltage can be output to this pin by setting the PMM control register. The 1.2-V voltage can be measured by channel A4.

The analog-to-digital conversion can be started by software or a hardware trigger. [Table 9-20](#) shows the trigger sources that are available.

**Table 9-20. ADC Trigger Signal Connections**

| ADCSHSx |         | TRIGGER SOURCE               |
|---------|---------|------------------------------|
| BINARY  | DECIMAL |                              |
| 00      | 0       | ADCSC bit (software trigger) |
| 01      | 1       | RTC event                    |
| 10      | 2       | TA1.1B                       |
| 11      | 3       | eCOMP0 COUT                  |

### 9.10.13 eCOMP0

This device features one enhanced comparator. The enhanced comparator is an analog voltage comparator with a built-in 6-bit DAC as an internal voltage reference. The integrated 6-bit DAC can be set to 64 steps for the comparator reference voltage. This module has 4-level programmable hysteresis and configurable power modes: high-power and low-power modes.

The eCOMP0 supports a propagation delay up to 1  $\mu$ s in high-power mode. In low-power mode, eCOMP0 supports 3.2- $\mu$ s delay with 1.5- $\mu$ A leakage at room temperature, which can be an ideal wake-up source in LPM3 for a voltage monitor.

eCOMP0 contains a programmable 6-bit DAC that can use the internal shared reference (1.5 V, 2.0 V, or 2.5 V) for a high-precision comparison threshold. In addition to the internal shared reference, a low-power 1.2-V

reference is fixed at channel 2 of both the inverting and noninverting paths and allows the DAC to be turned off to reduce power consumption.

The eCOMP0 supports external inputs and internal inputs (see [Table 9-21](#)) and outputs (see [Table 9-22](#))

**Table 9-21. eCOMP0 Input Channel Connections**

| CPPSEL OR CPNSEL | eCOMP0 CHANNELS           |
|------------------|---------------------------|
| 000              | P1.1/.../COMP0.0          |
| 001              | P2.2/.../COMP0.1          |
| 010              | Low-power 1.2-V reference |
| 011              | P5.7/.../COMP0.2          |
| 100              | P6.0/.../COMP0.3          |
| 101              | N/A                       |
| 110              | eCOMP0 6-bit DAC          |

**Table 9-22. eCOMP0 Output Channel Connections**

| ECOMP0 OUT | EXTERNAL PINOUT, MODULE                   |
|------------|-------------------------------------------|
| 1          | P3.4                                      |
| 2          | TB0 (TB0OUTH), TB1 (TB1OUTH), ADC trigger |

#### 9.10.14 CapTivate Technology

The CapTivate module measures changes in the capacitance of a sensing electrode with a charge-transfer measurement method. It is functional in AM, LPM0, LPM3, and LPM4. The CapTivate module can periodically wake the CPU from LPM0, LPM3, or LPM4 based on a CapTivate timer source such as ACLK or VLO clock. The CapTivate module supports the following touch-sensing capability:

- 16 CapTivate I/Os supporting up to 16 electrodes in self-capacitance mode or 64 electrodes in mutual-capacitance mode
- 4 CapTivate measurement blocks to enable parallel scanning of up to 4 electrodes simultaneously (one electrode per block)
- Each CapTivate block can be individually configured in self or mutual mode, and each CapTivate I/O can be used for either self or mutual capacitance electrodes.
- Support synchronizing the start of a conversion to an external trigger, such as a zero-crossing event
- Includes a wake-on-touch state machine with processing logic to perform filter calculations and threshold detection
- Includes hardware accelerated oversampling and frequency hopping to enable reduced CPU loading in applications that require noise immunity
- Noise-attenuating charge transfer circuit with adjustable input impedance enabling robustness in the presence of conducted and radiated noise with low CPU post-processing requirements
- Selectable electrode charge voltage (DVCC or CapTivate VREG), allowing the designer to optimize for high sensitivity in the presence of conducted and radiated noise or stability across DVCC supply voltage variation
- Adjustable on-chip sampling capacitor size to support calibration of low-capacitance electrodes

To learn more about MSP MCUs featuring CapTivate™ technology, see the [CapTivate™ Technology Guide](#).

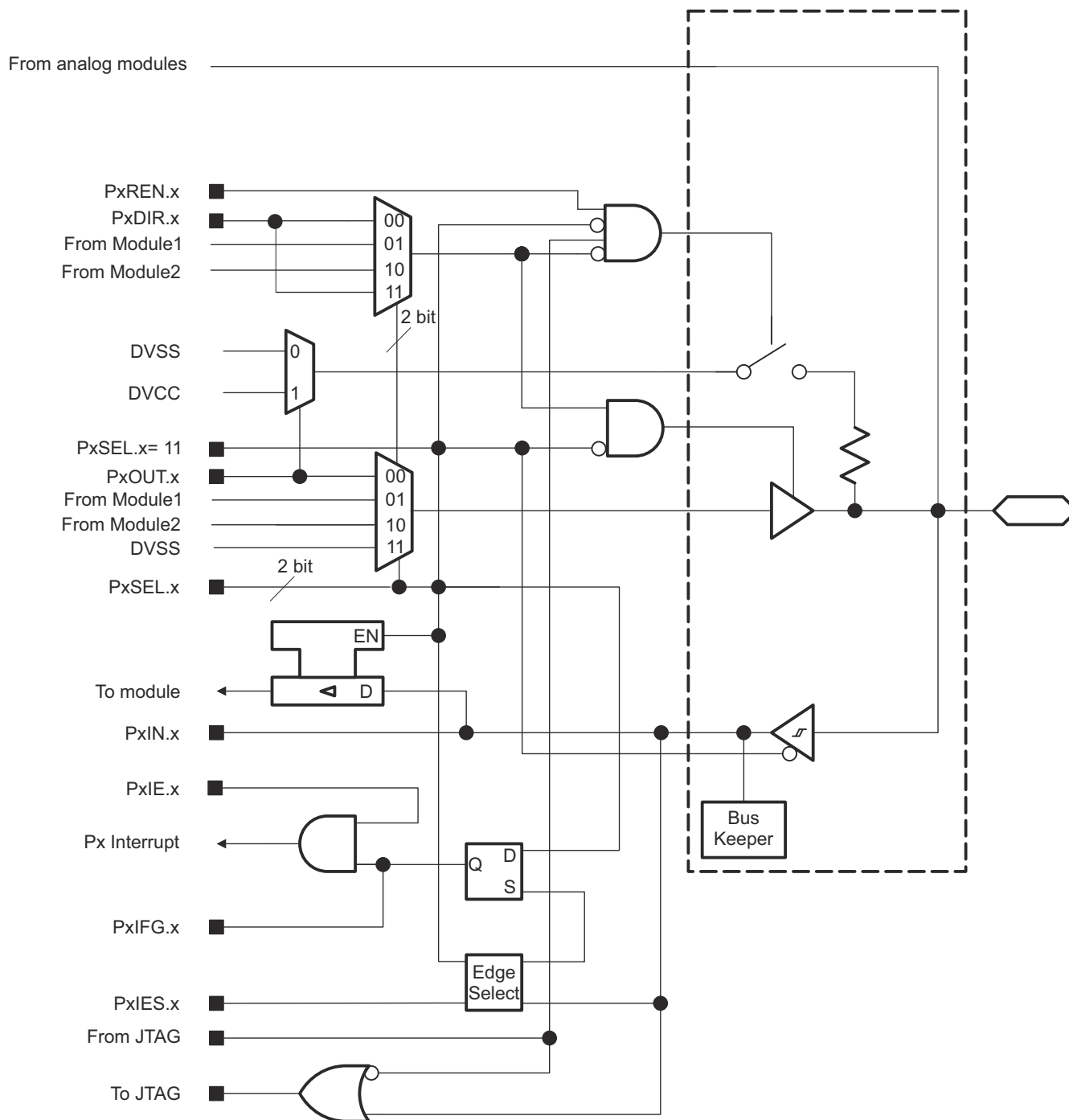
#### 9.10.15 Embedded Emulation Module (EEM)

The EEM supports real-time in-system debugging. The EEM on these devices has the following features:

- Three hardware triggers or breakpoints on memory access
- One hardware trigger or breakpoint on CPU register write access
- Up to four hardware triggers can be combined to form complex triggers or breakpoints
- One cycle counter
- Clock control on module level
- EEM version: S

## 9.11 Input/Output Diagrams

Figure 9-4 shows the overall port diagram.



NOTE: For details on the specific analog modules, digital function modules, interrupts, and JTAG, see the Port Pin Functions table.

**Figure 9-4. Port Input/Output With Schmitt Trigger**

### 9.11.1 Port P1 (P1.0 to P1.7) Input/Output With Schmitt Trigger

Table 9-23 summarizes the selection of the pin functions.

**Table 9-23. Port P1 (P1.0 to P1.7) Pin Functions**

| PIN NAME (P1.x)                        | x | FUNCTION         | CONTROL BITS AND SIGNALS <sup>(1)</sup> |        |          |
|----------------------------------------|---|------------------|-----------------------------------------|--------|----------|
|                                        |   |                  | P1DIR.x                                 | P1SELx | JTAG     |
| P1.0/UCB0STE/TA0CLK/A0/Veref+          | 0 | P1.0 (I/O)       | I: 0; O: 1                              | 00     | 0        |
|                                        |   | UCB0STE          | X                                       | 01     | 0        |
|                                        |   | TA0CLK           | 0                                       | 10     | 0        |
|                                        |   | A0, Veref+       | X                                       | 11     | N/A      |
| P1.1/UCB0CLK/TA0.1/COMP0.0/A1          | 1 | P1.1 (I/O)       | I: 0; O: 1                              | 00     | 0        |
|                                        |   | UCB0CLK          | X                                       | 01     | 0        |
|                                        |   | TA0.CCI1A        | 0                                       | 10     | 0        |
|                                        |   | TA0.1            | 1                                       |        |          |
|                                        |   | A1, COMP0.0      | X                                       | 11     | N/A      |
| P1.2/UCB0SIMO/UCB0SDA/TA0.2/A2/Veref-  | 2 | P1.2 (I/O)       | I: 0; O: 1                              | 00     | 0        |
|                                        |   | UCB0SIMO/UCB0SDA | X                                       | 01     | 0        |
|                                        |   | TA0.CCI2A        | 0                                       | 10     | 0        |
|                                        |   | TA0.2            | 1                                       |        |          |
|                                        |   | A2, Veref-       | X                                       | 11     | N/A      |
| P1.3/UCB0SOMI/UCB0SCL/MCLK/A3          | 3 | P1.3 (I/O)       | I: 0; O: 1                              | 00     | 0        |
|                                        |   | UCB0SOMI/UCB0SCL | X                                       | 01     | 0        |
|                                        |   | MCLK             | 1                                       | 10     | 0        |
|                                        |   | A3               | X                                       | 11     | N/A      |
| P1.4/UCATXD/UCASIMO/TA1.2/TCK/A4/VREF+ | 4 | P1.4 (I/O)       | I: 0; O: 1                              | 00     | Disabled |
|                                        |   | UCATXD/UCASIMO   | X                                       | 01     | Disabled |
|                                        |   | TA1.CCI2A        | 0                                       | 10     | Disabled |
|                                        |   | TA1.2            | 1                                       |        |          |
|                                        |   | A4, VREF+        | X                                       | 11     | Disabled |
|                                        |   | JTAG TCK         | X                                       | X      | TCK      |
| P1.5/UCARXD/UCASOMI/TA1.1/TMS/A5       | 5 | P1.5 (I/O)       | I: 0; O: 1                              | 00     | Disabled |
|                                        |   | UCARXD/UCASOMI   | X                                       | 01     | Disabled |
|                                        |   | TA1.CCI1A        | 0                                       | 10     | Disabled |
|                                        |   | TA1.1            | 1                                       |        |          |
|                                        |   | A5               | X                                       | 11     | Disabled |
|                                        |   | JTAG TMS         | X                                       | X      | TMS      |
| P1.6/UCACLK/TA1CLK/TDI/TCLK/A6         | 6 | P1.6 (I/O)       | I: 0; O: 1                              | 00     | Disabled |
|                                        |   | UCACLK           | X                                       | 01     | Disabled |
|                                        |   | TA1CLK           | 0                                       | 10     | Disabled |
|                                        |   | A6               | X                                       | 11     | Disabled |
|                                        |   | JTAG TDI/TCLK    | X                                       | X      | TDI/TCLK |
| P1.7/UCASTE/SMCLK/TDO/A7               | 7 | P1.7 (I/O)       | I: 0; O: 1                              | 00     | Disabled |
|                                        |   | UCASTE           | X                                       | 01     | Disabled |
|                                        |   | SMCLK            | 1                                       | 10     | Disabled |
|                                        |   | A7               | X                                       | 11     | Disabled |
|                                        |   | JTAG TDO         | X                                       | X      | TDO      |

(1) X = don't care

### 9.11.2 Port P2 (P2.0 to P2.7) Input/Output With Schmitt Trigger

Table 9-24 summarizes the selection of the pin functions.

#### Note

#### CapTlvate shared with alternative functions

The CapTlvate function can be powered by 1.5 V or 3.3 V.

To prevent pad damage when changing the function, check the external application circuit of each pad before enabling the alternative function, when 1.5 V is selected.

**Table 9-24. Port P2 (P2.0 to P2.7) Pin Functions**

| PIN NAME (P2.x)              | x | FUNCTION         | CONTROL BITS AND SIGNALS <sup>(1)</sup> |                                |
|------------------------------|---|------------------|-----------------------------------------|--------------------------------|
|                              |   |                  | P2DIR.x                                 | P2SELx                         |
| P2.0/XOUT                    | 0 | P2.0 (I/O)       | I: 0; O: 1                              | 00                             |
|                              |   | XOUT             | X                                       | 01                             |
| P2.1/XIN                     | 1 | P2.1 (I/O)       | I: 0; O: 1                              | 00                             |
|                              |   | XIN              | X                                       | 01                             |
| P2.2/SYNC/ACLK/COMP0.1       | 2 | P2.2 (I/O)       | I: 0; O: 1                              | 00                             |
|                              |   | SYNC             | 0                                       | 01                             |
|                              |   | ACLK             | 1                                       | 10                             |
|                              |   | COMP0.1          | X                                       | 11                             |
| P2.3/TA2.0/CAP0.2            | 3 | P2.3 (I/O)       | I: 0; O: 1                              | 00                             |
|                              |   | TA2.CCI0A        | 0                                       | 01                             |
|                              |   | TA2.0            | 1                                       |                                |
|                              |   | CAP0.2           | X                                       | P2SELx = 11, or from CapTlvate |
| P2.4/UCA1CLK/CAP1.1          | 4 | P2.4 (I/O)       | I: 0; O: 1                              | 00                             |
|                              |   | UCA1CLK          | X                                       | 01                             |
|                              |   | CAP1.1           | X                                       | P2SELx = 11, or from CapTlvate |
| P2.5/UCA1RXD/UCA1SOMI/CAP1.2 | 5 | P2.5 (I/O)       | I: 0; O: 1                              | 00                             |
|                              |   | UCA1RXD/UCA1SOMI | X                                       | 01                             |
|                              |   | CAP1.2           | X                                       | P2SELx = 11, or from CapTlvate |
| P2.6/UCA1TXD/UCA1SIMO/CAP1.3 | 6 | P2.6 (I/O)       | I: 0; O: 1                              | 00                             |
|                              |   | UCA1TXD/UCA1SIMO | X                                       | 01                             |
|                              |   | CAP1.3           | X                                       | P2SELx = 11, or from CapTlvate |
| P2.7/UCB1STE/CAP3.0          | 7 | P2.7 (I/O)       | I: 0; O: 1                              | 0                              |
|                              |   | UCB1STE          | X                                       | 01                             |
|                              |   | CAP3.0           | X                                       | P2SELx = 11, or from CapTlvate |

(1) X = don't care

### 9.11.3 Port P3 (P3.0 to P3.7) Input/Output With Schmitt Trigger

Table 9-25 summarizes the selection of the pin functions.

#### Note

#### CapTlvate shared with alternative functions

The CapTlvate function can be powered by 1.5 V or 3.3 V.

To prevent pad damage when changing the function, check the external application circuit of each pad before enabling the alternative function, when 1.5 V is selected.

**Table 9-25. Port P3 (P3.0 to P3.7) Pin Functions**

| PIN NAME (P3.x)              | x | FUNCTION         | CONTROL BITS AND SIGNALS <sup>(1)</sup> |                                |
|------------------------------|---|------------------|-----------------------------------------|--------------------------------|
|                              |   |                  | P3DIR.x                                 | P3SEL.x                        |
| P3.0/TA2.2/CAP0.0            | 0 | filter9          | I: 0; O: 1                              | 00                             |
|                              |   | TA2.CCI2A        | 0                                       | 01                             |
|                              |   | TA2.2            | 1                                       |                                |
|                              |   | CAP0.0           | X                                       | P3SELx = 11, or from CapTlvate |
| P3.1/UCA1STE/ CAP1.0         | 1 | P3.1 (I/O)       | I: 0; O: 1                              | 00                             |
|                              |   | UCA1STE          | X                                       | 01                             |
|                              |   | CAP1.0           | X                                       | P3SELx = 11, or from CapTlvate |
| P3.2/UCB1SIMO/UCB1SDA/CAP3.2 | 2 | P3.2 (I/O)       | I: 0; O: 1                              | 00                             |
|                              |   | UCB1SIMO/UCB1SDA | X                                       | 01                             |
|                              |   | CAP3.2           | X                                       | P3SELx = 11, or from CapTlvate |
| P3.3/TA2.1/CAP0.1            | 3 | P3.3 (I/O)       | I: 0; O: 1                              | 00                             |
|                              |   | TA2.CCI1A        | 0                                       | 01                             |
|                              |   | TA2.1            | 1                                       |                                |
|                              |   | CAP0.1           | X                                       | P3SELx = 11, or from CapTlvate |
| P3.4/TA2CLK/COMP0OUT/CAP0.3  | 4 | P3.4 (I/O)       | I: 0; O: 1                              | 00                             |
|                              |   | TA2CLK           | 0                                       | 01                             |
|                              |   | COMP0OUT         | 1                                       | 10                             |
|                              |   | CAP0.2           | X                                       | P3SELx = 11, or from CapTlvate |
| P3.5/UCB1CLK/TB0TRG/CAP3.1   | 5 | P3.5 (I/O)       | I: 0; O: 1                              | 00                             |
|                              |   | UCB1CLK          | X                                       | 01                             |
|                              |   | TB0TRG           | 0                                       | 10                             |
|                              |   | CAP3.1           | X                                       | P3SELx = 11, or from CapTlvate |
| P3.6/UCB1SOMI/UCB1SCL/CAP3.3 | 6 | P3.6 (I/O)       | I: 0; O: 1                              | 00                             |
|                              |   | UCB1SOMI/UCB1SCL | X                                       | 01                             |
|                              |   | CAP3.3           | X                                       | P3SELx = 11, or from CapTlvate |

**Table 9-25. Port P3 (P3.0 to P3.7) Pin Functions (continued)**

| PIN NAME (P3.x)   | x | FUNCTION   | CONTROL BITS AND SIGNALS <sup>(1)</sup> |                                |
|-------------------|---|------------|-----------------------------------------|--------------------------------|
|                   |   |            | P3DIR.x                                 | P3SEL.x                        |
| P3.7/TA3.2/CAP2.0 | 7 | P3.7 (I/O) | I: 0; O: 1                              | 00                             |
|                   |   | TA3.CCI2A  | 0                                       | 01                             |
|                   |   | TA3.2      | 1                                       |                                |
|                   |   | CAP2.0     | X                                       | P3SELx = 11, or from CapTlvate |

(1) X = don't care

### 9.11.4 Port P4 (P4.0 to P4.7) Input/Output With Schmitt Trigger

Table 9-26 summarizes the selection of the pin functions.

#### Note

#### CapTlvate shared with alternative functions

The CapTlvate function can be powered by 1.5 V or 3.3 V.

To prevent pad damage when changing the function, check the external application circuit of each pad before enabling the alternative function, when 1.5 V is selected.

**Table 9-26. Port P4 (P4.0 to P4.7) Pin Functions**

| PIN NAME (P4.x)                | x | FUNCTION         | CONTROL BITS AND SIGNALS <sup>(1)</sup> |                                |
|--------------------------------|---|------------------|-----------------------------------------|--------------------------------|
|                                |   |                  | P4DIR.x                                 | P4SEL.x                        |
| P4.0/TA3.1/CAP2.1              | 0 | P4.0 (I/O)       | I: 0; O: 1                              | 00                             |
|                                |   | TA3.CCI1A        | 0                                       | 01                             |
|                                |   | TA3.1            | 1                                       |                                |
|                                |   | CAP2.1           | X                                       | P4SELx = 11, or from CapTlvate |
| P4.1/TA3.0/CAP2.2              | 1 | P4.1 (I/O)       | I: 0; O: 1                              | 00                             |
|                                |   | TA3.CCI0A        | 0                                       | 01                             |
|                                |   | TA3.0            | 1                                       |                                |
|                                |   | CAP2.2           | X                                       | P4SELx = 11, or from CapTlvate |
| P4.2/TA3CLK/CAP2.3             | 2 | P4.2 (I/O)       | I: 0; O: 1                              | 00                             |
|                                |   | TA3CLK           | 0                                       | 01                             |
|                                |   | CAP2.3           | X                                       | P4SELx = 11, or from CapTlvate |
| P4.3/UCB1SOMI/UCB1SCL/TB0.5/A8 | 3 | P4.3 (I/O)       | I: 0; O: 1                              | 00                             |
|                                |   | UCB1SOMI/UCB1SCL | X                                       | 01                             |
|                                |   | TB0.CCI5A        | 0                                       | 10                             |
|                                |   | TB0.5            | 1                                       |                                |
|                                |   | A8               | X                                       | 11                             |
| P4.4/UCB1SIMO/UCB1SDA/TB0.6/A9 | 4 | P4.4 (I/O)       | I: 0; O: 1                              | 00                             |
|                                |   | UCB1SIMO/UCB1SDA | X                                       | 01                             |
|                                |   | TB0.CCI6A        | 0                                       | 10                             |
|                                |   | TB0.6            | 1                                       |                                |
|                                |   | A9               | X                                       | 11                             |
| P4.5/UCB0SOMI/UCB0SCL/TA3.2    | 5 | P4.5 (I/O)       | I: 0; O: 1                              | 00                             |
|                                |   | UCB0SOMI/UCB0SCL | X                                       | 01                             |
|                                |   | TA3.CCI2A        | 0                                       | 10                             |
|                                |   | TA3.2            | 1                                       |                                |
| P4.6/UCB0SIMO/UCB0SDA/TA3.1    | 6 | P4.6 (I/O)       | I: 0; O: 1                              | 00                             |
|                                |   | UCB0SIMO/UCB0SDA | X                                       | 01                             |
|                                |   | TA3.CCI1A        | 0                                       | 10                             |
|                                |   | TA3.1            | 1                                       |                                |

**Table 9-26. Port P4 (P4.0 to P4.7) Pin Functions (continued)**

| PIN NAME (P4.x)    | x | FUNCTION   | CONTROL BITS AND SIGNALS <sup>(1)</sup> |         |
|--------------------|---|------------|-----------------------------------------|---------|
|                    |   |            | P4DIR.x                                 | P4SEL.x |
| P4.7/UCA0STE/TB0.1 | 7 | P4.7 (I/O) | I: 0; O: 1                              | 00      |
|                    |   | UCA0STE    | X                                       | 01      |
|                    |   | TB0.CCI1A  | 0                                       | 10      |
|                    |   | TB0.1      | 1                                       |         |

(1) X = don't care

### 9.11.5 Port P5 (P5.0 to P5.7) Input/Output With Schmitt Trigger

Table 9-27 summarizes the selection of the pin functions.

**Table 9-27. Port P5 (P5.0 to P5.7) Pin Functions**

| PIN NAME (P5.x)             | x | FUNCTION         | CONTROL BITS AND SIGNALS <sup>(1)</sup> |         |
|-----------------------------|---|------------------|-----------------------------------------|---------|
|                             |   |                  | P5DIR.x                                 | P5SEL.x |
| P5.0/UCA0CLK/TB0.2          | 0 | P5.0 (I/O)       | I: 0; O: 1                              | 00      |
|                             |   | UCA0CLK          | X                                       | 01      |
|                             |   | TB0.CCI2A        | 0                                       | 10      |
|                             |   | TB0.2            | 1                                       |         |
| P5.1/UCA0RXD/UCA0SOMI/TB0.3 | 1 | P5.1 (I/O)       | I: 0; O: 1                              | 00      |
|                             |   | UCA0RXD/UCA0SOMI | X                                       | 01      |
|                             |   | TB0.CCI3A        | 0                                       | 10      |
|                             |   | TB0.3            | 1                                       |         |
| P5.2/UCA0TXD/UCA0SIMO/TB0.4 | 2 | P5.2 (I/O)       | I: 0; O: 1                              | 00      |
|                             |   | UCA0TXD/UCA0SIMO | X                                       | 01      |
|                             |   | TB0.CCI4A        | 0                                       | 10      |
|                             |   | TB0.4            | 1                                       |         |
| P5.3/UCB1CLK/TA3.0/A10      | 3 | P5.3 (I/O)       | I: 0; O: 1                              | 00      |
|                             |   | UCB1CLK          | X                                       | 01      |
|                             |   | TA3.CCI0A        | 0                                       | 10      |
|                             |   | TA3.0            | 1                                       |         |
|                             |   | A10              | X                                       | 11      |
| P5.4/UCB1STE/TA3CLK/A11     | 4 | P5.4 (I/O)       | I: 0; O: 1                              | 00      |
|                             |   | UCB1STE          | X                                       | 01      |
|                             |   | TA3CLK           | 0                                       | 10      |
|                             |   | A11              | X                                       | 11      |
| P5.5/UCB0CLK/TA2CLK         | 5 | P5.5 (I/O)       | I: 0; O: 1                              | 00      |
|                             |   | UCB0CLK          | X                                       | 01      |
|                             |   | TA2CLK           | 0                                       | 10      |
| P5.6/UCB0STE/TA2.0          | 6 | P5.6 (I/O)       | I: 0; O: 1                              | 00      |
|                             |   | UCB0STE          | X                                       | 01      |
|                             |   | TA2.CCI0A        | 0                                       | 10      |
|                             |   | TA2.0            | 1                                       |         |
| P5.7/TA2.1/COMP0.2          | 7 | P5.7 (I/O)       | I: 0; O: 1                              | 00      |
|                             |   | TA2.CCI1A        | 0                                       | 01      |
|                             |   | TA2.1            | 1                                       |         |
|                             |   | COMP0.2          | X                                       | 11      |

(1) X = don't care

### 9.11.6 Port P6 (P6.0 to P6.2) Input/Output With Schmitt Trigger

Table 9-28 summarizes the selection of the pin functions.

**Table 9-28. Port P6 (P6.0 to P6.2) Pin Functions**

| PIN NAME (P6.x)    | x | FUNCTION   | CONTROL BITS AND SIGNALS <sup>(1)</sup> |         |
|--------------------|---|------------|-----------------------------------------|---------|
|                    |   |            | P6DIR.x                                 | P6SEL.x |
| P6.0/TA2.2/COMP0.3 | 0 | P6.0 (I/O) | I: 0; O: 1                              | 00      |
|                    |   | TA2.CCI2A  | 0                                       | 01      |
|                    |   | TA2.2      | 1                                       |         |
|                    |   | COMP0.3    | X                                       | 11      |
| P6.1/TB0CLK        | 1 | P6.1 (I/O) | I: 0; O: 1                              | 00      |
|                    |   | TB0CLK     | 0                                       | 01      |
| P6.2/TB0.0         | 2 | P6.2 (I/O) | I: 0; O: 1                              | 00      |
|                    |   | TB0.CCI0A  | 0                                       | 01      |
|                    |   | TB0.0      | 1                                       |         |

(1) X = don't care

## 9.12 Device Descriptors

[Table 9-29](#) lists the Device IDs. [Table 9-30](#) lists the contents of the device descriptor tag-length-value (TLV) structure.

**Table 9-29. Device IDs**

| DEVICE       | DEVICE ID |       |
|--------------|-----------|-------|
|              | 1A05h     | 1A04h |
| MSP430FR2676 | 83h       | 28h   |
| MSP430FR2675 | 83h       | 29h   |
| MSP430FR2673 | 83h       | 38h   |
| MSP430FR2672 | 83h       | 39h   |

**Table 9-30. Device Descriptors**

| DESCRIPTION       |                          | ADDRESS | VALUE                          |
|-------------------|--------------------------|---------|--------------------------------|
| Information block | Info length              | 1A00h   | 06h                            |
|                   | CRC length               | 1A01h   | 06h                            |
|                   | CRC value <sup>(1)</sup> | 1A02h   | Per unit                       |
|                   |                          | 1A03h   | Per unit                       |
|                   | Device ID                | 1A04h   | See <a href="#">Table 9-29</a> |
|                   |                          | 1A05h   |                                |
|                   | Hardware revision        | 1A06h   | Per unit                       |
|                   | Firmware revision        | 1A07h   | Per unit                       |
| Die record        | Die record tag           | 1A08h   | 08h                            |
|                   | Die record length        | 1A09h   | 0Ah                            |
|                   | Lot wafer ID             | 1A0Ah   | Per unit                       |
|                   |                          | 1A0Bh   | Per unit                       |
|                   |                          | 1A0Ch   | Per unit                       |
|                   |                          | 1A0Dh   | Per unit                       |
|                   | Die X position           | 1A0Eh   | Per unit                       |
|                   |                          | 1A0Fh   | Per unit                       |
|                   | Die Y position           | 1A10h   | Per unit                       |
|                   |                          | 1A11h   | Per unit                       |
|                   | Test result              | 1A12h   | Per unit                       |
|                   |                          | 1A13h   | Per unit                       |

**Table 9-30. Device Descriptors (continued)**

| DESCRIPTION                   |                                                               | ADDRESS | VALUE    |
|-------------------------------|---------------------------------------------------------------|---------|----------|
| ADC calibration               | ADC calibration tag                                           | 1A14h   | 11h      |
|                               | ADC calibration length                                        | 1A15h   | 10h      |
|                               | ADC gain factor <sup>(3)</sup>                                | 1A16h   | Per unit |
|                               |                                                               | 1A17h   | Per unit |
|                               | ADC offset <sup>(4)</sup>                                     | 1A18h   | Per unit |
|                               |                                                               | 1A19h   | Per unit |
|                               | ADC internal shared 1.5-V reference, temperature sensor 30°C  | 1A1Ah   | Per unit |
|                               |                                                               | 1A1Bh   | Per unit |
|                               | ADC internal shared 1.5-V reference, temperature sensor 105°C | 1A1Ch   | Per unit |
|                               |                                                               | 1A1Dh   | Per unit |
|                               | ADC internal shared 2.0-V reference, temperature sensor 30°C  | 1A1Eh   | Per unit |
|                               |                                                               | 1A1Fh   | Per unit |
|                               | ADC internal shared 2.0-V reference, temperature sensor 105°C | 1A20h   | Per unit |
|                               |                                                               | 1A21h   | Per unit |
| Reference and DCO calibration | ADC internal shared 2.5-V reference, temperature sensor 30°C  | 1A22h   | Per unit |
|                               |                                                               | 1A23h   | Per unit |
|                               | ADC internal shared 2.5-V reference, temperature sensor 105°C | 1A24h   | Per unit |
|                               |                                                               | 1A25h   | Per unit |
|                               | Internal shared reference Calibration tag                     | 1A26h   | 12h      |
|                               | Internal shared reference Calibration length                  | 1A27h   | 0Ah      |
|                               | Internal shared 1.5-V reference factor                        | 1A28h   | Per unit |
|                               |                                                               | 1A29h   | Per unit |
|                               | Internal shared 2.0-V reference factor                        | 1A2Ah   | Per unit |
|                               |                                                               | 1A2Bh   | Per unit |
|                               | Internal shared 2.5-V reference factor                        | 1A2Ch   | Per unit |
|                               |                                                               | 1A2Dh   | Per unit |
|                               | DCO tap settings for 16 MHz, temperature 30°C                 | 1A2Eh   | Per unit |
|                               |                                                               | 1A2Fh   | Per unit |
|                               | DCO tap settings for 24 MHz, temperature 30°C <sup>(2)</sup>  | 1A30h   | Per unit |
|                               |                                                               | 1A31h   | Per unit |

(1) CRC value covers the checksum from 0x1A04h to 0x1AF7h by applying CRC-CCITT-16 polynomial of  $x^{16} + x^{12} + x^5 + 1$ .

(2) This value can be directly loaded into the DCO bits in the CSCTL0 register to get an accurate 24-MHz frequency at room temperature, especially when MCU exits from LPM3 and below. TI also suggests to use a predivider to decrease the frequency if the temperature drift might result an overshoot faster than 24 MHz.

(3) ADC gain: the gain correction factor is measured at 2.4 V and room temperature using ADCSREFx = 0x7, an external reference without internal buffer.  $V_{R+} = V_{\text{eref+}}$ ,  $V_{R-} = V_{\text{eref-}}$ . Other settings can result in different factors.

(4) ADC offset: the offset correction factor is measured at 2.4 V and room temperature using ADCSREFx = 0x7, an external reference without internal buffer.  $V_{R+} = V_{\text{eref+}}$ ,  $V_{R-} = V_{\text{eref-}}$ . Other settings can result in different factors

## 9.13 Memory

### 9.13.1 Memory Organization

Table 9-31 summarizes the memory organization of the devices.

**Table 9-31. Memory Organization**

|                                                                              | ACCESS                                                | MSP430FR2676                              | MSP430FR2675                             | MSP430FR2673                             | MSP430FR2672                            |
|------------------------------------------------------------------------------|-------------------------------------------------------|-------------------------------------------|------------------------------------------|------------------------------------------|-----------------------------------------|
| Bootloader (BSL2) memory (ROM)                                               | Read only                                             | 1KB<br>FFFFFh to FFC00h                   | 1KB<br>FFFFFh to FFC00h                  | 1KB<br>FFFFFh to FFC00h                  | 1KB<br>FFFFFh to FFC00h                 |
| CapTIvate libraries and driver libraries (ROM)                               | Read only                                             | 16KB<br>C3FFFh to C0000h                  | 16KB<br>C3FFFh to C0000h                 | 16KB<br>C3FFFh to C0000h                 | 16KB<br>C3FFFh to C0000h                |
| Memory (FRAM)<br>Main: interrupt vectors and signatures<br>Main: code memory | Read/Write<br>(Optional Write Protect) <sup>(1)</sup> | 64KB<br>FFFFh to FF80h<br>17FFFh to 8000h | 32KB<br>FFFFh to FF80h<br>FFFFh to 8000h | 16KB<br>FFFFh to FF80h<br>FFFFh to C000h | 8KB<br>FFFFh to FF80h<br>FFFFh to E000h |
| RAM                                                                          | Read/Write                                            | 8KB<br>3FFFh to 2000h                     | 6KB<br>37FFh to 2000h                    | 4KB<br>2FFFh to 2000h                    | 2KB<br>27FFh to 2000h                   |
| Information memory (FRAM)                                                    | Read/Write<br>(Optional Write Protect) <sup>(2)</sup> | 512 bytes<br>19FFh to 1800h               | 512 bytes<br>19FFh to 1800h              | 512 bytes<br>19FFh to 1800h              | 512 bytes<br>19FFh to 1800h             |
| Bootloader (BSL1) memory (ROM)                                               | Read only                                             | 2KB<br>17FFh to 1000h                     | 2KB<br>17FFh to 1000h                    | 2KB<br>17FFh to 1000h                    | 2KB<br>17FFh to 1000h                   |
| Peripherals                                                                  | Read/Write                                            | 4KB<br>0FFFh to 0020h                     | 4KB<br>0FFFh to 0020h                    | 4KB<br>0FFFh to 0020h                    | 4KB<br>0FFFh to 0020h                   |
| Tiny RAM                                                                     | Read/Write                                            | 26 bytes<br>001Fh to 0006h                | 26 bytes<br>001Fh to 0006h               | 26 bytes<br>001Fh to 0006h               | 26 bytes<br>001Fh to 0006h              |
| Reserved <sup>(3)</sup>                                                      | Read only                                             | 6 bytes<br>0005h to 0000h                 | 6 bytes<br>0005h to 0000h                | 6 bytes<br>0005h to 0000h                | 6 bytes<br>0005h to 0000h               |

- (1) The Program FRAM can be write protected by setting PFWP bit in SYSCFG0 register. See the SYS chapter in the [MP430FR4xx and MP430FR2xx Family User's Guide](#) for more details
- (2) The Information FRAM can be write protected by setting DFWP bit in SYSCFG0 register. See the SYS chapter in the [MP430FR4xx and MP430FR2xx Family User's Guide](#) for more details
- (3) Read as: D032h at 00h (Opcode: BIS.W LPM4, SR), 00F0h at 02h (Opcode: BIS.W LPM4, SR), 3FFFh at 04h (Opcode: JMP\$)

### 9.13.2 Peripheral File Map

Table 9-32 lists the available peripherals and the register base address for each.

**Table 9-32. Peripherals Summary**

| MODULE NAME                                         | BASE ADDRESS | SIZE  |
|-----------------------------------------------------|--------------|-------|
| Special Functions (see Table 9-33)                  | 0100h        | 0010h |
| PMM (see Table 9-34)                                | 0120h        | 0020h |
| SYS (see Table 9-35)                                | 0140h        | 0040h |
| CS (see Table 9-36)                                 | 0180h        | 0020h |
| FRAM (see Table 9-37)                               | 01A0h        | 0010h |
| CRC (see Table 9-38)                                | 01C0h        | 0008h |
| WDT (see Table 9-39)                                | 01CCh        | 0002h |
| Port P1, P2 (see Table 9-40)                        | 0200h        | 0020h |
| Port P3, P4 (see Table 9-41)                        | 0220h        | 0020h |
| Port P5, P6 (see Table 9-42)                        | 0240h        | 0020h |
| RTC (see Table 9-43)                                | 0300h        | 0010h |
| Timer0_A3 (see Table 9-44)                          | 0380h        | 0030h |
| Timer1_A3 (see Table 9-45)                          | 03C0h        | 0030h |
| Timer2_A3 (see Table 9-46)                          | 0400h        | 0030h |
| Timer3_A3 (see Table 9-47)                          | 0440h        | 0030h |
| Timer0_B7 (see Table 9-48)                          | 0480h        | 0030h |
| MPY32 (see Table 9-49)                              | 04C0h        | 0030h |
| eUSCI_A0 (see Table 9-50)                           | 0500h        | 0020h |
| eUSCI_A1 (see Table 9-51)                           | 0520h        | 0020h |
| eUSCI_B0 (see Table 9-52)                           | 0540h        | 0030h |
| eUSCI_B1 (see Table 9-53)                           | 0580h        | 0030h |
| Backup Memory (see Table 9-54)                      | 0660h        | 0020h |
| ADC (see Table 9-55)                                | 0700h        | 0040h |
| eCOMP0 (see Table 9-56)                             | 08E0h        | 0020h |
| CapTivate (see CapTivate Design Center for details) | 0A00h        | 0200h |

**Table 9-33. Special Function Registers (Base Address: 0100h)**

| REGISTER DESCRIPTION  | ACRONYM | OFFSET |
|-----------------------|---------|--------|
| SFR interrupt enable  | SFRIE1  | 00h    |
| SFR interrupt flag    | SFRIFG1 | 02h    |
| SFR reset pin control | SFRRPCR | 04h    |

**Table 9-34. PMM Registers (Base Address: 0120h)**

| REGISTER DESCRIPTION | ACRONYM | OFFSET |
|----------------------|---------|--------|
| PMM control 0        | PMMCTL0 | 00h    |
| PMM control 1        | PMMCTL1 | 02h    |
| PMM control 2        | PMMCTL2 | 04h    |
| PMM interrupt flags  | PMMIFG  | 0Ah    |
| PM5 control 0        | PM5CTL0 | 10h    |

**Table 9-35. SYS Registers (Base Address: 0140h)**

| REGISTER DESCRIPTION          | ACRONYM | OFFSET |
|-------------------------------|---------|--------|
| System control                | SYSCTL  | 00h    |
| Bootloader configuration area | SYSBSLC | 02h    |

**Table 9-35. SYS Registers (Base Address: 0140h) (continued)**

| REGISTER DESCRIPTION        | ACRONYM   | OFFSET |
|-----------------------------|-----------|--------|
| JTAG mailbox control        | SYSJMBBC  | 06h    |
| JTAG mailbox input 0        | SYSJMBI0  | 08h    |
| JTAG mailbox input 1        | SYSJMBI1  | 0Ah    |
| JTAG mailbox output 0       | SYSJMBO0  | 0Ch    |
| JTAG mailbox output 1       | SYSJMBO1  | 0Eh    |
| Bus error vector generator  | SYSBERRIV | 18h    |
| User NMI vector generator   | SYSUNIV   | 1Ah    |
| System NMI vector generator | SYSSNIV   | 1Ch    |
| Reset vector generator      | SYSRSTIV  | 1Eh    |
| System configuration 0      | SYSCFG0   | 20h    |
| System configuration 1      | SYSCFG1   | 22h    |
| System configuration 2      | SYSCFG2   | 24h    |
| System configuration 3      | SYSCFG3   | 26h    |

**Table 9-36. CS Registers (Base Address: 0180h)**

| REGISTER DESCRIPTION | ACRONYM | OFFSET |
|----------------------|---------|--------|
| CS control 0         | CSCTL0  | 00h    |
| CS control 1         | CSCTL1  | 02h    |
| CS control 2         | CSCTL2  | 04h    |
| CS control 3         | CSCTL3  | 06h    |
| CS control 4         | CSCTL4  | 08h    |
| CS control 5         | CSCTL5  | 0Ah    |
| CS control 6         | CSCTL6  | 0Ch    |
| CS control 7         | CSCTL7  | 0Eh    |
| CS control 8         | CSCTL8  | 10h    |

**Table 9-37. FRAM Registers (Base Address: 01A0h)**

| REGISTER DESCRIPTION | ACRONYM | OFFSET |
|----------------------|---------|--------|
| FRAM control 0       | FRCTL0  | 00h    |
| General control 0    | GCCTL0  | 04h    |
| General control 1    | GCCTL1  | 06h    |

**Table 9-38. CRC Registers (Base Address: 01C0h)**

| REGISTER DESCRIPTION          | ACRONYM   | OFFSET |
|-------------------------------|-----------|--------|
| CRC data input                | CRC16DI   | 00h    |
| CRC data input reverse byte   | CRCDIRB   | 02h    |
| CRC initialization and result | CRCINIRES | 04h    |
| CRC result reverse byte       | CRCRESR   | 06h    |

**Table 9-39. WDT Registers (Base Address: 01CCh)**

| REGISTER DESCRIPTION   | ACRONYM | OFFSET |
|------------------------|---------|--------|
| Watchdog timer control | WDTCTL  | 00h    |

**Table 9-40. Port P1, P2 Registers (Base Address: 0200h)**

| REGISTER DESCRIPTION | ACRONYM | OFFSET |
|----------------------|---------|--------|
| Port P1 input        | P1IN    | 00h    |
| Port P1 output       | P1OUT   | 02h    |
| Port P1 direction    | P1DIR   | 04h    |

**Table 9-40. Port P1, P2 Registers (Base Address: 0200h) (continued)**

| REGISTER DESCRIPTION          | ACRONYM | OFFSET |
|-------------------------------|---------|--------|
| Port P1 pulling enable        | P1REN   | 06h    |
| Port P1 selection 0           | P1SEL0  | 0Ah    |
| Port P1 selection 1           | P1SEL1  | 0Ch    |
| Port P1 interrupt vector word | P1IV    | 0Eh    |
| Port P1 complement selection  | P1SELC  | 16h    |
| Port P1 interrupt edge select | P1IES   | 18h    |
| Port P1 interrupt enable      | P1IE    | 1Ah    |
| Port P1 interrupt flag        | P1IFG   | 1Ch    |
| Port P2 input                 | P2IN    | 01h    |
| Port P2 output                | P2OUT   | 03h    |
| Port P2 direction             | P2DIR   | 05h    |
| Port P2 pulling enable        | P2REN   | 07h    |
| Port P2 selection 0           | P2SEL0  | 0Bh    |
| Port P2 selection 1           | P2SEL1  | 0Dh    |
| Port P2 interrupt vector word | P2IV    | 1Eh    |
| Port P2 complement selection  | P2SELC  | 17h    |
| Port P2 interrupt edge select | P2IES   | 19h    |
| Port P2 interrupt enable      | P2IE    | 1Bh    |
| Port P2 interrupt flag        | P2IFG   | 1Dh    |

**Table 9-41. Port P3, P4 Registers (Base Address: 0220h)**

| REGISTER DESCRIPTION          | ACRONYM | OFFSET |
|-------------------------------|---------|--------|
| Port P3 input                 | P3IN    | 00h    |
| Port P3 output                | P3OUT   | 02h    |
| Port P3 direction             | P3DIR   | 04h    |
| Port P3 pulling enable        | P3REN   | 06h    |
| Port P3 selection 0           | P3SEL0  | 0Ah    |
| Port P3 selection 1           | P3SEL1  | 0Ch    |
| Port P3 interrupt vector word | P3IV    | 0Eh    |
| Port P3 complement selection  | P3SELC  | 16h    |
| Port P3 interrupt edge select | P3IES   | 18h    |
| Port P3 interrupt enable      | P3IE    | 1Ah    |
| Port P3 interrupt flag        | P3IFG   | 1Ch    |
| Port P4 input                 | P4IN    | 01h    |
| Port P4 output                | P4OUT   | 03h    |
| Port P4 direction             | P4DIR   | 05h    |
| Port P4 pulling enable        | P4REN   | 07h    |
| Port P4 selection 0           | P4SEL0  | 0Bh    |
| Port P4 selection 1           | P4SEL1  | 0Dh    |
| Port P4 interrupt vector word | P4IV    | 1Eh    |
| Port P4 complement selection  | P4SELC  | 17h    |
| Port P4 interrupt edge select | P4IES   | 19h    |
| Port P4 interrupt enable      | P4IE    | 1Bh    |
| Port P4 interrupt flag        | P4IFG   | 1Dh    |

**Table 9-42. Port P5, P6 Registers (Base Address: 0240h)**

| REGISTER DESCRIPTION          | ACRONYM | OFFSET |
|-------------------------------|---------|--------|
| Port P5 input                 | P5IN    | 00h    |
| Port P5 output                | P5OUT   | 02h    |
| Port P5 direction             | P5DIR   | 04h    |
| Port P5 pulling enable        | P5REN   | 06h    |
| Port P5 selection 0           | P5SEL0  | 0Ah    |
| Port P5 selection 1           | P5SEL1  | 0Ch    |
| Port P5 interrupt vector word | P5IV    | 0Eh    |
| Port P5 complement selection  | P5SELC  | 16h    |
| Port P5 interrupt edge select | P5IES   | 18h    |
| Port P5 interrupt enable      | P5IE    | 1Ah    |
| Port P5 interrupt flag        | P5IFG   | 1Ch    |
| Port P6 input                 | P6IN    | 01h    |
| Port P6 output                | P6OUT   | 03h    |
| Port P6 direction             | P6DIR   | 05h    |
| Port P6 pulling enable        | P6REN   | 07h    |
| Port P6 selection 0           | P6SEL0  | 0Bh    |
| Port P6 selection 1           | P6SEL1  | 0Dh    |
| Port P6 interrupt vector word | P6IV    | 1Eh    |
| Port P6 complement selection  | P6SELC  | 17h    |
| Port P6 interrupt edge select | P6IES   | 19h    |
| Port P6 interrupt enable      | P6IE    | 1Bh    |
| Port P6 interrupt flag        | P6IFG   | 1Dh    |

**Table 9-43. RTC Registers (Base Address: 0300h)**

| REGISTER DESCRIPTION | ACRONYM | OFFSET |
|----------------------|---------|--------|
| RTC control          | RTCCTL  | 00h    |
| RTC interrupt vector | RTCIV   | 04h    |
| RTC modulo           | RTCMOD  | 08h    |
| RTC counter          | RTCCNT  | 0Ch    |

**Table 9-44. Timer0\_A3 Registers (Base Address: 0380h)**

| REGISTER DESCRIPTION      | ACRONYM  | OFFSET |
|---------------------------|----------|--------|
| TA0 control               | TA0CTL   | 00h    |
| Capture/compare control 0 | TA0CCTL0 | 02h    |
| Capture/compare control 1 | TA0CCTL1 | 04h    |
| Capture/compare control 2 | TA0CCTL2 | 06h    |
| TA0 counter               | TA0R     | 10h    |
| Capture/compare 0         | TA0CCR0  | 12h    |
| Capture/compare 1         | TA0CCR1  | 14h    |
| Capture/compare 2         | TA0CCR2  | 16h    |
| TA0 expansion 0           | TA0EX0   | 20h    |
| TA0 interrupt vector      | TA0IV    | 2Eh    |

**Table 9-45. Timer1\_A3 Registers (Base Address: 03C0h)**

| REGISTER DESCRIPTION      | ACRONYM  | OFFSET |
|---------------------------|----------|--------|
| TA1 control               | TA1CTL   | 00h    |
| Capture/compare control 0 | TA1CCTL0 | 02h    |

**Table 9-45. Timer1\_A3 Registers (Base Address: 03C0h) (continued)**

| REGISTER DESCRIPTION      | ACRONYM  | OFFSET |
|---------------------------|----------|--------|
| Capture/compare control 1 | TA1CCTL1 | 04h    |
| Capture/compare control 2 | TA1CCTL2 | 06h    |
| TA1 counter               | TA1R     | 10h    |
| Capture/compare 0         | TA1CCR0  | 12h    |
| Capture/compare 1         | TA1CCR1  | 14h    |
| Capture/compare 2         | TA1CCR2  | 16h    |
| TA1 expansion 0           | TA1EX0   | 20h    |
| TA1 interrupt vector      | TA1IV    | 2Eh    |

**Table 9-46. Timer2\_A3 Registers (Base Address: 0400h)**

| REGISTER DESCRIPTION      | ACRONYM  | OFFSET |
|---------------------------|----------|--------|
| TA2 control               | TA2CTL   | 00h    |
| Capture/compare control 0 | TA2CCTL0 | 02h    |
| Capture/compare control 1 | TA2CCTL1 | 04h    |
| Capture/compare control 2 | TA2CCTL2 | 06h    |
| TA2 counter               | TA2R     | 10h    |
| Capture/compare 0         | TA2CCR0  | 12h    |
| Capture/compare 1         | TA2CCR1  | 14h    |
| Capture/compare 2         | TA2CCR2  | 16h    |
| TA2 expansion 0           | TA2EX0   | 20h    |
| TA2 interrupt vector      | TA2IV    | 2Eh    |

**Table 9-47. Timer3\_A3 Registers (Base Address: 0440h)**

| REGISTER DESCRIPTION      | ACRONYM  | OFFSET |
|---------------------------|----------|--------|
| TA3 control               | TA3CTL   | 00h    |
| Capture/compare control 0 | TA3CCTL0 | 02h    |
| Capture/compare control 1 | TA3CCTL1 | 04h    |
| Capture/compare control 2 | TA3CCTL2 | 06h    |
| TA3 counter               | TA3R     | 10h    |
| Capture/compare 0         | TA3CCR0  | 12h    |
| Capture/compare 1         | TA3CCR1  | 14h    |
| Capture/compare 2         | TA3CCR2  | 16h    |
| TA3 expansion 0           | TA3EX0   | 20h    |
| TA3 interrupt vector      | TA3IV    | 2Eh    |

**Table 9-48. Timer0\_B7 Registers (Base Address: 0480h)**

| REGISTER DESCRIPTION      | ACRONYM  | OFFSET |
|---------------------------|----------|--------|
| TB0 control               | TB0CTL   | 00h    |
| Capture/compare control 0 | TB0CCTL0 | 02h    |
| Capture/compare control 1 | TB0CCTL1 | 04h    |
| Capture/compare control 2 | TB0CCTL2 | 06h    |
| Capture/compare control 3 | TB0CCTL3 | 08h    |
| Capture/compare control 4 | TB0CCTL4 | 0Ah    |
| Capture/compare control 5 | TB0CCTL5 | 0Ch    |
| Capture/compare control 6 | TB0CCTL6 | 0Eh    |
| TB0 counter               | TB0R     | 10h    |
| Capture/compare 0         | TB0CCR0  | 12h    |

**Table 9-48. Timer0\_B7 Registers (Base Address: 0480h) (continued)**

| REGISTER DESCRIPTION | ACRONYM | OFFSET |
|----------------------|---------|--------|
| Capture/compare 1    | TB0CCR1 | 14h    |
| Capture/compare 2    | TB0CCR2 | 16h    |
| Capture/compare 3    | TB0CCR3 | 18h    |
| Capture/compare 4    | TB0CCR4 | 1Ah    |
| Capture/compare 5    | TB0CCR5 | 1Ch    |
| Capture/compare 6    | TB0CCR6 | 1Eh    |
| TB0 expansion 0      | TB0EX0  | 20h    |
| TB0 interrupt vector | TB0IV   | 2Eh    |

**Table 9-49. MPY32 Registers (Base Address: 04C0h)**

| REGISTER DESCRIPTION                                    | ACRONYM   | OFFSET |
|---------------------------------------------------------|-----------|--------|
| 16-bit operand 1 – multiply                             | MPY       | 00h    |
| 16-bit operand 1 – signed multiply                      | MPYS      | 02h    |
| 16-bit operand 1 – multiply accumulate                  | MAC       | 04h    |
| 16-bit operand 1 – signed multiply accumulate           | MACS      | 06h    |
| 16-bit operand 2                                        | OP6       | 08h    |
| 16 × 16 result low word                                 | RESLO     | 0Ah    |
| 16 × 16 result high word                                | RESHI     | 0Ch    |
| 16 × 16 sum extension                                   | SUMEXT    | 0Eh    |
| 32-bit operand 1 – multiply low word                    | MPY32L    | 10h    |
| 32-bit operand 1 – multiply high word                   | MPY32H    | 12h    |
| 32-bit operand 1 – signed multiply low word             | MPYS32L   | 14h    |
| 32-bit operand 1 – signed multiply high word            | MPYS32H   | 16h    |
| 32-bit operand 1 – multiply accumulate low word         | MAC32L    | 18h    |
| 32-bit operand 1 – multiply accumulate high word        | MAC32H    | 1Ah    |
| 32-bit operand 1 – signed multiply accumulate low word  | MACS32L   | 1Ch    |
| 32-bit operand 1 – signed multiply accumulate high word | MACS32H   | 1Eh    |
| 32-bit operand 2 – low word                             | OP2L      | 20h    |
| 32-bit operand 2 – high word                            | OP2H      | 22h    |
| 32 × 32 result 0 – least significant word               | RES0      | 24h    |
| 32 × 32 result 1                                        | RES1      | 26h    |
| 32 × 32 result 2                                        | RES2      | 28h    |
| 32 × 32 result 3 – most significant word                | RES3      | 2Ah    |
| MPY32 control 0                                         | MPY32CTL0 | 2Ch    |

**Table 9-50. eUSCI\_A0 Registers (Base Address: 0500h)**

| REGISTER DESCRIPTION       | ACRONYM   | OFFSET |
|----------------------------|-----------|--------|
| eUSCI_A control word 0     | UCA0CTLW0 | 00h    |
| eUSCI_A control word 1     | UCA0CTLW1 | 02h    |
| eUSCI_A control rate 0     | UCA0BR0   | 06h    |
| eUSCI_A control rate 1     | UCA0BR1   | 07h    |
| eUSCI_A modulation control | UCA0MCTLW | 08h    |
| eUSCI_A status             | UCA0STAT  | 0Ah    |
| eUSCI_A receive buffer     | UCA0RXBUF | 0Ch    |
| eUSCI_A transmit buffer    | UCA0TXBUF | 0Eh    |
| eUSCI_A LIN control        | UCA0ABCTL | 10h    |

**Table 9-50. eUSCI\_A0 Registers (Base Address: 0500h) (continued)**

| REGISTER DESCRIPTION          | ACRONYM     | OFFSET |
|-------------------------------|-------------|--------|
| eUSCI_A IrDA transmit control | IUCA0IRTCTL | 12h    |
| eUSCI_A IrDA receive control  | IUCA0IRRCTL | 13h    |
| eUSCI_A interrupt enable      | UCA0IE      | 1Ah    |
| eUSCI_A interrupt flags       | UCA0IFG     | 1Ch    |
| eUSCI_A interrupt vector word | UCA0IV      | 1Eh    |

**Table 9-51. eUSCI\_A1 Registers (Base Address: 0520h)**

| REGISTER DESCRIPTION          | ACRONYM     | OFFSET |
|-------------------------------|-------------|--------|
| eUSCI_A control word 0        | UCA1CTLW0   | 00h    |
| eUSCI_A control word 1        | UCA1CTLW1   | 02h    |
| eUSCI_A control rate 0        | UCA1BR0     | 06h    |
| eUSCI_A control rate 1        | UCA1BR1     | 07h    |
| eUSCI_A modulation control    | UCA1MCTLW   | 08h    |
| eUSCI_A status                | UCA1STAT    | 0Ah    |
| eUSCI_A receive buffer        | UCA1RXBUF   | 0Ch    |
| eUSCI_A transmit buffer       | UCA1TXBUF   | 0Eh    |
| eUSCI_A LIN control           | UCA1ABCTL   | 10h    |
| eUSCI_A IrDA transmit control | IUCA1IRTCTL | 12h    |
| eUSCI_A IrDA receive control  | IUCA1IRRCTL | 13h    |
| eUSCI_A interrupt enable      | UCA1IE      | 1Ah    |
| eUSCI_A interrupt flags       | UCA1IFG     | 1Ch    |
| eUSCI_A interrupt vector word | UCA1IV      | 1Eh    |

**Table 9-52. eUSCI\_B0 Registers (Base Address: 0540h)**

| REGISTER DESCRIPTION           | ACRONYM     | OFFSET |
|--------------------------------|-------------|--------|
| eUSCI_B control word 0         | UCB0CTLW0   | 00h    |
| eUSCI_B control word 1         | UCB0CTLW1   | 02h    |
| eUSCI_B bit rate 0             | UCB0BR0     | 06h    |
| eUSCI_B bit rate 1             | UCB0BR1     | 07h    |
| eUSCI_B status word            | UCB0STATW   | 08h    |
| eUSCI_B byte counter threshold | UCB0TBCNT   | 0Ah    |
| eUSCI_B receive buffer         | UCB0RXBUF   | 0Ch    |
| eUSCI_B transmit buffer        | UCB0TXBUF   | 0Eh    |
| eUSCI_B I2C own address 0      | UCB0I2COA0  | 14h    |
| eUSCI_B I2C own address 1      | UCB0I2COA1  | 16h    |
| eUSCI_B I2C own address 2      | UCB0I2COA2  | 18h    |
| eUSCI_B I2C own address 3      | UCB0I2COA3  | 1Ah    |
| eUSCI_B receive address        | UCB0ADDRX   | 1Ch    |
| eUSCI_B address mask           | UCB0ADDMASK | 1Eh    |
| eUSCI_B I2C slave address      | UCB0I2CSA   | 20h    |
| eUSCI_B interrupt enable       | UCB0IE      | 2Ah    |
| eUSCI_B interrupt flags        | UCB0IFG     | 2Ch    |
| eUSCI_B interrupt vector word  | UCB0IV      | 2Eh    |

**Table 9-53. eUSCI\_B1 Registers (Base Address: 0580h)**

| REGISTER DESCRIPTION   | ACRONYM   | OFFSET |
|------------------------|-----------|--------|
| eUSCI_B control word 0 | UCB1CTLW0 | 00h    |

**Table 9-53. eUSCI\_B1 Registers (Base Address: 0580h) (continued)**

| REGISTER DESCRIPTION           | ACRONYM     | OFFSET |
|--------------------------------|-------------|--------|
| eUSCI_B control word 1         | UCB1CTLW1   | 02h    |
| eUSCI_B bit rate 0             | UCB1BR0     | 06h    |
| eUSCI_B bit rate 1             | UCB1BR1     | 07h    |
| eUSCI_B status word            | UCB1STATW   | 08h    |
| eUSCI_B byte counter threshold | UCB1TBCNT   | 0Ah    |
| eUSCI_B receive buffer         | UCB1RXBUF   | 0Ch    |
| eUSCI_B transmit buffer        | UCB1TXBUF   | 0Eh    |
| eUSCI_B I2C own address 0      | UCB1I2COA0  | 14h    |
| eUSCI_B I2C own address 1      | UCB1I2COA1  | 16h    |
| eUSCI_B I2C own address 2      | UCB1I2COA2  | 18h    |
| eUSCI_B I2C own address 3      | UCB1I2COA3  | 1Ah    |
| eUSCI_B receive address        | UCB1ADDRX   | 1Ch    |
| eUSCI_B address mask           | UCB1ADDMASK | 1Eh    |
| eUSCI_B I2C slave address      | UCB1I2CSA   | 20h    |
| eUSCI_B interrupt enable       | UCB1IE      | 2Ah    |
| eUSCI_B interrupt flags        | UCB1IFG     | 2Ch    |
| eUSCI_B interrupt vector word  | UCB1IV      | 2Eh    |

**Table 9-54. Backup Memory Registers (Base Address: 0660h)**

| REGISTER DESCRIPTION | ACRONYM  | OFFSET |
|----------------------|----------|--------|
| Backup memory 0      | BAKMEM0  | 00h    |
| Backup memory 1      | BAKMEM1  | 02h    |
| Backup memory 2      | BAKMEM2  | 04h    |
| Backup memory 3      | BAKMEM3  | 06h    |
| Backup memory 4      | BAKMEM4  | 08h    |
| Backup memory 5      | BAKMEM5  | 0Ah    |
| Backup memory 6      | BAKMEM6  | 0Ch    |
| Backup memory 7      | BAKMEM7  | 0Eh    |
| Backup memory 8      | BAKMEM8  | 10h    |
| Backup memory 9      | BAKMEM9  | 12h    |
| Backup memory 10     | BAKMEM10 | 14h    |
| Backup memory 11     | BAKMEM11 | 16h    |
| Backup memory 12     | BAKMEM12 | 18h    |
| Backup memory 13     | BAKMEM13 | 1Ah    |
| Backup memory 14     | BAKMEM14 | 1Ch    |
| Backup memory 15     | BAKMEM15 | 1Eh    |

**Table 9-55. ADC Registers (Base Address: 0700h)**

| REGISTER DESCRIPTION                 | REGISTER | OFFSET |
|--------------------------------------|----------|--------|
| ADC control 0                        | ADCCTL0  | 00h    |
| ADC control 1                        | ADCCTL1  | 02h    |
| ADC control 2                        | ADCCTL2  | 04h    |
| ADC window comparator low threshold  | ADCLO    | 06h    |
| ADC window comparator high threshold | ADCHI    | 08h    |
| ADC memory control 0                 | ADCMCTL0 | 0Ah    |
| ADC conversion memory                | ADCMEM0  | 12h    |

**Table 9-55. ADC Registers (Base Address: 0700h) (continued)**

| REGISTER DESCRIPTION      | REGISTER | OFFSET |
|---------------------------|----------|--------|
| ADC interrupt enable      | ADCIE    | 1Ah    |
| ADC interrupt flags       | ADCIFG   | 1Ch    |
| ADC interrupt vector word | ADCIV    | 1Eh    |

**Table 9-56. eCOMP Registers (Base Address: 08E0h)**

| REGISTER DESCRIPTION            | REGISTER  | OFFSET |
|---------------------------------|-----------|--------|
| Comparator control 0            | CP0CTL0   | 00h    |
| Comparator control 1            | CP0CTL1   | 02h    |
| Comparator interrupt            | CP0INT    | 06h    |
| Comparator interrupt vector     | CP0IV     | 08h    |
| Comparator built-in DAC control | CP0DACCTL | 10h    |

## 9.14 Identification

### 9.14.1 Revision Identification

The device revision information is included as part of the top-side marking on the device package. The device-specific errata sheet describes these markings.

The hardware revision is also stored in the Device Descriptor structure in the Info Block section. For details on this value, see the Hardware Revision entries in [Section 9.12](#).

### 9.14.2 Device Identification

The device type can be identified from the top-side marking on the device package. The device-specific errata sheet describes these markings.

A device identification value is also stored in the Device Descriptor structure in the Info Block section. For details on this value, see the Device ID entries in [Section 9.12](#).

### 9.14.3 JTAG Identification

Programming through the JTAG interface, including reading and identifying the JTAG ID, is described in [MSP430 Programming With the JTAG Interface](#).

## 10 Applications, Implementation, and Layout

### Note

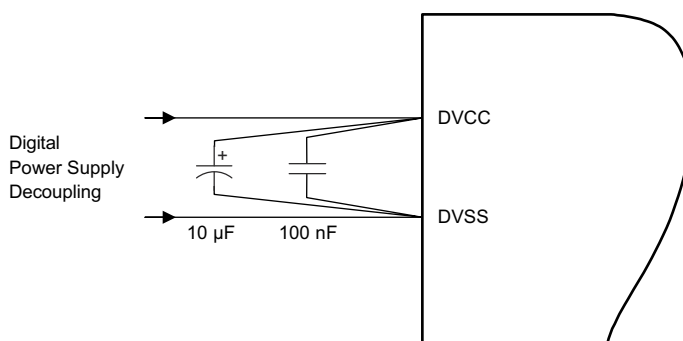
Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes, as well as validating and testing their design implementation to confirm system functionality.

### 10.1 Device Connection and Layout Fundamentals

This section discusses the recommended guidelines when designing with the MSP430 devices. These guidelines are to make sure that the device has proper connections for powering, programming, debugging, and optimum analog performance.

#### 10.1.1 Power Supply Decoupling and Bulk Capacitors

TI recommends connecting a combination of a 10- $\mu$ F plus a 100-nF low-ESR ceramic decoupling capacitor to the DVCC and DVSS pins. Higher-value capacitors may be used but can impact supply rail ramp-up time. Decoupling capacitors must be placed as close as possible to the pins that they decouple (within a few millimeters). Additionally, TI recommends separated grounds with a single-point connection for better noise isolation from digital-to-analog circuits on the board and to achieve high analog accuracy.



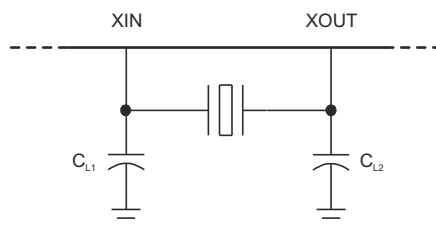
**Figure 10-1. Power Supply Decoupling**

#### 10.1.2 External Oscillator

This device supports only a low-frequency crystal (32 kHz) on the XIN and XOUT pins. External bypass capacitors for the crystal oscillator pins are required.

It is also possible to apply digital clock signals to the XIN input pin that meet the specifications of the respective oscillator if the appropriate XT1BYPASS mode is selected. In this case, the associated XOUT pin can be used for other purposes. If the XIN and XOUT pins are not used, they must be terminated according to [Section 7.6](#).

[Figure 10-2](#) shows a typical connection diagram.



**Figure 10-2. Typical Crystal Connection**

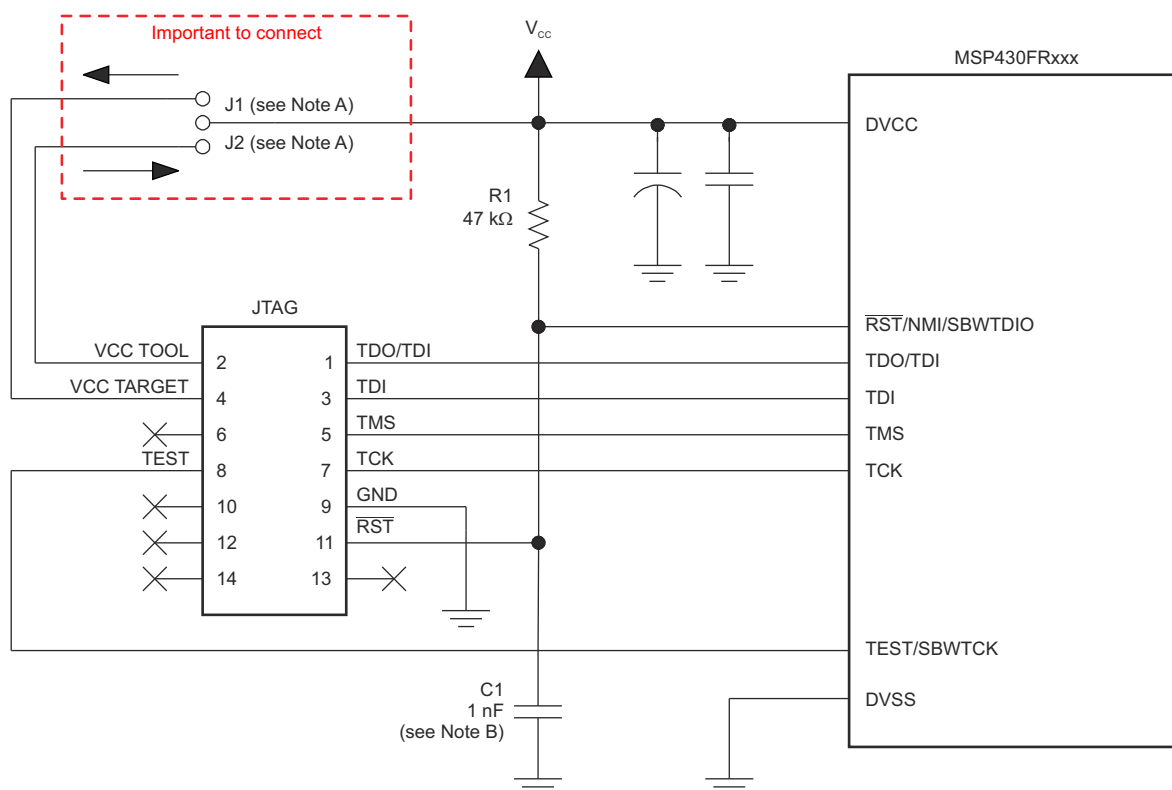
See [MSP430 32-kHz Crystal Oscillators](#) for more information on selecting, testing, and designing a crystal oscillator with the MSP430 devices.

### 10.1.3 JTAG

With the proper connections, the debugger and a hardware JTAG interface (such as the MSP-FET or MSP-FET430UIF) can be used to program and debug code on the target board. In addition, the connections also support the MSP-GANG production programmers, thus providing an easy way to program prototype boards, if desired. Figure 10-3 shows the connections between the 14-pin JTAG connector and the target device required to support in-system programming and debugging for 4-wire JTAG communication. Figure 10-4 shows the connections for 2-wire JTAG mode (Spy-Bi-Wire).

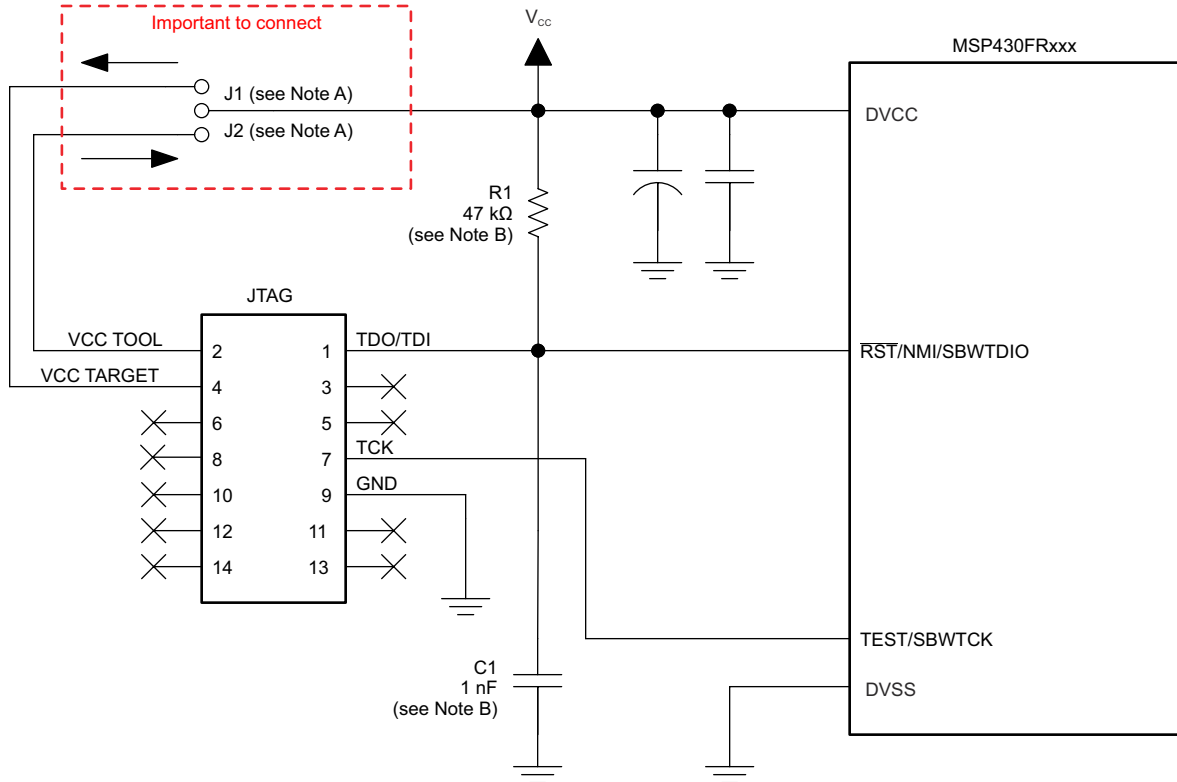
The connections for the MSP-FET and MSP-FET430UIF interface modules and the MSP-GANG are identical. Both can supply  $V_{CC}$  to the target board (through pin 2). In addition, the MSP-FET and MSP-FET430UIF interface modules and MSP-GANG have a  $V_{CC}$  sense feature that, if used, requires an alternate connection (pin 4 instead of pin 2). The  $V_{CC}$  sense feature detects the local  $V_{CC}$  present on the target board (that is, a battery or other local power supply) and adjusts the output signals accordingly. Figure 10-3 and Figure 10-4 show a jumper block that supports both scenarios of supplying  $V_{CC}$  to the target board. If this flexibility is not required, the desired  $V_{CC}$  connections may be hard-wired to eliminate the jumper block. Pins 2 and 4 must not be connected at the same time.

For additional design information regarding the JTAG interface, see the [MSP430 Hardware Tools User's Guide](#).



- A. If a local target power supply is used, make connection J1. If power from the debug or programming adapter is used, make connection J2.
- B. The upper limit for C1 is 1.1 nF when using current TI tools.

**Figure 10-3. Signal Connections for 4-Wire JTAG Communication**



- Make connection J1 if a local target power supply is used, or make connection J2 if the target is powered from the debug or programming adapter.
- The device  $\overline{\text{RST}}/\text{NMI}/\text{SBWTIO}$  pin is used in 2-wire mode for bidirectional communication with the device during JTAG access, and any capacitance that is attached to this signal may affect the ability to establish a connection with the device. The upper limit for C1 is 1.1 nF when using current TI tools.

**Figure 10-4. Signal Connections for 2-Wire JTAG Communication (Spy-Bi-Wire)**

#### 10.1.4 Reset

The reset pin can be configured as a reset function (default) or as an NMI function in the Special Function Register (SFR), SFRRPCR.

In reset mode, the  $\overline{\text{RST}}/\text{NMI}$  pin is active low, and a pulse applied to this pin that meets the reset timing specifications generates a BOR-type device reset.

Setting SYSNMI causes the  $\overline{\text{RST}}/\text{NMI}$  pin to be configured as an external NMI source. The external NMI is edge sensitive, and its edge is selectable by SYSNMIIES. Setting the NMIIE enables the interrupt of the external NMI. When an external NMI event occurs, the NMIIFG is set.

The  $\overline{\text{RST}}/\text{NMI}$  pin can have either a pullup or pulldown that is enabled or not. SYSRSTUP selects either pullup or pulldown, and SYSRSTRE causes the pullup (default) or pulldown to be enabled (default) or not. If the  $\overline{\text{RST}}/\text{NMI}$  pin is unused, it is required either to select and enable the internal pullup or to connect an external 47-kΩ pullup resistor to the  $\overline{\text{RST}}/\text{NMI}$  pin with a 10-nF pulldown capacitor. The pulldown capacitor should not exceed 1.1 nF when using devices with Spy-Bi-Wire interface in Spy-Bi-Wire mode or in 4-wire JTAG mode with TI tools like FET interfaces or GANG programmers.

See the [MP430FR4xx and MP430FR2xx Family User's Guide](#) for more information on the referenced control registers and bits.

#### 10.1.5 Unused Pins

For details on the connection of unused pins, see [Section 7.6](#).

### 10.1.6 General Layout Recommendations

- Proper grounding and short traces for external crystal to reduce parasitic capacitance. See [MSP430 32-kHz Crystal Oscillators](#) for recommended layout guidelines.
- Proper bypass capacitors on DVCC and reference pins, if used.
- Avoid routing any high-frequency signal close to an analog signal line. For example, keep digital switching signals such as PWM or JTAG signals away from the oscillator circuit.
- Proper ESD level protection should be considered to protect the device from unintended high-voltage electrostatic discharge. See [MSP430 System-Level ESD Considerations](#) for guidelines.

### 10.1.7 Do's and Don'ts

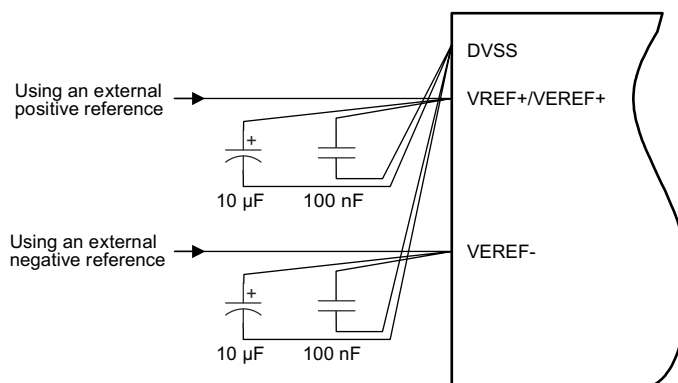
During power up, power down, and device operation, DVCC must not exceed the limits specified in [Section 8.1, Absolute Maximum Ratings](#). Exceeding the specified limits may cause malfunction of the device including erroneous writes to RAM and FRAM.

## 10.2 Peripheral- and Interface-Specific Design Information

### 10.2.1 ADC Peripheral

#### 10.2.1.1 Partial Schematic

[Figure 10-5](#) shows the recommended decoupling circuit when an external voltage reference is used.



**Figure 10-5. ADC Grounding and Noise Considerations**

#### 10.2.1.2 Design Requirements

As with any high-resolution ADC, appropriate printed-circuit-board layout and grounding techniques should be followed to eliminate ground loops, unwanted parasitic effects, and noise.

Ground loops are formed when return current from the ADC flows through paths that are common with other analog or digital circuitry. If care is not taken, this current can generate small unwanted offset voltages that can add to or subtract from the reference or input voltages of the ADC. The general guidelines in [Section 10.1.1](#) combined with the connections shown in [Figure 10-5](#) prevent this.

Quickly switching digital signals and noisy power supply lines can corrupt the conversion results, so keep the ADC input trace shielded from those digital and power supply lines. Putting the MCU in low-power mode during the ADC conversion improves the ADC performance in a noisy environment. If the device includes the analog power pair inputs (AVCC and AVSS), TI recommends a noise-free design using separate analog and digital ground planes with a single-point connection to achieve high accuracy.

[Figure 10-5](#) shows the recommended decoupling circuit when an external voltage reference is used. The internal reference module has a maximum drive current as described in the sections *ADC Pin Enable* and *1.2-V Reference Settings* of the [MSP430FR4xx and MSP430FR2xx Family User's Guide](#).

The reference voltage must be a stable voltage for accurate measurements. The capacitor values that are selected in the general guidelines filter out the high- and low-frequency ripple before the reference voltage enters

the device. In this case, the 10- $\mu$ F capacitor buffers the reference pin and filters low-frequency ripple. A 100-nF bypass capacitor filters high-frequency noise.

#### **10.2.1.3 Layout Guidelines**

Components that are shown in the partial schematic (see [Figure 10-5](#)) should be placed as close as possible to the respective device pins to avoid long traces, because they add additional parasitic capacitance, inductance, and resistance on the signal.

Avoid routing analog input signals close to a high-frequency pin (for example, a high-frequency PWM), because the high-frequency switching can be coupled into the analog signal.

### **10.2.2 CapTIvate Peripheral**

This section provides a brief introduction to the CapTIvate technology with examples of PCB layout and performance from the design kit. A more detailed description of the CapTIvate technology and the tools needed to be successful, application development tools, hardware design guides, and software library, can be found in the [CapTIvate™ Technology Guide](#).

#### **10.2.2.1 Device Connection and Layout Fundamentals**

##### **10.2.2.2**

To learn more on how to design the CapTIvate Technology, see the [Capacitive Touch Design Flow for MSP430™ MCUs With CapTIvate™ Technology](#) application report.

### 10.2.2.3 Measurements

The following measurements are taken from the [CapTivate Technology Design Center](#), using the [CAPTIVATE-PHONE](#) and [CAPTIVATE-BSWP](#) panels. Unless otherwise stated, the settings used are the out-of-box settings, which can be found in the example projects. The intent of these measurements is to show performance in a configuration that is readily available and reproducible.



Figure 10-6. CAPTIVATE-PHONE and CAPTIVATE-BSWP Panels

#### 10.2.2.3.1 SNR

The [Sensitivity, SNR, and Design Margin in Capacitive Touch Applications](#) application report provides a specific view for analyzing the signal-to-noise ratio of each element.

#### 10.2.2.3.2 Sensitivity

To show sensitivity, in terms of farads, the internal reference capacitor is used as the change in capacitance. In the mutual-capacitance case, the 0.1-pF capacitor is used. In the self-capacitance case, the 1-pF reference capacitor is used. For simplicity, the results for only button 1 on both the CAPTIVATE-PHONE and CAPTIVATE-BSWP panels are reported in [Table 10-1](#).

Table 10-1. Button Sensitivity

| CONVERSION COUNT | CONVERSION GAIN | CAPTIVATE-PHONE BUTTON 1 |                          | CAPTIVATE-BSWP BUTTON 1 |                        |
|------------------|-----------------|--------------------------|--------------------------|-------------------------|------------------------|
|                  |                 | CONVERSION TIME (μs)     | COUNTS FOR 0.1-pF CHANGE | CONVERSION TIME (μs)    | COUNTS FOR 1-pF CHANGE |
| 100              | 100             | 25                       | 6                        | 50                      | 8                      |
| 200              | 200             | 50                       | 10                       | 100                     | 16                     |
| 200              | 100             | 50                       | 21                       | 100                     | 31                     |
| 800              | 400             | 200                      | 70                       | 400                     | 112                    |
| 800              | 200             | 200                      | 140                      | 400                     | 202                    |
| 800              | 100             | 200                      | 257                      | 400                     | 333                    |

An alternative measure in sensitivity is the ability to resolve capacitance change over a wide range of base capacitance. [Table 10-2](#) shows example conversion times (for a self-mode measurement of discrete capacitors) that can be used to achieve the desired resolution for a given parasitic load capacitance.

**Table 10-2. Button Sensitivity**

| CAPACITANCE<br>Cp (pF) <sup>(1)</sup> | CONVERSION<br>COUNT/GAIN | CONVERSION<br>TIME (μs) | COUNTS FOR<br>0.130-pF<br>CHANGE | COUNTS FOR<br>0.260-pF<br>CHANGE | COUNTS FOR<br>0.520-pF<br>CHANGE |
|---------------------------------------|--------------------------|-------------------------|----------------------------------|----------------------------------|----------------------------------|
| 23                                    | 400/100                  | 200                     | 10                               | 23                               | 35                               |
| 50                                    | 550/100                  | 275                     | 11                               | 24                               | 37                               |
| 78                                    | 650/100                  | 325                     | 11                               | 23                               | 36                               |
| 150                                   | 850/100                  | 425                     | 11                               | 22                               | 35                               |
| 150 <sup>(2)</sup>                    | 1200/200                 | 600                     | 11                               | 23                               | 37                               |
| 200 <sup>(2)</sup>                    | 1200/150                 | 600                     | 13                               | 26                               | 41                               |

(1) These measurements were taken with the CapTlvate MCU processor board with the 470-Ω series resistors replaced with 0-Ω resistors.

(2) 0-V discharge voltage is used.

#### 10.2.2.3.3 Power

The low-power mode LPM3 and LPM4 specifications in [Section 8.7](#) are derived from the CapTlvate technology design kit as indicated in the notes.

### 10.3 CapTlvate Technology Evaluation

[Table 10-3](#) lists tools that demonstrate the use of the MSP430FR267x devices. See [CapTlvate Evaluation Tools](#) to get started with evaluating the CapTlvate technology in various real-world application scenarios. Consult these evaluation tool designs for additional guidance regarding schematics, layout, and software implementation.

**Table 10-3. Evaluation Tools**

| DESIGN NAME                             | LINK                                                                                          |
|-----------------------------------------|-----------------------------------------------------------------------------------------------|
| Capacitive touch MSP430FR2676 MCU board | <a href="http://www.ti.com/tool/CAPTIVATE-FR2676">http://www.ti.com/tool/CAPTIVATE-FR2676</a> |

## 11 Device and Documentation Support

### 11.1 Getting Started and Next Steps

For more information on the MSP low-power microcontrollers and the tools and libraries that are available to help with your development, visit the [MSP430™ ultra-low-power sensing & measurement MCUs overview](#).

### 11.2 Device Nomenclature

To designate the stages in the product development cycle, TI assigns prefixes to the part numbers of all MSP MCU devices. Each MSP MCU commercial family member has one of two prefixes: MSP or XMS. These prefixes represent evolutionary stages of product development from engineering prototypes (XMS) through fully qualified production devices (MSP).

**XMS** – Experimental device that is not necessarily representative of the final device's electrical specifications

**MSP** – Fully qualified production device

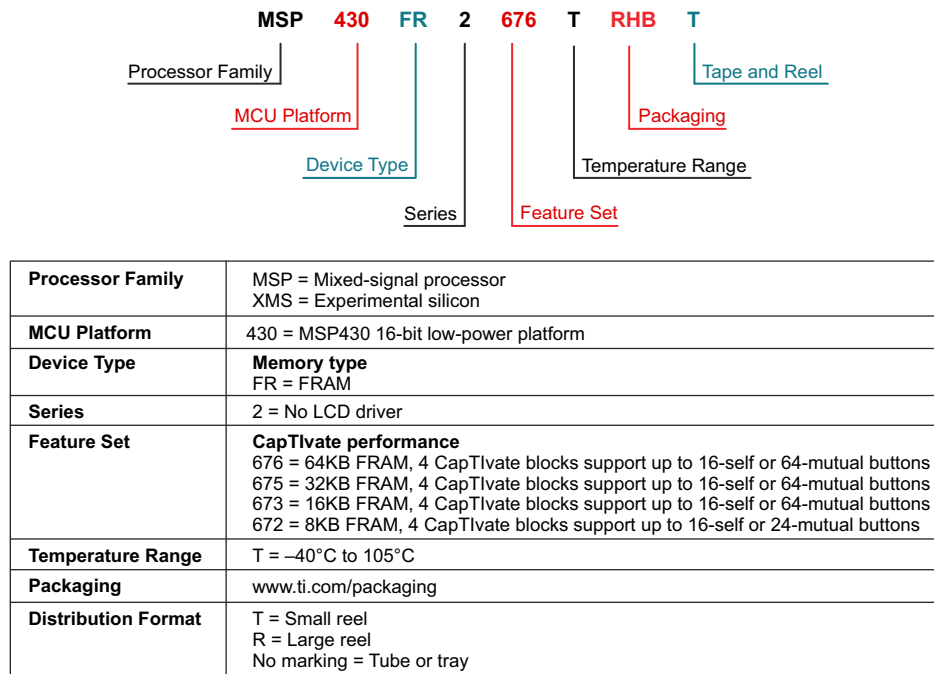
XMS devices are shipped against the following disclaimer:

"Developmental product is intended for internal evaluation purposes."

MSP devices have been characterized fully, and the quality and reliability of the device have been demonstrated fully. TI's standard warranty applies.

Predictions show that prototype devices (XMS) have a greater failure rate than the standard production devices. TI recommends that these devices not be used in any production system because their expected end-use failure rate still is undefined. Only qualified production devices are to be used.

TI device nomenclature also includes a suffix with the device family name. This suffix indicates the temperature range, package type, and distribution format. [Figure 11-1](#) provides a legend for reading the complete device name.



**Figure 11-1. Device Nomenclature**

## 11.3 Tools and Software

Table 11-1 lists the debug features supported by these microcontrollers. See the [Code Composer Studio™ IDE for MSP430™ MCUs User's Guide](#) for details on the available features.

**Table 11-1. Hardware Features**

| MSP430<br>ARCHITECTURE | 4-WIRE<br>JTAG | 2-WIRE<br>JTAG | BREAK-<br>POINTS<br>(N) | RANGE<br>BREAK-<br>POINTS | CLOCK<br>CONTROL | STATE<br>SEQUENCER | TRACE<br>BUFFER | LPMx.5<br>DEBUGGING<br>SUPPORT | EEM<br>VERSION |
|------------------------|----------------|----------------|-------------------------|---------------------------|------------------|--------------------|-----------------|--------------------------------|----------------|
| MSP430Xv2              | Yes            | Yes            | 3                       | Yes                       | Yes              | No                 | No              | No                             | S              |

### Design Kits and Evaluation Modules

#### Capacitive touch MSP430FR2676 MCU board

The MSP430FR2676 CapTivate touch MCU board (CAPTIVATE-FR2676) is a simple evaluation board for evaluating capacitive touch and proximity sensors through the use of plug-in sensor boards (sold separately).

#### Target development board for MSP430FR2476 MCU

The MSP-TS430PT48A microcontroller development board is a standalone ZIF socket target board used to program and debug the MSP430 in-system through the JTAG interface or the Spy Bi-Wire (2-wire JTAG) protocol. This development board supports the MSP430FR2476 FRAM devices in a 48-pin QFP package (TI package code: PT).

### Software

#### MSP430Ware™ Software

MSP430Ware software is a collection of code examples, data sheets, and other design resources for all MSP430 devices delivered in a convenient package. In addition to providing a complete collection of existing MSP430 design resources, MSP430Ware software also includes a high-level API called MSP430 Driver Library. This library makes it easy to program MSP430 hardware. MSP430Ware software is available as a component of CCS or as a stand-alone package.

#### MSP430FR267x, MSP430FR247x Code Examples

C code examples that configure each of the integrated peripherals for various application needs.

#### MSP Driver Library

The driver library's abstracted API keeps you above the bits and bytes of the MSP430 hardware by providing easy-to-use function calls. Thorough documentation is delivered through a helpful API guide, which includes details on each function call and the recognized parameters. Developers can use driver library functions to write complete projects with minimal overhead.

#### MSP EnergyTrace™ Technology

EnergyTrace technology for MSP430 microcontrollers is an energy-based code analysis tool that measures and displays the application's energy profile and helps to optimize it for ultra-low-power consumption.

#### ULP (Ultra-Low Power) Advisor

ULP Advisor™ software is a tool for guiding developers to write more efficient code to fully utilize the unique ultra-low power features of MSP and MSP432 microcontrollers. Aimed at both experienced and new microcontroller developers, ULP Advisor checks your code against a thorough ULP checklist to squeeze every last nano amp out of your application. At build time, ULP Advisor will provide notifications and remarks to highlight areas of your code that can be further optimized for lower power.

## FRAM Embedded Software Utilities for MSP Ultra-Low-Power Microcontrollers

The FRAM Utilities is designed to grow as a collection of embedded software utilities that leverage the ultra-low-power and virtually unlimited write endurance of FRAM. The utilities are available for MSP430FRxx FRAM microcontrollers and provide example code to help start application development. Included utilities include Compute Through Power Loss (CTPL). CTPL is utility API set that enables ease of use with LPMx.5 low-power modes and a powerful shutdown mode that allows an application to save and restore critical system components when a power loss is detected.

## IEC60730 Software Package

The IEC60730 MSP430 software package helps you comply with IEC 60730-1:2010 (Automatic Electrical Controls for Household and Similar Use – Part 1: General Requirements) for up to Class B products, which includes home appliances, arc detectors, power converters, power tools, e-bikes, and many others. The IEC60730 MSP430 software package can be embedded in applications that run on MSP430 MCUs to help simplify the certification efforts of functional safety compliant consumer devices to IEC 60730-1:2010 Class B.

## Fixed-Point Math Library for MSP

The MSP IQmath and Qmath Libraries are a collection of highly optimized and high-precision mathematical functions for C programmers to seamlessly port a floating-point algorithm into fixed-point code on MSP430 and MSP432 devices. These routines are typically used in computationally intensive real-time applications where optimal execution speed, high accuracy, and ultra-low energy are critical. By using the IQmath and Qmath libraries, it is possible to achieve execution speeds considerably faster and energy consumption considerably lower than equivalent code written using floating-point math.

## Floating-Point Math Library for MSP430

Continuing to innovate in the low power and low cost microcontroller space, TI brings you MSPMATHLIB. Leveraging the intelligent peripherals of our devices, this floating point math library of scalar functions brings you up to 26x better performance. Mathlib is easy to integrate into your designs. This library is free and is integrated in both Code Composer Studio IDE and IAR Embedded Workbench IDE.

## Development Tools

### Code Composer Studio™ Integrated Development Environment for MSP Microcontrollers

Code Composer Studio integrated development environment (IDE) supports all MSP microcontroller devices. Code Composer Studio IDE comprises a suite of embedded software utilities used to develop and debug embedded applications. It includes an optimizing C/C++ compiler, source code editor, project build environment, debugger, profiler, and many other features.

### IAR Embedded Workbench® IDE

IAR Embedded Workbench IDE for MSP430 MCUs is a complete C/C++ compiler toolchain for building and debugging embedded applications based on MSP430 microcontrollers. The debugger can be used for source and disassembly code with support for complex code and data breakpoints. It also provides a hardware simulator that allows debugging without a physical target connected.

### Uniflash Standalone Flash Tool

CCS Uniflash is a stand-alone tool used to program on-chip flash memory on TI MCUs. Uniflash has a GUI, command line, and scripting interface. Uniflash is a software tool available by TI Cloud Tools or desktop application download from the TI web page.

## [MSP MCU Programmer and Debugger](#)

The MSP-FET is a powerful emulation development tool – often called a debug probe – that lets users quickly begin application development on MSP low-power microcontrollers (MCU). Creating MCU software usually requires downloading the resulting binary program to the MSP device for validation and debugging. The MSP-FET provides a debug communication pathway between a host computer and the target MSP. Furthermore, the MSP-FET also provides a backchannel UART connection between the computer's USB interface and the MSP UART. This affords the MSP programmer a convenient method for communicating serially between the MSP and a terminal running on the computer.

## [MSP-GANG Production Programmer](#)

The MSP Gang Programmer can program up to eight identical MSP430 or MSP432 flash or FRAM devices at the same time. The MSP Gang Programmer connects to a host PC using a standard RS-232 or USB connection and provides flexible programming options that allow the user to fully customize the process. The MSP Gang Programmer is provided with an expansion board, called the Gang Splitter, that implements the interconnections between the MSP Gang Programmer and multiple target devices.

## [TIREX Resource Explorer \(TIRex\)](#)

An online portal to examples, libraries, executables, and documentation for your device and development board. TIRex can be accessed directly in Code Composer Studio IDE or in TI Cloud Tools.

## [TI Cloud Tools](#)

Start development immediately on [dev.ti.com](http://dev.ti.com). Begin by using the Resource Explorer interface to quickly find all the files you need. Then, edit, build, and debug embedded applications in the cloud, using industry-leading Code Composer Studio Cloud IDE.

## [GCC - Compiler for MSP](#)

MSP430 and MSP432 GCC open source packages are complete debugger and open source C/C++ compiler toolchains for building and debugging embedded applications based on MSP430 and MSP432 microcontrollers. These free GCC compilers support all MSP430 and MSP432 devices without code size limitations. In addition, these compilers can be used stand-alone from the command-line or within Code Composer Studio v6.0 or later. Get started today whether you are using a Windows®, Linux®, or macOS® environment.

## **11.4 Documentation Support**

The following documents describe the MSP430FR267x microcontrollers. Copies of these documents are available on the Internet at [www.ti.com](http://www.ti.com).

### **Receiving Notification of Document Updates**

To receive notification of documentation updates—including silicon errata—go to the product folder for your device on [ti.com](http://ti.com) (for example, [MSP430FR2676](#)). In the upper right corner, click the "Alert me" button. This registers you to receive a weekly digest of product information that has changed (if any). For change details, check the revision history of any revised document.

### **Errata**

#### [MSP430FR2676 Device Erratasheet](#)

Describes the known exceptions to the functional specifications.

#### [MSP430FR2675 Device Erratasheet](#)

Describes the known exceptions to the functional specifications.

## User's Guides

### [MSP430FR4xx and MSP430FR2xx Family User's Guide](#)

Detailed description of all modules and peripherals available in this device family.

### [MSP430™ FRAM Devices Bootloader \(BSL\) User's Guide](#)

The bootloader (BSL) on MSP430 microcontrollers (MCUs) lets users communicate with embedded memory in the MSP430 MCU during the prototyping phase, final production, and in service. Both the programmable memory (FRAM memory) and the data memory (RAM) can be modified as required.

### [MSP430™ Programming With the JTAG Interface](#)

This document describes the functions that are required to erase, program, and verify the memory module of the MSP430 flash-based and FRAM-based microcontroller families using the JTAG communication port.

### [MSP430™ Hardware Tools User's Guide](#)

This manual describes the hardware of the TI MSP-FET430 Flash Emulation Tool (FET). The FET is the program development tool for the MSP430 ultra-low-power microcontroller. Both available interface types, the parallel port interface and the USB interface, are described.

## Application Reports

### [MSP430 32-kHz Crystal Oscillators](#)

Selection of the right crystal, correct load circuit, and proper board layout are important for a stable crystal oscillator. This application report summarizes crystal oscillator function and explains the parameters to select the correct crystal for MSP430 ultra-low-power operation. In addition, hints and examples for correct board layout are given. The document also contains detailed information on the possible oscillator tests to ensure stable oscillator operation in mass production.

### [MSP430 System-Level ESD Considerations](#)

System-level ESD has become increasingly demanding with silicon technology scaling towards lower voltages and the need for designing cost-effective and ultra-low-power components. This application report addresses ESD topics to help board designers and OEMs understand and design robust system-level designs.

## 11.5 Support Resources

[TI E2E™ support forums](#) are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

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## 11.6 Trademarks

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macOS® is a registered trademark of Apple, Inc.

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## 11.7 Electrostatic Discharge Caution



This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

## 11.8 Export Control Notice

Recipient agrees to not knowingly export or re-export, directly or indirectly, any product or technical data (as defined by the U.S., EU, and other Export Administration Regulations) including software, or any controlled product restricted by other applicable national regulations, received from disclosing party under nondisclosure obligations (if any), or any direct product of such technology, to any destination to which such export or re-export is restricted or prohibited by U.S. or other applicable laws, without obtaining prior authorization from U.S. Department of Commerce and other competent Government authorities to the extent required by those laws.

## 11.9 Glossary

[TI Glossary](#)      This glossary lists and explains terms, acronyms, and definitions.

## 12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, see the left-hand navigation.

## PACKAGING INFORMATION

| Orderable part number             | Status<br>(1) | Material type<br>(2) | Package   Pins  | Package qty   Carrier   | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6) |
|-----------------------------------|---------------|----------------------|-----------------|-------------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| <a href="#">MSP430FR2672TRHBR</a> | Active        | Production           | VQFN (RHB)   32 | 3000   LARGE T&R        | Yes         | SN                                   | Level-1-260C-UNLIM                | -40 to 105   | FR2672              |
| MSP430FR2672TRHBR.A               | Active        | Production           | VQFN (RHB)   32 | 3000   LARGE T&R        | Yes         | SN                                   | Level-1-260C-UNLIM                | -40 to 105   | FR2672              |
| <a href="#">MSP430FR2672TRHBT</a> | Active        | Production           | VQFN (RHB)   32 | 250   SMALL T&R         | Yes         | SN                                   | Level-1-260C-UNLIM                | -40 to 105   | FR2672              |
| MSP430FR2672TRHBT.A               | Active        | Production           | VQFN (RHB)   32 | 250   SMALL T&R         | Yes         | SN                                   | Level-1-260C-UNLIM                | -40 to 105   | FR2672              |
| <a href="#">MSP430FR2673TRHBR</a> | Active        | Production           | VQFN (RHB)   32 | 3000   LARGE T&R        | Yes         | SN                                   | Level-1-260C-UNLIM                | -40 to 105   | FR2673              |
| MSP430FR2673TRHBR.A               | Active        | Production           | VQFN (RHB)   32 | 3000   LARGE T&R        | Yes         | SN                                   | Level-1-260C-UNLIM                | -40 to 105   | FR2673              |
| <a href="#">MSP430FR2673TRHBT</a> | Active        | Production           | VQFN (RHB)   32 | 250   SMALL T&R         | Yes         | SN                                   | Level-1-260C-UNLIM                | -40 to 105   | FR2673              |
| MSP430FR2673TRHBT.A               | Active        | Production           | VQFN (RHB)   32 | 250   SMALL T&R         | Yes         | SN                                   | Level-1-260C-UNLIM                | -40 to 105   | FR2673              |
| <a href="#">MSP430FR2675TPT</a>   | Active        | Production           | LQFP (PT)   48  | 250   JEDEC TRAY (10+1) | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 105   | 430FR2675           |
| MSP430FR2675TPT.A                 | Active        | Production           | LQFP (PT)   48  | 250   JEDEC TRAY (10+1) | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 105   | 430FR2675           |
| <a href="#">MSP430FR2675TPTR</a>  | Active        | Production           | LQFP (PT)   48  | 1000   LARGE T&R        | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 105   | 430FR2675           |
| MSP430FR2675TPTR.A                | Active        | Production           | LQFP (PT)   48  | 1000   LARGE T&R        | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 105   | 430FR2675           |
| <a href="#">MSP430FR2675TRHAR</a> | Active        | Production           | VQFN (RHA)   40 | 2500   LARGE T&R        | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -40 to 105   | FR2675              |
| MSP430FR2675TRHAR.A               | Active        | Production           | VQFN (RHA)   40 | 2500   LARGE T&R        | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -40 to 105   | FR2675              |
| <a href="#">MSP430FR2675TRHAT</a> | Active        | Production           | VQFN (RHA)   40 | 250   SMALL T&R         | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -40 to 105   | FR2675              |
| MSP430FR2675TRHAT.A               | Active        | Production           | VQFN (RHA)   40 | 250   SMALL T&R         | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -40 to 105   | FR2675              |
| <a href="#">MSP430FR2675TRHBR</a> | Active        | Production           | VQFN (RHB)   32 | 3000   LARGE T&R        | Yes         | SN                                   | Level-1-260C-UNLIM                | -40 to 105   | FR2675              |
| MSP430FR2675TRHBR.A               | Active        | Production           | VQFN (RHB)   32 | 3000   LARGE T&R        | Yes         | SN                                   | Level-1-260C-UNLIM                | -40 to 105   | FR2675              |
| <a href="#">MSP430FR2675TRHBT</a> | Active        | Production           | VQFN (RHB)   32 | 250   SMALL T&R         | Yes         | SN                                   | Level-1-260C-UNLIM                | -40 to 105   | FR2675              |
| MSP430FR2675TRHBT.A               | Active        | Production           | VQFN (RHB)   32 | 250   SMALL T&R         | Yes         | SN                                   | Level-1-260C-UNLIM                | -40 to 105   | FR2675              |
| <a href="#">MSP430FR2676TPT</a>   | Active        | Production           | LQFP (PT)   48  | 250   JEDEC TRAY (10+1) | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 105   | 430FR2676           |
| MSP430FR2676TPT.A                 | Active        | Production           | LQFP (PT)   48  | 250   JEDEC TRAY (10+1) | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 105   | 430FR2676           |
| <a href="#">MSP430FR2676TPTR</a>  | Active        | Production           | LQFP (PT)   48  | 1000   LARGE T&R        | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 105   | 430FR2676           |
| MSP430FR2676TPTR.A                | Active        | Production           | LQFP (PT)   48  | 1000   LARGE T&R        | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 105   | 430FR2676           |
| <a href="#">MSP430FR2676TRHAR</a> | Active        | Production           | VQFN (RHA)   40 | 2500   LARGE T&R        | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -40 to 105   | FR2676              |
| MSP430FR2676TRHAR.A               | Active        | Production           | VQFN (RHA)   40 | 2500   LARGE T&R        | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -40 to 105   | FR2676              |

| Orderable part number             | Status<br>(1) | Material type<br>(2) | Package   Pins  | Package qty   Carrier | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6) |
|-----------------------------------|---------------|----------------------|-----------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| <a href="#">MSP430FR2676TRHAT</a> | Active        | Production           | VQFN (RHA)   40 | 250   SMALL T&R       | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -40 to 105   | FR2676              |
| MSP430FR2676TRHAT.A               | Active        | Production           | VQFN (RHA)   40 | 250   SMALL T&R       | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -40 to 105   | FR2676              |
| <a href="#">MSP430FR2676TRHBR</a> | Active        | Production           | VQFN (RHB)   32 | 3000   LARGE T&R      | Yes         | SN                                   | Level-1-260C-UNLIM                | -40 to 105   | FR2676              |
| MSP430FR2676TRHBR.A               | Active        | Production           | VQFN (RHB)   32 | 3000   LARGE T&R      | Yes         | SN                                   | Level-1-260C-UNLIM                | -40 to 105   | FR2676              |
| <a href="#">MSP430FR2676TRHBT</a> | Active        | Production           | VQFN (RHB)   32 | 250   SMALL T&R       | Yes         | SN                                   | Level-1-260C-UNLIM                | -40 to 105   | FR2676              |
| MSP430FR2676TRHBT.A               | Active        | Production           | VQFN (RHB)   32 | 250   SMALL T&R       | Yes         | SN                                   | Level-1-260C-UNLIM                | -40 to 105   | FR2676              |

<sup>(1)</sup> **Status:** For more details on status, see our [product life cycle](#).

<sup>(2)</sup> **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

<sup>(3)</sup> **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

<sup>(4)</sup> **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

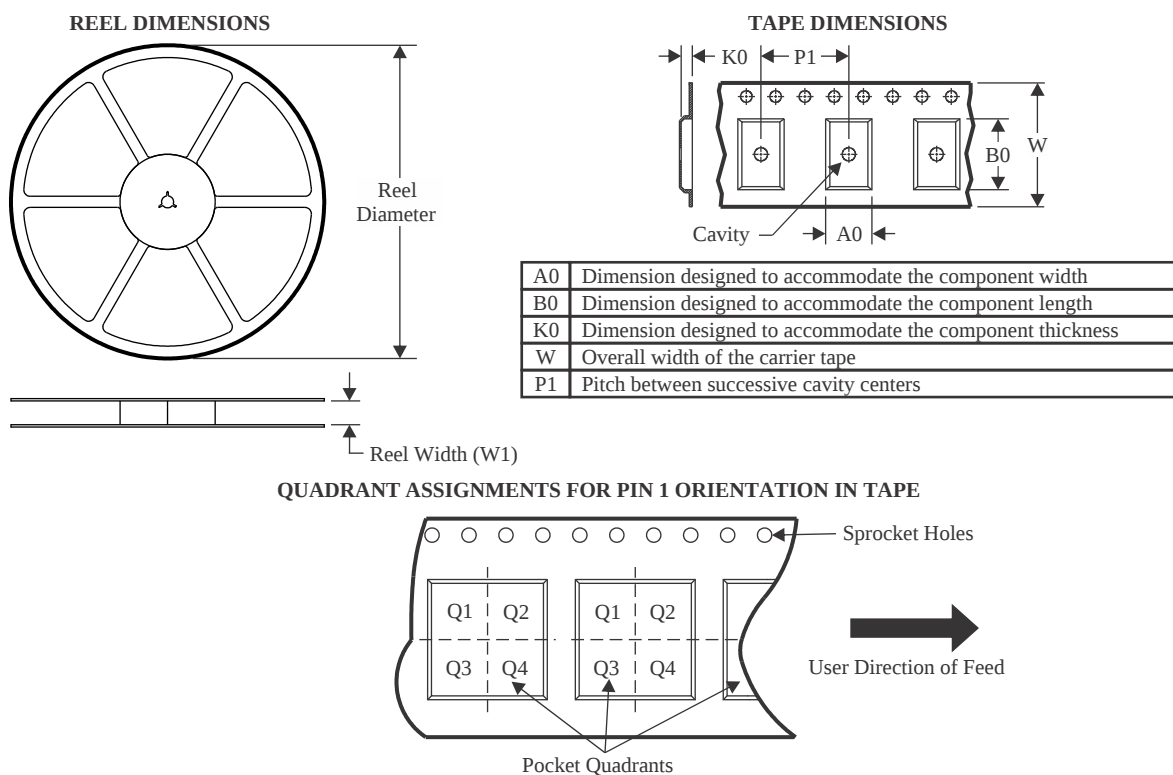
<sup>(5)</sup> **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

<sup>(6)</sup> **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "-" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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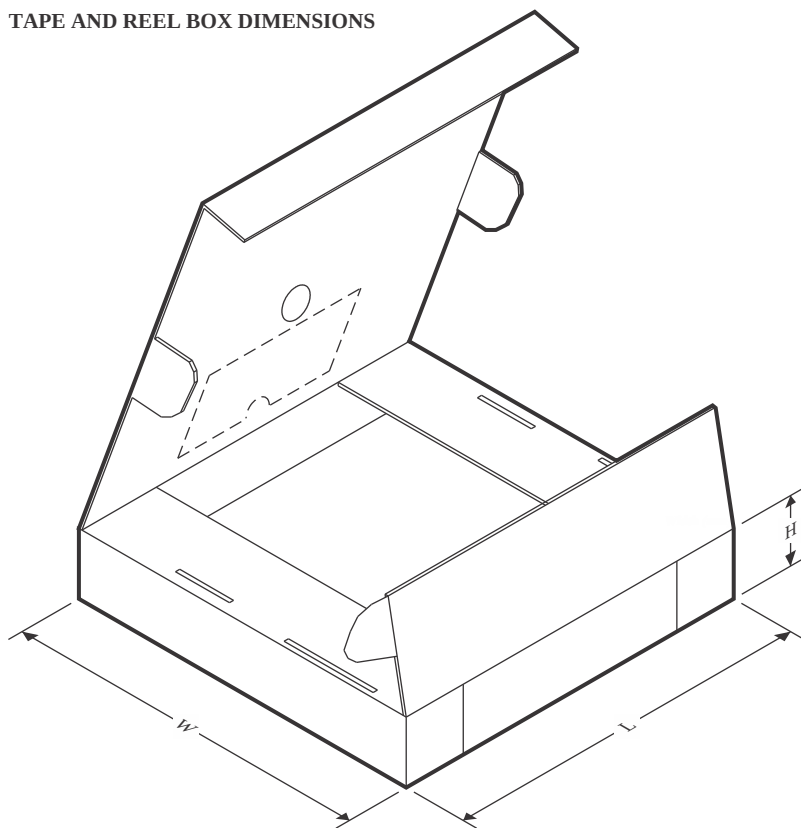
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**TAPE AND REEL INFORMATION**


\*All dimensions are nominal

| Device            | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|-------------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| MSP430FR2672TRHBR | VQFN         | RHB             | 32   | 3000 | 330.0              | 12.4               | 5.3     | 5.3     | 1.1     | 8.0     | 12.0   | Q2            |
| MSP430FR2672TRHBT | VQFN         | RHB             | 32   | 250  | 180.0              | 12.4               | 5.3     | 5.3     | 1.1     | 8.0     | 12.0   | Q2            |
| MSP430FR2673TRHBR | VQFN         | RHB             | 32   | 3000 | 330.0              | 12.4               | 5.3     | 5.3     | 1.1     | 8.0     | 12.0   | Q2            |
| MSP430FR2673TRHBT | VQFN         | RHB             | 32   | 250  | 180.0              | 12.4               | 5.3     | 5.3     | 1.1     | 8.0     | 12.0   | Q2            |
| MSP430FR2675TPTR  | LQFP         | PT              | 48   | 1000 | 330.0              | 16.4               | 9.6     | 9.6     | 1.9     | 12.0    | 16.0   | Q2            |
| MSP430FR2675TPTR  | LQFP         | PT              | 48   | 1000 | 330.0              | 16.4               | 9.6     | 9.6     | 1.9     | 12.0    | 16.0   | Q2            |
| MSP430FR2675TRHAR | VQFN         | RHA             | 40   | 2500 | 330.0              | 16.4               | 6.3     | 6.3     | 1.1     | 12.0    | 16.0   | Q2            |
| MSP430FR2675TRHAT | VQFN         | RHA             | 40   | 250  | 180.0              | 16.4               | 6.3     | 6.3     | 1.1     | 12.0    | 16.0   | Q2            |
| MSP430FR2675TRHBR | VQFN         | RHB             | 32   | 3000 | 330.0              | 12.4               | 5.3     | 5.3     | 1.1     | 8.0     | 12.0   | Q2            |
| MSP430FR2675TRHBT | VQFN         | RHB             | 32   | 250  | 180.0              | 12.4               | 5.3     | 5.3     | 1.1     | 8.0     | 12.0   | Q2            |
| MSP430FR2676TPTR  | LQFP         | PT              | 48   | 1000 | 330.0              | 16.4               | 9.6     | 9.6     | 1.9     | 12.0    | 16.0   | Q2            |
| MSP430FR2676TPTR  | LQFP         | PT              | 48   | 1000 | 330.0              | 16.4               | 9.6     | 9.6     | 1.9     | 12.0    | 16.0   | Q2            |
| MSP430FR2676TRHAR | VQFN         | RHA             | 40   | 2500 | 330.0              | 16.4               | 6.3     | 6.3     | 1.1     | 12.0    | 16.0   | Q2            |
| MSP430FR2676TRHAT | VQFN         | RHA             | 40   | 250  | 180.0              | 16.4               | 6.3     | 6.3     | 1.1     | 12.0    | 16.0   | Q2            |
| MSP430FR2676TRHBR | VQFN         | RHB             | 32   | 3000 | 330.0              | 12.4               | 5.3     | 5.3     | 1.1     | 8.0     | 12.0   | Q2            |
| MSP430FR2676TRHBT | VQFN         | RHB             | 32   | 250  | 180.0              | 12.4               | 5.3     | 5.3     | 1.1     | 8.0     | 12.0   | Q2            |

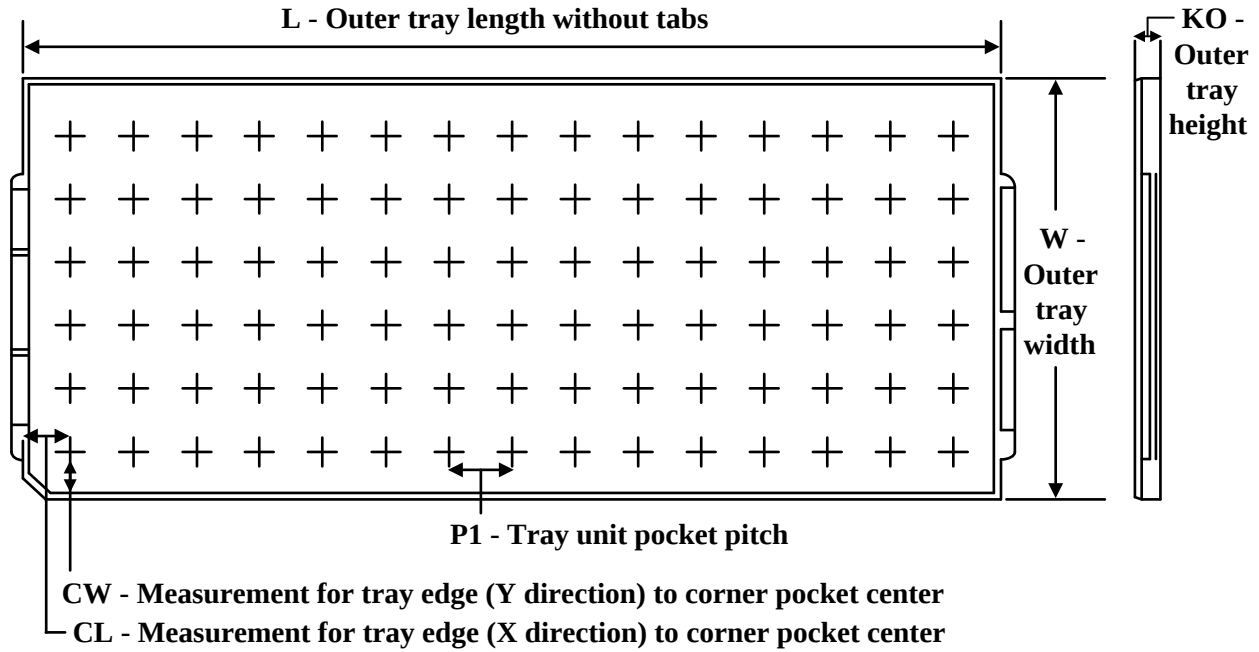
## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

| Device            | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|-------------------|--------------|-----------------|------|------|-------------|------------|-------------|
| MSP430FR2672TRHBR | VQFN         | RHB             | 32   | 3000 | 360.0       | 360.0      | 36.0        |
| MSP430FR2672TRHBT | VQFN         | RHB             | 32   | 250  | 210.0       | 185.0      | 35.0        |
| MSP430FR2673TRHBR | VQFN         | RHB             | 32   | 3000 | 360.0       | 360.0      | 36.0        |
| MSP430FR2673TRHBT | VQFN         | RHB             | 32   | 250  | 210.0       | 185.0      | 35.0        |
| MSP430FR2675TPTR  | LQFP         | PT              | 48   | 1000 | 350.0       | 350.0      | 43.0        |
| MSP430FR2675TPTR  | LQFP         | PT              | 48   | 1000 | 336.6       | 336.6      | 31.8        |
| MSP430FR2675TRHAR | VQFN         | RHA             | 40   | 2500 | 360.0       | 360.0      | 36.0        |
| MSP430FR2675TRHAT | VQFN         | RHA             | 40   | 250  | 210.0       | 185.0      | 35.0        |
| MSP430FR2675TRHBR | VQFN         | RHB             | 32   | 3000 | 360.0       | 360.0      | 36.0        |
| MSP430FR2675TRHBT | VQFN         | RHB             | 32   | 250  | 210.0       | 185.0      | 35.0        |
| MSP430FR2676TPTR  | LQFP         | PT              | 48   | 1000 | 350.0       | 350.0      | 43.0        |
| MSP430FR2676TPTR  | LQFP         | PT              | 48   | 1000 | 336.6       | 336.6      | 31.8        |
| MSP430FR2676TRHAR | VQFN         | RHA             | 40   | 2500 | 360.0       | 360.0      | 36.0        |
| MSP430FR2676TRHAT | VQFN         | RHA             | 40   | 250  | 210.0       | 185.0      | 35.0        |
| MSP430FR2676TRHBR | VQFN         | RHB             | 32   | 3000 | 360.0       | 360.0      | 36.0        |
| MSP430FR2676TRHBT | VQFN         | RHB             | 32   | 250  | 210.0       | 185.0      | 35.0        |

## TRAY



Chamfer on Tray corner indicates Pin 1 orientation of packed units.

\*All dimensions are nominal

| Device            | Package Name | Package Type | Pins | SPQ | Unit array matrix | Max temperature (°C) | L (mm) | W (mm) | K0 (μm) | P1 (mm) | CL (mm) | CW (mm) |
|-------------------|--------------|--------------|------|-----|-------------------|----------------------|--------|--------|---------|---------|---------|---------|
| MSP430FR2675TPT   | PT           | LQFP         | 48   | 250 | 10 x 25           | 150                  | 315    | 135.9  | 7620    | 12.2    | 11.1    | 11.25   |
| MSP430FR2675TPT   | PT           | LQFP         | 48   | 250 | 10 x 25           | 150                  | 315    | 135.9  | 7620    | 12.2    | 11.1    | 11.25   |
| MSP430FR2675TPT.A | PT           | LQFP         | 48   | 250 | 10 x 25           | 150                  | 315    | 135.9  | 7620    | 12.2    | 11.1    | 11.25   |
| MSP430FR2675TPT.A | PT           | LQFP         | 48   | 250 | 10 x 25           | 150                  | 315    | 135.9  | 7620    | 12.2    | 11.1    | 11.25   |
| MSP430FR2676TPT   | PT           | LQFP         | 48   | 250 | 10 x 25           | 150                  | 315    | 135.9  | 7620    | 12.2    | 11.1    | 11.25   |
| MSP430FR2676TPT   | PT           | LQFP         | 48   | 250 | 10 x 25           | 150                  | 315    | 135.9  | 7620    | 12.2    | 11.1    | 11.25   |
| MSP430FR2676TPT.A | PT           | LQFP         | 48   | 250 | 10 x 25           | 150                  | 315    | 135.9  | 7620    | 12.2    | 11.1    | 11.25   |
| MSP430FR2676TPT.A | PT           | LQFP         | 48   | 250 | 10 x 25           | 150                  | 315    | 135.9  | 7620    | 12.2    | 11.1    | 11.25   |

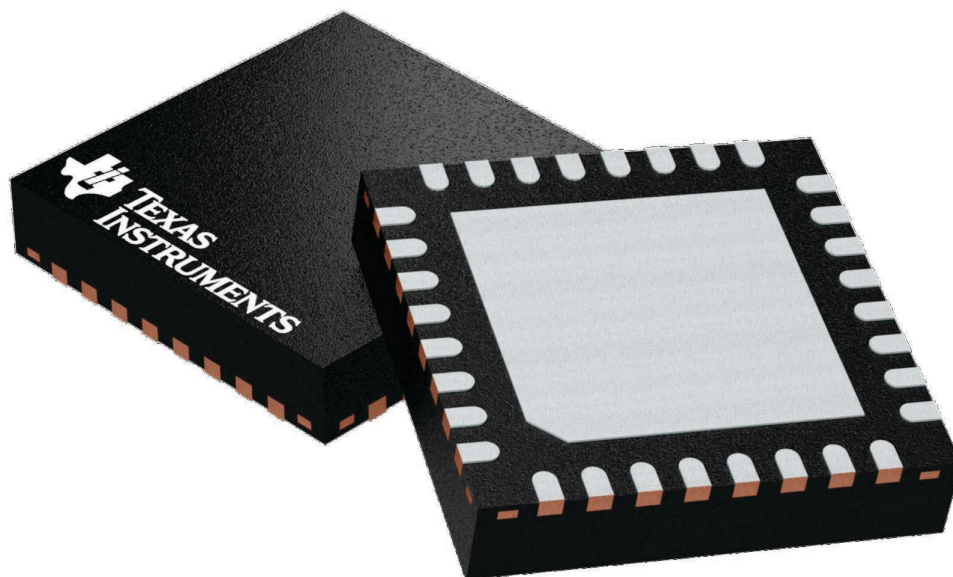
## GENERIC PACKAGE VIEW

**RHB 32**

**VQFN - 1 mm max height**

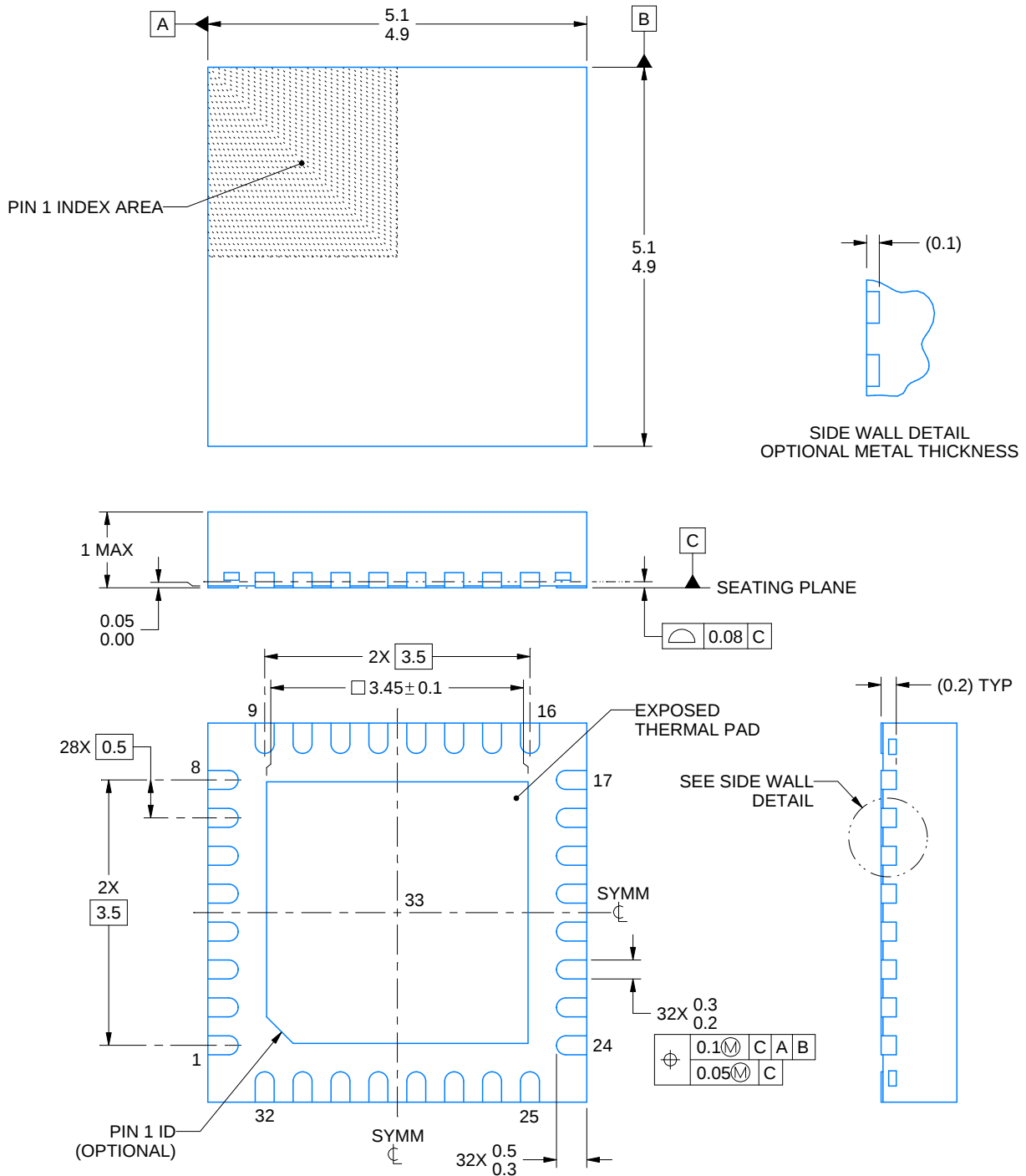
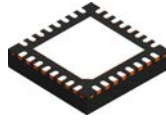
5 x 5, 0.5 mm pitch

PLASTIC QUAD FLATPACK - NO LEAD



Images above are just a representation of the package family, actual package may vary.  
Refer to the product data sheet for package details.

4224745/A



4223442/B 08/2019

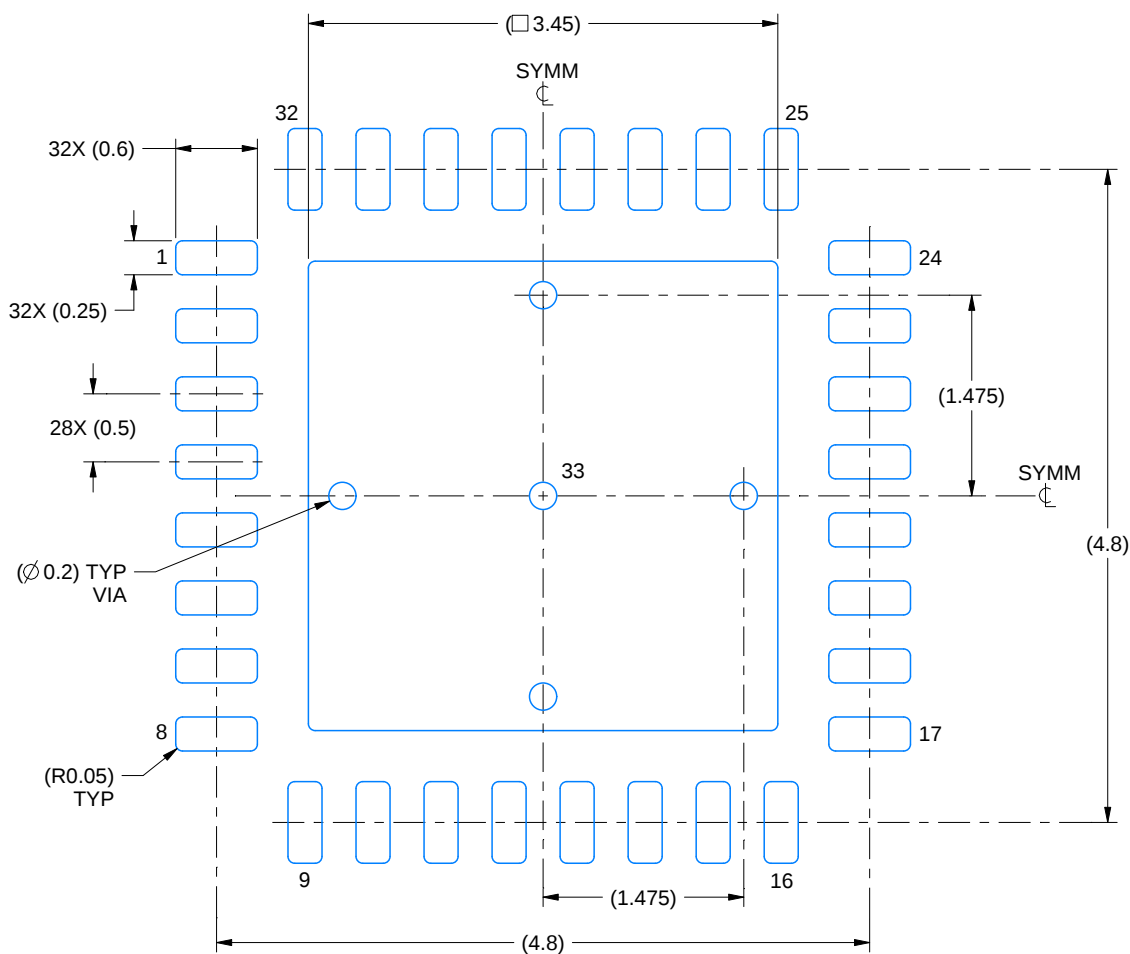
## NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.

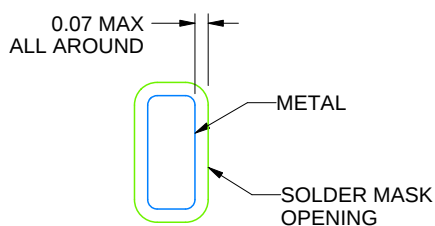
**RHB0032E**

### VQFN - 1 mm max height

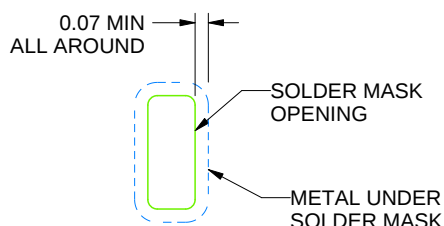
PLASTIC QUAD FLATPACK - NO LEAD



LAND PATTERN EXAMPLE  
SCALE:18X



NON SOLDER MASK  
DEFINED  
(PREFERRED)



SOLDER MASK  
DEFINED

## SOLDER MASK DETAILS

4223442/B 08/2019

NOTES: (continued)

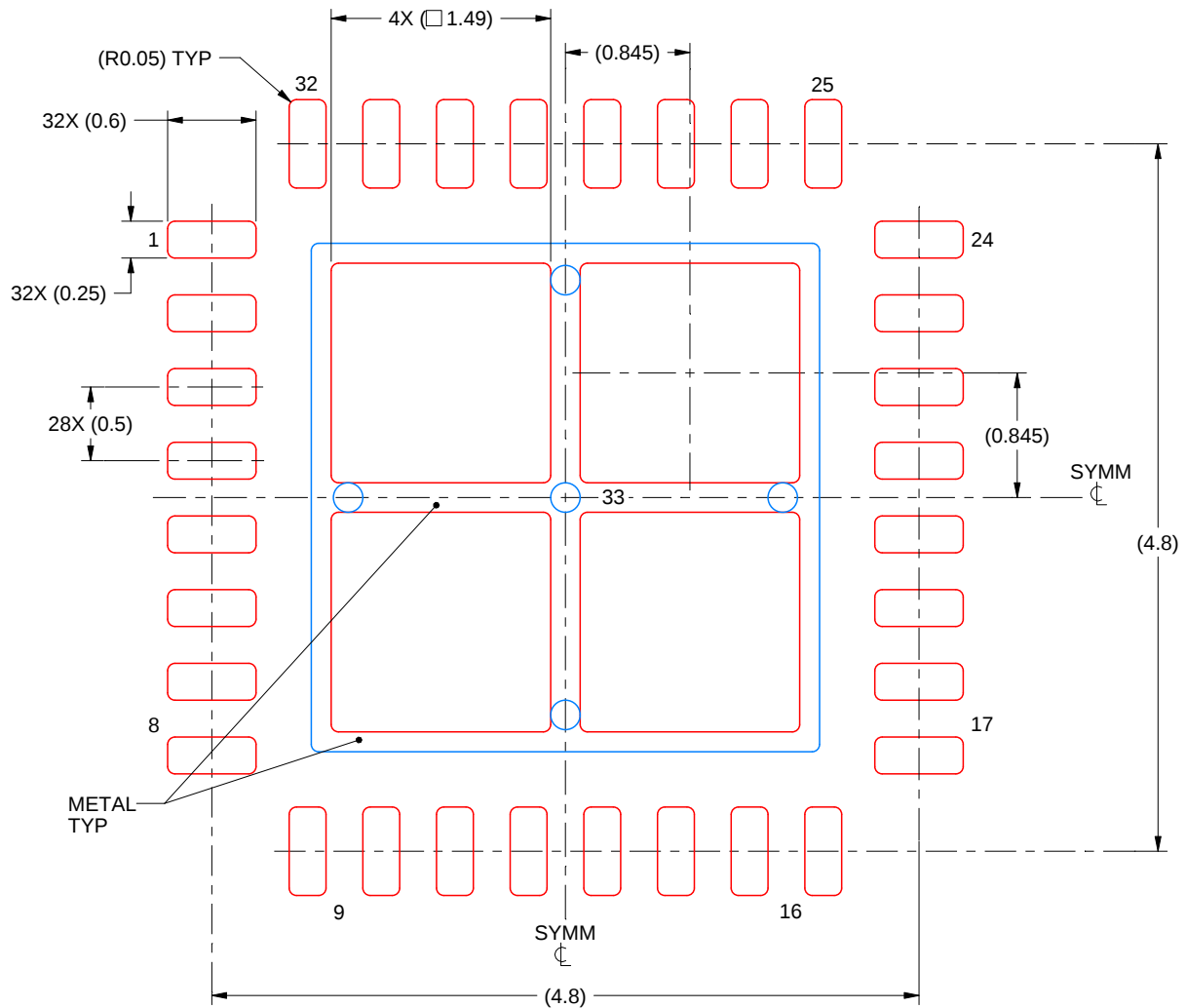
4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 ([www.ti.com/lit/slua271](http://www.ti.com/lit/slua271)).
5. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.

# EXAMPLE STENCIL DESIGN

RHB0032E

VQFN - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



**SOLDER PASTE EXAMPLE**  
BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD 33:  
75% PRINTED SOLDER COVERAGE BY AREA UNDER PACKAGE  
SCALE:20X

4223442/B 08/2019

NOTES: (continued)

6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

## GENERIC PACKAGE VIEW

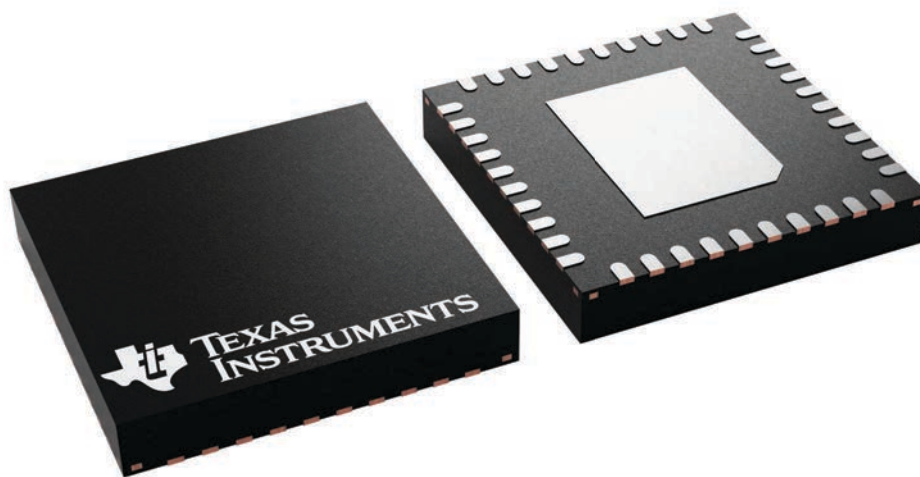
**RHA 40**

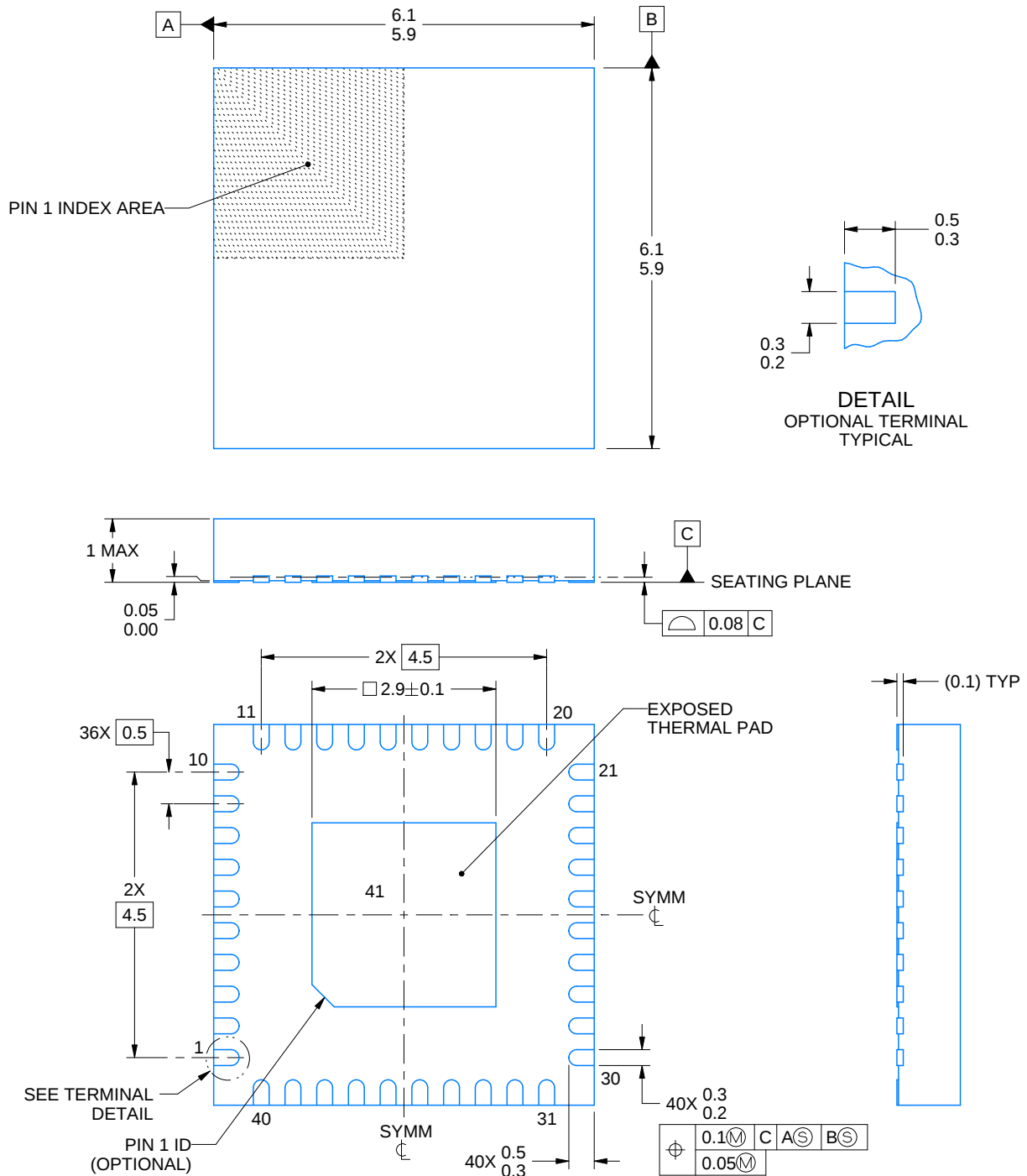
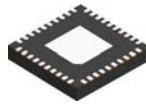
**VQFN - 1 mm max height**

6 x 6, 0.5 mm pitch

PLASTIC QUAD FLATPACK - NO LEAD

This image is a representation of the package family, actual package may vary.  
Refer to the product data sheet for package details.





4225822/A 03/2020

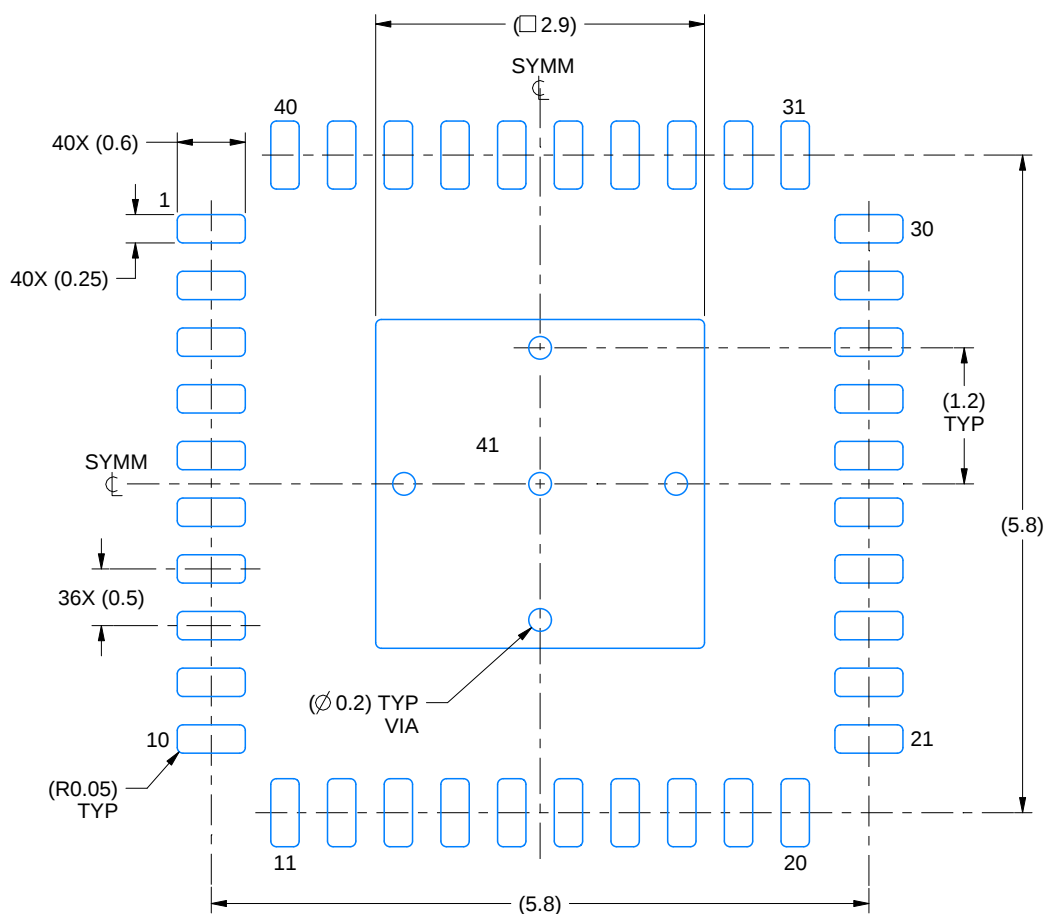
## NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.

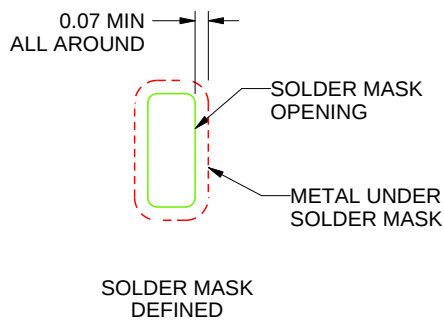
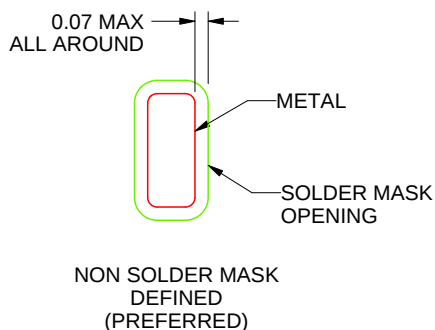
**RHA0040D**

### VQFN - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



LAND PATTERN EXAMPLE  
SCALE:15X



## SOLDER MASK DETAILS

4225822/A 03/2020

NOTES: (continued)

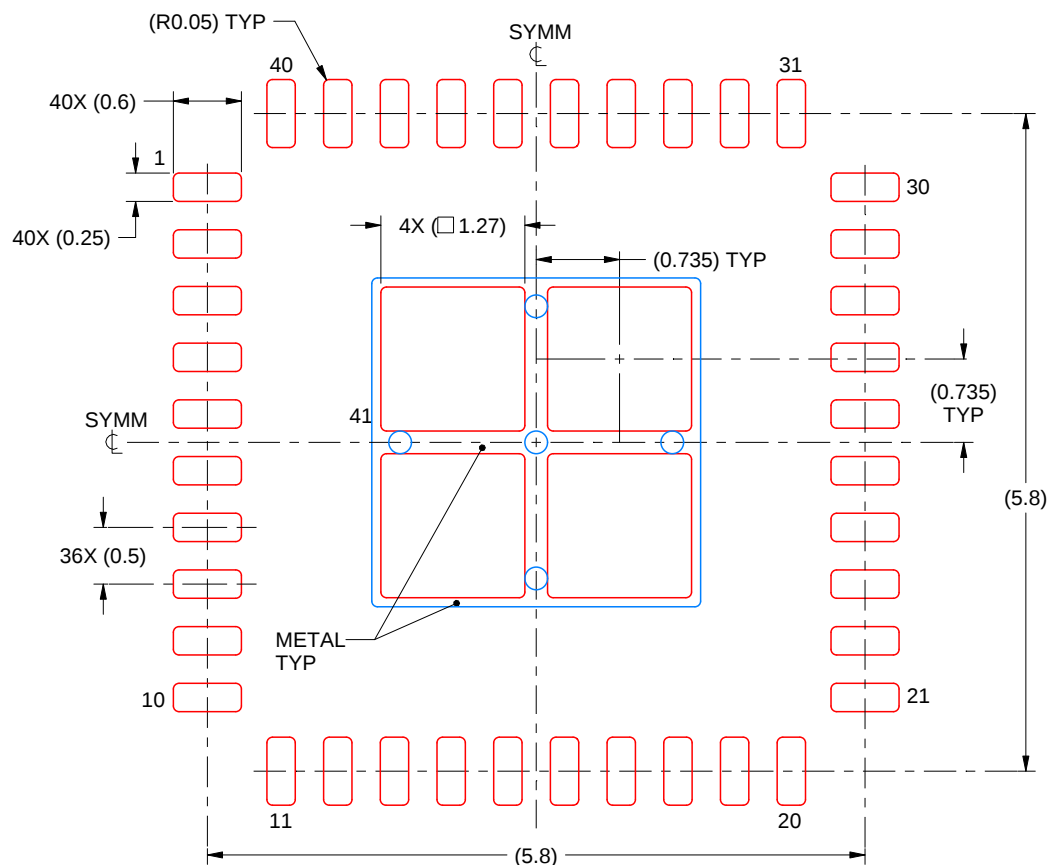
4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 ([www.ti.com/lit/sluea271](http://www.ti.com/lit/sluea271)).
5. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view.

# EXAMPLE STENCIL DESIGN

RHA0040D

VQFN - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



**SOLDER PASTE EXAMPLE**  
BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD 41:  
76.46% PRINTED SOLDER COVERAGE BY AREA UNDER PACKAGE  
SCALE:15X

4225822/A 03/2020

NOTES: (continued)

6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

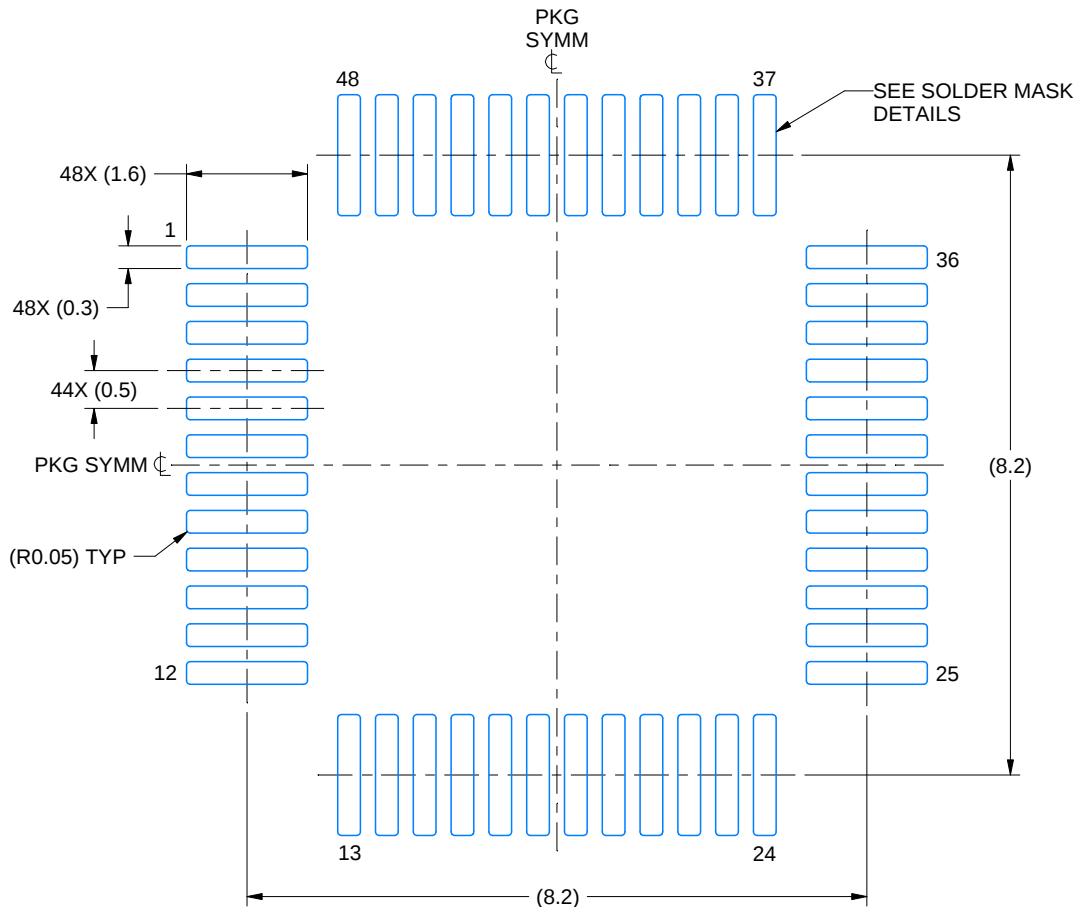


# EXAMPLE BOARD LAYOUT

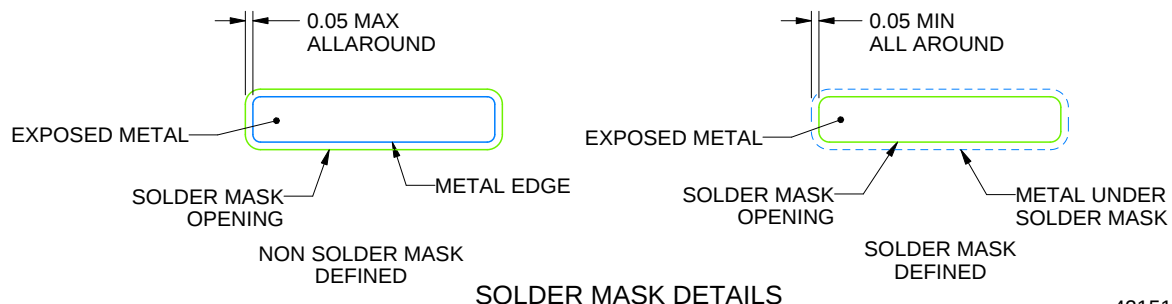
PT0048A

LQFP - 1.6 mm max height

LOW PROFILE QUAD FLATPACK



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE 10.000



SOLDER MASK DETAILS

4215159/B 11/2023

NOTES: (continued)

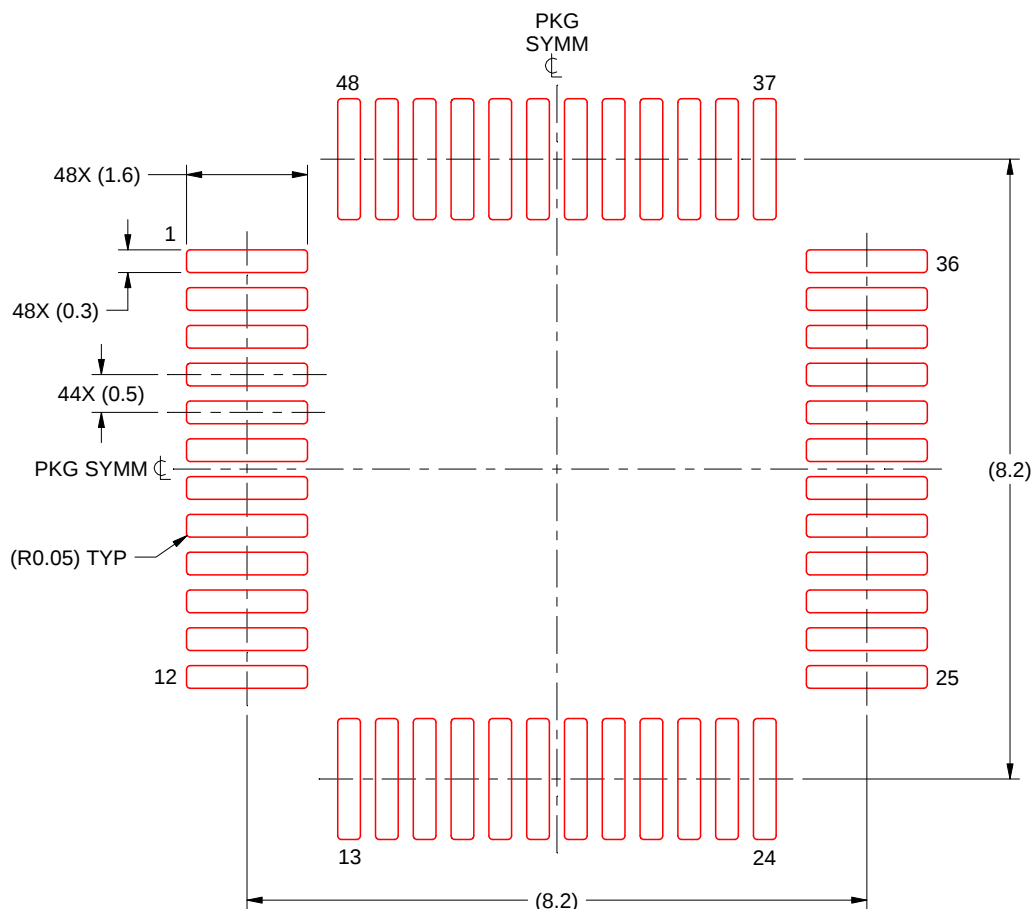
5. Publication IPC-7351 may have alternate designs.
6. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

# EXAMPLE STENCIL DESIGN

PT0048A

LQFP - 1.6 mm max height

LOW PROFILE QUAD FLATPACK



SOLDER PASTE EXAMPLE  
BASED ON 0.1 mm THICK STENCIL  
SCALE: 10X

4215159/B 11/2023

NOTES: (continued)

7. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
8. Board assembly site may have different recommendations for stencil design.

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