



# MSP430F51x2, MSP430F51x1 Mixed-Signal Microcontrollers

## 1 Device Overview

### 1.1 Features

- Low Supply-Voltage Range:  
3.6 V Down to 1.8 V
  - Ultra-Low Power Consumption
    - Active Mode (AM): 180  $\mu$ A/MHz
    - Standby Mode (LPM3 WDT Mode, 3 V): 1.1  $\mu$ A
    - Off Mode (LPM4 RAM Retention, 3 V): 0.9  $\mu$ A
    - Shutdown Mode (LPM4.5, 3 V): 0.25  $\mu$ A
  - Wake up From Standby Mode in Less Than 5  $\mu$ s
  - 16-Bit RISC Architecture, Extended Memory, 40-ns Instruction Cycle Time
  - Flexible Power-Management System
    - Fully Integrated LDO With Programmable Regulated Core Supply Voltage
    - Supply Voltage Supervision, Monitoring, and Brownout
  - Unified Clock System
    - FLL Control Loop for Frequency Stabilization
    - Low-Power Low-Frequency Internal Clock Source (VLO)
    - Low-Frequency Trimmed Internal Reference Source (REFO)
    - 32-kHz Crystals (XT1)
    - High-Frequency Crystals up to 25 MHz (XT1)
  - Hardware Multiplier Supports 32-Bit Operations
  - 3-Channel DMA
  - Up to Twelve 5-V-Tolerant Digital Push/Pull I/Os With up to 20-mA Drive Strength<sup>(1)</sup>
  - 16-Bit Timer TD0 With Three Capture/Compare Registers and Support of High-Resolution Mode
  - 16-Bit Timer TD1 With Three Capture/Compare Registers and Support of High-Resolution Mode
  - 16-Bit Timer TA0 With Three Capture/Compare Registers
  - Universal Serial Communication Interfaces (USCIs)<sup>(1)</sup>
    - USC1\_A0 Supports:
      - Enhanced UART Supports Automatic Baud-Rate Detection
      - IrDA Encoder and Decoder
      - Synchronous SPI
    - USC1\_B0 Supports:
      - I<sup>2</sup>C
      - Synchronous SPI
  - 10-Bit 200-ksps Analog-to-Digital Converter (ADC)
    - Internal Reference
    - Sample-and-Hold
    - Autoscan Feature
    - Up to 8 External Channels and 2 Internal Channels, Including Temperature Sensor<sup>(1)</sup>
  - Up to 16-Channel On-Chip Comparator Including an Ultra-Low-Power Mode<sup>(1)</sup>
  - Serial Onboard Programming, No External Programming Voltage Needed
  - [Device Comparison](#) Summarizes the Available Family Members
  - Available in 40-Pin QFN (RSB), 38-Pin TSSOP (DA), and 40-Pin Die-Sized BGA (YFF) Packages
- (1) Full functionality in the 40-pin QFN package options. For the available features of other packages, see [Signal Descriptions](#).

### 1.2 Applications

- Analog and Digital Sensor Systems
- LED Lighting
- Digital Power Supplies
- Motor Controls
- Remote Controls
- Thermostats



### 1.3 Description

The TI MSP family of ultra-low-power microcontrollers consists of several devices featuring different sets of peripherals targeted for various applications. The architecture, combined with five low-power modes, is optimized to achieve extended battery life in portable measurement applications. The device 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 devices to wake up from low-power modes to active mode in less than 5  $\mu$ s.

The MSP430F51x2 microcontrollers include two 16-bit high-resolution timers, two USCIs (USCI\_A0 and USCI\_B0), a 32-bit hardware multiplier, a high-performance 10-bit ADC, an on-chip comparator, a 3-channel DMA, 5-V tolerant I/Os, and up to 29 I/O pins.

The MSP430F51x1 microcontrollers include two 16-bit high-resolution timers, two USCIs (USCI\_A0 and USCI\_B0), a 32-bit hardware multiplier, an on-chip comparator, a 3-channel DMA, 5-V tolerant I/Os, and up to 29 I/O pins.

Typical applications for these devices include analog and digital sensor systems, LED lighting, digital power supplies, motor controls, remote controls, thermostats, digital timers, and hand-held meters.

For complete module descriptions, see the [MSP430F5xx and MSP430F6xx Family User's Guide](#).

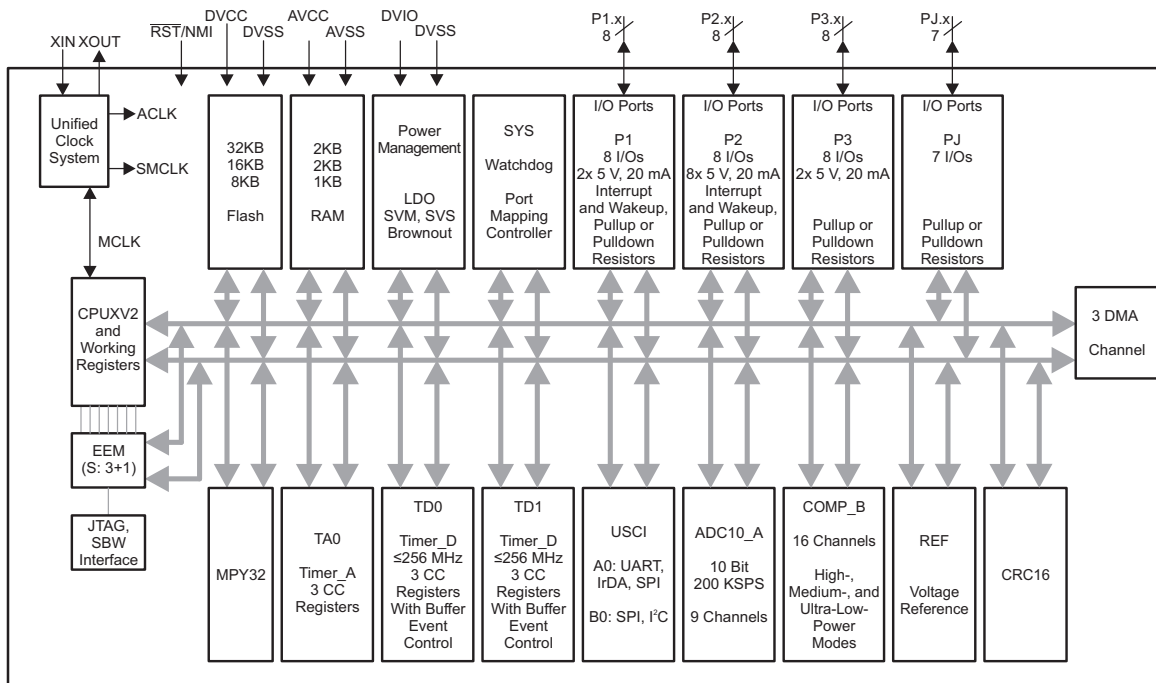
**Device Information<sup>(1)</sup>**

| PART NUMBER     | PACKAGE    | BODY SIZE <sup>(2)</sup>      |
|-----------------|------------|-------------------------------|
| MSP430F5172IYFF | DSBGA (40) | See <a href="#">Section 8</a> |
| MSP430F5172IRSB | WQFN (40)  | 5 mm × 5 mm                   |
| MSP430F5172IDA  | TSSOP (38) | 12.5 mm × 6.2 mm              |

- (1) For the most current part, package, and ordering information, see the *Package Option Addendum* in [Section 8](#), or see the TI website at [www.ti.com](http://www.ti.com).
- (2) The dimensions shown here are approximations. For the package dimensions with tolerances, see the *Mechanical Data* in [Section 8](#).

## 1.4 Functional Block Diagrams

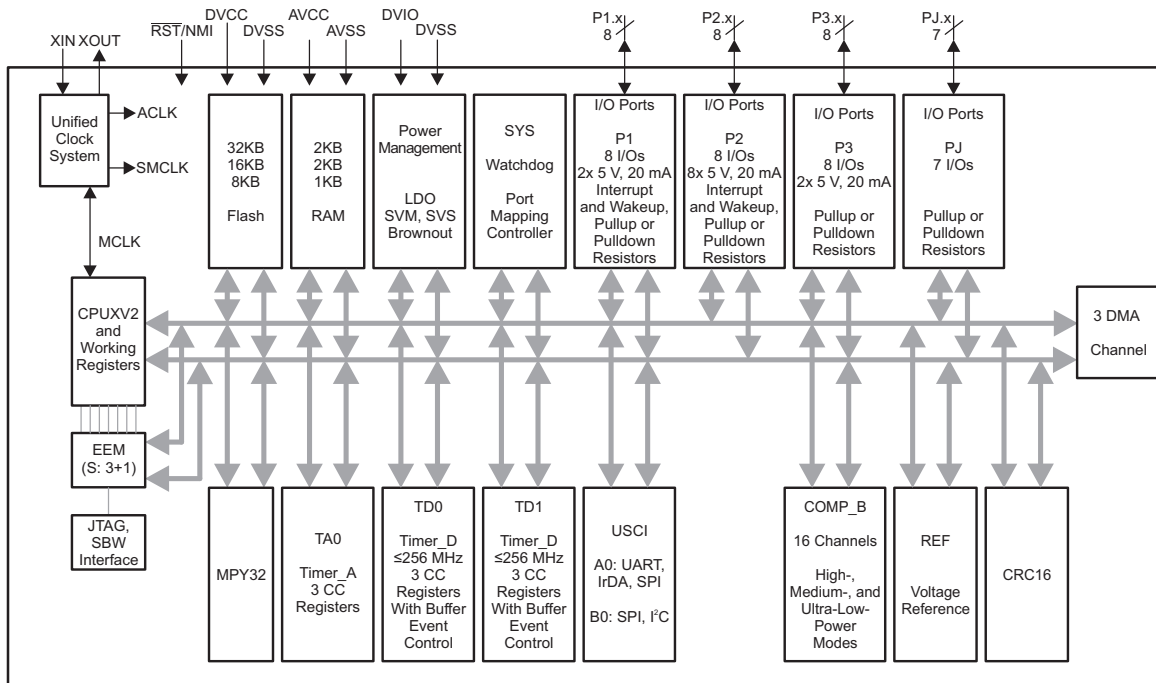
Figure 1-1 shows the functional block diagram for the MSP430F51x2 devices.



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Figure 1-1. Functional Block Diagram, MSP430F51x2

Figure 1-2 shows the functional block diagram for the MSP430F51x1 devices.



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Figure 1-2. Functional Block Diagram, MSP430F51x1

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## 2 Revision History

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|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------|
| <ul style="list-style-type: none"> <li>Added typical conditions statements at the beginning of <a href="#">Section 5, Specifications</a> .....</li> <li>Updated <a href="#">Section 7.4, Documentation Support</a>.....</li> </ul> | <a href="#">14</a><br><a href="#">101</a> |

### 3 Device Comparison

Table 3-1 summarizes the available family members.

**Table 3-1. Device Comparison<sup>(1)(2)</sup>**

| DEVICE      | FLASH<br>(KB) | SRAM<br>(KB) | Timer_A <sup>(3)</sup> | Timer_D <sup>(4)</sup> | USCI                             |                                     | ADC10_A<br>(Ch) | Comp_B<br>(Ch) | I/Os | PACKAGE  |
|-------------|---------------|--------------|------------------------|------------------------|----------------------------------|-------------------------------------|-----------------|----------------|------|----------|
|             |               |              |                        |                        | CHANNEL A:<br>UART, IrDA,<br>SPI | CHANNEL B:<br>SPI, I <sup>2</sup> C |                 |                |      |          |
| MSP430F5172 | 32            | 2            | 3                      | 3, 3                   | 1                                | 1                                   | 9 ext, 2 int    | 16             | 31   | 40 QFN   |
|             |               |              |                        |                        |                                  |                                     | 8 ext, 2 int    | 15             | 29   | 40 DSBGA |
|             |               |              |                        |                        |                                  |                                     |                 |                |      | 38 TSSOP |
| MSP430F5152 | 16            | 2            | 3                      | 3, 3                   | 1                                | 1                                   | 9 ext, 2 int    | 16             | 31   | 40 QFN   |
|             |               |              |                        |                        |                                  |                                     | 8 ext, 2 int    | 15             | 29   | 40 DSBGA |
|             |               |              |                        |                        |                                  |                                     |                 |                |      | 38 TSSOP |
| MSP430F5132 | 8             | 1            | 3                      | 3, 3                   | 1                                | 1                                   | 9 ext, 2 int    | 16             | 31   | 40 QFN   |
|             |               |              |                        |                        |                                  |                                     | 8 ext, 2 int    | 15             | 29   | 40 DSBGA |
|             |               |              |                        |                        |                                  |                                     |                 |                |      | 38 TSSOP |
| MSP430F5171 | 32            | 2            | 3                      | 3, 3                   | 1                                | 1                                   | –               | 16             | 31   | 40 QFN   |
|             |               |              |                        |                        |                                  |                                     |                 | 15             | 29   | 40 DSBGA |
|             |               |              |                        |                        |                                  |                                     |                 |                |      | 38 TSSOP |
| MSP430F5151 | 16            | 2            | 3                      | 3, 3                   | 1                                | 1                                   | –               | 16             | 31   | 40 QFN   |
|             |               |              |                        |                        |                                  |                                     |                 | 15             | 29   | 40 DSBGA |
|             |               |              |                        |                        |                                  |                                     |                 |                |      | 38 TSSOP |
| MSP430F5131 | 8             | 1            | 3                      | 3, 3                   | 1                                | 1                                   | –               | 16             | 31   | 40 QFN   |
|             |               |              |                        |                        |                                  |                                     |                 | 15             | 29   | 40 DSBGA |
|             |               |              |                        |                        |                                  |                                     |                 |                |      | 38 TSSOP |

- (1) For the most current package and ordering information, see the *Package Option Addendum* in [Section 8](#), or see the TI website at [www.ti.com](http://www.ti.com).
- (2) Package drawings, thermal data, and symbolization are available at [www.ti.com/packaging](http://www.ti.com/packaging).
- (3) Each number in the sequence represents an instantiation of Timer\_A with its associated number of capture compare registers and PWM output generators available. For example, a number sequence of 3, 5 would represent two instantiations of Timer\_A, the first instantiation having 3 and the second instantiation having 5 capture compare registers and PWM output generators, respectively.
- (4) Each number in the sequence represents an instantiation of Timer\_D with its associated number of capture compare registers and PWM output generators available. For example, a number sequence of 3, 5 would represent two instantiations of Timer\_D, the first instantiation having 3 and the second instantiation having 5 capture compare registers and PWM output generators, respectively.

### 3.1 Related Products

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

**TI 16-bit and 32-bit microcontrollers** High-performance, low-power solutions to enable the autonomous future

**Products for MSP430 ultra-low-power sensing and measurement microcontrollers** One platform. One ecosystem. Endless possibilities.

**Products for MSP430 ultra-low-power microcontrollers** MCUs for metrology, monitoring, system control, and communications

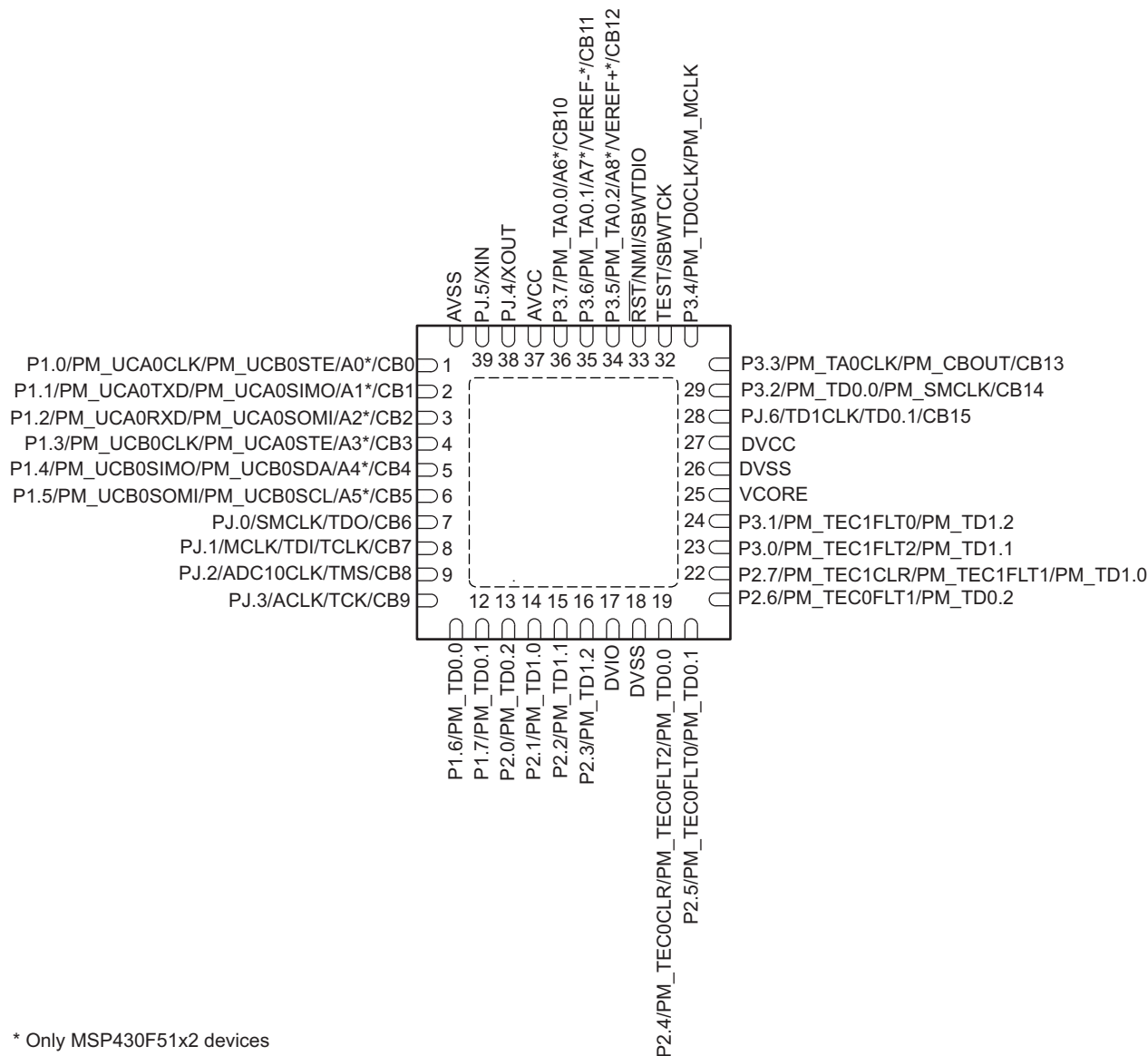
**Companion Products for MSP430F5172** Review products that are frequently purchased or used in conjunction with this product.

**Reference Designs for MSP430F5172** TI Designs Reference Design Library is a robust reference design library that spans analog, embedded processor, and connectivity. Created by TI experts to help you jump start your system design, all TI Designs include schematic or block diagrams, BOMs, and design files to speed your time to market. Search and download designs at [ti.com/tidesigns](http://ti.com/tidesigns).

## 4 Terminal Configuration and Functions

### 4.1 Pin Diagrams

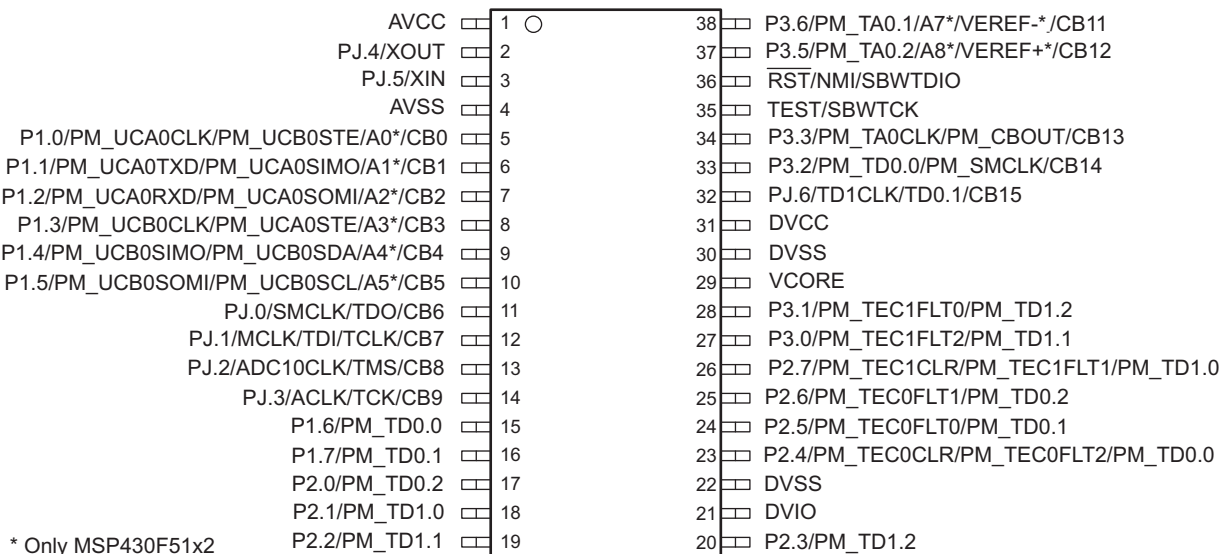
Figure 4-1 shows the pinout for the 40-pin RSB package.



\* Only MSP430F51x2 devices

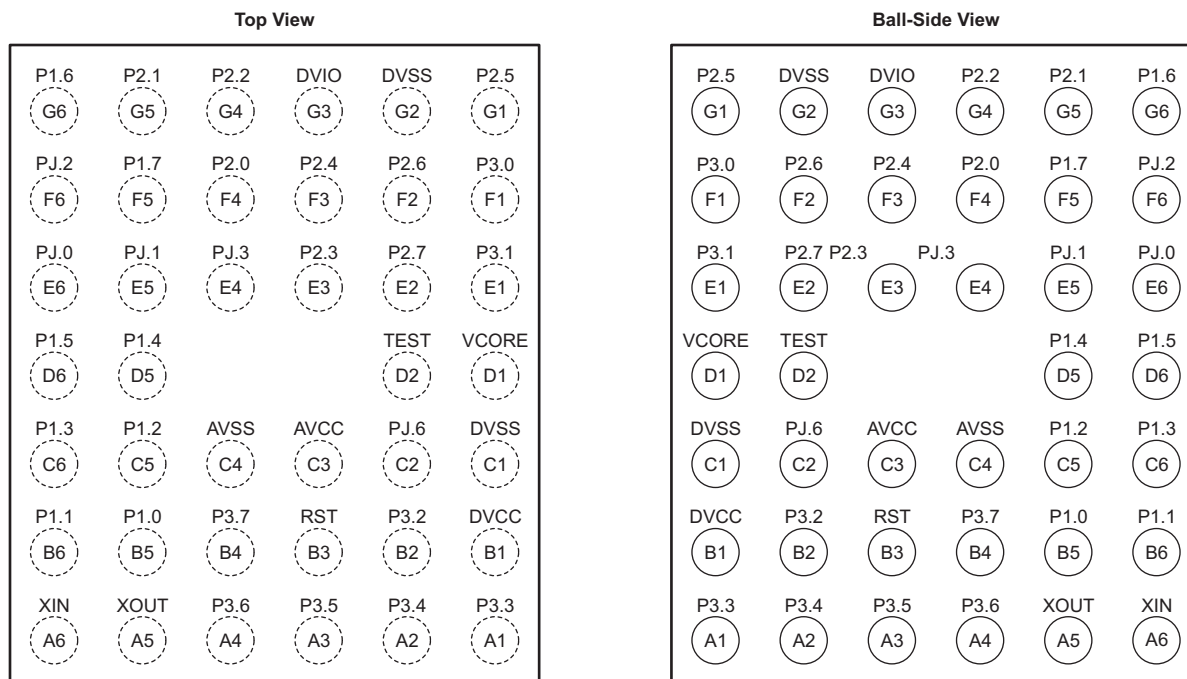
Figure 4-1. 40-Pin RSB Package (Top View)

Figure 4-2 shows the pinout for the 38-pin DA package.



**Figure 4-2. 38-Pin DA Package (Top View)**

Figure 4-3 shows the pinout for the 40-pin YFF package. For the package dimensions, see the *Mechanical Data* in [Section 8](#).



**Figure 4-3. 40-Pin YFF Package (Top View and Bottom View)**

## 4.2 Signal Descriptions

Table 4-1 describes the signals for all device and package variants.

**Table 4-1. Signal Descriptions**

| TERMINAL                                                              |                    |    |     | I/O <sup>(1)</sup>       | DESCRIPTION                                                                                                                                                                                                                                                                                                                                       |
|-----------------------------------------------------------------------|--------------------|----|-----|--------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| NAME                                                                  | NO. <sup>(2)</sup> |    |     |                          |                                                                                                                                                                                                                                                                                                                                                   |
|                                                                       | RSB                | DA | YFF |                          |                                                                                                                                                                                                                                                                                                                                                   |
| P1.0/<br>PM_UCA0CLK/<br><br>PM_UCB0STE/<br>A0 <sup>(3)</sup> /<br>CB0 | 1                  | 5  | B5  | I/O                      | General-purpose digital I/O with reconfigurable port mapping secondary function <sup>(4)</sup><br>Default mapping: Clock signal input – USCI_A0 SPI slave mode; Clock signal output – USCI_A0 SPI master mode<br>Default mapping: Slave transmit enable – USCI_B0 SPI mode<br>Analog input A0 – 10-bit ADC <sup>(3)</sup><br>Comparator_B Input 0 |
| P1.1/<br>PM_UCA0TXD/<br>PM_UCA0SIMO/<br>A1 <sup>(3)</sup> /<br>CB1    | 2                  | 6  | B6  | I/O                      | General-purpose digital I/O<br>Default mapping: Transmit data – USCI_A0 UART mode<br>Default mapping: Slave in, master out – USCI_A0 SPI mode<br>Analog input A1 – 10-bit ADC <sup>(3)</sup><br>Comparator_B Input 1                                                                                                                              |
| P1.2/<br>PM_UCA0RXD/<br>PM_UCA0SOMI/<br>A2 <sup>(3)</sup> /<br>CB2    | 3                  | 7  | C5  | I/O                      | General-purpose digital I/O with reconfigurable port mapping secondary function<br>Default mapping: Receive data – USCI_A0 UART mode<br>Default mapping: Slave out, master in – USCI_A0 SPI mode<br>Analog input A2 – 10-bit ADC <sup>(3)</sup><br>Comparator_B Input 2                                                                           |
| P1.3/<br>PM_UCB0CLK/<br><br>PM_UCA0STE/<br>A3 <sup>(3)</sup> /<br>CB3 | 4                  | 8  | C6  | I/O                      | General-purpose digital I/O with reconfigurable port mapping secondary function<br>Default mapping: Clock signal input – USCI_B0 SPI slave mode; Clock signal output – USCI_B0 SPI master mode<br>Default mapping: Slave transmit enable – USCI_A0 SPI mode<br>Analog input A3 – 10-bit ADC <sup>(3)</sup><br>Comparator_B Input 3                |
| P1.4/<br>PM_UCB0SIMO/<br>PM_UCB0SDA/<br>A4 <sup>(3)</sup> /<br>CB4    | 5                  | 9  | D5  | I/O                      | General-purpose digital I/O with reconfigurable port mapping secondary function<br>Default mapping: Slave in, master out – USCI_B0 SPI mode<br>Default mapping: I <sup>2</sup> C data – USCI_B0 I <sup>2</sup> C mode<br>Analog input A4 – 10-bit ADC <sup>(3)</sup><br>Comparator_B Input 4                                                      |
| P1.5/<br>PM_UCB0SOMI/<br>PM_UCB0SCL/<br>A5 <sup>(3)</sup> /<br>CB5    | 6                  | 10 | D6  | I/O                      | General-purpose digital I/O with reconfigurable port mapping secondary function<br>Default mapping: Slave out, master in – USCI_B0 SPI mode<br>Default mapping: I <sup>2</sup> C clock – USCI_B0 I <sup>2</sup> C mode<br>Analog input A5 – 10-bit ADC <sup>(3)</sup><br>Comparator_B Input 5                                                     |
| PJ.0/<br>SMCLK/<br>TDO/<br>CB6                                        | 7                  | 11 | E6  | I/O                      | General-purpose digital I/O<br>SMCLK clock output<br>Test data output port<br>Comparator_B Input 6                                                                                                                                                                                                                                                |
| PJ.1/<br>MCLK/<br>TDI/TCLK/<br>CB7                                    | 8                  | 12 | E5  | I/O                      | General-purpose digital I/O<br>MCLK clock output<br>Test data input or test clock input<br>Comparator_B Input 7                                                                                                                                                                                                                                   |
| PJ.2/<br>ADC10CLK/<br>TMS/<br>CB8                                     | 9                  | 13 | F6  | I/O                      | General-purpose digital I/O<br>ADC10_A clock output<br>Test mode select<br>Comparator_B Input 8                                                                                                                                                                                                                                                   |
| PJ.3/<br>ACLK/<br>TCK/<br>CB9                                         | 10                 | 14 | E4  | I/O                      | General-purpose digital I/O<br>ACLK output port<br>Test clock<br>Comparator_B Input 9                                                                                                                                                                                                                                                             |
| P1.6/<br>PM_TD0.0                                                     | 11                 | 15 | G6  | I/O,<br>DV <sub>IO</sub> | General-purpose digital I/O with reconfigurable port mapping secondary function<br>Default mapping: TD0 CCR0 compare output/capture input                                                                                                                                                                                                         |

(1) I = input, O = output

(2) N/A = not available on this package offering

(3) The ADC10\_A module is available on MSP430F51x2 devices. The secondary pin functions Ax (ADC10\_A channel x) available only in MSP430F51x2 devices.

(4) For details on the Port Mapping Controller, see Section 6.9.2.

**Table 4-1. Signal Descriptions (continued)**

| TERMINAL                                         |                    |    |     | I/O <sup>(1)</sup>       | DESCRIPTION                                                                                                                                                                                                                                                |
|--------------------------------------------------|--------------------|----|-----|--------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| NAME                                             | NO. <sup>(2)</sup> |    |     |                          |                                                                                                                                                                                                                                                            |
|                                                  | RSB                | DA | YFF |                          |                                                                                                                                                                                                                                                            |
| P1.7/<br>PM_TD0.1                                | 12                 | 16 | F5  | I/O,<br>DV <sub>IO</sub> | General-purpose digital I/O with reconfigurable port mapping secondary function<br>Default mapping: TD0 CCR1 compare output/capture input                                                                                                                  |
| P2.0/<br>PM_TD0.2                                | 13                 | 17 | F4  | I/O,<br>DV <sub>IO</sub> | General-purpose digital I/O with reconfigurable port mapping secondary function<br>Default mapping: TD0 CCR2 compare output/capture input                                                                                                                  |
| P2.1/<br>PM_TD1.0                                | 14                 | 18 | G5  | I/O,<br>DV <sub>IO</sub> | General-purpose digital I/O with reconfigurable port mapping secondary function<br>Default mapping: TD1 CCR0 compare output/capture input                                                                                                                  |
| P2.2/<br>PM_TD1.1                                | 15                 | 19 | G4  | I/O,<br>DV <sub>IO</sub> | General-purpose digital I/O with reconfigurable port mapping secondary function<br>Default mapping: TD1 CCR1 compare output/capture input                                                                                                                  |
| P2.3/<br>PM_TD1.2                                | 16                 | 20 | E3  | I/O,<br>DV <sub>IO</sub> | General-purpose digital I/O with reconfigurable port mapping secondary function<br>Default mapping: TD1 CCR2 compare output/capture input                                                                                                                  |
| DVIO                                             | 17                 | 21 | G3  |                          | 5-V tolerant digital I/O power supply                                                                                                                                                                                                                      |
| DVSS                                             | 18                 | 22 | G2  |                          | Digital ground supply                                                                                                                                                                                                                                      |
| P2.4/<br>PM_TEC0CLR/<br>PM_TEC0FLT2/<br>PM_TD0.0 | 19                 | 23 | F3  | I/O,<br>DV <sub>IO</sub> | General-purpose digital I/O with reconfigurable port mapping secondary function<br>Default mapping: TD0 external clear input<br>Default mapping: TD0 fault input channel 2 (controlled by module input enable)<br>Default mapping: TD0 CCR0 compare output |
| P2.5/<br>PM_TEC0FLT0/<br>PM_TD0.1                | 20                 | 24 | G1  | I/O,<br>DV <sub>IO</sub> | General-purpose digital I/O with reconfigurable port mapping secondary function<br>Default mapping: TD0 fault input channel 0<br>Default mapping: TD0 CCR1 compare output                                                                                  |
| P2.6/<br>PM_TEC0FLT1/<br>PM_TD0.2                | 21                 | 25 | F2  | I/O,<br>DV <sub>IO</sub> | General-purpose digital I/O with reconfigurable port mapping secondary function<br>Default mapping: TD0 fault input channel 1<br>Default mapping: TD0 CCR2 compare output                                                                                  |
| P2.7/<br>PM_TEC1CLR/<br>PM_TEC1FLT1/<br>PM_TD1.0 | 22                 | 26 | E2  | I/O,<br>DV <sub>IO</sub> | General-purpose digital I/O with reconfigurable port mapping secondary function<br>Default mapping: TD1 external clear<br>Default mapping: TD1 fault input channel 1 (controlled by module input enable)<br>Default mapping: TD1 CCR0 compare output       |
| P3.0/<br>PM_TEC1FLT2/<br>PM_TD1.1                | 23                 | 27 | F1  | I/O,<br>DV <sub>IO</sub> | General-purpose digital I/O with reconfigurable port mapping secondary function<br>Default mapping: TD1 fault input channel 2<br>Default mapping: TD1 CCR1 compare output                                                                                  |
| P3.1/<br>PM_TEC1FLT0/<br>PM_TD1.2                | 24                 | 28 | E1  | I/O,<br>DV <sub>IO</sub> | General-purpose digital I/O with reconfigurable port mapping secondary function<br>Default mapping: TD1 fault input channel 0<br>Default mapping: TD1 CCR2 compare output                                                                                  |
| VCORE                                            | 25                 | 29 | D1  |                          | Regulated core power supply                                                                                                                                                                                                                                |
| DVSS                                             | 26                 | 30 | C1  |                          | Digital ground supply                                                                                                                                                                                                                                      |
| DVCC                                             | 27                 | 31 | B1  |                          | Digital power supply                                                                                                                                                                                                                                       |
| PJ.6/<br>TD1CLK/<br>TD0.1/<br>CB15               | 28                 | 32 | C2  | I/O                      | General-purpose digital I/O<br>TD1 clock input<br>TD0 CCR1 compare output<br>Comparator_B Input 15                                                                                                                                                         |
| P3.2/<br>PM_TD0.0/<br>PM_SMCLK/<br>CB14          | 29                 | 33 | B2  | I/O                      | General-purpose digital I/O with reconfigurable port mapping secondary function<br>Default mapping: TD0 CCR0 capture input<br>Default mapping: SMCLK output<br>Comparator_B Input 14                                                                       |
| P3.3/<br>PM_TA0CLK/<br>PM_CBOUT/<br>CB13         | 30                 | 34 | A1  | I/O                      | General-purpose digital I/O with reconfigurable port mapping secondary function<br>Default mapping: TA0 clock input<br>Default mapping: Comparator_B output<br>Comparator_B Input 13                                                                       |
| P3.4/<br>PM_TD0CLK/<br>PM_MCLK                   | 31                 | –  | A2  | I/O                      | General-purpose digital I/O with reconfigurable port mapping secondary function<br>Default mapping: TD0 clock input<br>Default mapping: MCLK output                                                                                                        |
| TEST/<br>SBWTCK                                  | 32                 | 35 | D2  |                          | Test mode pin – select digital I/O on JTAG pins<br>Spy-Bi-Wire input clock                                                                                                                                                                                 |
| RST/<br>NMI/<br>SBWTDIO                          | 33                 | 36 | B3  |                          | Reset input active low <sup>(5)</sup><br>Nonmaskable interrupt input<br>Spy-Bi-Wire data input/output                                                                                                                                                      |

(5) When this pin is configured as reset, the internal pullup resistor is enabled by default.

**Table 4-1. Signal Descriptions (continued)**

| TERMINAL                                                     |                    |    |     | I/O <sup>(1)</sup> | DESCRIPTION                                                                                                                                                                                                                                                                                                    |
|--------------------------------------------------------------|--------------------|----|-----|--------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| NAME                                                         | NO. <sup>(2)</sup> |    |     |                    |                                                                                                                                                                                                                                                                                                                |
|                                                              | RSB                | DA | YFF |                    |                                                                                                                                                                                                                                                                                                                |
| P3.5/<br>PM TA0.2/<br>A8 <sup>(3)</sup> /<br>VEREF+/<br>CB12 | 34                 | 37 | A3  | I/O                | General-purpose digital I/O with reconfigurable port mapping secondary function<br>Default mapping: TA0 CCR2 compare output/capture input<br>Analog input A8 – 10-bit ADC <sup>(3)</sup><br>Positive terminal for the ADC reference voltage for an external applied reference voltage<br>Comparator_B Input 12 |
| P3.6/<br>PM TA0.1/<br>A7 <sup>(3)</sup> /<br>VEREF-/<br>CB11 | 35                 | 38 | A4  | I/O                | General-purpose digital I/O with reconfigurable port mapping secondary function<br>Default mapping: TA0 CCR1 compare output/capture input<br>Analog input A7 – 10-bit ADC <sup>(3)</sup><br>Negative terminal for the ADC reference voltage for an external applied reference voltage<br>Comparator_B Input 11 |
| P3.7/<br>PM TA0.0/<br>A6 <sup>(3)</sup> /<br>CB10            | 36                 | –  | B4  | I/O                | General-purpose digital I/O with reconfigurable port mapping secondary function<br>Default mapping: TA0 CCR0 compare output/capture input<br>Analog input A6 – 10-bit ADC <sup>(3)</sup><br>Comparator_B Input 10                                                                                              |
| AVCC                                                         | 37                 | 1  | C3  |                    | Analog power supply                                                                                                                                                                                                                                                                                            |
| PJ.4/<br>XOUT                                                | 38                 | 2  | A5  | I/O                | General-purpose digital I/O<br>Output terminal of crystal oscillator                                                                                                                                                                                                                                           |
| PJ.5/<br>XIN                                                 | 39                 | 3  | A6  | I/O                | General-purpose digital I/O<br>Input terminal for crystal oscillator                                                                                                                                                                                                                                           |
| AVSS                                                         | 40                 | 4  | C4  |                    | Analog ground supply                                                                                                                                                                                                                                                                                           |
| QFN pad                                                      | –                  | NA | NA  |                    | Recommended to connect to DVSS externally                                                                                                                                                                                                                                                                      |

## 5 Specifications

All graphs in this section are for typical conditions, unless otherwise noted.

Typical (TYP) values are specified at  $V_{CC} = 3.3\text{ V}$  and  $T_A = 25^\circ\text{C}$ , unless otherwise noted.

### 5.1 Absolute Maximum Ratings<sup>(1)</sup>

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

|                                                                          | MIN  | MAX            | UNIT |
|--------------------------------------------------------------------------|------|----------------|------|
| Voltage $V_{CC}$ applied at DVCC to DVSS                                 | −0.3 | 4.1 V          | V    |
| Voltage $V_{IO}$ applied at VIO to DVSS                                  | −0.3 | 6.1 V          | V    |
| Voltage applied to any pin (excluding V <sub>CORE</sub> ) <sup>(2)</sup> | −0.3 | $V_{CC} + 0.3$ | V    |
| Diode current at any device pin                                          |      | ±2             | mA   |
| Maximum operating junction temperature, $T_J$                            |      | 95             | °C   |
| Storage temperature, $T_{stg}$                                           | −55  | 150            | °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) All voltages referenced to  $V_{SS}$ .  $V_{CORE}$  is for internal device usage only. No external DC loading or voltage should be applied.

### 5.2 ESD Ratings

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

- (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.

### 5.3 Recommended Operating Conditions

|                          |                                                                                                                       | MIN                    | NOM | MAX | UNIT |
|--------------------------|-----------------------------------------------------------------------------------------------------------------------|------------------------|-----|-----|------|
| $V_{CC}$                 | Supply voltage during program execution and flash programming<br>$V_{(AVCC)} = V_{(DVCC)} = V_{CC}$ <sup>(1)(2)</sup> | PMMCOREVx = 0          | 1.8 | 3.6 | V    |
|                          |                                                                                                                       | PMMCOREVx = 0, 1       | 2.0 | 3.6 |      |
|                          |                                                                                                                       | PMMCOREVx = 0, 1, 2    | 2.2 | 3.6 |      |
|                          |                                                                                                                       | PMMCOREVx = 0, 1, 2, 3 | 2.4 | 3.6 |      |
| $V_{IO}$                 | Supply voltage of pins P1.6, P1.7, P2.0 to P2.7, P3.0, and P3.1 supplied by VIO <sup>(3)(4)</sup>                     | 1.8                    |     | 5.5 | V    |
| $V_{SS}$                 | Supply voltage $V_{(AVSS)} = V_{(DVSS)} = V_{SS}$                                                                     |                        | 0   |     | V    |
| $T_A$                    | Operating free-air temperature                                                                                        | −40                    |     | 85  | °C   |
| $T_J$                    | Operating junction temperature                                                                                        | −40                    |     | 85  | °C   |
| $C_{(VCORE)}$            | Recommended capacitor at V <sub>CORE</sub> <sup>(5)</sup>                                                             |                        | 470 |     | nF   |
| $C_{(DVCC)}/C_{(VCORE)}$ | Capacitor ratio of DVCC to V <sub>CORE</sub>                                                                          | 10                     |     |     |      |

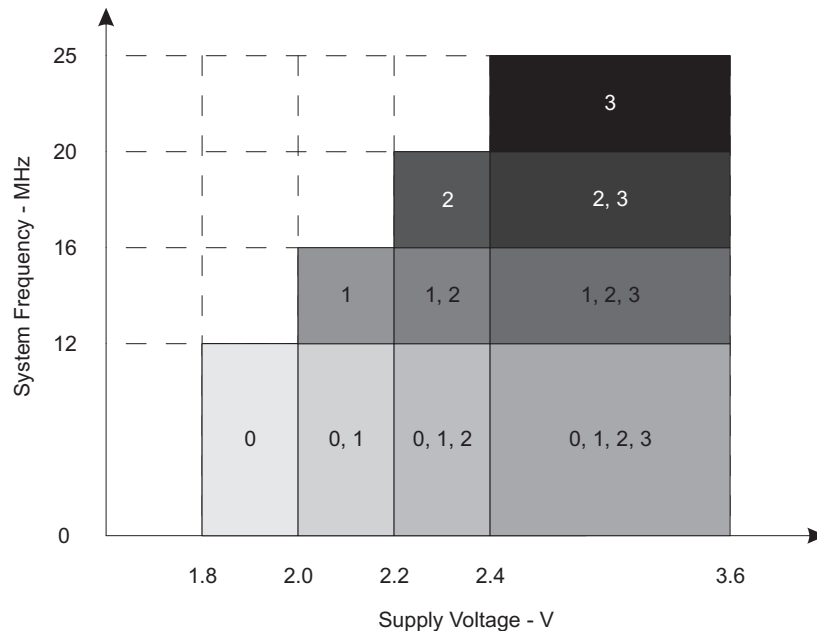
- (1) TI recommends powering AVCC and DVCC from the same source. A maximum difference of 0.3 V between  $V_{(AVCC)}$  and  $V_{(DVCC)}$  can be tolerated during power up and operation.
- (2) The minimum supply voltage is defined by the supervisor SVS levels when it is enabled. See the [Section 5.28](#) threshold parameters for the exact values and further details.
- (3) If DVIO is not supplied by the same source as DVCC, TI recommends powering AVCC and DVCC before powering DVIO. At DVCC and AVCC voltages higher than 1.8 V, the maximum difference of 0.3 V between DVIO and (DVCC and AVCC) can be exceeded. DVIO must be higher than or equal to DVCC.  
Increased cross current can flow into DVCC if DVIO is less than  $(DVCC - 0.3\text{ V})$ , with a maximum current flowing when DVIO is equal to  $DVCC/2$ . To avoid high currents into DVCC, DVIO must be higher than or equal to DVCC, DVIO must not float, and DVIO must be turned off quickly. TI recommends pulling the DVIO pins to low before disabling DVIO.
- (4) For best cross-current prevention, voltage applied to DVIO should not be lower than DVCC. However, if DVIO is switched off during operation, due to application requirements, DVIO should be pulled to ground to prevent a floating voltage.
- (5) A capacitor tolerance of ±20% or better is required.

## Recommended Operating Conditions (continued)

|                     |                                                                                                                 | MIN                                                                                                   | NOM | MAX | UNIT |     |
|---------------------|-----------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|-----|-----|------|-----|
| f <sub>SYSTEM</sub> | Processor frequency (maximum MCLK frequency) <sup>(6)</sup> <sup>(7)</sup><br>(see <a href="#">Figure 5-1</a> ) | PMMCOREVx = 0,<br>1.8 V ≤ V <sub>CC</sub> ≤ 3.6 V<br>(default condition)                              |     | 0   | 12   | MHz |
|                     |                                                                                                                 | PMMCOREVx = 1,<br>2.0 V ≤ V <sub>CC</sub> ≤ 3.6 V                                                     |     | 0   | 16   |     |
|                     |                                                                                                                 | PMMCOREVx = 2,<br>2.2 V ≤ V <sub>CC</sub> ≤ 3.6 V                                                     |     | 0   | 20   |     |
|                     |                                                                                                                 | PMMCOREVx = 3,<br>2.4 V ≤ V <sub>CC</sub> ≤ 3.6 V                                                     |     | 0   | 25   |     |
| P <sub>INT</sub>    | Internal power dissipation                                                                                      | V <sub>CC</sub> × I <sub>(DVCC)</sub>                                                                 |     |     |      | W   |
| P <sub>IO</sub>     | I/O power dissipation of the I/O pins powered by DVCC                                                           | (V <sub>CC</sub> – V <sub>IOH</sub> ) × I <sub>IOH</sub> +<br>V <sub>IOL</sub> × I <sub>IOL</sub>     |     |     |      | W   |
| P <sub>IO5</sub>    | I/O power dissipation of the I/O pins powered by VIO                                                            | (V <sub>IO</sub> – V <sub>IOH5</sub> ) × I <sub>IOH5</sub> +<br>V <sub>IOL5</sub> × I <sub>IOL5</sub> |     |     |      | W   |
| P <sub>MAX</sub>    | Maximum allowed power dissipation, P <sub>MAX</sub> > P <sub>IO</sub> + P <sub>IO5</sub> + P <sub>INT</sub>     | (T <sub>J</sub> – T <sub>A</sub> ) / R <sub>θJA</sub>                                                 |     |     |      | W   |

(6) The MSP430™ CPU is clocked directly with MCLK. Both the high and low phase of MCLK must not exceed the pulse duration of the specified maximum frequency.

(7) Modules may have a different maximum input clock specification. See the specification of the respective module in this data sheet.



NOTE: The numbers within the fields denote the supported PMMCOREVx settings.

**Figure 5-1. Frequency vs Supply Voltage**

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

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

| PARAMETER              | EXECUTION<br>MEMORY | V <sub>CC</sub> | PMMCOREVx | FREQUENCY (f <sub>DCO</sub> = f <sub>MCLK</sub> = f <sub>SMCLK</sub> ) |      |       |      |        |      |        |     |        |      | UNIT |
|------------------------|---------------------|-----------------|-----------|------------------------------------------------------------------------|------|-------|------|--------|------|--------|-----|--------|------|------|
|                        |                     |                 |           | 1 MHz                                                                  |      | 8 MHz |      | 12 MHz |      | 20 MHz |     | 25 MHz |      |      |
|                        |                     |                 |           | TYP                                                                    | MAX  | TYP   | MAX  | TYP    | MAX  | TYP    | MAX | TYP    | MAX  |      |
| I <sub>AM, Flash</sub> | Flash               | 3 V             | 0         | 0.24                                                                   | 0.27 | 1.48  | 1.60 |        |      |        |     |        |      | mA   |
|                        |                     |                 | 1         | 0.26                                                                   |      | 1.66  |      | 2.48   | 2.7  |        |     |        |      |      |
|                        |                     |                 | 2         | 0.28                                                                   |      | 1.83  |      | 2.72   |      | 4.50   | 4.8 |        |      |      |
|                        |                     |                 | 3         | 0.28                                                                   |      | 1.83  |      | 2.66   |      | 4.40   |     | 5.60   | 6.15 |      |
| I <sub>AM, RAM</sub>   | RAM                 | 3 V             | 0         | 0.17                                                                   | 0.2  | 0.89  | 0.97 |        |      |        |     |        |      | mA   |
|                        |                     |                 | 1         | 0.18                                                                   |      | 1.00  |      | 1.49   | 1.62 |        |     |        |      |      |
|                        |                     |                 | 2         | 0.20                                                                   |      | 1.14  |      | 1.68   |      | 2.75   | 3.0 |        |      |      |
|                        |                     |                 | 3         | 0.20                                                                   |      | 1.20  |      | 1.78   |      | 2.92   |     | 3.64   | 4.0  |      |

## 5.5 Low-Power Mode Supply Currents (Into $V_{CC}$ ) Excluding External Current

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

| PARAMETER                                               | $V_{CC}$ | PMMCOREVx | -40°C |      | 25°C |      | 60°C |      | 85°C |     | UNIT          |
|---------------------------------------------------------|----------|-----------|-------|------|------|------|------|------|------|-----|---------------|
|                                                         |          |           | TYP   | MAX  | TYP  | MAX  | TYP  | MAX  | TYP  | MAX |               |
| $I_{LPM0, 1\text{MHz}}$ Low-power mode 0                | 2.2 V    | 0         | 82    | 90   | 85   | 90   | 87   | 95   | 85   | 100 | $\mu\text{A}$ |
|                                                         | 3 V      | 3         | 88    | 100  | 85   | 100  | 90   | 104  | 88   | 104 |               |
| $I_{LPM2}$ Low-power mode 2                             | 2.2 V    | 0         | 10    | 12.5 | 10   | 12   | 10   | 12.5 | 12.5 | 13  | $\mu\text{A}$ |
|                                                         | 3 V      | 3         | 9     | 11.5 | 11   | 13   | 11   | 15   | 12   | 14  |               |
| $I_{LPM3, \text{XT1LF}}$ Low-power mode 3, crystal mode | 2.2 V    | 0         | 1.7   | –    | 1.8  | 2.0  | 2.5  | –    | 3.5  | 6.0 | $\mu\text{A}$ |
|                                                         | 3 V      |           | 2.0   | –    | 2.0  | 2.2  | 3.0  | –    | 3.7  | 6.0 |               |
|                                                         | 2.2 V    | 1         | 1.8   | –    | 1.9  | –    | 2.5  | –    | 4.0  | –   |               |
|                                                         | 3 V      |           | 2.1   | –    | 2.2  | –    | 2.5  | –    | 4.0  | –   |               |
|                                                         | 2.2 V    | 2         | 1.8   | –    | 2.0  | –    | 2.5  | –    | 4.2  | –   |               |
|                                                         | 3 V      |           | 2.0   | –    | 2.2  | –    | 2.8  | –    | 4.2  | –   |               |
|                                                         | 2.2 V    | 3         | 1.9   | –    | 2.0  | 2.5  | 2.9  | –    | 4.8  | 6.5 |               |
|                                                         | 3 V      |           | 2.1   | –    | 2.2  | 2.5  | 3.0  | –    | 5.2  | 7.0 |               |
| $I_{LPM3, \text{VLO}}$ Low-power mode 3, VLO mode       | 2.2 V    | 0         | 1.0   | –    | 1.0  | 1.25 | 1.6  | –    | 3.5  | 4.5 | $\mu\text{A}$ |
|                                                         | 3 V      |           | 1.1   | –    | 1.2  | 1.4  | 1.5  | –    | 3.6  | 5.0 |               |
|                                                         | 2.2 V    | 1         | 1.0   | –    | 1.1  | –    | 1.8  | –    | 3.0  | –   |               |
|                                                         | 3 V      |           | 1.3   | –    | 1.1  | –    | 2.0  | –    | 3.2  | –   |               |
|                                                         | 2.2 V    | 2         | 1.1   | –    | 1.1  | –    | 1.8  | –    | 3.1  | –   |               |
|                                                         | 3 V      |           | 1.1   | –    | 1.2  | –    | 2.0  | –    | 3.2  | –   |               |
|                                                         | 2.2 V    | 3         | 1.1   | –    | 1.1  | 1.4  | 1.9  | –    | 3.5  | 5.0 |               |
|                                                         | 3 V      |           | 1.1   | –    | 1.2  | 1.5  | 2.1  | –    | 4.0  | 5.2 |               |
| $I_{LPM4}$ Low-power mode 4                             | 3 V      | 0         | 0.8   | –    | 0.9  | 1.3  | 1.4  | –    | 3.5  | 4.7 | $\mu\text{A}$ |
|                                                         |          | 1         | 0.8   | –    | 1.0  | –    | 1.4  | –    | 3.5  | –   |               |
|                                                         |          | 2         | 0.8   | –    | 1.0  | –    | 1.5  | –    | 3.6  | –   |               |
|                                                         |          | 3         | 0.9   | –    | 1.0  | 1.3  | 1.6  | –    | 3.6  | 5.0 |               |
| $I_{LPM4.5}$ Low-power mode 4.5                         | 2.2 V    | x         | 0.06  | –    | 0.20 | 0.26 | 0.33 | –    | 0.60 | 0.9 | $\mu\text{A}$ |
|                                                         | 3 V      | x         | 0.07  | –    | 0.25 | 0.29 | 0.37 | –    | 0.77 | 0.9 |               |

(1) All inputs are tied to 0 V or to  $V_{CC}$ . Outputs do not source or sink any current. DVIO = DVCC = AVCC.

(2) The currents are characterized with a Micro Crystal MS1V-T1K SMD crystal with a load capacitance of 12.5 pF. The internal and external load capacitance are chosen to closely match the required 9 pF.

## 5.6 Thermal Resistance Characteristics

| THERMAL METRIC                                                  |                         |            | VALUE      | UNIT |      |
|-----------------------------------------------------------------|-------------------------|------------|------------|------|------|
| $\theta_{JA}$ Junction-to-ambient thermal resistance, still air | Low-K board (JESD51-3)  | QFN (RSB)  | 87         | °C/W |      |
|                                                                 |                         | TSSOP (DA) | 109        |      |      |
|                                                                 | High-K board (JESD51-7) | QFN (RSB)  | 35         |      |      |
|                                                                 |                         | TSSOP (DA) | 69         |      |      |
| $\theta_{JC}$ Junction-to-case thermal resistance               |                         |            | QFN (RSB)  | 36   | °C/W |
|                                                                 |                         |            | TSSOP (DA) | 19   |      |

## 5.7 Schmitt-Trigger Inputs – General-Purpose I/O (P1.0 to P1.5, P3.2 to P3.7, and PJ.0 to PJ.6)

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

| PARAMETER                                                  | TEST CONDITIONS                                                  | $V_{CC}$ | MIN  | TYP | MAX  | UNIT       |
|------------------------------------------------------------|------------------------------------------------------------------|----------|------|-----|------|------------|
| $V_{IT+}$ Positive-going input threshold voltage           |                                                                  | 1.8 V    | 0.80 |     | 1.40 | V          |
|                                                            |                                                                  | 3 V      | 1.50 |     | 2.10 |            |
| $V_{IT-}$ Negative-going input threshold voltage           |                                                                  | 1.8 V    | 0.45 |     | 1.00 | V          |
|                                                            |                                                                  | 3 V      | 0.75 |     | 1.65 |            |
| $V_{hys}$ Input voltage hysteresis ( $V_{IT+} - V_{IT-}$ ) |                                                                  | 1.8 V    | 0.3  |     | 0.8  | V          |
|                                                            |                                                                  | 3 V      | 0.4  |     | 1.0  |            |
| $R_{Pull}$ Pullup or pulldown resistor <sup>(1)</sup>      | For pullup: $V_{IN} = V_{SS}$<br>For pulldown: $V_{IN} = V_{CC}$ |          | 20   | 35  | 50   | k $\Omega$ |
| $C_I$ Input capacitance                                    | $V_{IN} = V_{SS}$ or $V_{CC}$                                    |          |      | 5   |      | pF         |

(1) Also applies to  $\overline{RST}$  pin when pullup or pulldown resistor is enabled.

## 5.8 Schmitt-Trigger Inputs – General-Purpose I/O (P1.6 and P1.7, P2.0 to P2.7, and P3.0 and P3.1)

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

| PARAMETER                                                  | TEST CONDITIONS                                                  | $V_{IO}$ | MIN  | TYP | MAX  | UNIT       |
|------------------------------------------------------------|------------------------------------------------------------------|----------|------|-----|------|------------|
| $V_{IT+}$ Positive-going input threshold voltage           |                                                                  | 1.8 V    | 0.80 |     | 1.40 | V          |
|                                                            |                                                                  | 3 V      | 1.20 |     | 2.00 |            |
|                                                            |                                                                  | 5 V      | 2.10 |     | 2.50 |            |
| $V_{IT-}$ Negative-going input threshold voltage           |                                                                  | 1.8 V    | 0.45 |     | 0.90 | V          |
|                                                            |                                                                  | 3 V      | 0.75 |     | 1.30 |            |
|                                                            |                                                                  | 5 V      | 1.10 |     | 1.60 |            |
| $V_{hys}$ Input voltage hysteresis ( $V_{IT+} - V_{IT-}$ ) |                                                                  | 1.8 V    | 0.27 |     | 0.45 | V          |
|                                                            |                                                                  | 3 V      | 0.45 |     | 0.65 |            |
|                                                            |                                                                  | 5 V      | 0.9  |     | 1.2  |            |
| $R_{Pull}$ Pullup or pulldown resistor                     | For pullup: $V_{IN} = V_{SS}$<br>For pulldown: $V_{IN} = V_{CC}$ |          | 20   | 35  | 50   | k $\Omega$ |
| $C_I$ Input capacitance                                    | $V_{IN} = V_{SS}$ or $V_{CC}$                                    |          |      | 5   |      | pF         |

## 5.9 Inputs – Ports P1 and P2<sup>(1)</sup>

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

| PARAMETER                                            | TEST CONDITIONS                                                                               | $V_{CC}$ or $V_{IO}$ | MIN | MAX | UNIT |
|------------------------------------------------------|-----------------------------------------------------------------------------------------------|----------------------|-----|-----|------|
| $t_{(int)}$ External interrupt timing <sup>(2)</sup> | Port P1.0 to P1.5,<br>external trigger pulse duration to set interrupt flag                   | 1.8 V to 3.6 V       | 20  |     | ns   |
|                                                      | Port P1.6 and P1.7 and P2.0 to P2.7,<br>external trigger pulse duration to set interrupt flag | 1.8 V to 5 V         | 25  |     |      |

(1) Some devices may contain additional ports with interrupts. See the block diagram and terminal function descriptions.

(2) An external signal sets the interrupt flag every time the minimum interrupt pulse duration  $t_{(int)}$  is met. It may be set by trigger signals shorter than  $t_{(int)}$ .

## 5.10 Leakage Current – General-Purpose I/O

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 |
|--------------------------------------|--------------------------------|-----------------------------------------------|-----------------------------------|----------------|-----|-----|------|
| I <sub>lkg</sub> (P <sub>x.y</sub> ) | High-impedance leakage current | Port P1.0 to P1.5, P3.0 to P3.7, PJ.0 to PJ.6 | See <sup>(1)</sup> <sup>(2)</sup> | 1.8 V to 3.6 V | ±1  | ±50 | nA   |
|                                      |                                | Port P1.6 and P1.7, P2.0 to P2.7              |                                   |                |     |     |      |

(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.

## 5.11 Outputs – Ports P1, P3, PJ (Full Drive Strength, P1.0 to P1.5, P3.2 to P3.7, PJ.0 to PJ.6)

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

| PARAMETER       |                           | TEST CONDITIONS                              | V <sub>CC</sub> | MIN                    | MAX                    | UNIT |
|-----------------|---------------------------|----------------------------------------------|-----------------|------------------------|------------------------|------|
| V <sub>OH</sub> | High-level output voltage | I <sub>(OHmax)</sub> = –3 mA <sup>(1)</sup>  | 1.8 V           | V <sub>CC</sub> – 0.25 | V <sub>CC</sub>        | V    |
|                 |                           | I <sub>(OHmax)</sub> = –10 mA <sup>(2)</sup> |                 | V <sub>CC</sub> – 0.60 | V <sub>CC</sub>        |      |
|                 |                           | I <sub>(OHmax)</sub> = –5 mA <sup>(1)</sup>  | 3 V             | V <sub>CC</sub> – 0.25 | V <sub>CC</sub>        |      |
|                 |                           | I <sub>(OHmax)</sub> = –15 mA <sup>(2)</sup> |                 | V <sub>CC</sub> – 0.60 | V <sub>CC</sub>        |      |
| V <sub>OL</sub> | Low-level output voltage  | I <sub>(OLmax)</sub> = 3 mA <sup>(1)</sup>   | 1.8 V           | V <sub>SS</sub>        | V <sub>SS</sub> + 0.25 | V    |
|                 |                           | I <sub>(OLmax)</sub> = 10 mA <sup>(2)</sup>  |                 | V <sub>SS</sub>        | V <sub>SS</sub> + 0.60 |      |
|                 |                           | I <sub>(OLmax)</sub> = 5 mA <sup>(1)</sup>   | 3 V             | V <sub>SS</sub>        | V <sub>SS</sub> + 0.25 |      |
|                 |                           | I <sub>(OLmax)</sub> = 15 mA <sup>(2)</sup>  |                 | V <sub>SS</sub>        | V <sub>SS</sub> + 0.60 |      |

(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 maximum total current, I<sub>(OHmax)</sub> and I<sub>(OLmax)</sub>, for all outputs combined should not exceed ±100 mA to hold the maximum voltage drop specified.

## 5.12 Outputs – Ports P1 to P3 (Full Drive Strength, P1.6 and P1.7, P2.0 to P2.7, P3.0 and P3.1)

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

| PARAMETER        |                           | TEST CONDITIONS                               | V <sub>IO</sub> | MIN                    | MAX                    | UNIT |
|------------------|---------------------------|-----------------------------------------------|-----------------|------------------------|------------------------|------|
| V <sub>OH5</sub> | High-level output voltage | I <sub>(OH5max)</sub> = –3 mA <sup>(1)</sup>  | 1.8 V           | V <sub>IO</sub> – 0.25 | V <sub>IO</sub>        | V    |
|                  |                           | I <sub>(OH5max)</sub> = –10 mA <sup>(2)</sup> |                 | V <sub>IO</sub> – 0.60 | V <sub>IO</sub>        |      |
|                  |                           | I <sub>(OH5max)</sub> = –5 mA <sup>(1)</sup>  | 3 V             | V <sub>IO</sub> – 0.25 | V <sub>IO</sub>        |      |
|                  |                           | I <sub>(OH5max)</sub> = –15 mA <sup>(2)</sup> |                 | V <sub>IO</sub> – 0.60 | V <sub>IO</sub>        |      |
|                  |                           | I <sub>(OH5max)</sub> = –7 mA <sup>(1)</sup>  | 5 V             | V <sub>IO</sub> – 0.25 | V <sub>IO</sub>        |      |
|                  |                           | I <sub>(OH5max)</sub> = –20 mA <sup>(2)</sup> |                 | V <sub>IO</sub> – 0.60 | V <sub>IO</sub>        |      |
| V <sub>OL5</sub> | Low-level output voltage  | I <sub>(OL5max)</sub> = 3 mA <sup>(1)</sup>   | 1.8 V           | V <sub>SS</sub>        | V <sub>SS</sub> + 0.25 | V    |
|                  |                           | I <sub>(OL5max)</sub> = 10 mA <sup>(2)</sup>  |                 | V <sub>SS</sub>        | V <sub>SS</sub> + 0.60 |      |
|                  |                           | I <sub>(OL5max)</sub> = 5 mA <sup>(1)</sup>   | 3 V             | V <sub>SS</sub>        | V <sub>SS</sub> + 0.25 |      |
|                  |                           | I <sub>(OL5max)</sub> = 15 mA <sup>(2)</sup>  |                 | V <sub>SS</sub>        | V <sub>SS</sub> + 0.60 |      |
|                  |                           | I <sub>(OL5max)</sub> = 7 mA <sup>(1)</sup>   | 5 V             | V <sub>SS</sub>        | V <sub>SS</sub> + 0.25 |      |
|                  |                           | I <sub>(OL5max)</sub> = 20 mA <sup>(2)</sup>  |                 | V <sub>SS</sub>        | V <sub>SS</sub> + 0.60 |      |

(1) The maximum total current, I<sub>(OH5max)</sub> and I<sub>(OL5max)</sub>, for all outputs combined should not exceed ±48 mA to hold the maximum voltage drop specified.

(2) The maximum total current, I<sub>(OH5max)</sub> and I<sub>(OL5max)</sub>, for all outputs combined should not exceed ±200 mA to hold the maximum voltage drop specified.

### 5.13 Outputs – Ports P1, P3, PJ (Reduced Drive Strength, P1.0 to P1.5, P3.2 to P3.7, PJ.0 to PJ.6)

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 |
|-------------------------------------------|---------------------------------------------|-----------------|------------------------|------------------------|------|
| V <sub>OH</sub> High-level output voltage | I <sub>(OHmax)</sub> = –1 mA <sup>(2)</sup> | 1.8 V           | V <sub>CC</sub> – 0.25 | V <sub>CC</sub>        | V    |
|                                           | I <sub>(OHmax)</sub> = –3 mA <sup>(3)</sup> |                 | V <sub>CC</sub> – 0.60 | V <sub>CC</sub>        |      |
|                                           | I <sub>(OHmax)</sub> = –2 mA <sup>(2)</sup> | 3 V             | V <sub>CC</sub> – 0.25 | V <sub>CC</sub>        |      |
|                                           | I <sub>(OHmax)</sub> = –6 mA <sup>(3)</sup> |                 | V <sub>CC</sub> – 0.60 | V <sub>CC</sub>        |      |
| V <sub>OL</sub> Low-level output voltage  | I <sub>(OLmax)</sub> = 1 mA <sup>(2)</sup>  | 1.8 V           | V <sub>SS</sub>        | V <sub>SS</sub> + 0.25 | V    |
|                                           | I <sub>(OLmax)</sub> = 3 mA <sup>(3)</sup>  |                 | V <sub>SS</sub>        | V <sub>SS</sub> + 0.60 |      |
|                                           | I <sub>(OLmax)</sub> = 2 mA <sup>(2)</sup>  | 3 V             | V <sub>SS</sub>        | V <sub>SS</sub> + 0.25 |      |
|                                           | I <sub>(OLmax)</sub> = 6 mA <sup>(3)</sup>  |                 | V <sub>SS</sub>        | V <sub>SS</sub> + 0.60 |      |

(1) Selecting reduced drive strength may reduce EMI.

(2) 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.

(3) The maximum total current, I<sub>(OHmax)</sub> and I<sub>(OLmax)</sub>, for all outputs combined, should not exceed ±100 mA to hold the maximum voltage drop specified.

### 5.14 Outputs – Ports P1 to P3 (Reduced Drive Strength, P1.6 and P1.7, P2.0 to P2.7, P3.0 and P3.1)

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

| PARAMETER                                  | TEST CONDITIONS                               | V <sub>IO</sub> | MIN                    | MAX                    | UNIT |
|--------------------------------------------|-----------------------------------------------|-----------------|------------------------|------------------------|------|
| V <sub>OH5</sub> High-level output voltage | I <sub>(OH5max)</sub> = –1 mA <sup>(2)</sup>  | 1.8 V           | V <sub>IO</sub> – 0.25 | V <sub>IO</sub>        | V    |
|                                            | I <sub>(OH5max)</sub> = –3 mA <sup>(3)</sup>  |                 | V <sub>IO</sub> – 0.60 | V <sub>IO</sub>        |      |
|                                            | I <sub>(OH5max)</sub> = –2 mA <sup>(2)</sup>  | 3 V             | V <sub>IO</sub> – 0.25 | V <sub>IO</sub>        |      |
|                                            | I <sub>(OH5max)</sub> = –6 mA <sup>(3)</sup>  |                 | V <sub>IO</sub> – 0.60 | V <sub>IO</sub>        |      |
|                                            | I <sub>(OH5max)</sub> = –4 mA <sup>(2)</sup>  | 5.0 V           | V <sub>IO</sub> – 0.25 | V <sub>IO</sub>        |      |
|                                            | I <sub>(OH5max)</sub> = –12 mA <sup>(3)</sup> |                 | V <sub>IO</sub> – 0.60 | V <sub>IO</sub>        |      |
| V <sub>OL5</sub> Low-level output voltage  | I <sub>(OL5max)</sub> = 1 mA <sup>(2)</sup>   | 1.8 V           | V <sub>SS</sub>        | V <sub>SS</sub> + 0.25 | V    |
|                                            | I <sub>(OL5max)</sub> = 3 mA <sup>(3)</sup>   |                 | V <sub>SS</sub>        | V <sub>SS</sub> + 0.60 |      |
|                                            | I <sub>(OL5max)</sub> = 2 mA <sup>(2)</sup>   | 3 V             | V <sub>SS</sub>        | V <sub>SS</sub> + 0.25 |      |
|                                            | I <sub>(OL5max)</sub> = 6 mA <sup>(3)</sup>   |                 | V <sub>SS</sub>        | V <sub>SS</sub> + 0.60 |      |
|                                            | I <sub>(OH5max)</sub> = 4 mA <sup>(2)</sup>   | 5.0 V           | V <sub>SS</sub>        | V <sub>SS</sub> + 0.25 |      |
|                                            | I <sub>(OL5max)</sub> = 12 mA <sup>(3)</sup>  |                 | V <sub>SS</sub>        | V <sub>SS</sub> + 0.60 |      |

(1) Selecting reduced drive strength may reduce EMI.

(2) The maximum total current, I<sub>(OH5max)</sub> and I<sub>(OL5max)</sub>, for all outputs combined, should not exceed ±48 mA to hold the maximum voltage drop specified.

(3) The maximum total current, I<sub>(OH5max)</sub> and I<sub>(OL5max)</sub>, for all outputs combined, should not exceed ±200 mA to hold the maximum voltage drop specified.

## 5.15 Output Frequency – Ports P1.0 to P1.5, P3.2 to P3.7, PJ.0 to PJ.6

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

| PARAMETER       |                                   | TEST CONDITIONS                                                                               |                                             | MIN | MAX | UNIT |
|-----------------|-----------------------------------|-----------------------------------------------------------------------------------------------|---------------------------------------------|-----|-----|------|
| $f_{P_{x,y}}$   | Port output frequency (with load) | PJ.0/SMCLK<br>$C_L = 20 \text{ pF}$ , $R_L = 1 \text{ k}\Omega$ <sup>(1)</sup> <sup>(2)</sup> | $V_{CC} = 1.8 \text{ V}$ ,<br>PMMCOREVx = 0 | 16  |     | MHz  |
|                 |                                   |                                                                                               | $V_{CC} = 3 \text{ V}$ ,<br>PMMCOREVx = 3   | 25  |     |      |
| $f_{Port\_CLK}$ | Clock output frequency            | PJ.3/ACLK<br>PJ.0/SMCLK<br>PJ.1/MCLK<br>$C_L = 20 \text{ pF}$ <sup>(2)</sup>                  | $V_{CC} = 1.8 \text{ V}$ ,<br>PMMCOREVx = 0 | 16  |     | MHz  |
|                 |                                   |                                                                                               | $V_{CC} = 3 \text{ V}$ ,<br>PMMCOREVx = 3   | 25  |     |      |

(1) A resistive divider with  $2 \times 0.5 \text{ k}\Omega$  between  $V_{CC}$  and  $V_{SS}$  is used as load. The output is connected to the center tap of the divider.

(2) The output voltage reaches at least 10% and 90%  $V_{CC}$  at the specified toggle frequency.

## 5.16 Output Frequency – Ports P1.6 and P1.7, P2.0 to P2.7, P3.0 and P3.1

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

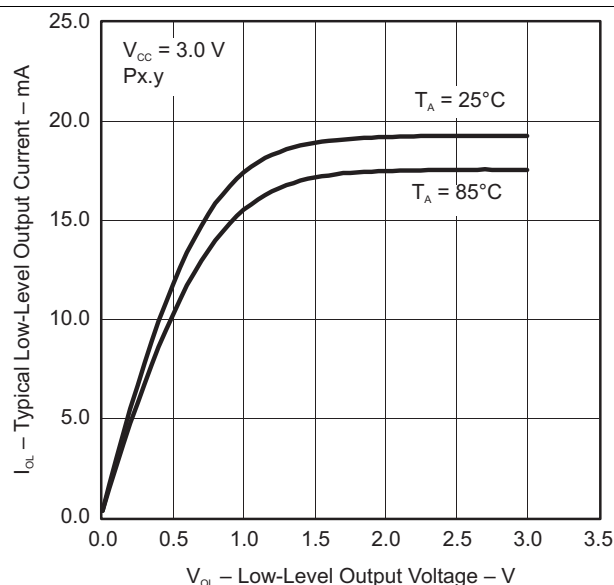
| PARAMETER       |                                   | TEST CONDITIONS                                                                                                      |                                                                        | MIN | MAX | UNIT |
|-----------------|-----------------------------------|----------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------|-----|-----|------|
| $f_{P_{x,y}}$   | Port output frequency (with load) | P1.6 port mapper SMCLK from P3.4,<br>$C_L = 20 \text{ pF}$ , $R_L = 1 \text{ k}\Omega$ <sup>(1)</sup> <sup>(2)</sup> | $V_{CC} = 1.8 \text{ V}$ , $V_{IO} = 1.8 \text{ V}$ ,<br>PMMCOREVx = 0 | 16  |     | MHz  |
|                 |                                   |                                                                                                                      | $V_{CC} = 3 \text{ V}$ , $V_{IO} = 3 \text{ V}$ ,<br>PMMCOREVx = 3     | 25  |     |      |
|                 |                                   |                                                                                                                      | $V_{CC} = 3 \text{ V}$ , $V_{IO} = 5 \text{ V}$ ,<br>PMMCOREVx = 3     | 25  |     |      |
| $f_{Port\_CLK}$ | Clock output frequency            | P1.6 port mapper SMCLK from P3.4,<br>$C_L = 20 \text{ pF}$ <sup>(2)</sup>                                            | $V_{CC} = 1.8 \text{ V}$ , $V_{IO} = 1.8 \text{ V}$ ,<br>PMMCOREVx = 0 | 16  |     | MHz  |
|                 |                                   |                                                                                                                      | $V_{CC} = 3 \text{ V}$ , $V_{IO} = 3 \text{ V}$ ,<br>PMMCOREVx = 3     | 25  |     |      |
|                 |                                   |                                                                                                                      | $V_{CC} = 3 \text{ V}$ , $V_{IO} = 5 \text{ V}$ ,<br>PMMCOREVx = 3     | 25  |     |      |

(1) A resistive divider with  $2 \times 0.5 \text{ k}\Omega$  between  $V_{CC}$  and  $V_{SS}$  is used as load. The output is connected to the center tap of the divider.

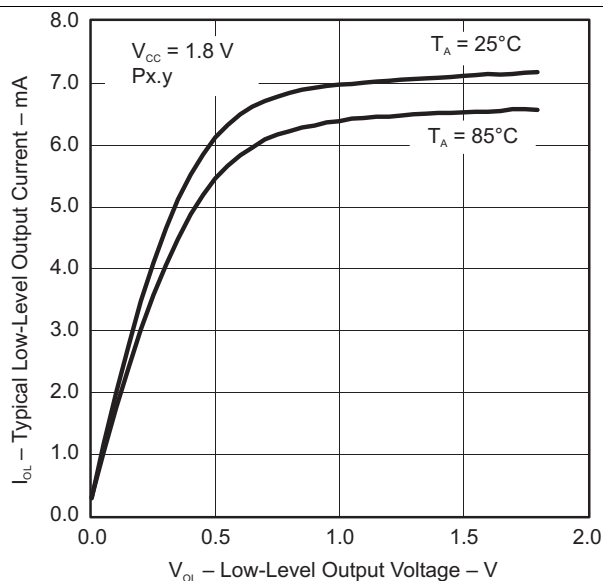
(2) The output voltage reaches at least 10% and 90%  $V_{CC}$  at the specified toggle frequency.

## 5.17 Typical Characteristics – Outputs, Reduced Drive Strength (PxDS.y = 0), Ports P1.0 to P1.5, P3.2 to P3.7, PJ.0 to PJ.6

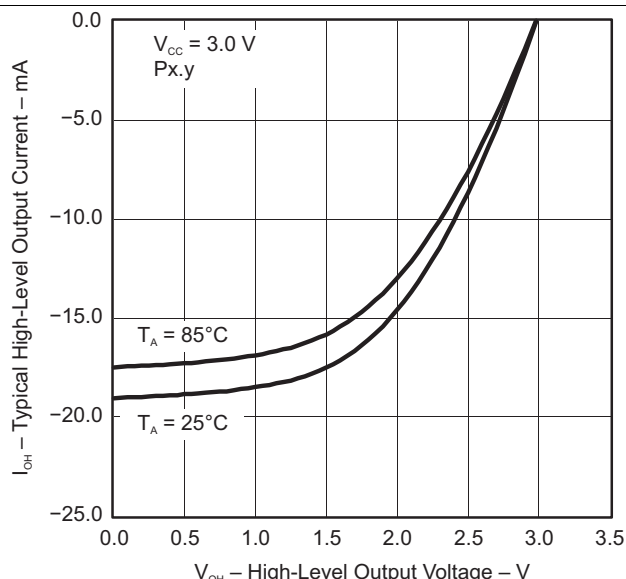
over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)



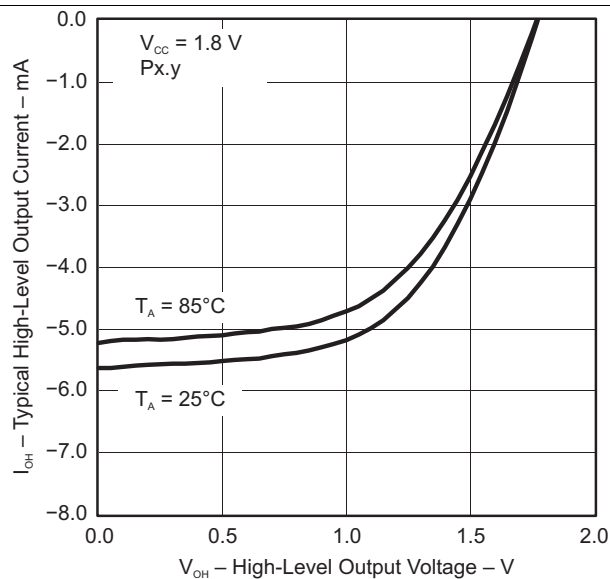
**Figure 5-2. Typical Low-Level Output Current vs Low-Level Output Voltage**



**Figure 5-3. Typical Low-Level Output Current vs Low-Level Output Voltage**



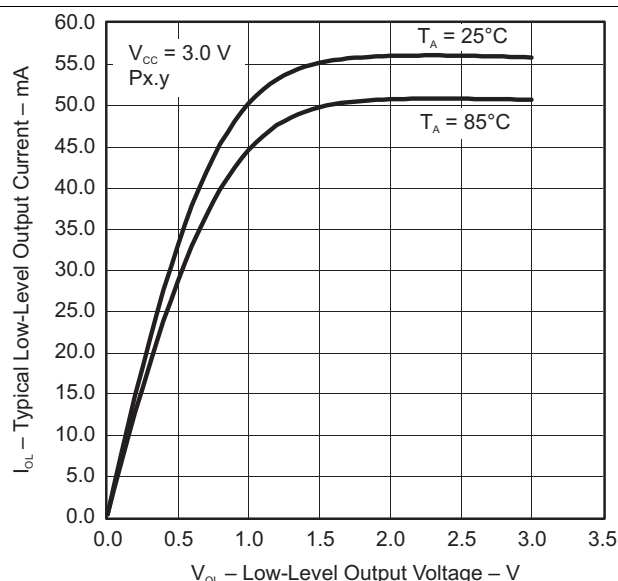
**Figure 5-4. Typical High-Level Output Current vs High-Level Output Voltage**



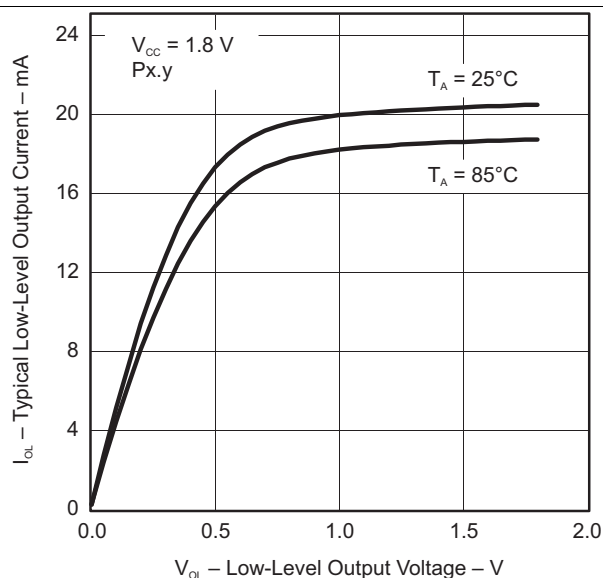
**Figure 5-5. Typical High-Level Output Current vs High-Level Output Voltage**

## 5.18 Typical Characteristics – Outputs, Full Drive Strength (PxDS.y = 1), Ports P1.0 to P1.5, P3.2 to P3.7, PJ.0 to PJ.6

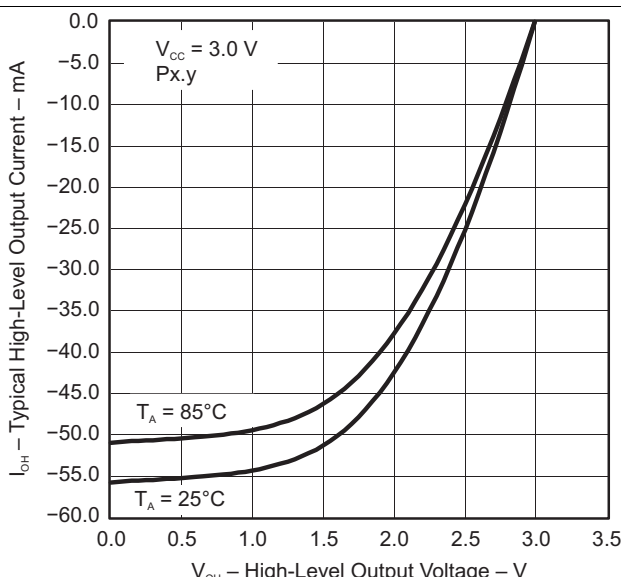
over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)



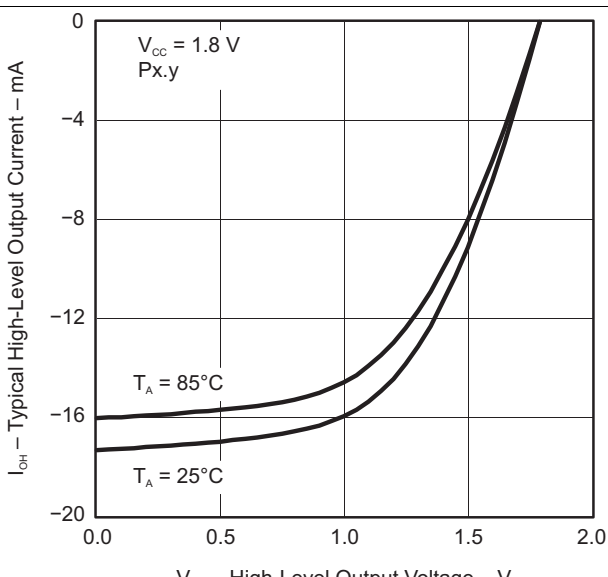
**Figure 5-6. Typical Low-Level Output Current vs Low-Level Output Voltage**



**Figure 5-7. Typical Low-Level Output Current vs Low-Level Output Voltage**



**Figure 5-8. Typical High-Level Output Current vs High-Level Output Voltage**



**Figure 5-9. Typical High-Level Output Current vs High-Level Output Voltage**

## 5.19 Typical Characteristics – Outputs, Reduced Drive Strength (PxDS.y = 0), Ports P1.6 and P1.7, P2.0 to P2.7, P3.0 and P3.1

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

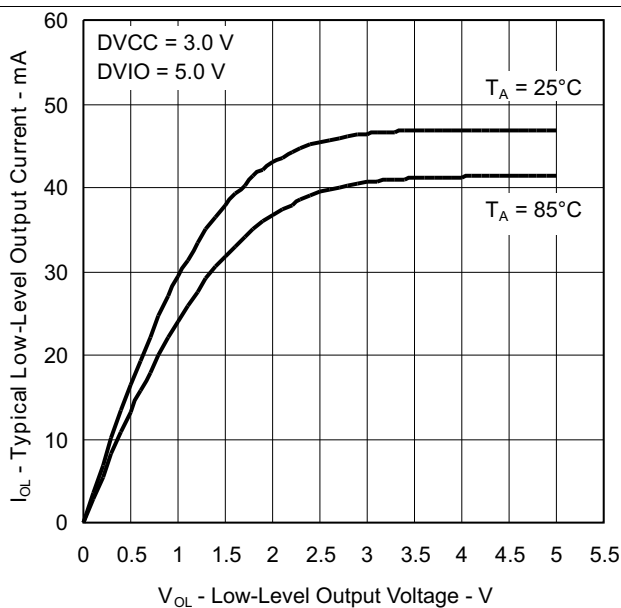


Figure 5-10. Typical Low-Level Output Current vs Low-Level Output Voltage

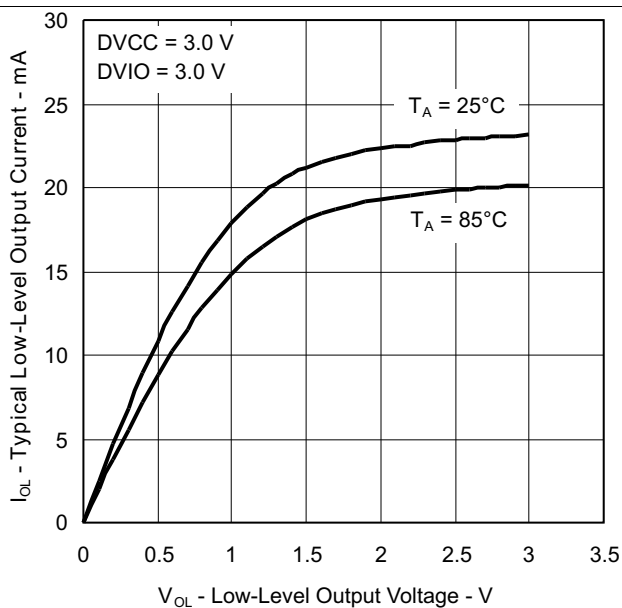


Figure 5-11. Typical Low-Level Output Current vs Low-Level Output Voltage

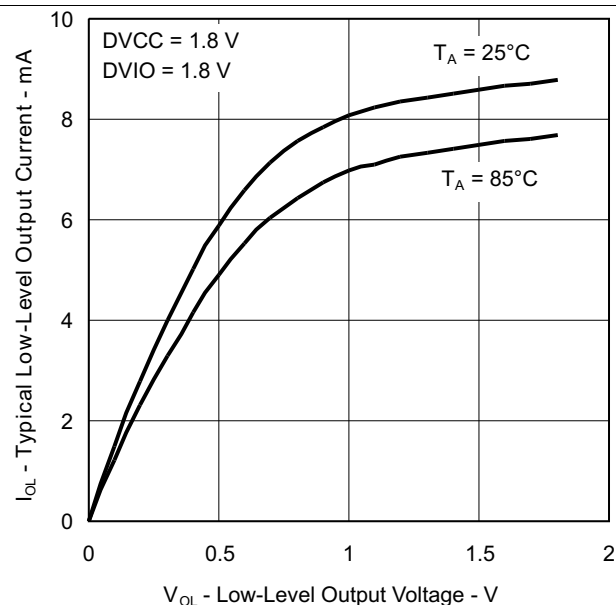


Figure 5-12. Typical Low-Level Output Current vs Low-Level Output Voltage

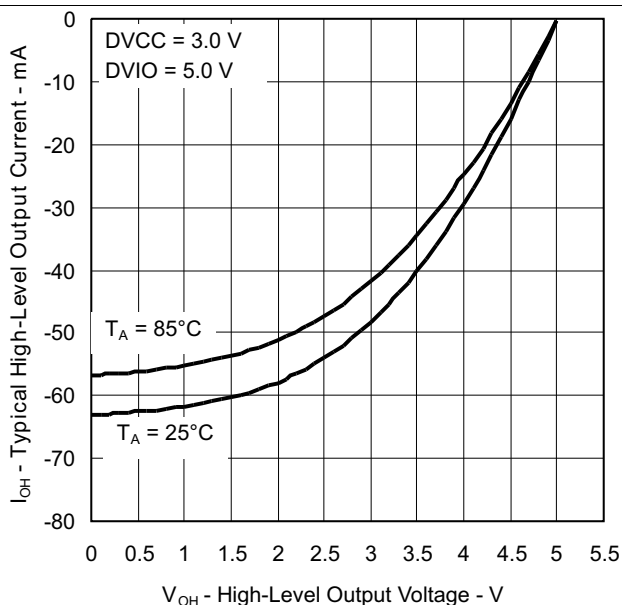
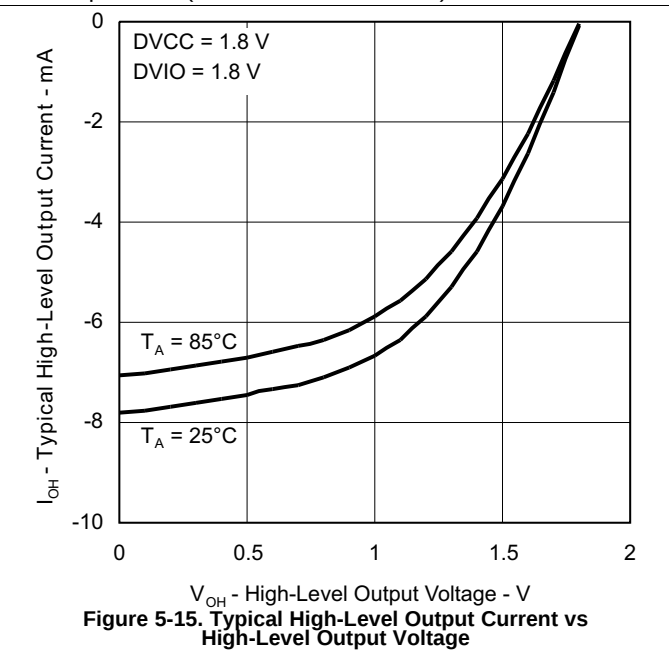
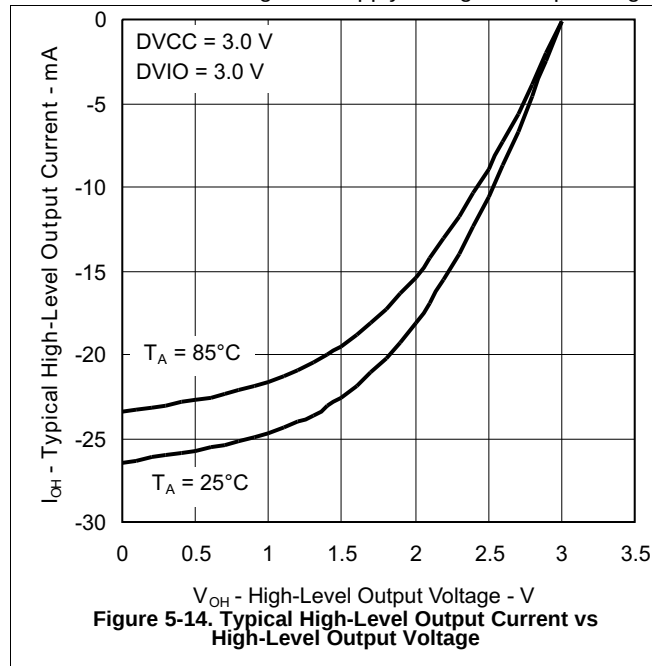


Figure 5-13. Typical High-Level Output Current vs High-Level Output Voltage

## Typical Characteristics – Outputs, Reduced Drive Strength (PxDS.y = 0), Ports P1.6 and P1.7, P2.0 to P2.7, P3.0 and P3.1 (continued)

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



## 5.20 Typical Characteristics – Outputs, Full Drive Strength (PxDS.y = 1), Ports P1.6 and P1.7, P2.0 to P2.7, P3.0 and P3.1

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

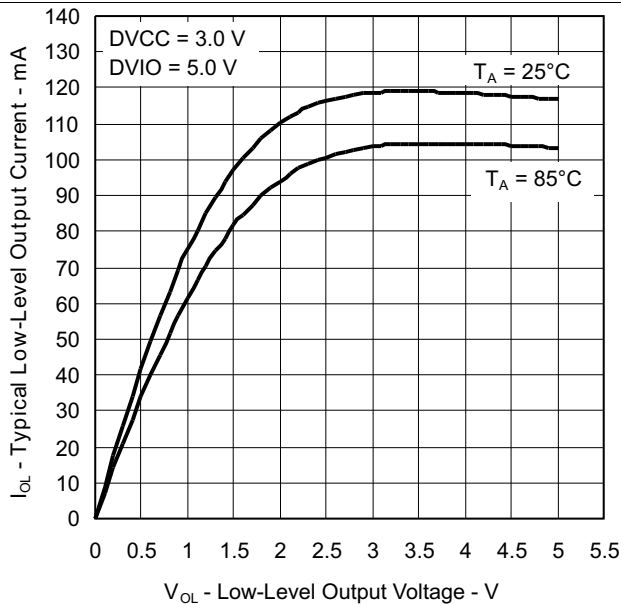


Figure 5-16. Typical Low-Level Output Current vs Low-Level Output Voltage

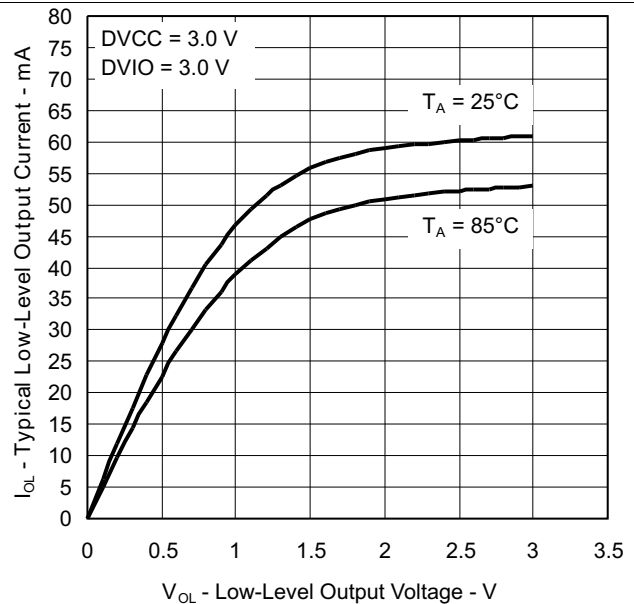


Figure 5-17. Typical Low-Level Output Current vs Low-Level Output Voltage

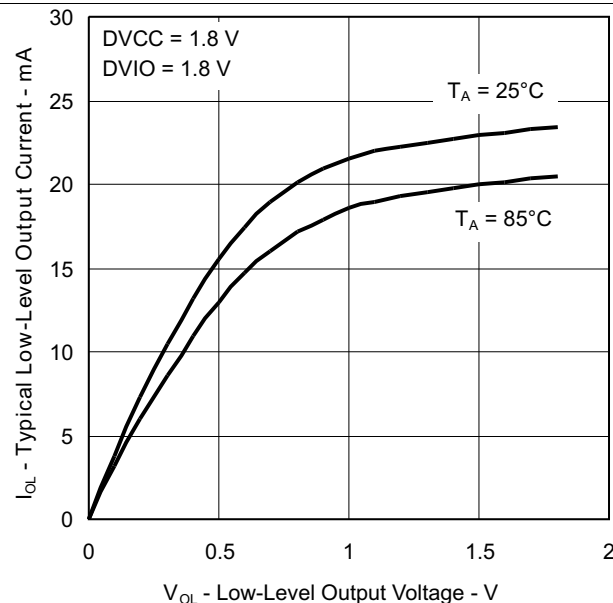


Figure 5-18. Typical Low-Level Output Current vs Low-Level Output Voltage

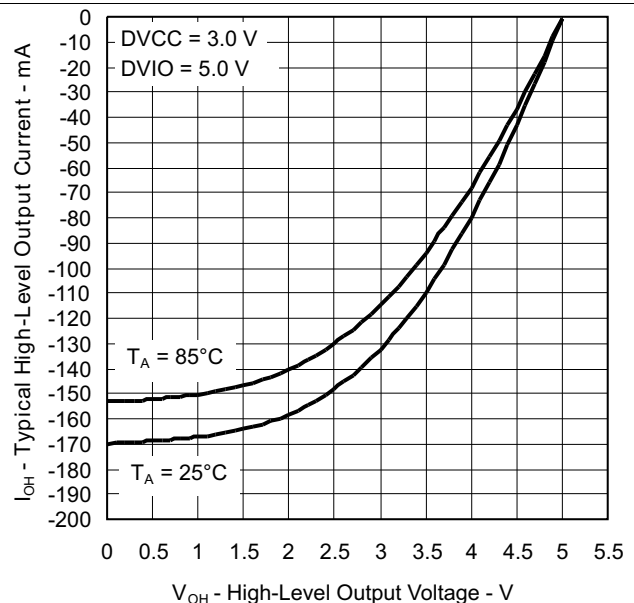
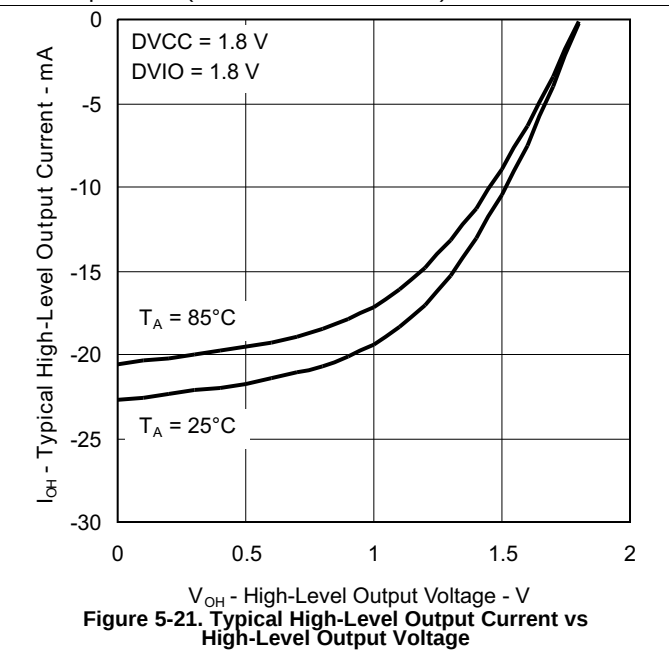
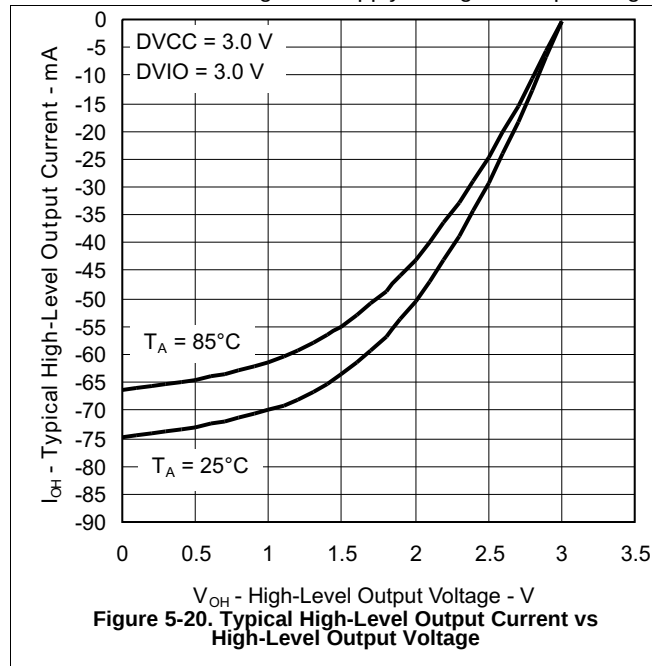


Figure 5-19. Typical High-Level Output Current vs High-Level Output Voltage

## Typical Characteristics – Outputs, Full Drive Strength (PxDS.y = 1), Ports P1.6 and P1.7, P2.0 to P2.7, P3.0 and P3.1 (continued)

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



## 5.21 Crystal Oscillator, XT1, Low-Frequency Mode

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 |
|------------------------|--------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------|-----------------|-------|--------|-----|------|
| I <sub>DVCC,LF</sub>   | Differential XT1 oscillator crystal current consumption from lowest drive setting, LF mode | f <sub>OSC</sub> = 32768 Hz, XTS = 0, XT1BYPASS = 0, XT1DRIVE <sub>x</sub> = 1, T <sub>A</sub> = 25°C                             | 3 V             | 0.075 |        |     | μA   |
|                        |                                                                                            | f <sub>OSC</sub> = 32768 Hz, XTS = 0, XT1BYPASS = 0, XT1DRIVE <sub>x</sub> = 2, T <sub>A</sub> = 25°C                             |                 | 0.170 |        |     |      |
|                        |                                                                                            | f <sub>OSC</sub> = 32768 Hz, XTS = 0, XT1BYPASS = 0, XT1DRIVE <sub>x</sub> = 3, T <sub>A</sub> = 25°C                             |                 | 0.290 |        |     |      |
| f <sub>XT1,LF0</sub>   | XT1 oscillator crystal frequency, LF mode                                                  | XTS = 0, XT1BYPASS = 0                                                                                                            |                 | 32768 |        |     | Hz   |
| f <sub>XT1,LF,SW</sub> | XT1 oscillator logic-level square-wave input frequency, LF mode                            | XTS = 0, XT1BYPASS = 1                                                                                                            |                 | 10    | 32.768 | 50  | kHz  |
| OA <sub>LF</sub>       | Oscillation allowance for LF crystals                                                      | XTS = 0, XT1BYPASS = 0, XT1DRIVE <sub>x</sub> = 0, f <sub>XT1,LF</sub> = 32768 Hz, C <sub>L,eff</sub> = 6 pF                      |                 | 210   |        |     | kΩ   |
|                        |                                                                                            | XTS = 0, XT1BYPASS = 0, XT1DRIVE <sub>x</sub> = 1, f <sub>XT1,LF</sub> = 32768 Hz, C <sub>L,eff</sub> = 12 pF                     |                 | 300   |        |     |      |
| C <sub>L,eff</sub>     | Integrated effective load capacitance, LF mode                                             | XTS = 0, XCAP <sub>x</sub> = 0                                                                                                    |                 | 1     |        |     | pF   |
|                        |                                                                                            | XTS = 0, XCAP <sub>x</sub> = 1                                                                                                    |                 | 5.5   |        |     |      |
|                        |                                                                                            | XTS = 0, XCAP <sub>x</sub> = 2                                                                                                    |                 | 8.5   |        |     |      |
|                        |                                                                                            | XTS = 0, XCAP <sub>x</sub> = 3                                                                                                    |                 | 12.0  |        |     |      |
| Duty cycle, LF mode    |                                                                                            | XTS = 0, Measured at ACLK, f <sub>XT1,LF</sub> = 32768 Hz                                                                         |                 | 30%   | 70%    |     |      |
| f <sub>Fault,LF</sub>  | Oscillator fault frequency, LF mode                                                        | XTS = 0                                                                                                                           |                 | 10    | 10000  |     | Hz   |
| t <sub>START,LF</sub>  | Start-up time, LF mode                                                                     | f <sub>OSC</sub> = 32768 Hz, XTS = 0, XT1BYPASS = 0, XT1DRIVE <sub>x</sub> = 0, T <sub>A</sub> = 25°C, C <sub>L,eff</sub> = 12 pF | 3 V             | 1000  |        |     | ms   |
|                        |                                                                                            | f <sub>OSC</sub> = 32768 Hz, XTS = 0, XT1BYPASS = 0, XT1DRIVE <sub>x</sub> = 3, T <sub>A</sub> = 25°C, C <sub>L,eff</sub> = 12 pF |                 | 500   |        |     |      |

## 5.22 Crystal Oscillator, XT1, High-Frequency Mode<sup>(1)</sup>

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 |
|--------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------|-----------------|-----|-----|-----|------|
| I <sub>DVCC,HF</sub><br>Differential XT1 oscillator crystal current consumption from lowest drive setting, HF mode | f <sub>OSC</sub> = 4 MHz,<br>XTS = 1, XOSCOFF = 0,<br>XT1BYPASS = 0, XT1DRIVE <sub>Ex</sub> = 0,<br>T <sub>A</sub> = 25°C              | 3 V             |     | 200 |     | μA   |
|                                                                                                                    | f <sub>OSC</sub> = 12 MHz,<br>XTS = 1, XOSCOFF = 0,<br>XT1BYPASS = 0, XT1DRIVE <sub>Ex</sub> = 1,<br>T <sub>A</sub> = 25°C             |                 |     | 260 |     |      |
|                                                                                                                    | f <sub>OSC</sub> = 20 MHz,<br>XTS = 1, XOSCOFF = 0,<br>XT1BYPASS = 0, XT1DRIVE <sub>Ex</sub> = 2,<br>T <sub>A</sub> = 25°C             |                 |     | 325 |     |      |
|                                                                                                                    | f <sub>OSC</sub> = 32 MHz,<br>XTS = 1, XOSCOFF = 0,<br>XT1BYPASS = 0, XT1DRIVE <sub>Ex</sub> = 3,<br>T <sub>A</sub> = 25°C             |                 |     | 450 |     |      |
| f <sub>XT1,HF0</sub><br>XT1 oscillator crystal frequency, HF mode 0                                                | XTS = 1,<br>XT1BYPASS = 0, XT1DRIVE <sub>Ex</sub> = 0 <sup>(2)</sup>                                                                   |                 | 4   |     | 8   | MHz  |
| f <sub>XT1,HF1</sub><br>XT1 oscillator crystal frequency, HF mode 1                                                | XTS = 1,<br>XT1BYPASS = 0, XT1DRIVE <sub>Ex</sub> = 1 <sup>(2)</sup>                                                                   |                 | 8   |     | 16  | MHz  |
| f <sub>XT1,HF2</sub><br>XT1 oscillator crystal frequency, HF mode 2                                                | XTS = 1,<br>XT1BYPASS = 0, XT1DRIVE <sub>Ex</sub> = 2 <sup>(2)</sup>                                                                   |                 | 16  |     | 24  | MHz  |
| f <sub>XT1,HF3</sub><br>XT1 oscillator crystal frequency, HF mode 3                                                | XTS = 1,<br>XT1BYPASS = 0, XT1DRIVE <sub>Ex</sub> = 3 <sup>(2)</sup>                                                                   |                 | 24  |     | 32  | MHz  |
| f <sub>XT1,HF,SW</sub><br>XT1 oscillator logic-level square-wave input frequency, HF mode                          | XTS = 1,<br>XT1BYPASS = 1 <sup>(3) (2)</sup>                                                                                           |                 | 0.7 |     | 32  | MHz  |
| O <sub>AHF</sub><br>Oscillation allowance for HF crystals <sup>(4)</sup>                                           | XTS = 1,<br>XT1BYPASS = 0, XT1DRIVE <sub>Ex</sub> = 0,<br>f <sub>XT1,HF</sub> = 6 MHz, C <sub>L,eff</sub> = 15 pF                      |                 |     | 450 |     | Ω    |
|                                                                                                                    | XTS = 1,<br>XT1BYPASS = 0, XT1DRIVE <sub>Ex</sub> = 1,<br>f <sub>XT1,HF</sub> = 12 MHz, C <sub>L,eff</sub> = 15 pF                     |                 |     | 320 |     |      |
|                                                                                                                    | XTS = 1,<br>XT1BYPASS = 0, XT1DRIVE <sub>Ex</sub> = 2,<br>f <sub>XT1,HF</sub> = 20 MHz, C <sub>L,eff</sub> = 15 pF                     |                 |     | 200 |     |      |
|                                                                                                                    | XTS = 1,<br>XT1BYPASS = 0, XT1DRIVE <sub>Ex</sub> = 3,<br>f <sub>XT1,HF</sub> = 32 MHz, C <sub>L,eff</sub> = 15 pF                     |                 |     | 200 |     |      |
| t <sub>START,HF</sub><br>Start-up time, HF mode                                                                    | f <sub>OSC</sub> = 6 MHz, XTS = 1,<br>XT1BYPASS = 0, XT1DRIVE <sub>Ex</sub> = 0,<br>T <sub>A</sub> = 25°C, C <sub>L,eff</sub> = 15 pF  | 3 V             |     | 0.5 |     | ms   |
|                                                                                                                    | f <sub>OSC</sub> = 20 MHz, XTS = 1,<br>XT1BYPASS = 0, XT1DRIVE <sub>Ex</sub> = 2,<br>T <sub>A</sub> = 25°C, C <sub>L,eff</sub> = 15 pF |                 |     | 0.3 |     |      |
| C <sub>L,eff</sub><br>Integrated effective load capacitance, HF mode <sup>(5) (6)</sup>                            | XTS = 1                                                                                                                                |                 |     | 1   |     | pF   |

- (1) To improve EMI on the XT1 oscillator the following guidelines should be observed.
- Keep the traces 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) Maximum frequency of operation of the entire device cannot be exceeded.

(3) When XT1BYPASS is set, the VLO, REFO, XT1 circuits are automatically powered down.

(4) Oscillation allowance is based on a safety factor of 5 for recommended crystals.

(5) Includes parasitic bond and package capacitance (approximately 2 pF per pin).

Because the PCB adds additional capacitance, verify the correct load by measuring the ACLK frequency. For a correct setup, the effective load capacitance should always match the specification of the used crystal.

(6) Requires external capacitors at both terminals. Values are specified by crystal manufacturers.

## Crystal Oscillator, XT1, High-Frequency Mode<sup>(1)</sup> (continued)

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 |
|-----------------------------------------------------------------------------|-------------------------------------------------------------|-----------------|-----|-----|-----|------|
| Duty cycle, HF mode                                                         | XTS = 1, Measured at ACLK,<br>f <sub>XT1,HF2</sub> = 20 MHz |                 | 40% | 50% | 60% |      |
| f <sub>Fault,HF</sub> Oscillator fault frequency,<br>HF mode <sup>(7)</sup> | XTS = 1 <sup>(8)</sup>                                      |                 | 30  |     | 300 | kHz  |

(7) Frequencies below the MIN specification set the fault flag. Frequencies above the MAX specification do not set the fault flag. Frequencies between the MIN and MAX specifications might set the flag.

(8) Measured with logic-level input frequency but also applies to operation with crystals.

## 5.23 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> | MIN | TYP | MAX | UNIT |
|------------------------------------------------------------------------|---------------------------------|-----------------|-----|-----|-----|------|
| f <sub>VLO</sub> VLO frequency                                         | Measured at ACLK                | 1.8 V to 3.6 V  | 6   | 9.4 | 14  | kHz  |
| df <sub>VLO</sub> /dT VLO frequency temperature drift                  | Measured at ACLK <sup>(1)</sup> | 1.8 V to 3.6 V  |     | 0.5 |     | %/°C |
| df <sub>VLO</sub> /dV <sub>CC</sub> VLO frequency supply voltage drift | Measured at ACLK <sup>(2)</sup> | 1.8 V to 3.6 V  |     | 4   |     | %/V  |
| Duty cycle                                                             | Measured at ACLK                | 1.8 V to 3.6 V  | 40% | 50% | 60% |      |

(1) Calculated using the box method: (MAX(–40°C to 85°C) – MIN(–40°C to 85°C)) / MIN(85°C – (–40°C)). The coefficient is negative.

(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). The coefficient is positive.

## 5.24 Internal Reference, Low-Frequency Oscillator (REFO)

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 |
|--------------------------------------------------------------------------|------------------------------------|------------------------|----------------|-------|-------|------|
| I <sub>REFO</sub> REFO oscillator current consumption                    | T <sub>A</sub> = 25°C              | 1.8 V to 3.6 V         |                | 3     |       | μA   |
| f <sub>REFO</sub>                                                        | REFO frequency calibrated          | Measured at ACLK       | 1.8 V to 3.6 V | 32768 |       | Hz   |
|                                                                          | REFO absolute tolerance calibrated | Full temperature range | 1.8 V to 3.6 V |       | ±3.5% |      |
|                                                                          |                                    | T <sub>A</sub> = 25°C  | 3 V            |       | ±1.5% |      |
| df <sub>REFO</sub> /dT REFO frequency temperature drift                  | Measured at ACLK <sup>(1)</sup>    | 1.8 V to 3.6 V         |                | 0.01  |       | %/°C |
| df <sub>REFO</sub> /dV <sub>CC</sub> REFO frequency supply voltage drift | Measured at ACLK <sup>(2)</sup>    | 1.8 V to 3.6 V         |                | 1.0   |       | %/V  |
| Duty cycle                                                               | Measured at ACLK                   | 1.8 V to 3.6 V         | 40%            | 50%   | 60%   |      |
| t <sub>START</sub> REFO start-up time                                    | 40%/60% duty cycle                 | 1.8 V to 3.6 V         |                | 25    |       | μs   |

(1) Calculated using the box method: (MAX(–40°C to 85°C) – MIN(–40°C to 85°C)) / MIN(85°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)

## 5.25 DCO Frequency

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted) (see [Figure 5-22](#))

| PARAMETER                                                          | TEST CONDITIONS                                                          | MIN  | TYP | MAX  | UNIT  |
|--------------------------------------------------------------------|--------------------------------------------------------------------------|------|-----|------|-------|
| $f_{DCO(0,0)}$ DCO frequency (0, 0) <sup>(1)</sup>                 | DCORSELx = 0, DCOx = 0, MODx = 0                                         | 0.07 |     | 0.20 | MHz   |
| $f_{DCO(0,31)}$ DCO frequency (0, 31) <sup>(1)</sup>               | DCORSELx = 0, DCOx = 31, MODx = 0                                        | 0.70 |     | 1.70 | MHz   |
| $f_{DCO(1,0)}$ DCO frequency (1, 0) <sup>(1)</sup>                 | DCORSELx = 1, DCOx = 0, MODx = 0                                         | 0.15 |     | 0.38 | MHz   |
| $f_{DCO(1,31)}$ DCO frequency (1, 31) <sup>(1)</sup>               | DCORSELx = 1, DCOx = 31, MODx = 0                                        | 1.47 |     | 3.45 | MHz   |
| $f_{DCO(2,0)}$ DCO frequency (2, 0) <sup>(1)</sup>                 | DCORSELx = 2, DCOx = 0, MODx = 0                                         | 0.32 |     | 0.75 | MHz   |
| $f_{DCO(2,31)}$ DCO frequency (2, 31) <sup>(1)</sup>               | DCORSELx = 2, DCOx = 31, MODx = 0                                        | 3.17 |     | 7.38 | MHz   |
| $f_{DCO(3,0)}$ DCO frequency (3, 0) <sup>(1)</sup>                 | DCORSELx = 3, DCOx = 0, MODx = 0                                         | 0.64 |     | 1.51 | MHz   |
| $f_{DCO(3,31)}$ DCO frequency (3, 31) <sup>(1)</sup>               | DCORSELx = 3, DCOx = 31, MODx = 0                                        | 6.07 |     | 14.0 | MHz   |
| $f_{DCO(4,0)}$ DCO frequency (4, 0) <sup>(1)</sup>                 | DCORSELx = 4, DCOx = 0, MODx = 0                                         | 1.3  |     | 3.2  | MHz   |
| $f_{DCO(4,31)}$ DCO frequency (4, 31) <sup>(1)</sup>               | DCORSELx = 4, DCOx = 31, MODx = 0                                        | 12.3 |     | 28.2 | MHz   |
| $f_{DCO(5,0)}$ DCO frequency (5, 0) <sup>(1)</sup>                 | DCORSELx = 5, DCOx = 0, MODx = 0                                         | 2.5  |     | 6.0  | MHz   |
| $f_{DCO(5,31)}$ DCO frequency (5, 31) <sup>(1)</sup>               | DCORSELx = 5, DCOx = 31, MODx = 0                                        | 23.7 |     | 54.1 | MHz   |
| $f_{DCO(6,0)}$ DCO frequency (6, 0) <sup>(1)</sup>                 | DCORSELx = 6, DCOx = 0, MODx = 0                                         | 4.6  |     | 10.7 | MHz   |
| $f_{DCO(6,31)}$ DCO frequency (6, 31) <sup>(1)</sup>               | DCORSELx = 6, DCOx = 31, MODx = 0                                        | 39.0 |     | 88.0 | MHz   |
| $f_{DCO(7,0)}$ DCO frequency (7, 0) <sup>(1)</sup>                 | DCORSELx = 7, DCOx = 0, MODx = 0                                         | 8.5  |     | 19.6 | MHz   |
| $f_{DCO(7,31)}$ DCO frequency (7, 31) <sup>(1)</sup>               | DCORSELx = 7, DCOx = 31, MODx = 0                                        | 60   |     | 135  | MHz   |
| $S_{DCORSEL}$ Frequency step between range DCORSEL and DCORSEL + 1 | $S_{RSEL} = f_{DCO(DCORSEL+1,DCO)} / f_{DCO(DCORSEL,DCO)}$               | 1.2  |     | 2.4  | ratio |
| $S_{DCO}$ Frequency step between tap DCO and DCO + 1               | $S_{DCO} = f_{DCO(DCORSEL,DCO+1)} / f_{DCO(DCORSEL,DCO)}$                | 1.02 |     | 1.12 | ratio |
| Duty cycle                                                         | Measured at SMCLK                                                        | 40%  | 50% | 60%  |       |
| $df_{DCO}/dT$ DCO frequency temperature drift                      | $f_{DCO} = 1 \text{ MHz}$ , $V_{CORE} = 1.2 \text{ V}$ , $2.0 \text{ V}$ |      | 0.1 |      | %/°C  |
| $df_{DCO}/dV_{CORE}$ DCO frequency voltage drift                   | $f_{DCO} = 1 \text{ MHz}$                                                |      | 1.9 |      | %/V   |

- (1) When selecting the proper DCO frequency range (DCORSELx), the target DCO frequency,  $f_{DCO}$ , should be set to reside within the range of  $f_{DCO(n,0),MAX} \leq f_{DCO} \leq f_{DCO(n,31),MIN}$ , where  $f_{DCO(n,0),MAX}$  represents the maximum frequency specified for the DCO frequency, range n, tap 0 (DCOx = 0) and  $f_{DCO(n,31),MIN}$  represents the minimum frequency specified for the DCO frequency, range n, tap 31 (DCOx = 31). This ensures that the target DCO frequency resides within the range selected. It should also be noted that if the actual  $f_{DCO}$  frequency for the selected range causes the FLL or the application to select tap 0 or 31, the DCO fault flag is set to report that the selected range is at its minimum or maximum tap setting.

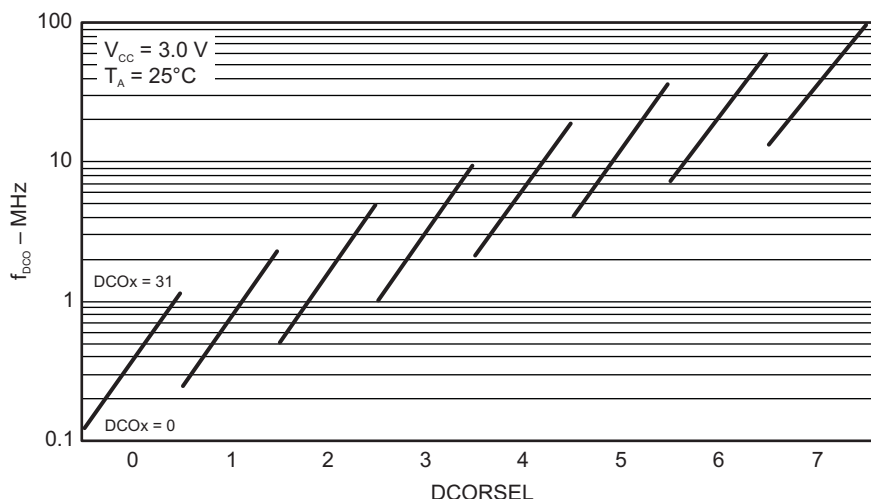


Figure 5-22. Typical DCO Frequency

## 5.26 PMM, Brownout Reset (BOR)

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

| PARAMETER               |                                                                                  | TEST CONDITIONS                   | MIN  | TYP  | MAX  | UNIT |
|-------------------------|----------------------------------------------------------------------------------|-----------------------------------|------|------|------|------|
| $V_{(DVCC\_BOR\_IT-)}$  | BOR <sub>H</sub> on voltage, DV <sub>CC</sub> falling level                      | $dDV_{CC}/dt < 3 \text{ V/s}$     |      |      | 1.45 | V    |
| $V_{(DVCC\_BOR\_IT+)}$  | BOR <sub>H</sub> off voltage, DV <sub>CC</sub> rising level                      | $dDV_{CC}/dt < 3 \text{ V/s}$     | 0.80 | 1.30 | 1.50 | V    |
| $V_{(DVCC\_BOR\_hys)}$  | BOR <sub>H</sub> hysteresis                                                      |                                   | 40   |      | 275  | mV   |
| $V_{(VCORE\_BOR\_IT-)}$ | BOR <sub>L</sub> on voltage, V <sub>CORE</sub> falling level                     | DV <sub>CC</sub> = 1.8 V to 3.6 V | 0.69 |      | 0.87 | V    |
| $V_{(VCORE\_BOR\_IT+)}$ | BOR <sub>L</sub> off voltage, V <sub>CORE</sub> rising level                     | DV <sub>CC</sub> = 1.8 V to 3.6 V | 0.83 |      | 1.05 | V    |
| $V_{(VCORE\_BOR\_hys)}$ | BOR <sub>L</sub> hysteresis                                                      |                                   | 60   |      | 200  | mV   |
| $t_{dBOR}$              | BOR <sub>L</sub> reset release time                                              |                                   |      |      | 2000 | μs   |
| $t_{RESET}$             | Pulse duration required at $\overline{RST}/\overline{NMI}$ pin to accept a reset |                                   | 2    |      |      | μs   |

## 5.27 PMM, Core Voltage

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

| PARAMETER        |                                              | TEST CONDITIONS                                                                                      | MIN | TYP  | MAX | UNIT |
|------------------|----------------------------------------------|------------------------------------------------------------------------------------------------------|-----|------|-----|------|
| $V_{CORE3(AM)}$  | Core voltage, active mode, PMMCOREV = 3      | $2.4 \text{ V} \leq DV_{CC} \leq 3.6 \text{ V}$ , $0 \text{ mA} \leq I(V_{CORE}) \leq 25 \text{ mA}$ |     | 1.90 |     | V    |
| $V_{CORE2(AM)}$  | Core voltage, active mode, PMMCOREV = 2      | $2.2 \text{ V} \leq DV_{CC} \leq 3.6 \text{ V}$ , $0 \text{ mA} \leq I(V_{CORE}) \leq 21 \text{ mA}$ |     | 1.80 |     | V    |
| $V_{CORE1(AM)}$  | Core voltage, active mode, PMMCOREV = 1      | $2.0 \text{ V} \leq DV_{CC} \leq 3.6 \text{ V}$ , $0 \text{ mA} \leq I(V_{CORE}) \leq 17 \text{ mA}$ |     | 1.60 |     | V    |
| $V_{CORE0(AM)}$  | Core voltage, active mode, PMMCOREV = 0      | $1.8 \text{ V} \leq DV_{CC} \leq 3.6 \text{ V}$ , $0 \text{ mA} \leq I(V_{CORE}) \leq 13 \text{ mA}$ |     | 1.40 |     | V    |
| $V_{CORE3(LPM)}$ | Core voltage, active mode, PMMCOREV = 3      | $2.4 \text{ V} \leq DV_{CC} \leq 3.6 \text{ V}$ , $0 \text{ mA} \leq I(V_{CORE}) \leq 30 \text{ μA}$ |     | 1.94 |     | V    |
| $V_{CORE2(LPM)}$ | Core voltage, low-current mode, PMMCOREV = 2 | $2.2 \text{ V} \leq DV_{CC} \leq 3.6 \text{ V}$ , $0 \text{ μA} \leq I(V_{CORE}) \leq 30 \text{ μA}$ |     | 1.84 |     | V    |
| $V_{CORE1(LPM)}$ | Core voltage, low-current mode, PMMCOREV = 1 | $2.0 \text{ V} \leq DV_{CC} \leq 3.6 \text{ V}$ , $0 \text{ μA} \leq I(V_{CORE}) \leq 30 \text{ μA}$ |     | 1.64 |     | V    |
| $V_{CORE0(LPM)}$ | Core voltage, low-current mode, PMMCOREV = 0 | $1.8 \text{ V} \leq DV_{CC} \leq 3.6 \text{ V}$ , $0 \text{ μA} \leq I(V_{CORE}) \leq 30 \text{ μA}$ |     | 1.44 |     | V    |

## 5.28 PMM, SVS High Side

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

| PARAMETER         |                                       | TEST CONDITIONS                                                      | MIN  | TYP  | MAX  | UNIT          |
|-------------------|---------------------------------------|----------------------------------------------------------------------|------|------|------|---------------|
| $I_{(SVSH)}$      | SVS current consumption               | SVSHE = 0, $DV_{CC} = 3.6\text{ V}$                                  |      | 0    |      | nA            |
|                   |                                       | SVSHE = 1, $DV_{CC} = 3.6\text{ V}$ , SVSHFP = 0                     |      | 200  |      |               |
|                   |                                       | SVSHE = 1, $DV_{CC} = 3.6\text{ V}$ , SVSHFP = 1                     |      | 2    |      | $\mu\text{A}$ |
| $V_{(SVSH\_IT-)}$ | SVS <sub>H</sub> on voltage level     | SVSHE = 1, SVSHRVL = 0                                               | 1.59 | 1.64 | 1.69 | V             |
|                   |                                       | SVSHE = 1, SVSHRVL = 1                                               | 1.79 | 1.84 | 1.91 |               |
|                   |                                       | SVSHE = 1, SVSHRVL = 2                                               | 1.98 | 2.04 | 2.11 |               |
|                   |                                       | SVSHE = 1, SVSHRVL = 3                                               | 2.10 | 2.16 | 2.23 |               |
| $V_{(SVSH\_IT+)}$ | SVS <sub>H</sub> off voltage level    | SVSHE = 1, SVSMHRRRL = 0                                             | 1.62 | 1.74 | 1.81 | V             |
|                   |                                       | SVSHE = 1, SVSMHRRRL = 1                                             | 1.88 | 1.94 | 2.01 |               |
|                   |                                       | SVSHE = 1, SVSMHRRRL = 2                                             | 2.07 | 2.14 | 2.21 |               |
|                   |                                       | SVSHE = 1, SVSMHRRRL = 3                                             | 2.20 | 2.26 | 2.33 |               |
|                   |                                       | SVSHE = 1, SVSMHRRRL = 4                                             | 2.32 | 2.40 | 2.48 |               |
|                   |                                       | SVSHE = 1, SVSMHRRRL = 5                                             | 2.56 | 2.70 | 2.84 |               |
|                   |                                       | SVSHE = 1, SVSMHRRRL = 6                                             | 2.85 | 3.00 | 3.15 |               |
|                   |                                       | SVSHE = 1, SVSMHRRRL = 7                                             | 2.85 | 3.00 | 3.15 |               |
| $t_{pd(SVSH)}$    | SVS <sub>H</sub> propagation delay    | SVSHE = 1, $dV_{DVCC}/dt = 10\text{ mV}/\mu\text{s}$ , SVSHFP = 1    |      | 2.5  |      | $\mu\text{s}$ |
|                   |                                       | SVSHE = 1, $dV_{DVCC}/dt = \pm 1\text{ mV}/\mu\text{s}$ , SVSHFP = 0 |      | 25   |      |               |
| $t_{(SVSH)}$      | SVS <sub>H</sub> on or off delay time | SVSHE = 0 $\rightarrow$ 1, SVSHFP = 1                                |      | 12.5 |      | $\mu\text{s}$ |
|                   |                                       | SVSHE = 0 $\rightarrow$ 1, SVSHFP = 0                                |      | 100  |      |               |
| $dV_{DVCC}/dt$    | $DV_{CC}$ rise time                   |                                                                      | 0    |      | 1000 | V/s           |

## 5.29 PMM, SVM High Side

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

| PARAMETER                                             | TEST CONDITIONS                                          | MIN  | TYP  | MAX  | UNIT |
|-------------------------------------------------------|----------------------------------------------------------|------|------|------|------|
| $I_{(SVMH)}$ SVM <sub>H</sub> current consumption     | SVMHE = 0, DV <sub>CC</sub> = 3.6 V                      |      | 0    |      | nA   |
|                                                       | SVMHE = 1, DV <sub>CC</sub> = 3.6 V, SVMHFP = 0          |      | 200  |      |      |
|                                                       | SVMHE = 1, DV <sub>CC</sub> = 3.6 V, SVMHFP = 1          |      | 2.0  |      | μA   |
| $V_{(SVMH)}$ SVM <sub>H</sub> on or off voltage level | SVMHE = 1, SVSMHRRRL = 0                                 | 1.65 | 1.74 | 1.86 | V    |
|                                                       | SVMHE = 1, SVSMHRRRL = 1                                 | 1.85 | 1.94 | 2.02 |      |
|                                                       | SVMHE = 1, SVSMHRRRL = 2                                 | 2.02 | 2.14 | 2.22 |      |
|                                                       | SVMHE = 1, SVSMHRRRL = 3                                 | 2.18 | 2.26 | 2.35 |      |
|                                                       | SVMHE = 1, SVSMHRRRL = 4                                 | 2.32 | 2.40 | 2.48 |      |
|                                                       | SVMHE = 1, SVSMHRRRL = 5                                 | 2.56 | 2.70 | 2.84 |      |
|                                                       | SVMHE = 1, SVSMHRRRL = 6                                 | 2.85 | 3.00 | 3.15 |      |
|                                                       | SVMHE = 1, SVSMHRRRL = 7                                 | 2.85 | 3.00 | 3.15 |      |
| $t_{pd(SVMH)}$ SVM <sub>H</sub> propagation delay     | SVMHE = 1, dV <sub>DVCC</sub> /dt = 10 mV/μs, SVMHFP = 1 |      | 2.5  |      | μs   |
|                                                       | SVMHE = 1, dV <sub>DVCC</sub> /dt = 1 mV/μs, SVMHFP = 0  |      | 20   |      | μs   |
| $t_{(SVMH)}$ SVM <sub>H</sub> on or off delay time    | SVMHE = 0 → 1, SVSHFP = 1                                |      | 12.5 |      | μs   |
|                                                       | SVMHE = 0 → 1, SVSHFP = 0                                |      | 100  |      |      |

## 5.30 PMM, SVS Low Side

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

| PARAMETER                                          | TEST CONDITIONS                                          | MIN | TYP  | MAX | UNIT |
|----------------------------------------------------|----------------------------------------------------------|-----|------|-----|------|
| $I_{(SVSL)}$ SVS <sub>L</sub> current consumption  | SVSLE = 0, PMMCOREV = 2                                  |     | 0    |     | nA   |
|                                                    | SVSLE = 1, PMMCOREV = 2, SVSLFP = 0                      |     | 200  |     |      |
|                                                    | SVSLE = 1, PMMCOREV = 2, SVSLFP = 1                      |     | 2.0  |     | μA   |
| $t_{(SVSL)}$ SVS <sub>L</sub> on or off delay time | SVSLE = 1, dV <sub>CORE</sub> /dt = 10 mV/μs, SVSLFP = 1 |     | 6    |     | μs   |
|                                                    | SVSLE = 1, dV <sub>CORE</sub> /dt = 1 mV/μs, SVSLFP = 0  |     | 50   |     |      |
| $t_{pd(SVSL)}$ SVS <sub>L</sub> propagation delay  | SVMHE = 0 → 1, SVSLFP = 1                                |     | 12.5 |     | μs   |
|                                                    | SVMHE = 0 → 1, SVSLFP = 0                                |     | 100  |     |      |

## 5.31 PMM, SVM Low Side

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

| PARAMETER                                          | TEST CONDITIONS                                          | MIN | TYP  | MAX | UNIT |
|----------------------------------------------------|----------------------------------------------------------|-----|------|-----|------|
| $I_{(SVML)}$ SVM <sub>L</sub> current consumption  | SVMLE = 0, PMMCOREV = 2                                  |     | 0    |     | nA   |
|                                                    | SVMLE = 1, PMMCOREV = 2, SVMLFP = 0                      |     | 200  |     |      |
|                                                    | SVMLE = 1, PMMCOREV = 2, SVMLFP = 1                      |     | 2.0  |     | μA   |
| $t_{pd(SVML)}$ SVM <sub>L</sub> propagation delay  | SVMLE = 1, dV <sub>CORE</sub> /dt = 10 mV/μs, SVMLFP = 1 |     | 2.5  |     | μs   |
|                                                    | SVMLE = 1, dV <sub>CORE</sub> /dt = 1 mV/μs, SVMLFP = 0  |     | 30   |     |      |
| $t_{(SVML)}$ SVM <sub>L</sub> on or off delay time | SVMLE = 0 → 1, SVSLFP = 1                                |     | 12.5 |     | μs   |
|                                                    | SVMLE = 0 → 1, SVSLFP = 0                                |     | 100  |     |      |

## 5.32 Wake-up Times From Low-Power Modes

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

| PARAMETER      |                                                                        | TEST CONDITIONS                                                 |                       | MIN | TYP | MAX | UNIT |
|----------------|------------------------------------------------------------------------|-----------------------------------------------------------------|-----------------------|-----|-----|-----|------|
| tFAST-WAKE-UP  | Wake-up time from LPM2, LPM3, or LPM4 to active mode <sup>(1)</sup>    | PMMCOREVx = SVSMLRRLx = n (where n = 0, 1, 2, or 3), SVSLFP = 1 | fMCLK ≥ 4 MHz         |     | 3   | 6.5 | μs   |
|                |                                                                        |                                                                 | 1 MHz < fMCLK < 4 MHz |     | 4   | 8.0 |      |
| tSLOW-WAKE-UP  | Wake-up time from LPM2, LPM3, or LPM4 to active mode <sup>(2)(3)</sup> | PMMCOREVx = SVSMLRRLx = n (where n = 0, 1, 2, or 3), SVSLFP = 0 |                       |     | 150 | 165 | μs   |
| tWAKE-UP LPM5  | Wake-up time from LPM4.5 to active mode <sup>(4)</sup>                 |                                                                 |                       |     | 2   | 3   | ms   |
| tWAKE-UP-RESET | Wake-up time from RST or BOR event to active mode <sup>(4)</sup>       |                                                                 |                       |     | 2   | 3   | ms   |

- (1) This value represents the time from the wake-up event to the first active edge of MCLK. The wake-up time depends on the performance mode of the low-side supervisor (SVSL) and low-side monitor (SVM<sub>L</sub>).  $t_{\text{WAKE-UP-FAST}}$  is possible with SVSL and SVM<sub>L</sub> in full performance mode or disabled. For specific register settings, see the *Low-Side SVS and SVM Control and Performance Mode Selection* section in the *Power Management Module and Supply Voltage Supervisor* chapter of the [MSP430x5xx and MSP430x6xx Family User's Guide](#).
- (2) This value represents the time from the wake-up event to the first active edge of MCLK. The wake-up time depends on the performance mode of the low-side supervisor (SVSL) and low-side monitor (SVM<sub>L</sub>).  $t_{\text{WAKE-UP-SLOW}}$  is set with SVSL and SVM<sub>L</sub> in normal mode (low current mode). For specific register settings, see the *Low-Side SVS and SVM Control and Performance Mode Selection* section in the *Power Management Module and Supply Voltage Supervisor* chapter of the [MSP430x5xx and MSP430x6xx Family User's Guide](#).
- (3) The wake-up times from LPM0 and LPM1 to AM are not specified. They are proportional to MCLK cycle time but are not affected by the performance mode settings as for LPM2, LPM3, and LPM4.
- (4) This value represents the time from the wake-up event to the reset vector execution.

## 5.33 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 |
|-----------------------------------------------|----------------------------------------------------------------------------|-----------------|-----|-----|------|
| $f_{\text{TA}}$ Timer_A input clock frequency | Internal: SMCLK or ACLK,<br>External: TACLK,<br>Duty cycle = 50% $\pm$ 10% | 1.8 V, 3 V      |     | 25  | MHz  |
| $t_{\text{TA,cap}}$ Timer_A capture timing    | All capture inputs, minimum pulse duration required for capture.           | 1.8 V, 3 V      | 20  |     | ns   |

## 5.34 USCI (UART Mode)

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 |
|---------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------|-----------------|-----|---------------------|-----|------|
| $f_{\text{USCI}}$ USCI input clock frequency                                                      | Internal: SMCLK or ACLK,<br>External: UCLK,<br>Duty cycle = 50% $\pm$ 10% |                 |     | $f_{\text{SYSTEM}}$ |     | MHz  |
| $f_{\text{max,BITCLK}}$ Maximum BITCLK clock frequency (equals baud rate in MBaud) <sup>(1)</sup> |                                                                           |                 | 1   |                     |     | MHz  |
| $t_{\text{r}}$ UART receive deglitch time                                                         |                                                                           | 2.2 V           | 50  | 150                 | 200 | ns   |
|                                                                                                   |                                                                           | 3 V             | 50  | 150                 | 200 |      |

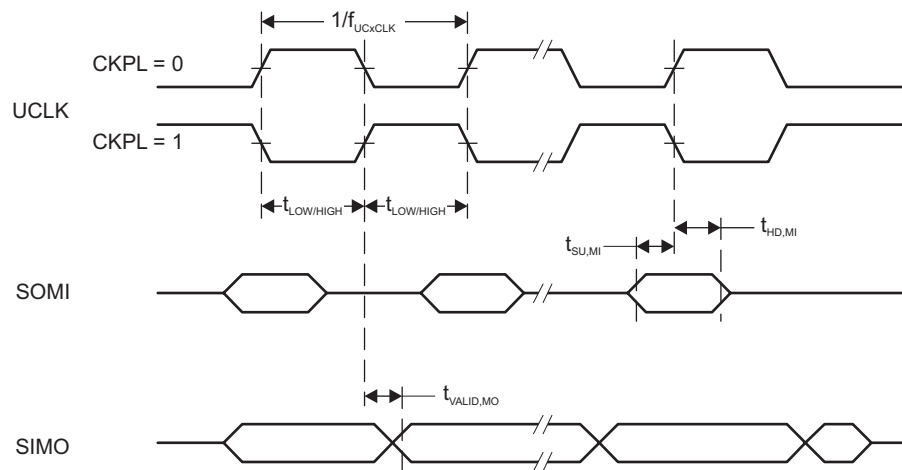
- (1) The DCO wake-up time must be considered in LPM3 and LPM4. The wake-up time must be considered in LPMx.5.

### 5.35 USCI (SPI Master Mode)

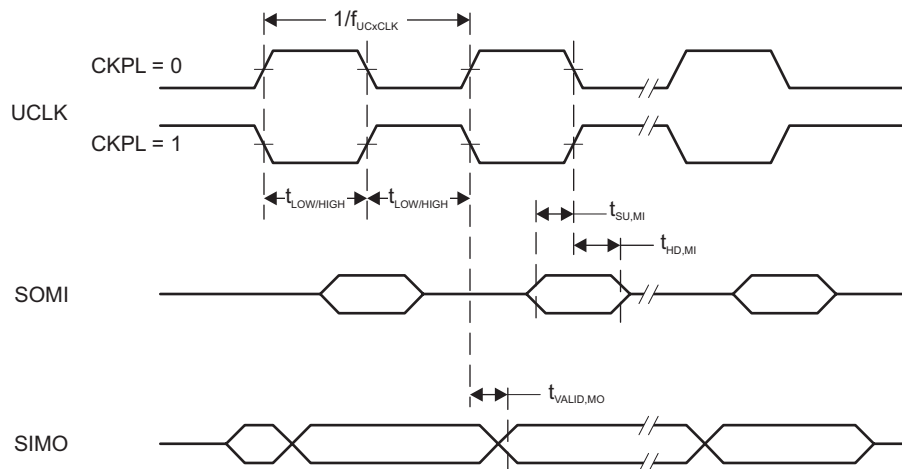
over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)<sup>(1)</sup> (see [Figure 5-23](#) and [Figure 5-24](#))

| PARAMETER             |                                            | TEST CONDITIONS                                                  | V <sub>CC</sub> | MIN                 | MAX | UNIT |
|-----------------------|--------------------------------------------|------------------------------------------------------------------|-----------------|---------------------|-----|------|
| f <sub>USCI</sub>     | USCI input clock frequency                 | SMCLK or ACLK,<br>Duty cycle = 50% ±10%                          |                 | f <sub>SYSTEM</sub> |     | MHz  |
| t <sub>SU,MI</sub>    | SOMI input data setup time                 | PMMCOREV = 0                                                     | 1.8 V           | 55                  |     | ns   |
|                       |                                            |                                                                  | 3 V             | 38                  |     |      |
|                       |                                            | PMMCOREV = 3                                                     | 2.4 V           | 30                  |     |      |
|                       |                                            |                                                                  | 3 V             | 25                  |     |      |
| t <sub>HD,MI</sub>    | SOMI input data hold time                  | PMMCOREV = 0                                                     | 1.8 V           | 0                   |     | ns   |
|                       |                                            |                                                                  | 3 V             | 0                   |     |      |
|                       |                                            | PMMCOREV = 3                                                     | 2.4 V           | 0                   |     |      |
|                       |                                            |                                                                  | 3 V             | 0                   |     |      |
| t <sub>VALID,MO</sub> | SIMO output data valid time <sup>(2)</sup> | UCLK edge to SIMO valid,<br>C <sub>L</sub> = 20 pF, PMMCOREV = 0 | 1.8 V           | 20                  |     | ns   |
|                       |                                            |                                                                  | 3 V             | 18                  |     |      |
|                       |                                            | UCLK edge to SIMO valid,<br>C <sub>L</sub> = 20 pF, PMMCOREV = 3 | 2.4 V           | 16                  |     |      |
|                       |                                            |                                                                  | 3 V             | 15                  |     |      |
| t <sub>HD,MO</sub>    | SIMO output data hold time <sup>(3)</sup>  | C <sub>L</sub> = 20 pF, PMMCOREV = 0                             | 1.8 V           | −10                 |     | ns   |
|                       |                                            |                                                                  | 3 V             | −8                  |     |      |
|                       |                                            | C <sub>L</sub> = 20 pF, PMMCOREV = 3                             | 2.4 V           | −10                 |     |      |
|                       |                                            |                                                                  | 3 V             | −8                  |     |      |

- (1)  $f_{UCxCLK} = 1/2t_{LO/HI}$  with  $t_{LO/HI} \geq \max(t_{VALID,MO}(USCI) + t_{SU,SI}(Slave), t_{SU,MI}(USCI) + t_{VALID,SO}(Slave))$   
For the slave parameters  $t_{SU,SI}(Slave)$  and  $t_{VALID,SO}(Slave)$ , 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 5-23](#) and [Figure 5-24](#).
- (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. See the timing diagrams in [Figure 5-23](#) and [Figure 5-24](#).



**Figure 5-23. SPI Master Mode, CKPH = 0**



**Figure 5-24. SPI Master Mode, CKPH = 1**

### 5.36 USCI (SPI Slave Mode)

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)<sup>(1)</sup> (see [Figure 5-25](#) and [Figure 5-26](#))

| PARAMETER                                                       | TEST CONDITIONS                                               | V <sub>CC</sub> | MIN | MAX | UNIT |
|-----------------------------------------------------------------|---------------------------------------------------------------|-----------------|-----|-----|------|
| $t_{STE,LEAD}$ STE lead time, STE low to clock                  | PMMCOREV = 0                                                  | 1.8 V           | 11  |     | ns   |
|                                                                 |                                                               | 3 V             | 8   |     |      |
|                                                                 | PMMCOREV = 3                                                  | 2.4 V           | 7   |     |      |
|                                                                 |                                                               | 3 V             | 6   |     |      |
| $t_{STE,LAG}$ STE lag time, Last clock to STE high              | PMMCOREV = 0                                                  | 1.8 V           | 3   |     | ns   |
|                                                                 |                                                               | 3 V             | 3   |     |      |
|                                                                 | PMMCOREV = 3                                                  | 2.4 V           | 3   |     |      |
|                                                                 |                                                               | 3 V             | 3   |     |      |
| $t_{STE,ACC}$ STE access time, STE low to SOMI data out         | PMMCOREV = 0                                                  | 1.8 V           |     | 66  | ns   |
|                                                                 |                                                               | 3 V             |     | 50  |      |
|                                                                 | PMMCOREV = 3                                                  | 2.4 V           |     | 36  |      |
|                                                                 |                                                               | 3 V             |     | 30  |      |
| $t_{STE,DIS}$ STE disable time, STE high to SOMI high impedance | PMMCOREV = 0                                                  | 1.8 V           |     | 30  | ns   |
|                                                                 |                                                               | 3 V             |     | 23  |      |
|                                                                 | PMMCOREV = 3                                                  | 2.4 V           |     | 16  |      |
|                                                                 |                                                               | 3 V             |     | 13  |      |
| $t_{SU,SI}$ SIMO input data setup time                          | PMMCOREV = 0                                                  | 1.8 V           | 5   |     | ns   |
|                                                                 |                                                               | 3 V             | 5   |     |      |
|                                                                 | PMMCOREV = 3                                                  | 2.4 V           | 2   |     |      |
|                                                                 |                                                               | 3 V             | 2   |     |      |
| $t_{HD,SI}$ SIMO input data hold time                           | PMMCOREV = 0                                                  | 1.8 V           | 5   |     | ns   |
|                                                                 |                                                               | 3 V             | 5   |     |      |
|                                                                 | PMMCOREV = 3                                                  | 2.4 V           | 5   |     |      |
|                                                                 |                                                               | 3 V             | 5   |     |      |
| $t_{VALID,SO}$ SOMI output data valid time <sup>(2)</sup>       | UCLK edge to SOMI valid, C <sub>L</sub> = 20 pF, PMMCOREV = 0 | 1.8 V           |     | 76  | ns   |
|                                                                 |                                                               | 3 V             |     | 60  |      |
|                                                                 | UCLK edge to SOMI valid, C <sub>L</sub> = 20 pF, PMMCOREV = 3 | 2.4 V           |     | 44  |      |
|                                                                 |                                                               | 3 V             |     | 40  |      |
| $t_{HD,SO}$ SOMI output data hold time <sup>(3)</sup>           | C <sub>L</sub> = 20 pF, PMMCOREV = 0                          | 1.8 V           | 18  |     | ns   |
|                                                                 |                                                               | 3 V             | 12  |     |      |
|                                                                 | C <sub>L</sub> = 20 pF, PMMCOREV = 3                          | 2.4 V           | 10  |     |      |
|                                                                 |                                                               | 3 V             | 8   |     |      |

- (1)  $f_{UCXCLK} = 1/2t_{LO/HI}$  with  $t_{LO/HI} \geq \max(t_{VALID,MO(Master)} + t_{SU,SI(USCI)}, t_{SU,MI(Master)} + t_{VALID,SO(USCI)})$   
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 5-25](#) and [Figure 5-26](#).
- (3) Specifies how long data on the SOMI output is valid after the output changing UCLK clock edge. See the timing diagrams in [Figure 5-25](#) and [Figure 5-26](#).

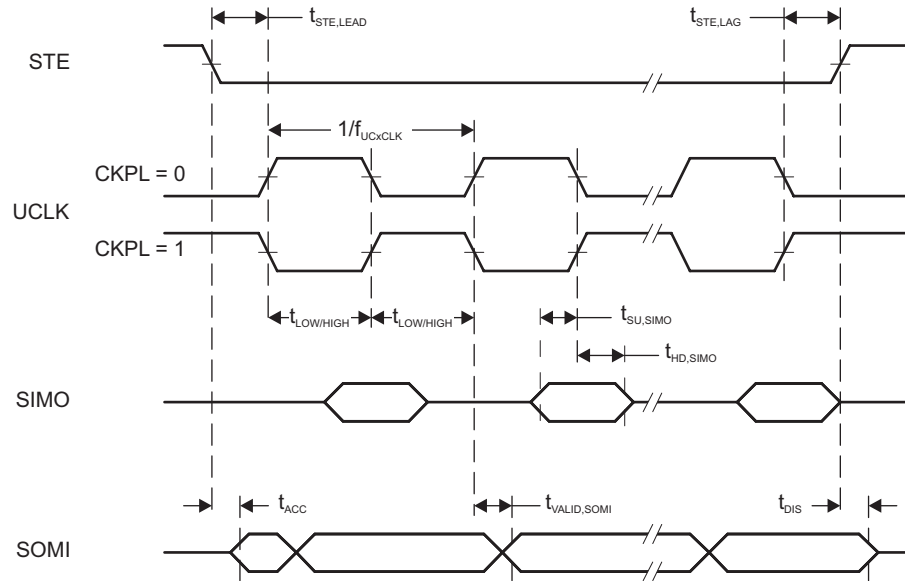


Figure 5-25. SPI Slave Mode, CKPH = 0

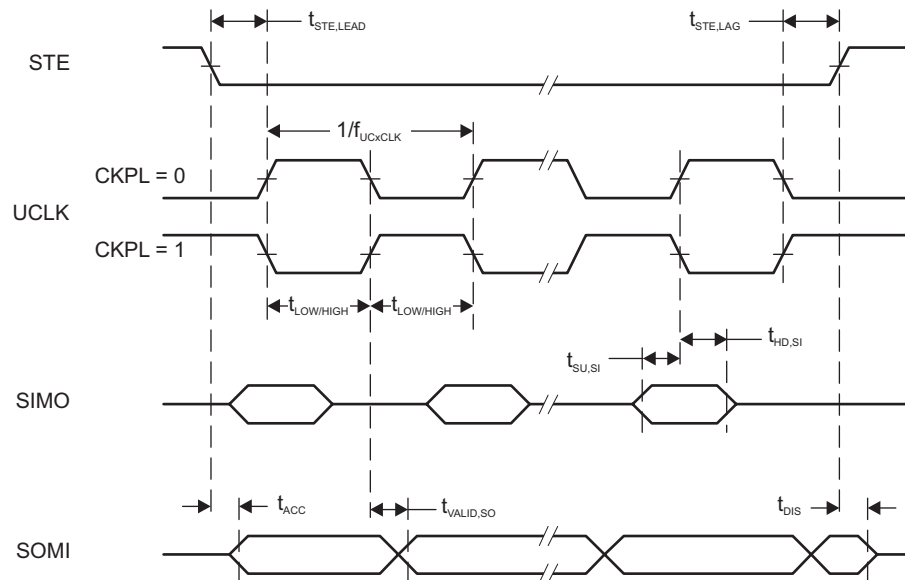
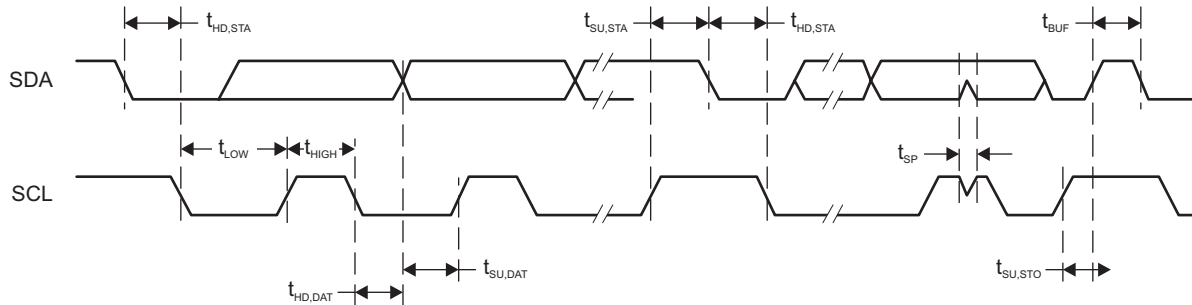


Figure 5-26. SPI Slave Mode, CKPH = 1

### 5.37 USCI (I<sup>2</sup>C Mode)

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted) (see [Figure 5-27](#))

| PARAMETER                                                           | TEST CONDITIONS                                                      | V <sub>CC</sub> | MIN                 | MAX | UNIT |
|---------------------------------------------------------------------|----------------------------------------------------------------------|-----------------|---------------------|-----|------|
| f <sub>USCI</sub> USCI input clock frequency                        | Internal: SMCLK or ACLK,<br>External: UCLK,<br>Duty cycle = 50% ±10% |                 | f <sub>SYSTEM</sub> |     | MHz  |
| f <sub>SCL</sub> SCL clock frequency                                |                                                                      | 2.2 V, 3 V      | 0                   | 400 | kHz  |
| t <sub>HD,STA</sub> Hold time (repeated) START                      | f <sub>SCL</sub> ≤ 100 kHz                                           | 2.2 V, 3 V      | 4.0                 |     | μs   |
|                                                                     | f <sub>SCL</sub> > 100 kHz                                           |                 | 0.6                 |     |      |
| t <sub>SU,STA</sub> Setup time for a repeated START                 | f <sub>SCL</sub> ≤ 100 kHz                                           | 2.2 V, 3 V      | 4.7                 |     | μs   |
|                                                                     | f <sub>SCL</sub> > 100 kHz                                           |                 | 0.6                 |     |      |
| t <sub>HD,DAT</sub> Data hold time                                  |                                                                      | 2.2 V, 3 V      | 0                   |     | ns   |
| t <sub>SU,DAT</sub> Data setup time                                 |                                                                      | 2.2 V, 3 V      | 250                 |     | ns   |
| t <sub>SU,STO</sub> Setup time for STOP                             | f <sub>SCL</sub> ≤ 100 kHz                                           | 2.2 V, 3 V      | 4.0                 |     | μs   |
|                                                                     | f <sub>SCL</sub> > 100 kHz                                           |                 | 0.6                 |     |      |
| t <sub>SP</sub> Pulse duration of spikes suppressed by input filter |                                                                      | 2.2 V           | 50                  | 600 | ns   |
|                                                                     |                                                                      | 3 V             | 50                  | 600 |      |



**Figure 5-27. I<sup>2</sup>C Mode Timing**

### 5.38 10-Bit ADC, Power Supply and Input Range Conditions (MSP430F51x2 Devices Only)

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 | TYP | MAX              | UNIT |
|----------------------|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|-----|-----|------------------|------|
| AV <sub>CC</sub>     | Analog supply voltage                                                             | AV <sub>CC</sub> and DV <sub>CC</sub> are connected together, AV <sub>SS</sub> and DV <sub>SS</sub> are connected together, V <sub>(AVSS)</sub> = V <sub>(DVSS)</sub> = 0 V |                 | 1.8 |     | 3.6              | V    |
| V <sub>(Ax)</sub>    | Analog input voltage range <sup>(2)</sup>                                         | All ADC10_A pins: P1.0 to P1.5 and P3.6 and P3.7 terminals                                                                                                                  |                 | 0   |     | AV <sub>CC</sub> | V    |
| I <sub>ADC10_A</sub> | Operating supply current into AVCC terminal, REF module and reference buffer off  | f <sub>ADC10CLK</sub> = 5 MHz, ADC10ON = 1, REFON = 0, SHT0 = 0, SHT1 = 0, ADC10DIV = 0, ADC10SREF = 00                                                                     | 2.2 V           |     | 60  | 90               | μA   |
|                      |                                                                                   |                                                                                                                                                                             | 3 V             |     | 75  | 100              |      |
|                      | Operating supply current into AVCC terminal, REF module on, reference buffer on   | f <sub>ADC10CLK</sub> = 5 MHz, ADC10ON = 1, REFON = 1, SHT0 = 0, SHT1 = 0, ADC10DIV = 0, ADC10SREF = 01                                                                     | 3 V             |     | 113 | 130              |      |
|                      | Operating supply current into AVCC terminal, REF module off, reference buffer on  | f <sub>ADC10CLK</sub> = 5 MHz, ADC10ON = 1, REFON = 0, SHT0 = 0, SHT1 = 0, ADC10DIV = 0, ADC10SREF = 10, VREF = 2.5 V                                                       | 3 V             |     | 105 | 125              |      |
| I <sub>ADC10_A</sub> | Operating supply current into AVCC terminal, REF module off, reference buffer off | f <sub>ADC10CLK</sub> = 5 MHz, ADC10ON = 1, REFON = 0, SHT0 = 0, SHT1 = 0, ADC10DIV = 0, ADC10SREF = 11, VREF = 2.5 V                                                       | 3 V             |     | 70  | 95               | μA   |
|                      |                                                                                   |                                                                                                                                                                             |                 |     |     |                  |      |
| C <sub>I</sub>       | Input capacitance                                                                 | Only one terminal Ax can be selected at one time from the pad to the ADC10_A capacitor array including wiring and pad                                                       | 2.2 V           |     | 3.5 |                  | pF   |
| R <sub>I</sub>       | Input MUX ON resistance                                                           | AV <sub>CC</sub> > 2.0 V, 0 V ≤ V <sub>Ax</sub> ≤ AV <sub>CC</sub>                                                                                                          |                 |     |     | 36               | kΩ   |
|                      |                                                                                   | 1.8V < AV <sub>CC</sub> < 2.0 V, 0 V ≤ V <sub>Ax</sub> ≤ AV <sub>CC</sub>                                                                                                   |                 |     |     | 96               |      |

(1) The leakage current is defined in the leakage current table with P6.x/Ax parameter.

(2) The analog input voltage range must be within the selected reference voltage range V<sub>R+</sub> to V<sub>R-</sub> for valid conversion results. The external reference voltage requires decoupling capacitors.

Two decoupling capacitors, 10 μF and 100 nF, should be connected to VREF to decouple the dynamic current required for an external reference source if it is used for the ADC10\_A. Also see the [MSP430x5xx and MSP430x6xx Family User's Guide](#).

### 5.39 10-Bit ADC, Timing Parameters (MSP430F51x2 Devices Only)

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>ADC10CLK</sub> |                                            | For specified performance of ADC10_A linearity parameters                                               | 2.2 V, 3 V      | 0.45 | 5                                 | 5.5 | MHz  |
| f <sub>ADC10OSC</sub> | Internal ADC10_A oscillator <sup>(1)</sup> | ADC10DIV = 0, f <sub>ADC10CLK</sub> = f <sub>ADC10OSC</sub>                                             | 2.2 V, 3 V      | 4.2  | 4.8                               | 5.4 | MHz  |
| t <sub>CONVERT</sub>  | Conversion time                            | REFON = 0, Internal oscillator, 12 ADC10CLK cycles, 10-bit mode, f <sub>ADC10OSC</sub> = 4 MHz to 5 MHz | 2.2 V, 3 V      | 2.4  |                                   | 3.0 | μs   |
|                       |                                            | External f <sub>ADC10CLK</sub> from ACLK, MCLK or SMCLK, ADC10SSEL ≠ 0                                  |                 |      | 12 ×<br>1 / f <sub>ADC10CLK</sub> |     |      |
| t <sub>ADC10ON</sub>  | Turnon settling time of the ADC            | See <sup>(2)</sup>                                                                                      |                 |      |                                   | 100 | ns   |
| t <sub>Sample</sub>   | Sampling time                              | R <sub>S</sub> = 1000 Ω, R <sub>I</sub> = 96 kΩ, C <sub>I</sub> = 3.5 pF <sup>(3)</sup>                 | 1.8 V           | 3    |                                   |     | μs   |
|                       |                                            | R <sub>S</sub> = 1000 Ω, R <sub>I</sub> = 36 kΩ, C <sub>I</sub> = 3.5 pF <sup>(3)</sup>                 | 3 V             | 1    |                                   |     |      |

(1) The ADC10OSC is sourced directly from MODOSC inside the UCS.

(2) The condition is that the error in a conversion started after t<sub>ADC10ON</sub> is less than ±0.5 LSB. The reference and input signal are already settled.

(3) Approximately eight Tau (τ) are required for an error of less than ±0.5 LSB

## 5.40 10-Bit ADC, Linearity Parameters (MSP430F51x2 Devices Only)

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

| PARAMETER      |                                            | TEST CONDITIONS                                                                                               | MIN | TYP | MAX   | UNIT |
|----------------|--------------------------------------------|---------------------------------------------------------------------------------------------------------------|-----|-----|-------|------|
| E <sub>I</sub> | Integral linearity error                   | 1.4 V ≤ (VEREF+ – VREF-) ≤ 1.6 V, C <sub>VEREF+</sub> = 20 pF                                                 |     |     | ±1.0  | LSB  |
|                |                                            | 1.6 V < (VEREF+ – VREF-) ≤ V <sub>AVCC</sub> , C <sub>VEREF+</sub> = 20 pF                                    |     |     | ±1.0  |      |
| E <sub>D</sub> | Differential linearity error               | 1.4 V ≤ (VEREF+ – VREF-),<br>C <sub>VEREF+</sub> = 20 pF                                                      |     |     | ±1.0  | LSB  |
| E <sub>O</sub> | Offset error                               | 1.4 V ≤ (VEREF+ – VREF-), C <sub>VEREF+</sub> = 20 pF,<br>Internal impedance of source R <sub>S</sub> < 100 Ω |     |     | ±1.0  | LSB  |
| E <sub>G</sub> | Gain error, external reference             | 1.4 V ≤ (VEREF+ – VREF-), C <sub>VEREF+</sub> = 20 pF                                                         |     |     | ±1.0  | LSB  |
|                | Gain error, external reference, buffered   |                                                                                                               |     |     | ±5    |      |
|                | Gain error, internal reference             | See <sup>(1)</sup>                                                                                            |     |     | ±1.5% | VREF |
| E <sub>T</sub> | Total unadjusted error, internal reference | See <sup>(1)</sup>                                                                                            |     |     | ±1.5% | VREF |

(1) Dominated by the absolute voltage of the integrated reference voltage.

## 5.41 REF, External Reference (MSP430F51x2 Devices Only)

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 | TYP  | MAX              | UNIT |
|--------------------------------------------------|-----------------------------------------------|--------------------------------------------------------------------------------------------------------------------------|-----------------|-----|------|------------------|------|
| VEREF+                                           | Positive external reference voltage input     | VEREF+ > VREF- <sup>(2)</sup>                                                                                            |                 | 1.4 |      | AV <sub>CC</sub> | V    |
| VEREF-                                           | Negative external reference voltage input     | VEREF+ > VREF- <sup>(3)</sup>                                                                                            |                 | 0   |      | 1.2              | V    |
| VEREF+ – VREF-                                   | Differential external reference voltage input | VEREF+ > VREF- <sup>(4)</sup>                                                                                            |                 | 1.4 |      | AV <sub>CC</sub> | V    |
| I <sub>(VEREF+)</sub> ,<br>I <sub>(VEREF-)</sub> | Static input current                          | 1.4 V ≤ VREF+ ≤ V(AVCC), VREF- = 0 V,<br>f <sub>ADC10CLK</sub> = 5 MHz, ADC10SHTX = 0x0001,<br>Conversion rate 200 ksp/s | 2.2 V, 3 V      |     | ±8.5 | ±26              | μA   |
|                                                  |                                               | 1.4 V ≤ VREF+ ≤ V(AVCC), VREF- = 0 V,<br>f <sub>ADC10CLK</sub> = 5 MHz, ADC10SHTX = 0x1000,<br>Conversion rate 20 ksp/s  | 2.2 V, 3 V      |     |      | ±1               |      |
| C <sub>(VEREF+/-)</sub>                          | Capacitance at VREF+ and VREF- terminals      | See <sup>(5)</sup>                                                                                                       |                 | 10  |      |                  | μF   |

(1) The external reference is used during ADC conversion to charge and discharge the capacitance array. The input capacitance, C<sub>I</sub>, is also the dynamic load for an external reference during conversion. The dynamic impedance of the reference supply should follow the recommendations on analog-source impedance to allow the charge to settle for 10-bit accuracy.

(2) The accuracy limits the minimum positive external reference voltage. Lower reference voltage levels may be applied with reduced accuracy requirements.

(3) The accuracy limits the maximum negative external reference voltage. Higher reference voltage levels may be applied with reduced accuracy requirements.

(4) The accuracy limits minimum external differential reference voltage. Lower differential reference voltage levels may be applied with reduced accuracy requirements.

(5) Two decoupling capacitors, 10 μF and 100 nF, should be connected to VREF to decouple the dynamic current required for an external reference source if it is used for the ADC10\_A. Also see the [MSP430x5xx and MSP430x6xx Family User's Guide](#).

## 5.42 REF, Built-In Reference (MSP430F51x2 Devices Only)

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  | TYP   | MAX  | UNIT   |
|------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------|------|-------|------|--------|
| V <sub>REF+</sub>            | REFVSEL = {2} for 2.5 V, REFON = 1                                                                                                                              | 3 V                            | 2.51 | ±1.5% |      | V      |
|                              | REFVSEL = {1} for 2.0 V, REFON = 1                                                                                                                              | 3 V                            | 1.99 | ±1.5% |      |        |
|                              | REFVSEL = {0} for 1.5 V, REFON = 1                                                                                                                              | 2.2 V, 3 V                     | 1.5  | ±1.5% |      |        |
| AV <sub>CC(min)</sub>        | REFVSEL = {0} for 1.5 V                                                                                                                                         |                                | 1.8  |       |      | V      |
|                              | REFVSEL = {1} for 2.0 V                                                                                                                                         |                                | 2.3  |       |      |        |
|                              | REFVSEL = {2} for 2.5 V                                                                                                                                         |                                | 2.8  |       |      |        |
| I <sub>REF+</sub>            | f <sub>ADC10CLK</sub> = 5 MHz, REFON = 1, REFBURST = 0, REFVSEL = {0} for 1.5 V                                                                                 | 3 V                            | 15.5 |       | 19   | μA     |
|                              | f <sub>ADC10CLK</sub> = 5 MHz, REFON = 1, REFBURST = 0, REFVSEL = {1} for 2.0 V                                                                                 | 3 V                            | 18   |       | 24   |        |
|                              | f <sub>ADC10CLK</sub> = 5 MHz, REFON = 1, REFBURST = 0, REFVSEL = {2} for 2.5 V                                                                                 | 3 V                            | 21   |       | 30   |        |
| TC <sub>REF+</sub>           | REFVSEL = {0, 1, 2}, REFON = 1                                                                                                                                  |                                | 30   |       | 50   | ppm/°C |
| I <sub>SENSOR</sub>          | REFON = 1, INCH = 0Ah, ADC10ON = 1, T <sub>A</sub> = 30°C                                                                                                       | 2.2 V                          | 150  |       | 180  | μA     |
|                              |                                                                                                                                                                 | 3 V                            | 150  |       | 190  |        |
| V <sub>SENSOR</sub>          | REFON = 1, INCH = 0Ah, ADC10ON = 1, T <sub>A</sub> = 30°C                                                                                                       | 2.2 V                          | 765  |       |      | mV     |
|                              |                                                                                                                                                                 | 3 V                            | 765  |       |      |        |
| V <sub>MID</sub>             | ADC10ON = 1, INCH = 0Bh, V <sub>MID</sub> ≈ 0.5 × V <sub>AVCC</sub>                                                                                             | 2.2 V                          | 1.06 | 1.1   | 1.14 | V      |
|                              |                                                                                                                                                                 | 3 V                            | 1.46 | 1.5   | 1.54 |        |
| t <sub>SENSOR (sample)</sub> | ADC10ON = 1, INCH = 0Ah, Error of conversion result ≤ 1 LSB                                                                                                     |                                | 30   |       |      | μs     |
| t <sub>VMID (sample)</sub>   | ADC10ON = 1, INCH = 0Bh, Error of conversion result ≤ 1 LSB                                                                                                     |                                | 1    |       |      | μs     |
| PSRR <sub>DC</sub>           | 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}, REFON = 1                                       |                                | 120  |       | 300  | μV/V   |
| PSRR <sub>AC</sub>           | AV <sub>CC</sub> = AV <sub>CC(min)</sub> to AV <sub>CC(max)</sub> , T <sub>A</sub> = 25°C, f = 1 kHz, ΔV <sub>pp</sub> = 100 mV, REFVSEL = {0, 1, 2}, REFON = 1 |                                | 6.4  |       |      | mV/V   |
| t <sub>SETTLE</sub>          | AV <sub>CC</sub> = AV <sub>CC(min)</sub> to AV <sub>CC(max)</sub> , REFVSEL = {0, 1, 2}, REFON = 0 → 1                                                          | T <sub>A</sub> = –40°C to 85°C |      | 23    | 125  | μs     |
|                              |                                                                                                                                                                 | T <sub>A</sub> = 25°C          |      | 23    | 50   |        |
|                              |                                                                                                                                                                 | T <sub>A</sub> = 85°C          |      | 16    | 25   |        |

- (1) The leakage current is defined in the leakage current table with P6.x/Ax parameter.
- (2) The internal reference current is supplied through the AV<sub>CC</sub> terminal. Consumption is independent of the ADC10ON control bit, unless a conversion is active. The REFON bit enables to settle the built-in reference before starting an A/D conversion.
- (3) Calculated using the box method: (MAX(–40°C to 85°C) – MIN(–40°C to 85°C)) / MIN(–40°C to 85°C) / (85°C – (–40°C)).
- (4) The sensor current I<sub>SENSOR</sub> is consumed if (ADC10ON = 1 and REFON = 1) or (ADC10ON = 1 and INCH = 0Ah and sample signal is high). When REFON = 1, I<sub>SENSOR</sub> is already included in I<sub>REF+</sub>.
- (5) The temperature sensor offset can be as much as ±20°C. TI recommends a single-point calibration to minimize the offset error of the built-in temperature sensor.
- (6) The typical equivalent impedance of the sensor is 51 kΩ. The sample time required includes the sensor-on time t<sub>SENSOR(on)</sub>.
- (7) The on-time t<sub>VMID(on)</sub> is included in the sampling time t<sub>VMID(sample)</sub>; no additional on time is needed.
- (8) The condition is that the error in a conversion started after t<sub>REFON</sub> is less than ±0.5 LSB.

## 5.43 Comparator\_B

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>CC</sub>        | Supply voltage                                                                    |                                                                                     |                 | 1.8                              |                                | 3.6                              | V      |
| I <sub>AVCC_COMP</sub> | Comparator operating supply current into AVCC, Excludes reference resistor ladder | CBPWRMD = 00, CBON = 1, CBR <sub>Sx</sub> = 00                                      | 1.8 V           |                                  |                                | 38                               | μA     |
|                        |                                                                                   |                                                                                     | 2.2 V           |                                  | 31                             | 38                               |        |
|                        |                                                                                   |                                                                                     | 3 V             |                                  | 32                             | 39                               |        |
|                        |                                                                                   | CBPWRMD = 01, CBON = 1, CBR <sub>Sx</sub> = 00                                      | 2.2 V, 3 V      |                                  | 10                             | 17                               |        |
|                        |                                                                                   | CBPWRMD = 10, CBON = 1, CBR <sub>Sx</sub> = 00                                      | 2.2 V, 3 V      |                                  | 0.2                            | 0.85                             |        |
| V <sub>REF</sub>       | Reference voltage level                                                           | CBREFL <sub>x</sub> = 01, CBREFACC = 0                                              | ≥1.8 V          | 1.42                             | 1.44                           | 1.46                             | V      |
|                        |                                                                                   | CBREFL <sub>x</sub> = 10, CBREFACC = 0                                              | ≥2.2 V          | 1.89                             | 1.92                           | 1.95                             |        |
|                        |                                                                                   | CBREFL <sub>x</sub> = 11, CBREFACC = 0                                              | ≥3.0 V          | 2.35                             | 2.39                           | 2.43                             |        |
| I <sub>AVCC_REF</sub>  | Quiescent current of resistor ladder into AVCC, Including REF module current      | CBREFACC = 1, CBREFL <sub>x</sub> = 01, CBR <sub>Sx</sub> = 10, REFON = 0, CBON = 0 | 2.2 V, 3 V      |                                  | 10                             | 17                               | μA     |
|                        |                                                                                   | CBREFACC = 0, CBREFL <sub>x</sub> = 01, CBR <sub>Sx</sub> = 10, REFON = 0, CBON = 0 | 2.2 V, 3 V      |                                  | 33                             | 40                               |        |
| V <sub>IC</sub>        | Common mode input range                                                           |                                                                                     |                 | 0                                |                                | V <sub>CC</sub> – 1              | V      |
| V <sub>OFFSET</sub>    | Input offset voltage                                                              | CBPWRMD = 00                                                                        |                 |                                  |                                | ±20                              | mV     |
|                        |                                                                                   | CBPWRMD = 01, 10                                                                    |                 |                                  |                                | ±10                              |        |
| C <sub>IN</sub>        | Input capacitance                                                                 |                                                                                     |                 |                                  | 5                              |                                  | pF     |
| R <sub>SIN</sub>       | Series input resistance                                                           | On (switch closed)                                                                  |                 |                                  | 3                              | 4                                | kΩ     |
|                        |                                                                                   | Off (switch opened)                                                                 |                 | 50                               |                                |                                  | MΩ     |
| t <sub>PD</sub>        | Propagation delay, response time                                                  | CBPWRMD = 00, CBF = 0                                                               |                 |                                  |                                | 450                              | ns     |
|                        |                                                                                   | CBPWRMD = 01, CBF = 0                                                               |                 |                                  |                                | 600                              |        |
|                        |                                                                                   | CBPWRMD = 10, CBF = 0                                                               |                 |                                  |                                | 50                               | μs     |
| t <sub>PD,filter</sub> | Propagation delay with filter active                                              | CBPWRMD = 00, CBON = 1, CBF = 1, CBF <sub>DLY</sub> = 00                            |                 | 0.35                             | 0.6                            | 1.5                              | μs     |
|                        |                                                                                   | CBPWRMD = 00, CBON = 1, CBF = 1, CBF <sub>DLY</sub> = 01                            |                 | 0.6                              | 1.0                            | 1.8                              |        |
|                        |                                                                                   | CBPWRMD = 00, CBON = 1, CBF = 1, CBF <sub>DLY</sub> = 10                            |                 | 1.0                              | 1.8                            | 3.4                              |        |
|                        |                                                                                   | CBPWRMD = 00, CBON = 1, CBF = 1, CBF <sub>DLY</sub> = 11                            |                 | 1.8                              | 3.4                            | 6.5                              |        |
| t <sub>EN_CMP</sub>    | Comparator enable time                                                            | CBON = 0 → 1, CBPWRMD = 00 or 01                                                    |                 |                                  | 1                              | 2                                | μs     |
|                        |                                                                                   | CBON = 0 → 1, CBPWRMD = 10                                                          |                 |                                  |                                | 100                              |        |
| t <sub>EN_REF</sub>    | Resistor reference enable time                                                    | CBON = 0 to CBON = 1                                                                |                 |                                  | 1.0                            | 1.5                              | μs     |
| TC <sub>CB_REF</sub>   | Temperature coefficient reference of V <sub>CB_REF</sub>                          |                                                                                     |                 |                                  |                                | 50                               | ppm/°C |
| V <sub>CB_REF</sub>    | Reference voltage for a given tap                                                 | V <sub>IN</sub> = reference into resistor ladder, n = 0 to 31                       |                 | V <sub>IN</sub> × (n + 0.5) / 32 | V <sub>IN</sub> × (n + 1) / 32 | V <sub>IN</sub> × (n + 1.5) / 32 | V      |

## 5.44 Timer\_D, Power Supply and Reference Clock

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 | TYP | MAX  | UNIT |
|------------------------|--------------------------------------------------------------------|---------------------------------------------------------------------------------|---------------------------------------|-----|-----|------|------|
| DV <sub>CC</sub>       | Digital supply voltage                                             | V <sub>(DVSS)</sub> = 0 V                                                       |                                       | 1.8 |     | 3.6  | V    |
| f <sub>REF,DCO</sub>   | Timer_D input reference clock frequency                            | PMMCOREVx = 0                                                                   | 1.8 V<br>≤ V <sub>CC</sub><br>≤ 3.6 V | 8   |     | 12.0 | MHz  |
|                        |                                                                    | PMMCOREVx = 1                                                                   | 2.0 V<br>≤ V <sub>CC</sub><br>≤ 3.6 V | 8   |     | 16.0 |      |
|                        |                                                                    | PMMCOREVx = 2                                                                   | 2.2 V<br>≤ V <sub>CC</sub><br>≤ 3.6 V | 8   |     | 20.0 |      |
|                        |                                                                    | PMMCOREVx = 3                                                                   | 2.4 V<br>≤ V <sub>CC</sub><br>≤ 3.6 V | 8   |     | 25.5 |      |
| I <sub>(64MHz)</sub>   | I <sub>(DVCC)</sub> at 64-MHz Timer_D clock, clock generator only  | f <sub>reference</sub> = 8 MHz, MCx = 0, TDHREGEN = 1, TDHMX = 0, TDHCLKCR = 0  |                                       |     | 253 | 320  | μA   |
| I <sub>(128MHz)</sub>  | I <sub>(DVCC)</sub> at 128-MHz Timer_D clock, clock generator only | f <sub>reference</sub> = 16 MHz, MCx = 0, TDHREGEN = 1, TDHMX = 0, TDHCLKCR = 0 |                                       |     | 285 | 360  | μA   |
| I <sub>(200MHz)</sub>  | I <sub>(DVCC)</sub> at 200-MHz Timer_D clock, clock generator only | f <sub>reference</sub> = 25 MHz, MCx = 0, TDHREGEN = 1, TDHMX = 0, TDHCLKCR = 1 |                                       |     | 280 | 345  | μA   |
| I <sub>(256MHz)</sub>  | I <sub>(DVCC)</sub> at 256-MHz Timer_D clock, clock generator only | f <sub>reference</sub> = 16 MHz, MCx = 0, TDHREGEN = 1, TDHMX = 1, TDHCLKCR = 1 |                                       |     | 265 | 330  | μA   |
| I <sub>(0,16,64)</sub> | I <sub>(DVCC)</sub>                                                | TDHCLKRx = 0, TDHCLKSRx = 16, TDHCLKTRIM = 64                                   | 2.2 V                                 |     | 244 |      | μA   |
|                        |                                                                    |                                                                                 | 3.0 V                                 |     | 295 | 325  |      |
| I <sub>(1,16,64)</sub> | I <sub>(DVCC)</sub>                                                | TDHCLKRx = 1, TDHCLKSRx = 16, TDHCLKTRIM = 64                                   | 2.2 V                                 |     | 282 |      | μA   |
|                        |                                                                    |                                                                                 | 3.0 V                                 |     | 300 | 400  |      |
| I <sub>(2,16,64)</sub> | I <sub>(DVCC)</sub>                                                | TDHCLKRx = 2, TDHCLKSRx = 16, TDHCLKTRIM = 64                                   | 2.2 V                                 |     | 358 |      | μA   |
|                        |                                                                    |                                                                                 | 3.0 V                                 |     | 414 | 470  |      |

(1) The leakage current is defined in the leakage current table with P6.x/Ax parameter.

## 5.45 Timer\_D, Local Clock Generator Frequency

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

| PARAMETER                                               | TEST CONDITIONS                                                                       | MIN | TYP | MAX | UNIT |
|---------------------------------------------------------|---------------------------------------------------------------------------------------|-----|-----|-----|------|
| $f_{\text{HRCG}(0,0,64)}$ HRCG frequency (0, 0, 64)     | TDHREGEN = 0, TDHMx = 0, TDHCLKCR = 1, TDHCLKRx = 0, TDHCLKSRx = 0, TDHCLKTRIM = 64   | 39  | 56  | 73  | MHz  |
|                                                         | TDHREGEN = 0, TDHMx = 1, TDHCLKCR = 1, TDHCLKRx = 0, TDHCLKSRx = 0, TDHCLKTRIM = 64   | 78  | 112 | 146 |      |
| $f_{\text{HRCG}(0,7,64)}$ HRCG frequency (0, 7, 64)     | TDHREGEN = 0, TDHMx = 0, TDHCLKCR = 1, TDHCLKRx = 0, TDHCLKSRx = 7, TDHCLKTRIM = 64   | 46  | 66  | 86  | MHz  |
|                                                         | TDHREGEN = 0, TDHMx = 1, TDHCLKCR = 1, TDHCLKRx = 0, TDHCLKSRx = 7, TDHCLKTRIM = 64   | 92  | 132 | 172 |      |
| $f_{\text{HRCG}(0,15,64)}$ HRCG frequency (0, 15, 64)   | TDHREGEN = 0, TDHMx = 0, TDHCLKCR = 1, TDHCLKRx = 0, TDHCLKSRx = 15, TDHCLKTRIM = 64  | 55  | 78  | 101 | MHz  |
|                                                         | TDHREGEN = 0, TDHMx = 1, TDHCLKCR = 1, TDHCLKRx = 0, TDHCLKSRx = 15, TDHCLKTRIM = 64  | 110 | 156 | 202 |      |
| $f_{\text{HRCG}(0,23,64)}$ HRCG frequency (0, 23, 64)   | TDHREGEN = 0, TDHMx = 0, TDHCLKCR = 1, TDHCLKRx = 0, TDHCLKSRx = 23, TDHCLKTRIM = 64  | 61  | 87  | 113 | MHz  |
|                                                         | TDHREGEN = 0, TDHMx = 1, TDHCLKCR = 1, TDHCLKRx = 0, TDHCLKSRx = 23, TDHCLKTRIM = 64  | 122 | 174 | 226 |      |
| $f_{\text{HRCG}(0,31,0)}$ HRCG frequency (0, 31, 0)     | TDHREGEN = 0, TDHMx = 0, TDHCLKCR = 1, TDHCLKRx = 0, TDHCLKSRx = 31, TDHCLKTRIM = 0   | 36  | 56  | 73  | MHz  |
|                                                         | TDHREGEN = 0, TDHMx = 1, TDHCLKCR = 1, TDHCLKRx = 0, TDHCLKSRx = 31, TDHCLKTRIM = 0   | 72  | 112 | 146 |      |
| $f_{\text{HRCG}(0,31,64)}$ HRCG frequency (0, 31, 64)   | TDHREGEN = 0, TDHMx = 0, TDHCLKCR = 1, TDHCLKRx = 0, TDHCLKSRx = 31, TDHCLKTRIM = 64  | 68  | 98  | 128 | MHz  |
|                                                         | TDHREGEN = 0, TDHMx = 1, TDHCLKCR = 1, TDHCLKRx = 0, TDHCLKSRx = 31, TDHCLKTRIM = 64  | 136 | 196 | 256 |      |
| $f_{\text{HRCG}(0,31,127)}$ HRCG frequency (0, 31, 127) | TDHREGEN = 0, TDHMx = 0, TDHCLKCR = 1, TDHCLKRx = 0, TDHCLKSRx = 31, TDHCLKTRIM = 127 | 97  | 138 | 180 | MHz  |
|                                                         | TDHREGEN = 0, TDHMx = 1, TDHCLKCR = 1, TDHCLKRx = 0, TDHCLKSRx = 31, TDHCLKTRIM = 127 | 196 | 176 | 360 |      |
| $f_{\text{HRCG}(1,0,64)}$ HRCG frequency (1, 0, 64)     | TDHREGEN = 0, TDHMx = 0, TDHCLKCR = 0, TDHCLKRx = 1, TDHCLKSRx = 0, TDHCLKTRIM = 64   | 71  | 101 | 131 | MHz  |
|                                                         | TDHREGEN = 0, TDHMx = 1, TDHCLKCR = 0, TDHCLKRx = 1, TDHCLKSRx = 0, TDHCLKTRIM = 64   | 142 | 202 | 262 |      |
| $f_{\text{HRCG}(1,7,64)}$ HRCG frequency (1, 7, 64)     | TDHREGEN = 0, TDHMx = 0, TDHCLKCR = 0, TDHCLKRx = 1, TDHCLKSRx = 7, TDHCLKTRIM = 64   | 84  | 120 | 156 | MHz  |
|                                                         | TDHREGEN = 0, TDHMx = 1, TDHCLKCR = 0, TDHCLKRx = 1, TDHCLKSRx = 7, TDHCLKTRIM = 64   | 168 | 240 | 312 |      |
| $f_{\text{HRCG}(1,15,64)}$ HRCG frequency (1, 15, 64)   | TDHREGEN = 0, TDHMx = 0, TDHCLKCR = 0, TDHCLKRx = 1, TDHCLKSRx = 15, TDHCLKTRIM = 64  | 97  | 139 | 182 | MHz  |
|                                                         | TDHREGEN = 0, TDHMx = 1, TDHCLKCR = 0, TDHCLKRx = 1, TDHCLKSRx = 15, TDHCLKTRIM = 64  | 196 | 278 | 364 |      |
| $f_{\text{HRCG}(1,23,64)}$ HRCG frequency (1, 23, 64)   | TDHREGEN = 0, TDHMx = 0, TDHCLKCR = 0, TDHCLKRx = 1, TDHCLKSRx = 23, TDHCLKTRIM = 64  | 108 | 154 | 200 | MHz  |
|                                                         | TDHREGEN = 0, TDHMx = 1, TDHCLKCR = 0, TDHCLKRx = 1, TDHCLKSRx = 23, TDHCLKTRIM = 64  | 216 | 308 | 400 |      |
| $f_{\text{HRCG}(1,31,0)}$ HRCG frequency (1, 31, 0)     | TDHREGEN = 0, TDHMx = 0, TDHCLKCR = 0, TDHCLKRx = 1, TDHCLKSRx = 31, TDHCLKTRIM = 0   | 68  | 97  | 126 | MHz  |
|                                                         | TDHREGEN = 0, TDHMx = 1, TDHCLKCR = 0, TDHCLKRx = 1, TDHCLKSRx = 31, TDHCLKTRIM = 0   | 136 | 194 | 252 |      |
| $f_{\text{HRCG}(1,31,64)}$ HRCG frequency (1, 31, 64)   | TDHREGEN = 0, TDHMx = 0, TDHCLKCR = 0, TDHCLKRx = 1, TDHCLKSRx = 31, TDHCLKTRIM = 64  | 123 | 175 | 227 | MHz  |
|                                                         | TDHREGEN = 0, TDHMx = 1, TDHCLKCR = 0, TDHCLKRx = 1, TDHCLKSRx = 31, TDHCLKTRIM = 64  | 246 | 350 | 454 |      |

## Timer\_D, Local Clock Generator Frequency (continued)

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

| PARAMETER                       |                                                            | TEST CONDITIONS                                                                                                        | MIN | TYP | MAX  | UNIT |
|---------------------------------|------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------|-----|-----|------|------|
| $f_{\text{HRCG}(1,31,127)}$     | HRCG frequency (1, 31, 127)                                | TDHREGEN = 0, TDHMx = 0, TDHCLKCR = 0,<br>TDHCLKRx = 1, TDHCLKSRx = 31,<br>TDHCLKTRIM = 127                            | 169 | 241 | 313  | MHz  |
|                                 |                                                            | TDHREGEN = 0, TDHMx = 1, TDHCLKCR = 0,<br>TDHCLKRx = 1, TDHCLKSRx = 31,<br>TDHCLKTRIM = 127                            | 338 | 482 | 616  |      |
| $f_{\text{HRCG}(2,0,64)}$       | HRCG frequency (2, 0, 64)                                  | TDHREGEN = 0, TDHMx = 0, TDHCLKCR = 1,<br>TDHCLKRx = 2, TDHCLKSRx = 0, TDHCLKTRIM = 64                                 | 126 | 180 | 234  | MHz  |
|                                 |                                                            | TDHREGEN = 0, TDHMx = 1, TDHCLKCR = 1,<br>TDHCLKRx = 1, TDHCLKSRx = 0, TDHCLKTRIM = 64                                 | 252 | 360 | 468  |      |
| $f_{\text{HRCG}(2,7,64)}$       | HRCG frequency (2, 7, 64)                                  | TDHREGEN = 0, TDHMx = 0, TDHCLKCR = 1,<br>TDHCLKRx = 2, TDHCLKSRx = 7, TDHCLKTRIM = 64                                 | 138 | 208 | 270  | MHz  |
|                                 |                                                            | TDHREGEN = 0, TDHMx = 1, TDHCLKCR = 1,<br>TDHCLKRx = 2, TDHCLKSRx = 7, TDHCLKTRIM = 6                                  | 276 | 416 | 540  |      |
| $f_{\text{HRCG}(2,15,64)}$      | HRCG frequency (2, 15, 64)                                 | TDHREGEN = 0, TDHMx = 0, TDHCLKCR = 1,<br>TDHCLKRx = 2, TDHCLKSRx = 15, TDHCLKTRIM = 64                                | 168 | 240 | 312  | MHz  |
|                                 |                                                            | TDHREGEN = 0, TDHMx = 1, TDHCLKCR = 1,<br>TDHCLKRx = 2, TDHCLKSRx = 15, TDHCLKTRIM = 64                                | 336 | 480 | 624  |      |
| $f_{\text{HRCG}(2,23,64)}$      | HRCG frequency (2, 23, 64)                                 | TDHREGEN = 0, TDHMx = 0, TDHCLKCR = 1,<br>TDHCLKRx = 2, TDHCLKSRx = 23, TDHCLKTRIM = 64                                | 189 | 270 | 351  | MHz  |
|                                 |                                                            | TDHREGEN = 0, TDHMx = 1, TDHCLKCR = 1,<br>TDHCLKRx = 2, TDHCLKSRx = 23, TDHCLKTRIM = 64                                | 378 | 540 | 702  |      |
| $f_{\text{HRCG}(2,31,0)}$       | HRCG frequency (2, 31, 0)                                  | TDHREGEN = 0, TDHMx = 0, TDHCLKCR = 1,<br>TDHCLKRx = 2, TDHCLKSRx = 31, TDHCLKTRIM = 0                                 | 119 | 170 | 221  | MHz  |
|                                 |                                                            | TDHREGEN = 0, TDHMx = 1, TDHCLKCR = 1,<br>TDHCLKRx = 2, TDHCLKSRx = 31, TDHCLKTRIM = 0                                 | 238 | 340 | 442  |      |
| $f_{\text{HRCG}(2,31,64)}$      | HRCG frequency (2, 31, 64)                                 | TDHREGEN = 0, TDHMx = 0, TDHCLKCR = 1,<br>TDHCLKRx = 2, TDHCLKSRx = 31, TDHCLKTRIM = 64                                | 212 | 303 | 394  | MHz  |
|                                 |                                                            | TDHREGEN = 0, TDHMx = 1, TDHCLKCR = 1,<br>TDHCLKRx = 2, TDHCLKSRx = 31, TDHCLKTRIM = 64                                | 424 | 606 | 788  |      |
| $f_{\text{HRCG}(2,31,127)}$     | HRCG frequency (2, 31, 127)                                | TDHREGEN = 0, TDHMx = 0, TDHCLKCR = 1,<br>TDHCLKRx = 2, TDHCLKSRx = 31,<br>TDHCLKTRIM = 127                            | 290 | 413 | 537  | MHz  |
|                                 |                                                            | TDHREGEN = 0, TDHMx = 1, TDHCLKCR = 1,<br>TDHCLKRx = 2, TDHCLKSRx = 31,<br>TDHCLKTRIM = 127                            | 580 | 826 | 1074 |      |
| $S_{\text{HRCG},0,\text{SR}}$   | TDHCLKSRx step size in range 0                             | $S_{\text{HRCGSR}} = f_{\text{HRCGSR}(\text{HRCGSR}+1)} - f_{\text{HRCG}(\text{HRCGSR})}$                              | 120 | 185 | 225  | kHz  |
| $S_{\text{HRCG},1,\text{SR}}$   | TDHCLKSRx step size in range 1                             | $S_{\text{HRCGSR}} = f_{\text{HRCGSR}(\text{HRCGSR}+1)} - f_{\text{HRCG}(\text{HRCGSR})}$                              | 220 | 325 | 395  | kHz  |
| $S_{\text{HRCG},2,\text{SR}}$   | TDHCLKSRx step size in range 2                             | $S_{\text{HRCGSR}} = f_{\text{HRCGSR}(\text{HRCGSR}+1)} - f_{\text{HRCG}(\text{HRCGSR})}$                              | 400 | 555 | 700  | kHz  |
| $S_{\text{HRCG},0,\text{TRIM}}$ | $0 \geq \text{TDHCLKTRIMx} < 16$ ,<br>step size in range 0 | $S_{\text{HRCGSR}} = f_{\text{HRCGSR}(\text{HRCGTRIM}+1)} - f_{\text{HRCG}(\text{HRCGTRIM})}$ ,<br>TDHCLKSRx = X, Y, Z | 55  | 85  | 120  | kHz  |
|                                 | $15 < \text{TDHCLKTRIMx} < 49$ ,<br>step size in range 1   |                                                                                                                        | 40  | 85  | 130  |      |
|                                 | $48 < \text{TDHCLKTRIMx} < 64$ ,<br>step size in range 2   |                                                                                                                        | 40  | 85  | 120  |      |
| $S_{\text{HRCG},1,\text{TRIM}}$ | $0 \geq \text{TDHCLKTRIMx} < 16$ ,<br>step size in range 0 | $S_{\text{HRCGSR}} = f_{\text{HRCGSR}(\text{HRCGTRIM}+1)} - f_{\text{HRCG}(\text{HRCGTRIM})}$ ,<br>TDHCLKSRx = X, Y, Z | 90  | 160 | 230  | kHz  |
|                                 | $15 < \text{TDHCLKTRIMx} < 49$ ,<br>step size in range 1   |                                                                                                                        | 80  | 160 | 230  |      |
|                                 | $48 < \text{TDHCLKTRIMx} < 64$ ,<br>step size in range 2   |                                                                                                                        | 80  | 160 | 230  |      |

## Timer\_D, Local Clock Generator Frequency (continued)

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

| PARAMETER                                  |                                                | TEST CONDITIONS                                                                                               | MIN | TYP | MAX   | UNIT |
|--------------------------------------------|------------------------------------------------|---------------------------------------------------------------------------------------------------------------|-----|-----|-------|------|
| S <sub>HRCG,2,TRIM</sub>                   | 0 >= TDHCLKTRIMx < 16,<br>step size in range 0 | S <sub>HRCGSR</sub> = f <sub>HRCGSR</sub> (HRCGTRIM+1) – f <sub>HRCG</sub> (HRCGTRIM),<br>TDHCLKSRx = X, Y, Z | 150 | 230 | 360   | kHz  |
|                                            | 15 < TDHCLKTRIMx < 49,<br>step size in range 1 |                                                                                                               | 130 | 230 | 350   |      |
|                                            | 48 < TDHCLKTRIMx < 32,<br>step size in range 2 |                                                                                                               | 100 | 230 | 340   |      |
| df <sub>HRCG</sub> /dT                     | HRCG frequency<br>temperature drift            | f <sub>HRCG</sub> = 8 MHz, TDHREGEN = 0                                                                       |     |     | ±0.17 | %/°C |
|                                            |                                                | f <sub>HRCG</sub> = 16 MHz, TDHREGEN = 0                                                                      |     |     | ±0.16 |      |
|                                            |                                                | f <sub>HRCG</sub> = 25 MHz, TDHREGEN = 0                                                                      |     |     | ±0.16 |      |
|                                            |                                                | f <sub>HRCG</sub> = 8, 16, or 25 MHz, TDHREGEN = 1                                                            |     | 0   |       |      |
| df <sub>HRCG</sub> /<br>dV <sub>DVCC</sub> | HRCG frequency voltage drift                   | f <sub>HRCG</sub> = 8, 16, or 25 MHz, TDHREGEN = 0                                                            | 0   |     | 5     | %/V  |
|                                            |                                                | f <sub>HRCG</sub> = 8, 16, or 25 MHz, TDHREGEN = 1                                                            |     | 0   |       |      |
| t <sub>SETTLE</sub>                        | Settling time                                  | TDHEN = 0 → 1, TDHFW = 0                                                                                      | 3   | 5   | 9     | μs   |
|                                            | Settling time, fast wake-up                    | TDHEN = 0 → 1, TDHFW = 1                                                                                      |     |     | 1.5   |      |

## 5.46 Timer\_D, Trimmed Clock Frequencies

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

| PARAMETER                           |                                                                   | TEST CONDITIONS                                   | MIN   | TYP | MAX   | UNIT |
|-------------------------------------|-------------------------------------------------------------------|---------------------------------------------------|-------|-----|-------|------|
| Frequency tolerance during trimming |                                                                   |                                                   | –0.5% |     | +0.5% |      |
| f <sub>TRIM(64MHz)</sub>            | TDHMx = 0, TDHREGEN = 0, TDHCLKCR = 0,<br>TDHxCTL1 = TDHxCTL1_64  | T <sub>A</sub> = 25°C,<br>V <sub>CC</sub> = 1.8 V | 63    | 64  | 65    | MHz  |
| f <sub>TRIM(128MHz)</sub>           | TDHMx = 0, TDHREGEN = 0, TDHCLKCR = 1,<br>TDHxCTL1 = TDHxCTL1_128 | T <sub>A</sub> = 25°C,<br>V <sub>CC</sub> = 2.0 V | 126   | 128 | 130   | MHz  |
| f <sub>TRIM(200MHz)</sub>           | TDHMx = 0, TDHREGEN = 0, TDHCLKCR = 1,<br>TDHxCTL1 = TDHxCTL1_200 | T <sub>A</sub> = 25°C,<br>V <sub>CC</sub> = 2.4 V | 197   | 200 | 203   | MHz  |
| f <sub>TRIM(256MHz)</sub>           | TDHMx = 1, TDHREGEN = 0, TDHCLKCR = 1,<br>TDHxCTL1 = TDHxCTL1_256 | T <sub>A</sub> = 25°C,<br>V <sub>CC</sub> = 2.2 V | 250   | 256 | 262   | MHz  |

## 5.47 Timer\_D, Frequency Multiplication Mode

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

| PARAMETER                       |                                                                                         | TEST CONDITIONS                                   | MIN | TYP | MAX | UNIT |
|---------------------------------|-----------------------------------------------------------------------------------------|---------------------------------------------------|-----|-----|-----|------|
| External frequency tolerance    |                                                                                         |                                                   |     | 0%  |     |      |
| E <sub>(TDHREGEN = 1,64)</sub>  | f <sub>reference</sub> = 8 MHz, TDHMx = 0, TDHREGEN = 1,<br>TDHCLKCR = 0, TDHCLKRx = 0  | T <sub>A</sub> = 25°C,<br>V <sub>CC</sub> = 1.8 V | –1% |     | +1% |      |
| E <sub>(TDHREGEN = 1,128)</sub> | f <sub>reference</sub> = 16 MHz, TDHMx = 0, TDHREGEN = 1,<br>TDHCLKCR = 1, TDHCLKRx = 0 | T <sub>A</sub> = 25°C,<br>V <sub>CC</sub> = 2.0 V | –1% |     | +1% |      |
| E <sub>(TDHREGEN = 1,200)</sub> | f <sub>reference</sub> = 25 MHz, TDHMx = 0, TDHREGEN = 1,<br>TDHCLKCR = 1, TDHCLKRx = 0 | T <sub>A</sub> = 25°C,<br>V <sub>CC</sub> = 2.4 V | –1% |     | +1% |      |
| E <sub>(TDHREGEN = 1,256)</sub> | f <sub>reference</sub> = 16 MHz, TDHMx = 1, TDHREGEN = 1,<br>TDHCLKCR = 1, TDHCLKRx = 0 | T <sub>A</sub> = 25°C,<br>V <sub>CC</sub> = 2.2 V | –1% |     | +1% |      |

## 5.48 Timer\_D, Input Capture and Output Compare Timing

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

| PARAMETER                |                                                                                                                                               | TEST CONDITIONS                                       | MIN | TYP | MAX | UNIT |
|--------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------|-----|-----|-----|------|
| $t_{TD,cap}$             | Timer_D input capture timing, minimum pulse duration to trigger input capture event                                                           | $f_{MAX} = 262 \text{ MHz}$                           |     | 4   |     | ns   |
| $t_{TD0,cap,matching}$   | Timer0_D input capture timing, matching between input capture channels P1.6 to P1.7 and P2.0                                                  | $f_{MAX} = 262 \text{ MHz}$                           |     | 1   | 2   | LSB  |
|                          | Timer0_D input capture timing, matching between input capture channels. P2.4 to P2.5 and P2.6                                                 | $f_{MAX} = 262 \text{ MHz}$                           |     | 3   | 4   |      |
| $t_{TD1,cap,matching}$   | Timer1_D input capture timing, matching between input capture channels P2.1 to P2.2 and P2.3                                                  | $f_{MAX} = 262 \text{ MHz}$                           |     | 2   | 3   | LSB  |
|                          | Timer1_D input capture timing, matching between input capture channels. P2.7 to P3.0 and P3.1                                                 | $f_{MAX} = 262 \text{ MHz}$                           |     | 2   | 4   |      |
| $t_{TD01,cap,matching}$  | Timer0_D and Timer1_D input capture timing, matching between input capture channels. Timer0_D is the high-resolution clock generator source.  | $f_{MAX} = 262 \text{ MHz}$                           |     | 4   | 8   | LSB  |
| $t_{TD0,comp,matching}$  | Timer0_D output compare timing, matching between output capture compare channels for pins P1.6, P1.7, and P2.0                                | Rising edges, $f_{MAX} = 262 \text{ MHz}$             |     |     | 4   | ns   |
|                          |                                                                                                                                               | Falling edges, $f_{MAX} = 262 \text{ MHz}$            |     |     | 4   |      |
|                          |                                                                                                                                               | Rising and falling edges, $f_{MAX} = 262 \text{ MHz}$ |     |     | 8   |      |
| $t_{TD1,comp,matching}$  | Timer1_D output compare timing, matching between output capture compare channels for pins P2.1, P2.2, and P2.3                                | Rising edges, $f_{MAX} = 262 \text{ MHz}$             |     |     | 4   | ns   |
|                          |                                                                                                                                               | Falling edges, $f_{MAX} = 262 \text{ MHz}$            |     |     | 4   |      |
|                          |                                                                                                                                               | Rising and falling edges, $f_{MAX} = 262 \text{ MHz}$ |     |     | 8   |      |
| $t_{TD01,comp,matching}$ | Timer0_D and Timer1_D output compare timing, matching between output compare channels. Timer0_D is the high-resolution clock generator source | All edges, $f_{MAX} = 262 \text{ MHz}$                |     |     | 8   | LSB  |

## 5.49 Flash Memory

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

| PARAMETER                               |                                                                                                  | T <sub>J</sub> | MIN             | TYP             | MAX | UNIT   |
|-----------------------------------------|--------------------------------------------------------------------------------------------------|----------------|-----------------|-----------------|-----|--------|
| DV <sub>CC(PGM/ERASE)</sub>             | Program and erase supply voltage                                                                 |                | 1.8             |                 | 3.6 | V      |
| I <sub>PGM</sub>                        | Supply current from DV <sub>CC</sub> during program                                              |                |                 | 3               | 5   | mA     |
| I <sub>ERASE</sub>                      | Supply current from DV <sub>CC</sub> during erase                                                |                |                 | 2               | 6.5 | mA     |
| I <sub>MERASE</sub> , I <sub>BANK</sub> | Supply current from DV <sub>CC</sub> during mass erase or bank erase                             |                |                 | 2               | 6.5 | mA     |
| t <sub>CPT</sub>                        | Cumulative program time <sup>(1)</sup>                                                           |                |                 |                 | 16  | ms     |
|                                         | Program and erase endurance                                                                      |                | 10 <sup>4</sup> | 10 <sup>5</sup> |     | cycles |
| t <sub>Retention</sub>                  | Data retention duration                                                                          | 25°C           | 100             |                 |     | years  |
| t <sub>Word</sub>                       | Word or byte program time <sup>(2)</sup>                                                         |                | 64              |                 | 85  | μs     |
| t <sub>Block, 0</sub>                   | Block program time for first byte or word <sup>(2)</sup>                                         |                | 49              |                 | 65  | μs     |
| t <sub>Block, 1–(N–1)</sub>             | Block program time for each additional byte or word, except for last byte or word <sup>(2)</sup> |                | 37              |                 | 49  | μs     |
| t <sub>Block, N</sub>                   | Block program time for last byte or word <sup>(2)</sup>                                          |                | 55              |                 | 73  | μs     |
| t <sub>Mass Erase</sub>                 | Mass erase time <sup>(2)</sup>                                                                   |                | 23              |                 | 32  | ms     |
| t <sub>Seg Erase</sub>                  | Segment erase time <sup>(2)</sup>                                                                |                | 23              |                 | 32  | ms     |
| f <sub>MCLK,MGR</sub>                   | MCLK frequency in marginal read mode (FCLK4.MGR0 = 1 or FCTL4.MGR1 = 1)                          |                | 0               |                 | 1   | MHz    |

- (1) The cumulative program time must not be exceeded when writing to a 128-byte flash block. This parameter applies to all programming methods: individual word or byte write and block write modes.
- (2) These values are hardwired into the state machine of the flash controller.

## 5.50 JTAG 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 V      | 0     |     | 20  | MHz  |
| t <sub>SBW,Low</sub>  | Spy-Bi-Wire low clock pulse duration                                                 | 2.2 V, 3 V      | 0.025 |     | 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 V      |       |     | 1   | 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     |     | 5   | MHz  |
|                       |                                                                                      | 3 V             | 0     |     | 10  |      |
| R <sub>internal</sub> | Internal pulldown resistance on TEST                                                 | 2.2 V, 3 V      | 45    | 60  | 80  | kΩ   |

- (1) Tools that access the Spy-Bi-Wire interface must wait for the minimum t<sub>SBW,En</sub> time after pulling the TEST/SBWTCK pin high before applying the first SBWTCK clock edge.
- (2) f<sub>TCK</sub> may be restricted to meet the timing requirements of the module selected.

## 6 Detailed Description

### 6.1 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, stack pointer, status register, and constant generator, respectively. The remaining registers are general-purpose registers (see [Figure 6-1](#)).

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

|                          |           |
|--------------------------|-----------|
| Program Counter          | PC/R0     |
| Stack Pointer            | SP/R1     |
| Status Register          | SR/CG1/R2 |
| Constant Generator       | CG2/R3    |
| General-Purpose Register | R4        |
| General-Purpose Register | R5        |
| General-Purpose Register | R6        |
| General-Purpose Register | R7        |
| General-Purpose Register | R8        |
| General-Purpose Register | R9        |
| General-Purpose Register | R10       |
| General-Purpose Register | R11       |
| General-Purpose Register | R12       |
| General-Purpose Register | R13       |
| General-Purpose Register | R14       |
| General-Purpose Register | R15       |

**Figure 6-1. Integrated CPU Registers**

## 6.2 Instruction Set

The instruction set consists of the original 51 instructions with three formats and seven address modes and additional instructions for the expanded address range. Each instruction can operate on word and byte data. [Table 6-1](#) lists examples of the three types of instruction formats; [Table 6-2](#) lists the address modes.

**Table 6-1. Instruction Word Formats**

| FORMAT                            | EXAMPLE   | OPERATION                                 |
|-----------------------------------|-----------|-------------------------------------------|
| Dual operands, source-destination | ADD R4,R5 | $R4 + R5 \rightarrow R5$                  |
| Single operands, destination only | CALL R8   | $PC \rightarrow (TOS), R8 \rightarrow PC$ |
| Relative jump, un/conditional     | JNE       | Jump-on-equal bit = 0                     |

**Table 6-2. Address Mode Descriptions**

| ADDRESS MODE           | S <sup>(1)</sup> | D <sup>(1)</sup> | SYNTAX             | EXAMPLE          | OPERATION                                             |
|------------------------|------------------|------------------|--------------------|------------------|-------------------------------------------------------|
| Register               | +                | +                | MOV Rs,Rd          | MOV R10,R11      | $R10 \rightarrow R11$                                 |
| Indexed                | +                | +                | MOV X(Rn),Y(Rm)    | MOV 2(R5),6(R6)  | $M(2+R5) \rightarrow M(6+R6)$                         |
| Symbolic (PC relative) | +                | +                | MOV EDE,TONI       |                  | $M(EDE) \rightarrow M(TONI)$                          |
| Absolute               | +                | +                | MOV & MEM, & TCDAT |                  | $M(MEM) \rightarrow M(TCDAT)$                         |
| Indirect               | +                |                  | MOV @Rn,Y(Rm)      | MOV @R10,Tab(R6) | $M(R10) \rightarrow M(Tab+R6)$                        |
| Indirect autoincrement | +                |                  | MOV @Rn+,Rm        | MOV @R10+,R11    | $M(R10) \rightarrow R11$<br>$R10 + 2 \rightarrow R10$ |
| Immediate              | +                |                  | MOV #X,TONI        | MOV #45,TONI     | $\#45 \rightarrow M(TONI)$                            |

(1) S = source, D = destination

## 6.3 Operating Modes

The MSP430 has one active mode and six software-selectable low-power modes of operation. An interrupt event can wake up the device from any of the five low-power modes, service the request, and restore back to the low-power mode on return from the interrupt program.

Software can configure the following operating modes:

- Active mode (AM)
  - All clocks are active
- Low-power mode 0 (LPM0)
  - CPU is disabled
  - ACLK and SMCLK remain active
  - MCLK is disabled
  - FLL loop control remains active
- Low-power mode 1 (LPM1)
  - CPU is disabled
  - FLL loop control is disabled
  - ACLK and SMCLK remain active
  - MCLK is disabled
- Low-power mode 2 (LPM2)
  - CPU is disabled
  - MCLK, FLL loop control, and DCOCLK are disabled
  - DC generator of the DCO remains enabled
  - ACLK remains active
- Low-power mode 3 (LPM3)
  - CPU is disabled
  - MCLK, FLL loop control, and DCOCLK are disabled
  - DC generator of the DCO is disabled
  - ACLK remains active
- Low-power mode 4 (LPM4)
  - CPU is disabled
  - ACLK is disabled
  - MCLK, FLL loop control, and DCOCLK are disabled
  - DC generator of the DCO is disabled
  - Crystal oscillator is stopped
  - Complete data retention
- Low-power mode 5 (LPM4.5)
  - Internal regulator disabled
  - No data retention
  - Wake-up input from  $\overline{\text{RST/NMI}}$ , P1, and P2

## 6.4 Interrupt Vector Addresses

The interrupt vectors and the power-up start address are in the address range 0FFFFh to 0FF80h (see [Table 6-3](#)). The vector contains the 16-bit address of the appropriate interrupt-handler instruction sequence.

**Table 6-3. Interrupt Sources, Flags, and Vectors**

| INTERRUPT SOURCE                                                                                                    | INTERRUPT FLAG                                                                                                            | SYSTEM INTERRUPT | WORD ADDRESS | PRIORITY    |
|---------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|------------------|--------------|-------------|
| <b>System Reset</b><br>Power up<br>External reset<br>Watchdog time-out, key violation<br>Flash memory key violation | WDTIFG, KEYV (SYSRSTIV) <sup>(1) (2)</sup>                                                                                | Reset            | 0FFFEh       | 63, highest |
| <b>System NMI</b><br>PMM<br>Vacant memory access<br>JTAG mailbox                                                    | SVMLIFG, SVMHIFG, DLYLIFG, DLYHIFG,<br>VLRIFG, VLRHIFG, VMAIFG, JMBNIFG,<br>JMBOUTIFG (SYSSNIV) <sup>(1)</sup>            | (Non)maskable    | 0FFFCh       | 62          |
| <b>User NMI</b><br>NMI<br>Oscillator fault<br>Flash memory access violation                                         | NMIIFG, OFIFG, ACCVIFG (SYSUNIV) <sup>(1) (2)</sup>                                                                       | (Non)maskable    | 0FFFAh       | 61          |
| Comp_B                                                                                                              | CBIIFG, CBIFG (CBIV) <sup>(1) (3)</sup>                                                                                   | Maskable         | 0FFF8h       | 60          |
| TEC0                                                                                                                | TEC0FLTIFG, TEC0EXCLRIFG,<br>TEC0AXCLRIFG <sup>(1) (3)</sup>                                                              | Maskable         | 0FFF6h       | 59          |
| TD0                                                                                                                 | TD0CCR0 CCIFG0 <sup>(3)</sup>                                                                                             | Maskable         | 0FFF4h       | 58          |
| <b>TD0</b>                                                                                                          | TD0CCR1 CCIFG1, ... TD0CCR2 CCIFG2,<br>TD0IFG, TD0HFLIFG, TD0HFHIFG, TD0HLKIFG,<br>TD0HUNLKIFG (TD0IV) <sup>(1) (3)</sup> | Maskable         | 0FFF2h       | 57          |
| Watchdog Timer_A interval timer mode                                                                                | WDTIFG                                                                                                                    | Maskable         | 0FFF0h       | 56          |
| USCI_A0 receive or transmit                                                                                         | UCA0RXIFG, UCA0TXIFG (UCA0IV) <sup>(1) (3)</sup>                                                                          | Maskable         | 0FFEEh       | 55          |
| USCI_B0 receive or transmit                                                                                         | UCB0RXIFG, UCB0TXIFG, I <sup>2</sup> C Status Interrupt<br>Flags (UCB0IV) <sup>(1) (3)</sup>                              | Maskable         | 0FFECCh      | 54          |
| ADC10_A (MSP430F51x2 only)                                                                                          | ADC10IFG0, ADC10INIFG, ADC10LOIFG,<br>ADC10HIIFG, ADC10TOVIFG, ADC10OVIFG<br>(ADC10IV) <sup>(1) (3)</sup>                 | Maskable         | 0FFEAh       | 53          |
| TA0                                                                                                                 | TA0CCR0 CCIFG0 <sup>(3)</sup>                                                                                             | Maskable         | 0FFE8h       | 52          |
| TA0                                                                                                                 | TA0CCR1 CCIFG1 ... TA0CCR2 CCIFG2,<br>TA0IFG (TA0IV) <sup>(1) (3)</sup>                                                   | Maskable         | 0FFE6h       | 51          |
| DMA                                                                                                                 | DMA0IFG, DMA1IFG, DMA2IFG (DMAIV) <sup>(1) (3)</sup>                                                                      | Maskable         | 0FFE4h       | 50          |
| TEC1                                                                                                                | TEC1FLTIFG, TEC1EXCLRIFG,<br>TEC1AXCLRIFG <sup>(1) (3)</sup>                                                              | Maskable         | 0FFE2h       | 49          |
| TD1                                                                                                                 | TD1CCR0 CCIFG0 <sup>(3)</sup>                                                                                             | Maskable         | 0FFE0h       | 48          |
| TD1                                                                                                                 | TD1CCR1 CCIFG1 ... TD1CCR2 CCIFG2,<br>TD1IFG, TD1HFLIFG, TD1HFHIFG, TD1HLKIFG,<br>TD1HUNLKIFG (TD1IV) <sup>(1) (3)</sup>  | Maskable         | 0FFDEh       | 47          |
| I/O port P1                                                                                                         | P1IFG.0 to P1IFG.7 (P1IV) <sup>(1) (3)</sup>                                                                              | Maskable         | 0FFDCh       | 46          |
| I/O port P2                                                                                                         | P2IFG.0 to P2IFG.7 (P2IV) <sup>(1) (3)</sup>                                                                              | Maskable         | 0FFDAh       | 45          |
| Reserved                                                                                                            | Reserved <sup>(4)</sup>                                                                                                   |                  | 0FFD8h       | 44          |
|                                                                                                                     |                                                                                                                           |                  | ⋮            | ⋮           |
|                                                                                                                     |                                                                                                                           |                  | 0FF80h       | 0, lowest   |

(1) Multiple source flags

(2) A reset is generated if the CPU tries to fetch instructions from within peripheral space or vacant memory space.

(Non)maskable: the individual interrupt enable bit can disable an interrupt event, but the general interrupt enable bit cannot disable it.

(3) Interrupt flags are in the module.

(4) Reserved interrupt vectors at addresses are not used in this device and can be used for regular program code if necessary. To maintain compatibility with other devices, TI recommends reserving these locations.

## 6.5 Memory Organization

Table 6-4 summarizes the memory map of all devices.

**Table 6-4. Memory Organization**

|                                                       |               | MSP430F5132,<br>MSP430F5131        | MSP430F5152,<br>MSP430F5151        | MSP430F5172,<br>MSP430F5171        |
|-------------------------------------------------------|---------------|------------------------------------|------------------------------------|------------------------------------|
| Memory<br>Main: interrupt vector<br>Main: code memory | Size          | 8KB                                | 16KB                               | 32KB                               |
|                                                       | Flash         | 00FFFFh–00FF80h<br>00FFFFh–00E000h | 00FFFFh–00FF80h<br>00FFFFh–00C000h | 00FFFFh–00FF80h<br>00FFFFh–008000h |
| RAM                                                   | Size          | 1KB                                | 2KB                                | 2KB                                |
|                                                       | Sector 0      | 001FFFh–001C00h                    | 0023FFh–001C00h                    | 0023FFh–001C00h                    |
| Information memory<br>(Flash)                         | Size          | 512 Byte                           | 512 Byte                           | 512 Byte                           |
|                                                       | Info A        | 128B<br>0019FFh–001980h            | 128B<br>0019FFh–001980h            | 128B<br>0019FFh–001980h            |
|                                                       | Info B        | 128B<br>00197Fh–001900h            | 128B<br>00197Fh–001900h            | 128B<br>00197Fh–001900h            |
|                                                       | Info C        | 128B<br>0018FFh–001880h            | 128B<br>0018FFh–001880h            | 128B<br>0018FFh–001880h            |
|                                                       | Info D        | 128B<br>00187Fh–001800h            | 128B<br>00187Fh–001800h            | 128B<br>00187Fh–001800h            |
| Bootloader (BSL)<br>memory                            | Size          | 2K                                 | 2KB                                | 2KB                                |
|                                                       | BSL 3         | 512B<br>0017FFh–001600h            | 512B<br>0017FFh–001600h            | 512B<br>0017FFh–001600h            |
|                                                       | BSL 2         | 512B<br>0015FFh–001400h            | 512B<br>0015FFh–001400h            | 512B<br>0015FFh–001400h            |
|                                                       | BSL 1         | 512B<br>0013FFh–001200h            | 512B<br>0013FFh–001200h            | 512B<br>0013FFh–001200h            |
|                                                       | BSL 0         | 512B<br>0011FFh–001000h            | 512B<br>0011FFh–001000h            | 512B<br>0011FFh–001000h            |
| Peripherals                                           | Size<br>Flash | 4KB<br>000FFFh–000000h             | 4KB<br>000FFFh–000000h             | 4KB<br>000FFFh–000000h             |

## 6.6 Bootloader (BSL)

The BSL lets users program the flash memory or RAM using a UART serial interface. Access to the device memory by the BSL is protected by user-defined password. A bootloader security key is provided to disable the BSL completely or to disable the erasure of the flash if an invalid password is supplied. For complete description of the features of the BSL and its implementation, see [MSP430 Programming With the Bootloader \(BSL\)](#). Table 6-5 lists the pins required for BSL access.

**Table 6-5. BSL Functions**

| BSL FUNCTION                                      | DESCRIPTION            |                         |                          |
|---------------------------------------------------|------------------------|-------------------------|--------------------------|
|                                                   | 40-PIN QFN RSB PACKAGE | 38-PIN TSSOP DA PACKAGE | 40-PIN DSBGA YFF PACKAGE |
| $\overline{\text{RST}}/\text{NMI}/\text{SBWTDIO}$ | Entry sequence signal  | Entry sequence signal   | Entry sequence signal    |
| TEST/SBWTK                                        | Entry sequence signal  | Entry sequence signal   | Entry sequence signal    |
| Data transmit                                     | P3.7 - 36              | P3.5 - 37               | P3.7 - B4                |
| Data receive                                      | P3.6 - 35              | P3.6 - 38               | P3.6 - A4                |
| VCC                                               | Power supply           | Power supply            | Power supply             |
| VSS                                               | Ground supply          | Ground supply           | Ground supply            |

## 6.7 Flash Memory

The flash memory can be programmed through the JTAG port, Spy-Bi-Wire (SBW), the BSL, or in system by the CPU. The CPU can perform single-byte, single-word, and long-word writes to the flash memory. Features of the flash memory include:

- Flash memory has n segments of main memory and four segments of information memory (A to D) of 128 bytes each. Each segment in main memory is 512 bytes in size.
- Segments 0 to n may be erased in one step, or each segment may be individually erased.
- Segments A to D can be erased individually, or as a group with segments 0 to n. Segments A to D are also called *information memory*.
- Segment A can be locked separately.

## 6.8 RAM

The RAM is made up of n sectors. Each sector can be completely powered down to save leakage; however, all data is lost. Features of the RAM include:

- RAM has n sectors. The size of a sector can be found in [Section 6.5](#).
- Each sector 0 to n can be complete disabled; however, data retention is lost.
- Each sector 0 to n automatically enters low-power retention mode when possible.

## 6.9 Peripherals

Peripherals are connected to the CPU through data, address, and control buses. The peripherals can be managed using all instructions. For complete module descriptions, see the [MSP430x5xx and MSP430x6xx Family User's Guide](#).

### 6.9.1 Digital I/O

Up to three 8-bit I/O ports are implemented. Port PJ contains seven individual I/O pins, common to all devices.

- 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.
- Programmable drive strength on all ports.
- All 8 bits of ports P1 and P2 support edge-selectable interrupt input.
- Read and write access to port-control registers is supported by all instructions.
- Ports can be accessed byte-wise. P1 and P2 can also be accessed word-wise (PA).
- The input and output voltage levels of the pins supplied by DV<sub>IO</sub> (see [Table 4-1](#)) are defined by the voltage supplied by DV<sub>IO</sub> (up to 5 V).

## 6.9.2 Port Mapping Controller

The port mapping controller allows the flexible and reconfigurable mapping of digital functions to Port P1, Port P2, and Port P3 (see [Table 6-6](#)).

**Table 6-6. Port Mapping Mnemonics and Functions**

| VALUE                    | PxMAPy MNEMONIC | INPUT PIN FUNCTION                                                                                                         | OUTPUT PIN FUNCTION          |
|--------------------------|-----------------|----------------------------------------------------------------------------------------------------------------------------|------------------------------|
| 0                        | PM_NONE         | None                                                                                                                       | DVSS                         |
| 1                        | PM_UCA0CLK      | USCI_A0 clock input/output (direction controlled by USCI)                                                                  |                              |
|                          | PM_UCB0STE      | USCI_B0 SPI slave transmit enable (direction controlled by USCI)                                                           |                              |
| 2                        | PM_UCA0TXD      | USCI_A0 UART TXD (Direction controlled by USCI – output)                                                                   |                              |
|                          | PM_UCA0SIMO     | USCI_A0 SPI slave in master out (direction controlled by USCI)                                                             |                              |
| 3                        | PM_UCB0SOMI     | USCI_B0 SPI slave out master in (direction controlled by USCI)                                                             |                              |
|                          | PM_UCB0SCL      | USCI_B0 I <sup>2</sup> C clock (open drain and direction controlled by USCI)                                               |                              |
| 4                        | PM_UCA0RXD      | USCI_A0 UART RXD (Direction controlled by USCI – input)                                                                    |                              |
|                          | PM_UCA0SOMI     | USCI_A0 SPI slave out master in (direction controlled by USCI)                                                             |                              |
| 5                        | PM_UCB0SIMO     | USCI_B0 SPI slave in master out (direction controlled by USCI)                                                             |                              |
|                          | PM_UCB0SDA      | USCI_B0 I <sup>2</sup> C data (open drain and direction controlled by USCI)                                                |                              |
| 6                        | PM_UCB0CLK      | USCI_B0 clock input/output (direction controlled by USCI)                                                                  |                              |
|                          | PM_UCA0STE      | USCI_A0 SPI slave transmit enable (direction controlled by USCI)                                                           |                              |
| 7                        | PM_TD0.0        | TD0 input capture channel 0                                                                                                | TD0 output compare channel 0 |
| 8                        | PM_TD0.1        | TD0 input capture channel 1                                                                                                | TD0 output compare channel 1 |
| 9                        | PM_TD0.2        | TD0 input capture channel 2                                                                                                | TD0 output compare channel 2 |
| 10                       | PM_TD1.0        | TD1 input capture channel 0                                                                                                | TD1 output compare channel 0 |
| 11                       | PM_TD1.1        | TD1 input capture channel 1                                                                                                | TD1 output compare channel 1 |
| 12                       | PM_TD1.2        | TD1 input capture channel 2                                                                                                | TD1 output compare channel 2 |
| 13                       | PM_CLR1TD0.0    | TD0 external clear input                                                                                                   | TD0 output compare channel 0 |
|                          | PM_FLT1_2TD0.0  | TD0 fault input channel 2                                                                                                  |                              |
| 14                       | PM_FLT1_0TD0.1  | TD0 fault input channel 0                                                                                                  | TD0 output compare channel 1 |
| 15                       | PM_FLT1_1TD0.2  | TD0 fault input channel 1                                                                                                  | TD0 output compare channel 2 |
| 16                       | PM_CLR2TD1.0    | TD1 external clear input (controlled by module input enable)                                                               | TD1 output compare channel 0 |
|                          | PM_FLT2_1TD1.0  | TD1 fault input channel 1 (controlled by module input enable)                                                              |                              |
| 17                       | PM_FLT2_2TD1.1  | TD1 fault input channel 2                                                                                                  | TD1 output compare channel 1 |
| 18                       | PM_FLT2_0TD1.2  | TD1 fault input channel 0                                                                                                  | TD1 output compare channel 2 |
| 19                       | PM_TD0.0SMCLK   | TD0 input capture channel 0                                                                                                | SMCLK output                 |
| 20                       | PM_TA0CLKCBOUT  | TA0 input clock                                                                                                            | Comparator_B output          |
| 21                       | PM_TD0CLKMCLK   | TD0 input clock                                                                                                            | MCLK output                  |
| 22                       | PM_TA0_0        | TA0 input capture channel 0                                                                                                | TA0 output compare channel 0 |
| 23                       | PM_TA0_1        | TA0 input capture channel 1                                                                                                | TA0 output compare channel 1 |
| 24                       | PM_TA0_2        | TA0 input capture channel 2                                                                                                | TA0 output compare channel 2 |
| 25                       | PM_DMAE0SMCLK   | DMAE0 input                                                                                                                | SMCLK output                 |
| 26                       | PM_DMAE1MCLK    | DMAE1 input                                                                                                                | MCLK output                  |
| 27                       | PM_DMAE2SVM     | DMAE2 input                                                                                                                | SVM output                   |
| 28                       | PM_TD0OUTH      | TD0 3-state input                                                                                                          | ADC10CLK                     |
| 29                       | PM_TD1OUTH      | TD1 3-state input                                                                                                          | ACLK                         |
| 30                       | Reserved        | None                                                                                                                       | DVSS                         |
| 31 (0FFh) <sup>(1)</sup> | PM_ANALOG       | Disables the output driver and the input Schmitt-trigger to prevent parasitic cross currents when applying analog signals. |                              |

(1) The value of the PM\_ANALOG mnemonic is set to 0FFh. The port mapping registers are only 5 bits wide, and the upper bits are ignored, which results in a read out value of 31.

Table 6-7 lists the default assignments for all pins that support port mapping.

**Table 6-7. Default Mapping**

| PIN                                      | PxMAPy MNEMONIC                | INPUT PIN FUNCTION                                                                                                                  | OUTPUT PIN FUNCTION                                                             |
|------------------------------------------|--------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------|
| P1.0/PM_UCA0CLK/<br>PM_UCB0STE/A0/CB0    | PM_UCA0CLK<br>PM_UCB0STE       | USCI_A0 clock input/output<br>(direction controlled by USCI)                                                                        | USCI_B0 SPI slave transmit enable<br>(direction controlled by USCI)             |
| P1.1/PM_UCA0TXD/<br>PM_UCA0SIMO/A1/CB1   | PM_UCA0TXD<br>PM_UCA0SIMO      | USCI_A0 UART TXD (Direction<br>controlled by USCI – output)                                                                         | USCI_A0 SPI slave in master out<br>(direction controlled by USCI)               |
| P1.2/PM_UCA0RXD/<br>PM_UCA0SOMI/A2/CB2   | PM_UCA0RXD<br>PM_UCA0SOMI      | USCI_A0 UART RXD (Direction<br>controlled by USCI – input)                                                                          | USCI_A0 SPI slave out master in<br>(direction controlled by USCI)               |
| P1.3/PM_UCB0CLK/<br>PM_UCA0STE/A3/CB3    | PM_UCB0CLK<br>PM_UCA0STE       | USCI_B0 clock input/output<br>(direction controlled by USCI)                                                                        | USCI_A0 SPI slave transmit enable<br>(direction controlled by USCI)             |
| P1.4/PM_UCB0SIMO/<br>PM_UCB0SDA/A4/CB4   | PM_UCB0SIMO<br>PM_UCB0SDA      | USCI_B0 SPI slave in master out<br>(direction controlled by USCI)                                                                   | USCI_B0 I <sup>2</sup> C data (open drain and<br>direction controlled by USCI)  |
| P1.5/PM_UCB0SOMI/<br>PM_UCB0SCL/A5/CB5   | PM_UCB0SOMI<br>PM_UCB0SCL      | USCI_B0 SPI slave out master in<br>(direction controlled by USCI)                                                                   | USCI_B0 I <sup>2</sup> C clock (open drain and<br>direction controlled by USCI) |
| P1.6/PM_TD0.0                            | PM_TD0.0                       | TD0 input capture channel 0                                                                                                         | TD0 output compare channel 0                                                    |
| P1.7/PM_TD0.1                            | PM_TD0.1                       | TD0 input capture channel 1                                                                                                         | TD0 output compare channel 1                                                    |
| P2.0/PM_TD0.2                            | PM_TD0.2                       | TD0 input capture channel 2                                                                                                         | TD0 output compare channel 2                                                    |
| P2.1/PM_TD1.0                            | PM_TD1.0                       | TD1 input capture channel 0                                                                                                         | TD1 output compare channel 0                                                    |
| P2.2/PM_TD1.1                            | PM_TD1.1                       | TD1 input capture channel 1                                                                                                         | TD1 output compare channel 1                                                    |
| P2.3/PM_TD1.2                            | PM_TD1.2                       | TD1 input capture channel 2                                                                                                         | TD1 output compare channel 2                                                    |
| P2.4/PM_TEC0CLR/<br>PM_TEC0FLT2/PM_TD0.0 | PM_CLR1TD0.0<br>PM_FLT1_2TD0.0 | TD0 external clear input (controlled<br>by module input enable)<br>TD0 fault input channel 2<br>(controlled by module input enable) | TD0 output compare channel 0                                                    |
| P2.5/PM_TEC0FLT0/PM_TD0.1                | PM_FLT1_0TD0.1                 | TD0 fault input channel 0                                                                                                           | TD0 output compare channel 1                                                    |
| P2.6/PM_TEC0FLT1/PM_TD0.2                | PM_FLT1_1TD0.2                 | TD0 fault input channel 1                                                                                                           | TD0 output compare channel 2                                                    |
| P2.7/PM_TEC1CLR/<br>PM_TEC1FLT1/PM_TD1.0 | PM_CLR2TD1.0<br>PM_FLT2_1TD1.0 | TD1 external clear input (controlled<br>by module input enable)<br>TD1 fault input channel 1<br>(controlled by module input enable) | TD1 output compare channel 0                                                    |
| P3.0/PM_TEC1FLT2/<br>PM_TD1.1            | PM_FLT2_2TD1.1                 | TD1 fault input channel 2                                                                                                           | TD1 output compare channel 1                                                    |
| P3.1/PM_TEC1FLT0/<br>PM_TD1.2            | PM_FLT2_0TD1.2                 | TD1 fault input channel 0                                                                                                           | TD1 output compare channel 2                                                    |
| P3.2/PM_TD0.0/<br>PM_SMCLK/CB14          | PM_TD0.0SMCLK                  | TD0 input capture channel 0                                                                                                         | SMCLK output                                                                    |
| P3.3/PM_TA0CLK/<br>PM_CBOUT/CB13         | PM_TA0CLKCBOUT                 | TA0 input clock                                                                                                                     | Comparator_B output                                                             |
| P3.4/PM_TD0CLK/<br>PM_MCLK               | PM_TD0CLKMCLK                  | TD0 input clock                                                                                                                     | MCLK output                                                                     |
| P3.5/PM_TA0.2/<br>VEREF+/CB12            | PM_TA3_2                       | TA0 input capture channel 0                                                                                                         | TA0 output compare channel 0                                                    |
| P3.6/PM_TA0.1/A7<br>VEREF-/CB11          | PM_TA3_1                       | TA0 input capture channel 1                                                                                                         | TA0 output compare channel 1                                                    |
| P3.7/PM_TA0.0/<br>A6/CB10                | PM_TA3_0                       | TA0 input capture channel 2                                                                                                         | TA0 output compare channel 2                                                    |

### 6.9.3 Oscillator and System Clock

The clock system (Unified Clock System [UCS]) module includes support for a 32-kHz watch crystal oscillator and high-frequency crystal oscillator, an internal very-low-power low-frequency oscillator (VLO), an internal trimmed low-frequency oscillator (REFO), and an integrated internal digitally controlled oscillator (DCO). The UCS module is designed to meet the requirements of both low system cost and low power consumption. The UCS module features digital frequency locked loop (FLL) hardware that, in conjunction with a digital modulator, stabilizes the DCO frequency to a programmable multiple of the watch crystal frequency. The internal DCO provides a fast turnon clock source and stabilizes in less than 5  $\mu$ s. The UCS module provides the following clock signals:

- Auxiliary clock (ACLK), sourced from a 32-kHz watch crystal or high-frequency crystal (XT1), the internal low-frequency oscillator (VLO), the trimmed low-frequency oscillator (REFO), or the internal digitally-controlled oscillator DCO.
- Main clock (MCLK), the system clock used by the CPU. MCLK can be sourced by same sources available to ACLK.
- Sub-Main clock (SMCLK), the subsystem clock used by the peripheral modules. SMCLK can be sourced by same sources available to ACLK.
- ACLK/n, the buffered output of ACLK, ACLK/2, ACLK/4, ACLK/8, ACLK/16, ACLK/32.

### 6.9.4 Power-Management Module (PMM)

The PMM includes an integrated voltage regulator that supplies the core voltage to the device and contains programmable output levels to provide for power optimization. The PMM also includes supply voltage supervisor (SVS) and supply voltage monitoring (SVM) circuitry, and brownout protection. The brownout circuit provides the proper internal reset signal to the device during power on and power off. The SVS and SVM circuitry detects if the supply voltage drops below a user-selectable level and supports both supply voltage supervision (the device is automatically reset) and supply voltage monitoring (the device is not automatically reset). SVS and SVM circuitry is available on the primary supply and core supply.

### 6.9.5 Hardware Multiplier

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

### 6.9.6 Watchdog Timer (WDT\_A)

The primary function of the watchdog timer (WDT\_A) 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.

### 6.9.7 System Module (SYS)

The SYS module handles many of the system functions within the device. These include power-on reset and power-up clear handling, NMI source selection and management, reset interrupt vector generators, bootloader entry mechanisms, and configuration management (device descriptors) (see [Table 6-8](#)). It also includes a data exchange mechanism using JTAG that is called a JTAG mailbox and that can be used in the application.

**Table 6-8. System Module Interrupt Vector Registers**

| INTERRUPT VECTOR REGISTER | INTERRUPT EVENT                | WORD ADDRESS | OFFSET     | PRIORITY |
|---------------------------|--------------------------------|--------------|------------|----------|
| SYSRSTIV, System Reset    | No interrupt pending           | 019Eh        | 00h        | Highest  |
|                           | Brownout (BOR)                 |              | 02h        |          |
|                           | RST/NMI (POR)                  |              | 04h        |          |
|                           | PMMSWBOR (BOR)                 |              | 06h        |          |
|                           | LPM5 wake-up (BOR)             |              | 08h        |          |
|                           | Security violation (BOR)       |              | 0Ah        |          |
|                           | SVSL (POR)                     |              | 0Ch        |          |
|                           | SVSH (POR)                     |              | 0Eh        |          |
|                           | SVML_OVP (POR)                 |              | 10h        |          |
|                           | SVMH_OVP (POR)                 |              | 12h        |          |
|                           | PMMSWPOR (POR)                 |              | 14h        |          |
|                           | WDT time-out (PUC)             |              | 16h        |          |
|                           | WDT key violation (PUC)        |              | 18h        |          |
|                           | KEYV flash key violation (PUC) |              | 1Ah        |          |
|                           | Reserved                       |              | 1Ch        |          |
|                           | Peripheral area fetch (PUC)    |              | 1Eh        |          |
|                           | PMM key violation (PUC)        |              | 20h        |          |
|                           | Reserved                       |              | 22h to 3Eh | Lowest   |
| SYSSNIV, System NMI       | No interrupt pending           | 019Ch        | 00h        | Highest  |
|                           | SVMLIFG                        |              | 02h        |          |
|                           | SVMHIFG                        |              | 04h        |          |
|                           | DLYLIFG                        |              | 06h        |          |
|                           | DLYHIFG                        |              | 08h        |          |
|                           | VMAIFG                         |              | 0Ah        |          |
|                           | JMBINIFG                       |              | 0Ch        |          |
|                           | JMBOUTIFG                      |              | 0Eh        |          |
|                           | VLRIFG                         |              | 10h        |          |
|                           | VLRHIFG                        |              | 12h        |          |
|                           | Reserved                       |              | 14h to 1Eh | Lowest   |
| SYSUNIV, User NMI         | No interrupt pending           | 019Ah        | 00h        | Highest  |
|                           | NMIIFG                         |              | 02h        |          |
|                           | OFIFG                          |              | 04h        |          |
|                           | ACCVIFG                        |              | 06h        |          |
|                           | Reserved                       |              | 08h to 1Eh | Lowest   |

### 6.9.8 DMA Controller

The DMA controller allows movement of data from one memory address to another without CPU intervention. For example, the DMA controller can be used to move data from the ADC10\_A conversion memory to RAM. Using the DMA controller can increase the throughput of peripheral modules. The DMA controller reduces system power consumption by allowing the CPU to remain in sleep mode, without having to wake to move data to or from a peripheral. [Table 6-9](#) lists the triggers that can be assigned to start a DMA transfer.

**Table 6-9. DMA Trigger Assignments<sup>(1)</sup>**

| TRIGGER | CHANNEL       |               |               |
|---------|---------------|---------------|---------------|
|         | 0             | 1             | 2             |
| 0       | DMAREQ        | DMAREQ        | DMAREQ        |
| 1       | TA0CCR0 CCIFG | TA0CCR0 CCIFG | TA0CCR0 CCIFG |
| 2       | TA0CCR2 CCIFG | TA0CCR2 CCIFG | TA0CCR2 CCIFG |
| 3       | TD0CCR0 CCIFG | TD0CCR0 CCIFG | TD0CCR0 CCIFG |
| 4       | TD0CCR2 CCIFG | TD0CCR2 CCIFG | TD0CCR2 CCIFG |
| 5       | TD1CCR0 CCIFG | TD1CCR0 CCIFG | TD1CCR0 CCIFG |
| 6       | TD1CCR2 CCIFG | TD1CCR2 CCIFG | TD1CCR2 CCIFG |
| 7       | Reserved      | Reserved      | Reserved      |
| 8       | Reserved      | Reserved      | Reserved      |
| 9       | Reserved      | Reserved      | Reserved      |
| 10      | Reserved      | Reserved      | Reserved      |
| 11      | Reserved      | Reserved      | Reserved      |
| 12      | Reserved      | Reserved      | Reserved      |
| 13      | Reserved      | Reserved      | Reserved      |
| 14      | Reserved      | Reserved      | Reserved      |
| 15      | Reserved      | Reserved      | Reserved      |
| 16      | UCA0RXIFG     | UCA0RXIFG     | UCA0RXIFG     |
| 17      | UCA0TXIFG     | UCA0TXIFG     | UCA0TXIFG     |
| 18      | UCB0RXIFG     | UCB0RXIFG     | UCB0RXIFG     |
| 19      | UCB0TXIFG     | UCB0TXIFG     | UCB0TXIFG     |
| 20      | Reserved      | Reserved      | Reserved      |
| 21      | Reserved      | Reserved      | Reserved      |
| 22      | Reserved      | Reserved      | Reserved      |
| 23      | Reserved      | Reserved      | Reserved      |
| 24      | ADC10IFG0     | ADC10IFG0     | ADC10IFG0     |
| 25      | Reserved      | Reserved      | Reserved      |
| 26      | Reserved      | Reserved      | Reserved      |
| 27      | Reserved      | Reserved      | Reserved      |
| 28      | Reserved      | Reserved      | Reserved      |
| 29      | MPY ready     | MPY ready     | MPY ready     |
| 30      | DMA2IFG       | DMA0IFG       | DMA1IFG       |
| 31      | DMAE0         | DMAE0         | DMAE0         |

(1) Reserved DMA triggers may be used by other devices in the family. Reserved DMA triggers do not cause any DMA trigger event when selected.

## 6.9.9 Universal Serial Communication Interface (USCI)

The USCI modules are used for serial data communication. The USCI module supports synchronous communication protocols such as SPI (3- or 4-pin) and I<sup>2</sup>C, and asynchronous communication protocols such as UART, enhanced UART with automatic baudrate detection, and IrDA. Each USCI module contains two modules, A and B.

The USCI\_Ax module provides support for SPI (3- or 4-pin), UART, enhanced UART, or IrDA.

The USCI\_Bx module provides support for SPI (3- or 4-pin) or I<sup>2</sup>C.

### 6.9.10 TA0

TA0 is a 16-bit timer/counter with three capture/compare registers. TA0 can support multiple capture/compares, PWM outputs, and interval timing (see [Table 6-10](#)). TA0 also has extensive interrupt capabilities. Interrupts may be generated from the counter on overflow conditions and from each of the capture/compare registers.

**Table 6-10. TA0 Signal Connections**

| INPUT PIN NUMBER       |                         |                          | DEVICE<br>INPUT<br>SIGNAL | MODULE<br>INPUT<br>SIGNAL | MODULE<br>BLOCK | MODULE<br>OUTPUT<br>SIGNAL | DEVICE<br>OUTPUT<br>SIGNAL | OUTPUT PIN NUMBER                                            |                                                              |                                                              |
|------------------------|-------------------------|--------------------------|---------------------------|---------------------------|-----------------|----------------------------|----------------------------|--------------------------------------------------------------|--------------------------------------------------------------|--------------------------------------------------------------|
| RSB<br>(40-PIN<br>QFN) | DA<br>(38-PIN<br>TSSOP) | YFF<br>(40-PIN<br>DSBGA) |                           |                           |                 |                            |                            | RSB<br>(40-PIN<br>QFN)                                       | DA<br>(38-PIN<br>TSSOP)                                      | YFF<br>(40-PIN<br>DSBGA)                                     |
| P3.3 - 30              | P3.3 - 34               | P3.3 - G6                | TA0CLK                    | TACLK                     | Timer           | NA                         | NA                         | –                                                            | –                                                            | –                                                            |
| ACLK<br>(internal)     | ACLK                    | ACLK                     | ACLK                      | ACLK                      |                 |                            |                            | –                                                            | –                                                            | –                                                            |
| SMCLK<br>(internal)    | SMCLK                   | SMCLK                    | SMCLK                     | SMCLK                     |                 |                            |                            | –                                                            | –                                                            | –                                                            |
| P3.3 - 30              | P3.3 - 34               | P3.3 - G6                | TA0CLK                    | TACLK                     |                 |                            |                            | –                                                            | –                                                            | –                                                            |
| P3.7 - 36              | –                       | P3.7 - G4                | TA0.0                     | CCI0A                     | CCR0            | TA0                        | TA0.0                      | P3.7 - 36                                                    | –                                                            | P3.7 - G4                                                    |
| –                      | –                       | –                        | CBOU                      | CCI0B                     |                 |                            |                            | –                                                            | –                                                            | –                                                            |
| –                      | –                       | –                        | V <sub>SS</sub>           | GND                       |                 |                            |                            | –                                                            | –                                                            | –                                                            |
| –                      | –                       | –                        | V <sub>CC</sub>           | V <sub>CC</sub>           |                 |                            |                            | –                                                            | –                                                            | –                                                            |
| P3.6 - 35              | –                       | P3.6 - G3                | TA0.1                     | CCI1A                     | CCR1            | TA1                        | TA0.1                      | P3.6 - 35                                                    | P3.6 - 38                                                    | P3.6 - G3                                                    |
| –                      | –                       | –                        | ACLK                      | CCI1B                     |                 |                            |                            | ADC10_A <sup>(1)</sup><br>(internal)<br>ADC10SHS<br>x = 001b | ADC10_A <sup>(1)</sup><br>(internal)<br>ADC10SHS<br>x = 001b | ADC10_A <sup>(1)</sup><br>(internal)<br>ADC10SHS<br>x = 001b |
| –                      | –                       | –                        | V <sub>SS</sub>           | GND                       |                 |                            |                            | –                                                            | –                                                            | –                                                            |
| –                      | –                       | –                        | V <sub>CC</sub>           | V <sub>CC</sub>           |                 |                            |                            | –                                                            | –                                                            | –                                                            |
| P3.5 - 34              | P3.5 - 37               | P3.5 - F3                | TA0.2                     | CCI2A                     | CCR2            | TA2                        | TA0.2                      | P3.5 - 34                                                    | P3.5 - 37                                                    | P3.5 - F3                                                    |
| –                      | –                       | –                        | V <sub>SS</sub>           | CCI2B                     |                 |                            |                            | –                                                            | –                                                            | –                                                            |
| –                      | –                       | –                        | V <sub>SS</sub>           | GND                       |                 |                            |                            | –                                                            | –                                                            | –                                                            |
| –                      | –                       | –                        | V <sub>CC</sub>           | V <sub>CC</sub>           |                 |                            |                            | –                                                            | –                                                            | –                                                            |

(1) The ADC10\_A trigger is available on MSP430F51x2 devices.

## 6.9.11 TD0

TD0 is a 16-bit timer/counter with three capture/compare registers supporting up to 256-MHz (4-ns) resolution. TD0 can support multiple capture/compares, PWM outputs, and interval timing (see [Table 6-11](#)). TD0 also has extensive interrupt capabilities. Interrupts may be generated from the counter on overflow conditions and from each of the capture/compare registers. External fault inputs as well as a external timer counter clear is supported along with interrupt flags from the TEC0 module.

**Table 6-11. TD0 Signal Connections**

| INPUT PIN NUMBER         |                          |                          | DEVICE<br>INPUT<br>SIGNAL | MODULE<br>INPUT<br>SIGNAL | MODULE<br>BLOCK | MODULE<br>OUTPUT<br>SIGNAL | DEVICE<br>OUTPUT<br>SIGNAL | OUTPUT PIN NUMBER                                            |                                                              |                                                              |
|--------------------------|--------------------------|--------------------------|---------------------------|---------------------------|-----------------|----------------------------|----------------------------|--------------------------------------------------------------|--------------------------------------------------------------|--------------------------------------------------------------|
| RSB<br>(40-PIN<br>QFN)   | DA<br>(38-PIN<br>TSSOP)  | YFF<br>(40-PIN<br>DSBGA) |                           |                           |                 |                            |                            | RSB<br>(40-PIN<br>QFN)                                       | DA<br>(38-PIN<br>TSSOP)                                      | YFF<br>(40-PIN<br>DSBGA)                                     |
| P3.4 - 31                | —                        | P3.4 - G5                | TD0CLK                    | TDCLK                     | Timer           | NA                         | NA                         | —                                                            | —                                                            | —                                                            |
| ACLK<br>(internal)       | ACLK<br>(internal)       | ACLK<br>(internal)       | ACLK                      | ACLK                      |                 |                            |                            | —                                                            | —                                                            | —                                                            |
| SMCLK<br>(internal)      | SMCLK<br>(internal)      | SMCLK<br>(internal)      | SMCLK                     | SMCLK                     |                 |                            |                            | —                                                            | —                                                            | —                                                            |
| P3.4 - 31                | —                        | P3.4 - G5                | TD0CLK                    | TDCLK                     |                 |                            |                            | —                                                            | —                                                            | —                                                            |
| —                        | —                        | —                        | —                         | CLK0                      |                 |                            |                            | —                                                            | —                                                            | —                                                            |
| P2.4 - 19                | P2.4 - 23                | P2.4 - B4                | TEC0CLR                   | TECXCLR                   |                 |                            |                            | —                                                            | —                                                            | —                                                            |
| P1.6 - 11 <sup>(1)</sup> | P1.6 - 15 <sup>(1)</sup> | P1.6 - A1 <sup>(1)</sup> | TD0.0                     | CCI0A                     | CCR0            | TD0                        | TD0                        | P1.6 - 11 <sup>(1)</sup>                                     | P1.6 - 15 <sup>(1)</sup>                                     | P1.6 - A1 <sup>(1)</sup>                                     |
| P3.2 - 29                | P3.2 - 33                | P3.2 - F5                | TD0.0                     | CCI0B                     |                 |                            |                            | P2.4 - 19                                                    | P2.4 - 23                                                    | P2.4 - B4                                                    |
| —                        | —                        | —                        | V <sub>SS</sub>           | GND                       |                 |                            |                            | ADC10_A<br>(internal)<br>ADC10SHS<br>x = 010b <sup>(2)</sup> | ADC10_A<br>(internal)<br>ADC10SHS<br>x = 010b <sup>(2)</sup> | ADC10_A<br>(internal)<br>ADC10SHS<br>x = 010b <sup>(2)</sup> |
| —                        | —                        | —                        | V <sub>CC</sub>           | V <sub>CC</sub>           |                 |                            |                            | —                                                            | —                                                            | —                                                            |
| P2.5 - 20                | P2.5 - 24                | P2.5 - A6                | TEC0FLT0                  | TECXFLT0                  |                 |                            |                            | —                                                            | —                                                            | —                                                            |
| P1.7 - 12 <sup>(1)</sup> | P1.7 - 16 <sup>(1)</sup> | P1.7 - B2 <sup>(1)</sup> | TD0.1                     | CCI1A                     | CCR1            | TD1                        | TD1                        | P1.7 - 12 <sup>(1)</sup>                                     | P1.7 - 16 <sup>(1)</sup>                                     | P1.7 - B2 <sup>(1)</sup>                                     |
| CBOU<br>(internal)       | CBOU<br>(internal)       | CBOU<br>(internal)       | TD0.1                     | CCI1B                     |                 |                            |                            | PJ.6 - 28                                                    | PJ.6 - 32                                                    | PJ.6 - E5                                                    |
| —                        | —                        | —                        | V <sub>SS</sub>           | GND                       |                 |                            |                            | P2.5 - 20                                                    | P2.5 - 24                                                    | P2.5 - A6                                                    |
| —                        | —                        | —                        | V <sub>CC</sub>           | V <sub>CC</sub>           |                 |                            |                            | ADC10_A<br>(internal)<br>ADC10SHS<br>x = 011b <sup>(2)</sup> | ADC10_A<br>(internal)<br>ADC10SHS<br>x = 011b <sup>(2)</sup> | ADC10_A<br>(internal)<br>ADC10SHS<br>x = 011b <sup>(2)</sup> |
| P2.6 - 21                | P2.6 - 20                | P2.6 - B5                | TEC0FLT1                  | TECXFLT1                  |                 |                            |                            | —                                                            | —                                                            | —                                                            |
| P2.0 - 13 <sup>(1)</sup> | P2.0 - 17 <sup>(1)</sup> | P2.0 - B3 <sup>(1)</sup> | TD0.2                     | CCI2A                     | CCR2            | TD2                        | TD2                        | P2.0 - 13 <sup>(1)</sup>                                     | P2.0 - 17 <sup>(1)</sup>                                     | P2.0 - B3 <sup>(1)</sup>                                     |
| ACLK<br>(internal)       | ACLK<br>(internal)       | ACLK<br>(internal)       | TD0.2                     | CCI2B                     |                 |                            |                            | P2.6 - 21                                                    | P2.6 - 25                                                    | P2.6 - B5                                                    |
| —                        | —                        | —                        | V <sub>SS</sub>           | GND                       |                 |                            |                            | —                                                            | —                                                            | —                                                            |
| —                        | —                        | —                        | V <sub>CC</sub>           | V <sub>CC</sub>           |                 |                            |                            | —                                                            | —                                                            | —                                                            |
| P2.4 - 19                | P2.4 - 23                | P2.4 - B4                | TEC0FLT2                  | TECXFLT2                  |                 |                            |                            | —                                                            | —                                                            | —                                                            |

(1) Pins P1.6 for TD0.0, P1.7 for TD0.1, and P2.0 for TD0.2 are optimized for matching.

(2) The ADC10\_A trigger is available on MSP430F51x2 devices.

### 6.9.12 TD1

TD1 is a 16-bit timer/counter with three capture/compare registers supporting up to 256-MHz (4-ns) resolution. TD1 can support multiple capture/compares, PWM outputs, and interval timing (see [Table 6-12](#)). TD1 also has extensive interrupt capabilities. Interrupts may be generated from the counter on overflow conditions and from each of the capture/compare registers. External fault inputs as well as a external timer counter clear is supported along with interrupt flags from the TEC0 module.

**Table 6-12. TD1 Signal Connections**

| INPUT PIN NUMBER         |                          |                          | DEVICE<br>INPUT<br>SIGNAL | MODULE<br>INPUT<br>SIGNAL | MODULE<br>BLOCK | MODULE<br>OUTPUT<br>SIGNAL | DEVICE<br>OUTPUT<br>SIGNAL | OUTPUT PIN NUMBER        |                          |                          |
|--------------------------|--------------------------|--------------------------|---------------------------|---------------------------|-----------------|----------------------------|----------------------------|--------------------------|--------------------------|--------------------------|
| RSB<br>(40-PIN<br>QFN)   | DA<br>(38-PIN<br>TSSOP)  | YFF<br>(40-PIN<br>DSBGA) |                           |                           |                 |                            |                            | RSB<br>(40-PIN<br>QFN)   | DA<br>(38-PIN<br>TSSOP)  | YFF<br>(40-PIN<br>DSBGA) |
| PJ.6 - 28                | PJ.6 - 32                | PJ.6 - E5                | TD1CLK                    | TDCLK                     | Timer           | NA                         | NA                         | –                        | –                        | –                        |
| ACLK<br>(internal)       | ACLK<br>(internal)       | ACLK<br>(internal)       | ACLK                      | ACLK                      |                 |                            |                            | –                        | –                        | –                        |
| SMCLK(inte<br>rnal)      | SMCLK                    | SMCLK                    | SMCLK                     | SMCLK                     |                 |                            |                            | –                        | –                        | –                        |
| PJ.6 - 28                | PJ.6 - 32                | PJ.6 - E5                | TD1CLK                    | TDCLK                     |                 |                            |                            | –                        | –                        | –                        |
| –                        | –                        | –                        | from TD0<br>(internal)    | CLK0                      |                 |                            |                            | –                        | –                        | –                        |
| P2.7 - 22                | P2.7 - 26                | P2.7 - C5                | TEC1CLR                   | TECxCLR                   |                 |                            |                            | –                        | –                        | –                        |
| P2.1 - 14 <sup>(1)</sup> | P2.1 - 18 <sup>(1)</sup> | P2.1 - A2                | TD1.0                     | CCI0A                     | CCR0            | TD0                        | TD0                        | P2.1 - 14 <sup>(1)</sup> | P2.1 - 18 <sup>(1)</sup> | P2.1 - A2 <sup>(1)</sup> |
| –                        | –                        | –                        | TD1.0                     | CCI0B                     |                 |                            |                            | P2.7 - 22                | P2.7 - 26                | P2.7 - C5                |
| –                        | –                        | –                        | V <sub>SS</sub>           | GND                       |                 |                            |                            | –                        | –                        | –                        |
| –                        | –                        | –                        | V <sub>CC</sub>           | V <sub>CC</sub>           |                 |                            |                            | –                        | –                        | –                        |
| P3.1 - 24                | P3.1 - 28                | P3.1 - C6                | TEC1FLT0                  | TECXFLT0                  |                 |                            |                            | –                        | –                        | –                        |
| P2.2 - 15 <sup>(1)</sup> | P2.2 - 19 <sup>(1)</sup> | P2.2 - A3                | TD1.1                     | CCI1A                     | CCR1            | TD1                        | TD1                        | P2.2 - 15 <sup>(1)</sup> | P2.2 - 19 <sup>(1)</sup> | P2.2 - A3 <sup>(1)</sup> |
| CBOU<br>T(interna<br>l)  | CBOU<br>T(interna<br>l)  | CBOU<br>T(interna<br>l)  | TD1.1                     | CCI1B                     |                 |                            |                            | P3.0 - 23                | P3.0 - 27                | P3.0 - B6                |
| –                        | –                        | –                        | V <sub>SS</sub>           | GND                       |                 |                            |                            | –                        | –                        | –                        |
| –                        | –                        | –                        | V <sub>CC</sub>           | V <sub>CC</sub>           |                 |                            |                            | –                        | –                        | –                        |
| P2.7 - 22                | P2.7 - 26                | P2.7 - C5                | TEC1FLT1                  | TECXFLT1                  |                 |                            |                            | –                        | –                        | –                        |
| P2.3 - 16 <sup>(1)</sup> | P2.3 - 20 <sup>(1)</sup> | P2.3 - C4                | TD1.2                     | CCI2A                     | CCR2            | TD2                        | TD2                        | P2.3 - 16 <sup>(1)</sup> | P2.3 - 20 <sup>(1)</sup> | P2.3 - C4 <sup>(1)</sup> |
| ACLK<br>(internal)       | ACLK<br>(internal)       | ACLK<br>(internal)       | TD1.2                     | CCI2B                     |                 |                            |                            | P3.1 - 24                | P3.1 - 28                | P3.1 - C6                |
| –                        | –                        | –                        | V <sub>SS</sub>           | GND                       |                 |                            |                            | –                        | –                        | –                        |
| –                        | –                        | –                        | V <sub>CC</sub>           | V <sub>CC</sub>           |                 |                            |                            | –                        | –                        | –                        |
| P3.0 - 23                | P3.0 - 27                | P3.0 - B6                | TEC1FLT2                  | TECXFLT2                  |                 |                            |                            | –                        | –                        | –                        |

(1) Pins P2.1 for TD1.0, P2.2 for TD1.1, and P2.3 for TD1.2 are optimized for matching.

### 6.9.13 *Comparator\_B*

The primary function of the Comparator\_B module is to support precision slope analog-to-digital conversions, battery voltage supervision, and monitoring of external analog signals.

### 6.9.14 *ADC10\_A (MSP430F51x2 Only)*

The ADC10\_A module supports fast 10-bit analog-to-digital conversions. The module implements a 10-bit SAR core, sample select control, reference generator, and a conversion result buffer. A window comparator with lower and upper limits allows CPU-independent result monitoring with three window comparator interrupt flags.

### 6.9.15 *CRC16*

The CRC16 module produces a signature based on a sequence of entered data values and can be used for data checking purposes. The CRC16 module signature is based on the CRC-CCITT standard.

### 6.9.16 *Reference (REF) Module Voltage Reference*

The REF is responsible for generation of all critical reference voltages that can be used by the various analog peripherals in the device.

### 6.9.17 *Embedded Emulation Module (EEM) (S Version)*

The EEM supports real-time in-system debugging. The S version of the EEM 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

### 6.9.18 Peripheral File Map

Table 6-13 lists the base address and offset range for the registers of all peripherals.

**Table 6-13. Peripherals**

| MODULE NAME                                    | BASE ADDRESS | OFFSET ADDRESS RANGE |
|------------------------------------------------|--------------|----------------------|
| Special Functions (see Table 6-14)             | 0100h        | 000h–01Fh            |
| PMM (see Table 6-15)                           | 0120h        | 000h–010h            |
| Flash Control (see Table 6-16)                 | 0140h        | 000h–00Fh            |
| CRC16 (see Table 6-17)                         | 0150h        | 000h–007h            |
| RAM Control (see Table 6-18)                   | 0158h        | 000h–001h            |
| Watchdog (see Table 6-19)                      | 015Ch        | 000h–001h            |
| UCS (see Table 6-20)                           | 0160h        | 000h–01Fh            |
| SYS (see Table 6-21)                           | 0180h        | 000h–01Fh            |
| Shared Reference (see Table 6-22)              | 01B0h        | 000h–001h            |
| Port Mapping Control (see Table 6-23)          | 01C0h        | 000h–007h            |
| Port Mapping Port P1 (see Table 6-24)          | 01C8h        | 000h–007h            |
| Port Mapping Port P2 (see Table 6-25)          | 01D0h        | 000h–007h            |
| Port Mapping Port P3 (see Table 6-26)          | 01D8h        | 000h–007h            |
| Port P1, P2 (see Table 6-27)                   | 0200h        | 000h–01Fh            |
| Port P3 (see Table 6-28)                       | 0220h        | 000h–01Fh            |
| Port PJ (see Table 6-29)                       | 0320h        | 000h–01Fh            |
| TA0 (see Table 6-30)                           | 03C0h        | 000h–03Fh            |
| 32-Bit Hardware Multiplier (see Table 6-31)    | 04C0h        | 000h–02Fh            |
| DMA General Control (see Table 6-32)           | 0500h        | 000h–00Fh            |
| DMA Channel 0 (see Table 6-33)                 | 0500h        | 010h–00Ah            |
| DMA Channel 1 (see Table 6-34)                 | 0500h        | 020h–00Ah            |
| DMA Channel 2 (see Table 6-35)                 | 0500h        | 030h–00Ah            |
| USCI_A0 (see Table 6-36)                       | 05C0h        | 000h–01Fh            |
| USCI_B0 (see Table 6-36)                       | 05E0h        | 000h–01Fh            |
| ADC10_A (see Table 6-38)<br>(MSP430F51x2 only) | 0740h        | 000h–01Fh            |
| Comparator_B (see Table 6-39)                  | 08C0h        | 000h–00Fh            |
| TD0 (see Table 6-40)                           | 0B00h        | 000h–03Fh            |
| TEC0 (see Table 6-42)                          | 0C00h        | 000h–007h            |
| TD1 (see Table 6-41)                           | 0B40h        | 000h–03Fh            |
| TEC1 (see Table 6-43)                          | 0C20h        | 000h–007h            |

**Table 6-14. Special Function Registers (Base Address: 0100h)**

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

**Table 6-15. PMM Registers (Base Address: 0120h)**

| REGISTER DESCRIPTION     | REGISTER | OFFSET |
|--------------------------|----------|--------|
| PMM control 0            | PMMCTL0  | 00h    |
| PMM control 1            | PMMCTL1  | 02h    |
| SVS high-side control    | SVSMHCTL | 04h    |
| SVS low-side control     | SVSMLCTL | 06h    |
| PMM interrupt flags      | PMMIFG   | 0Ch    |
| PMM interrupt enable     | PMMIE    | 0Eh    |
| PMM power mode 5 control | PM5CTL0  | 10h    |

**Table 6-16. Flash Control Registers (Base Address: 0140h)**

| REGISTER DESCRIPTION | REGISTER | OFFSET |
|----------------------|----------|--------|
| Flash control 1      | FCTL1    | 00h    |
| Flash control 3      | FCTL3    | 04h    |
| Flash control 4      | FCTL4    | 06h    |

**Table 6-17. CRC16 Registers (Base Address: 0150h)**

| REGISTER DESCRIPTION | REGISTER   | OFFSET |
|----------------------|------------|--------|
| CRC data input       | CRC16DI    | 00h    |
| CRC result           | CRC16INRES | 04h    |

**Table 6-18. RAM Control Registers (Base Address: 0158h)**

| REGISTER DESCRIPTION | REGISTER | OFFSET |
|----------------------|----------|--------|
| RAM control 0        | RCCTL0   | 00h    |

**Table 6-19. Watchdog Registers (Base Address: 015Ch)**

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

**Table 6-20. UCS Registers (Base Address: 0160h)**

| REGISTER DESCRIPTION | REGISTER | OFFSET |
|----------------------|----------|--------|
| UCS control 0        | UCSCTL0  | 00h    |
| UCS control 1        | UCSCTL1  | 02h    |
| UCS control 2        | UCSCTL2  | 04h    |
| UCS control 3        | UCSCTL3  | 06h    |
| UCS control 4        | UCSCTL4  | 08h    |
| UCS control 5        | UCSCTL5  | 0Ah    |
| UCS control 6        | UCSCTL6  | 0Ch    |
| UCS control 7        | UCSCTL7  | 0Eh    |
| UCS control 8        | UCSCTL8  | 10h    |

**Table 6-21. SYS Registers (Base Address: 0180h)**

| REGISTER DESCRIPTION          | REGISTER  | OFFSET |
|-------------------------------|-----------|--------|
| System control                | SYSCTL    | 00h    |
| Bootloader configuration area | SYSBSLC   | 02h    |
| JTAG mailbox control          | SYSJMBC   | 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   | SYSNIV    | 1Ch    |
| Reset vector generator        | SYSRSTIV  | 1Eh    |

**Table 6-22. Shared Reference Registers (Base Address: 01B0h)**

| REGISTER DESCRIPTION     | REGISTER | OFFSET |
|--------------------------|----------|--------|
| Shared reference control | REFCTL   | 00h    |

**Table 6-23. Port Mapping Control (Base Address: 01C0h)**

| REGISTER DESCRIPTION  | REGISTER | OFFSET |
|-----------------------|----------|--------|
| Port mapping password | PMAPPWD  | 00h    |
| Port mapping control  | PMAPCTL  | 02h    |

**Table 6-24. Port Mapping for Port P1 (Base Address: 01C8h)**

| REGISTER DESCRIPTION | REGISTER | OFFSET |
|----------------------|----------|--------|
| Port P1.0 mapping    | P1MAP0   | 00h    |
| Port P1.1 mapping    | P1MAP1   | 01h    |
| Port P1.2 mapping    | P1MAP2   | 02h    |
| Port P1.3 mapping    | P1MAP3   | 03h    |
| Port P1.4 mapping    | P1MAP4   | 04h    |
| Port P1.5 mapping    | P1MAP5   | 05h    |
| Port P1.6 mapping    | P1MAP6   | 06h    |
| Port P1.7 mapping    | P1MAP7   | 07h    |

**Table 6-25. Port Mapping for Port P2 (Base Address: 01D0h)**

| REGISTER DESCRIPTION | REGISTER | OFFSET |
|----------------------|----------|--------|
| Port P2.0 mapping    | P2MAP0   | 00h    |
| Port P2.1 mapping    | P2MAP2   | 01h    |
| Port P2.2 mapping    | P2MAP2   | 02h    |
| Port P2.3 mapping    | P2MAP3   | 03h    |
| Port P2.4 mapping    | P2MAP4   | 04h    |
| Port P2.5 mapping    | P2MAP5   | 05h    |
| Port P2.6 mapping    | P2MAP6   | 06h    |
| Port P2.7 mapping    | P2MAP7   | 07h    |

**Table 6-26. Port Mapping for Port P3 (Base Address: 01D8h)**

| REGISTER DESCRIPTION | REGISTER | OFFSET |
|----------------------|----------|--------|
| Port P3.0 mapping    | P3MAP0   | 00h    |
| Port P3.1 mapping    | P3MAP1   | 01h    |
| Port P3.2 mapping    | P3MAP2   | 02h    |
| Port P3.3 mapping    | P3MAP3   | 03h    |
| Port P3.4 mapping    | P3MAP4   | 04h    |
| Port P3.5 mapping    | P3MAP5   | 05h    |
| Port P3.6 mapping    | P3MAP6   | 06h    |
| Port P3.7 mapping    | P3MAP7   | 07h    |

**Table 6-27. Port Registers Port P1, P2 (Base Addresses: 0200h)**

| REGISTER DESCRIPTION          | REGISTER | OFFSET |
|-------------------------------|----------|--------|
| Port P1 input                 | P1IN     | 00h    |
| Port P1 output                | P1OUT    | 02h    |
| Port P1 direction             | P1DIR    | 04h    |
| Port P1 resistor enable       | P1REN    | 06h    |
| Port P1 drive strength        | P1DS     | 08h    |
| Port P1 selection             | P1SEL    | 0Ah    |
| Port P1 interrupt vector word | P1IV     | 0Eh    |
| 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 resistor enable       | P2REN    | 07h    |
| Port P2 drive strength        | P2DS     | 09h    |
| Port P2 selection             | P2SEL    | 0Bh    |
| Port P2 interrupt vector word | P2IV     | 1Eh    |
| Port P2 interrupt edge select | P2IES    | 19h    |
| Port P2 interrupt enable      | P2IE     | 1Bh    |
| Port P2 interrupt flag        | P2IFG    | 1Dh    |

**Table 6-28. Port Registers P3 (Base Addresses: 0220h)**

| REGISTER DESCRIPTION    | REGISTER | OFFSET |
|-------------------------|----------|--------|
| Port P3 input           | P3IN     | 00h    |
| Port P3 output          | P3OUT    | 02h    |
| Port P3 direction       | P3DIR    | 04h    |
| Port P3 resistor enable | P3REN    | 06h    |
| Port P3 drive strength  | P3DS     | 08h    |
| Port P3 selection       | P3SEL    | 0Ah    |

**Table 6-29. Port Registers PJ (Base Addresses: 0320h)**

| REGISTER DESCRIPTION    | REGISTER | OFFSET |
|-------------------------|----------|--------|
| Port PJ input           | PJIN     | 00h    |
| Port PJ output          | PJOUT    | 02h    |
| Port PJ direction       | PJDIR    | 04h    |
| Port PJ resistor enable | PJREN    | 06h    |
| Port PJ drive strength  | PJDS     | 08h    |
| Port PJ selection       | PJSEL    | 0Ah    |

**Table 6-30. TA0 Registers (Base Address: 03C0h)**

| REGISTER DESCRIPTION      | REGISTER | 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 6-31. 32-Bit Hardware Multiplier Registers (Base Address: 04C0h)**

| REGISTER DESCRIPTION                                    | REGISTER  | 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                                        | OP2       | 08h    |
| 16 × 16 result low word                                 | RESLO     | 0Ah    |
| 16 × 16 result high word                                | RESHI     | 0Ch    |
| 16 × 16 sum extension register                          | 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 6-32. DMA General Control (Base Address: 0500h)**

| REGISTER DESCRIPTION | REGISTER | OFFSET |
|----------------------|----------|--------|
| DMA module control 0 | DMACTL0  | 00h    |
| DMA module control 1 | DMACTL1  | 02h    |
| DMA module control 2 | DMACTL2  | 04h    |
| DMA module control 3 | DMACTL3  | 06h    |
| DMA module control 4 | DMACTL4  | 08h    |
| DMA interrupt vector | DMAIV    | 0Eh    |

**Table 6-33. DMA Channel 0 (Base Address: 0510h)**

| REGISTER DESCRIPTION                   | REGISTER | OFFSET |
|----------------------------------------|----------|--------|
| DMA channel 0 control                  | DMA0CTL  | 00h    |
| DMA channel 0 source address low       | DMA0SAL  | 02h    |
| DMA channel 0 source address high      | DMA0SAH  | 04h    |
| DMA channel 0 destination address low  | DMA0DAL  | 06h    |
| DMA channel 0 destination address high | DMA0DAH  | 08h    |
| DMA channel 0 transfer size            | DMA0SZ   | 0Ah    |

**Table 6-34. DMA Channel 1 (Base Address: 0520h)**

| REGISTER DESCRIPTION                   | REGISTER | OFFSET |
|----------------------------------------|----------|--------|
| DMA channel 1 control                  | DMA1CTL  | 00h    |
| DMA channel 1 source address low       | DMA1SAL  | 02h    |
| DMA channel 1 source address high      | DMA1SAH  | 04h    |
| DMA channel 1 destination address low  | DMA1DAL  | 06h    |
| DMA channel 1 destination address high | DMA1DAH  | 08h    |
| DMA channel 1 transfer size            | DMA1SZ   | 0Ah    |

**Table 6-35. DMA Channel 2 (Base Address: 0530h)**

| REGISTER DESCRIPTION                   | REGISTER | OFFSET |
|----------------------------------------|----------|--------|
| DMA channel 2 control                  | DMA2CTL  | 00h    |
| DMA channel 2 source address low       | DMA2SAL  | 02h    |
| DMA channel 2 source address high      | DMA2SAH  | 04h    |
| DMA channel 2 destination address low  | DMA2DAL  | 06h    |
| DMA channel 2 destination address high | DMA2DAH  | 08h    |
| DMA channel 2 transfer size            | DMA2SZ   | 0Ah    |

**Table 6-36. USCI0\_A Registers (Base Address: 05C0h)**

| REGISTER DESCRIPTION       | REGISTER   | OFFSET |
|----------------------------|------------|--------|
| USCI control 0             | UCA0CTL0   | 01h    |
| USCI control 1             | UCA0CTL1   | 00h    |
| USCI baud rate 0           | UCA0BR0    | 06h    |
| USCI baud rate 1           | UCA0BR1    | 07h    |
| USCI modulation control    | UCA0MCTL   | 08h    |
| USCI status                | UCA0STAT   | 0Ah    |
| USCI receive buffer        | UCA0RXBUF  | 0Ch    |
| USCI transmit buffer       | UCA0TXBUF  | 0Eh    |
| USCI LIN control           | UCA0ABCTL  | 10h    |
| USCI IrDA transmit control | UCA0IRTCTL | 12h    |
| USCI IrDA receive control  | UCA0IRRCTL | 13h    |
| USCI interrupt enable      | UCA0IE     | 1Ch    |
| USCI interrupt flags       | UCA0IFG    | 1Dh    |
| USCI interrupt vector word | UCA0IV     | 1Eh    |

**Table 6-37. USCI0\_B Registers (Base Address: 05E0h)**

| REGISTER DESCRIPTION             | REGISTER  | OFFSET |
|----------------------------------|-----------|--------|
| USCI synchronous control 0       | UCB0CTL0  | 00h    |
| USCI synchronous control 1       | UCB0CTL1  | 01h    |
| USCI synchronous bit rate 0      | UCB0BR0   | 06h    |
| USCI synchronous bit rate 1      | UCB0BR1   | 07h    |
| USCI synchronous status          | UCB0STAT  | 0Ah    |
| USCI synchronous receive buffer  | UCB0RXBUF | 0Ch    |
| USCI synchronous transmit buffer | UCB0TXBUF | 0Eh    |
| USCI I2C own address             | UCB0I2COA | 10h    |
| USCI I2C slave address           | UCB0I2CSA | 12h    |
| USCI interrupt enable            | UCB0IE    | 1Ch    |
| USCI interrupt flags             | UCB0IFG   | 1Dh    |
| USCI interrupt vector word       | UCB0IV    | 1Eh    |

**Table 6-38. ADC10\_A Registers (MSP430F51x2 Devices Only) (Base Address: 0740h)**

| REGISTER DESCRIPTION                     | REGISTER   | OFFSET |
|------------------------------------------|------------|--------|
| ADC10_A control 0                        | ADC10CTL0  | 00h    |
| ADC10_A control 1                        | ADC10CTL1  | 02h    |
| ADC10_A control 2                        | ADC10CTL2  | 04h    |
| ADC10_A window comparator low threshold  | ADC10LO    | 06h    |
| ADC10_A window comparator high threshold | ADC10HI    | 08h    |
| ADC10_A memory control register 0        | ADC10MCTL0 | 0Ah    |
| ADC10_A conversion memory register       | ADC10MEM0  | 12h    |
| ADC10_A interrupt enable                 | ADC10IE    | 1Ah    |
| ADC10_A interrupt flags                  | ADC10IGH   | 1Ch    |
| ADC10_A interrupt vector word            | ADC10IV    | 1Eh    |

**Table 6-39. Comparator\_B Registers (Base Address: 08C0h)**

| REGISTER DESCRIPTION               | REGISTER | OFFSET |
|------------------------------------|----------|--------|
| Comparator_B control 0             | CBCTL0   | 00h    |
| Comparator_B control 1             | CBCTL1   | 02h    |
| Comparator_B control 2             | CBCTL2   | 04h    |
| Comparator_B control 3             | CBCTL3   | 06h    |
| Comparator_B interrupt             | CBINT    | 0Ch    |
| Comparator_B interrupt vector word | CBIV     | 0Eh    |

**Table 6-40. TD0 Registers (Base Address: 0B00h)**

| REGISTER DESCRIPTION          | REGISTER | OFFSET |
|-------------------------------|----------|--------|
| TD0 control 0                 | TD0CTL0  | 00h    |
| TD0 control 1                 | TD0CTL1  | 02h    |
| TD0 control 2                 | TD0CTL2  | 04h    |
| TD0 counter                   | TD0R     | 06h    |
| Capture/compare control 0     | TD0CCTL0 | 08h    |
| Capture/compare 0             | TD0CCR0  | 0Ah    |
| Capture/compare latch 0       | TD0CL0   | 0Ch    |
| Capture/compare control 1     | TD0CCTL1 | 0Eh    |
| Capture/compare 1             | TD0CCR1  | 10h    |
| Capture/compare latch 1       | TD0CL1   | 12h    |
| Capture/compare control 2     | TD0CCTL2 | 14h    |
| Capture/compare 2             | TD0CCR2  | 16h    |
| Capture/compare latch 2       | TD0CL2   | 18h    |
| TD0 high-resolution control 0 | TD0HCTL0 | 38h    |
| TD0 high-resolution control 1 | TD0HCTL1 | 3Ah    |
| TD0 high-resolution interrupt | TD0HINT  | 3Ch    |
| TD0 interrupt vector          | TD0IV    | 3Eh    |

**Table 6-41. TD1 Registers (Base Address: 0B40h)**

| REGISTER DESCRIPTION          | REGISTER | OFFSET |
|-------------------------------|----------|--------|
| TD1 control 0                 | TD1CTL0  | 00h    |
| TD1 control 1                 | TD1CTL1  | 02h    |
| TD1 control 2                 | TD1CTL2  | 04h    |
| TD1 counter                   | TD1R     | 06h    |
| Capture/compare control 0     | TD1CCTL0 | 08h    |
| Capture/compare 0             | TD1CCR0  | 0Ah    |
| Capture/compare latch 0       | TD1CL0   | 0Ch    |
| Capture/compare control 1     | TD1CCTL1 | 0Eh    |
| Capture/compare 1             | TD1CCR1  | 10h    |
| Capture/compare latch 1       | TD1CL1   | 12h    |
| Capture/compare control 2     | TD1CCTL2 | 14h    |
| Capture/compare 2             | TD1CCR2  | 16h    |
| Capture/compare latch 2       | TD1CL2   | 18h    |
| TD1 high-resolution control 0 | TD1HCTL0 | 38h    |
| TD1 high-resolution control 1 | TD1HCTL1 | 3Ah    |
| TD1 high-resolution interrupt | TD1HINT  | 3Ch    |
| TD1 interrupt vector          | TD1IV    | 3Eh    |

**Table 6-42. TEC0 Registers (Base Address: 0C00h)**

| REGISTER DESCRIPTION                            | REGISTER | OFFSET |
|-------------------------------------------------|----------|--------|
| Timer event control 0 external control 0        | TEC0CTL0 | 00h    |
| Timer event control 0 external control          | TEC0CTL1 | 02h    |
| Timer event control 0 external control          | TEC0CTL2 | 04h    |
| Timer event control 0 status                    | TEC0STA  | 06h    |
| Timer event control 0 external interrupt        | TEC0XINT | 08h    |
| Timer event control 0 external interrupt vector | TEC0IV   | 0Ah    |

**Table 6-43. TEC1 Registers (Base Address: 0C20h)**

| REGISTER DESCRIPTION                            | REGISTER | OFFSET |
|-------------------------------------------------|----------|--------|
| Timer event control 1 external control 0        | TEC1CTL0 | 00h    |
| Timer event control 1 external control          | TEC1CTL1 | 02h    |
| Timer event control 1 external control          | TEC1CTL2 | 04h    |
| Timer event control 1 status                    | TEC1STA  | 06h    |
| Timer event control 1 external interrupt        | TEC1XINT | 08h    |
| Timer event control 1 external interrupt vector | TEC1IV   | 0Ah    |

## 6.10 Input/Output Diagrams

### 6.10.1 Port P1 (P1.0 to P1.5) Input/Output With Schmitt Trigger

Figure 6-2 shows the port diagram. Table 6-44 summarizes the selection of the pin function.

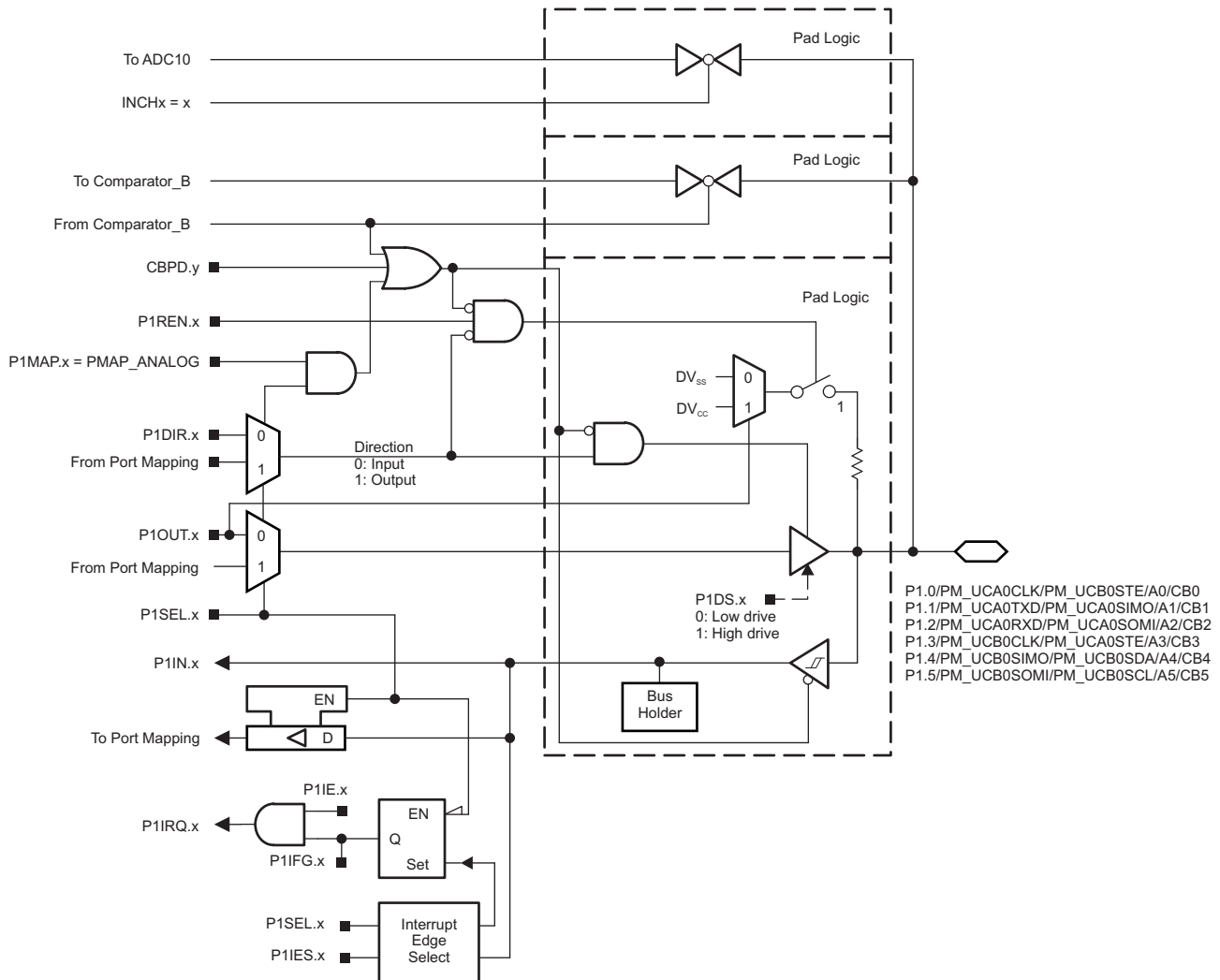


Figure 6-2. Port P1 (P1.0 to P1.5) Diagram

**Table 6-44. Port P1 (P1.0 to P1.5) Pin Functions**

| PIN NAME (P1.x)                      | x | FUNCTION                                  | CONTROL BITS OR SIGNALS <sup>(1)</sup> |         |                 |           |
|--------------------------------------|---|-------------------------------------------|----------------------------------------|---------|-----------------|-----------|
|                                      |   |                                           | P1DIR.x                                | P1SEL.x | P1MAP.x         | CBPD.y    |
| P1.0/<br>PM_UCA0CLK/<br>PM_UCB0STE/  | 0 | P1.x (I/O)                                | I: 0; O: 1                             | 0       | X               | 0         |
|                                      |   | UCA0CLK/UCB0STE <sup>(2) (3)</sup>        | 0                                      | 1       | default         | 0         |
| A0/                                  |   | A0 <sup>(4)</sup>                         | X                                      | 1       | 31<br>INCHx = 0 | X         |
| CB0                                  |   | CB0                                       | X                                      | X       | X               | 1 (y = 0) |
| P1.1/<br>PM_UCA0TXD/<br>PM_UCA0SIMO/ | 1 | P1.x (I/O)                                | I: 0; O: 1                             | 0       | X               | 0         |
|                                      |   | PM_UCA0TXD/PM_UCA0SIMO <sup>(2)</sup>     | 0                                      | 1       | default         | 0         |
| A1/                                  |   | A1 <sup>(4)</sup>                         | X                                      | 1       | 31<br>INCHx = 1 | X         |
| CB1                                  |   | CB1                                       | X                                      | X       | X               | 1 (y = 1) |
| P1.2/<br>PM_UCA0RXD/<br>PM_UCA0SOMI/ | 2 | P1.x (I/O)                                | I: 0; O: 1                             | 0       | X               | 0         |
|                                      |   | PM_UCA0RXD/PM_UCA0SOMI <sup>(2)</sup>     | 0                                      | 1       | default         | 0         |
| A2/                                  |   | A2 <sup>(4)</sup>                         | X                                      | 1       | 31<br>INCHx = 2 | X         |
| CB2                                  |   | CB2                                       | X                                      | X       | X               | 1 (y = 2) |
| P1.3/<br>PM_UCB0CLK/<br>PM_UCA0STE/  | 3 | P1.x (I/O)                                | I: 0; O: 1                             | 0       | X               | 0         |
|                                      |   | UCB0CLK/UCA0STE <sup>(2)</sup>            | 0                                      | 1       | default         | 0         |
| A3/                                  |   | A3 <sup>(4)</sup>                         | X                                      | 1       | 31<br>INCHx = 3 | X         |
| CB3                                  |   | CB3                                       | X                                      | X       | X               | 1 (y = 3) |
| P1.4/<br>PM_UCB0SIMO/<br>PM_UCB0SDA/ | 4 | P1.x (I/O)                                | I: 0; O: 1                             | 0       | X               | 0         |
|                                      |   | PM_UCB0SIMO/PM_UCB0SDA <sup>(2) (5)</sup> | 0                                      | 1       | default         | 0         |
| A4/                                  |   | A4 <sup>(4)</sup>                         | X                                      | 1       | 31<br>INCHx = 4 | X         |
| CB4                                  |   | CB4                                       | X                                      | X       | X               | 1 (y = 4) |
| P1.5/<br>PM_UCB0SOMI/<br>PM_UCB0SCL/ | 5 | P1.x (I/O)                                | I: 0; O: 1                             | 0       | X               | 0         |
|                                      |   | PM_UCB0SOMI/PM_UCB0SCL <sup>(2) (5)</sup> | 0                                      | 1       | default         | 0         |
| A5/                                  |   | A5 <sup>(4)</sup>                         | X                                      | 1       | 31<br>INCHx = 5 | X         |
| CB5                                  |   | CB5                                       | X                                      | X       | X               | 1 (y = 5) |

(1) X = Don't care

(2) The pin direction is controlled by the USCI module.

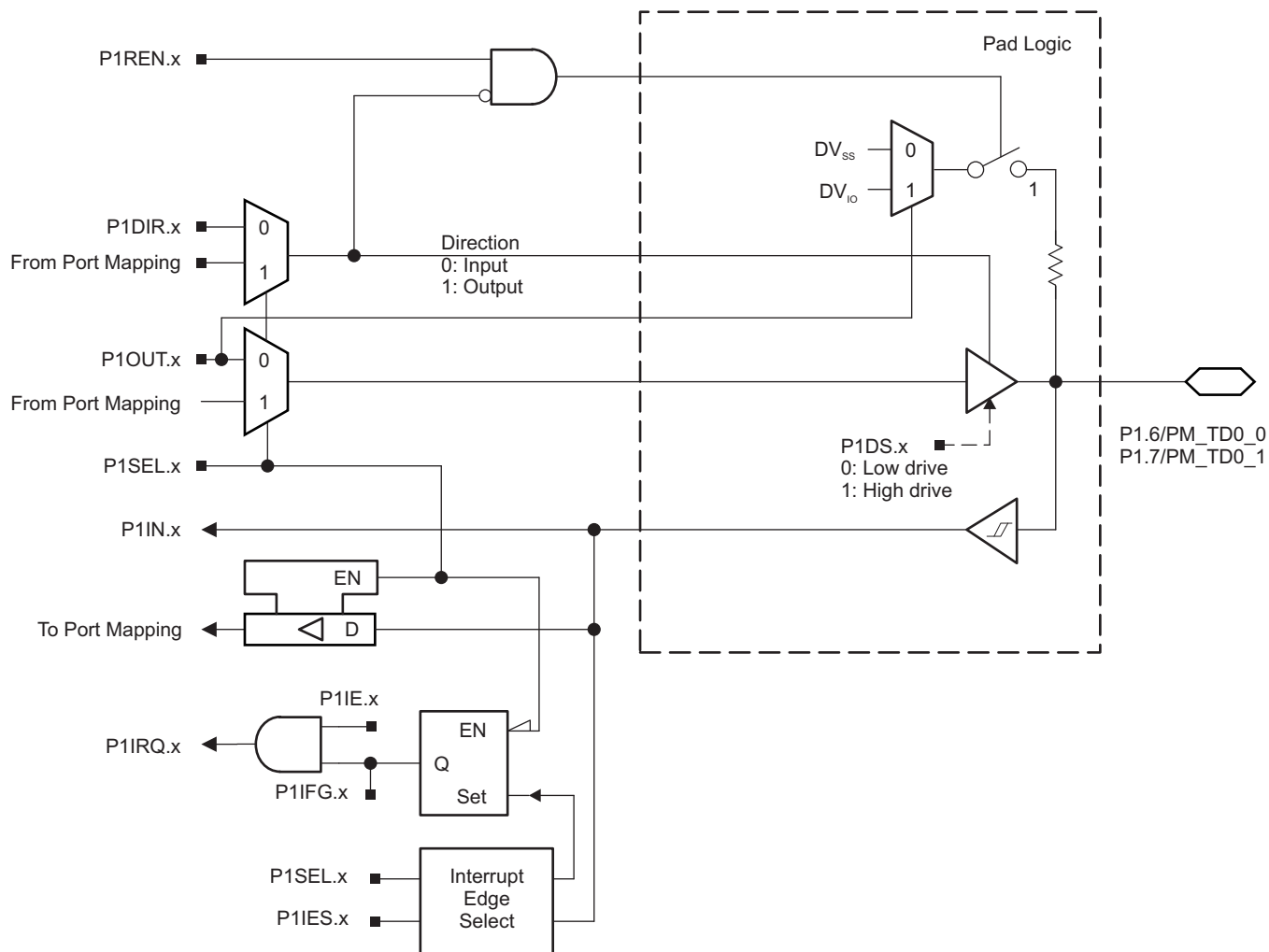
(3) UCA0CLK function takes precedence over UCB0STE function. If the pin is required as UCA0CLK input or output, USCI\_B0 is forced to 3-wire SPI mode if 4-wire SPI mode is selected.

(4) MSP430F51x2 device only

(5) If the I<sup>2</sup>C functionality is selected, the output drives only the logical 0 to V<sub>SS</sub> level.

### 6.10.2 Port P1 (P1.6 to P1.7) Input/Output With Schmitt Trigger

Figure 6-3 shows the port diagram. Table 6-45 summarizes the selection of the pin function.



### Figure 6-3. Port P1 (P1.6 and P1.7) Diagram

### Table 6-45. Port P1 (P1.6 and P1.7) Pin Functions

| PIN NAME (P1.x)   | x | FUNCTION   | CONTROL BITS OR SIGNALS <sup>(1)</sup> |         |         |
|-------------------|---|------------|----------------------------------------|---------|---------|
|                   |   |            | P1DIR.x                                | P1SEL.x | P1MAP.x |
| P1.6/<br>PM_TD0.0 | 6 | P1.x (I/O) | I: 0; O: 1                             | 0       | X       |
|                   |   | TD0.CCI0A  | 0                                      | 1       | default |
|                   |   | TD0.TA0    | 1                                      | 1       | default |
| P1.7/<br>PM_TD0.1 | 7 | P1.x (I/O) | I: 0; O: 1                             | 0       | X       |
|                   |   | TD0.CCI1A  | 0                                      | 1       | default |
|                   |   | TD0.TA1    | 1                                      | 1       | default |

(1)  $X = \text{Don't care}$

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

Figure 6-4 shows the port diagram. Table 6-46 summarizes the selection of the pin function.

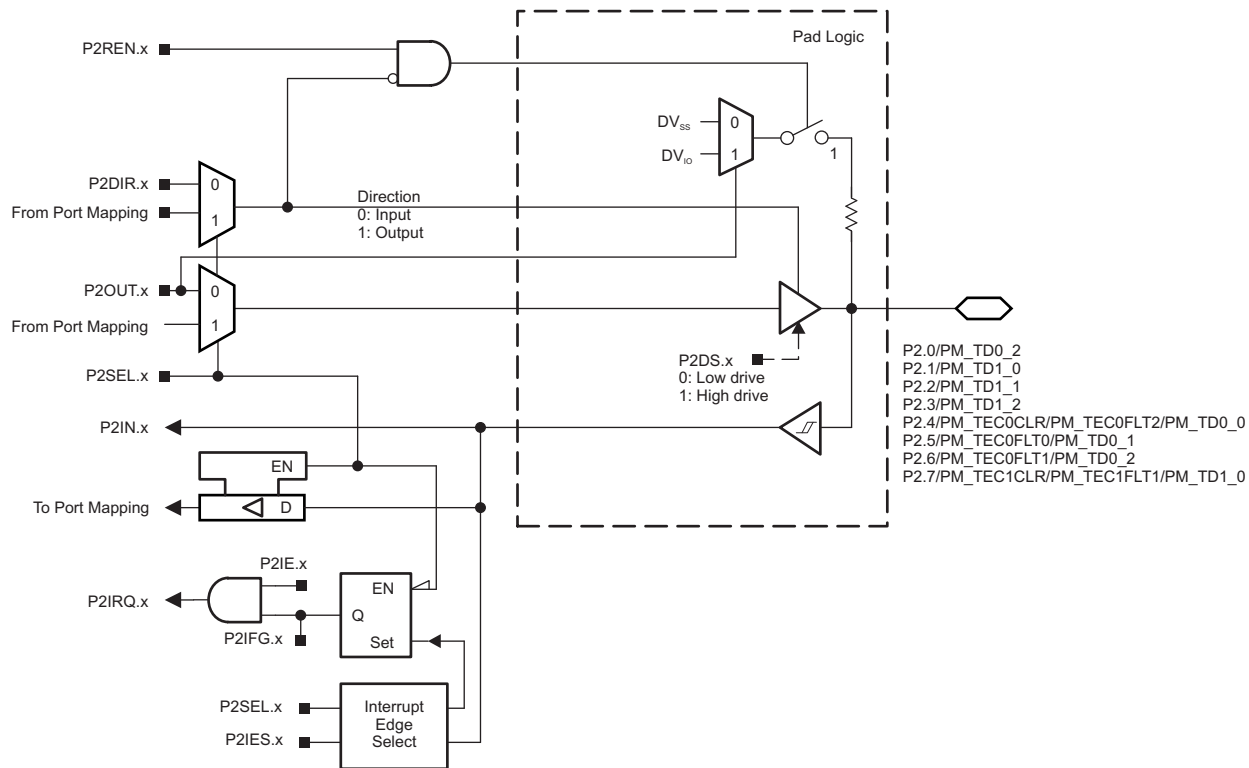


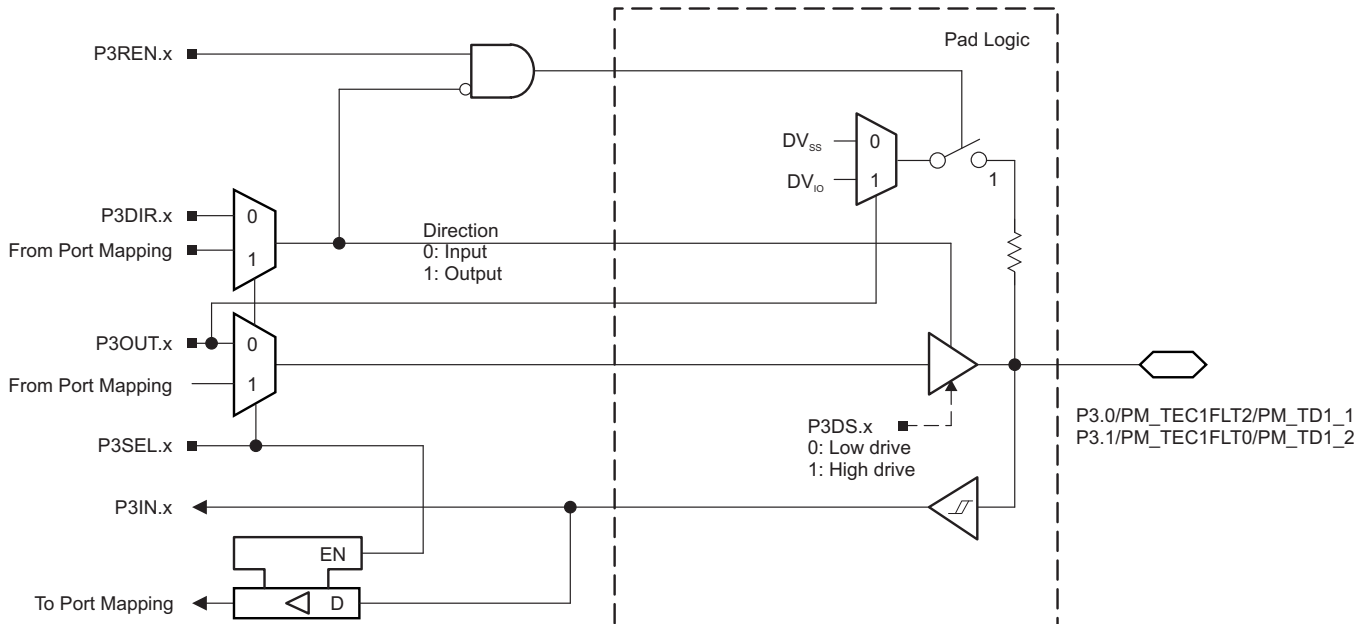
Figure 6-4. Port P2 (P2.0 to P2.7) Diagram

**Table 6-46. Port P2 (P2.0 to P2.7) Pin Functions**

| PIN NAME (P2.x)                                  | x | FUNCTION                                                       | CONTROL BITS OR SIGNALS |         |         |
|--------------------------------------------------|---|----------------------------------------------------------------|-------------------------|---------|---------|
|                                                  |   |                                                                | P2DIR.x                 | P2SEL.x | P2MAP.x |
| P2.0/<br>PM_TD0.2                                | 0 | P2.x (I/O)                                                     | I: 0; O: 1              | 0       | X       |
|                                                  |   | TD0.CCI2A                                                      | 0                       | 1       | default |
|                                                  |   | TD0.TA2                                                        | 1                       | 1       | default |
| P2.1/<br>PM_TD1.0                                | 1 | P2.x (I/O)                                                     | I: 0; O: 1              | 0       | X       |
|                                                  |   | TD1.CCI0A                                                      | 0                       | 1       | default |
|                                                  |   | TD1.TA0                                                        | 1                       | 1       | default |
| P2.2/<br>PM_TD1.1                                | 2 | P2.x (I/O)                                                     | I: 0; O: 1              | 0       | X       |
|                                                  |   | TD1.CCI1A                                                      | 0                       | 1       | default |
|                                                  |   | TD1.TA1                                                        | 1                       | 1       | default |
| P2.3/<br>PM_TD1.2                                | 3 | P2.x (I/O)                                                     | I: 0; O: 1              | 0       | 0       |
|                                                  |   | TD1.CCI2A                                                      | 0                       | 1       | default |
|                                                  |   | TD1.TA2                                                        | 1                       | 1       | default |
| P2.4/<br>PM_TEC0CLR/<br>PM_TEC0FLT2/<br>PM_TD0.0 | 4 | P2.x (I/O)                                                     | I: 0; O: 1              | 0       | X       |
|                                                  |   | TD0.TECEXTCLR, controlled by enable signals in the TEC0 module | 0                       | 1       | default |
|                                                  |   | TD0.TECXFLT2, controlled by enable signals in the TEC0 module  | 0                       | 1       | default |
|                                                  |   | TD0.TA0                                                        | 1                       | 1       | default |
| P2.5/<br>PM_TEC0FLT0/<br>PM_TD0.1                | 5 | P2.x (I/O)                                                     | I: 0; O: 1              | 0       | x       |
|                                                  |   | TD0.TECXFLT0, controlled by enable signals in the TEC0 module  | 0                       | 1       | default |
|                                                  |   | TD0.TA1                                                        | 1                       | 1       | default |
| P2.6/<br>PM_TEC0FLT1/<br>PM_TD0.2                | 6 | P2.x (I/O)                                                     | I: 0; O: 1              | 0       | X       |
|                                                  |   | TD0.TECXFLT1, controlled by enable signals in the TEC0 module  | 0                       | 1       | default |
|                                                  |   | TD0.TA2                                                        | 1                       | 1       | default |
| P2.7/<br>PM_TEC1CLR/<br>PM_TEC1FLT1/<br>PM_TD1.0 | 7 | P2.x (I/O)                                                     | I: 0; O: 1              | 0       | X       |
|                                                  |   | TD1.TECEXTCLR, controlled by enable signals in the TEC1 module | 0                       | 1       | default |
|                                                  |   | TD1.TECXFLT1, controlled by enable signals in the TEC1 module  | 0                       | 1       | default |
|                                                  |   | TD1.TA0                                                        | 1                       | 1       | default |

#### 6.10.4 Port P3 (P3.0 and P3.1) Input/Output With Schmitt Trigger

Figure 6-5 shows the port diagram. Table 6-47 summarizes the selection of the pin function.



**Figure 6-5. Port P3 (P3.0 and P3.1) Diagram**

**Table 6-47. Port P3 (P3.0 and P3.1) Pin Functions**

| PIN NAME (P3.x)                   | x | FUNCTION                                                      | CONTROL BITS OR SIGNALS |         |         |
|-----------------------------------|---|---------------------------------------------------------------|-------------------------|---------|---------|
|                                   |   |                                                               | P3DIR.x                 | P3SEL.x | P3MAP.x |
| P3.0/<br>PM_TEC1FLT2/<br>PM_TD1.1 | 0 | P3.x (I/O)                                                    | I: 0; O: 1              | 0       | X       |
|                                   |   | TD1.TECXFLT2, controlled by enable signals in the TEC1 module | 0                       | 1       | default |
|                                   |   | TD1.TA1                                                       | 1                       | 1       | default |
| P3.1/<br>PM_TEC1FLT0/<br>PM_TD1.2 | 1 | P3.x (I/O)                                                    | I: 0; O: 1              | 0       | X       |
|                                   |   | TD1.TECXFLT0, controlled by enable signals in the TEC1 module | 0                       | 1       | default |
|                                   |   | TD1.TA2                                                       | 1                       | 1       | default |

### 6.10.5 Port P3 (P3.2 and P3.3) Input/Output With Schmitt Trigger

Figure 6-6 shows the port diagram. Table 6-48 summarizes the selection of the pin function.

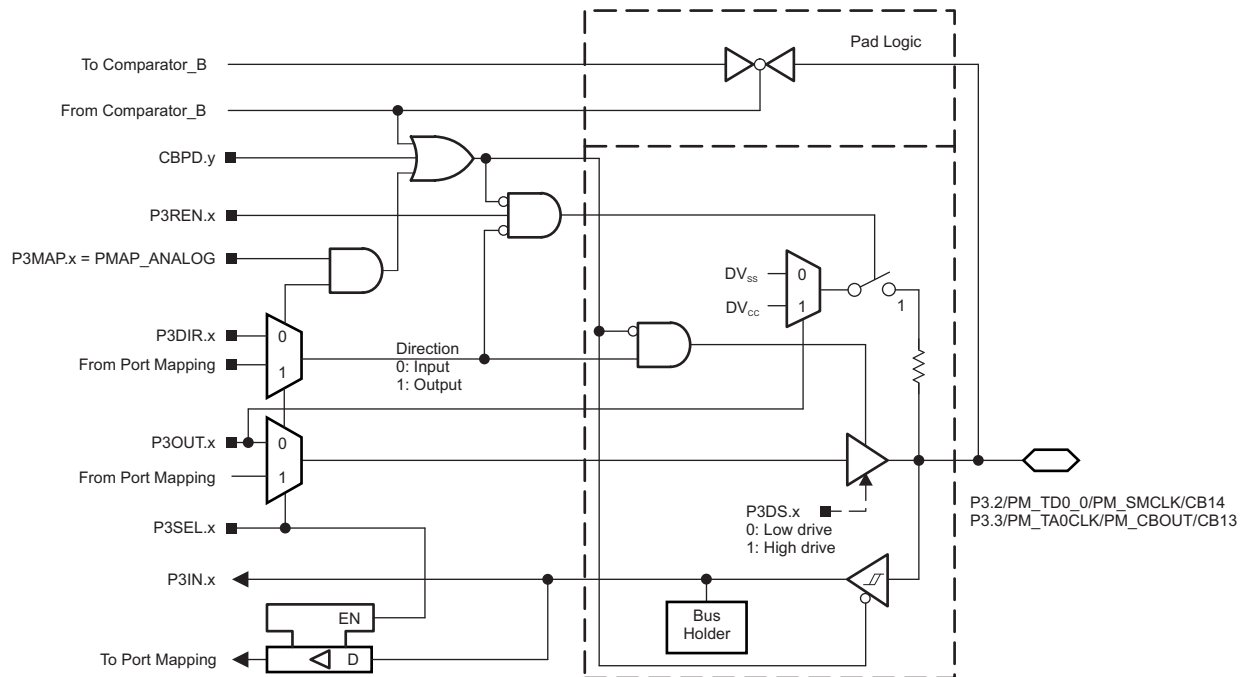


Figure 6-6. Port P3 (P3.2 and P3.3) Diagram

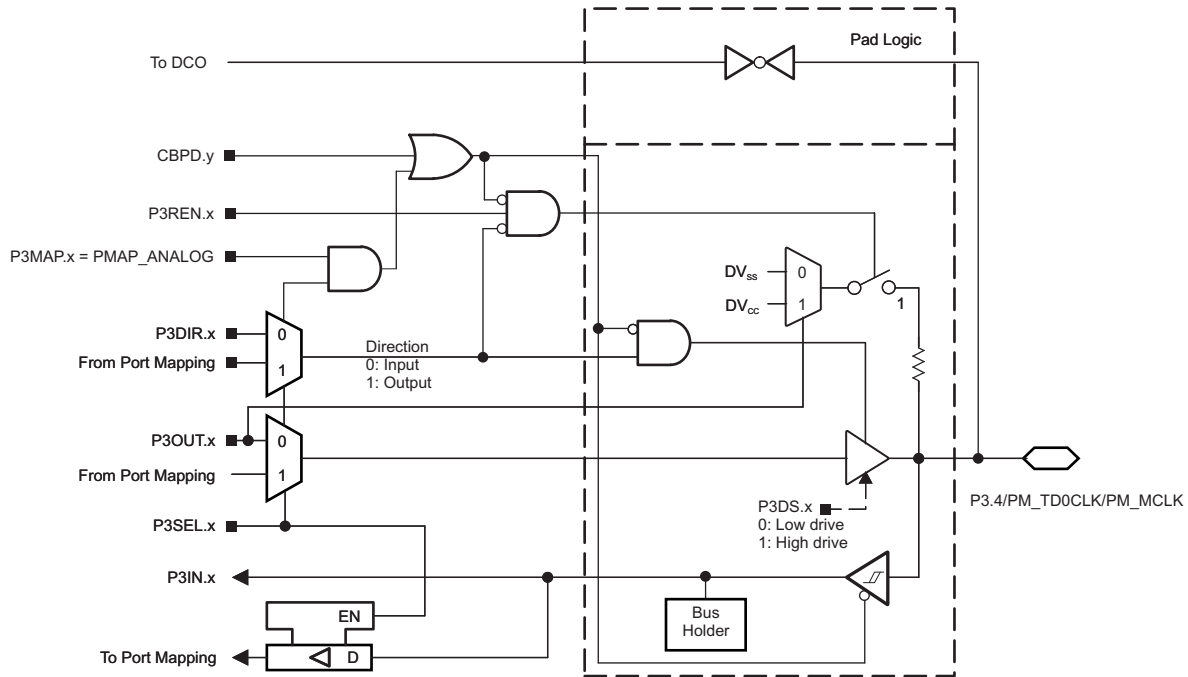
Table 6-48. Port P3 (P3.2 and P3.3) Pin Functions

| PIN NAME (P3.x)                          | x | FUNCTION     | CONTROL BITS OR SIGNALS <sup>(1)</sup> |         |         |            |
|------------------------------------------|---|--------------|----------------------------------------|---------|---------|------------|
|                                          |   |              | P3DIR.x                                | P3SEL.x | P3MAP.x | CBPD.y     |
| P3.2/<br>PM_TD0.0/<br>PM_SMCLK/<br>CB14  | 2 | P3.x (I/O)   | I: 0; O: 1                             | 0       | X       | 0          |
|                                          |   | TD0.CCI0A    | 0                                      | 1       | default | 0          |
|                                          |   | SMCLK output | 1                                      | 1       | default | 0          |
|                                          |   | CB14         | X                                      | X       | X       | 1 (y = 14) |
| P3.3/<br>PM_TA0CLK/<br>PM_CBOUT/<br>CB13 | 3 | P3.x (I/O)   | I: 0; O: 1                             | 0       | X       | 0          |
|                                          |   | TA0.TA0CLK   | 0                                      | 1       | default | 0          |
|                                          |   | CBOUT        | 1                                      | 1       | default | 0          |
|                                          |   | CB13         | X                                      | X       | X       | 1 (y = 13) |

(1) X = Don't care

### 6.10.6 Port P3 (P3.4) Input/Output With Schmitt Trigger

Figure 6-7 shows the port diagram. Table 6-49 summarizes the selection of the pin function.



**Figure 6-7. Port P3 (P3.4) Diagram**

**Table 6-49. Port P3 (P3.4) Pin Functions**

| PIN NAME (P3.x) | x | FUNCTION        | CONTROL BITS OR SIGNALS <sup>(1)</sup> |         |         |   |
|-----------------|---|-----------------|----------------------------------------|---------|---------|---|
|                 |   |                 | P3DIR.x                                | P3SEL.x | P3MAP.x |   |
| P3.4/           | 4 | P3.x (I/O)      | I: 0; O: 1                             | 0       | X       | 0 |
| PM_TD0CLK/      |   | TD0 clock input | 0                                      | 1       | default | 0 |
| PM_MCLK         |   | MCLK output     | 1                                      | 1       | default | 0 |

(1) X = Don't care

### 6.10.7 Port P3 (P3.5) Input/Output With Schmitt Trigger

Figure 6-8 shows the port diagram. Table 6-50 summarizes the selection of the pin function.

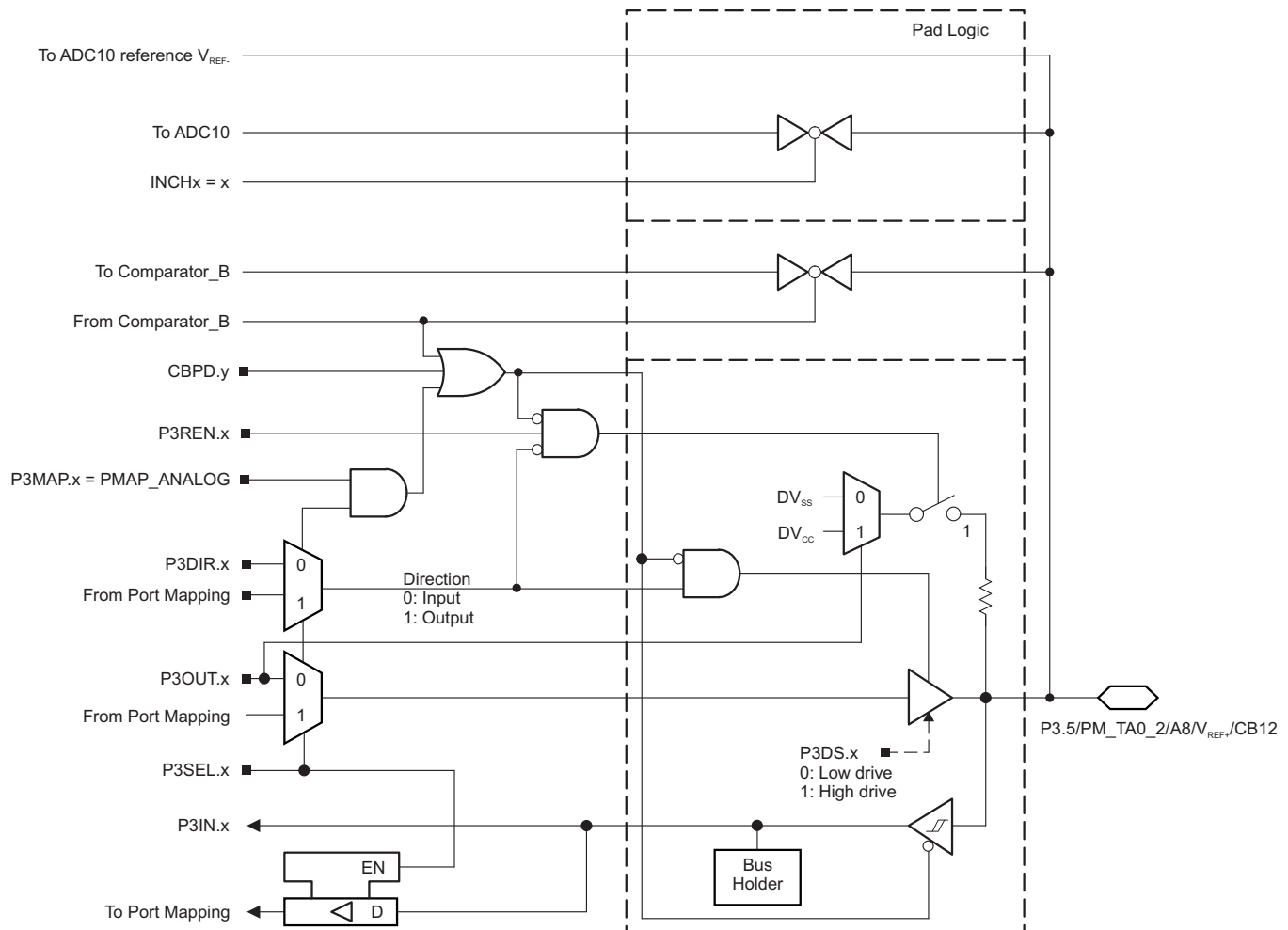


Figure 6-8. Port P3 (P3.5) Diagram

Table 6-50. Port P3 (P3.5) Pin Functions

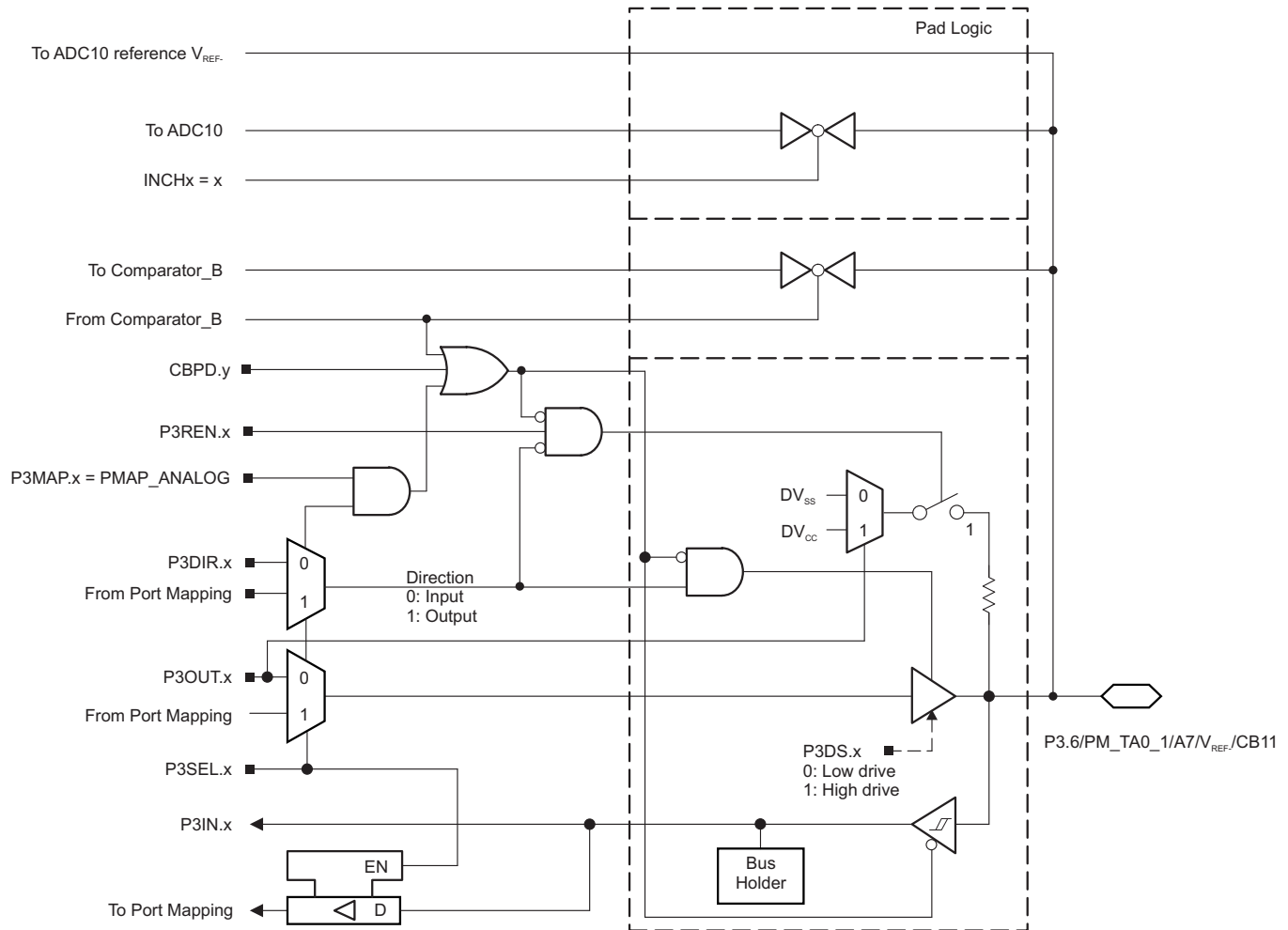
| PIN NAME (P3.x) | x | FUNCTION              | CONTROL BITS OR SIGNALS <sup>(1)</sup> |         |         |            |
|-----------------|---|-----------------------|----------------------------------------|---------|---------|------------|
|                 |   |                       | P3DIR.x                                | P3SEL.x | P3MAP.x | CBPD.y     |
| P3.5/           | 5 | P3.x (I/O)            | I: 0; O: 1                             | 0       | X       | 0          |
| PM_TA0.2/       |   | TA0.CCI2A             | 0                                      | 1       | default | 0          |
|                 |   | TA0.TA2               | 1                                      | 1       | default | 0          |
| VEREF+/-        |   | VEREF+ <sup>(2)</sup> | X                                      | 1       | 31      | X          |
| A8/             |   | A8 <sup>(2)</sup>     | X                                      | 1       | INCHx=8 | X          |
| CB12            |   | CB12                  | X                                      | X       | X       | 1 (y = 12) |

(1) X = Don't care

(2) MSP430F51x2 devices only.

### 6.10.8 Port P3 (P3.6) Input/Output With Schmitt Trigger

Figure 6-9 shows the port diagram. Table 6-51 summarizes the selection of the pin function.



**Figure 6-9. Port P3 (P3.6) Diagram**

**Table 6-51. Port P3 (P3.6) Pin Functions**

| PIN NAME (P3.x) | x | FUNCTION                  | CONTROL BITS OR SIGNALS <sup>(1)</sup> |         |                 |            |
|-----------------|---|---------------------------|----------------------------------------|---------|-----------------|------------|
|                 |   |                           | P3DIR.x                                | P3SEL.x | P3MAP.x         | CBPD.y     |
| P3.6/           | 6 | P3.x (I/O) <sup>(2)</sup> | I: 0; O: 1                             | 0       | X               | 0          |
| PM_TA0.1/       |   | TA0.CCR0                  | 0                                      | 1       | default         | 0          |
|                 |   | TA0.TA1                   | 1                                      | 1       | default         | 0          |
| VEREF-/         |   | VEREF- <sup>(3)</sup>     | X                                      | 1       | 31              | X          |
| A7/             |   | A7 <sup>(3)</sup>         | X                                      | 1       | 31<br>INCHx = 7 | X          |
| CB11            |   | CB11                      | X                                      | X       | 0               | 1 (y = 11) |

- (1) X = Don't care  
(2) Default condition.  
(3) MSP430F51x2 devices only.

### 6.10.9 Port P3 (P3.7) Input/Output With Schmitt Trigger

Figure 6-10 shows the port diagram. Table 6-52 summarizes the selection of the pin function.

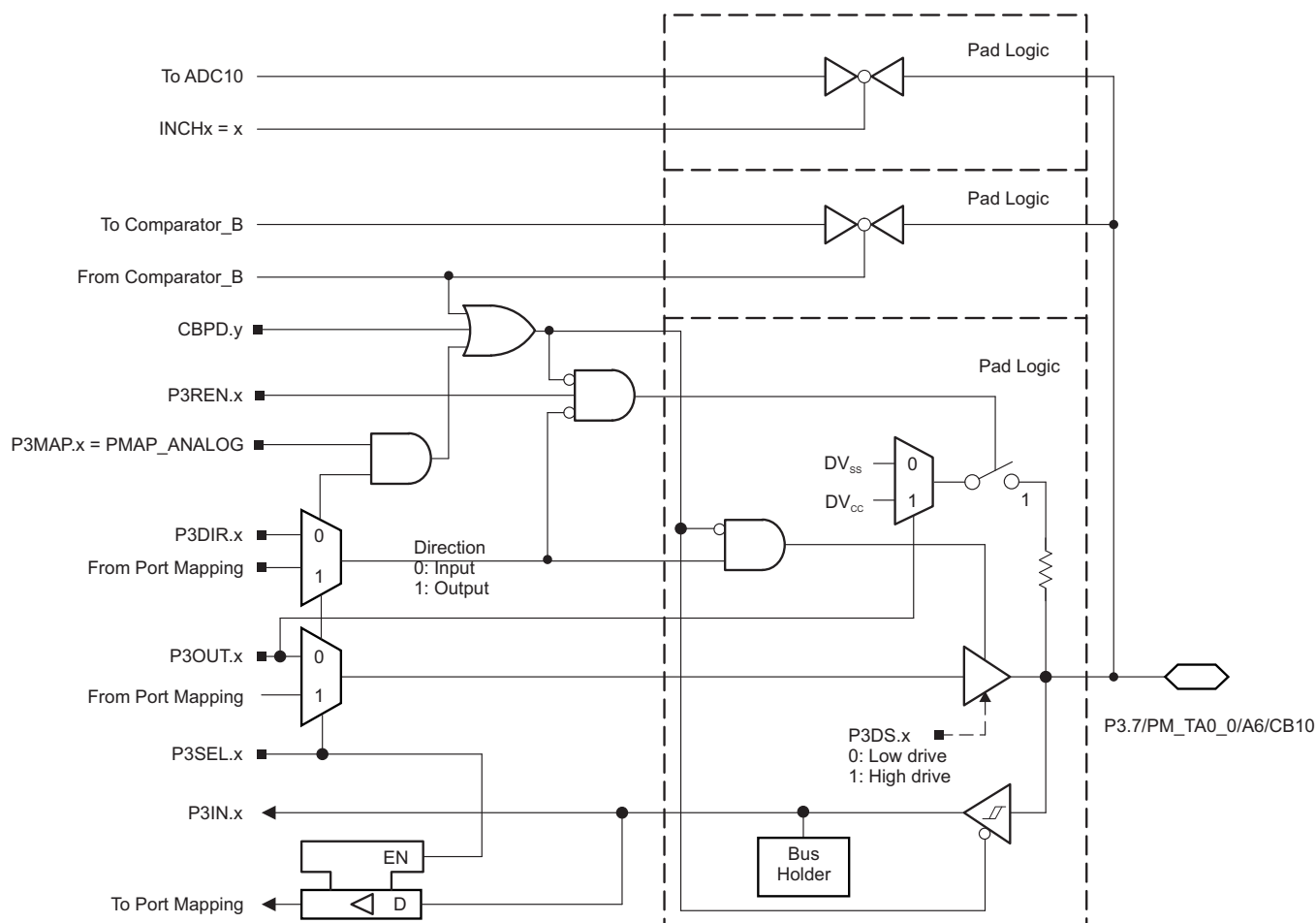


Figure 6-10. Port P3 (P3.7) Diagram

Table 6-52. Port P3 (P3.7) Pin Functions

| PIN NAME (P3.x) | x | FUNCTION                  | CONTROL BITS OR SIGNALS <sup>(1)</sup> |         |                            |            |
|-----------------|---|---------------------------|----------------------------------------|---------|----------------------------|------------|
|                 |   |                           | P3DIR.x                                | P3SEL.2 | P3MAP.x                    | CBPD.y     |
| P3.7/           | 7 | P3.x (I/O) <sup>(1)</sup> | I: 0; O: 1                             | 0       | X                          | 0          |
| PM_TA0.0/       |   | TA0.CCR0                  | 0                                      | 1       | default                    | 0          |
|                 |   | TA0.TA0                   | 1                                      | 1       | default                    | 0          |
| A6/             |   | A6 <sup>(2)</sup>         | X                                      | 1       | <sup>31</sup><br>INCHx = 6 | X          |
| CB10            |   | CB10                      | X                                      | X       | 0                          | 1 (y = 10) |

(1) X = Don't care

(2) MSP430F51x2 devices only.



### 6.10.11 Port J (PJ.1 to PJ.3) JTAG Pins TMS, TCK, TDI/TCLK, Input/Output With Schmitt Trigger or Output

Figure 6-12 shows the port diagram. Table 6-53 summarizes the selection of the pin function.

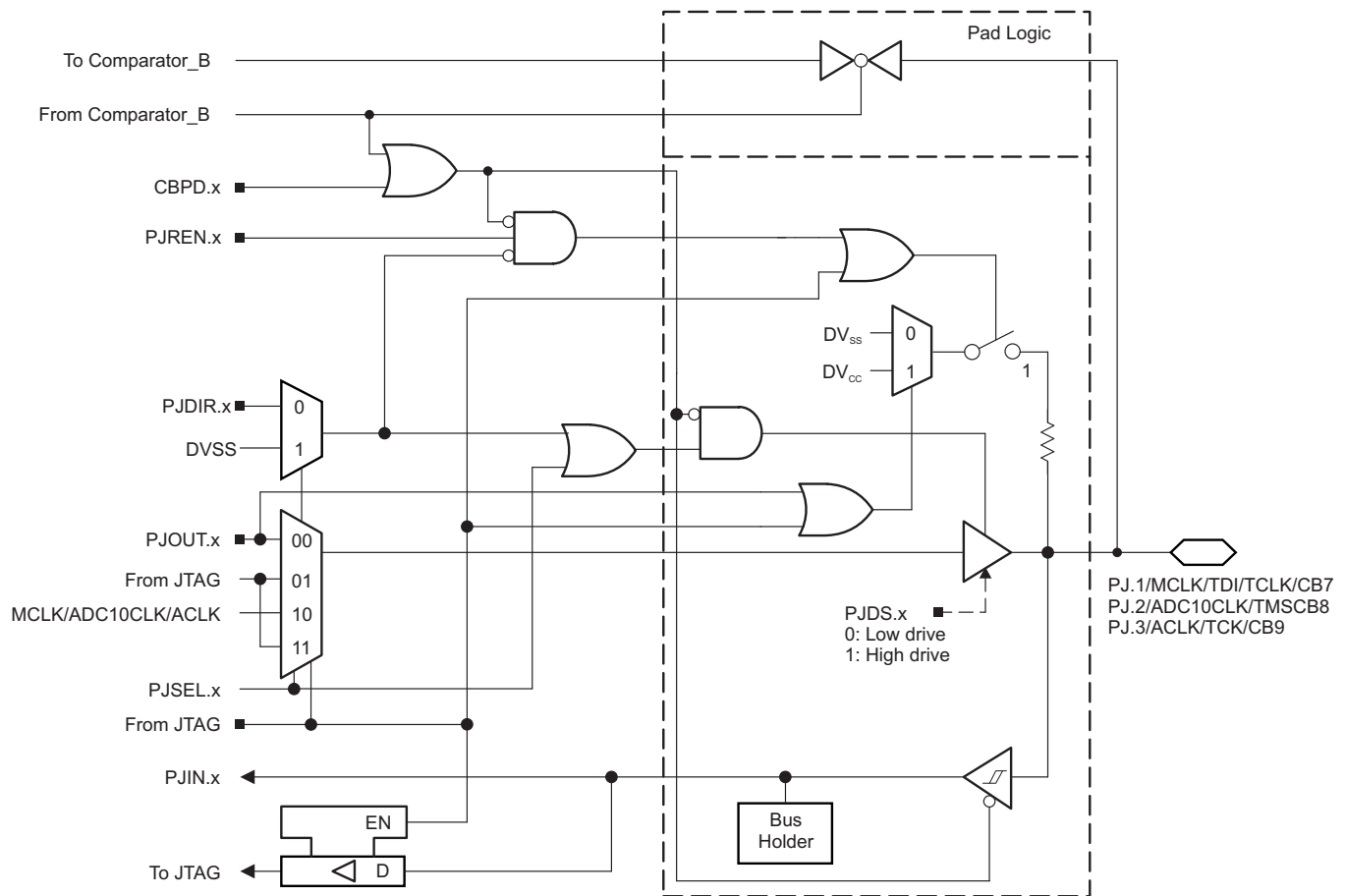


Figure 6-12. Port PJ (PJ.1 to PJ.3) Diagram

**Table 6-53. Port PJ (PJ.0 to PJ.3) Pin Functions**

| PIN NAME (PJ.x)                    | x | FUNCTION                       | CONTROL BITS OR SIGNALS <sup>(1)</sup> |         |           |           |
|------------------------------------|---|--------------------------------|----------------------------------------|---------|-----------|-----------|
|                                    |   |                                | PJDIR.x                                | PJSEL.x | JTAG MODE | CBPD.y    |
| PJ.0/<br>SMCLK/<br>TDO/<br>CB6     | 0 | PJ.x (I/O) <sup>(2)</sup>      | I: 0; O: 1                             | 0       | 0         | 0         |
|                                    |   | SMCLK                          | 1                                      | 1       | 0         | 0         |
|                                    |   | TDO <sup>(3)</sup>             | X                                      | X       | 1         | X         |
|                                    |   | CB6                            | X                                      | X       | 0         | 1 (y = 6) |
| PJ.1/<br>MCLK/<br>TDI/TCLK/<br>CB7 | 1 | PJ.x (I/O) <sup>(2)</sup>      | I: 0; O: 1                             | 0       | 0         | 0         |
|                                    |   | MCLK                           | 1                                      | 1       | 0         | 0         |
|                                    |   | TDI/TCLK <sup>(3) (4)</sup>    | X                                      | X       | 1         | X         |
|                                    |   | CB7                            | 0                                      | X       | 0         | 1 (y = 7) |
| PJ.2/<br>ADC10CLK/<br>TMS/<br>CB8  | 2 | PJ.x (I/O) <sup>(2)</sup>      | I: 0; O: 1                             | 0       | 0         | 0         |
|                                    |   | ADC10CLK (See <sup>(5)</sup> ) | 1                                      | 1       | 0         | 0         |
|                                    |   | TMS <sup>(3) (4)</sup>         | X                                      | X       | 1         | X         |
|                                    |   | CB8                            | X                                      | X       | 0         | 1 (y = 8) |
| PJ.3/<br>ACLK/<br>TCK/<br>CB9      | 3 | PJ.x (I/O) <sup>(2)</sup>      | I: 0; O: 1                             | 0       | 0         | 0         |
|                                    |   | ACLK                           | 1                                      | 1       | 0         | 0         |
|                                    |   | TCK <sup>(3) (4)</sup>         | X                                      | X       | 1         | X         |
|                                    |   | CB9                            | X                                      | X       | 0         | 1 (y = 9) |

(1) X = Don't care

(2) Default condition

(3) The pin direction is controlled by the JTAG module.

(4) In JTAG mode, pullups are activated automatically on TMS, TCK, and TDI/TCLK. PJREN.x are don't care.

(5) MSP430F51x2 device only.

### 6.10.12 Port J (PJ.4) Input/Output With Schmitt Trigger

Figure 6-13 shows the port diagram. Table 6-54 summarizes the selection of the pin function.

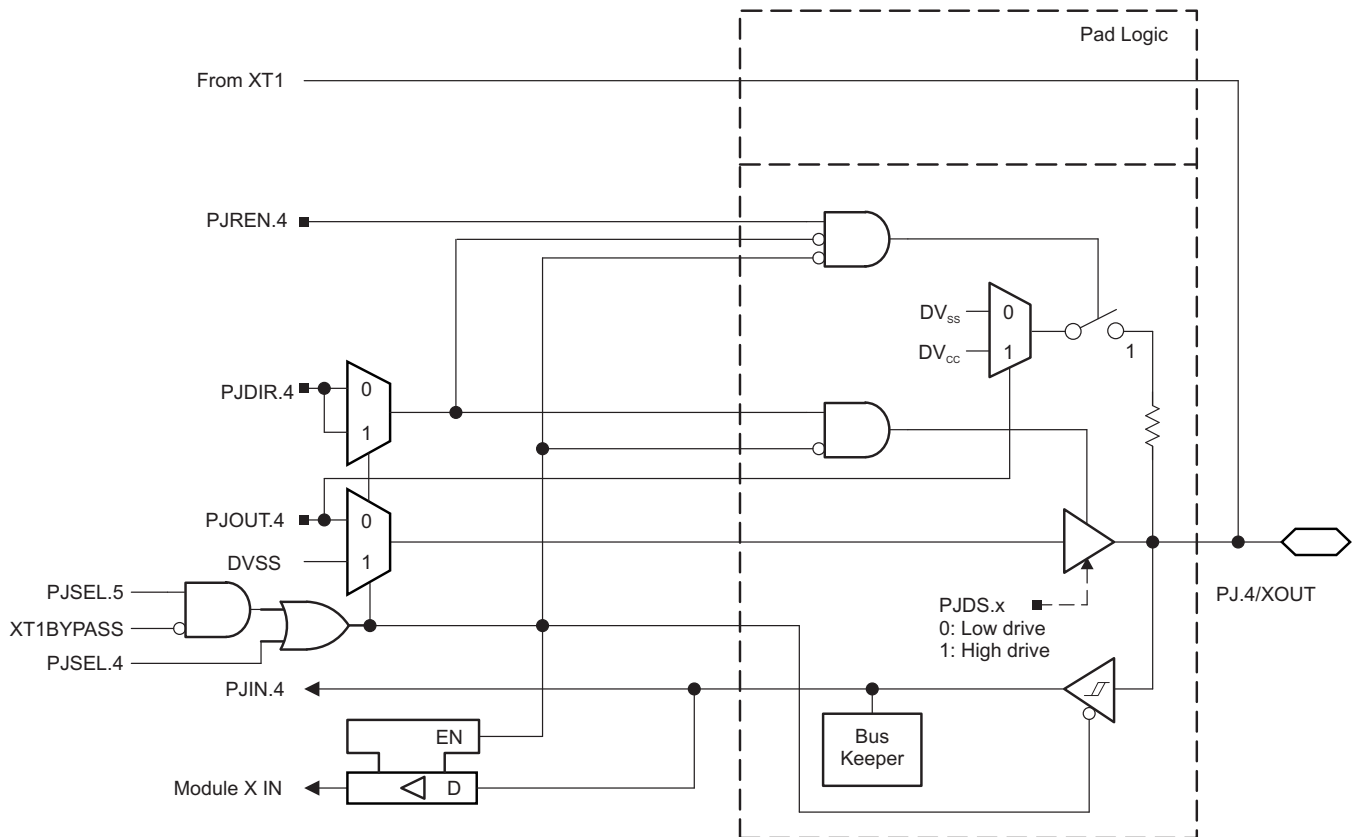
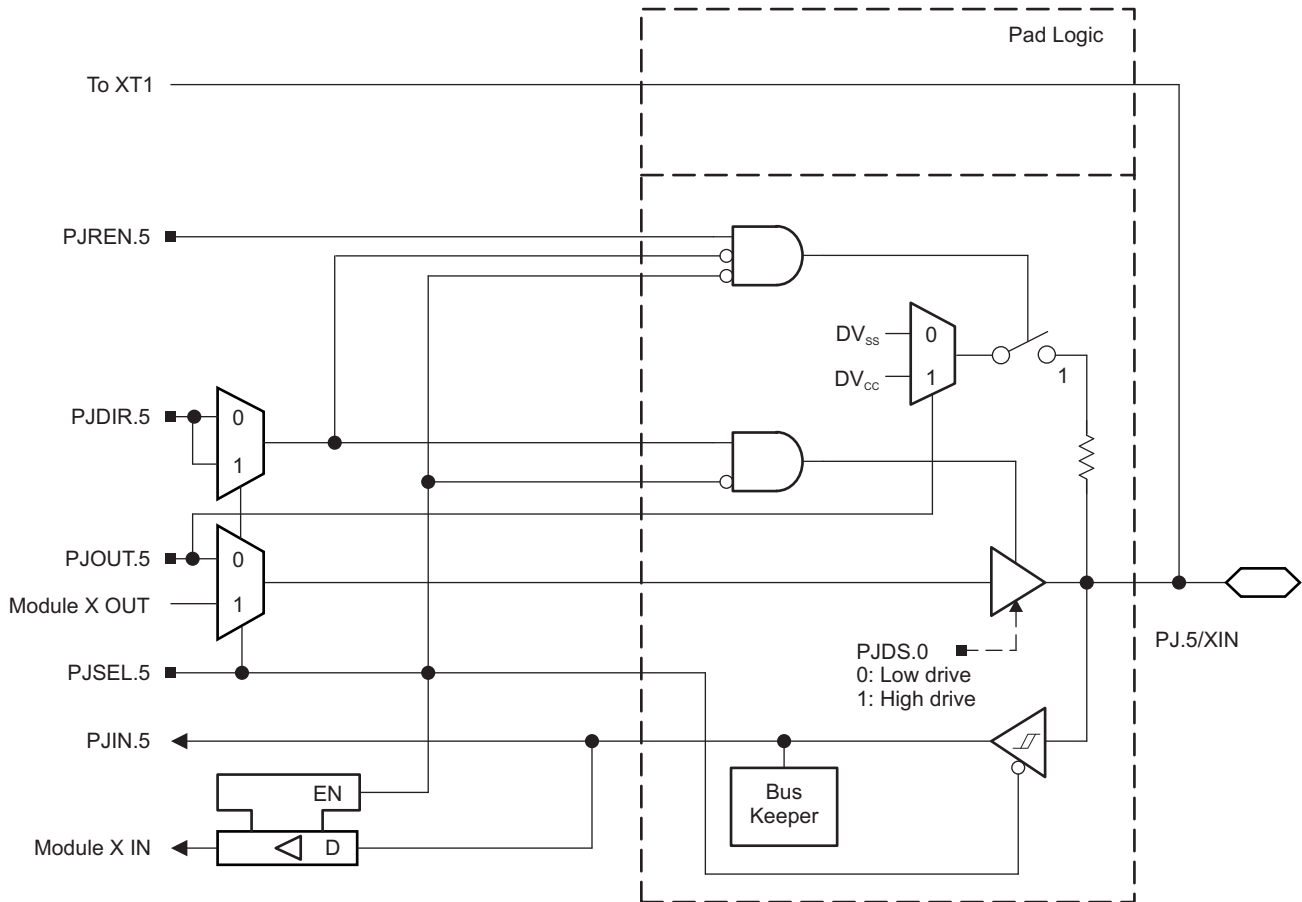


Figure 6-13. Port PJ (PJ.4) Diagram

### 6.10.13 Port J (PJ.5) Input/Output With Schmitt Trigger

Figure 6-14 shows the port diagram. Table 6-54 summarizes the selection of the pin function.



### Figure 6-14. Port PJ (PJ.5) Diagram

### Table 6-54. Port PJ (PJ.4 and PJ.5) Pin Functions

| PIN NAME (PJ.x) | x | FUNCTION                         | CONTROL BITS OR SIGNALS <sup>(1)</sup> |         |         |           |
|-----------------|---|----------------------------------|----------------------------------------|---------|---------|-----------|
|                 |   |                                  | PJDIR.x                                | PJSEL.4 | PJSEL.5 | XT1BYPASS |
| PJ.4/           | 4 | PJ.4 (I/O)                       | I: 0; O: 1                             | 0       | 0       | X         |
| XOUT            |   | XOUT crystal mode <sup>(2)</sup> |                                        |         | 1       | 1         |
| PJ.5/           | 5 | PJ.5 (I/O) <sup>(2)</sup>        | I: 0; O: 1                             | X       | 0       | x         |
| XIN             |   | XIN crystal mode <sup>(3)</sup>  | X                                      | X       | 1       | 0         |
|                 |   | XIN bypass mode <sup>(3)</sup>   | X                                      | X       | 1       | 1         |

(1)  $X = \text{Don't care}$

(2) Setting PJSEL.5 causes the general-purpose I/O to be disabled in crystal mode. When using bypass mode, PJ.4 can be used as general-purpose I/O.

(3) Setting PJSEL.5 causes the general-purpose I/O to be disabled. Pending the setting of XT1BYPASS, PJ.5 is configured for crystal mode or bypass mode.

#### 6.10.14 Port J (PJ.6) Input/Output With Schmitt Trigger

Figure 6-15 shows the port diagram. Table 6-55 summarizes the selection of the pin function.

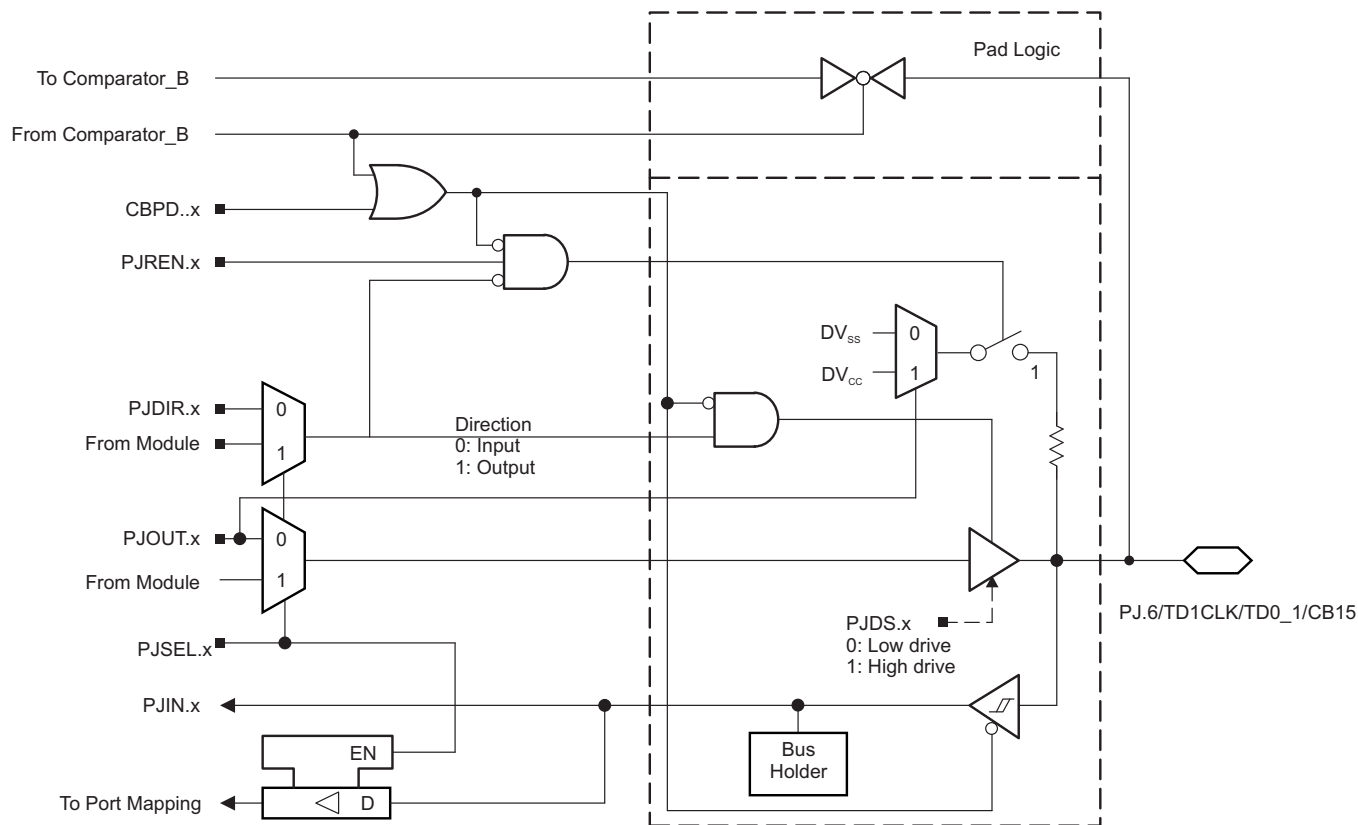


Figure 6-15. Port PJ (PJ.6) Diagram

Table 6-55. Port PJ (PJ.6) Pin Functions

| PIN NAME (PJ.x) | x | FUNCTION        | CONTROL BITS OR SIGNALS <sup>(1)</sup> |         |            |
|-----------------|---|-----------------|----------------------------------------|---------|------------|
|                 |   |                 | PJDIRE.x                               | PJDSE.x | CBPD.y     |
| PJ.6/           | 6 | PJ.x (I/O)      | I: 0; O: 1                             | 0       | 0          |
| TD1CLK/         |   | TD1 clock input | 0                                      | 1       | 0          |
| TD0.1/          |   | TD0.TA1         | 1                                      | 1       | 0          |
| CB15            |   | CB15            | X                                      | X       | 1 (y = 15) |

(1) X = Don't care

## 6.11 Device Descriptors

Table 6-56 and Table 6-57 list the complete contents of the device descriptor tag-length-value (TLV) structure for the MSP430F51x2 and MSP430F51x1 devices, respectively.

**Table 6-56. MSP430F51x2 Device Descriptor Table<sup>(1)</sup>**

| DESCRIPTION          |                                                | ADDRESS | SIZE<br>(bytes) | VALUE    |          |          |          |          |          |
|----------------------|------------------------------------------------|---------|-----------------|----------|----------|----------|----------|----------|----------|
|                      |                                                |         |                 | F5172    |          | F5152    |          | F5132    |          |
|                      |                                                |         |                 | RSB, YFF | DA       | RSB      | DA       | RSB      | DA       |
| Info Block           | Info length                                    | 0x1A00  | 1               | 0x06     | 0x06     | 0x06     | 0x06     | 0x06     | 0x06     |
|                      | CRC length                                     | 0x1A01  | 1               | 0x06     | 0x06     | 0x06     | 0x06     | 0x06     | 0x06     |
|                      | CRC value                                      | 0x1A02  | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
|                      | Device ID                                      | 0x1A04  | 1               | 0x30     | 0x30     | 0x2C     | 0x2C     | 0x28     | 0x28     |
|                      | Device ID                                      | 0x1A05  | 1               | 0x80     | 0x80     | 0x80     | 0x80     | 0x80     | 0x80     |
|                      | Hardware revision                              | 0x1A06  | 1               | 0x30     | 030      | 0x30     | 0x30     | 0x30     | 0x30     |
|                      | Firmware revision                              | 0x1A07  | 1               | 0x10     | 0x10     | 0x10     | 0x10     | 0x10     | 0x10     |
| Die Record           | Die record tag                                 | 0x1A08  | 1               | 0x08     | 08       | 0x08     | 08       | 0x08     | 08       |
|                      | Die record length                              | 0x1A09  | 1               | 0x0A     | 0A       | 0x0A     | 0A       | 0x0A     | 0A       |
|                      | Lot/wafer ID                                   | 0x1A0A  | 4               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
|                      | Die X position                                 | 0x1A0Eh | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
|                      | Die Y position                                 | 0x1A10  | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
|                      | Test results                                   | 0x1A12  | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
| ADC10 Calibration    | ADC10 calibration tag                          | 0x1A14  | 1               | 0x13     | 0x13     | 0x13     | 0x13     | 0x13     | 0x13     |
|                      | ADC10 calibration length                       | 0x1A15  | 1               | 0x10     | 0x10     | 0x10     | 0x10     | 0x10     | 0x10     |
|                      | ADC gain factor                                | 0x1A16  | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
|                      | ADC offset                                     | 0x1A18  | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
|                      | ADC 1.5-V reference<br>Temperature sensor 30°C | 0x1A1A  | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
|                      | ADC 1.5-V reference<br>Temperature sensor 85°C | 0x1A1C  | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
|                      | ADC 2.0-V reference<br>Temperature sensor 30°C | 0x1A1Eh | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
|                      | ADC 2.0-V reference<br>Temperature sensor 85°C | 0x1A20  | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
|                      | ADC 2.5-V reference<br>Temperature sensor 30°C | 0x1A22  | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
|                      | ADC 2.5-V reference<br>Temperature sensor 85°C | 0x1A24  | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
| REF User Calibration | REF tag                                        | 0x1A26  | 1               | 0x12     | 0x12     | 0x12     | 0x12     | 0x12     | 0x12     |
|                      | REF length                                     | 0x1A27  | 1               | 0x06     | 0x06     | 0x06     | 0x06     | 0x06     | 0x06     |
|                      | REF 1.5-V reference                            | 0x1A28  | 2               | 0xFF     | 0xFF     | 0xFF     | 0xFF     | 0xFF     | 0xFF     |
|                      | REF 2.0-V reference                            | 0x1A2A  | 2               | 0xFF     | 0xFF     | 0xFF     | 0xFF     | 0xFF     | 0xFF     |
|                      | REF 2.5-V reference                            | 0x1A2C  | 2               | 0xFF     | 0xFF     | 0xFF     | 0xFF     | 0xFF     | 0xFF     |
| Timer_D0 Calibration | Timer_D tag                                    | 0x1A2E  | 1               | 0x15     | 0x15     | 0x15     | 0x15     | 0x15     | 0x15     |
|                      | Timer_D length                                 | 0x1A2F  | 1               | 0x08     | 0x08     | 0x08     | 0x08     | 0x08     | 0x08     |
|                      | Timer_D 64-MHz frequency                       | 0x1A30  | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
|                      | Timer_D 128-MHz frequency                      | 0x1A32  | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
|                      | Timer_D 200-MHz frequency                      | 0x1A34  | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
|                      | Timer_D 256-MHz frequency                      | 0x1A36  | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
| Timer_D1 Calibration | Timer_D tag                                    | 0x1A38  | 1               | 0x15     | 0x15     | 0x15     | 0x15     | 0x15     | 0x15     |
|                      | Timer_D length                                 | 0x1A39  | 1               | 0x08     | 0x08     | 0x08     | 0x08     | 0x08     | 0x08     |
|                      | Timer_D 64-MHz frequency                       | 0x1A3A  | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
|                      | Timer_D 128-MHz frequency                      | 0x1A3C  | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
|                      | Timer_D 200-MHz frequency                      | 0x1A3E  | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
|                      | Timer_D 256-MHz frequency                      | 0x1A40  | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |

(1) NA = Not applicable

**Table 6-56. MSP430F51x2 Device Descriptor Table<sup>(1)</sup> (continued)**

| DESCRIPTION              |                              | ADDRESS | SIZE<br>(bytes) | VALUE    |        |         |        |         |        |
|--------------------------|------------------------------|---------|-----------------|----------|--------|---------|--------|---------|--------|
|                          |                              |         |                 | F5172    |        | F5152   |        | F5132   |        |
|                          |                              |         |                 | RSB, YFF | DA     | RSB     | DA     | RSB     | DA     |
| Peripheral<br>Descriptor | Peripheral descriptor tag    | 0x1A42  | 1               | 0x02     | 0x02   | 0x02    | 0x02   | 0x02    | 0x02   |
|                          | Peripheral descriptor length | 0x1A43  | 1               | 0x53     | 0x53   | 0x53    | 0x53   | 0x53    | 0x53   |
|                          | BSL memory                   | 0x1A44  | 2               | 0x8A08   | 0x8A08 | 0x8A08  | 0x8A08 | 0x8A08  | 0x8A08 |
|                          | Information memory           | 0x1A46  | 2               | 0x860C   | 0x860C | 0x860C  | 0x860C | 0x860C  | 0x860C |
|                          | RAM                          | 0x1A48  | 2               | 0x2A0E   | 0x2A0E | 0x2A0E  | 0x2A0E | 0x280E  | 0x280E |
|                          | Main memory                  | 0x1A4A  | 2               | 0x9240   | 0x9240 | 0x9060  | 0x9060 | 0x8E70  | 0x8E70 |
|                          | Delimiter                    | 0x1A4C  | 1               | 0x00     | 0x00   | 0x00    | 0x00   | 0x00    | 0x00   |
|                          | Peripheral count             | 0x1A4D  | 1               | 0x1C     | 0x1C   | 0x1B    | 0x1B   | 0x1B    | 0x1B   |
|                          | MSP430CPUXV2                 | 0x1A4E  | 2               | 0x2300   | 0x2300 | 0x2300  | 0x2300 | 0x2300  | 0x2300 |
|                          | SBW                          | 0x1A50  | 2               | 0x0F00   | 0x0F00 | 0x0F00  | 0x0F00 | 0x0F00  | 0x0F00 |
|                          | EEM-S                        | 0x1A52  | 2               | 0x0300   | 0x0300 | 0x0300  | 0x0300 | 0x0300  | 0x0300 |
|                          | TI BSL                       | 0x1A54  | 2               | 0xFC00   | 0xFC00 | 0xFC00  | 0xFC00 | 0xFC00  | 0xFC00 |
|                          | SFR                          | 0x1A56  | 2               | 0x4110   | 0x4110 | 0x4110  | 0x4110 | 0x4110  | 0x4110 |
|                          | PMM                          | 0x1A58  | 2               | 0x3002   | 0x3002 | 0x3002  | 0x3002 | 0x3002  | 0x3002 |
|                          | FCTL                         | 0x1A5A  | 2               | 0x3802   | 0x3802 | 0x3802  | 0x3802 | 0x3802  | 0x3802 |
|                          | CRC16                        | 0x1A5C  | 2               | 0x3C01   | 0x3C01 | 0x3C01  | 0x3C01 | 0x3C01  | 0x3C01 |
|                          | CRC16_RB                     | 0x1A5E  | 2               | 0x3D00   | 0x3D00 | 0x3D00  | 0x3D00 | 0x3D00  | 0x3D00 |
|                          | RAMCTL                       | 0x1A60  | 2               | 0x4400   | 0x4400 | 0x4400  | 0x4400 | 0x4400  | 0x4400 |
|                          | WDT_A                        | 0x1A62  | 2               | 0x4000   | 0x4000 | 0x4000  | 0x4000 | 0x4000  | 0x4000 |
|                          | UCS                          | 0x1A64  | 2               | 0x4801   | 0x4801 | 0x4801  | 0x4801 | 0x4801  | 0x4801 |
|                          | SYS                          | 0x1A66  | 2               | 0x4202   | 0x4202 | 0x4202  | 0x4202 | 0x4202  | 0x4202 |
|                          | Shared REF                   | 0x1A68  | 2               | 0xA003   | 0xA003 | 0xA003  | 0xA003 | 0xA003  | 0xA003 |
|                          | Port Mapping                 | 0x1A6A  | 2               | 0x1001   | 0x1001 | 0x1001  | 0x1001 | 0x1001  | 0x1001 |
|                          | Port 1/2                     | 0x1A6C  | 2               | 0x5104   | 0x5104 | 0x5104  | 0x5104 | 0x5104  | 0x5104 |
|                          | Port 3/4                     | 0x1A6E  | 2               | 0x5202   | 0x5202 | 0x5202  | 0x5202 | 0x5202  | 0x5202 |
|                          | Port J                       | 0x1A70  | 2               | 0x5F10   | 0x5F10 | 0x5F10  | 0x5F10 | 0x5F10  | 0x5F10 |
|                          | TA0                          | 0x1A72  | 2               | 0x610A   | 0x610A | 0x610A  | 0x610A | 0x610A  | 0x610A |
|                          | MPY32                        | 0x1A74  | 2               | 0x8510   | 0x8510 | 0x8510  | 0x8510 | 0x8510  | 0x8510 |
|                          | DMA with 3 channels          | 0x1A76  | 2               | 0x4704   | 0x4704 | 0x4704  | 0x4704 | 0x4704  | 0x4704 |
|                          | USCI_A0/B0                   | 0x1A78  | 2               | 0x900C   | 0x900C | 0x900C  | 0x900C | 0x900C  | 0x900C |
|                          | ADC10_A                      | 0x1A7A  | 2               | 0xD318   | 0xD318 | 0xD318  | 0xD318 | 0xD318  | 0xD318 |
|                          | COMP_B                       | 0x1A7C  | 2               | 0xA818   | 0xA818 | 0x1A919 | 0xA818 | 0x1A919 | 0xA818 |
|                          | TIMER_D0                     | 0x1A7E  | 2               | 0xD624   | 0xD624 | 0xD624  | 0xD624 | 0xD624  | 0xD624 |
|                          | TIMER_D1                     | 0x1A80  | 2               | 0x6D04   | 0x6D04 | 0x6D04  | 0x6D04 | 0x6D04  | 0x6D04 |
|                          | TEC_0                        | 0x1A82  | 2               | 0x700C   | 0x700C | 0x700C  | 0x700C | 0x700C  | 0x700C |
|                          | TEC_1                        | 0x1A84  | 2               | 0x7002   | 0x7002 | 0x7002  | 0x7002 | 0x7002  | 0x7002 |

**Table 6-56. MSP430F51x2 Device Descriptor Table<sup>(1)</sup> (continued)**

| DESCRIPTION |               | ADDRESS         | SIZE<br>(bytes) | VALUE    |      |       |      |       |      |
|-------------|---------------|-----------------|-----------------|----------|------|-------|------|-------|------|
|             |               |                 |                 | F5172    |      | F5152 |      | F5132 |      |
|             |               |                 |                 | RSB, YFF | DA   | RSB   | DA   | RSB   | DA   |
| Interrupts  | COMP_B        | 0x1A86          | 1               | 0xA8     | 0xA8 | 0xA8  | 0xA8 | 0xA8  | 0xA8 |
|             | TEC_0         | 0x1A87          | 1               | 0x6D     | 0x6D | 0x6D  | 0x6D | 0x6D  | 0x6D |
|             | TIMER_D0      | 0x1A88          | 1               | 0x62     | 0x62 | 0x62  | 0x62 | 0x62  | 0x62 |
|             | TIMER_D0      | 0x1A89          | 1               | 0x63     | 0x63 | 0x63  | 0x63 | 0x63  | 0x63 |
|             | WDTIFG        | 0x1A8A          | 1               | 0x40     | 0x40 | 0x40  | 0x40 | 0x40  | 0x40 |
|             | USCI_A0       | 0x1A8B          | 1               | 0x90     | 0x90 | 0x90  | 0x90 | 0x90  | 0x90 |
|             | USCI_B0       | 0x1A8C          | 1               | 0x91     | 0x91 | 0x91  | 0x91 | 0x91  | 0x91 |
|             | ADC10_A       | 0x1A8D          | 1               | 0xD0     | 0xD0 | 0xD0  | 0xD0 | 0xD0  | 0xD0 |
|             | TA0.CCIFG0    | 0x1A8E          | 1               | 0x60     | 0x60 | 0x60  | 0x60 | 0x60  | 0x60 |
|             | TA0.CCIFG1..4 | 0x1A8F          | 1               | 0x61     | 0x61 | 0x61  | 0x61 | 0x61  | 0x61 |
|             | DMA           | 0x1A90          | 1               | 0x46     | 0x46 | 0x46  | 0x46 | 0x46  | 0x46 |
|             | TEC_1         | 0x1A91          | 1               | 0x6E     | 0x6E | 0x6E  | 0x6E | 0x6E  | 0x6E |
|             | TIMER_D1      | 0x1A92          | 1               | 0x64     | 0x64 | 0x64  | 0x64 | 0x64  | 0x64 |
|             | TIMER_D1      | 0x1A93          | 1               | 0x65     | 0x65 | 0x65  | 0x65 | 0x65  | 0x65 |
|             | Port P1       | 0x1A94          | 1               | 0x50     | 0x50 | 0x50  | 0x50 | 0x50  | 0x50 |
|             | Port P2       | 0x1A95          | 1               | 0x51     | 0x51 | 0x51  | 0x51 | 0x51  | 0x51 |
|             | Delimiter     | 0x1A96          | 1               | 0x00     | 0x00 | 0x00  | 0x00 | 0x00  | 0x00 |
| Empty       | Unused memory | 0x1A97 - 0x1AB9 |                 | 0xFF     | 0xFF | 0xFF  | 0xFF | 0xFF  | 0xFF |

**Table 6-57. MSP430F51x1 Device Descriptor Table<sup>(1)</sup>**

| DESCRIPTION |                   | ADDRESS | SIZE<br>(bytes) | VALUE    |          |          |          |          |          |
|-------------|-------------------|---------|-----------------|----------|----------|----------|----------|----------|----------|
|             |                   |         |                 | F5171    |          | F5151    |          | F5131    |          |
|             |                   |         |                 | RSB      | DA       | RSB      | DA       | RSB      | DA       |
| Info Block  | Info length       | 0x1A00  | 1               | 0x06     | 0x06     | 0x06     | 0x06     | 0x06     | 0x06     |
|             | CRC length        | 0x1A01  | 1               | 0x06     | 0x06     | 0x06     | 0x06     | 0x06     | 0x06     |
|             | CRC value         | 0x1A02  | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
|             | Device ID         | 0x1A04  | 1               | 0x2E     | 0x2E     | 0x2A     | 0x2A     | 0x26     | 0x26     |
|             | Device ID         | 0x1A05  | 1               | 0x80     | 0x80     | 0x80     | 0x80     | 0x80     | 0x80     |
|             | Hardware revision | 0x1A06  | 1               | 0x30     | 0x30     | 0x30     | 0x30     | 0x30     | 0x30     |
|             | Firmware revision | 0x1A07  | 1               | 0x10     | 0x10     | 0x10     | 0x10     | 0x10     | 0x10     |
| Die Record  | Die record tag    | 0x1A08  | 1               | 0x08     | 08       | 0x08     | 08       | 0x08     | 08       |
|             | Die record length | 0x1A09  | 1               | 0x0A     | 0A       | 0x0A     | 0A       | 0x0A     | 0A       |
|             | Lot/wafer ID      | 0x1A0A  | 4               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
|             | Die X position    | 0x1A0Eh | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
|             | Die Y position    | 0x1A10  | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
|             | Test results      | 0x1A12  | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |

(1) NA = Not applicable

**Table 6-57. MSP430F51x1 Device Descriptor Table<sup>(1)</sup> (continued)**

| DESCRIPTION          |                                                | ADDRESS | SIZE<br>(bytes) | VALUE    |          |          |          |          |          |
|----------------------|------------------------------------------------|---------|-----------------|----------|----------|----------|----------|----------|----------|
|                      |                                                |         |                 | F5171    |          | F5151    |          | F5131    |          |
|                      |                                                |         |                 | RSB      | DA       | RSB      | DA       | RSB      | DA       |
| ADC10 Calibration    | ADC10 calibration tag                          | 0x1A14  | 1               | 0x05     | 0x05     | 0x05     | 0x05     | 0x05     | 0x05     |
|                      | ADC10 calibration length                       | 0x1A15  | 1               | 0x10     | 0x10     | 0x10     | 0x10     | 0x10     | 0x10     |
|                      | ADC gain factor                                | 0x1A16  | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
|                      | ADC offset                                     | 0x1A18  | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
|                      | ADC 1.5-V reference<br>Temperature sensor 30°C | 0x1A1A  | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
|                      | ADC 1.5-V reference<br>Temperature sensor 85°C | 0x1A1C  | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
|                      | ADC 2.0-V reference<br>Temperature sensor 30°C | 0x1A1Eh | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
|                      | ADC 2.0-V reference<br>Temperature sensor 85°C | 0x1A20  | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
|                      | ADC 2.5-V reference<br>Temperature sensor 30°C | 0x1A22  | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
|                      | ADC 2.5-V reference<br>Temperature sensor 85°C | 0x1A24  | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
| REF User Calibration | REF tag                                        | 0x1A26  | 1               | 0x12     | 0x12     | 0x12     | 0x12     | 0x12     | 0x12     |
|                      | REF length                                     | 0x1A27  | 1               | 0x06     | 0x06     | 0x06     | 0x06     | 0x06     | 0x06     |
|                      | REF 1.5-V reference                            | 0x1A28  | 2               | 0xFF     | 0xFF     | 0xFF     | 0xFF     | 0xFF     | 0xFF     |
|                      | REF 2.0-V reference                            | 0x1A2A  | 2               | 0xFF     | 0xFF     | 0xFF     | 0xFF     | 0xFF     | 0xFF     |
|                      | REF 2.5-V reference                            | 0x1A2C  | 2               | 0xFF     | 0xFF     | 0xFF     | 0xFF     | 0xFF     | 0xFF     |
| Timer_D0 Calibration | Timer_D tag                                    | 0x1A2E  | 1               | 0x15     | 0x15     | 0x15     | 0x15     | 0x15     | 0x15     |
|                      | Timer_D length                                 | 0x1A2F  | 1               | 0x08     | 0x08     | 0x08     | 0x08     | 0x08     | 0x08     |
|                      | Timer_D 64-MHz frequency                       | 0x1A30  | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
|                      | Timer_D 128-MHz frequency                      | 0x1A32  | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
|                      | Timer_D 200-MHz frequency                      | 0x1A34  | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
|                      | Timer_D 256-MHz frequency                      | 0x1A36  | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
| Timer_D1 Calibration | Timer_D tag                                    | 0x1A38  | 1               | 0x15     | 0x15     | 0x15     | 0x15     | 0x15     | 0x15     |
|                      | Timer_D length                                 | 0x1A39  | 1               | 0x08     | 0x08     | 0x08     | 0x08     | 0x08     | 0x08     |
|                      | Timer_D 64-MHz frequency                       | 0x1A3A  | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
|                      | Timer_D 128-MHz frequency                      | 0x1A3C  | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
|                      | Timer_D 200-MHz frequency                      | 0x1A3E  | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |
|                      | Timer_D 256-MHz frequency                      | 0x1A40  | 2               | Per unit | Per unit | Per unit | Per unit | Per unit | Per unit |

**Table 6-57. MSP430F51x1 Device Descriptor Table<sup>(1)</sup> (continued)**

| DESCRIPTION              |                              | ADDRESS | SIZE<br>(bytes) | VALUE  |        |        |        |        |        |
|--------------------------|------------------------------|---------|-----------------|--------|--------|--------|--------|--------|--------|
|                          |                              |         |                 | F5171  |        | F5151  |        | F5131  |        |
|                          |                              |         |                 | RSB    | DA     | RSB    | DA     | RSB    | DA     |
| Peripheral<br>Descriptor | Peripheral descriptor tag    | 0x1A42  | 1               | 0x02   | 0x02   | 0x02   | 0x02   | 0x02   | 0x02   |
|                          | Peripheral descriptor length | 0x1A43  | 1               | 0x51   | 0x51   | 0x51   | 0x51   | 0x51   | 0x51   |
|                          | BSL memory                   | 0x1A44  | 2               | 0x8A08 | 0x8A08 | 0x8A08 | 0x8A08 | 0x8A08 | 0x8A08 |
|                          | Information memory           | 0x1A46  | 2               | 0x860C | 0x860C | 0x860C | 0x860C | 0x860C | 0x860C |
|                          | RAM                          | 0x1A48  | 2               | 0x2A0E | 0x2A0E | 0x2A0E | 0x2A0E | 0x280E | 0x280E |
|                          | Main memory                  | 0x1A4A  | 2               | 0x9240 | 0x9240 | 0x9060 | 0x9060 | 0x8E70 | 0x8E70 |
|                          | Delimiter                    | 0x1A4C  | 1               | 0x00   | 0x00   | 0x00   | 0x00   | 0x00   | 0x00   |
|                          | Peripheral count             | 0x1A4D  | 1               | 0x1B   | 0x1B   | 0x1B   | 0x1B   | 0x1B   | 0x1B   |
|                          | MSP430CPUXV2                 | 0x1A4E  | 2               | 0x2300 | 0x2300 | 0x2300 | 0x2300 | 0x2300 | 0x2300 |
|                          | SBW                          | 0x1A50  | 2               | 0x0F00 | 0x0F00 | 0x0F00 | 0x0F00 | 0x0F00 | 0x0F00 |
|                          | EEM-S                        | 0x1A52  | 2               | 0x0300 | 0x0300 | 0x0300 | 0x0300 | 0x0300 | 0x0300 |
|                          | TI BSL                       | 0x1A54  | 2               | 0xFC00 | 0xFC00 | 0xFC00 | 0xFC00 | 0xFC00 | 0xFC00 |
|                          | SFR                          | 0x1A56  | 2               | 0x4110 | 0x4110 | 0x4110 | 0x4110 | 0x4110 | 0x4110 |
|                          | PMM                          | 0x1A58  | 2               | 0x3002 | 0x3002 | 0x3002 | 0x3002 | 0x3002 | 0x3002 |
|                          | FCTL                         | 0x1A5A  | 2               | 0x3802 | 0x3802 | 0x3802 | 0x3802 | 0x3802 | 0x3802 |
|                          | CRC16                        | 0x1A5C  | 2               | 0x3C01 | 0x3C01 | 0x3C01 | 0x3C01 | 0x3C01 | 0x3C01 |
|                          | CRC16_RB                     | 0x1A5E  | 2               | 0x3D00 | 0x3D00 | 0x3D00 | 0x3D00 | 0x3D00 | 0x3D00 |
|                          | RAMCTL                       | 0x1A60  | 2               | 0x4400 | 0x4400 | 0x4400 | 0x4400 | 0x4400 | 0x4400 |
|                          | WDT_A                        | 0x1A62  | 2               | 0x4000 | 0x4000 | 0x4000 | 0x4000 | 0x4000 | 0x4000 |
|                          | UCS                          | 0x1A64  | 2               | 0x4801 | 0x4801 | 0x4801 | 0x4801 | 0x4801 | 0x4801 |
|                          | SYS                          | 0x1A66  | 2               | 0x4202 | 0x4202 | 0x4202 | 0x4202 | 0x4202 | 0x4202 |
|                          | Shared REF                   | 0x1A68  | 2               | 0xA003 | 0xA003 | 0xA003 | 0xA003 | 0xA003 | 0xA003 |
|                          | Port Mapping                 | 0x1A6A  | 2               | 0x1001 | 0x1001 | 0x1001 | 0x1001 | 0x1001 | 0x1001 |
|                          | Port 1/2                     | 0x1A6C  | 2               | 0x5104 | 0x5104 | 0x5104 | 0x5104 | 0x5104 | 0x5104 |
|                          | Port 3/4                     | 0x1A6E  | 2               | 0x5202 | 0x5202 | 0x5202 | 0x5202 | 0x5202 | 0x5202 |
|                          | Port J                       | 0x1A70  | 2               | 0x5F10 | 0x5F10 | 0x5F10 | 0x5F10 | 0x5F10 | 0x5F10 |
|                          | TA0                          | 0x1A72  | 2               | 0x610A | 0x610A | 0x610A | 0x610A | 0x610A | 0x610A |
|                          | MPY32                        | 0x1A74  | 2               | 0x8510 | 0x8510 | 0x8510 | 0x8510 | 0x8510 | 0x8510 |
|                          | DMA with 3 channels          | 0x1A76  | 2               | 0x4704 | 0x4704 | 0x4704 | 0x4704 | 0x4704 | 0x4704 |
|                          | USCI_A0/B0                   | 0x1A78  | 2               | 0x900C | 0x900C | 0x900C | 0x900C | 0x900C | 0x900C |
|                          | COMP_B                       | 0x1A7A  | 2               | 0xA830 | 0xA830 | 0xA830 | 0xA830 | 0xA830 | 0xA830 |
|                          | TIMER_D0                     | 0x1A7C  | 2               | 0xD624 | 0xD624 | 0xD624 | 0xD624 | 0xD624 | 0xD624 |
|                          | TIMER_D1                     | 0x1A7E  | 2               | 0x6D04 | 0x6D04 | 0x6D04 | 0x6D04 | 0x6D04 | 0x6D04 |
|                          | TEC_0                        | 0x1A80  | 2               | 0x700C | 0x700C | 0x700C | 0x700C | 0x700C | 0x700C |
|                          | TEC_1                        | 0x1A82  | 2               | 0x7002 | 0x7002 | 0x7002 | 0x7002 | 0x7002 | 0x7002 |

**Table 6-57. MSP430F51x1 Device Descriptor Table<sup>(1)</sup> (continued)**

| DESCRIPTION |               | ADDRESS           | SIZE<br>(bytes) | VALUE |      |       |      |       |      |
|-------------|---------------|-------------------|-----------------|-------|------|-------|------|-------|------|
|             |               |                   |                 | F5171 |      | F5151 |      | F5131 |      |
|             |               |                   |                 | RSB   | DA   | RSB   | DA   | RSB   | DA   |
| Interrupts  | COMP_B        | 0x1A83            | 1               | 0xA8  | 0xA8 | 0xA8  | 0xA8 | 0xA8  | 0xA8 |
|             | TEC_0         | 0x1A84            | 1               | 0x6D  | 0x6D | 0x6D  | 0x6D | 0x6D  | 0x6D |
|             | TIMER_D0      | 0x1A85            | 1               | 0x62  | 0x62 | 0x62  | 0x62 | 0x62  | 0x62 |
|             | TIMER_D0      | 0x1A86            | 1               | 0x63  | 0x63 | 0x63  | 0x63 | 0x63  | 0x63 |
|             | WDTIFG        | 0x1A87            | 1               | 0x40  | 0x40 | 0x40  | 0x40 | 0x40  | 0x40 |
|             | USCI_A0       | 0x1A88            | 1               | 0x90  | 0x90 | 0x90  | 0x90 | 0x90  | 0x90 |
|             | USCI_B0       | 0x1A89            | 1               | 0x91  | 0x91 | 0x91  | 0x91 | 0x91  | 0x91 |
|             | ADC10_A       | 0x1A8A            | 1               | 0xD0  | 0xD0 | 0xD0  | 0xD0 | 0xD0  | 0xD0 |
|             | TA0.CCIFG0    | 0x1A8B            | 1               | 0x60  | 0x60 | 0x60  | 0x60 | 0x60  | 0x60 |
|             | TA0.CCIFG1..4 | 0x1A8C            | 1               | 0x61  | 0x61 | 0x61  | 0x61 | 0x61  | 0x61 |
|             | DMA           | 0x1A8D            | 1               | 0x46  | 0x46 | 0x46  | 0x46 | 0x46  | 0x46 |
|             | TEC_1         | 0x1A8E            | 1               | 0x6E  | 0x6E | 0x6E  | 0x6E | 0x6E  | 0x6E |
|             | TIMER_D1      | 0x1A8F            | 1               | 0x64  | 0x64 | 0x64  | 0x64 | 0x64  | 0x64 |
|             | TIMER_D1      | 0x1A90            | 1               | 0x65  | 0x65 | 0x65  | 0x65 | 0x65  | 0x65 |
|             | Port P1       | 0x1A91            | 1               | 0x50  | 0x50 | 0x50  | 0x50 | 0x50  | 0x50 |
|             | Port P2       | 0x1A92            | 1               | 0x51  | 0x51 | 0x51  | 0x51 | 0x51  | 0x51 |
|             | Delimiter     | 0x1A93            | 1               | 0x00  | 0x00 | 0x00  | 0x00 | 0x00  | 0x00 |
| Empty       | Unused Memory | 0x1A94–<br>0x1AB9 |                 | 0xFF  | 0xFF | 0xFF  | 0xFF | 0xFF  | 0xFF |

## 7 Device and Documentation Support

### 7.1 Getting Started and Next Steps

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

### 7.2 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

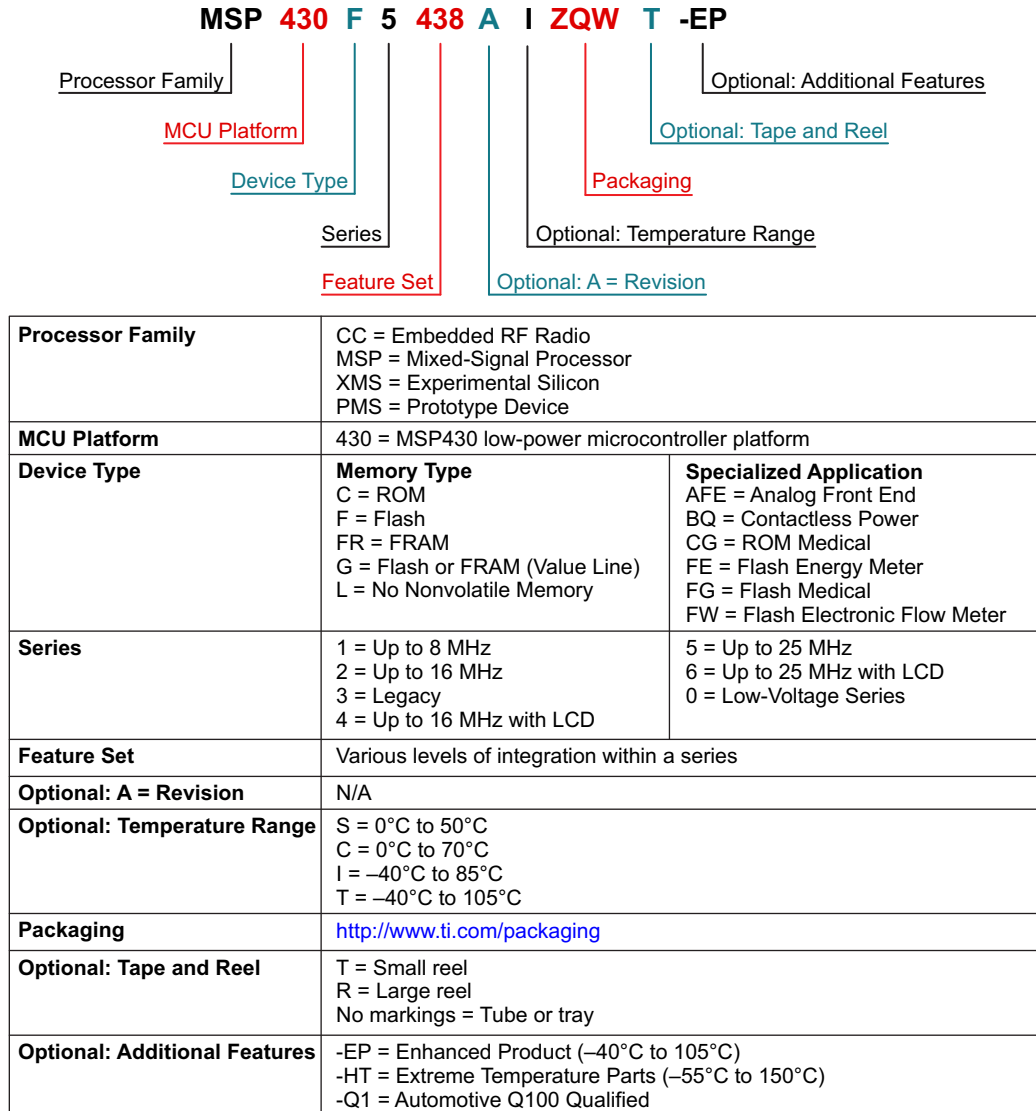
XMS devices are shipped against the following disclaimer:

"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 7-1](#) provides a legend for reading the complete device name.



**Figure 7-1. Device Nomenclature**

## 7.3 Tools and Software

All MSP microcontrollers are supported by a wide variety of software and hardware development tools. Tools are available from TI and various third parties. See them all at [MSP430 Ultra-Low-Power MCUs – Tools & software](#).

Table 7-1 lists the debug features of these MCUs. See the [Code Composer Studio IDE for MSP430 User's Guide](#) for details on the available features.

**Table 7-1. Hardware Debug 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 |
|------------------------|----------------|----------------|-------------------------|---------------------------|------------------|--------------------|-----------------|--------------------------------|
| MSP430Xv2              | Yes            | Yes            | 3                       | Yes                       | Yes              | No                 | No              | No                             |

### Design Kits and Evaluation Modules

**MSP430 40-Pin Package Board and USB Programmer** The MSP-FET430U40 is a bundle featuring a standalone 40-pin ZIF socket target board which is used to program and debug the MSP430 MCU in-system through the JTAG interface or the Spy Bi-Wire (2-wire JTAG) protocol and the MSP-FET Flash Emulation Tool.

**MSP430 40-Pin Target Development Board for MSP430F5x MCUs** The MSP-TS430RSB40 is a stand-alone 40-pin ZIF socket target board that is used to program and debug the MSP430 MCU in-system through the JTAG interface or the Spy Bi-Wire (2-wire JTAG) protocol.

### 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 MSP Driver Library. This library makes it easy to program MSP430 hardware. MSP430Ware software is available as a component of Code Composer Studio™ IDE or as a stand-alone package.

**MSP430F51x2, MSP430F51x1 Code Examples** C Code examples are available for every MSP device that configures each of the integrated peripherals for various application needs.

**MSP Driver Library** 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.

**IEC60730 Software Package** The IEC60730 MSP430 software package was developed to be useful in assisting customers in complying 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 customer applications running on MSP430s to help simplify the customer's 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 and IAR IDEs. Read the user's guide for an in depth look at the math library and relevant benchmarks.

## Development Tools

**Code Composer Studio™ Integrated Development Environment for MSP Microcontrollers** Code Composer Studio is an integrated development environment (IDE) that supports all MSP microcontroller devices. Code Composer Studio 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. The intuitive IDE provides a single user interface taking you through each step of the application development flow. Familiar utilities and interfaces allow users to get started faster than ever before. Code Composer Studio combines the advantages of the Eclipse software framework with advanced embedded debug capabilities from TI resulting in a compelling feature-rich development environment for embedded developers. When using CCS with an MSP MCU, a unique and powerful set of plugins and embedded software utilities are made available to fully leverage the MSP microcontroller.

**Command-Line Programmer** MSP Flasher is an open-source shell-based interface for programming MSP microcontrollers through a FET programmer or eZ430 using JTAG or Spy-Bi-Wire (SBW) communication. MSP Flasher can download binary files (.txt or .hex) files directly to the MSP microcontroller without an IDE.

**MSP MCU Programmer and Debugger** The MSP-FET is a powerful emulation development tool – often called a debug probe – which allows users to 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. It also supports loading programs (often called firmware) to the MSP target using the BSL (bootloader) through the UART and I<sup>2</sup>C communication protocols.

**MSP-GANG Production Programmer** The MSP Gang Programmer is an MSP430 or MSP432 device programmer that 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. Eight cables are provided that connect the expansion board to eight target devices (through JTAG or Spy-Bi-Wire connectors). The programming can be done with a PC or as a stand-alone device. A PC-side graphical user interface is also available and is DLL-based.

## 7.4 Documentation Support

The following documents describe the MSP430F51x2 and MSP430F51x1 devices. 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 links to the product folder, see [Section 7.5](#)). 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

**MSP430F5172 Device Erratasheet** Describes the known exceptions to the functional specifications for all silicon revisions of the device.

**MSP430F5152 Device Erratasheet** Describes the known exceptions to the functional specifications for all silicon revisions of the device.

**MSP430F5132 Device Erratasheet** Describes the known exceptions to the functional specifications for all silicon revisions of the device.

**MSP430F5171 Device Erratasheet** Describes the known exceptions to the functional specifications for all silicon revisions of the device.

**MSP430F5151 Device Erratasheet** Describes the known exceptions to the functional specifications for all silicon revisions of the device.

**MSP430F5131 Device Erratasheet** Describes the known exceptions to the functional specifications for all silicon revisions of the device.

### User's Guides

**MSP430F5xx and MSP430F6xx Family User's Guide** Detailed information on the modules and peripherals available in this device family.

**MSP430 Flash Device Bootloader (BSL) User's Guide** The MSP430 bootloader (BSL) lets users communicate with embedded memory in the MSP430 microcontroller during the prototyping phase, final production, and in service. Both the programmable memory (flash memory) and the data memory (RAM) can be modified as required. Do not confuse the bootloader with the bootstrap loader programs found in some digital signal processors (DSPs) that automatically load program code (and data) from external memory to the internal memory of the DSP.

**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. In addition, it describes how to program the JTAG access security fuse that is available on all MSP430 devices. This document describes device access using both the standard 4-wire JTAG interface and the 2-wire JTAG interface, which is also referred to as Spy-Bi-Wire (SBW).

**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 three different ESD topics to help board designers and OEMs understand and design robust system-level designs: (1) Component-level ESD testing and system-level ESD testing, their differences and why component-level ESD rating does not ensure system-level robustness. (2) General design guidelines for system-level ESD protection at different levels including enclosures, cables, PCB layout, and on-board ESD protection devices. (3) Introduction to System Efficient ESD Design (SEED), a co-design methodology of on-board and on-chip ESD protection to achieve system-level ESD robustness, with example simulations and test results. A few real-world system-level ESD protection design examples and their results are also discussed.

## 7.5 Related Links

[Table 7-2](#) lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to sample or buy.

**Table 7-2. Related Links**

| PARTS       | PRODUCT FOLDER             | ORDER NOW                  | TECHNICAL DOCUMENTS        | TOOLS & SOFTWARE           | SUPPORT & COMMUNITY        |
|-------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| MSP430F5172 | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> |
| MSP430F5152 | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> |
| MSP430F5132 | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> |
| MSP430F5171 | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> |
| MSP430F5151 | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> |
| MSP430F5131 | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> |

## 7.6 Community Resources

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's [Terms of Use](#).

### TI E2E™ Community

*TI's Engineer-to-Engineer (E2E) Community.* Created to foster collaboration among engineers. At [e2e.ti.com](http://e2e.ti.com), you can ask questions, share knowledge, explore ideas, and help solve problems with fellow engineers.

### TI Embedded Processors Wiki

*Texas Instruments Embedded Processors Wiki.* Established to help developers get started with embedded processors from Texas Instruments and to foster innovation and growth of general knowledge about the hardware and software surrounding these devices.

## 7.7 Trademarks

MSP430, MSP430Ware, Code Composer Studio, EnergyTrace, ULP Advisor, E2E are trademarks of Texas Instruments.

All other trademarks are the property of their respective owners.

## 7.8 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.

## 7.9 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.

## 7.10 Glossary

**TI Glossary** This glossary lists and explains terms, acronyms, and definitions.

## 8 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, refer to the left-hand navigation.

**PACKAGING INFORMATION**

| Orderable Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package<br>Qty | Eco Plan<br>(2)            | Lead/Ball Finish<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples                 |
|------------------|---------------|--------------|--------------------|------|----------------|----------------------------|-------------------------|----------------------|--------------|-------------------------|-------------------------|
| MSP430F5131IDA   | ACTIVE        | TSSOP        | DA                 | 38   | 40             | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-2-260C-1 YEAR  | -40 to 85    | M430F5131               | <a href="#">Samples</a> |
| MSP430F5131IDAR  | ACTIVE        | TSSOP        | DA                 | 38   | 2000           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-2-260C-1 YEAR  | -40 to 85    | M430F5131               | <a href="#">Samples</a> |
| MSP430F5131IRSB  | ACTIVE        | WQFN         | RSB                | 40   | 3000           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-2-260C-1 YEAR  | -40 to 85    | M430<br>F5131           | <a href="#">Samples</a> |
| MSP430F5131IRSBT | ACTIVE        | WQFN         | RSB                | 40   | 250            | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-2-260C-1 YEAR  | -40 to 85    | M430<br>F5131           | <a href="#">Samples</a> |
| MSP430F5131IYFFR | ACTIVE        | DSBGA        | YFF                | 40   | 3000           | Green (RoHS<br>& no Sb/Br) | SNAGCU                  | Level-1-260C-UNLIM   | -40 to 85    | M430F5131               | <a href="#">Samples</a> |
| MSP430F5131IYFFT | ACTIVE        | DSBGA        | YFF                | 40   | 250            | Green (RoHS<br>& no Sb/Br) | SNAGCU                  | Level-1-260C-UNLIM   | -40 to 85    | M430F5131               | <a href="#">Samples</a> |
| MSP430F5132IDA   | ACTIVE        | TSSOP        | DA                 | 38   | 40             | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-2-260C-1 YEAR  | -40 to 85    | M430F5132               | <a href="#">Samples</a> |
| MSP430F5132IDAR  | ACTIVE        | TSSOP        | DA                 | 38   | 2000           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-2-260C-1 YEAR  | -40 to 85    | M430F5132               | <a href="#">Samples</a> |
| MSP430F5132IRSB  | ACTIVE        | WQFN         | RSB                | 40   | 3000           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-2-260C-1 YEAR  | -40 to 85    | M430<br>F5132           | <a href="#">Samples</a> |
| MSP430F5132IRSBT | ACTIVE        | WQFN         | RSB                | 40   | 250            | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-2-260C-1 YEAR  | -40 to 85    | M430<br>F5132           | <a href="#">Samples</a> |
| MSP430F5132IYFFR | ACTIVE        | DSBGA        | YFF                | 40   | 3000           | Green (RoHS<br>& no Sb/Br) | SNAGCU                  | Level-1-260C-UNLIM   | -40 to 85    | M430F5132               | <a href="#">Samples</a> |
| MSP430F5132IYFFT | ACTIVE        | DSBGA        | YFF                | 40   | 250            | Green (RoHS<br>& no Sb/Br) | SNAGCU                  | Level-1-260C-UNLIM   | -40 to 85    | M430F5132               | <a href="#">Samples</a> |
| MSP430F5151IDA   | ACTIVE        | TSSOP        | DA                 | 38   | 40             | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-2-260C-1 YEAR  | -40 to 85    | M430F5151               | <a href="#">Samples</a> |
| MSP430F5151IDAR  | NRND          | TSSOP        | DA                 | 38   | 2000           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-2-260C-1 YEAR  | -40 to 85    | M430F5151               |                         |
| MSP430F5151IRSB  | ACTIVE        | WQFN         | RSB                | 40   | 3000           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-2-260C-1 YEAR  | -40 to 85    | M430<br>F5151           | <a href="#">Samples</a> |
| MSP430F5151IRSBT | ACTIVE        | WQFN         | RSB                | 40   | 250            | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-2-260C-1 YEAR  | -40 to 85    | M430<br>F5151           | <a href="#">Samples</a> |
| MSP430F5151IYFFR | ACTIVE        | DSBGA        | YFF                | 40   | 3000           | Green (RoHS<br>& no Sb/Br) | SNAGCU                  | Level-1-260C-UNLIM   | -40 to 85    | M430F5151               | <a href="#">Samples</a> |

| Orderable Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package<br>Qty | Eco Plan<br>(2)            | Lead/Ball Finish<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples                 |
|------------------|---------------|--------------|--------------------|------|----------------|----------------------------|-------------------------|----------------------|--------------|-------------------------|-------------------------|
| MSP430F5151IYFFT | ACTIVE        | DSBGA        | YFF                | 40   | 250            | Green (RoHS<br>& no Sb/Br) | SNAGCU                  | Level-1-260C-UNLIM   | -40 to 85    | M430F5151               | <a href="#">Samples</a> |
| MSP430F5152IDA   | ACTIVE        | TSSOP        | DA                 | 38   | 40             | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-2-260C-1 YEAR  | -40 to 85    | M430F5152               | <a href="#">Samples</a> |
| MSP430F5152IDAR  | ACTIVE        | TSSOP        | DA                 | 38   | 2000           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-2-260C-1 YEAR  | -40 to 85    | M430F5152               | <a href="#">Samples</a> |
| MSP430F5152IRSB  | ACTIVE        | WQFN         | RSB                | 40   | 3000           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-2-260C-1 YEAR  | -40 to 85    | M430<br>F5152           | <a href="#">Samples</a> |
| MSP430F5152IRSBT | ACTIVE        | WQFN         | RSB                | 40   | 250            | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-2-260C-1 YEAR  | -40 to 85    | M430<br>F5152           | <a href="#">Samples</a> |
| MSP430F5152IYFFR | ACTIVE        | DSBGA        | YFF                | 40   | 3000           | Green (RoHS<br>& no Sb/Br) | SNAGCU                  | Level-1-260C-UNLIM   | -40 to 85    | M430F5152               | <a href="#">Samples</a> |
| MSP430F5152IYFFT | ACTIVE        | DSBGA        | YFF                | 40   | 250            | Green (RoHS<br>& no Sb/Br) | SNAGCU                  | Level-1-260C-UNLIM   | -40 to 85    | M430F5152               | <a href="#">Samples</a> |
| MSP430F5171IDA   | ACTIVE        | TSSOP        | DA                 | 38   | 40             | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-2-260C-1 YEAR  | -40 to 85    | M430F5171               | <a href="#">Samples</a> |
| MSP430F5171IDAR  | ACTIVE        | TSSOP        | DA                 | 38   | 2000           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-2-260C-1 YEAR  | -40 to 85    | M430F5171               | <a href="#">Samples</a> |
| MSP430F5171IRSB  | ACTIVE        | WQFN         | RSB                | 40   | 3000           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-2-260C-1 YEAR  | -40 to 85    | M430<br>F5171           | <a href="#">Samples</a> |
| MSP430F5171IRSBT | ACTIVE        | WQFN         | RSB                | 40   | 250            | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-2-260C-1 YEAR  | -40 to 85    | M430<br>F5171           | <a href="#">Samples</a> |
| MSP430F5171IYFFR | ACTIVE        | DSBGA        | YFF                | 40   | 3000           | Green (RoHS<br>& no Sb/Br) | SNAGCU                  | Level-1-260C-UNLIM   | -40 to 85    | M430F5171               | <a href="#">Samples</a> |
| MSP430F5171IYFFT | ACTIVE        | DSBGA        | YFF                | 40   | 250            | Green (RoHS<br>& no Sb/Br) | SNAGCU                  | Level-1-260C-UNLIM   | -40 to 85    | M430F5171               | <a href="#">Samples</a> |
| MSP430F5172IDA   | ACTIVE        | TSSOP        | DA                 | 38   | 40             | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-2-260C-1 YEAR  | -40 to 85    | M430F5172               | <a href="#">Samples</a> |
| MSP430F5172IDAR  | ACTIVE        | TSSOP        | DA                 | 38   | 2000           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-2-260C-1 YEAR  | -40 to 85    | M430F5172               | <a href="#">Samples</a> |
| MSP430F5172IRSB  | ACTIVE        | WQFN         | RSB                | 40   | 3000           | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-2-260C-1 YEAR  | -40 to 85    | M430<br>F5172           | <a href="#">Samples</a> |
| MSP430F5172IRSBT | ACTIVE        | WQFN         | RSB                | 40   | 250            | Green (RoHS<br>& no Sb/Br) | CU NIPDAU               | Level-2-260C-1 YEAR  | -40 to 85    | M430<br>F5172           | <a href="#">Samples</a> |
| MSP430F5172IYFFR | ACTIVE        | DSBGA        | YFF                | 40   | 3000           | Green (RoHS<br>& no Sb/Br) | SNAGCU                  | Level-1-260C-UNLIM   | -40 to 85    | M430F5172               | <a href="#">Samples</a> |

| Orderable Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package<br>Qty | Eco Plan<br>(2)            | Lead/Ball Finish<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples                 |
|------------------|---------------|--------------|--------------------|------|----------------|----------------------------|-------------------------|----------------------|--------------|-------------------------|-------------------------|
| MSP430F5172IYFFT | ACTIVE        | DSBGA        | YFF                | 40   | 250            | Green (RoHS<br>& no Sb/Br) | SNAGCU                  | Level-1-260C-UNLIM   | -40 to 85    | M430F5172               | <a href="#">Samples</a> |

(1) The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSOLETE:** TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

**RoHS Exempt:** TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

**Green:** TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

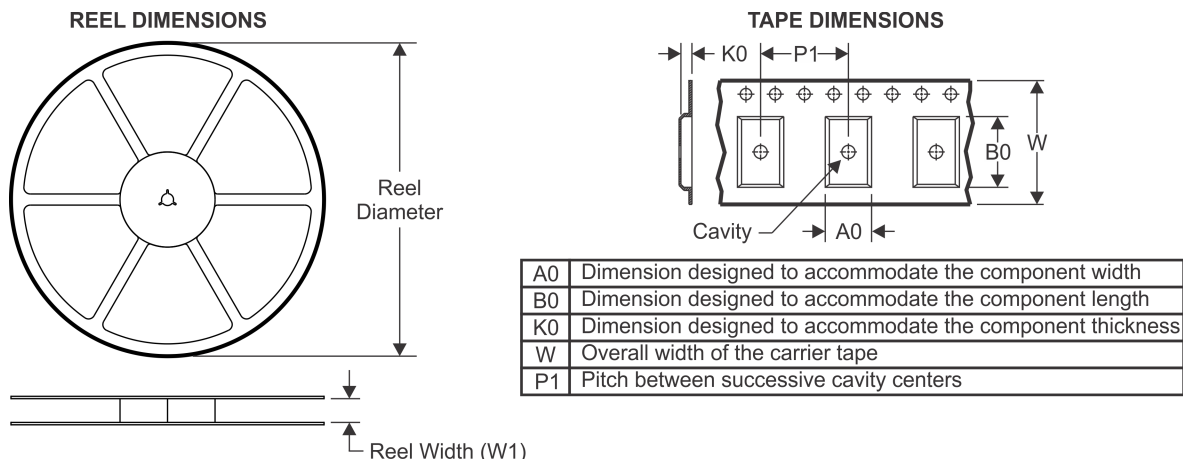
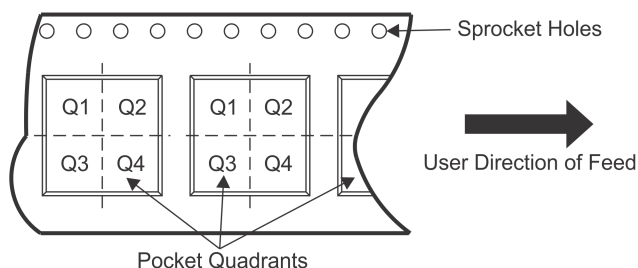
(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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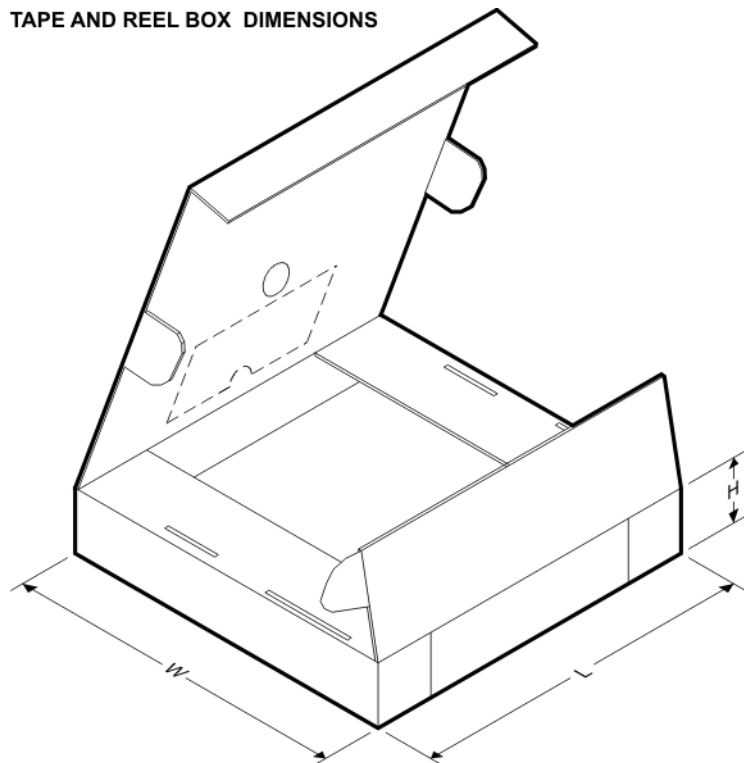
**TAPE AND REEL INFORMATION**

**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**


\*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 |
|------------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| MSP430F5131IDAR  | TSSOP        | DA              | 38   | 2000 | 330.0              | 24.4               | 8.6     | 13.0    | 1.8     | 12.0    | 24.0   | Q1            |
| MSP430F5131IRSB  | WQFN         | RSB             | 40   | 3000 | 330.0              | 12.4               | 5.3     | 5.3     | 1.1     | 8.0     | 12.0   | Q2            |
| MSP430F5131IRSBT | WQFN         | RSB             | 40   | 250  | 180.0              | 12.4               | 5.3     | 5.3     | 1.1     | 8.0     | 12.0   | Q2            |
| MSP430F5131IYFFR | DSBGA        | YFF             | 40   | 3000 | 180.0              | 8.4                | 2.86    | 3.16    | 0.69    | 4.0     | 8.0    | Q1            |
| MSP430F5131IYFFT | DSBGA        | YFF             | 40   | 250  | 180.0              | 8.4                | 2.86    | 3.16    | 0.69    | 4.0     | 8.0    | Q1            |
| MSP430F5132IDAR  | TSSOP        | DA              | 38   | 2000 | 330.0              | 24.4               | 8.6     | 13.0    | 1.8     | 12.0    | 24.0   | Q1            |
| MSP430F5132IRSB  | WQFN         | RSB             | 40   | 3000 | 330.0              | 12.4               | 5.3     | 5.3     | 1.1     | 8.0     | 12.0   | Q2            |
| MSP430F5132IRSBT | WQFN         | RSB             | 40   | 250  | 180.0              | 12.4               | 5.3     | 5.3     | 1.1     | 8.0     | 12.0   | Q2            |
| MSP430F5132IYFFR | DSBGA        | YFF             | 40   | 3000 | 180.0              | 8.4                | 2.86    | 3.16    | 0.69    | 4.0     | 8.0    | Q1            |
| MSP430F5132IYFFT | DSBGA        | YFF             | 40   | 250  | 180.0              | 8.4                | 2.86    | 3.16    | 0.69    | 4.0     | 8.0    | Q1            |
| MSP430F5151IDAR  | TSSOP        | DA              | 38   | 2000 | 330.0              | 24.4               | 8.6     | 13.0    | 1.8     | 12.0    | 24.0   | Q1            |
| MSP430F5151IRSB  | WQFN         | RSB             | 40   | 3000 | 330.0              | 12.4               | 5.3     | 5.3     | 1.1     | 8.0     | 12.0   | Q2            |
| MSP430F5151IRSBT | WQFN         | RSB             | 40   | 250  | 180.0              | 12.4               | 5.3     | 5.3     | 1.1     | 8.0     | 12.0   | Q2            |
| MSP430F5151IYFFR | DSBGA        | YFF             | 40   | 3000 | 180.0              | 8.4                | 2.86    | 3.16    | 0.69    | 4.0     | 8.0    | Q1            |
| MSP430F5151IYFFT | DSBGA        | YFF             | 40   | 250  | 180.0              | 8.4                | 2.86    | 3.16    | 0.69    | 4.0     | 8.0    | Q1            |
| MSP430F5152IDAR  | TSSOP        | DA              | 38   | 2000 | 330.0              | 24.4               | 8.6     | 13.0    | 1.8     | 12.0    | 24.0   | Q1            |
| MSP430F5152IRSB  | WQFN         | RSB             | 40   | 3000 | 330.0              | 12.4               | 5.3     | 5.3     | 1.1     | 8.0     | 12.0   | Q2            |
| MSP430F5152IRSBT | WQFN         | RSB             | 40   | 250  | 180.0              | 12.4               | 5.3     | 5.3     | 1.1     | 8.0     | 12.0   | Q2            |

| 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 |
|------------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| MSP430F5152IYFFR | DSBGA        | YFF             | 40   | 3000 | 180.0              | 8.4                | 2.86    | 3.16    | 0.69    | 4.0     | 8.0    | Q1            |
| MSP430F5152IYFFT | DSBGA        | YFF             | 40   | 250  | 180.0              | 8.4                | 2.86    | 3.16    | 0.69    | 4.0     | 8.0    | Q1            |
| MSP430F5171IDAR  | TSSOP        | DA              | 38   | 2000 | 330.0              | 24.4               | 8.6     | 13.0    | 1.8     | 12.0    | 24.0   | Q1            |
| MSP430F5171IRSB  | WQFN         | RSB             | 40   | 3000 | 330.0              | 12.4               | 5.3     | 5.3     | 1.1     | 8.0     | 12.0   | Q2            |
| MSP430F5171IRSBT | WQFN         | RSB             | 40   | 250  | 180.0              | 12.4               | 5.3     | 5.3     | 1.1     | 8.0     | 12.0   | Q2            |
| MSP430F5171IYFFR | DSBGA        | YFF             | 40   | 3000 | 180.0              | 8.4                | 2.86    | 3.16    | 0.69    | 4.0     | 8.0    | Q1            |
| MSP430F5171IYFFT | DSBGA        | YFF             | 40   | 250  | 180.0              | 8.4                | 2.86    | 3.16    | 0.69    | 4.0     | 8.0    | Q1            |
| MSP430F5172IDAR  | TSSOP        | DA              | 38   | 2000 | 330.0              | 24.4               | 8.6     | 13.0    | 1.8     | 12.0    | 24.0   | Q1            |
| MSP430F5172IRSB  | WQFN         | RSB             | 40   | 3000 | 330.0              | 12.4               | 5.3     | 5.3     | 1.1     | 8.0     | 12.0   | Q2            |
| MSP430F5172IRSBT | WQFN         | RSB             | 40   | 250  | 180.0              | 12.4               | 5.3     | 5.3     | 1.1     | 8.0     | 12.0   | Q2            |
| MSP430F5172IYFFR | DSBGA        | YFF             | 40   | 3000 | 180.0              | 8.4                | 2.86    | 3.16    | 0.69    | 4.0     | 8.0    | Q1            |
| MSP430F5172IYFFT | DSBGA        | YFF             | 40   | 250  | 180.0              | 8.4                | 2.86    | 3.16    | 0.69    | 4.0     | 8.0    | Q1            |

## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

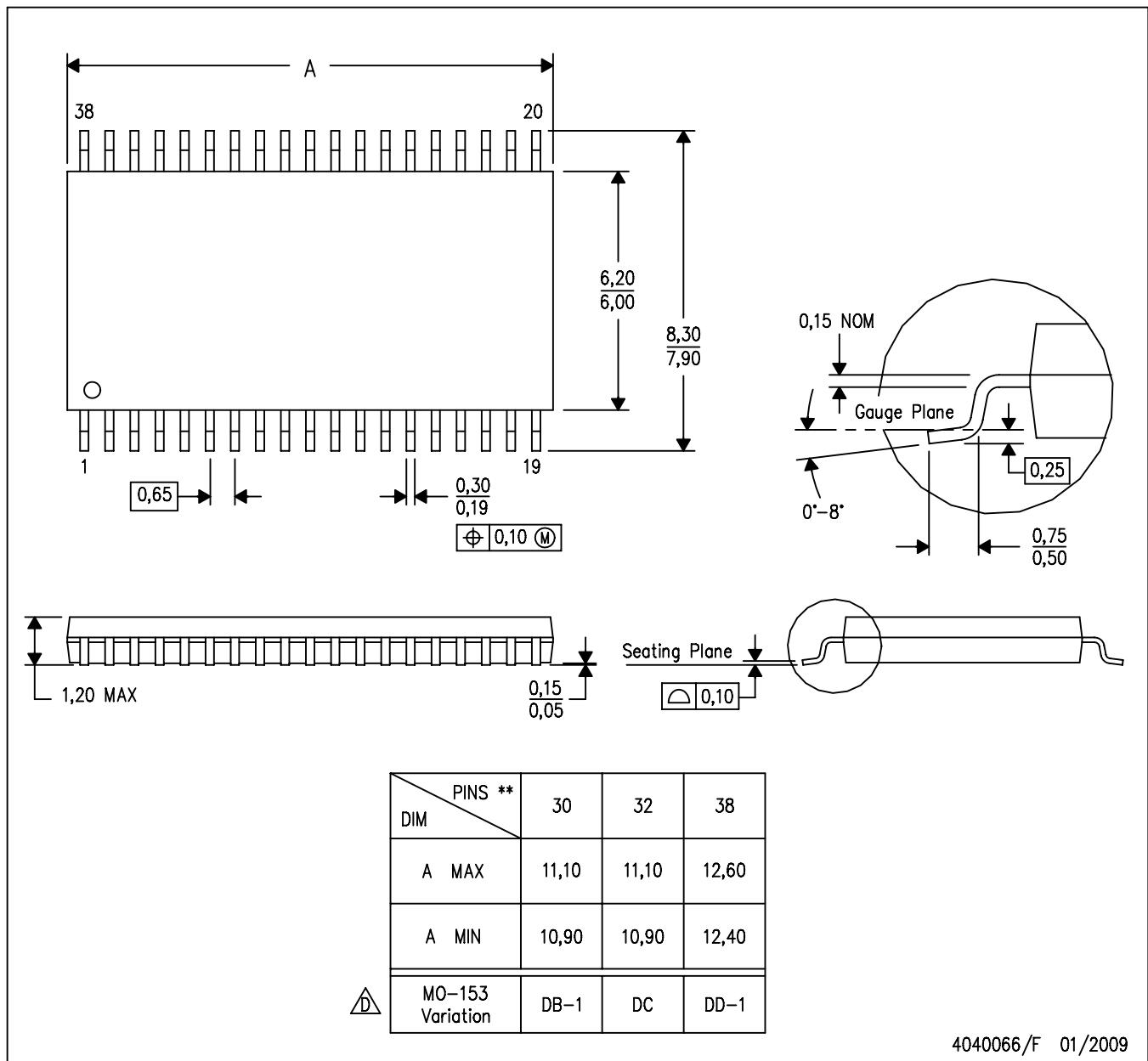
| Device           | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|------------------|--------------|-----------------|------|------|-------------|------------|-------------|
| MSP430F5131IDAR  | TSSOP        | DA              | 38   | 2000 | 350.0       | 350.0      | 43.0        |
| MSP430F5131IRSB  | WQFN         | RSB             | 40   | 3000 | 367.0       | 367.0      | 35.0        |
| MSP430F5131IRSBT | WQFN         | RSB             | 40   | 250  | 210.0       | 185.0      | 35.0        |
| MSP430F5131IYFFR | DSBGA        | YFF             | 40   | 3000 | 182.0       | 182.0      | 20.0        |
| MSP430F5131IYFFT | DSBGA        | YFF             | 40   | 250  | 182.0       | 182.0      | 20.0        |

| Device           | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|------------------|--------------|-----------------|------|------|-------------|------------|-------------|
| MSP430F5132IDAR  | TSSOP        | DA              | 38   | 2000 | 350.0       | 350.0      | 43.0        |
| MSP430F5132IRSB  | WQFN         | RSB             | 40   | 3000 | 367.0       | 367.0      | 35.0        |
| MSP430F5132IRSBT | WQFN         | RSB             | 40   | 250  | 210.0       | 185.0      | 35.0        |
| MSP430F5132IYFFR | DSBGA        | YFF             | 40   | 3000 | 182.0       | 182.0      | 20.0        |
| MSP430F5132IYFFT | DSBGA        | YFF             | 40   | 250  | 182.0       | 182.0      | 20.0        |
| MSP430F5151IDAR  | TSSOP        | DA              | 38   | 2000 | 350.0       | 350.0      | 43.0        |
| MSP430F5151IRSB  | WQFN         | RSB             | 40   | 3000 | 367.0       | 367.0      | 35.0        |
| MSP430F5151IRSBT | WQFN         | RSB             | 40   | 250  | 210.0       | 185.0      | 35.0        |
| MSP430F5151IYFFR | DSBGA        | YFF             | 40   | 3000 | 182.0       | 182.0      | 20.0        |
| MSP430F5151IYFFT | DSBGA        | YFF             | 40   | 250  | 182.0       | 182.0      | 20.0        |
| MSP430F5152IDAR  | TSSOP        | DA              | 38   | 2000 | 350.0       | 350.0      | 43.0        |
| MSP430F5152IRSB  | WQFN         | RSB             | 40   | 3000 | 367.0       | 367.0      | 35.0        |
| MSP430F5152IRSBT | WQFN         | RSB             | 40   | 250  | 210.0       | 185.0      | 35.0        |
| MSP430F5152IYFFR | DSBGA        | YFF             | 40   | 3000 | 182.0       | 182.0      | 20.0        |
| MSP430F5152IYFFT | DSBGA        | YFF             | 40   | 250  | 182.0       | 182.0      | 20.0        |
| MSP430F5171IDAR  | TSSOP        | DA              | 38   | 2000 | 350.0       | 350.0      | 43.0        |
| MSP430F5171IRSB  | WQFN         | RSB             | 40   | 3000 | 367.0       | 367.0      | 35.0        |
| MSP430F5171IRSBT | WQFN         | RSB             | 40   | 250  | 210.0       | 185.0      | 35.0        |
| MSP430F5171IYFFR | DSBGA        | YFF             | 40   | 3000 | 182.0       | 182.0      | 20.0        |
| MSP430F5171IYFFT | DSBGA        | YFF             | 40   | 250  | 182.0       | 182.0      | 20.0        |
| MSP430F5172IDAR  | TSSOP        | DA              | 38   | 2000 | 350.0       | 350.0      | 43.0        |
| MSP430F5172IRSB  | WQFN         | RSB             | 40   | 3000 | 367.0       | 367.0      | 35.0        |
| MSP430F5172IRSBT | WQFN         | RSB             | 40   | 250  | 210.0       | 185.0      | 35.0        |
| MSP430F5172IYFFR | DSBGA        | YFF             | 40   | 3000 | 182.0       | 182.0      | 20.0        |
| MSP430F5172IYFFT | DSBGA        | YFF             | 40   | 250  | 182.0       | 182.0      | 20.0        |

DA (R-PDSO-G\*\*)

38 PIN SHOWN

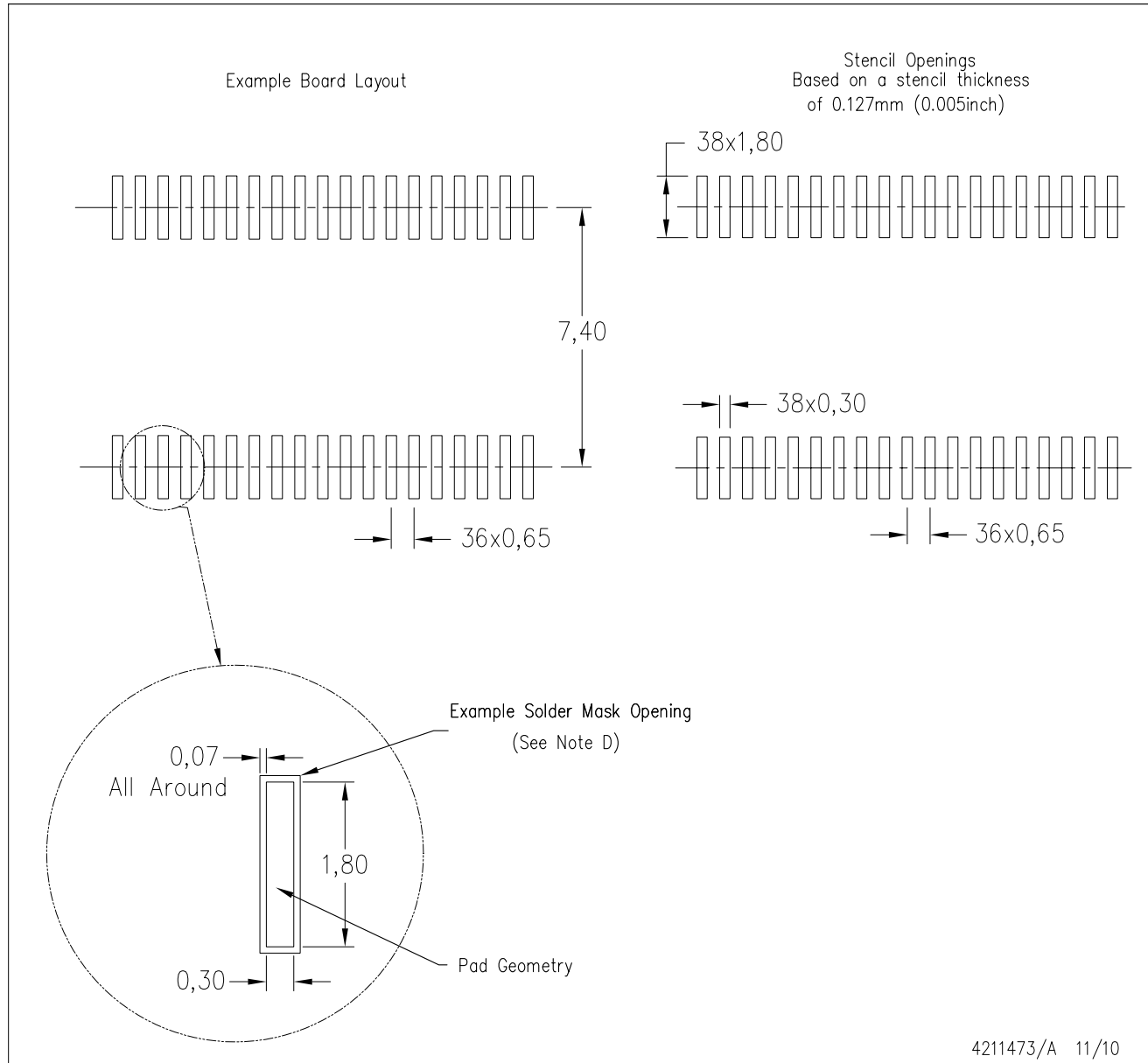
PLASTIC SMALL-OUTLINE PACKAGE



- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
  - D. Falls within JEDEC MO-153, except 30 pin body length.

DA (R-PDSO-G38)

PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Example stencil design based on a 50% volumetric metal load solder paste. Refer to IPC-7525 for other stencil recommendations.
  - D. Contact the board fabrication site for recommended soldermask tolerances.

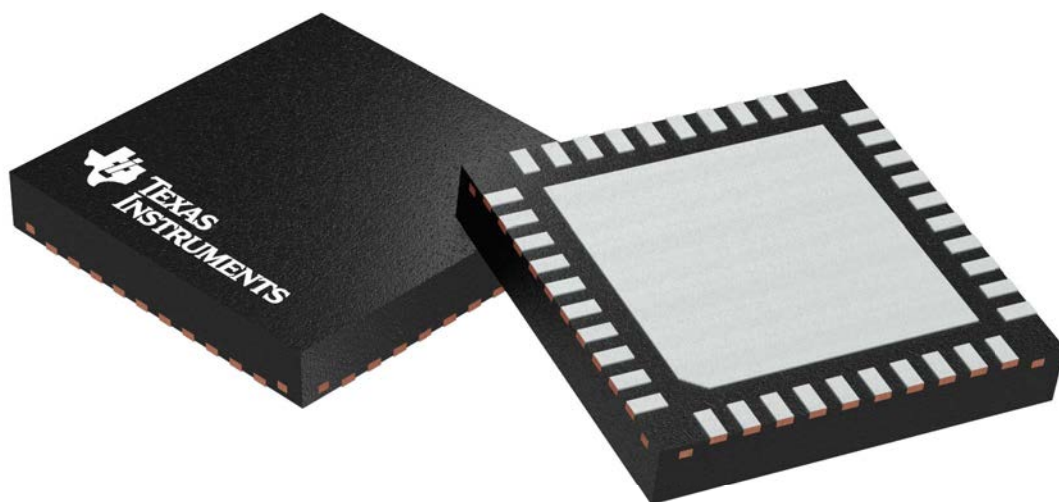
## GENERIC PACKAGE VIEW

**RSB 40**

**WQFN - 0.8 mm max height**

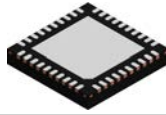
**5 x 5 mm, 0.4 mm pitch**

PLASTIC QUAD FLATPACK - NO LEAD

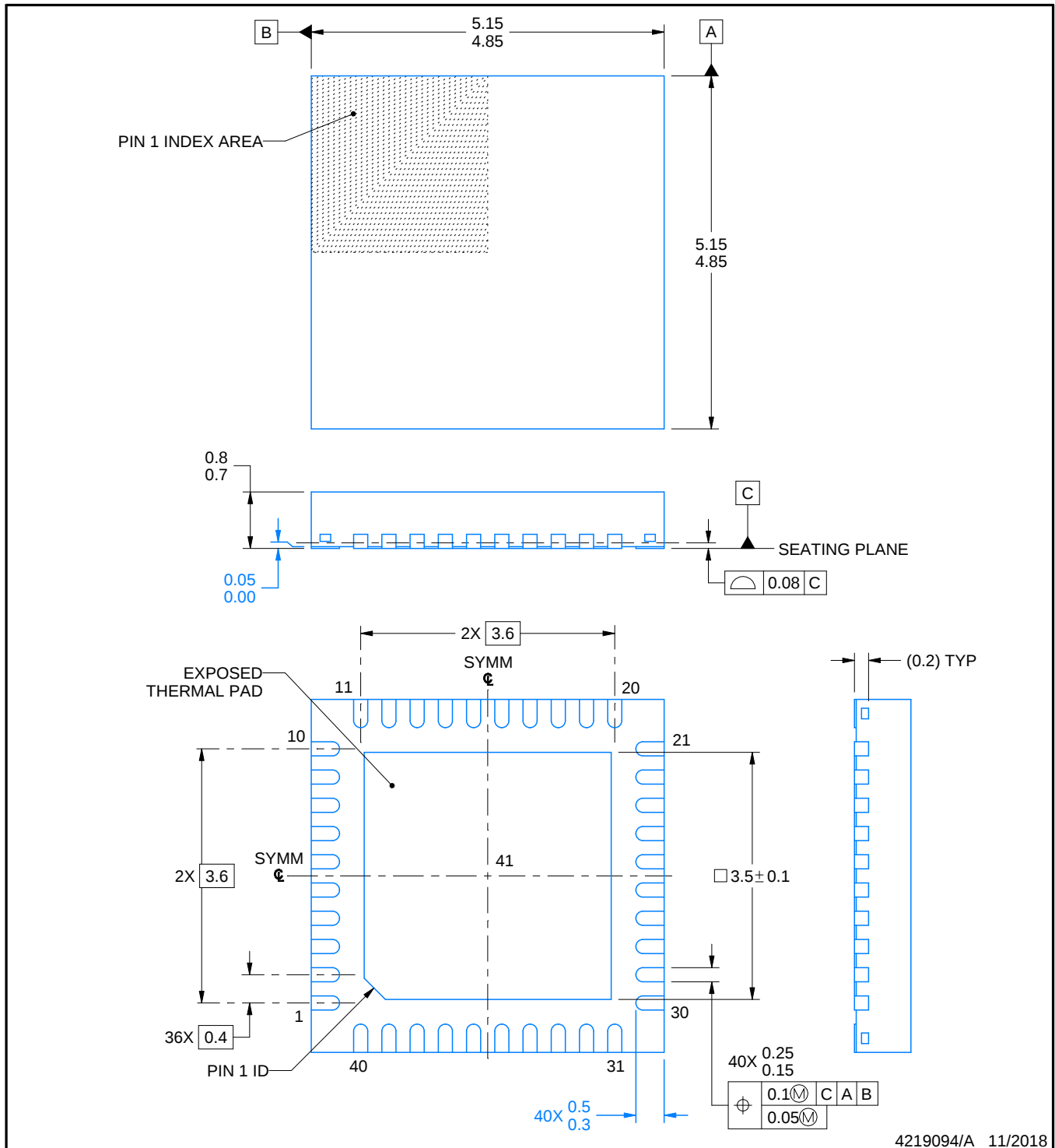


Images above are just a representation of the package family, actual package may vary.  
Refer to the product data sheet for package details.

4207182/D

**RSB0040B****PACKAGE OUTLINE****WQFN - 0.8 mm max height**

PLASTIC QUAD FLATPACK - NO LEAD



4219094/A 11/2018

**NOTES:**

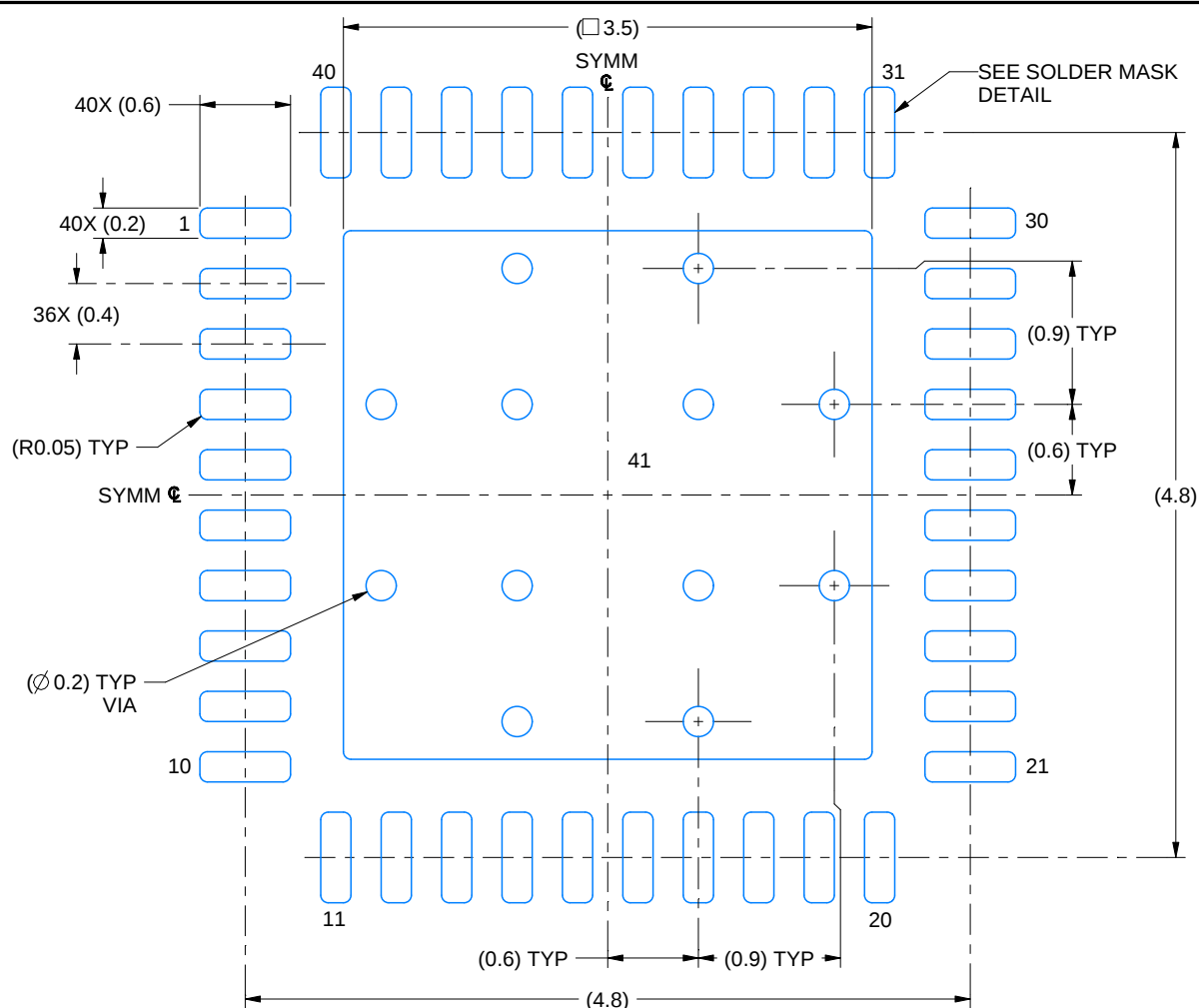
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.

# EXAMPLE BOARD LAYOUT

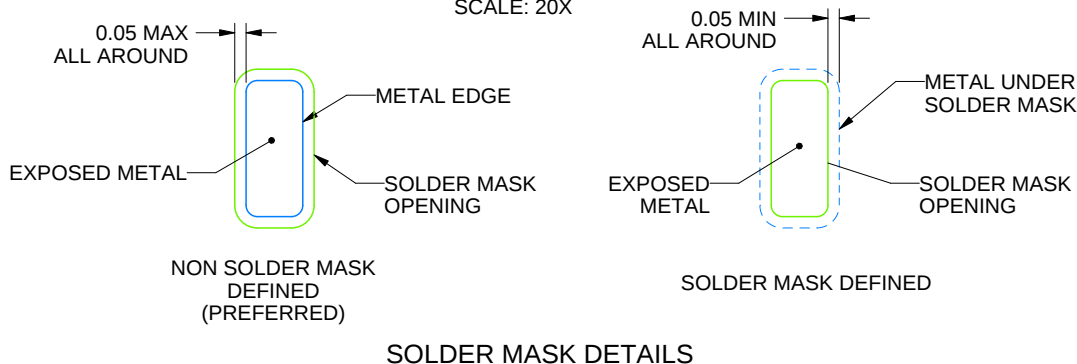
RSB0040B

WQFN - 0.8 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE: 20X



4219094/A 11/2018

NOTES: (continued)

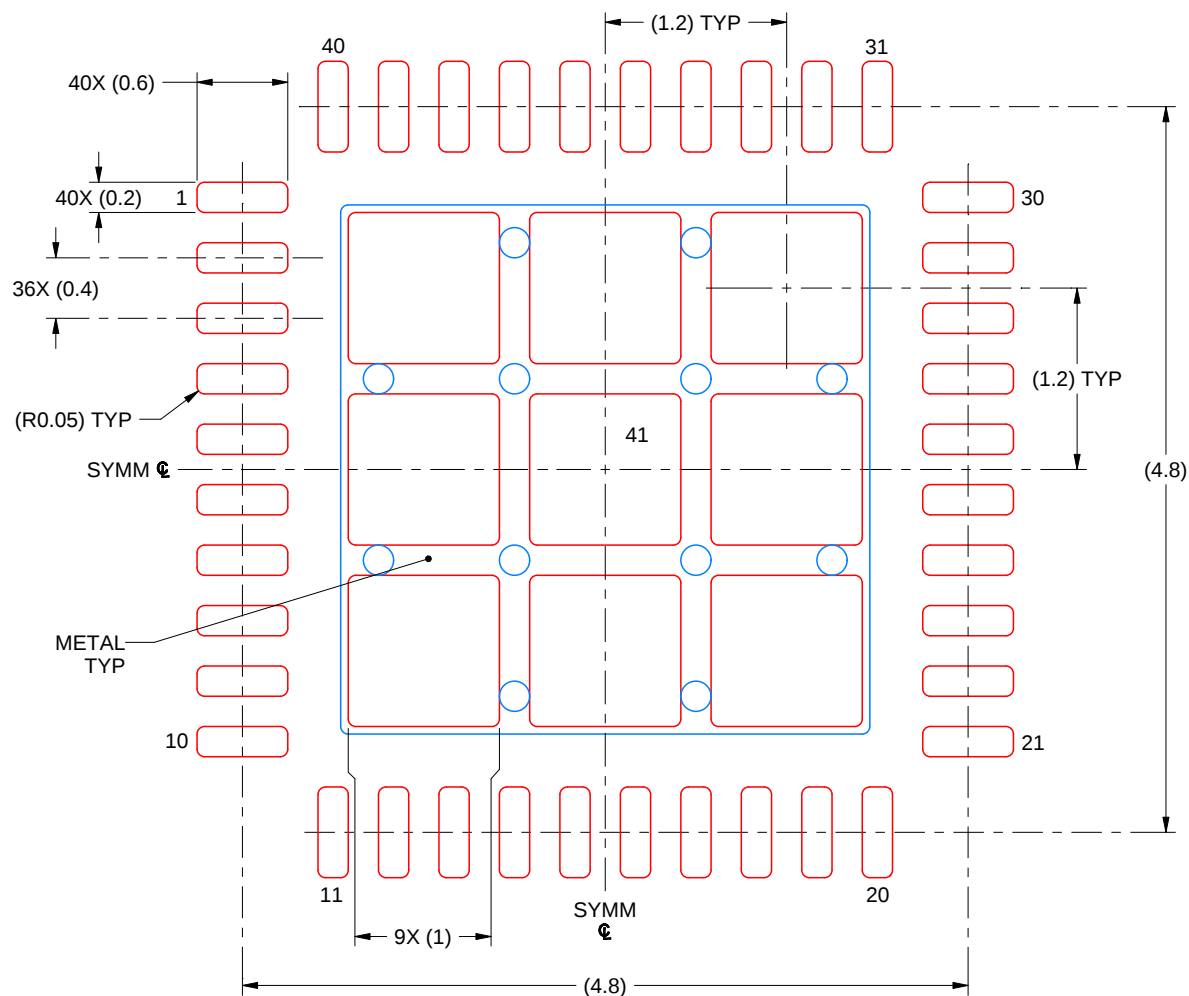
4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 ([www.ti.com/lit/sluea271](http://www.ti.com/lit/sluea271)).
5. Vias are optional depending on application, refer to device data sheet. If any vias are implemented,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

# EXAMPLE STENCIL DESIGN

RSB0040B

WQFN - 0.8 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



SOLDER PASTE EXAMPLE  
 BASED ON 0.125 MM THICK STENCIL  
 SCALE: 20X

EXPOSED PAD 41  
 73% PRINTED SOLDER COVERAGE BY AREA UNDER PACKAGE

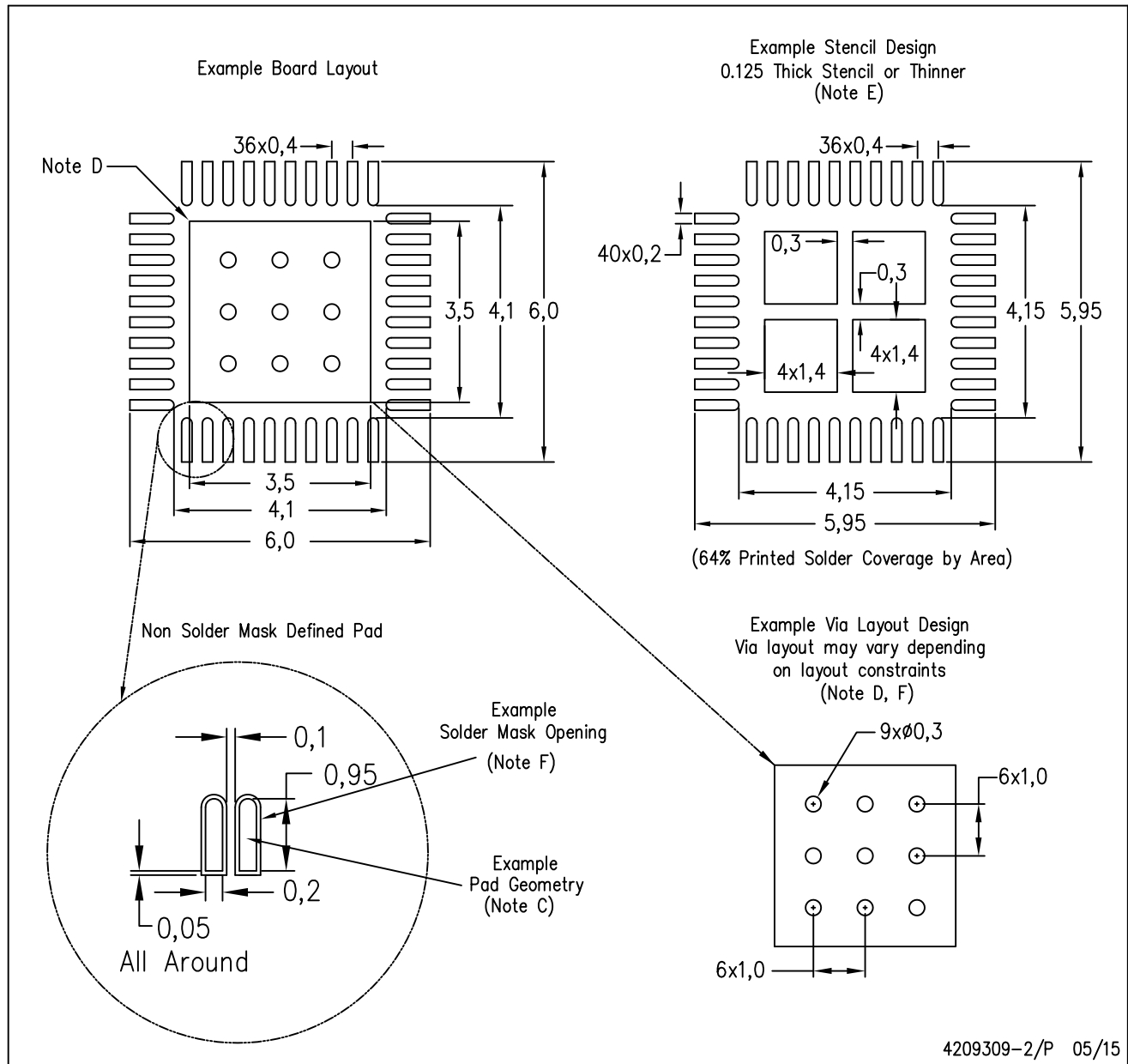
4219094/A 11/2018

NOTES: (continued)

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

RSB (S-PWQFN-N40)

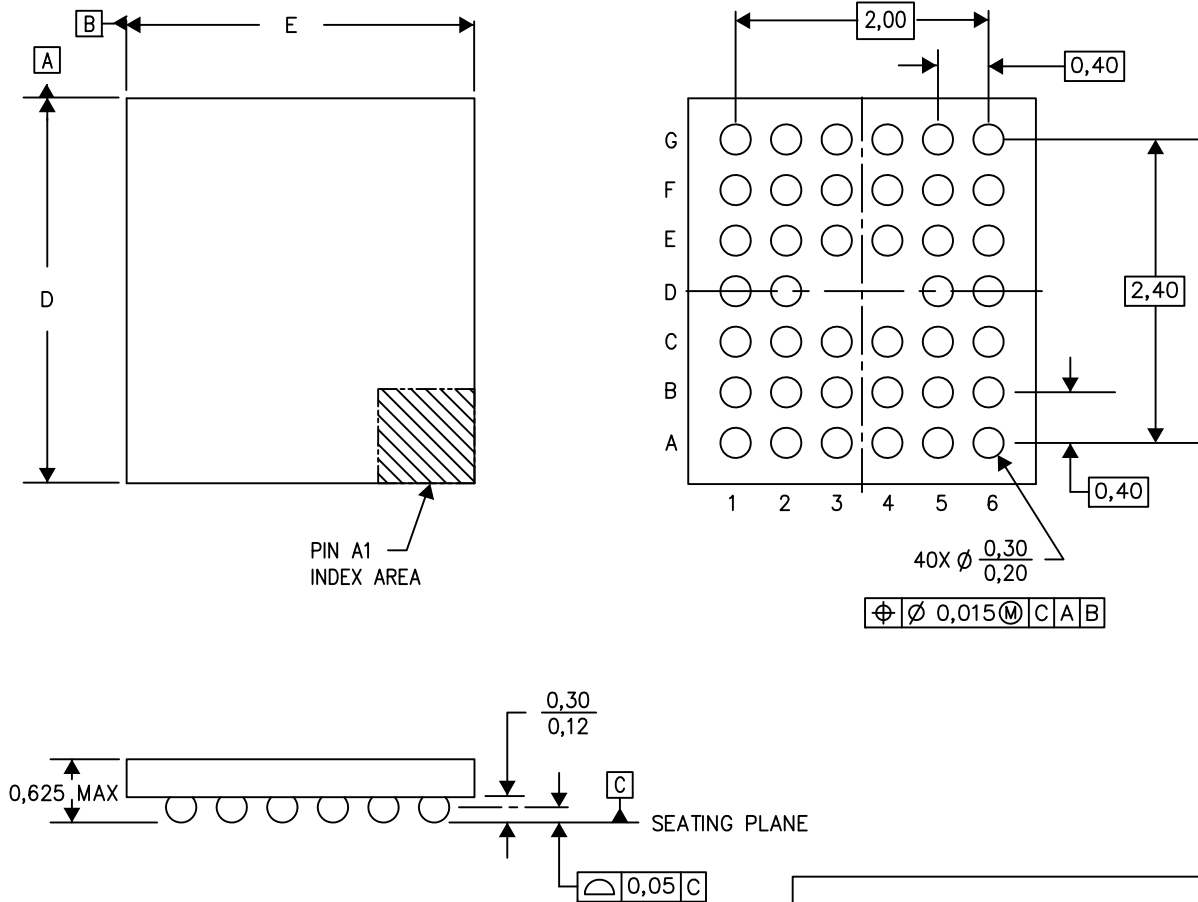
PLASTIC QUAD FLATPACK NO-LEAD



- NOTES:
- All linear dimensions are in millimeters.
  - This drawing is subject to change without notice.
  - Publication IPC-7351 is recommended for alternate designs.
  - This package is designed to be soldered to a thermal pad on the board. Refer to Application Note, Quad Flat-Pack Packages, Texas Instruments Literature No. SLUA271, and also the Product Data Sheets for specific thermal information, via requirements, and recommended board layout. These documents are available at [www.ti.com](http://www.ti.com) <<http://www.ti.com>>.
  - Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC 7525 for stencil design considerations.
  - Customers should contact their board fabrication site for recommended solder mask tolerances and via tenting recommendations for vias placed in the thermal pad.

YFF (R-XBGA-N40)

DIE-SIZE BALL GRID ARRAY



D: Max = 3.09 mm, Min = 3.03 mm

E: Max = 2.79 mm, Min = 2.73 mm

4207625-35/A0 12/13

- NOTES:
- A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
  - B. This drawing is subject to change without notice.
  - C. NanoFree™ package configuration.

NanoFree is a trademark of Texas Instruments.

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