

# MSP430F14x、MSP430F14x1、MSP430F13x 混合信号微控制器

## 1 器件概述

### 1.1 特性

- 低电源电压范围：1.8V 至 3.6V
- 超低功耗：
  - 激活模式：280 $\mu$ A（在 1MHz 频率和 2.2V 电压条件下）
  - 待机模式：1.6 $\mu$ A
  - 关闭模式（RAM 保持）：0.1 $\mu$ A
- 5 种省电模式
- 可在不到 6 $\mu$ s 的时间内从待机模式唤醒
- 16 位精简指令集 (RISC) 架构，125ns 指令周期时间
- 具有内部基准、采样保持和自动扫描功能的 12 位模数转换器 (ADC)
- 具有 7 个捕捉/比较及影子寄存器的 16 位 Timer\_B
- 具有 3 个捕捉/比较寄存器的 16 位 Timer\_A
- 片载比较器
- 串行板上编程、无需外部编程电压、通过安全保险丝实现的可编程代码保护
- 串行通信接口 (USART)，作为异步 UART 或同步 SPI 接口
  - MSP430F14x 和 MSP430F14x1 器件上有两个 USART (USART0、USART1)
  - MSP430F13x 器件上有一个 USART (USART0)
- 系列成员（另请参阅 [器件比较](#)）
  - MSP430F133
    - 8KB + 256B 闪存，256B RAM
  - MSP430F135
    - 16KB + 256B 闪存，512B RAM
  - MSP430F147、MSP430F1471
    - 32KB + 256B 闪存，1KB RAM
  - MSP430F148、MSP430F1481
    - 48KB + 256B 闪存，2KB RAM
  - MSP430F149、MSP430F1491
    - 60KB + 256B 闪存，2KB RAM

### 1.2 应用

- 传感器系统
- 工业控制
- 手持仪表

### 1.3 说明

德州仪器 (TI) MSP430™ 系列的超低功耗微控制器 (MCU) 包含多款器件，这些器件配备了不同的外设集以满足各类应用的需求。该架构可与五种低功耗模式配合使用，专为在便携式测量应用中延长电池使用寿命而进行了优化。该器件具有功能强大的 16 位 RISC CPU、16 位寄存器和有助于获得最大编码效率的常数发生器。数控振荡器 (DCO) 可在不到 6 $\mu$ s 的时间内完成从低功耗模式到激活模式的唤醒。

MSP430F13x、MSP430F14x 和 MSP430F14x1 MCU 支持两个内置 16 位计时器、快速 12 位 ADC（在 MSP430F13x 和 MSP430F14x 器件上）、一个 USART（在 MSP430F13x 器件上）或两个 USART（在 MSP430F14x 和 MSP430F14x1 器件上），以及 48 个 I/O 引脚。硬件乘法器可提高性能，并提供型号众多且具有代码和硬件兼容性的器件系列解决方案。

要获得完整的模块说明，请参见 [《MSP430x1xx 系列用户指南》](#)。



器件信息<sup>(1)</sup>

| 部件号             | 封装        | 封装尺寸 <sup>(2)</sup> |
|-----------------|-----------|---------------------|
| MSP430F149IPM   | LQFP (64) | 10mm × 10mm         |
| MSP430F149IPAG  | TQFP (64) | 10mm × 10mm         |
| MSP430F1491IRTD | VQFN (64) | 9mm × 9mm           |

(1) 要获得最新的器件、封装和订购信息，请参见封装选项附录（节 8），或者访问 TI 网站 [www.ti.com.cn](http://www.ti.com.cn)。  
(2) 这里显示的尺寸为近似值。要获得包含误差值的封装尺寸，请参见机械数据（节 8）。

## 1.4 功能框图

图 1-1 显示了 MSP430F13x MCU 的功能方框图。

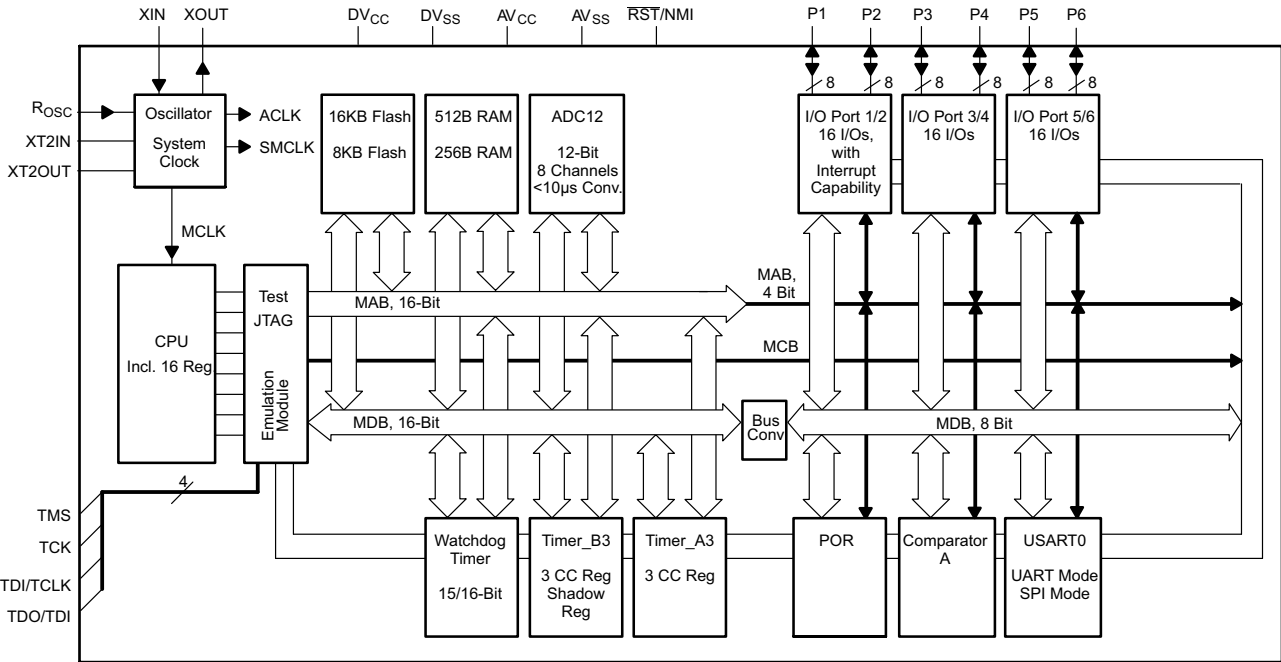


图 1-1. 功能方框图，MSP430F13x

图 1-2 显示了 MSP430F14x MCU 的功能方框图。

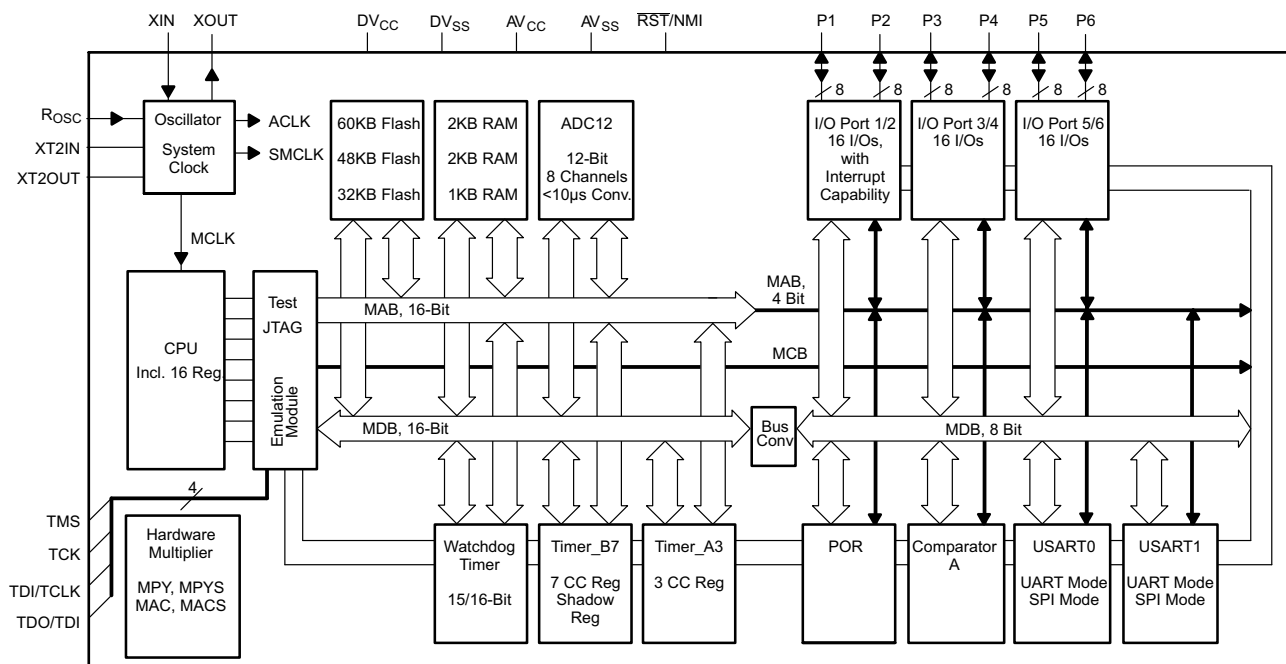


图 1-2. 功能方框图, MSP430F14x

图 1-3 显示了 MSP430F14x1 MCU 的功能方框图。

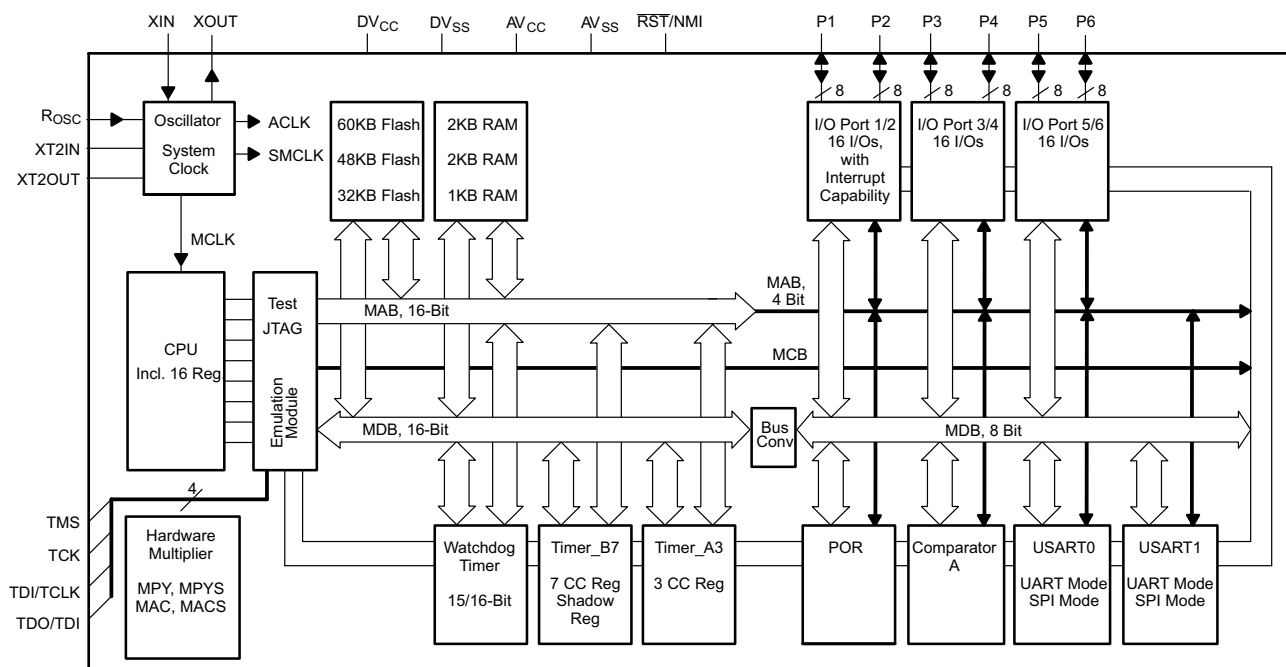


图 1-3. 功能方框图, MSP430F14x1

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## 2 修订历史记录

注：之前版本的页码可能与当前版本有所不同。

| Changes from February 12, 2009 to May 23, 2018                                                                                                                                                                          | Page               |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------|
| • 通篇更改了文档的格式和组织结构 .....                                                                                                                                                                                                 | <a href="#">1</a>  |
| • 添加了节 1.2应用 .....                                                                                                                                                                                                      | <a href="#">1</a>  |
| • Added Section 3, Device Comparison .....                                                                                                                                                                              | <a href="#">6</a>  |
| • Added Section 5.2, ESD Ratings .....                                                                                                                                                                                  | <a href="#">16</a> |
| • Removed note (2) with duplicate information from the $f_{LXT1}$ parameter in Section 5.3, Recommended Operating Conditions .....                                                                                      | <a href="#">16</a> |
| • Removed duplicate conditions "XTS = 0, SELM = 0 or 1" from the second row of Test Conditions on the $I_{(AM)}$ parameter in Section 5.4, Supply Current Into $AV_{CC}$ and $DV_{CC}$ Excluding External Current ..... | <a href="#">17</a> |
| • Added Section 5.5, Thermal Resistance Characteristics .....                                                                                                                                                           | <a href="#">18</a> |
| • Removed ADC12DIV from the equation in the TYP value of the $t_{CONVERT}$ parameter (because ADC12CLK is after division) in Section 5.26, 12-Bit ADC, Timing Parameters .....                                          | <a href="#">30</a> |
| • Changed all instances of <i>bootstrap loader</i> to <i>bootloader</i> throughout document .....                                                                                                                       | <a href="#">35</a> |
| • 添加了节 7器件和文档支持 .....                                                                                                                                                                                                   | <a href="#">59</a> |

## 3 Device Comparison

Table 3-1 summarizes the features of the device variants in this data sheet.

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

| Device      | Flash | SRAM      | Timer_A <sup>(3)</sup> | Timer_B <sup>(4)</sup> | USART | COMP_A | ADC12<br>(Channels) | I/Os | Package                               |
|-------------|-------|-----------|------------------------|------------------------|-------|--------|---------------------|------|---------------------------------------|
| MSP430F149  | 60KB  | 2KB       | 3                      | 7                      | 2     | 1      | 8                   | 48   | 64-pin PM<br>64-pin PAG<br>64-pin RTD |
| MSP430F1491 | 60KB  | 2KB       | 3                      | 7                      | 2     | 1      | 8                   | 48   | 64-pin PM<br>64-pin RTD               |
| MSP430F148  | 48KB  | 2KB       | 3                      | 7                      | 2     | 1      | 8                   | 48   | 64-pin PM<br>64-pin PAG<br>64-pin RTD |
| MSP430F1481 | 48KB  | 2KB       | 3                      | 7                      | 2     | 1      | 8                   | 48   | 64-pin PM<br>64-pin RTD               |
| MSP430F147  | 32KB  | 1KB       | 3                      | 7                      | 2     | 1      | 8                   | 48   | 64-pin PM<br>64-pin PAG<br>64-pin RTD |
| MSP430F1471 | 32KB  | 1KB       | 3                      | 7                      | 2     | 1      | 8                   | 48   | 64-pin PM<br>64-pin RTD               |
| MSP430F135  | 16KB  | 512 bytes | 3                      | 3                      | 1     | 1      | 8                   | 48   | 64-pin PM<br>64-pin PAG<br>64-pin RTD |
| MSP430F133  | 8KB   | 256 bytes | 3                      | 3                      | 1     | 1      | 8                   | 48   | 64-pin PM<br>64-pin PAG<br>64-pin RTD |

(1) For the most current package and ordering information, see the *Package Option Addendum* in 节 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\_B 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\_B, 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 microcontrollers** One platform. One ecosystem. Endless possibilities.

**Products for other MSP430 microcontrollers** MCUs for metrology, monitoring, system control, and communications

**Companion Products for MSP430F149** Review products that are frequently purchased or used with this product.

**Reference Designs** The 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.

## 4 Terminal Configuration and Functions

### 4.1 Pin Diagrams

Figure 4-1 shows the pinout for the MSP430F133 and MSP430F135 MCUs in the 64-pin PM, PAG, and RTD packages.

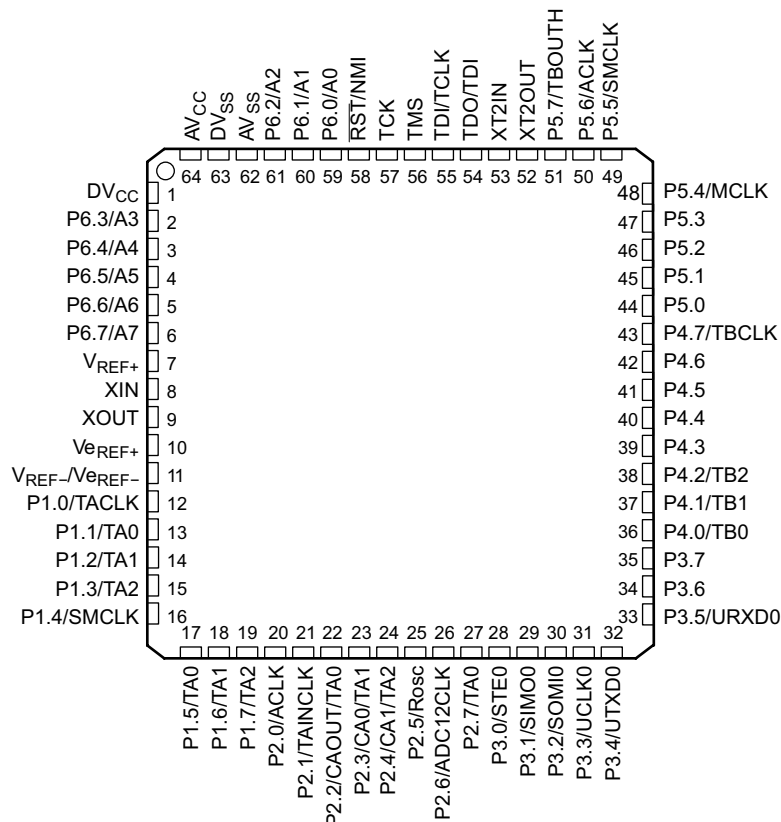


Figure 4-1. 64-Pin PM, PAG, or RTD Package (Top View) for MSP430F133 and MSP430F135

Figure 4-2 shows the pinout for the MSP430F147, MSP430F148, and MSP430F149 MCUs in the 64-pin PM, PAG, and RTD packages.

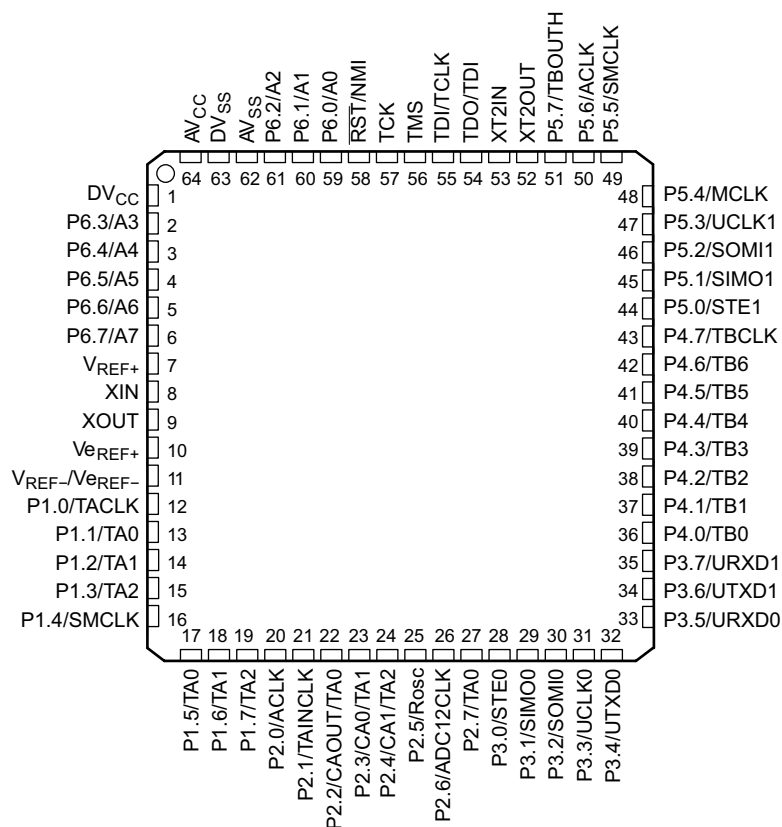
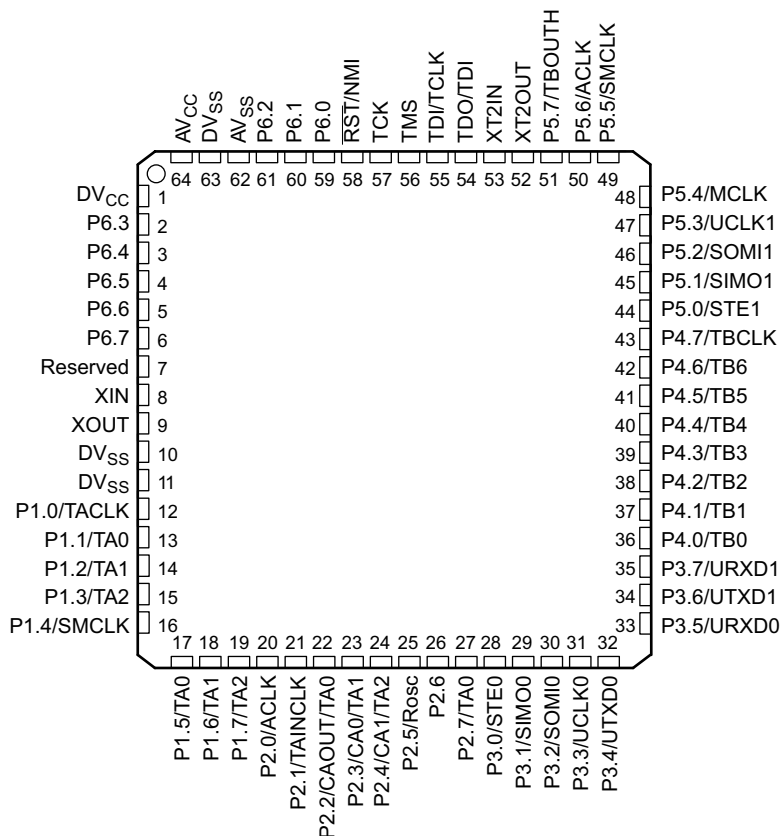


Figure 4-2. 64-Pin PM, PAG, or RTD Package (Top View) for MSP430F147, MSP430F148, and MSP430F149

Figure 4-3 shows the pinout for the MSP430F1471, MSP430F1481, and MSP430F1491 MCUs in the 64-pin PM and RTD packages.



**Figure 4-3. 64-Pin PM or RTD Package (Top View) for MSP430F1471, MSP430F1481, and MSP430F1491**

## 4.2 Signal Descriptions

[Table 4-1](#) describes the signals for the MSP430F13x and MSP430F14x MCUs. See [Table 4-2](#) for the MSP430F14x1 signal descriptions.

**Table 4-1. Signal Descriptions for MSP430F13x and MSP430F14x**

| SIGNAL NAME           | PIN NO. | I/O | DESCRIPTION                                                                                            |
|-----------------------|---------|-----|--------------------------------------------------------------------------------------------------------|
| AV <sub>CC</sub>      | 64      |     | Analog supply voltage, positive terminal. Supplies the analog portion of the ADC.                      |
| AV <sub>SS</sub>      | 62      |     | Analog supply voltage, negative terminal. Supplies the analog portion of the ADC.                      |
| DV <sub>CC</sub>      | 1       |     | Digital supply voltage, positive terminal. Supplies all digital parts.                                 |
| DV <sub>SS</sub>      | 63      |     | Digital supply voltage, negative terminal. Supplies all digital parts.                                 |
| P1.0/TACLK            | 12      | I/O | General-purpose digital I/O pin<br>Timer_A, clock signal TACLK input                                   |
| P1.1/TA0              | 13      | I/O | General-purpose digital I/O pin<br>Timer_A, capture: CCI0A input, compare: Out0 output<br>BSL transmit |
| P1.2/TA1              | 14      | I/O | General-purpose digital I/O pin<br>Timer_A, capture: CCI0A input, compare: Out0 output<br>BSL transmit |
| P1.3/TA2              | 15      | I/O | General-purpose digital I/O pin<br>Timer_A, capture: CCI2A input, compare: Out2 output                 |
| P1.4/SMCLK            | 16      | I/O | General-purpose digital I/O pin<br>SMCLK signal output                                                 |
| P1.5/TA0              | 17      | I/O | General-purpose digital I/O pin<br>Timer_A, compare: Out0 output                                       |
| P1.6/TA1              | 18      | I/O | General-purpose digital I/O pin<br>Timer_A, compare: Out1 output                                       |
| P1.7/TA2              | 19      | I/O | General-purpose digital I/O pin<br>Timer_A, compare: Out2 output/                                      |
| P2.0/ACLK             | 20      | I/O | General-purpose digital I/O pin<br>ACLK output                                                         |
| P2.1/TAINCLK          | 21      | I/O | General-purpose digital I/O pin<br>Timer_A, clock signal at INCLK                                      |
| P2.2/CAOUT/TA0        | 22      | I/O | General-purpose digital I/O pin<br>Comparator_A output<br>Timer_A, capture: CCI0B input<br>BSL receive |
| P2.3/CA0/TA1          | 23      | I/O | General-purpose digital I/O pin<br>Timer_A, compare: Out1 output<br>Comparator_A input                 |
| P2.4/CA1/TA2          | 24      | I/O | General-purpose digital I/O pin<br>Timer_A, compare: Out2 output<br>Comparator_A input                 |
| P2.5/R <sub>OSC</sub> | 25      | I/O | General-purpose digital I/O pin<br>input for external resistor defining the DCO nominal frequency      |
| P2.6/ADC12CLK         | 26      | I/O | General-purpose digital I/O pin<br>Conversion clock for ADC                                            |
| P2.7/TA0              | 27      | I/O | General-purpose digital I/O pin<br>Timer_A, compare: Out0 output                                       |
| P3.0/STE0             | 28      | I/O | General-purpose digital I/O pin<br>Slave transmit enable for USART0 in SPI mode                        |
| P3.1/SIMO0            | 29      | I/O | General-purpose digital I/O pin<br>Slave in/master out of USART0 in SPI mode                           |
| P3.2/SOMI0            | 30      | I/O | General-purpose digital I/O pin<br>Slave out/master in of USART0 in SPI mode                           |
| P3.3/UCLK0            | 31      | I/O | General-purpose digital I/O<br>USART0 clock: external input in UART or SPI mode, output in SPI mode    |
| P3.4/UTXD0            | 32      | I/O | General-purpose digital I/O pin<br>Transmit data out for USART0 in UART mode                           |

**Table 4-1. Signal Descriptions for MSP430F13x and MSP430F14x (continued)**

| SIGNAL NAME               | PIN NO. | I/O | DESCRIPTION                                                                                                        |
|---------------------------|---------|-----|--------------------------------------------------------------------------------------------------------------------|
| P3.5/URXD0                | 33      | I/O | General-purpose digital I/O pin<br>Receive data in for USART0 in UART mode                                         |
| P3.6/UTXD1 <sup>(1)</sup> | 34      | I/O | General-purpose digital I/O pin<br>Transmit data out for USART1 in UART mode                                       |
| P3.7/URXD1 <sup>(1)</sup> | 35      | I/O | General-purpose digital I/O pin<br>Receive data in for USART1 in UART mode                                         |
| P4.0/TB0                  | .36     | I/O | General-purpose digital I/O pin<br>Timer_B, capture: CCI0A or CCI0B input, compare: Out0 output                    |
| P4.1/TB1                  | 37      | I/O | General-purpose digital I/O pin<br>Timer_B, capture: CCI1A or CCI1B input, compare: Out1 output                    |
| P4.2/TB2                  | 38      | I/O | General-purpose digital I/O pin<br>Timer_B, capture: CCI2A or CCI2B input, compare: Out2 output                    |
| P4.3/TB3 <sup>(1)</sup>   | 39      | I/O | General-purpose digital I/O pin<br>Timer_B, capture: CCI3A or CCI3B input, compare: Out3 output                    |
| P4.4/TB4 <sup>(1)</sup>   | 40      | I/O | General-purpose digital I/O pin<br>Timer_B, capture: CCI4A or CCI4B input, compare: Out4 output                    |
| P4.5/TB5 <sup>(1)</sup>   | 41      | I/O | General-purpose digital I/O pin<br>Timer_B, capture: CCI5A or CCI5B input, compare: Out5 output                    |
| P4.6/TB6 <sup>(1)</sup>   | 42      | I/O | General-purpose digital I/O pin<br>Timer_B, capture: CCI6A or CCI6B input, compare: Out6 output                    |
| P4.7/TBCLK                | 43      | I/O | General-purpose digital I/O pin<br>Timer_B, clock signal TBCLK input                                               |
| P5.0/STE1 <sup>(1)</sup>  | 44      | I/O | General-purpose digital I/O pin<br>Slave transmit enable for USART1 in SPI mode                                    |
| P5.1/SIMO1 <sup>(1)</sup> | 45      | I/O | General-purpose digital I/O pin<br>Slave in/master out of USART1 in SPI mode                                       |
| P5.2/SOMI1 <sup>(1)</sup> | 46      | I/O | General-purpose digital I/O pin<br>Slave out/master in of USART1 in SPI mode                                       |
| P5.3/UCLK1 <sup>(1)</sup> | 47      | I/O | General-purpose digital I/O pin<br>USART1 clock: external input in UART or SPI mode, output in SPI mode            |
| P5.4/MCLK                 | 48      | I/O | General-purpose digital I/O pin<br>Main system clock MCLK output                                                   |
| P5.5/SMCLK                | 49      | I/O | General-purpose digital I/O pin<br>Submain system clock SMCLK output                                               |
| P5.6/ACLK                 | 50      | I/O | General-purpose digital I/O pin<br>Auxiliary clock ACLK output                                                     |
| P5.7/TBOUTH               | 51      | I/O | General-purpose digital I/O pin<br>Switch all PWM digital output ports to high impedance for Timer_B7 (TB0 to TB6) |
| P6.0/A0                   | 59      | I/O | General-purpose digital I/O pin<br>Analog input A0 for ADC                                                         |
| P6.1/A1                   | 60      | I/O | General-purpose digital I/O pin<br>Analog input A1 for ADC                                                         |
| P6.2/A2                   | 61      | I/O | General-purpose digital I/O pin<br>Analog input A2 for ADC                                                         |
| P6.3/A3                   | 2       | I/O | General-purpose digital I/O pin<br>Analog input A3 for ADC                                                         |
| P6.4/A4                   | 3       | I/O | General-purpose digital I/O pin<br>Analog input A4 for ADC                                                         |
| P6.5/A5                   | 4       | I/O | General-purpose digital I/O pin<br>Analog input A5 for ADC                                                         |
| P6.6/A6                   | 5       | I/O | General-purpose digital I/O pin<br>Analog input A6 for ADC                                                         |
| P6.7/A7                   | 6       | I/O | General-purpose digital I/O pin<br>Analog input A7 for ADC                                                         |

(1) MSP430F14x devices only

**Table 4-1. Signal Descriptions for MSP430F13x and MSP430F14x (continued)**

| SIGNAL NAME                        | PIN NO. | I/O | DESCRIPTION                                                                                                                               |
|------------------------------------|---------|-----|-------------------------------------------------------------------------------------------------------------------------------------------|
| $\overline{\text{RST}}/\text{NMI}$ | 58      | I   | Reset input<br>Nonmaskable interrupt input port<br>Bootloader start                                                                       |
| TCK                                | 57      | I   | Test clock, the clock input port for device programming test and bootloader start                                                         |
| TDI/TCLK                           | 55      | I   | Test data input or test clock input. The device protection fuse is connected to TDI/TCLK.                                                 |
| TDO/TDI                            | 54      | I/O | Test data output or programming data input                                                                                                |
| TMS                                | 56      | I   | Test mode select, used as an input port for device programming and test                                                                   |
| VeREF+                             | 10      | I   | Input for an external reference voltage to the ADC                                                                                        |
| VREF+                              | 7       | O   | Output of positive terminal of the reference voltage in the ADC                                                                           |
| VREF–/VeREF–                       | 11      | I   | Negative terminal for the ADC reference voltage for both sources, the internal reference voltage or an external applied reference voltage |
| XIN                                | 8       | I   | Input port for crystal oscillator XT1, standard or watch crystals can be connected                                                        |
| XOUT                               | 9       | O   | Output terminal of crystal oscillator XT1                                                                                                 |
| XT2IN                              | 53      | I   | Input port for crystal oscillator XT2, only standard crystals can be connected                                                            |
| XT2OUT                             | 52      | O   | Output terminal of crystal oscillator XT2                                                                                                 |
| QFN Pad                            | NA      | NA  | QFN package pad, connect to DV <sub>SS</sub>                                                                                              |

Table 4-2 describes the signals for the MSP430F14x1 MCUs. See Table 4-1 for the MSP430F13x and MSP430F14x signal descriptions.

**Table 4-2. Signal Descriptions for MSP430F14x1**

| SIGNAL NAME           | PIN NO. | I/O | DESCRIPTION                                                                                            |
|-----------------------|---------|-----|--------------------------------------------------------------------------------------------------------|
| AV <sub>CC</sub>      | 64      |     | Analog supply voltage positive terminal                                                                |
| AV <sub>SS</sub>      | 62      |     | Analog supply voltage negative terminal                                                                |
| DV <sub>CC</sub>      | 1       |     | Digital supply voltage, positive terminal. Supplies all digital parts.                                 |
| DV <sub>SS</sub>      | 63      |     | Digital supply voltage, negative terminal. Supplies all digital parts.                                 |
| P1.0/TACLK            | 12      | I/O | General-purpose digital I/O pin<br>Timer_A, clock signal TACLK input                                   |
| P1.1/TA0              | 13      | I/O | General-purpose digital I/O pin<br>Timer_A, capture: CCI0A input, compare: Out0 output<br>BSL transmit |
| P1.2/TA1              | 14      | I/O | General-purpose digital I/O pin<br>Timer_A, capture: CCI1A input, compare: Out1 output                 |
| P1.3/TA2              | 15      | I/O | General-purpose digital I/O pin<br>Timer_A, capture: CCI2A input, compare: Out2 output                 |
| P1.4/SMCLK            | 16      | I/O | General-purpose digital I/O pin<br>SMCLK signal output                                                 |
| P1.5/TA0              | 17      | I/O | General-purpose digital I/O pin<br>Timer_A, compare: Out0 output                                       |
| P1.6/TA1              | 18      | I/O | General-purpose digital I/O pin<br>Timer_A, compare: Out1 output                                       |
| P1.7/TA2              | 19      | I/O | General-purpose digital I/O pin<br>Timer_A, compare: Out2 output                                       |
| P2.0/ACLK             | 20      | I/O | General-purpose digital I/O pin<br>ACLK output                                                         |
| P2.1/TAINCLK          | 21      | I/O | General-purpose digital I/O pin<br>Timer_A, clock signal at INCLK                                      |
| P2.2/CAOUT/TA0        | 22      | I/O | General-purpose digital I/O pin<br>Timer_A, capture: CCI0B input<br>Comparator_A output<br>BSL receive |
| P2.3/CA0/TA1          | 23      | I/O | General-purpose digital I/O pin<br>Timer_A, compare: Out1 output<br>Comparator_A input                 |
| P2.4/CA1/TA2          | 24      | I/O | General-purpose digital I/O pin<br>Timer_A, compare: Out2 output<br>Comparator_A input                 |
| P2.5/R <sub>OSC</sub> | 25      | I/O | General-purpose digital I/O pin<br>Input for external resistor defining the DCO nominal frequency      |
| P2.6                  | 26      | I/O | General-purpose digital I/O pin                                                                        |
| P2.7/TA0              | 27      | I/O | General-purpose digital I/O pin<br>Timer_A, compare: Out0 output                                       |
| P3.0/STE0             | 28      | I/O | General-purpose digital I/O pin<br>Slave transmit enable for USART0 in SPI mode                        |
| P3.1/SIMO0            | 29      | I/O | General-purpose digital I/O pin<br>Slave in/master out of USART0 in SPI mode                           |
| P3.2/SOMI0            | 30      | I/O | General-purpose digital I/O pin<br>Slave out/master in of USART0 in SPI mode                           |
| P3.3/UCLK0            | 31      | I/O | General-purpose digital I/O<br>USART0 clock: external input in UART or SPI mode, output in SPI mode    |
| P3.4/UTXD0            | 32      | I/O | General-purpose digital I/O pin<br>Transmit data out for USART0 in UART mode                           |
| P3.5/URXD0            | 33      | I/O | General-purpose digital I/O pin<br>Receive data in for USART0 in UART mode                             |

**Table 4-2. Signal Descriptions for MSP430F14x1 (continued)**

| SIGNAL NAME                        | PIN NO. | I/O | DESCRIPTION                                                                                                        |
|------------------------------------|---------|-----|--------------------------------------------------------------------------------------------------------------------|
| P3.6/UTXD1                         | 34      | I/O | General-purpose digital I/O pin<br>Transmit data out for USART1 in UART mode                                       |
| P3.7/URXD1                         | 35      | I/O | General-purpose digital I/O pin<br>Receive data in for USART1 in UART mode                                         |
| P4.0/TB0                           | .36     | I/O | General-purpose digital I/O pin<br>Timer_B, capture: CCI0A or CCI0B input, compare: Out0 output                    |
| P4.1/TB1                           | 37      | I/O | General-purpose digital I/O pin<br>Timer_B, capture: CCI1A or CCI1B input, compare: Out1 output                    |
| P4.2/TB2                           | 38      | I/O | General-purpose digital I/O pin<br>Timer_B, capture: CCI2A or CCI2B input, compare: Out2 output                    |
| P4.3/TB3                           | 39      | I/O | General-purpose digital I/O pin<br>Timer_B, capture: CCI3A or CCI3B input, compare: Out3 output                    |
| P4.4/TB4                           | 40      | I/O | General-purpose digital I/O pin<br>Timer_B, capture: CCI4A or CCI4B input, compare: Out4 output                    |
| P4.5/TB5                           | 41      | I/O | General-purpose digital I/O pin<br>Timer_B, capture: CCI5A or CCI5B input, compare: Out5 output                    |
| P4.6/TB6                           | 42      | I/O | General-purpose digital I/O pin<br>Timer_B, capture: CCI6A or CCI6B input, compare: Out6 output                    |
| P4.7/TBCLK                         | 43      | I/O | General-purpose digital I/O pin<br>Timer_B, clock signal TBCLK input                                               |
| P5.0/STE1                          | 44      | I/O | General-purpose digital I/O pin<br>Slave transmit enable for USART1 in SPI mode                                    |
| P5.1/SIMO1                         | 45      | I/O | General-purpose digital I/O pin<br>Slave in/master out of USART1 in SPI mode                                       |
| P5.2/SOMI1                         | 46      | I/O | General-purpose digital I/O pin<br>Slave out/master in of USART1 in SPI mode                                       |
| P5.3/UCLK1                         | 47      | I/O | General-purpose digital I/O pin<br>USART1 clock: external input in UART or SPI mode, output in SPI mode            |
| P5.4/MCLK                          | 48      | I/O | General-purpose digital I/O pin<br>Main system clock MCLK output                                                   |
| P5.5/SMCLK                         | 49      | I/O | General-purpose digital I/O pin<br>Submain system clock SMCLK output                                               |
| P5.6/ACLK                          | 50      | I/O | General-purpose digital I/O pin<br>Auxiliary clock ACLK output                                                     |
| P5.7/TBOUTH                        | 51      | I/O | General-purpose digital I/O pin<br>Switch all PWM digital output ports to high impedance for Timer_B7 (TB0 to TB6) |
| P6.0                               | 59      | I/O | General-purpose digital I/O pin                                                                                    |
| P6.1                               | 60      | I/O | General-purpose digital I/O pin                                                                                    |
| P6.2                               | 61      | I/O | General-purpose digital I/O pin                                                                                    |
| P6.3                               | 2       | I/O | General-purpose digital I/O pin                                                                                    |
| P6.4                               | 3       | I/O | General-purpose digital I/O pin                                                                                    |
| P6.5                               | 4       | I/O | General-purpose digital I/O pin                                                                                    |
| P6.6                               | 5       | I/O | General-purpose digital I/O pin                                                                                    |
| P6.7                               | 6       | I/O | General-purpose digital I/O pin                                                                                    |
| $\overline{\text{RST}}/\text{NMI}$ | 58      | I   | Reset input<br>Nonmaskable interrupt input port<br>Bootloader start                                                |
| TCK                                | 57      | I   | Test clock, the clock input port for device programming test and bootloader start                                  |
| TDI/TCLK                           | 55      | I   | Test data input or test clock input. The device protection fuse is connected to TDI/TCLK.                          |
| TDO/TDI                            | 54      | I/O | Test data output or programming data input                                                                         |
| TMS                                | 56      | I   | Test mode select, used as an input port for device programming and test                                            |
| DV <sub>SS</sub>                   | 10      | I   | Connect to DV <sub>SS</sub>                                                                                        |
| Reserved                           | 7       |     | Reserved, do not connect externally                                                                                |

**Table 4-2. Signal Descriptions for MSP430F14x1 (continued)**

| SIGNAL NAME      | PIN NO. | I/O | DESCRIPTION                                                                         |
|------------------|---------|-----|-------------------------------------------------------------------------------------|
| DV <sub>SS</sub> | 11      | I   | Connect to DV <sub>SS</sub>                                                         |
| XIN              | 8       | I   | Input port for crystal oscillator XT1. Standard or watch crystals can be connected. |
| XOUT             | 9       | O   | Output terminal of crystal oscillator XT1                                           |
| XT2IN            | 53      | I   | Input port for crystal oscillator XT2. Only standard crystals can be connected.     |
| XT2OUT           | 52      | O   | Output terminal of crystal oscillator XT2                                           |
| QFN Pad          | NA      | NA  | QFN package pad, connect to DV <sub>SS</sub>                                        |

## 5 Specifications

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

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

|                                           | MIN                 | MAX            | UNIT |
|-------------------------------------------|---------------------|----------------|------|
| Voltage applied at $V_{CC}$ to $V_{SS}$   | -0.3                | 4.1            | V    |
| Voltage applied to any pin <sup>(2)</sup> | -0.3                | $V_{CC} + 0.3$ | V    |
| Diode current at any device terminal      |                     | ±2             | mA   |
| Storage temperature                       | Programmed device   | -40            | °C   |
|                                           | Unprogrammed device | -55            |      |

- (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 voltage values are with respect to  $V_{SS}$ , unless otherwise noted. The JTAG fuse-blow voltage,  $V_{FB}$ , is allowed to exceed the absolute maximum rating. The voltage is applied to the TDI/TCLK pin when blowing the JTAG fuse.

### 5.2 ESD Ratings

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

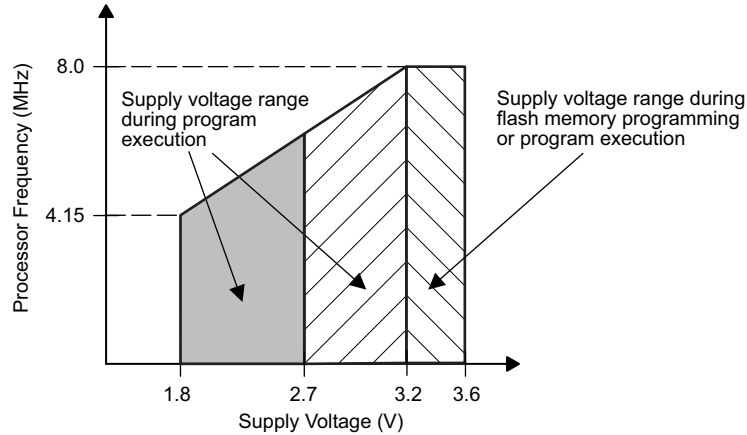
- (1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process. Pins listed as ±1000 V may actually have higher performance.
- (2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process. Pins listed as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

### 5.3 Recommended Operating Conditions

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

|                     |                                                                         |                                          | MIN  | NOM   | MAX  | UNIT |
|---------------------|-------------------------------------------------------------------------|------------------------------------------|------|-------|------|------|
| V <sub>CC</sub>     | Supply voltage (AV <sub>CC</sub> = DV <sub>CC</sub> = V <sub>CC</sub> ) | During program execution                 | 1.8  |       | 3.6  | V    |
|                     |                                                                         | During flash memory programming          | 2.7  |       | 3.6  |      |
| V <sub>SS</sub>     | Supply voltage (AV <sub>SS</sub> = DV <sub>SS</sub> = V <sub>SS</sub> ) |                                          | 0    |       | 0    | V    |
| T <sub>A</sub>      | Operating free-air temperature                                          |                                          | −40  |       | 85   | °C   |
| f <sub>LFXT1</sub>  | LFXT1 crystal frequency <sup>(1)</sup>                                  | LF selected, XTS = 0, watch crystal      |      | 32768 |      | Hz   |
|                     |                                                                         | XT1 selected, XTS = 1, ceramic resonator | 450  |       | 8000 | kHz  |
|                     |                                                                         | XT1 selected, XTS = 1, crystal           | 1000 |       | 8000 |      |
| f <sub>XT2</sub>    | XT2 crystal frequency <sup>(1)</sup>                                    | Ceramic resonator                        | 450  |       | 8000 | kHz  |
|                     |                                                                         | Crystal                                  | 1000 |       | 8000 |      |
| f <sub>SYSTEM</sub> | Processor frequency (signal MCLK)                                       | V <sub>CC</sub> = 1.8 V                  | DC   |       | 4.15 | MHz  |
|                     |                                                                         | V <sub>CC</sub> = 3.6 V                  | DC   |       | 8    |      |

- (1) In LF mode, the LFXT1 oscillator requires a watch crystal. TI recommends a 5.1-M $\Omega$  resistor from XOUT to  $V_{SS}$  when  $V_{CC} < 2.5$  V. In XT1 mode, the LFXT1 and XT2 oscillators accept a ceramic resonator or crystal up to 4.15 MHz at  $V_{CC} \geq 2.2$  V. In XT1 mode, the LFXT1 and XT2 oscillators accept a ceramic resonator or crystal up to 8 MHz at  $V_{CC} \geq 2.8$  V.



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

## 5.4 Supply Current Into AV<sub>CC</sub> and DV<sub>CC</sub> Excluding External Current

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

| PARAMETER                                                                 | TEST CONDITIONS                                                                                                  | T <sub>A</sub> | V <sub>CC</sub> | MIN | TYP | MAX | UNIT |
|---------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------|----------------|-----------------|-----|-----|-----|------|
| I <sub>(AM)</sub> Active mode supply current <sup>(1)</sup>               | f <sub>(MCLK)</sub> = f <sub>(SMCLK)</sub> = 1 MHz,<br>f <sub>(ACLK)</sub> = 32768 Hz,<br>XTS = 0, SELM = 0 or 1 | –40°C to 85°C  | 2.2 V           |     | 280 | 360 | μA   |
|                                                                           |                                                                                                                  |                | 3 V             |     | 420 | 560 |      |
|                                                                           | f <sub>(MCLK)</sub> = f <sub>(SMCLK)</sub> = f <sub>(ACLK)</sub> = 4096 Hz,<br>XTS = 0, SELM = 3                 | –40°C to 85°C  | 2.2 V           |     | 2.5 | 7   |      |
|                                                                           |                                                                                                                  |                | 3 V             |     | 9   | 20  |      |
| I <sub>(LPM0)</sub> Low-power mode 0 (LPM0) supply current <sup>(1)</sup> |                                                                                                                  | –40°C to 85°C  | 2.2 V           |     | 32  | 45  | μA   |
|                                                                           |                                                                                                                  |                | 3 V             |     | 55  | 70  |      |
| I <sub>(LPM2)</sub> Low-power mode 2 (LPM2) supply current                | f <sub>(MCLK)</sub> = f <sub>(SMCLK)</sub> = 0 MHz,<br>f <sub>(ACLK)</sub> = 32768 Hz, SCG0 = 0                  | –40°C to 85°C  | 2.2 V           |     | 11  | 14  | μA   |
|                                                                           |                                                                                                                  |                | 3 V             |     | 17  | 22  |      |
| I <sub>(LPM3)</sub> Low-power mode 3 (LPM3) supply current                | f <sub>(MCLK)</sub> = f <sub>(SMCLK)</sub> = 0 MHz,<br>f <sub>(ACLK)</sub> = 32768 Hz, SCG0 = 1 <sup>(2)</sup>   | –40°C          | 2.2 V           |     | 0.8 | 1.5 | μA   |
|                                                                           |                                                                                                                  | 25°C           |                 |     | 0.9 | 1.5 |      |
|                                                                           |                                                                                                                  | 85°C           |                 |     | 1.6 | 2.8 |      |
|                                                                           |                                                                                                                  | –40°C          | 3 V             |     | 1.8 | 2.2 |      |
|                                                                           |                                                                                                                  | 25°C           |                 |     | 1.6 | 1.9 |      |
|                                                                           |                                                                                                                  | 85°C           |                 |     | 2.3 | 3.9 |      |
| I <sub>(LPM4)</sub> Low-power mode 4 (LPM4) supply current                | f <sub>(MCLK)</sub> = f <sub>(SMCLK)</sub> = f <sub>(ACLK)</sub> = 0 MHz,<br>SCG0 = 1                            | –40°C          | 2.2 V           |     | 0.1 | 0.5 | μA   |
|                                                                           |                                                                                                                  | 25°C           |                 |     | 0.1 | 0.5 |      |
|                                                                           |                                                                                                                  | 85°C           |                 |     | 0.8 | 2.5 |      |
|                                                                           |                                                                                                                  | –40°C          | 3 V             |     | 0.1 | 0.5 |      |
|                                                                           |                                                                                                                  | 25°C           |                 |     | 0.1 | 0.5 |      |
|                                                                           |                                                                                                                  | 85°C           |                 |     | 0.8 | 2.5 |      |

(1) Timer\_B is clocked by f<sub>(DCOCLK)</sub> = 1 MHz. All inputs are tied to 0 V or to V<sub>CC</sub>. Outputs do not source or sink any current.

(2) Timer\_B is clocked by f<sub>(ACLK)</sub> = 32768 Hz. All inputs are tied to 0 V or to V<sub>CC</sub>. Outputs do not source or sink any current. The current consumption in LPM2 and LPM3 are measured with ACLK selected.

Current consumption of active mode versus system frequency

$$I_{(AM)} = I_{(AM)} [1 \text{ MHz}] \times f_{(\text{System})} [\text{MHz}]$$

Current consumption of active mode versus supply voltage

$$I_{(AM)} = I_{(AM)} [3 \text{ V}] + 175 \mu\text{A/V} \times (V_{\text{CC}} - 3 \text{ V})$$

## 5.5 Thermal Resistance Characteristics

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

| THERMAL METRIC <sup>(1)</sup> |                                                      | VALUE <sup>(2)</sup> |                    |               | UNIT |
|-------------------------------|------------------------------------------------------|----------------------|--------------------|---------------|------|
|                               |                                                      | 64-PIN<br>PM         | 64-PIN<br>PAG      | 64-PIN<br>RTD |      |
| R <sub>θJA</sub>              | Junction-to-ambient thermal resistance, still air    | 52.0                 | 52.7               | 25.0          | °C/W |
| R <sub>θJC(TOP)</sub>         | Junction-to-case (top) thermal resistance            | 14.4                 | 11.2               | 14.2          | °C/W |
| R <sub>θJB</sub>              | Junction-to-board thermal resistance                 | 23.0                 | 23.4               | 9.6           | °C/W |
| Ψ <sub>JB</sub>               | Junction-to-board thermal characterization parameter | 22.7                 | 23.1               | 9.5           | °C/W |
| Ψ <sub>JT</sub>               | Junction-to-top thermal characterization parameter   | 0.6                  | 0.3                | 0.2           | °C/W |
| R <sub>θJC(BOTTOM)</sub>      | Junction-to-case (bottom) thermal resistance         | N/A <sup>(3)</sup>   | N/A <sup>(3)</sup> | 1.3           | °C/W |

(1) For more information about traditional and new thermal metrics, see [Semiconductor and IC Package Thermal Metrics](#).

(2) These values are based on a JEDEC-defined 2S2P system (with the exception of the Theta JC (R<sub>θJC</sub>) value, which is based on a JEDEC-defined 1S0P system) and will change based on environment and application. For more information, see these EIA/JEDEC standards:

- JESD51-2, *Integrated Circuits Thermal Test Method Environmental Conditions - Natural Convection (Still Air)*
- JESD51-3, *Low Effective Thermal Conductivity Test Board for Leaded Surface Mount Packages*
- JESD51-7, *High Effective Thermal Conductivity Test Board for Leaded Surface Mount Packages*
- JESD51-9, *Test Boards for Area Array Surface Mount Package Thermal Measurements*

(3) N/A = not applicable

## 5.6 Schmitt-Trigger Inputs – Ports P1, P2, P3, P4, P5, and P6

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

| PARAMETER        |                                                                 | V <sub>CC</sub> | MIN | MAX | UNIT |
|------------------|-----------------------------------------------------------------|-----------------|-----|-----|------|
| V <sub>IT+</sub> | Positive-going input threshold voltage                          | 2.2 V           | 1.1 | 1.5 | V    |
|                  |                                                                 | 3 V             | 1.5 | 1.9 |      |
| V <sub>IT-</sub> | Negative-going input threshold voltage                          | 2.2 V           | 0.4 | 0.9 | V    |
|                  |                                                                 | 3 V             | 0.9 | 1.3 |      |
| V <sub>hys</sub> | Input voltage hysteresis (V <sub>IT+</sub> – V <sub>IT-</sub> ) | 2.2 V           | 0.3 | 1.1 | V    |
|                  |                                                                 | 3 V             | 0.5 | 1   |      |

## 5.7 Standard Inputs – $\overline{\text{RST}}$ /NMI, JTAG (TCK, TMS, TDI/TCLK, TDO/TDI)

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

| PARAMETER       |                          | V <sub>CC</sub> | MIN                   | MAX                   | UNIT |
|-----------------|--------------------------|-----------------|-----------------------|-----------------------|------|
| V <sub>IL</sub> | Low-level input voltage  | 2.2 V, 3 V      | V <sub>SS</sub>       | V <sub>SS</sub> + 0.6 | V    |
| V <sub>IH</sub> | High-level input voltage |                 | 0.8 × V <sub>CC</sub> | V <sub>CC</sub>       | V    |

## 5.8 Inputs – Px.y, TA<sub>x</sub>, TB<sub>x</sub>

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

| PARAMETER                                      |                                                              | TEST CONDITIONS                                                                          | V <sub>CC</sub> | MIN | MAX | UNIT  |
|------------------------------------------------|--------------------------------------------------------------|------------------------------------------------------------------------------------------|-----------------|-----|-----|-------|
| t <sub>(int)</sub>                             | External interrupt timing                                    | Port P1.x and P2.x, External trigger pulse duration to set interrupt flag <sup>(1)</sup> | 2.2 V, 3 V      | 1.5 |     | cycle |
|                                                |                                                              |                                                                                          | 2.2 V           | 62  |     | ns    |
|                                                |                                                              |                                                                                          | 3 V             | 50  |     |       |
| t <sub>(cap)</sub>                             | Timer A or Timer B capture timing                            | TA0, TA1, TA2, TB0, TB1, TB2, TB3, TB4, TB5, TB6 <sup>(2)</sup>                          | 2.2 V           | 62  |     | ns    |
|                                                |                                                              |                                                                                          | 3 V             | 50  |     |       |
| f <sub>(TAext)</sub> ,<br>f <sub>(TBext)</sub> | Timer_A or Timer_B clock frequency externally applied to pin | TACLK, TBCLK, INCLK: t <sub>(H)</sub> = t <sub>(L)</sub>                                 | 2.2 V           |     | 8   | MHz   |
|                                                |                                                              |                                                                                          | 3 V             |     | 10  |       |

(1) The external signal sets the interrupt flag every time the minimum t<sub>(int)</sub> cycle and time parameters are met. It may be set even with trigger signals shorter than t<sub>(int)</sub>. Both the cycle and timing specifications must be met to ensure the flag is set. t<sub>(int)</sub> is measured in MCLK cycles.

(2) Seven Timer\_B capture/compare registers in MSP430F14x and MSP430F14x devices, and three Timer\_B capture/compare registers in MSP430F13x devices.

## Inputs – Px.y, TAx, TBx (continued)

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

| PARAMETER                                                           | TEST CONDITIONS               | V <sub>CC</sub> | MIN | MAX | UNIT |
|---------------------------------------------------------------------|-------------------------------|-----------------|-----|-----|------|
| $f_{(TAint)}$ ,<br>$f_{(TBint)}$ Timer_A or Timer_B clock frequency | SMCLK or ACLK signal selected | 2.2 V           |     | 8   | MHz  |
|                                                                     |                               | 3 V             |     | 10  |      |

## 5.9 Leakage Current

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

| PARAMETER       | TEST CONDITIONS | V <sub>CC</sub> | MIN | MAX | UNIT |
|-----------------|-----------------|-----------------|-----|-----|------|
| $I_{lkg}(P1.x)$ | Port P1         | 2.2 V, 3 V      |     | ±50 | nA   |
| $I_{lkg}(P2.x)$ | Port P2         |                 |     | ±50 |      |
| $I_{lkg}(P6.x)$ | Port P6         |                 |     | ±50 |      |

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

(2) The port pin must be set as input, and the optional pullup or pulldown resistor must be disabled.

## 5.10 Outputs – Ports P1, P2, P3, P4, P5, and P6

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

| PARAMETER                                 | TEST CONDITIONS                      | V <sub>CC</sub> | MIN                    | MAX                    | UNIT |
|-------------------------------------------|--------------------------------------|-----------------|------------------------|------------------------|------|
| V <sub>OH</sub> High-level output voltage | $I_{(OHmax)} = -1 \text{ mA}^{(1)}$  | 2.2 V           | V <sub>CC</sub> – 0.25 | V <sub>CC</sub>        | V    |
|                                           | $I_{(OHmax)} = -6 \text{ mA}^{(2)}$  |                 | V <sub>CC</sub> – 0.60 | V <sub>CC</sub>        |      |
|                                           | $I_{(OHmax)} = 1 \text{ mA}^{(1)}$   | 3 V             | V <sub>CC</sub> – 0.25 | V <sub>CC</sub>        |      |
|                                           | $I_{(OHmax)} = -6 \text{ mA}^{(2)}$  |                 | V <sub>CC</sub> – 0.60 | V <sub>CC</sub>        |      |
| V <sub>OL</sub> Low-level output voltage  | $I_{(OLmax)} = 1.5 \text{ mA}^{(1)}$ | 2.2 V           | V <sub>SS</sub>        | V <sub>SS</sub> + 0.25 | V    |
|                                           | $I_{(OLmax)} = 6 \text{ mA}^{(2)}$   |                 | V <sub>SS</sub>        | V <sub>SS</sub> + 0.6  |      |
|                                           | $I_{(OLmax)} = 1.5 \text{ mA}^{(1)}$ | 3 V             | V <sub>SS</sub>        | V <sub>SS</sub> + 0.25 |      |
|                                           | $I_{(OLmax)} = 6 \text{ mA}^{(2)}$   |                 | V <sub>SS</sub>        | V <sub>SS</sub> + 0.6  |      |

(1) The maximum total current, I<sub>(OHmax)</sub> and I<sub>(OLmax)</sub>, for all outputs combined, must not exceed ±6 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, must not exceed ±24 mA to hold the maximum voltage drop specified.

## 5.11 Output Frequency

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

| PARAMETER                                     | TEST CONDITIONS                                                                                             | MIN                              | TYP | MAX                 | UNIT |
|-----------------------------------------------|-------------------------------------------------------------------------------------------------------------|----------------------------------|-----|---------------------|------|
| $f_{TAX}$ Timer_A or Timer_B output frequency | Internal clock source, SMCLK signal applied <sup>(1)</sup> , TA0 to TA2, TB0 to TB6, C <sub>L</sub> = 20 pF | DC                               |     | f <sub>SYSTEM</sub> | MHz  |
| $f_{ACLK}$                                    | Measured at P5.6/ACLK                                                                                       |                                  |     | f <sub>SYSTEM</sub> | MHz  |
| $f_{MCLK}$                                    | Measured at P5.4/MCLK                                                                                       |                                  |     | f <sub>SYSTEM</sub> |      |
| $f_{SMCLK}$                                   | Measured at P5.5/SMCLK                                                                                      |                                  |     | f <sub>SYSTEM</sub> |      |
| $t_{Xdc}$ Duty cycle of output frequency      | Measured at P2.0/ACLK, C <sub>L</sub> = 20 pF, V <sub>CC</sub> = 2.2 V or 3 V                               | $f_{ACLK} = f_{LFX1} = f_{XT1}$  |     | 60%                 |      |
|                                               |                                                                                                             | $f_{ACLK} = f_{LFX1} = f_{LF}$   |     | 70%                 |      |
|                                               |                                                                                                             | $f_{ACLK} = f_{LFX1/n}$          |     | 50%                 |      |
|                                               | Measured at P1.4/SMCLK, C <sub>L</sub> = 20 pF, V <sub>CC</sub> = 2.2 V or 3 V                              | $f_{SMCLK} = f_{LFX1} = f_{XT1}$ |     | 60%                 |      |
|                                               |                                                                                                             | $f_{SMCLK} = f_{LFX1} = f_{LF}$  |     | 65%                 |      |
|                                               |                                                                                                             | $f_{SMCLK} = f_{LFX1/n}$         |     | 50% – 15 ns         |      |
|                                               |                                                                                                             | $f_{SMCLK} = f_{DCOCLK}$         |     | 50% – 15 ns         |      |

(1) The limits of the system clock MCLK must be met; the MCLK frequency must not exceed the limits. MCLK and SMCLK frequencies can be different.

## 5.12 Typical Characteristics – Ports P1, P2, P3, P4, P5, and P6 Outputs

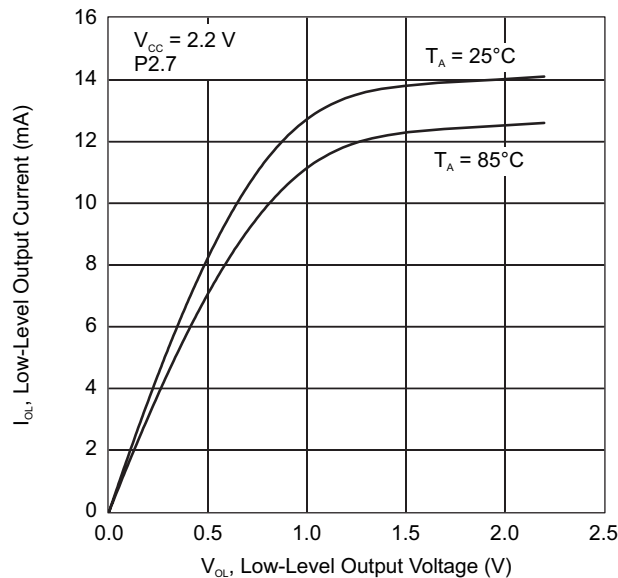


Figure 5-2. Typical Low-Level Output Current vs Low-Level Output Voltage

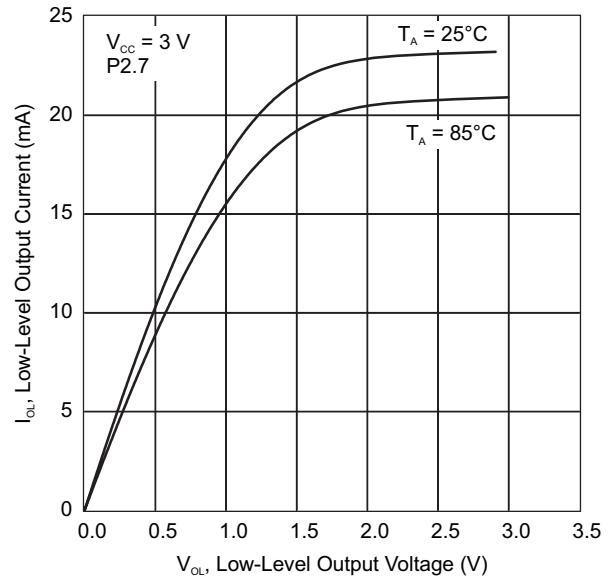


Figure 5-3. Typical Low-Level Output Current vs Low-Level Output Voltage

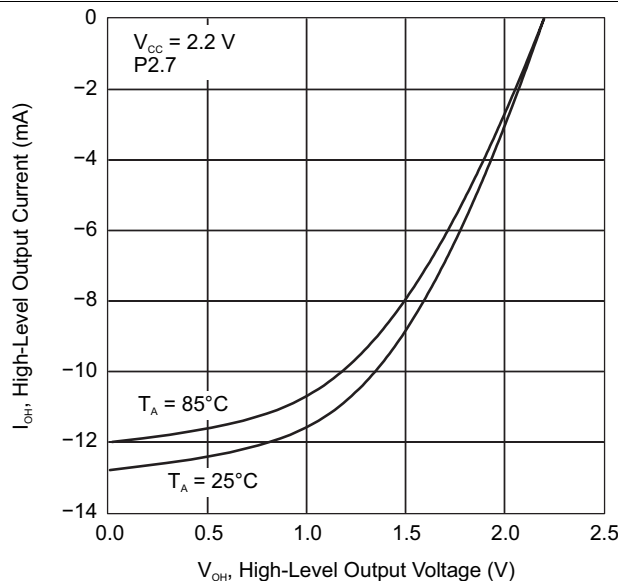


Figure 5-4. Typical High-Level Output Current vs High-Level Output Voltage

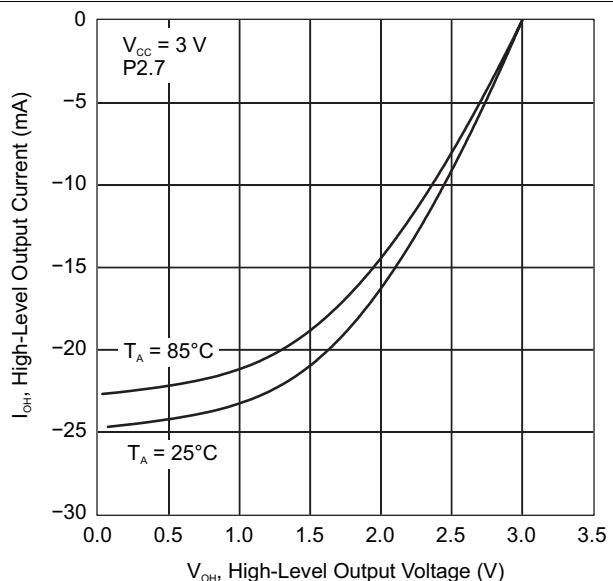


Figure 5-5. Typical High-Level Output Current vs High-Level Output Voltage

### 5.13 Wake-up Time From LPM3

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

| PARAMETER                                  | TEST CONDITIONS | V <sub>CC</sub> | MIN | MAX | UNIT |
|--------------------------------------------|-----------------|-----------------|-----|-----|------|
| t <sub>(LPM3)</sub> Wake-up time from LPM3 | f = 1 MHz       | 2.2 V, 3 V      |     | 6   | μs   |
|                                            | f = 2 MHz       |                 |     | 6   |      |
|                                            | f = 3 MHz       |                 |     | 6   |      |

### 5.14 RAM

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

| PARAMETER                                               | TEST CONDITIONS | MIN | MAX | UNIT |
|---------------------------------------------------------|-----------------|-----|-----|------|
| V <sub>RAMh</sub> Minimum supply voltage <sup>(1)</sup> | CPU halted      | 1.6 |     | V    |

- (1) This parameter defines the minimum supply voltage when the data in program memory RAM remain unchanged. No program execution should take place during this supply voltage condition.

### 5.15 Comparator\_A<sup>(1)</sup>

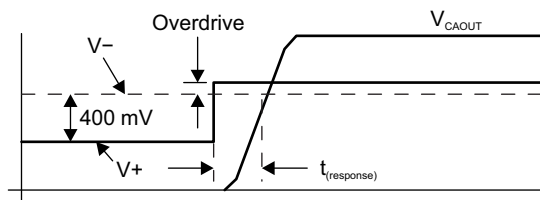
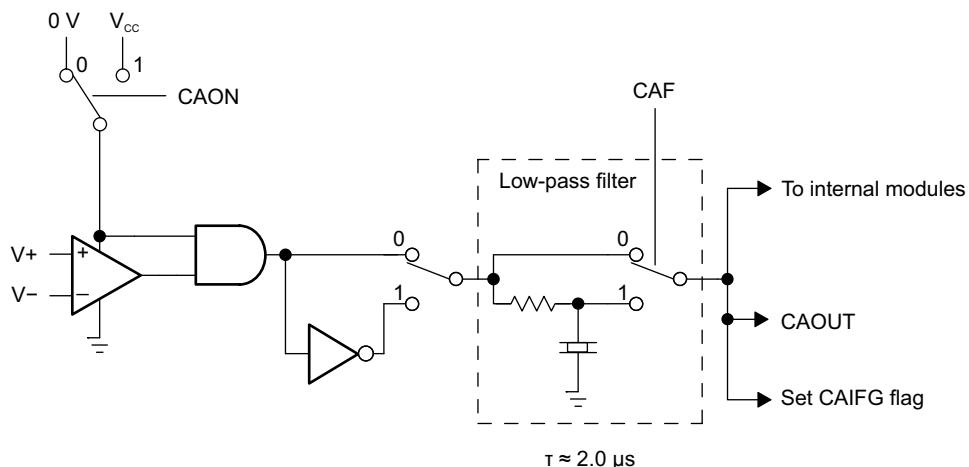
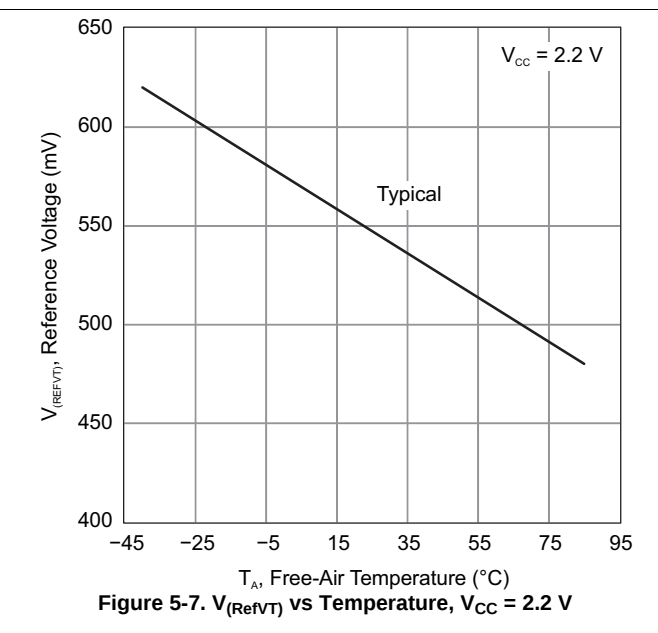
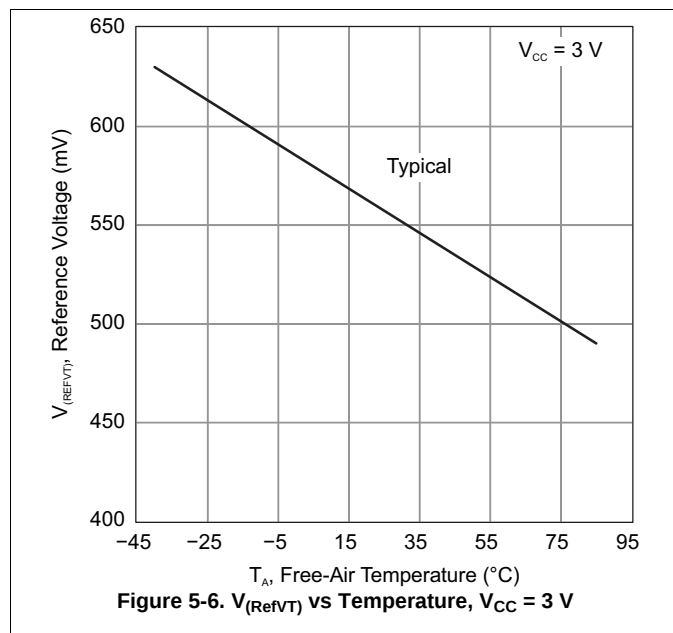
over recommended operating supply voltage and free-air temperature (unless otherwise noted)

| PARAMETER                                                                               | TEST CONDITIONS                                                                                  | V <sub>CC</sub> | MIN  | TYP  | MAX                 | UNIT |
|-----------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|-----------------|------|------|---------------------|------|
| I <sub>(DD)</sub> Supply current                                                        | CAON = 1 CARSEL = 0 CAREF = 0                                                                    | 2.2 V           |      | 25   | 40                  | μA   |
|                                                                                         |                                                                                                  | 3 V             |      | 45   | 60                  |      |
| I <sub>(Refladder/Refdiode)</sub> Reference ladder supply current                       | CAON = 1, CARSEL = 0, CAREF 1, 2, or 3, No load at P2.3/CA0/TA1 and P2.4/CA1/TA2                 | 2.2 V           |      | 30   | 50                  | μA   |
|                                                                                         |                                                                                                  | 3 V             |      | 45   | 71                  |      |
| V <sub>(IC)</sub> Common-mode input voltage                                             | CAON = 1                                                                                         | 2.2 V, 3 V      | 0    |      | V <sub>CC</sub> – 1 | V    |
| V <sub>(Ref025)</sub> Ratio of (voltage at 0.25 V <sub>CC</sub> node) / V <sub>CC</sub> | PCA0 = 1, CARSEL = 1, CAREF = 1, No load at P2.3/CA0/TA1 and P2.4/CA1/TA2                        | 2.2 V, 3 V      | 0.23 | 0.24 | 0.25                |      |
| V <sub>(Ref050)</sub> Ratio of (voltage at 0.5 V <sub>CC</sub> node) / V <sub>CC</sub>  | PCA0 = 1, CARSEL = 1, CAREF = 2, No load at P2.3/CA0/TA1 and P2.4/CA1/TA2                        | 2.2 V, 3 V      | 0.47 | 0.48 | 0.5                 |      |
| V <sub>(RefVT)</sub> Reference voltage (see Figure 5-6 and Figure 5-7)                  | PCA0 = 1, CARSEL = 1, CAREF = 3, No load at P2.3/CA0/TA1 and P2.4/CA1/TA2, T <sub>A</sub> = 85°C | 2.2 V           | 390  | 480  | 540                 | mV   |
|                                                                                         |                                                                                                  | 3 V             | 400  | 490  | 550                 |      |
| V <sub>(offset)</sub> Offset voltage <sup>(2)</sup>                                     |                                                                                                  | 2.2 V, 3 V      | –30  |      | 30                  | mV   |
| V <sub>hys</sub> Input hysteresis                                                       | CAON = 1                                                                                         | 2.2 V, 3 V      | 0    | 0.7  | 1.4                 | mV   |
| t <sub>(response LH)</sub> Low-to-high response time                                    | T <sub>A</sub> = 25°C, Overdrive = 10 mV, Without filter: CAF = 0                                | 2.2 V           | 130  | 210  | 300                 | ns   |
|                                                                                         |                                                                                                  | 3 V             | 80   | 150  | 240                 |      |
|                                                                                         | T <sub>A</sub> = 25°C, Overdrive = 10 mV, Without filter: CAF = 1                                | 2.2 V           | 1.4  | 1.9  | 3.4                 | μs   |
|                                                                                         |                                                                                                  | 3 V             | 0.9  | 1.5  | 2.6                 |      |
| t <sub>(response HL)</sub> High-to-low response time                                    | T <sub>A</sub> = 25°C, Overdrive = 10 mV, Without filter: CAF = 0                                | 2.2 V           | 130  | 210  | 300                 | ns   |
|                                                                                         |                                                                                                  | 3 V             | 80   | 150  | 240                 |      |
|                                                                                         | T <sub>A</sub> = 25°C, Overdrive = 10 mV, Without filter: CAF = 1                                | 2.2 V           | 1.4  | 1.9  | 3.4                 | μs   |
|                                                                                         |                                                                                                  | 3 V             | 0.9  | 1.5  | 2.6                 |      |

- (1) The leakage current for the Comparator\_A terminals is identical to the I<sub>(kgPx.x)</sub> specification.

- (2) The input offset voltage can be cancelled by using the CAEX bit to invert the Comparator\_A inputs on successive measurements. The two successive measurements are then summed together.

## 5.16 Typical Characteristics – Comparator\_A



## 5.17 PUC and POR

| PARAMETER                                                                                        | TEST CONDITIONS                  | V <sub>CC</sub> | MIN | TYP | MAX | UNIT |
|--------------------------------------------------------------------------------------------------|----------------------------------|-----------------|-----|-----|-----|------|
| t <sub>(POR_Delay)</sub> Internal time delay to release POR                                      |                                  |                 |     | 150 | 250 | μs   |
| V <sub>POR</sub> V <sub>CC</sub> threshold at which POR release delay time begins <sup>(1)</sup> | T <sub>A</sub> = -40°C           | 2.2 V, 3 V      | 1.4 |     | 1.8 | V    |
|                                                                                                  | T <sub>A</sub> = 25°C            |                 | 1.1 |     | 1.5 |      |
|                                                                                                  | T <sub>A</sub> = 85°C            |                 | 0.8 |     | 1.2 |      |
| V <sub>(min)</sub> V <sub>CC</sub> threshold required to generate a POR <sup>(2)</sup>           | V <sub>CC</sub>  dV/dt  ≥ 1 V/ms | 2.2 V, 3 V      | 0.2 |     |     | V    |
| t <sub>(reset)</sub> RST/NMI low time for PUC or POR                                             | Reset is accepted internally     | 2.2 V, 3 V      | 2   |     |     | μs   |

(1) V<sub>CC</sub> rise time dV/dt ≥ 1 V/ms

(2) When driving V<sub>CC</sub> low to generate a POR condition, drive V<sub>CC</sub> to 200 mV or lower with a dV/dt equal to or less than -1 V/ms. The corresponding rising V<sub>CC</sub> must also meet the dV/dt requirement equal to or greater than +1 V/ms.

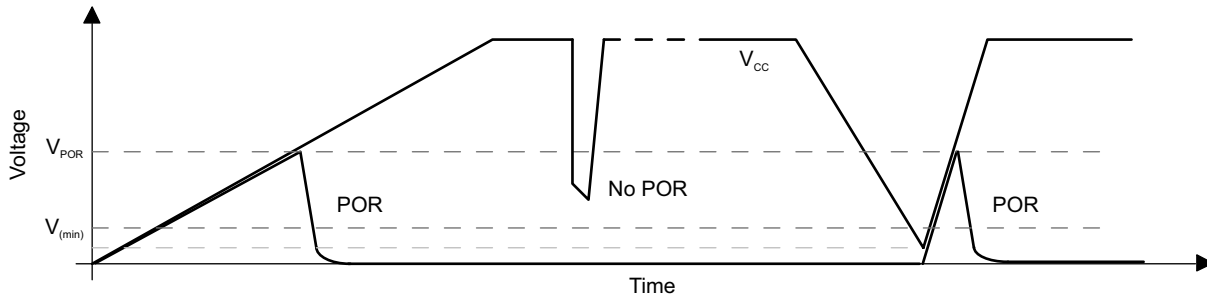


Figure 5-10. V<sub>POR</sub> vs Supply Voltage

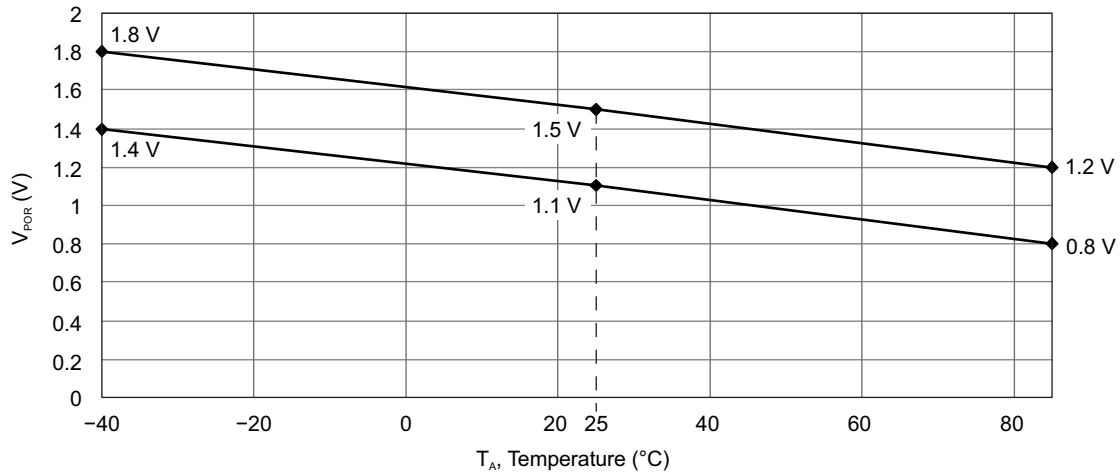


Figure 5-11. V<sub>POR</sub> vs Temperature

## 5.18 DCO Frequency<sup>(1)</sup>

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

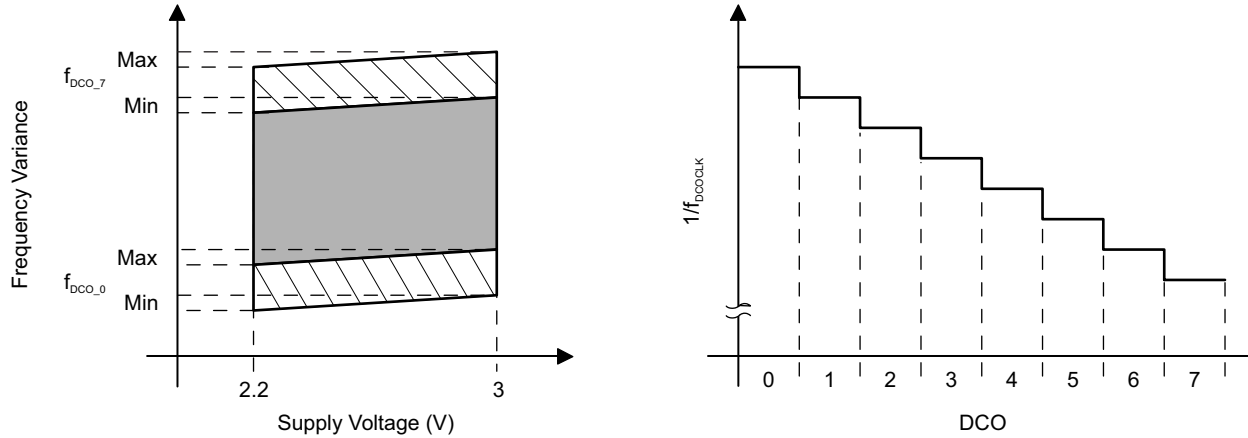
| PARAMETER            | TEST CONDITIONS                                                                  | V <sub>CC</sub> | MIN                         | TYP                         | MAX                         | UNIT |
|----------------------|----------------------------------------------------------------------------------|-----------------|-----------------------------|-----------------------------|-----------------------------|------|
| f <sub>DCO(03)</sub> | Rsel = 0, DCO = 3, MOD = 0, DCOR = 0, T <sub>A</sub> = 25°C                      | 2.2 V, 3 V      | 0.08                        | 0.12                        | 0.15                        | MHz  |
|                      |                                                                                  |                 | 0.08                        | 0.13                        | 0.16                        |      |
| f <sub>DCO(13)</sub> | Rsel = 1, DCO = 3, MOD = 0, DCOR = 0, T <sub>A</sub> = 25°C                      | 2.2 V, 3 V      | 0.14                        | 0.19                        | 0.23                        | MHz  |
|                      |                                                                                  |                 | 0.14                        | 0.18                        | 0.22                        |      |
| f <sub>DCO(23)</sub> | Rsel = 2, DCO = 3, MOD = 0, DCOR = 0, T <sub>A</sub> = 25°C                      | 2.2 V, 3 V      | 0.22                        | 0.30                        | 0.36                        | MHz  |
|                      |                                                                                  |                 | 0.22                        | 0.28                        | 0.34                        |      |
| f <sub>DCO(33)</sub> | Rsel = 3, DCO = 3, MOD = 0, DCOR = 0, T <sub>A</sub> = 25°C                      | 2.2 V, 3 V      | 0.37                        | 0.49                        | 0.59                        | MHz  |
|                      |                                                                                  |                 | 0.37                        | 0.47                        | 0.56                        |      |
| f <sub>DCO(43)</sub> | Rsel = 4, DCO = 3, MOD = 0, DCOR = 0, T <sub>A</sub> = 25°C                      | 2.2 V, 3 V      | 0.61                        | 0.77                        | 0.93                        | MHz  |
|                      |                                                                                  |                 | 0.61                        | 0.75                        | 0.90                        |      |
| f <sub>DCO(53)</sub> | Rsel = 5, DCO = 3, MOD = 0, DCOR = 0, T <sub>A</sub> = 25°C                      | 2.2 V, 3 V      | 1                           | 1.2                         | 1.5                         | MHz  |
|                      |                                                                                  |                 | 1                           | 1.3                         | 1.5                         |      |
| f <sub>DCO(63)</sub> | Rsel = 6, DCO = 3, MOD = 0, DCOR = 0, T <sub>A</sub> = 25°C                      | 2.2 V, 3 V      | 1.6                         | 1.9                         | 2.2                         | MHz  |
|                      |                                                                                  |                 | 1.69                        | 2.0                         | 2.29                        |      |
| f <sub>DCO(73)</sub> | Rsel = 7, DCO = 3, MOD = 0, DCOR = 0, T <sub>A</sub> = 25°C                      | 2.2 V, 3 V      | 2.4                         | 2.9                         | 3.4                         | MHz  |
|                      |                                                                                  |                 | 2.7                         | 3.2                         | 3.65                        |      |
| f <sub>DCO(47)</sub> | Rsel = 4, DCO = 7, MOD = 0, DCOR = 0, T <sub>A</sub> = 25°C                      | 2.2 V, 3 V      | f <sub>DCO40</sub><br>× 1.7 | f <sub>DCO40</sub><br>× 2.1 | f <sub>DCO40</sub><br>× 2.5 | MHz  |
| f <sub>DCO(77)</sub> | Rsel = 7, DCO = 7, MOD = 0, DCOR = 0, T <sub>A</sub> = 25°C                      | 2.2 V, 3 V      | 4                           | 4.5                         | 4.9                         | MHz  |
|                      |                                                                                  |                 | 4.4                         | 4.9                         | 5.4                         |      |
| S <sub>Rsel</sub>    | S <sub>Rsel</sub> = f <sub>Rsel+1</sub> / f <sub>Rsel</sub>                      | 2.2 V, 3 V      | 1.35                        | 1.65                        | 2                           |      |
| S <sub>DCO</sub>     | S <sub>DCO</sub> = f <sub>DCO+1</sub> / f <sub>DCO</sub>                         | 2.2 V, 3 V      | 1.07                        | 1.12                        | 1.16                        |      |
| D <sub>t</sub>       | Temperature drift <sup>(2)</sup> , Rsel = 4, DCO = 3, MOD = 0                    | 2.2 V, 3 V      | –0.31                       | –0.36                       | –0.40                       | %/°C |
|                      |                                                                                  |                 | –0.33                       | –0.38                       | –0.43                       |      |
| D <sub>V</sub>       | Drift with V <sub>CC</sub> variation <sup>(2)</sup> , Rsel = 4, DCO = 3, MOD = 0 | 2.2 V, 3 V      | 0                           | 5                           | 10                          | %/V  |

(1) The DCO frequency may not exceed the maximum system frequency defined by the processor frequency parameter, f<sub>SYSTEM</sub>.

(2) This parameter is not production tested.

### DCO Characteristics (see Figure 5-12)

- Individual devices have a minimum and maximum operation frequency. The specified parameters for  $f_{\text{DCO}(x0)}$  to  $f_{\text{DCO}(x7)}$  are valid for all devices.
- All ranges selected by  $\text{Rsel}(n)$  overlap with  $\text{Rsel}(n+1)$ ; for example,  $\text{Rsel}0$  overlaps with  $\text{Rsel}1$ , and  $\text{Rsel}6$  overlaps with  $\text{Rsel}7$ .
- DCO control bits  $\text{DCO}0$ ,  $\text{DCO}1$ , and  $\text{DCO}2$  have a step size as defined by parameter  $S_{\text{DCO}}$ .
- Modulation control bits  $\text{MOD}0$  to  $\text{MOD}4$  select how often  $f_{\text{DCO}+1}$  is used within the period of 32  $\text{DCOCLK}$  cycles. The frequency  $f_{(\text{DCO})}$  is used for the remaining cycles. The frequency is an average equal to  $f_{(\text{DCO})} \times 2^{\text{MOD}/32}$ .



**Figure 5-12. DCO Characteristics**

### 5.19 DCO When Using $R_{\text{osc}}$

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

| PARAMETER        |                                      | TEST CONDITIONS                                             | V <sub>CC</sub> | MIN       | TYP | MAX | UNIT |
|------------------|--------------------------------------|-------------------------------------------------------------|-----------------|-----------|-----|-----|------|
| f <sub>DCO</sub> | DCO output frequency                 | Rsel = 4, DCO = 3, MOD = 0, DCOR = 1, T <sub>A</sub> = 25°C | 2.2 V           | 1.8 ±15%  |     |     | MHz  |
|                  |                                      |                                                             | 3 V             | 1.95 ±15% |     |     |      |
| D <sub>t</sub>   | Temperature drift                    | Rsel = 4, DCO = 3, MOD = 0, DCOR = 1                        | 2.2 V, 3 V      | ±0.1      |     |     | %/°C |
| D <sub>v</sub>   | Drift with V <sub>CC</sub> variation | Rsel = 4, DCO = 3, MOD = 0, DCOR = 1                        | 2.2 V, 3 V      | 10        |     |     | %/°V |

(1)  $R_{\text{OSC}} = 100 \text{ k}\Omega$ , metal film resistor, type 0257, 0.6 W, 1% tolerance,  $T_K = \pm 50 \text{ ppm}/^\circ\text{C}$

## 5.20 Crystal Oscillator, LFXT1

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

| PARAMETER         |                                                | TEST CONDITIONS                  | V <sub>CC</sub> | MIN                   | TYP                   | MAX             | UNIT |
|-------------------|------------------------------------------------|----------------------------------|-----------------|-----------------------|-----------------------|-----------------|------|
| C <sub>XIN</sub>  | Integrated input capacitance                   | XTS = 0, LF oscillator selected  | 2.2 V, 3 V      | 12                    |                       |                 | pF   |
|                   |                                                | XTS = 1, XT1 oscillator selected |                 | 2                     |                       |                 |      |
| C <sub>XOUT</sub> | Integrated output capacitance                  | XTS = 0, LF oscillator selected  | 2.2 V, 3 V      | 12                    |                       |                 | pF   |
|                   |                                                | XTS = 1, XT1 oscillator selected |                 | 2                     |                       |                 |      |
| V <sub>IL</sub>   | Low-level input voltage at XIN <sup>(2)</sup>  |                                  | 2.2 V, 3 V      | V <sub>SS</sub>       | 0.2 × V <sub>CC</sub> |                 | V    |
| V <sub>IH</sub>   | High-level input voltage at XIN <sup>(2)</sup> |                                  | 2.2 V, 3 V      | 0.8 × V <sub>CC</sub> |                       | V <sub>CC</sub> | V    |

(1) The oscillator needs capacitors at both terminals, with values specified by the crystal manufacturer.

(2) Applies only when using an external logic-level clock source. Not applicable when using a crystal or resonator.

## 5.21 Crystal Oscillator, XT2

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

| PARAMETER                                                        | V <sub>CC</sub> | MIN                   | TYP                   | MAX             | UNIT |
|------------------------------------------------------------------|-----------------|-----------------------|-----------------------|-----------------|------|
| C <sub>XT2IN</sub> Input capacitance                             | 2.2 V, 3 V      | 2                     |                       |                 | pF   |
| C <sub>XT2OUT</sub> Output capacitance                           | 2.2 V, 3 V      | 2                     |                       |                 | pF   |
| V <sub>IL</sub> Low-level input voltage at XT2IN <sup>(2)</sup>  | 2.2 V, 3 V      | V <sub>SS</sub>       | 0.2 × V <sub>CC</sub> |                 | V    |
| V <sub>IH</sub> High-level input voltage at XT2IN <sup>(2)</sup> | 2.2 V, 3 V      | 0.8 × V <sub>CC</sub> |                       | V <sub>CC</sub> | V    |

(1) The oscillator needs capacitors at both terminals, with values specified by the crystal manufacturer.

(2) Applies only when using an external logic-level clock source. Not applicable when using a crystal or resonator.

## 5.22 USART0, USART1

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

| PARAMETER                                                      | V <sub>CC</sub> | MIN | TYP | MAX | UNIT |
|----------------------------------------------------------------|-----------------|-----|-----|-----|------|
| t <sub>(τ)</sub> USART0 or USART1 deglitch time <sup>(1)</sup> | 2.2 V           | 200 | 430 | 800 | ns   |
|                                                                | 3 V             | 150 | 280 | 500 |      |

(1) The signal applied to the USART0 USART1 receive terminal (URXD0 or URXD1) must meet the timing requirements of t<sub>(τ)</sub> to ensure that the URXS flip-flop is set. The URXS flip-flop is set with negative pulses meeting the minimum timing condition of t<sub>(τ)</sub>. The operating conditions to set the flag must be met independently from this timing constraint. The deglitch circuitry is active only on negative transitions on the URXD0 or URXD1 line.

## 5.23 12-Bit ADC, Power Supply and Input Range Conditions

over recommended operating supply voltage and 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    |                 | 2.2 |      | 3.6               | V    |
| V <sub>(P6.x/Ax)</sub> Analog input voltage <sup>(2)</sup>                                    | All P6.0/A0 to P6.7/A7 terminals, analog inputs selected in ADC12MCTLx register and P6Sel.x = 1, 0 ≤ x ≤ 7, V <sub>(AVSS)</sub> ≤ V <sub>(P6.x/Ax)</sub> ≤ V <sub>(AVCC)</sub> |                 | 0   |      | V <sub>AVCC</sub> | V    |
| I <sub>ADC12</sub> ADC operating supply current into AV <sub>CC</sub> terminal <sup>(3)</sup> | f <sub>ADC12CLK</sub> = 5.0 MHz, ADC12ON = 1, REFON = 0, SHT0 = 0, SHT1 = 0, ADC12DIV = 0                                                                                      | 2.2 V           |     | 0.65 | 1.3               | mA   |
|                                                                                               |                                                                                                                                                                                | 3 V             |     | 0.8  | 1.6               |      |
| I <sub>REF+</sub> REF operating supply current into AV <sub>CC</sub> terminal <sup>(4)</sup>  | f <sub>ADC12CLK</sub> = 5.0 MHz, ADC12ON = 0, REFON = 1, REF2_5V = 1                                                                                                           | 3 V             |     | 0.5  | 0.8               | mA   |
|                                                                                               | f <sub>ADC12CLK</sub> = 5.0 MHz, ADC12ON = 0, REFON = 1, REF2_5V = 0                                                                                                           | 2.2 V           |     | 0.5  | 0.8               |      |
|                                                                                               |                                                                                                                                                                                | 3 V             |     | 0.5  | 0.8               |      |
| C <sub>I</sub> Input capacitance <sup>(5)</sup>                                               | Only one P6.x/Ax terminal can be selected at one time                                                                                                                          | 2.2 V           |     |      | 40                | pF   |
| R <sub>I</sub> Input MUX ON resistance <sup>(5)</sup>                                         | 0 V ≤ V <sub>Ax</sub> ≤ V <sub>AVCC</sub>                                                                                                                                      | 3 V             |     |      | 2000              | Ω    |

(1) The leakage current is defined in the leakage current table.

(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.

(3) The internal reference supply current is not included in current consumption parameter I<sub>ADC12</sub>.

(4) The internal reference current is supplied through the AV<sub>CC</sub> terminal. Consumption is independent of the ADC12ON control bit, unless a conversion is active. The REFON bit enables to settle the built-in reference before starting a conversion.

(5) Not production tested, limits verified by design.

## 5.24 12-Bit ADC, External Reference

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

| PARAMETER                                                                                     | TEST CONDITIONS                                                | V <sub>CC</sub> | MIN | MAX               | UNIT |
|-----------------------------------------------------------------------------------------------|----------------------------------------------------------------|-----------------|-----|-------------------|------|
| V <sub>VeREF+</sub> Positive external reference input voltage                                 | V <sub>VeREF+</sub> > V <sub>VREF-/VeREF-</sub> <sup>(2)</sup> |                 | 1.4 | V <sub>AVCC</sub> | V    |
| V <sub>VREF-/VeREF-</sub> Negative external reference input voltage                           | V <sub>VeREF+</sub> > V <sub>VREF-/VeREF-</sub> <sup>(3)</sup> |                 | 0   | 1.2               | V    |
| V <sub>VeREF+</sub> – V <sub>VREF-/VeREF-</sub> Differential external reference input voltage | V <sub>VeREF+</sub> > V <sub>VREF-/VeREF-</sub> <sup>(4)</sup> |                 | 1.4 | V <sub>AVCC</sub> | V    |
| I <sub>VeREF+</sub> Static input current, VeREF+                                              | 0 V ≤ V <sub>VeREF+</sub> ≤ V <sub>AVCC</sub>                  | 2.2 V, 3 V      |     | ±1                | μA   |
| I <sub>VREF-/VeREF-</sub> Static input current, VeREF–                                        | 0 V ≤ V <sub>VREF–</sub> ≤ V <sub>AVCC</sub>                   | 2.2 V, 3 V      |     | ±1                | μA   |

(1) The external reference is used during 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 12-bit accuracy.

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

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

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

## 5.25 12-Bit ADC, Built-In Reference

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

| PARAMETER              | TEST CONDITIONS                                                                       | V <sub>CC</sub> | MIN                      | TYP | MAX  | UNIT   |
|------------------------|---------------------------------------------------------------------------------------|-----------------|--------------------------|-----|------|--------|
| V <sub>REF+</sub>      | REF2_5V = 1 for 2.5 V,<br>I <sub>VREF+</sub> ≤ I <sub>VREF+</sub> (max)               | 3 V             | 2.4                      | 2.5 | 2.6  | V      |
|                        | REF2_5V = 0 for 1.5 V,<br>I <sub>VREF+</sub> ≤ I <sub>VREF+</sub> (max)               | 2.2 V, 3 V      | 1.44                     | 1.5 | 1.56 |        |
| AV <sub>CC(min)</sub>  | REF2_5V = 0, I <sub>VREF+</sub> ≤ 1 mA                                                |                 | 2.2                      |     |      | V      |
|                        | REF2_5V = 1, I <sub>VREF+</sub> ≤ 0.5 mA                                              |                 | V <sub>REF+</sub> + 0.15 |     |      |        |
|                        | REF2_5V = 1, I <sub>VREF+</sub> ≤ 1 mA                                                |                 | V <sub>REF+</sub> + 0.15 |     |      |        |
| I <sub>VREF+</sub>     | Load current out of V <sub>REF+</sub> terminal                                        | 2.2 V           | 0.01                     |     | –0.5 | mA     |
|                        |                                                                                       | 3 V             |                          |     | –1   |        |
| I <sub>L(VREF)+</sub>  | Load-current regulation, V <sub>REF+</sub> terminal <sup>(1)</sup>                    | 2.2 V           |                          |     | ±2   | LSB    |
|                        |                                                                                       | 3 V             |                          |     | ±2   |        |
|                        | I <sub>VREF+</sub> = 500 µA ±100 µA,<br>Analog input voltage ≈ 0.75 V,<br>REF2_5V = 0 | 3 V             |                          |     | ±2   | LSB    |
| I <sub>DL(VREF)+</sub> | Load-current regulation,<br>V <sub>REF+</sub> terminal <sup>(2)</sup>                 | 3 V             |                          |     | 20   | ns     |
| C <sub>VREF+</sub>     | Capacitance at V <sub>REF+</sub> terminal <sup>(3)</sup>                              | 2.2 V, 3 V      | 5                        | 10  |      | µF     |
| T <sub>REF+</sub>      | Temperature coefficient of<br>built-in reference <sup>(1)</sup>                       | 2.2 V, 3 V      |                          |     | ±100 | ppm/°C |
| t <sub>REFON</sub>     | Settling time of reference<br>voltage <sup>(4)(1)</sup> (see Figure 5-13)             |                 |                          |     | 17   | ms     |

(1) Not production tested, limits characterized

(2) Not production tested, limits verified by design

(3) The internal buffer operational amplifier and the accuracy specifications require an external capacitor. All INL and DNL tests uses two capacitors between pins V<sub>REF+</sub> and AV<sub>SS</sub> and V<sub>REF–</sub>/V<sub>REF–</sub> and AV<sub>SS</sub>: 10-µF tantalum and 100-nF ceramic.

(4) The condition is that the error in a conversion started after t<sub>REFON</sub> is less than ±0.5 LSB. The settling time depends on the external capacitive load.

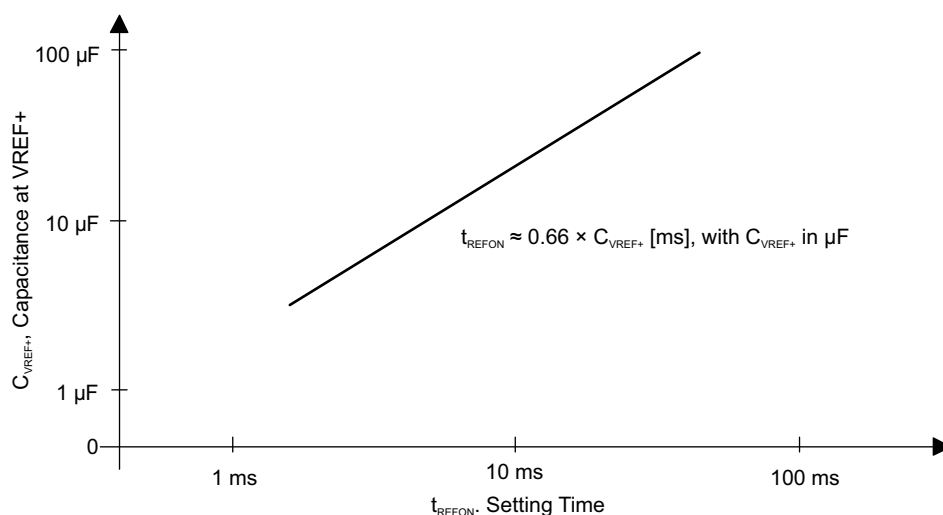
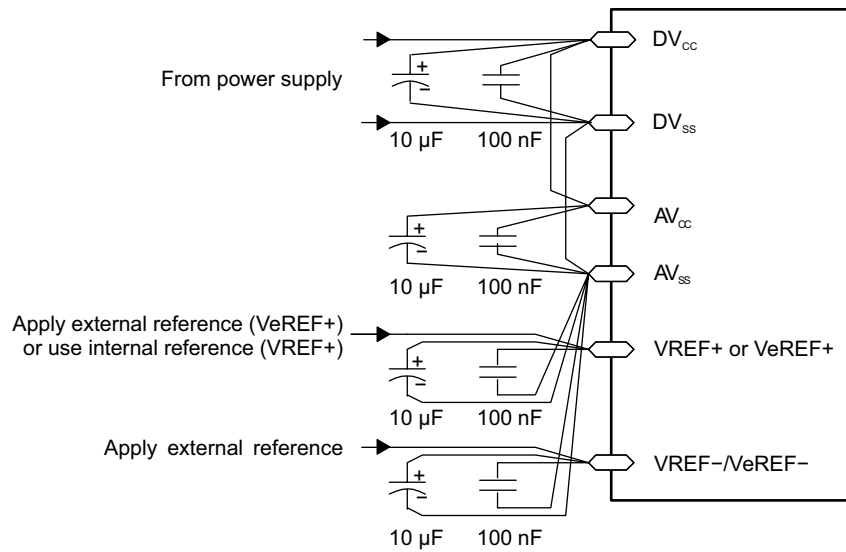
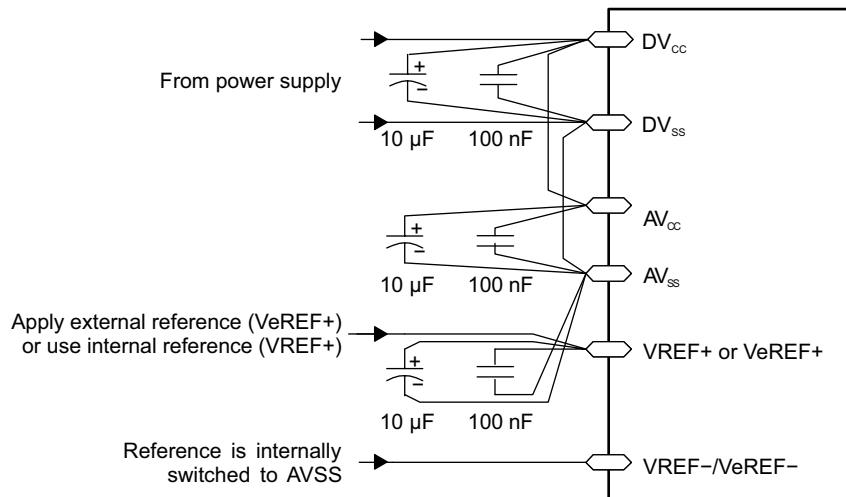


Figure 5-13. Typical Settling Time of Internal Reference (t<sub>REFON</sub>) vs External Capacitor on V<sub>REF+</sub>



**Figure 5-14. Supply Voltage and Reference Voltage Design,  $V_{REF-}/V_{eREF-}$  External Supply**



**Figure 5-15. Supply Voltage and Reference Voltage Design,  $V_{REF-}/V_{eREF-} = AVSS$ , Internally Connected**

## 5.26 12-Bit ADC, Timing Parameters

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

| PARAMETER                                                            | TEST CONDITIONS                                                                                                                                 | V <sub>CC</sub> | MIN  | TYP                             | MAX  | UNIT |
|----------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|------|---------------------------------|------|------|
| f <sub>ADC12CLK</sub> ADC clock frequency                            | For specified performance of ADC12 linearity parameters                                                                                         | 2.2 V, 3 V      | 0.45 | 5                               | 6.3  | MHz  |
| f <sub>ADC12OSC</sub> Internal ADC12 oscillator                      | ADC12DIV = 0, f <sub>ADC12CLK</sub> = f <sub>ADC12OSC</sub>                                                                                     | 2.2 V, 3 V      | 3.7  |                                 | 6.3  | MHz  |
| t <sub>CONVERT</sub> Conversion time                                 | C <sub>VREF+</sub> ≥ 5 μF, internal oscillator, f <sub>ADC12OSC</sub> = 3.7 MHz to 6.3 MHz                                                      | 2.2 V, 3 V      | 2.06 |                                 | 3.51 | μs   |
|                                                                      | External f <sub>ADC12CLK</sub> from ACLK, MCLK or SMCLK, ADC12SSEL ≠ 0                                                                          |                 |      | 13 ×<br>1/f <sub>ADC12CLK</sub> |      |      |
| t <sub>ADC12ON</sub> Turn-on settling time of the ADC <sup>(1)</sup> | See <sup>(2)</sup>                                                                                                                              |                 |      |                                 | 100  | ns   |
| t <sub>Sample</sub> Sampling time <sup>(1)</sup>                     | R <sub>S</sub> = 400 Ω, R <sub>I</sub> = 1000 Ω, C <sub>I</sub> = 30 pF, τ = [R <sub>S</sub> + R <sub>I</sub> ] × C <sub>I</sub> <sup>(3)</sup> | 3 V             | 1220 |                                 |      | ns   |
|                                                                      |                                                                                                                                                 | 2.2 V           | 1400 |                                 |      |      |

(1) Not production tested, limits verified by design

(2) The condition is that the error in a conversion started after t<sub>ADC12ON</sub> is less than ±0.5 LSB. The reference and input signal are already settled.

(3) Approximately 10 Tau (τ) are needed to get an error of less than ±0.5 LSB:

t<sub>Sample</sub> = ln(2<sup>n+1</sup>) × (R<sub>S</sub> + R<sub>I</sub>) × C<sub>I</sub> + 800 ns, where n = ADC resolution = 12, R<sub>S</sub> = external source resistance

## 5.27 12-Bit ADC, Linearity Parameters

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

| PARAMETER                                   | TEST CONDITIONS                                                                                                                                                                                                                         | V <sub>CC</sub> | MIN | TYP  | MAX  | UNIT |
|---------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|-----|------|------|------|
| E <sub>I</sub> Integral linearity error     | 1.4 V ≤ (V <sub>VeREF+</sub> – V <sub>VREF-/VeREF-</sub> ) <sub>min</sub> ≤ 1.6 V                                                                                                                                                       | 2.2 V, 3 V      |     |      | ±2   | LSB  |
|                                             | 1.6 V < (V <sub>VeREF+</sub> – V <sub>VREF-/VeREF-</sub> ) <sub>min</sub> ≤ V <sub>AVCC</sub>                                                                                                                                           |                 |     |      | ±1.7 |      |
| E <sub>D</sub> Differential linearity error | (V <sub>VeREF+</sub> – V <sub>VREF-/VeREF-</sub> ) <sub>min</sub> ≤ (V <sub>VeREF+</sub> – V <sub>VREF-/VeREF-</sub> ), C <sub>VREF+</sub> = 10 μF (tantalum) and 100 nF (ceramic)                                                      | 2.2 V, 3 V      |     |      | ±1   | LSB  |
| E <sub>O</sub> Offset error                 | (V <sub>VeREF+</sub> – V <sub>VREF-/VeREF-</sub> ) <sub>min</sub> ≤ (V <sub>VeREF+</sub> – V <sub>VREF-/VeREF-</sub> ), Internal impedance of source R <sub>S</sub> < 100 Ω, C <sub>VREF+</sub> = 10 μF (tantalum) and 100 nF (ceramic) | 2.2 V, 3 V      |     | ±2   | ±4   | LSB  |
| E <sub>G</sub> Gain error                   | (V <sub>VeREF+</sub> – V <sub>VREF-/VeREF-</sub> ) <sub>min</sub> ≤ (V <sub>VeREF+</sub> – V <sub>VREF-/VeREF-</sub> ), C <sub>VREF+</sub> = 10 μF (tantalum) and 100 nF (ceramic)                                                      | 2.2 V, 3 V      |     | ±1.1 | ±2   | LSB  |
| E <sub>T</sub> Total unadjusted error       | (V <sub>VeREF+</sub> – V <sub>VREF-/VeREF-</sub> ) <sub>min</sub> ≤ (V <sub>VeREF+</sub> – V <sub>VREF-/VeREF-</sub> ), C <sub>VREF+</sub> = 10 μF (tantalum) and 100 nF (ceramic)                                                      | 2.2 V, 3 V      |     | ±2   | ±5   | LSB  |

## 5.28 12-Bit ADC, Temperature Sensor and Built-In $V_{MID}$

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

| PARAMETER                                                                             | TEST CONDITIONS                                                  | $V_{CC}$ | MIN  | TYP  | MAX                | UNIT           |
|---------------------------------------------------------------------------------------|------------------------------------------------------------------|----------|------|------|--------------------|----------------|
| $I_{SENSOR}$ Operating supply current into $AV_{CC}$ terminal <sup>(1)</sup>          | REFON = 0, INCH = 0Ah, ADC12ON = N/A, $T_A = 25^\circ C$         | 2.2 V    |      | 40   | 120                | $\mu A$        |
|                                                                                       |                                                                  | 3 V      |      | 60   | 160                |                |
| $V_{SENSOR}$ Sensor output voltage <sup>(2)</sup>                                     | ADC12ON = 1, INCH = 0Ah, $T_A = 0^\circ C$                       | 2.2 V    |      | 986  | 986 $\pm 5\%$      | mV             |
|                                                                                       |                                                                  | 3 V      |      | 986  | 986 $\pm 5\%$      |                |
| $TC_{SENSOR}$ Temperature coefficient of sensor output voltage <sup>(2)</sup>         | ADC12ON = 1, INCH = 0Ah                                          | 2.2 V    |      | 3.55 | 3.55 $\pm 3\%$     | mV/ $^\circ C$ |
|                                                                                       |                                                                  | 3 V      |      | 3.55 | 3.55 $\pm 3\%$     |                |
| $t_{SENSOR(sample)}$ Sample time required if channel 10 is selected <sup>(2)(3)</sup> | ADC12ON = 1, INCH = 0Ah, Error of conversion result $\leq 1$ LSB | 2.2 V    | 30   |      |                    | $\mu s$        |
|                                                                                       |                                                                  | 3 V      | 30   |      |                    |                |
| $I_{VMID}$ Current into divider at channel 11 <sup>(4)</sup>                          | ADC12ON = 1, INCH = 0Bh                                          | 2.2 V    |      |      | N/A <sup>(5)</sup> | $\mu A$        |
|                                                                                       |                                                                  | 3 V      |      |      | N/A                |                |
| $V_{MID}$ $AV_{CC}$ divider at channel 11                                             | ADC12ON = 1, INCH = 0Bh, $V_{MID} \approx 0.5 \times V_{AVCC}$   | 2.2 V    |      | 1.1  | 1.1 $\pm 0.04$     | V              |
|                                                                                       |                                                                  | 3 V      |      | 1.5  | 1.5 $\pm 0.04$     |                |
| $t_{VMID(sample)}$ Sample time required if channel 11 is selected <sup>(6)</sup>      | ADC12ON = 1, INCH = 0Bh, Error of conversion result $\leq 1$ LSB | 2.2 V    | 1400 |      |                    | ns             |
|                                                                                       |                                                                  | 3 V      | 1220 |      |                    |                |

(1) The sensor current  $I_{SENSOR}$  is consumed if (ADC12ON = 1 and REFON = 1), or (ADC12ON = 1 AND INCH = 0Ah and sample signal is high). Therefore, it includes the constant current through the sensor and the reference.

(2) Not production tested, limits characterized

(3) The typical equivalent impedance of the sensor is 51 k $\Omega$ . The sample time required includes the sensor on-time,  $t_{SENSOR(on)}$ .

(4) No additional current is needed. The  $V_{MID}$  is used during sampling.

(5) N/A = Not applicable

(6) The on-time  $t_{VMID(on)}$  is included in the sampling time  $t_{VMID(sample)}$ ; no additional on time is needed.

## 5.29 Flash Memory

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

| PARAMETER                                                                            | TEST CONDITIONS           | MIN    | TYP    | MAX | UNIT      |
|--------------------------------------------------------------------------------------|---------------------------|--------|--------|-----|-----------|
| $V_{CC(PGM/ERASE)}$ Program and erase supply voltage                                 |                           | 2.7    |        | 3.6 | V         |
| $f_{FTG}$ Flash timing generator frequency                                           |                           | 257    |        | 476 | kHz       |
| $I_{PGM}$ Supply current from $DV_{CC}$ during program                               | $V_{CC} = 2.7$ V or 3.6 V |        | 3      | 5   | mA        |
| $I_{ERASE}$ Supply current from $DV_{CC}$ during erase                               | $V_{CC} = 2.7$ V or 3.6 V |        | 3      | 7   | mA        |
| $t_{CPT}$ Cumulative program time <sup>(1)</sup>                                     | $V_{CC} = 2.7$ V or 3.6 V |        |        | 4   | ms        |
| $t_{CMERASE}$ Cumulative mass erase time <sup>(2)</sup>                              | $V_{CC} = 2.7$ V or 3.6 V | 200    |        |     | ms        |
| Program and erase endurance <sup>(3)</sup>                                           |                           | $10^4$ | $10^5$ |     | cycles    |
| $t_{Retention}$ Data retention duration <sup>(3)</sup>                               | $T_J = 25^\circ C$        | 100    |        |     | years     |
| $t_{Word}$ Word or byte program time <sup>(3)</sup>                                  |                           |        | 35     |     | $t_{FTG}$ |
| $t_{Block, 0}$ Block program time for first byte or word <sup>(3)</sup>              |                           |        | 30     |     | $t_{FTG}$ |
| $t_{Block, 1-63}$ Block program time for each additional byte or word <sup>(3)</sup> |                           |        | 21     |     | $t_{FTG}$ |
| $t_{Block, End}$ Block program end-sequence wait time <sup>(3)</sup>                 |                           |        | 6      |     | $t_{FTG}$ |
| $t_{Mass Erase}$ Mass erase time <sup>(3)</sup>                                      |                           |        | 5297   |     | $t_{FTG}$ |
| $t_{Seg Erase}$ Segment erase time <sup>(3)</sup>                                    |                           |        | 4819   |     | $t_{FTG}$ |

(1) The cumulative program time must not be exceeded when writing to a 64-byte flash block. This parameter applies to all programming methods: individual word or byte write and block write modes.

(2) The mass erase duration generated by the flash timing generator is at least 11.1 ms ( = 5297  $\times 1/f_{FTG}$ , maximum = 5297  $\times 1/476$  kHz). To achieve the required cumulative mass erase time the flash controller mass erase operation can be repeated until this time is met. A worst case minimum of 19 cycles are required.

(3) These values are hardwired into the flash controller state machine ( $t_{FTG} = 1/f_{FTG}$ ).

## 5.30 JTAG Interface

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

| PARAMETER             |                                                  | V <sub>CC</sub> | MIN | TYP | MAX | UNIT |
|-----------------------|--------------------------------------------------|-----------------|-----|-----|-----|------|
| f <sub>TCK</sub>      | TCK input frequency <sup>(1)</sup>               | 2.2 V           | 0   |     | 5   | MHz  |
|                       |                                                  | 3 V             | 0   |     | 10  |      |
| R <sub>internal</sub> | Internal pullup resistance on TMS, TCK, TDI/TCLK | 2.2 V, 3 V      | 25  | 60  | 90  | kΩ   |

(1) f<sub>TCK</sub> may be restricted to meet the timing requirements of the module selected.

## 5.31 JTAG Fuse <sup>(1)</sup>

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

| PARAMETER           |                                               | T <sub>A</sub> | MIN | MAX | UNIT |
|---------------------|-----------------------------------------------|----------------|-----|-----|------|
| V <sub>CC(FB)</sub> | Supply voltage during fuse blow               | 25°C           | 2.5 |     | V    |
| V <sub>FB</sub>     | Voltage level on TDI/TCLK for fuse blow       |                | 6   | 7   | V    |
| I <sub>FB</sub>     | Supply current into TDI/TCLK during fuse blow |                |     | 100 | mA   |
| t <sub>FB</sub>     | Time to blow fuse                             |                |     | 1   | ms   |

(1) After the fuse is blown, no further access to the MSP430 JTAG/Test and emulation features is possible. The JTAG block is switched to bypass mode.

## 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, and can be handled with all instructions.

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.

|                          |           |
|--------------------------|-----------|
| 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. CPU Registers**

## 6.2 Instruction set

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

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

| INSTRUCTION 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, unconditional or 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 MSP430F13x, MSP430F14x, and MSP430F14x1 MCUs support one active mode and five software-selectable low-power modes of operation. An interrupt event can wake up the MCU from any of the low-power modes, service the request, and restore back to the low-power mode on return from the interrupt program.

The following operating modes can be configured by software:

- Active mode (AM)
  - All clocks are active
- Low-power mode 0 (LPM0)
  - CPU is disabled
  - ACLK and SMCLK remain active
  - MCLK is disabled
- Low-power mode 1 (LPM1)
  - CPU is disabled
  - ACLK and SMCLK remain active
  - MCLK is disabled
  - DC generator of the DCO is disabled if DCO not used in active mode
- Low-power mode 2 (LPM2)
  - CPU is disabled
  - MCLK and SMCLK are disabled
  - DC generator of the DCO remains enabled
  - ACLK remains active
- Low-power mode 3 (LPM3)
  - CPU is disabled
  - MCLK and SMCLK are disabled
  - DC generator of the DCO is disabled
  - ACLK remains active
- Low-power mode 4 (LPM4)
  - CPU is disabled
  - ACLK is disabled
  - MCLK and SMCLK are disabled
  - DC generator of the DCO is disabled
  - Crystal oscillator is stopped

## 6.4 Interrupt Vector Addresses

The interrupt vectors and the power-up starting address are in the address range 0FFFFh to 0FFE0h. 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    |
|----------------------------------------------------------|-----------------------------------------------------------|------------------------------|--------------|-------------|
| Power up<br>External reset<br>Watchdog<br>Flash memory   | WDTIFG<br>KEYV <sup>(1)</sup>                             | Reset                        | 0FFFEh       | 15, highest |
| NMI<br>Oscillator fault<br>Flash memory access violation | NMIIFG<br>OFIFG<br>ACCVIFG <sup>(1)</sup>                 | (Non)maskable <sup>(2)</sup> | 0FFFCh       | 14          |
| Timer_B7 <sup>(3)</sup>                                  | TBCCR0 CCIFG <sup>(4)</sup>                               | Maskable                     | 0FFFAh       | 13          |
| Timer_B7 <sup>(3)</sup>                                  | TBCCR1 to 6 CCIFGs,<br>TBIFG <sup>(1)(4)</sup>            | Maskable                     | 0FFF8h       | 12          |
| Comparator_A                                             | CAIFG                                                     | Maskable                     | 0FFF9h       | 11          |
| Watchdog timer                                           | WDTIFG                                                    | Maskable                     | 0FFF4h       | 10          |
| USART0 receive                                           | URXIFG0                                                   | Maskable                     | 0FFF2h       | 9           |
| USART0 transmit                                          | UTXIFG0                                                   | Maskable                     | 0FFF0h       | 8           |
| ADC12 <sup>(5)</sup>                                     | ADC12IFG <sup>(1)(4)</sup>                                | Maskable                     | 0FFEEh       | 7           |
| Timer_A3                                                 | TACCR0 CCIFG <sup>(4)</sup>                               | Maskable                     | 0FFECCh      | 6           |
| Timer_A3                                                 | TACCR1 CCIFG,<br>TACCR2 CCIFG,<br>TAIFG <sup>(1)(4)</sup> | Maskable                     | 0FFEAh       | 5           |
| I/O port P1 (eight flags)                                | P1IFG.0 to P1IFG.7 <sup>(1)(4)</sup>                      | Maskable                     | 0FFE8h       | 4           |
| USART1 receive                                           | URXIFG1                                                   | Maskable                     | 0FFE6h       | 3           |
| USART1 transmit                                          | UTXIFG1                                                   | Maskable                     | 0FFE4h       | 2           |
| I/O port P2 (eight flags)                                | P2IFG.0 to P2IFG.7 <sup>(1)(4)</sup>                      | Maskable                     | 0FFE2h       | 1           |
| –                                                        | –                                                         | –                            | 0FFE0h       | 0, lowest   |

(1) Multiple source flags

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

(3) Timer\_B7 in the MSP430F14x(1) MCUs has 7 CCRs, and Timer\_B3 in the MSP430F13x MCUs has 3 CCRs. In Timer\_B3, there are only interrupt flags TBCCR0, TBCCR1, and TBCCR2 CCIFGs and the interrupt-enable bits TBCCTL0, TBCCTL1, and TBCCTL2 CCIEs.

(4) Interrupt flags are located in the module.

(5) ADC12 is not implemented on the MSP430F14x1 devices.

## 6.5 Bootloader (BSL)

The MSP430 BSL lets users program the flash memory or RAM using a UART serial interface. Access to the MSP430 memory through the BSL is protected by a user-defined password. For complete description of the features of the BSL and its implementation, see the [MSP430™ Flash Device Bootloader \(BSL\) User's Guide](#). Table 6-4 lists the pin requirements for the BSL.

**Table 6-4. BSL Pin Requirements and Functions**

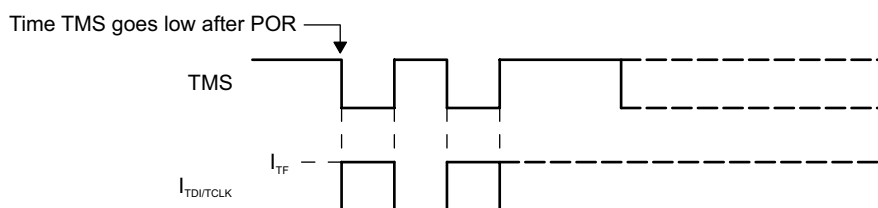
| BSL FUNCTION  | PM, PAG, AND RTD PACKAGE PINS |
|---------------|-------------------------------|
| Data transmit | 13 - P1.1                     |
| Data receive  | 22 - P2.2                     |

## 6.6 JTAG Fuse Check Mode

MSP430 MCUs that have the fuse on the TDI/TCLK terminal have a fuse check mode that tests the continuity of the fuse the first time the JTAG port is accessed after a power-on reset (POR). When activated, a fuse check current ( $I_{TF}$ ) of 1 mA at 3 V or 2.5 mA at 5 V can flow from the TDI/TCLK pin to ground if the fuse is not burned. Care must be taken to avoid accidentally activating the fuse check mode and increasing overall system power consumption.

Activation of the fuse check mode occurs with the first negative edge on the TMS pin after power up or if the TMS is being held low during power up. The second positive edge on the TMS pin deactivates the fuse check mode. After deactivation, the fuse check mode remains inactive until another POR occurs. After each POR the fuse check mode has the potential to be activated.

The fuse check current flows only when the fuse check mode is active and the TMS pin is in a low state (see Figure 6-2). Therefore, the additional current flow can be prevented by holding the TMS pin high (default condition).



**Figure 6-2. Fuse Check Mode Current**

## 6.7 Memory

Table 6-5 summarizes the memory map of all device variants.

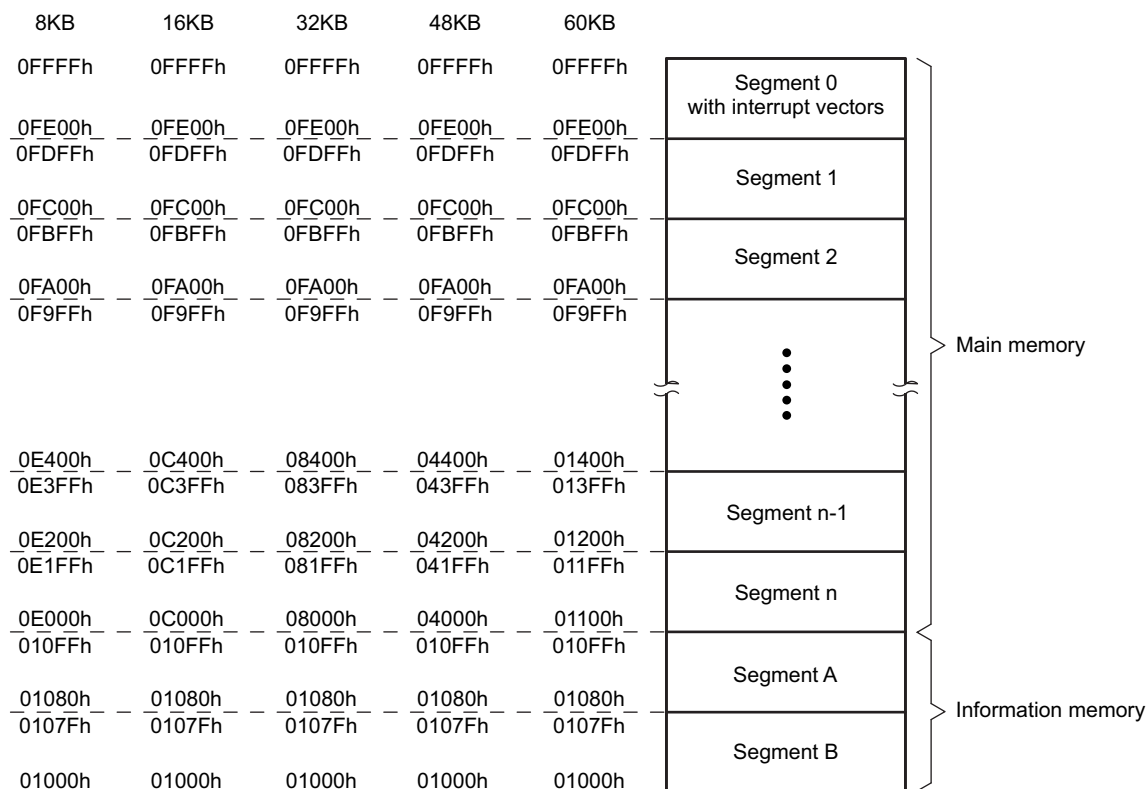
**Table 6-5. Memory Organization**

|                        |           | MSP430F133       | MSP430F135       | MSP430F147<br>MSP430F1471 | MSP430F148<br>MSP430F1481 | MSP430F149<br>MSP430F149 |
|------------------------|-----------|------------------|------------------|---------------------------|---------------------------|--------------------------|
| Memory (flash)         | Size      | 8KB              | 16KB             | 32KB                      | 48KB                      | 60KB                     |
| Main: interrupt vector | Flash     | 0FFFFh to 0FFE0h | 0FFFFh to 0FFE0h | 0FFFFh to 0FFE0h          | 0FFFFh to 0FFE0h          | 0FFFFh to 0FFE0h         |
| Main: code memory      | Flash     | 0FFFFh to 0E000h | 0FFFFh to 0C000h | 0FFFFh to 08000h          | 0FFFFh to 04000h          | 0FFFFh to 01100h         |
| Information memory     | Size      | 256 bytes        | 256 bytes        | 256 bytes                 | 256 bytes                 | 256 bytes                |
|                        | Flash     | 010FFh to 01000h | 010FFh to 01000h | 010FFh to 01000h          | 010FFh to 01000h          | 010FFh to 01000h         |
| Boot memory            | Size      | 1KB              | 1KB              | 1KB                       | 1KB                       | 1KB                      |
|                        | Flash     | 0FFFh to 0C00h   | 0FFFh to 0C00h   | 0FFFh to 0C00h            | 0FFFh to 0C00h            | 0FFFh to 0C00h           |
| RAM                    | Size      | 256 bytes        | 512 bytes        | 1KB                       | 2KB                       | 2KB                      |
|                        | RAM       | 02FFh to 0200h   | 03FFh to 0200h   | 05FFh to 0200h            | 09FFh to 0200h            | 09FFh to 0200h           |
| Peripherals            | 16-bit    | 01FFh to 0100h   | 01FFh to 0100h   | 01FFh to 0100h            | 01FFh to 0100h            | 01FFh to 0100h           |
|                        | 8-bit     | 0FFh to 010h     | 0FFh to 010h     | 0FFh to 010h              | 0FFh to 010h              | 0FFh to 010h             |
|                        | 8-bit SFR | 0Fh to 00h       | 0Fh to 00h       | 0Fh to 00h                | 0Fh to 00h                | 0Fh to 00h               |

### 6.7.1 Flash Memory

The flash memory can be programmed through the JTAG port, the bootloader, or in-system by the CPU. The CPU can perform single-byte and single-word writes to the flash memory. Features of the flash memory include:

- Flash memory has n segments of main memory and two segments of information memory (A and B) 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 and B can be erased individually, or as a group with segments 0 to n. Segments A and B are also called *information memory*.
- New devices may have some bytes programmed in the information memory (needed for test during manufacturing). The user should perform an erase of the information memory prior to the first use.



**Figure 6-3. Flash Memory**

## 6.7.2 Special Function Registers

Most interrupt and module-enable bits are collected in the lowest address space. Special-function register bits not allocated to a functional purpose are not physically present in the device. This arrangement provides simple software access.

**Figure 6-4. Interrupt Enable 1 Bit Register**

| 7      | 6      | 5      | 4     | 3        | 2 | 1     | 0     |
|--------|--------|--------|-------|----------|---|-------|-------|
| UTXIE0 | URXIE0 | ACCVIE | NMIE  | Reserved |   | OFIE  | WDTIE |
| R/W-0  | R/W-0  | R/W-0  | R/W-0 | R-0      |   | R/W-0 | R/W-0 |

**Table 6-6. Interrupt Enable 1 Register Field Descriptions**

| Bit | Field    | Type | Reset | Description                                                                                                                            |
|-----|----------|------|-------|----------------------------------------------------------------------------------------------------------------------------------------|
| 7   | UTXIE0   | R/W  | 0     | USART0: UART and SPI transmit interrupt enable                                                                                         |
| 6   | URXIE0   | R/W  | 0     | USART0: UART and SPI receive interrupt enable                                                                                          |
| 5   | ACCVIE   | R/W  | 0     | Flash access violation interrupt enable                                                                                                |
| 4   | NMIE     | R/W  | 0     | Nonmaskable interrupt enable                                                                                                           |
| 3-2 | Reserved | R    | 0     |                                                                                                                                        |
| 1   | OFIE     | R/W  | 0     | Oscillator-fault interrupt enable                                                                                                      |
| 0   | WDTIE    | R/W  | 0     | Watchdog timer interrupt enable. Inactive if watchdog mode is selected. Active if watchdog timer is configured in interval timer mode. |

**Figure 6-5. Interrupt Enable 2 Bit Register**

| 7        | 6 | 5      | 4      | 3 | 2        | 1 | 0 |
|----------|---|--------|--------|---|----------|---|---|
| Reserved |   | UTXIE1 | URXIE1 |   | Reserved |   |   |
| R-0      |   | R/W-0  | R/W-0  |   | R-0      |   |   |

**Table 6-7. Interrupt Enable 2 Register Field Descriptions**

| Bit | Field    | Type | Reset | Description                                    |
|-----|----------|------|-------|------------------------------------------------|
| 7-6 | Reserved | R    | 0     |                                                |
| 5   | UTXIE1   | R/W  | 0     | USART1: UART and SPI receive interrupt enable  |
| 4   | URXIE1   | R/W  | 0     | USART1: UART and SPI transmit interrupt enable |
| 3-0 | Reserved | R/W  | 0     |                                                |

**Figure 6-6. Interrupt Flag 1 Bit Register**

| 7       | 6       | 5        | 4      | 3        | 2 | 1     | 0       |
|---------|---------|----------|--------|----------|---|-------|---------|
| UTXIFG0 | URXIFG0 | Reserved | NMIIFG | Reserved |   | OFIFG | WDTIFG  |
| R/W-1   | R/W-0   | R-0      | R/W-0  | R-0      |   | R/W-1 | R/W-(0) |

**Table 6-8. Interrupt Flag 1 Register Field Descriptions**

| Bit | Field    | Type | Reset | Description                                                                                                                                                                         |
|-----|----------|------|-------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7   | UTXIFG0  | R/W  | 1     | USART0: UART and SPI transmit flag                                                                                                                                                  |
| 6   | URXIFG0  | R/W  | 0     | USART0: UART and SPI receive flag                                                                                                                                                   |
| 5   | Reserved | R    | 0     |                                                                                                                                                                                     |
| 4   | NMIIFG   | R/W  | 0     | Set by $\overline{\text{RST}}$ /NMI pin                                                                                                                                             |
| 3-2 | Reserved | R    | 0     |                                                                                                                                                                                     |
| 1   | OFIFG    | R/W  | 1     | Flag set on oscillator fault                                                                                                                                                        |
| 0   | WDTIFG   | R/W  | (0)   | Set on watchdog timer overflow (in watchdog mode) or security key violation. Reset on $V_{CC}$ power up or a reset condition at the $\overline{\text{RST}}$ /NMI pin in reset mode. |

**Figure 6-7. Interrupt Flag 2 Bit Register**

| 7        | 6 | 5       | 4       | 3        | 2 | 1 | 0 |
|----------|---|---------|---------|----------|---|---|---|
| Reserved |   | UTXIFG1 | URXIFG1 | Reserved |   |   |   |
| R-0      |   | R/W-1   | R/W-0   | R-0      |   |   |   |

**Table 6-9. Interrupt Flag 2 Register Field Descriptions**

| Bit | Field    | Type | Reset | Description                        |
|-----|----------|------|-------|------------------------------------|
| 7-6 | Reserved | R    | 0     |                                    |
| 5   | UTXIFG1  | R/W  | 1     | USART1: UART and SPI transmit flag |
| 4   | URXIFG1  | R/W  | 0     | USART1: UART and SPI receive flag  |
| 3-0 | Reserved | R    | 0     |                                    |

**Figure 6-8. Module Enable 1 Bit Register**

| 7     | 6               | 5        | 4 | 3 | 2 | 1 | 0 |
|-------|-----------------|----------|---|---|---|---|---|
| UTXE0 | URXE0<br>USPIE0 | Reserved |   |   |   |   |   |
| R/W-0 | R/W-0           | R-0      |   |   |   |   |   |

**Table 6-10. Module Enable 1 Bit Register Field Descriptions**

| Bit | Field           | Type | Reset | Description                                                                                               |
|-----|-----------------|------|-------|-----------------------------------------------------------------------------------------------------------|
| 7   | UTXE0           | R/W  | 0     | USART0: UART transmit enable                                                                              |
| 6   | URXE0<br>USPIE0 | R/W  | 0     | USART0: UART receive enable<br>USART0: SPI (synchronous peripheral interface) transmit and receive enable |
| 5-0 | Reserved        | R    | 0     |                                                                                                           |

**Figure 6-9. Module Enable 2 Bit Register**

| 7        | 6 | 5     | 4               | 3        | 2 | 1 | 0 |
|----------|---|-------|-----------------|----------|---|---|---|
| Reserved |   | UTXE1 | URXE1<br>USPIE1 | Reserved |   |   |   |
| R-0      |   | R/W-0 | R/W-0           | R-0      |   |   |   |

**Table 6-11. Module Enable 2 Bit Register Field Descriptions**

| Bit | Field           | Type | Reset | Description                                                                                               |
|-----|-----------------|------|-------|-----------------------------------------------------------------------------------------------------------|
| 7-6 | Reserved        | R    | 0     |                                                                                                           |
| 5   |                 | R/W  | 0     | USART1: UART transmit enable                                                                              |
| 4   | URXE1<br>USPIE1 | R/W  | 0     | USART1: UART receive enable<br>USART1: SPI (synchronous peripheral interface) transmit and receive enable |
| 3-0 | Reserved        | R    | 0     |                                                                                                           |

## 6.8 Peripherals

Peripherals are connected to the CPU through data, address, and control buses and can be handled using all instructions. For complete module descriptions, see the [MSP430x1xx Family User's Guide](#).

### 6.8.1 Digital I/O

Six 8-bit I/O ports are implemented: ports P1 to P6:

- All individual I/O bits are independently programmable.
- Any combination of input, output, and interrupt conditions is possible.
- Edge-selectable interrupt input capability for all the eight bits of ports P1 and P2.
- Read and write access to port-control registers is supported by all instructions.

### 6.8.2 Oscillator and System Clock

The clock system is supported by the basic clock module that includes support for a 32768-Hz watch crystal oscillator, an internal digitally controlled oscillator (DCO), and a high-frequency crystal oscillator. The basic clock module is designed to meet the requirements of both low system cost and low power consumption. The internal DCO provides a fast turn-on clock source and stabilizes in less than 6  $\mu$ s. The basic clock module provides the following clock signals:

- Auxiliary clock (ACLK), sourced from a 32768-Hz watch crystal or a high-frequency crystal
- Main clock (MCLK), the system clock used by the CPU
- Sub-Main clock (SMCLK), the subsystem clock used by the peripheral modules

### 6.8.3 Watchdog Timer (WDT)

The primary function of the WDT module is to perform a controlled system restart after a software problem occurs. If the selected time interval expires, a system reset is generated. If the watchdog function is not needed in an application, the module can be configured as an interval timer and can generate interrupts at selected time intervals.

### 6.8.4 Hardware Multiplier (MSP430F14x and MSP430F14x1 Only)

The multiplication operation is supported by a dedicated peripheral module. The module performs  $16 \times 16$ ,  $16 \times 8$ ,  $8 \times 16$ , and  $8 \times 8$  bit operations. The module is capable of supporting signed and unsigned multiplication as well as signed and unsigned multiply and accumulate operations. The result of an operation can be accessed immediately after the operands have been loaded into the peripheral registers. No additional clock cycles are required.

### 6.8.5 USART0

The hardware universal synchronous/asynchronous receive transmit (USART0) peripheral module is used for serial data communication. The USART supports synchronous SPI (3 or 4 pin) and asynchronous UART communication protocols, using double-buffered transmit and receive channels.

### 6.8.6 USART1 (MSP430F14x and MSP430F14x1 Only)

The MSP430F14x(1) has a second hardware universal synchronous/asynchronous receive transmit (USART1) peripheral module that is used for serial data communication. The USART supports synchronous SPI (3 or 4 pin) and asynchronous UART communication protocols, using double-buffered transmit and receive channels. Operation of USART1 is identical to USART0.

### 6.8.7 Comparator\_A

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

### 6.8.8 ADC12 (MSP430F14x and MSP430F13x Only)

The ADC12 module supports fast 12-bit analog-to-digital conversions. The module implements a 12-bit SAR core, sample select control, reference generator, and a 16-word conversion-and-control buffer. The conversion-and-control buffer allows up to 16 independent ADC samples to be converted and stored without CPU intervention.

### 6.8.9 Timer\_A3

Timer\_A3 is a 16-bit timer/counter with three capture/compare registers. Timer\_A3 can support multiple capture/compares, PWM outputs, and interval timing (see [Table 6-12](#)). Timer\_A3 also has extensive interrupt capabilities. Interrupts may be generated from the counter on overflow conditions and from each of the capture/compare registers.

**Table 6-12. Timer\_A3 Signal Connections**

| INPUT PIN NUMBER | DEVICE INPUT SIGNAL | MODULE INPUT NAME | MODULE BLOCK | MODULE OUTPUT SIGNAL | OUTPUT PIN NUMBER |
|------------------|---------------------|-------------------|--------------|----------------------|-------------------|
| 12 - P1.0        | TACLK               | TACLK             | Timer        | NA                   |                   |
|                  | ACLK                | ACLK              |              |                      |                   |
|                  | SMCLK               | SMCLK             |              |                      |                   |
| 21 - P2.1        | TAINCLK             | INCLK             |              |                      |                   |
| 13 - P1.1        | TA0                 | CCI0A             | CCR0         | TA0                  | 13 - P1.1         |
| 22 - P2.2        | TA0                 | CCI0B             |              |                      | 17 - P1.5         |
|                  | DV <sub>SS</sub>    | GND               |              |                      | 27 - P2.7         |
|                  | DV <sub>CC</sub>    | VCC               |              |                      |                   |
| 14 - P1.2        | TA1                 | CCI1A             | CCR1         | TA1                  |                   |
|                  | CAOUT (internal)    | CCI1B             |              |                      |                   |
|                  | DV <sub>SS</sub>    | GND               |              |                      |                   |
|                  | DV <sub>CC</sub>    | VCC               |              |                      |                   |
| 15 - P1.3        | TA2                 | CCI2A             | CCR2         | TA2                  |                   |
|                  | ACLK (internal)     | CCI2B             |              |                      |                   |
|                  | DV <sub>SS</sub>    | GND               |              |                      |                   |
|                  | DV <sub>CC</sub>    | VCC               |              |                      |                   |

### 6.8.10 Timer\_B3 (MSP430F13x Only)

Timer\_B3 is a 16-bit timer/counter with three capture/compare registers. Timer\_B3 can support multiple capture/compares, PWM outputs, and interval timing (see [Table 6-13](#)). Timer\_B3 also has extensive interrupt capabilities. Interrupts may be generated from the counter on overflow conditions and from each of the capture/compare registers.

### 6.8.11 Timer\_B7 (MSP430F14x and MSP430F14x1 Only)

Timer\_B7 is a 16-bit timer/counter with seven capture/compare registers. Timer\_B7 can support multiple capture/compares, PWM outputs, and interval timing (see [Table 6-13](#)). Timer\_B7 also has extensive interrupt capabilities. Interrupts may be generated from the counter on overflow conditions and from each of the capture/compare registers.

**Table 6-13. Timer\_B3 and Timer\_B7 Signal Connections<sup>(1)</sup>**

| INPUT PIN NUMBER | DEVICE INPUT SIGNAL | MODULE INPUT NAME | MODULE BLOCK | MODULE OUTPUT SIGNAL | OUTPUT PIN NUMBER |
|------------------|---------------------|-------------------|--------------|----------------------|-------------------|
| 43 - P4.7        | TBCLK               | TBCLK             | Timer        | NA                   |                   |
|                  | ACLK                | ACLK              |              |                      |                   |
|                  | SMCLK               | SMCLK             |              |                      |                   |
| 43 - P4.7        | TBCLK               | INCLK             |              |                      |                   |
| 36 - P4.0        | TB0                 | CCI0A             | CCR0         | TB0                  | 36 - P4.0         |
| 36 - P4.0        | TB0                 | CCI0B             |              |                      | ADC12 (internal)  |
|                  | DV <sub>SS</sub>    | GND               |              |                      |                   |
|                  | DV <sub>CC</sub>    | V <sub>CC</sub>   |              |                      |                   |
| 37 - P4.1        | TB1                 | CCI1A             | CCR1         | TB1                  | 37 - P4.1         |
| 37 - P4.1        | TB1                 | CCI1B             |              |                      | ADC12 (internal)  |
|                  | DV <sub>SS</sub>    | GND               |              |                      |                   |
|                  | DV <sub>CC</sub>    | V <sub>CC</sub>   |              |                      |                   |
| 38 - P4.2        | TB2                 | CCI2A             | CCR2         | TB2                  | 38 - P4.2         |
| 38 - P4.2        | TB2                 | CCI2B             |              |                      |                   |
|                  | DV <sub>SS</sub>    | GND               |              |                      |                   |
|                  | DV <sub>CC</sub>    | V <sub>CC</sub>   |              |                      |                   |
| 39 - P4.3        | TB3                 | CCI3A             | CCR3         | TB3                  | 39 - P4.3         |
| 39 - P4.3        | TB3                 | CCI3B             |              |                      |                   |
|                  | DV <sub>SS</sub>    | GND               |              |                      |                   |
|                  | DV <sub>CC</sub>    | V <sub>CC</sub>   |              |                      |                   |
| 40 - P4.4        | TB4                 | CCI4A             | CCR4         | TB4                  | 40 - P4.4         |
| 40 - P4.4        | TB4                 | CCI4B             |              |                      |                   |
|                  | DV <sub>SS</sub>    | GND               |              |                      |                   |
|                  | DV <sub>CC</sub>    | V <sub>CC</sub>   |              |                      |                   |
| 41 - P4.5        | TB5                 | CCI5A             | CCR5         | TB5                  | 41 - P4.5         |
| 41 - P4.5        | TB5                 | CCI5B             |              |                      |                   |
|                  | DV <sub>SS</sub>    | GND               |              |                      |                   |
|                  | DV <sub>CC</sub>    | V <sub>CC</sub>   |              |                      |                   |
| 42 - P4.6        | TB6                 | CCI6A             | CCR6         | TB6                  | 42 - P4.6         |
|                  | ACLK (internal)     | CCI6B             |              |                      |                   |
|                  | DV <sub>SS</sub>    | GND               |              |                      |                   |
|                  | DV <sub>CC</sub>    | V <sub>CC</sub>   |              |                      |                   |

(1) Timer\_B3 implements three capture/compare blocks (CCR0, CCR1 and CCR2).

## 6.8.12 Peripheral File Map

Table 6-14 lists the peripheral register that support word access. See Table 6-15 for the registers with byte access.

**Table 6-14. Peripherals With Word Access**

| MODULE             | REGISTER NAME                                    | ACRONYM | ADDRESS |
|--------------------|--------------------------------------------------|---------|---------|
| Watchdog           | Watchdog timer control                           | WDTCTL  | 0120h   |
| Timer_B7, Timer_B3 | Timer_B interrupt vector                         | TBIV    | 011Eh   |
|                    | Timer_B control                                  | TBCTL   | 0180h   |
|                    | Timer_B capture/compare control 0                | TBCCTL0 | 0182h   |
|                    | Timer_B capture/compare control 1                | TBCCTL1 | 0184h   |
|                    | Timer_B capture/compare control 2                | TBCCTL2 | 0186h   |
|                    | Timer_B capture/compare control 3 <sup>(1)</sup> | TBCCTL3 | 0188h   |
|                    | Timer_B capture/compare control 4 <sup>(1)</sup> | TBCCTL4 | 018Ah   |
|                    | Timer_B capture/compare control 5 <sup>(1)</sup> | TBCCTL5 | 018Ch   |
|                    | Timer_B capture/compare control 6 <sup>(1)</sup> | TBCCTL6 | 018Eh   |
|                    | Timer_B counter                                  | TBR     | 0190h   |
|                    | Timer_B capture/compare 0                        | TBCCR0  | 0192h   |
|                    | Timer_B capture/compare 1                        | TBCCR1  | 0194h   |
|                    | Timer_B capture/compare 2                        | TBCCR2  | 0196h   |
|                    | Timer_B capture/compare 3 <sup>(1)</sup>         | TBCCR3  | 0198h   |
|                    | Timer_B capture/compare 4 <sup>(1)</sup>         | TBCCR4  | 019Ah   |
|                    | Timer_B capture/compare 5 <sup>(1)</sup>         | TBCCR5  | 019Ch   |
|                    | Timer_B capture/compare 6 <sup>(1)</sup>         | TBCCR6  | 019Eh   |
| Timer_A3           | Timer_A interrupt vector                         | TAIV    | 012Eh   |
|                    | Timer_A control                                  | TACTL   | 0160h   |
|                    | Timer_A capture/compare control 0                | TACCTL0 | 0162h   |
|                    | Timer_A capture/compare control 1                | TACCTL1 | 0164h   |
|                    | Timer_A capture/compare control 2                | TACCTL2 | 0166h   |
|                    | Reserved                                         |         | 0168h   |
|                    | Reserved                                         |         | 016Ah   |
|                    | Reserved                                         |         | 016Ch   |
|                    | Reserved                                         |         | 016Eh   |
|                    | Timer_A counter                                  | TAR     | 0170h   |
|                    | Timer_A capture/compare 0                        | TACCR0  | 0172h   |
|                    | Timer_A capture/compare 1                        | TACCR1  | 0174h   |
|                    | Timer_A capture/compare 2                        | TACCR2  | 0176h   |
|                    | Reserved                                         |         | 0178h   |
|                    | Reserved                                         |         | 017Ah   |
|                    | Reserved                                         |         | 017Ch   |
|                    | Reserved                                         |         | 017Eh   |

(1) Timer\_B7 only, reserved for Timer\_B3

**Table 6-14. Peripherals With Word Access (continued)**

| MODULE                                                      | REGISTER NAME                            | ACRONYM | ADDRESS |
|-------------------------------------------------------------|------------------------------------------|---------|---------|
| Hardware multiplier<br>(MSP430F14x and<br>MSP430F14x1 only) | Sum extend                               | SUMEXT  | 013Eh   |
|                                                             | Result high word                         | RESHI   | 013Ch   |
|                                                             | Result low word                          | RESLO   | 013Ah   |
|                                                             | Operand 2                                | OP2     | 0138h   |
|                                                             | Multiply signed and accumulate operand 1 | MACS    | 0136h   |
|                                                             | Multiply and accumulate operand 1        | MAC     | 0134h   |
|                                                             | Multiply signed operand 1                | MPYS    | 0132h   |
|                                                             | Multiply unsigned operand 1              | MPY     | 0130h   |
| Flash                                                       | Flash control 3                          | FCTL1   | 012Ch   |
|                                                             | Flash control 2                          | FCTL2   | 012Ah   |
|                                                             | Flash control 1                          | FCTL1   | 0128h   |

**Table 6-14. Peripherals With Word Access (continued)**

| MODULE                     | REGISTER NAME         | ACRONYM     | ADDRESS |
|----------------------------|-----------------------|-------------|---------|
| ADC12 (not in MSP430F14x1) | Conversion memory 15  | ADC12MEM15  | 015Eh   |
|                            | Conversion memory 14  | ADC12MEM14  | 015Ch   |
|                            | Conversion memory 13  | ADC12MEM13  | 015Ah   |
|                            | Conversion memory 12  | ADC12MEM12  | 0158h   |
|                            | Conversion memory 11  | ADC12MEM11  | 0156h   |
|                            | Conversion memory 10  | ADC12MEM10  | 0154h   |
|                            | Conversion memory 9   | ADC12MEM9   | 0152h   |
|                            | Conversion memory 8   | ADC12MEM8   | 0150h   |
|                            | Conversion memory 7   | ADC12MEM7   | 014Eh   |
|                            | Conversion memory 6   | ADC12MEM6   | 014Ch   |
|                            | Conversion memory 5   | ADC12MEM5   | 014Ah   |
|                            | Conversion memory 4   | ADC12MEM4   | 0148h   |
|                            | Conversion memory 3   | ADC12MEM3   | 0146h   |
|                            | Conversion memory 2   | ADC12MEM2   | 0144h   |
|                            | Conversion memory 1   | ADC12MEM1   | 0142h   |
|                            | Conversion memory 0   | ADC12MEM0   | 0140h   |
|                            | Interrupt vector word | ADC12IV     | 01A8h   |
|                            | Interrupt enable      | ADC12IE     | 01A6h   |
|                            | Interrupt flag        | ADC12IFG    | 01A4h   |
|                            | ADC control 1         | ADC12CTL1   | 01A2h   |
|                            | ADC control 0         | ADC12CTL0   | 01A0h   |
|                            | ADC memory control 15 | ADC12MCTL15 | 08Fh    |
|                            | ADC memory control 14 | ADC12MCTL14 | 08Eh    |
|                            | ADC memory control 13 | ADC12MCTL13 | 08Dh    |
|                            | ADC memory control 12 | ADC12MCTL12 | 08Ch    |
|                            | ADC memory control 11 | ADC12MCTL11 | 08Bh    |
|                            | ADC memory control 10 | ADC12MCTL10 | 08Ah    |
|                            | ADC memory control 9  | ADC12MCTL9  | 089h    |
|                            | ADC memory control 8  | ADC12MCTL8  | 088h    |
|                            | ADC memory control 7  | ADC12MCTL7  | 087h    |
|                            | ADC memory control 6  | ADC12MCTL6  | 086h    |
|                            | ADC memory control 5  | ADC12MCTL5  | 085h    |
|                            | ADC memory control 4  | ADC12MCTL4  | 084h    |
|                            | ADC memory control 3  | ADC12MCTL3  | 083h    |
|                            | ADC memory control 2  | ADC12MCTL2  | 082h    |
|                            | ADC memory control 1  | ADC12MCTL1  | 081h    |
|                            | ADC memory control 0  | ADC12MCTL0  | 080h    |

Table 6-15 lists the peripheral register that support byte access. See Table 6-14 for the registers with word access.

**Table 6-15. Peripherals With Byte Access**

| MODULE                                   | REGISTER NAME                | ACRONYM | ADDRESS |
|------------------------------------------|------------------------------|---------|---------|
| USART1 (MSP430F14x and MSP430F14x1 only) | Transmit buffer              | U1TXBUF | 07Fh    |
|                                          | Receive buffer               | U1RXBUF | 07Eh    |
|                                          | Baud rate 1                  | U1BR1   | 07Dh    |
|                                          | Baud rate 0                  | U1BR0   | 07Ch    |
|                                          | Modulation control           | U1MCTL  | 07Bh    |
|                                          | Receive control              | U1RCTL  | 07Ah    |
|                                          | Transmit control             | U1TCTL  | 079h    |
|                                          | USART control                | U1CTL   | 078h    |
| USART0                                   | Transmit buffer              | U0TXBUF | 077h    |
|                                          | Receive buffer               | U0RXBUF | 076h    |
|                                          | Baud rate 1                  | U0BR1   | 075h    |
|                                          | Baud rate 0                  | U0BR0   | 074h    |
|                                          | Modulation control           | U0MCTL  | 073h    |
|                                          | Receive control              | U0RCTL  | 072h    |
|                                          | Transmit control             | U0TCTL  | 071h    |
|                                          | USART control                | U0CTL   | 070h    |
| Comparator_A                             | Comparator_A port disable    | CAPD    | 05Bh    |
|                                          | Comparator_A control 2       | CACTL2  | 05Ah    |
|                                          | Comparator_A control 1       | CACTL1  | 059h    |
| Basic Clock                              | Basic clock system control 2 | BCSCTL2 | 058h    |
|                                          | Basic clock system control 1 | BCSCTL1 | 057h    |
|                                          | DCO clock frequency control  | DCOCTL  | 056h    |
| Port P6                                  | Port P6 selection            | P6SEL   | 037h    |
|                                          | Port P6 direction            | P6DIR   | 036h    |
|                                          | Port P6 output               | P6OUT   | 035h    |
|                                          | Port P6 input                | P6IN    | 034h    |
| Port P5                                  | Port P5 selection            | P5SEL   | 033h    |
|                                          | Port P5 direction            | P5DIR   | 032h    |
|                                          | Port P5 output               | P5OUT   | 031h    |
|                                          | Port P5 input                | P5IN    | 030h    |
| Port P4                                  | Port P4 selection            | P4SEL   | 01Fh    |
|                                          | Port P4 direction            | P4DIR   | 01Eh    |
|                                          | Port P4 output               | P4OUT   | 01Dh    |
|                                          | Port P4 input                | P4IN    | 01Ch    |
| Port P3                                  | Port P3 selection            | P3SEL   | 01Bh    |
|                                          | Port P3 direction            | P3DIR   | 01Ah    |
|                                          | Port P3 output               | P3OUT   | 019h    |
|                                          | Port P3 input                | P3IN    | 018h    |

**Table 6-15. Peripherals With Byte Access (continued)**

| MODULE            | REGISTER NAME                 | ACRONYM | ADDRESS |
|-------------------|-------------------------------|---------|---------|
| Port P2           | Port P2 selection             | P2SEL   | 02Eh    |
|                   | Port P2 interrupt enable      | P2IE    | 02Dh    |
|                   | Port P2 interrupt edge select | P2IES   | 02Ch    |
|                   | Port P2 interrupt flag        | P2IFG   | 02Bh    |
|                   | Port P2 direction             | P2DIR   | 02Ah    |
|                   | Port P2 output                | P2OUT   | 029h    |
|                   | Port P2 input                 | P2IN    | 028h    |
| Port P1           | Port P1 selection             | P1SEL   | 026h    |
|                   | Port P1 interrupt enable      | P1IE    | 025h    |
|                   | Port P1 interrupt edge select | P1IES   | 024h    |
|                   | Port P1 interrupt flag        | P1IFG   | 023h    |
|                   | Port P1 direction             | P1DIR   | 022h    |
|                   | Port P1 output                | P1OUT   | 021h    |
|                   | Port P1 input                 | P1IN    | 020h    |
| Special Functions | SFR module enable 2           | ME2     | 005h    |
|                   | SFR module enable 1           | ME1     | 004h    |
|                   | SFR interrupt flag 2          | IFG2    | 003h    |
|                   | SFR interrupt flag 1          | IFG1    | 002h    |
|                   | SFR interrupt enable 2        | IE2     | 001h    |
|                   | SFR interrupt enable 1        | IE1     | 000h    |

## 6.9 Input/Output Diagrams

### 6.9.1 Port P1, Input/Output With Schmitt Trigger

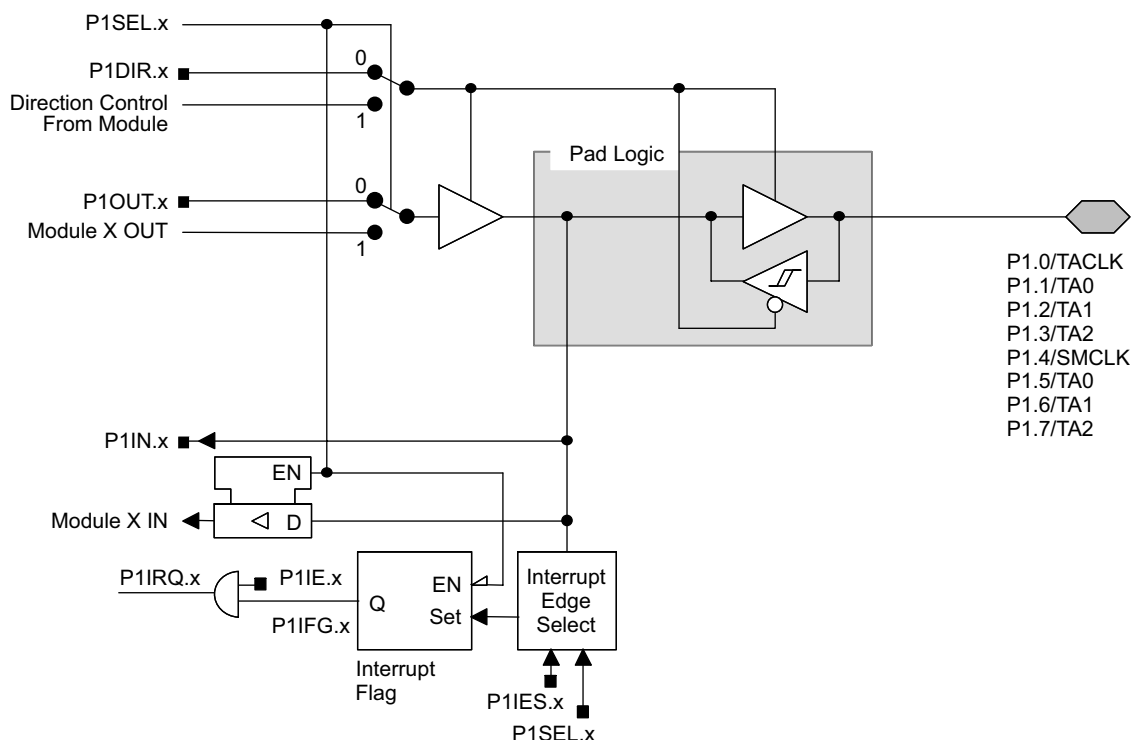


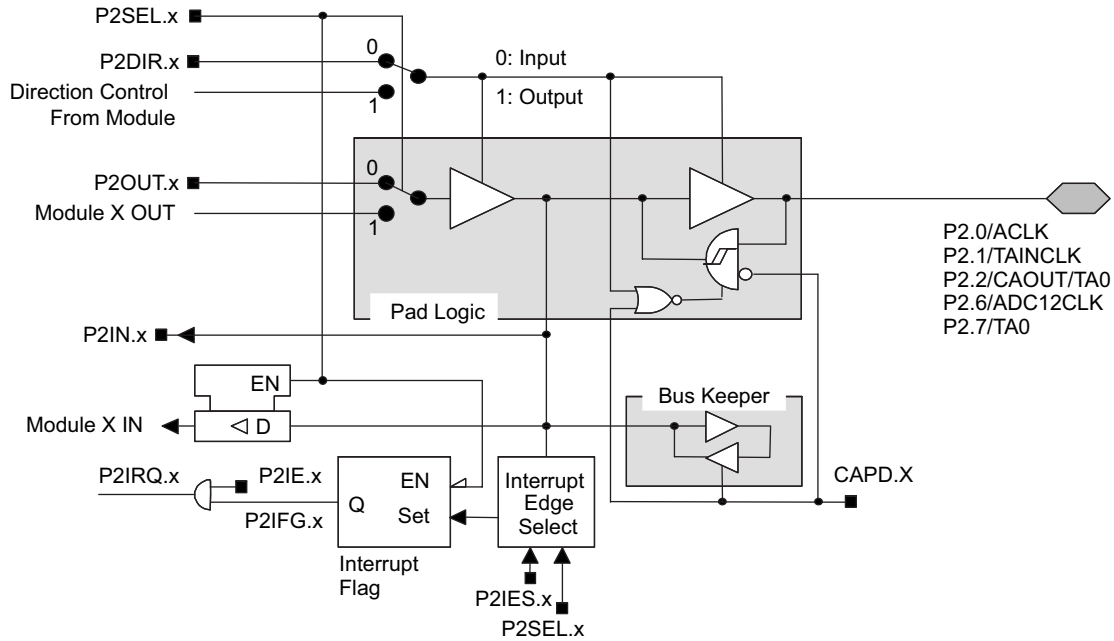
Figure 6-10. Port P1 (P1.0 to P1.7) Diagram

Table 6-16. Port P1 (P1.0 to P1.7) Pin Functions

| PnSel.x | PnDIR.x | DIRECTION CONTROL FROM MODULE | PnOUT.x | MODULE X OUT               | PnIN.x | MODULE X IN          | PnIE.x | PnIFG.x | PnIES.x |
|---------|---------|-------------------------------|---------|----------------------------|--------|----------------------|--------|---------|---------|
| P1Sel.0 | P1DIR.0 | P1DIR.0                       | P1OUT.0 | DV <sub>SS</sub>           | P1IN.0 | TACLK <sup>(1)</sup> | P1IE.0 | P1IFG.0 | P1IES.0 |
| P1Sel.1 | P1DIR.1 | P1DIR.1                       | P1OUT.1 | Out0 signal <sup>(1)</sup> | P1IN.1 | CCI0A <sup>(1)</sup> | P1IE.1 | P1IFG.1 | P1IES.1 |
| P1Sel.2 | P1DIR.2 | P1DIR.2                       | P1OUT.2 | Out1 signal <sup>(1)</sup> | P1IN.2 | CCI1A <sup>(1)</sup> | P1IE.2 | P1IFG.2 | P1IES.2 |
| P1Sel.3 | P1DIR.3 | P1DIR.3                       | P1OUT.3 | Out2 signal <sup>(1)</sup> | P1IN.3 | CCI2A <sup>(1)</sup> | P1IE.3 | P1IFG.3 | P1IES.3 |
| P1Sel.4 | P1DIR.4 | P1DIR.4                       | P1OUT.4 | SMCLK                      | P1IN.4 | unused               | P1IE.4 | P1IFG.4 | P1IES.4 |
| P1Sel.5 | P1DIR.5 | P1DIR.5                       | P1OUT.5 | Out0 signal <sup>(1)</sup> | P1IN.5 | unused               | P1IE.5 | P1IFG.5 | P1IES.5 |
| P1Sel.6 | P1DIR.6 | P1DIR.6                       | P1OUT.6 | Out1 signal <sup>(1)</sup> | P1IN.6 | unused               | P1IE.6 | P1IFG.6 | P1IES.6 |
| P1Sel.7 | P1DIR.7 | P1DIR.7                       | P1OUT.7 | Out2 signal <sup>(1)</sup> | P1IN.7 | unused               | P1IE.7 | P1IFG.7 | P1IES.7 |

(1) Signal from or to Timer<sub>A</sub>

## 6.9.2 Port P2, Input/Output With Schmitt Trigger



**Figure 6-11. Port P2 (P2.0 to P2.2, P2.6, and P2.7) Diagram**

**Table 6-17. Port P2 (P2.0 to P2.2, P2.6, and P2.7) Pin Functions**

| PnSel.x | PnDIR.x | DIRECTION<br>CONTROL<br>FROM<br>MODULE | PnOUT.x | MODULE X<br>OUT            | PnIN.x | MODULE X IN          | PnIE.x | PnIFG.x | PnIES.x |
|---------|---------|----------------------------------------|---------|----------------------------|--------|----------------------|--------|---------|---------|
| P2Sel.0 | P2DIR.0 | P2DIR.0                                | P2OUT.0 | ACLK                       | P2IN.0 | unused               | P2IE.0 | P2IFG.0 | P2IES.0 |
| P2Sel.1 | P2DIR.1 | P2DIR.1                                | P2OUT.1 | DV <sub>SS</sub>           | P2IN.1 | INCLK <sup>(1)</sup> | P2IE.1 | P2IFG.1 | P2IES.1 |
| P2Sel.2 | P2DIR.2 | P2DIR.2                                | P2OUT.2 | CAOUT <sup>(2)</sup>       | P2IN.2 | CCI0B <sup>(1)</sup> | P2IE.2 | P2IFG.2 | P2IES.2 |
| P2Sel.6 | P2DIR.6 | P2DIR.6                                | P2OUT.6 | ADC12CLK <sup>(3)</sup>    | P2IN.6 | unused               | P2IE.6 | P2IFG.6 | P2IES.6 |
| P2Sel.7 | P2DIR.7 | P2DIR.7                                | P2OUT.7 | Out0 signal <sup>(4)</sup> | P2IN.7 | unused               | P2IE.7 | P2IFG.7 | P2IES.7 |

- (1) Signal to Timer\_A  
(2) Signal from Comparator\_A  
(3) ADC12CLK signal is output of the 12-bit ADC module  
(4) Signal from Timer\_A

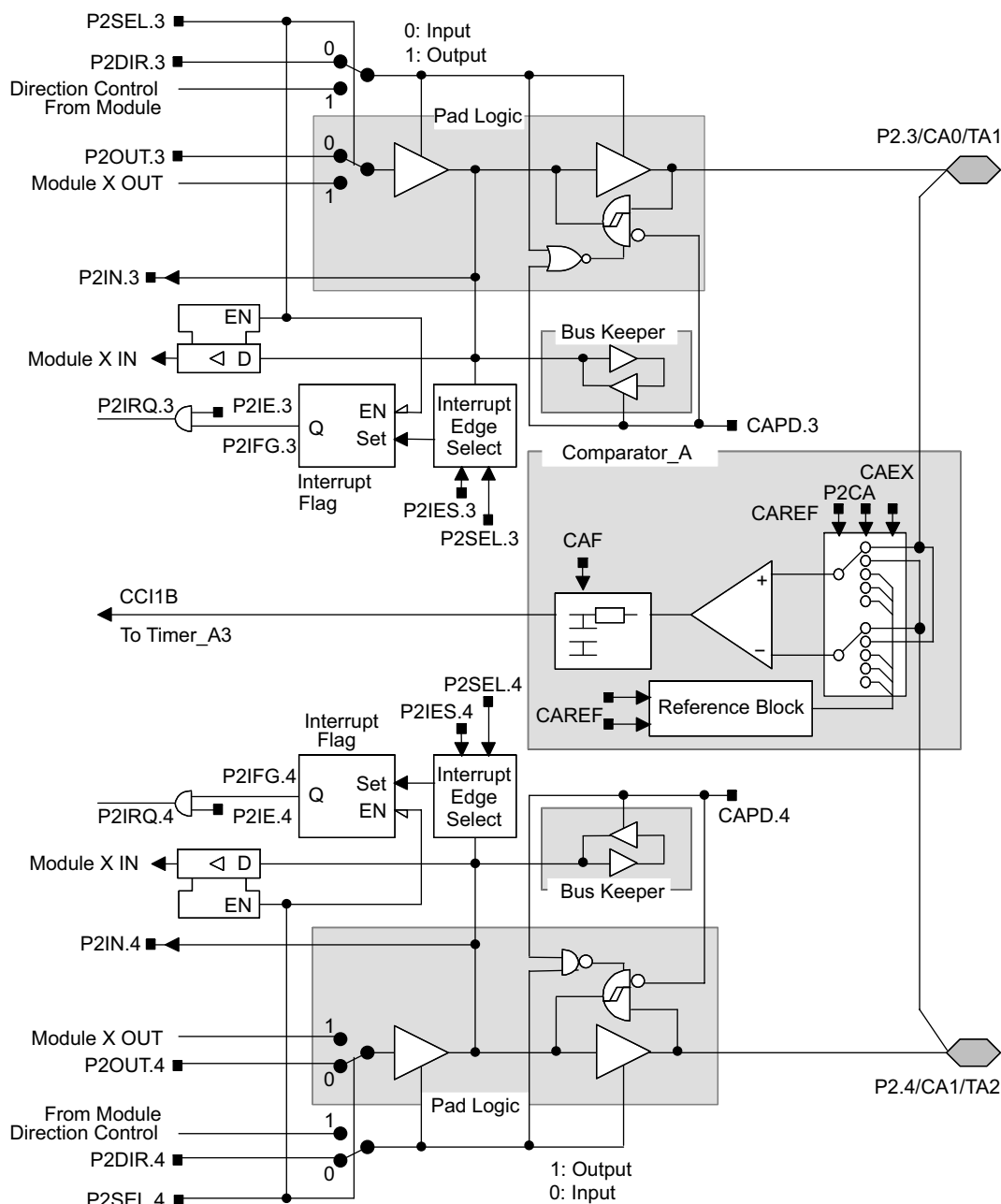


Figure 6-12. Port P2 (P2.3 and P2.4) Diagram

Table 6-18. Port P2 (P2.3 and P2.4) Pin Functions

| PnSel.x | PnDIR.x | DIRECTION<br>CONTROL<br>FROM<br>MODULE | PnOUT.x | MODULE X<br>OUT            | PnIN.x | MODULE X IN | PnIE.x | PnIFG.x | PnIES.x |
|---------|---------|----------------------------------------|---------|----------------------------|--------|-------------|--------|---------|---------|
| P2Sel.3 | P2DIR.3 | P2DIR.3                                | P2OUT.3 | Out1 signal <sup>(1)</sup> | P2IN.3 | unused      | P2IE.3 | P2IFG.3 | P2IES.3 |
| P2Sel.4 | P2DIR.4 | P2DIR.4                                | P2OUT.4 | Out2 signal <sup>(1)</sup> | P2IN.4 | unused      | P2IE.4 | P2IFG.4 | P2IES.4 |

(1) Signal from Timer\_A

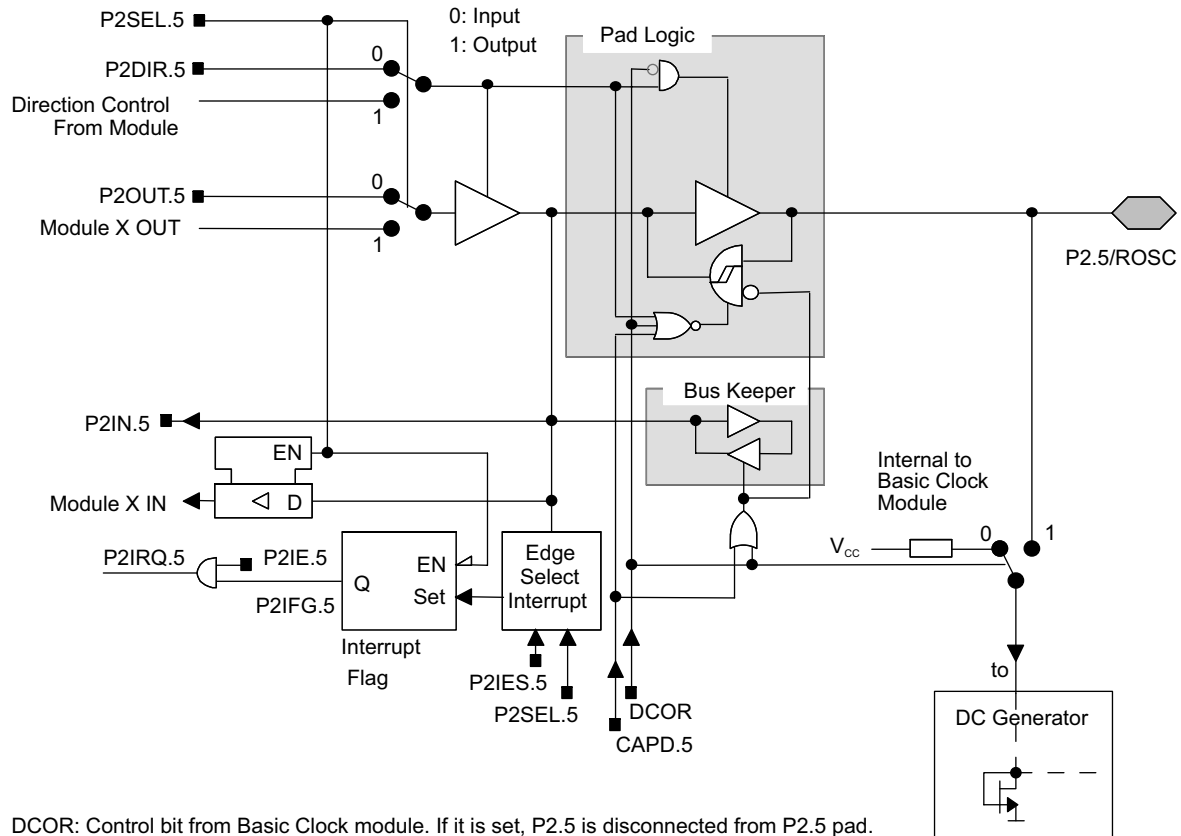


Figure 6-13. Port P2 (P2.5) Diagram

Table 6-19. Port P2 (P2.5) Pin Functions

| PnSel.x | PnDIR.x | DIRECTION<br>CONTROL<br>FROM<br>MODULE | PnOUT.x | MODULE X<br>OUT  | PnIN.x | MODULE X<br>IN | PnIE.x | PnIFG.x | PnIES.x |
|---------|---------|----------------------------------------|---------|------------------|--------|----------------|--------|---------|---------|
| P2Sel.5 | P2DIR.5 | P2DIR.5                                | P2OUT.5 | DV <sub>SS</sub> | P2IN.5 | unused         | P2IE.5 | P2IFG.5 | P2IES.5 |

### 6.9.3 Port P3, Input/Output With Schmitt Trigger

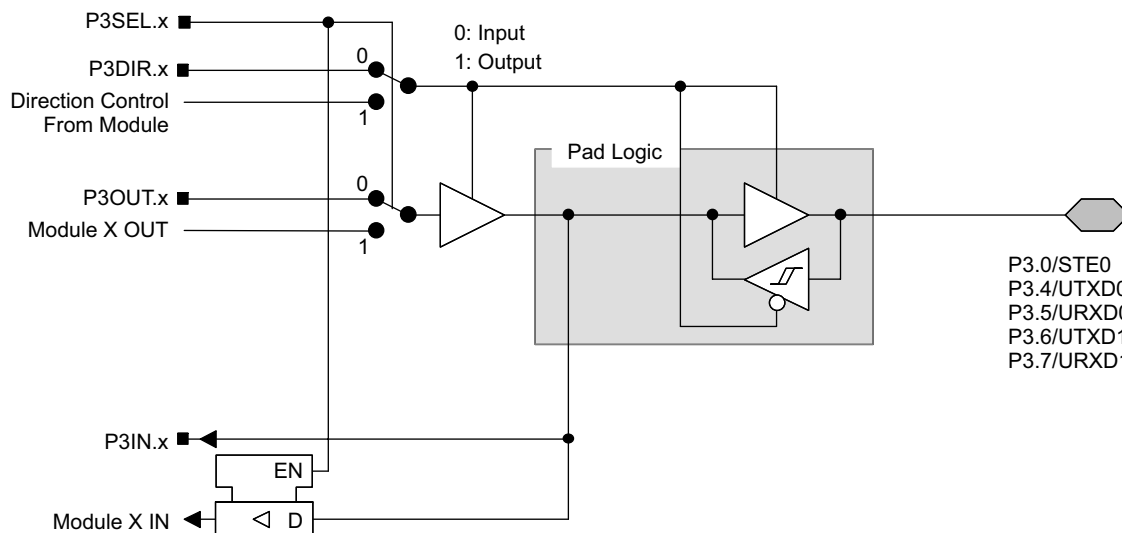


Figure 6-14. Port P3 (P3.0 and 3.4 to 3.7) Diagram

Table 6-20. Port P3 (P3.0 and 3.4 to 3.7) Pin Functions

| PnSel.x | PnDIR.x | DIRECTION CONTROL FROM MODULE | PnOUT.x | MODULE X OUT         | PnIN.x | MODULE X IN          |
|---------|---------|-------------------------------|---------|----------------------|--------|----------------------|
| P3Sel.0 | P3DIR.0 | DV <sub>SS</sub>              | P3OUT.0 | DV <sub>SS</sub>     | P3IN.0 | STE0                 |
| P3Sel.4 | P3DIR.4 | DV <sub>CC</sub>              | P3OUT.4 | UTXD0 <sup>(1)</sup> | P3IN.4 | Unused               |
| P3Sel.5 | P3DIR.5 | DV <sub>SS</sub>              | P3OUT.5 | DV <sub>SS</sub>     | P3IN.5 | URXD0 <sup>(2)</sup> |
| P3Sel.6 | P3DIR.6 | DV <sub>CC</sub>              | P3OUT.6 | UTXD1 <sup>(3)</sup> | P3IN.6 | unused               |
| P3Sel.7 | P3DIR.7 | DV <sub>SS</sub>              | P3OUT.7 | DV <sub>SS</sub>     | P3IN.7 | URXD1 <sup>(4)</sup> |

(1) Output from USART0 module

(2) Input to USART0 module

(3) Output from USART1 module in MSP430F14x and MSP430F14x1 devices, DV<sub>SS</sub> in MSP430F13x devices

(4) Input to USART1 module in MSP430F14x and MSP430F14x1 devices, unused in MSP430F13x devices

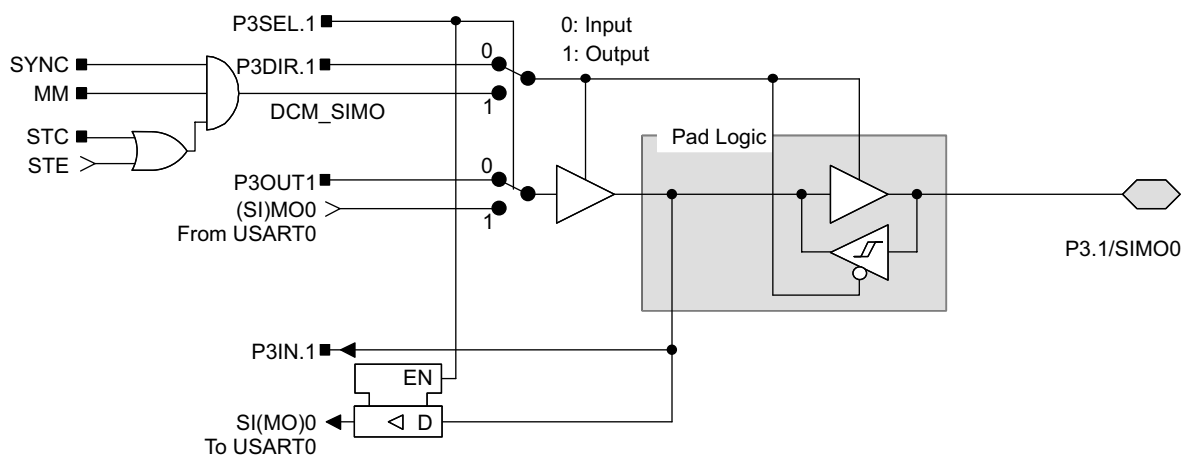


Figure 6-15. Port P3 (P3.1) Diagram

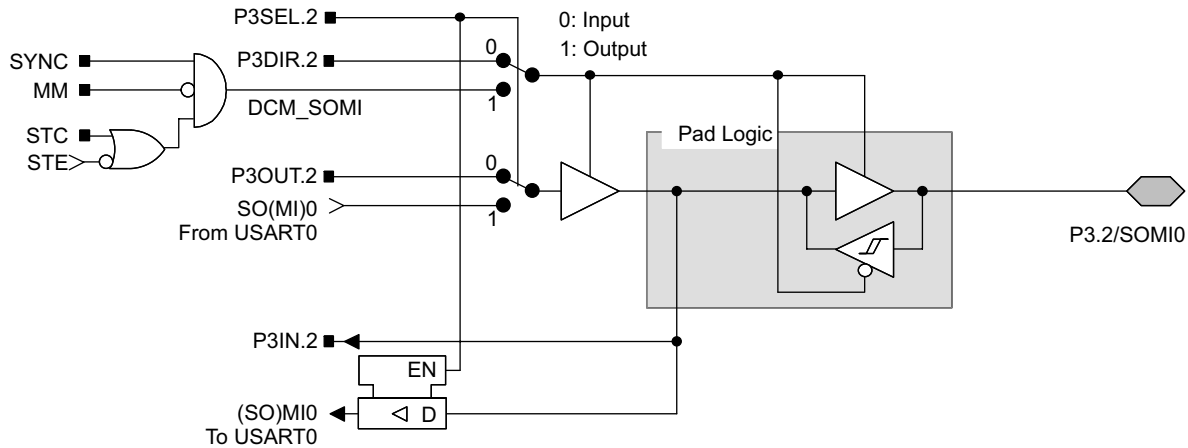
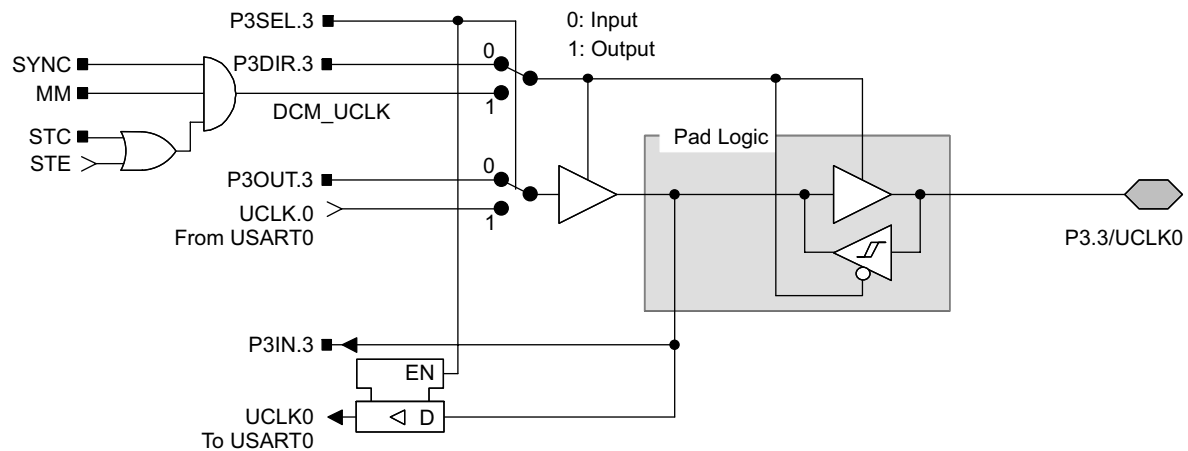


Figure 6-16. Port P3 (P3.2) Diagram



NOTE: UART mode: The UART clock can only be an input. If UART mode and UART function are selected, P3.3/UCLK0 is always an input.  
SPI slave mode: The clock applied to UCLK0 is used to shift data in and out.  
SPI master mode: The clock to shift data in and out is supplied to connected devices on pin P3.3/UCLK0 (in slave mode).

Figure 6-17. Port P3 (P3.3) Diagram

## 6.9.4 Port P4, Input/Output With Schmitt Trigger

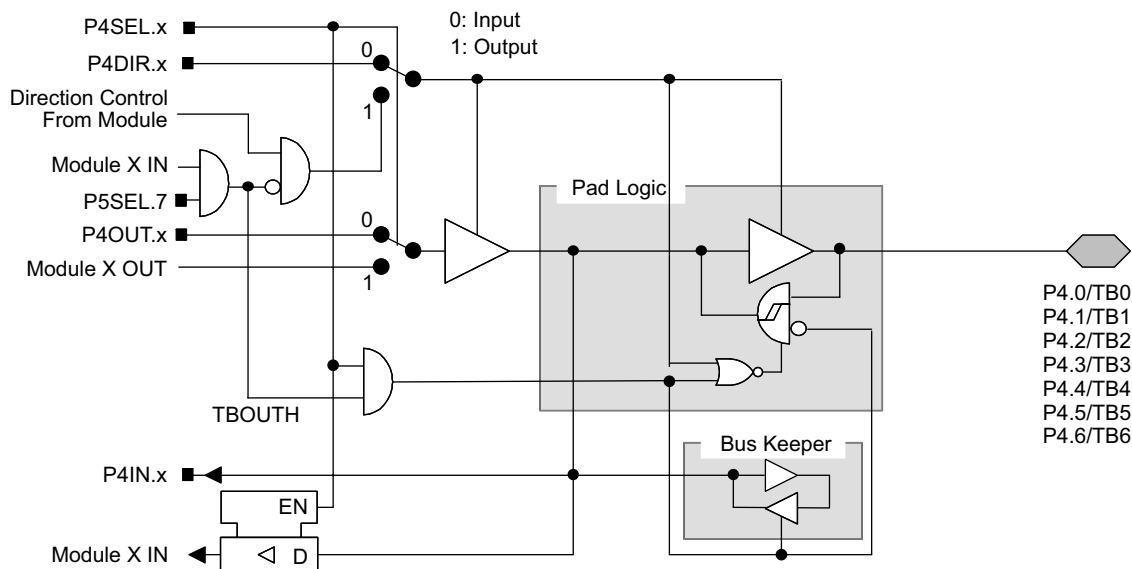


Figure 6-18. Port P4 (P4.0 to P4.6) Diagram

Table 6-21. Port P4 (P4.0 to P4.6) Pin Functions

| PnSel.x | PnDIR.x | DIRECTION CONTROL FROM MODULE | PnOUT.x | MODULE X OUT               | PnIN.x | MODULE X IN                  |
|---------|---------|-------------------------------|---------|----------------------------|--------|------------------------------|
| P4Sel.0 | P4DIR.0 | P4DIR.0                       | P4OUT.0 | Out0 signal <sup>(1)</sup> | P4IN.0 | CCI0A / CCI0B <sup>(2)</sup> |
| P4Sel.1 | P4DIR.1 | P4DIR.1                       | P4OUT.1 | Out1 signal <sup>(1)</sup> | P4IN.1 | CCI1A / CCI1B <sup>(2)</sup> |
| P4Sel.2 | P4DIR.2 | P4DIR.2                       | P4OUT.2 | Out2 signal <sup>(1)</sup> | P4IN.2 | CCI2A / CCI2B <sup>(2)</sup> |
| P4Sel.3 | P4DIR.3 | P4DIR.3                       | P4OUT.3 | Out3 signal <sup>(1)</sup> | P4IN.3 | CCI3A / CCI3B <sup>(2)</sup> |
| P4Sel.4 | P4DIR.4 | P4DIR.4                       | P4OUT.4 | Out4 signal <sup>(1)</sup> | P4IN.4 | CCI4A / CCI4B <sup>(2)</sup> |
| P4Sel.5 | P4DIR.5 | P4DIR.5                       | P4OUT.5 | Out5 signal <sup>(1)</sup> | P4IN.5 | CCI5A / CCI5B <sup>(2)</sup> |
| P4Sel.6 | P4DIR.6 | P4DIR.6                       | P4OUT.6 | Out6 signal <sup>(1)</sup> | P4IN.6 | CCI6A <sup>(2)</sup>         |

(1) Signal from Timer\_B

(2) Signal to Timer\_B

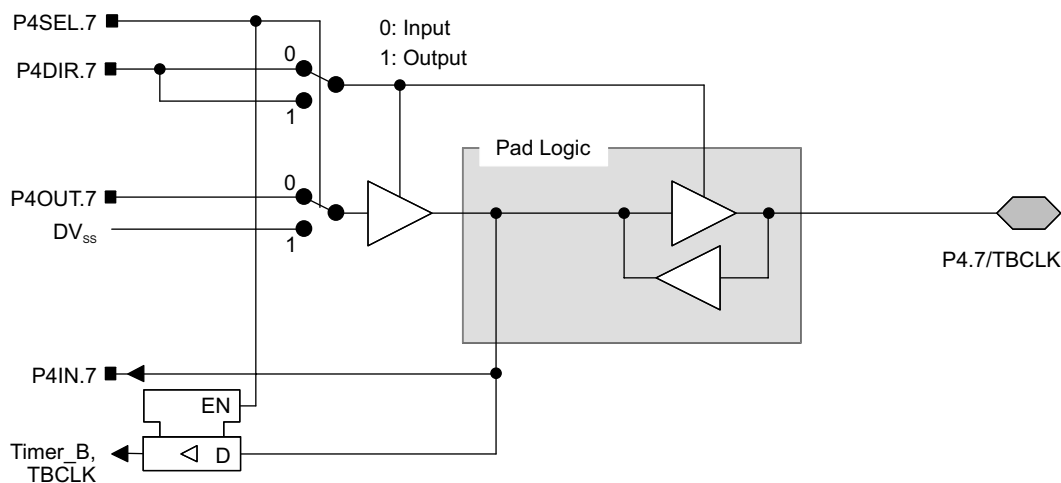
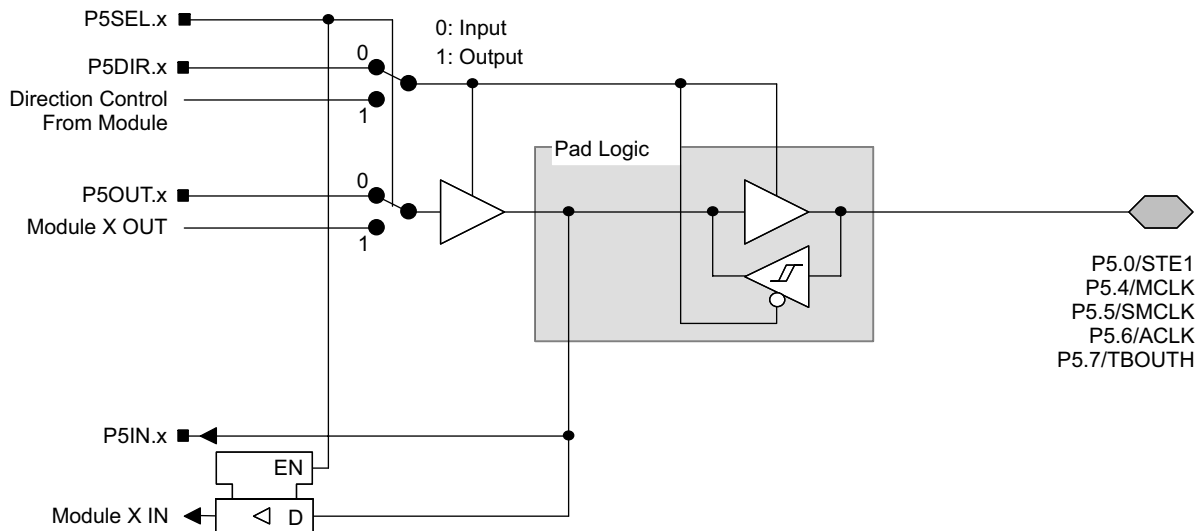


Figure 6-19. Port P4 (P4.7) Diagram

### 6.9.5 Port P5, Input/Output With Schmitt Trigger

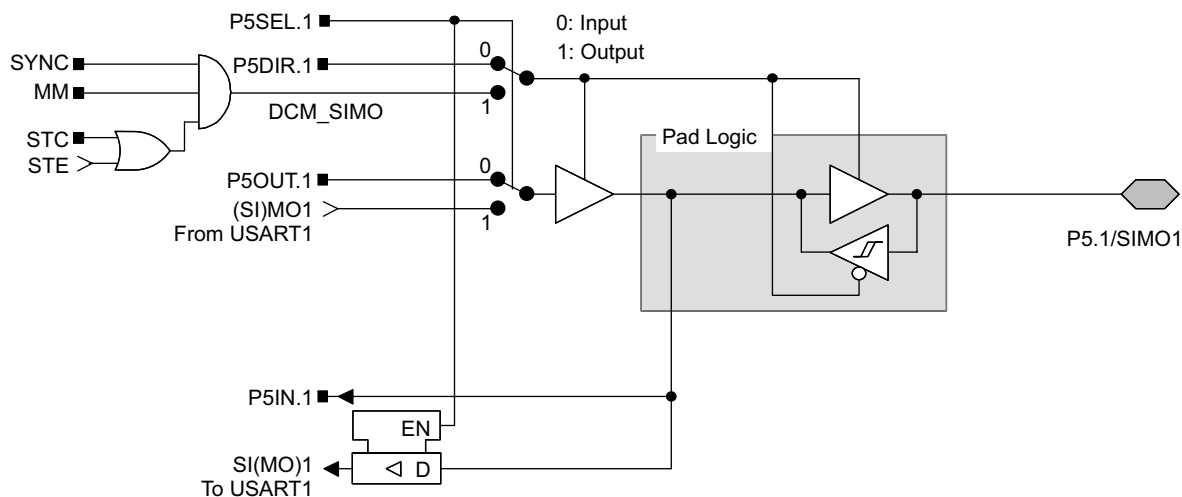


**Figure 6-20. Port P5 (P5.0 and P5.4 to P5.7) Diagram**

**Table 6-22. Port P5 (P5.0 and P5.4 to P5.7) Pin Functions**

| PnSel.x | PnDIR.x | DIRECTION CONTROL FROM MODULE | PnOUT.x | MODULE X OUT     | PnIN.x | MODULE X IN           |
|---------|---------|-------------------------------|---------|------------------|--------|-----------------------|
| P5Sel.0 | P5DIR.0 | DV <sub>SS</sub>              | P5OUT.0 | DV <sub>SS</sub> | P5IN.0 | STE.1                 |
| P5Sel.4 | P5DIR.4 | DV <sub>CC</sub>              | P5OUT.4 | MCLK             | P5IN.4 | unused                |
| P5Sel.5 | P5DIR.5 | DV <sub>CC</sub>              | P5OUT.5 | SMCLK            | P5IN.5 | unused                |
| P5Sel.6 | P5DIR.6 | DV <sub>CC</sub>              | P5OUT.6 | ACLK             | P5IN.6 | unused                |
| P5Sel.7 | P5DIR.7 | DV <sub>SS</sub>              | P5OUT.7 | DV <sub>SS</sub> | P5IN.7 | TBOUTH <sup>(1)</sup> |

(1) The TBOUTH signal is used by port module P4, pins P4.0 to P4.6. The function of TBOUTH is most useful when used with Timer\_B7.



**Figure 6-21. Port P5 (P5.1) Diagram**

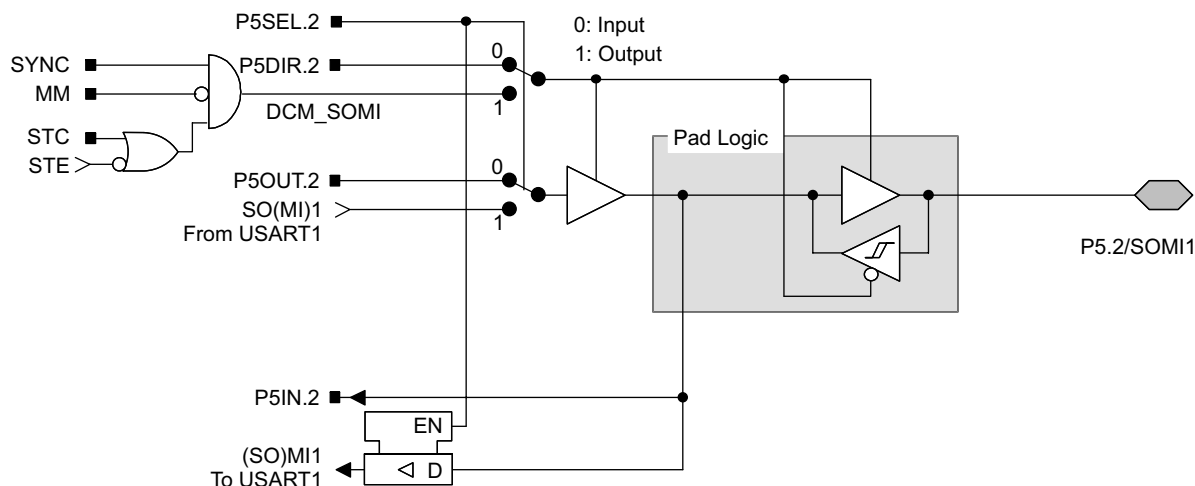
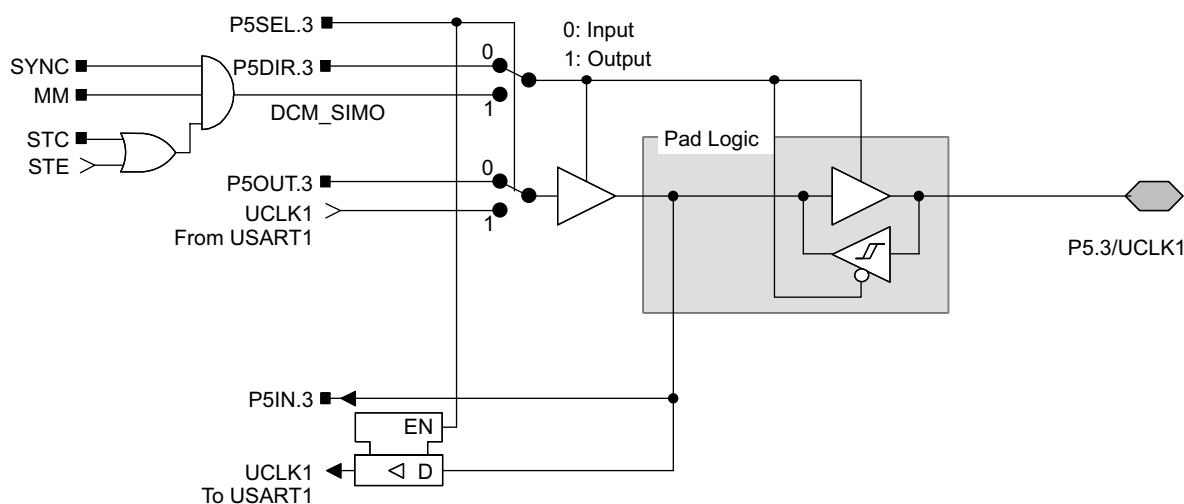


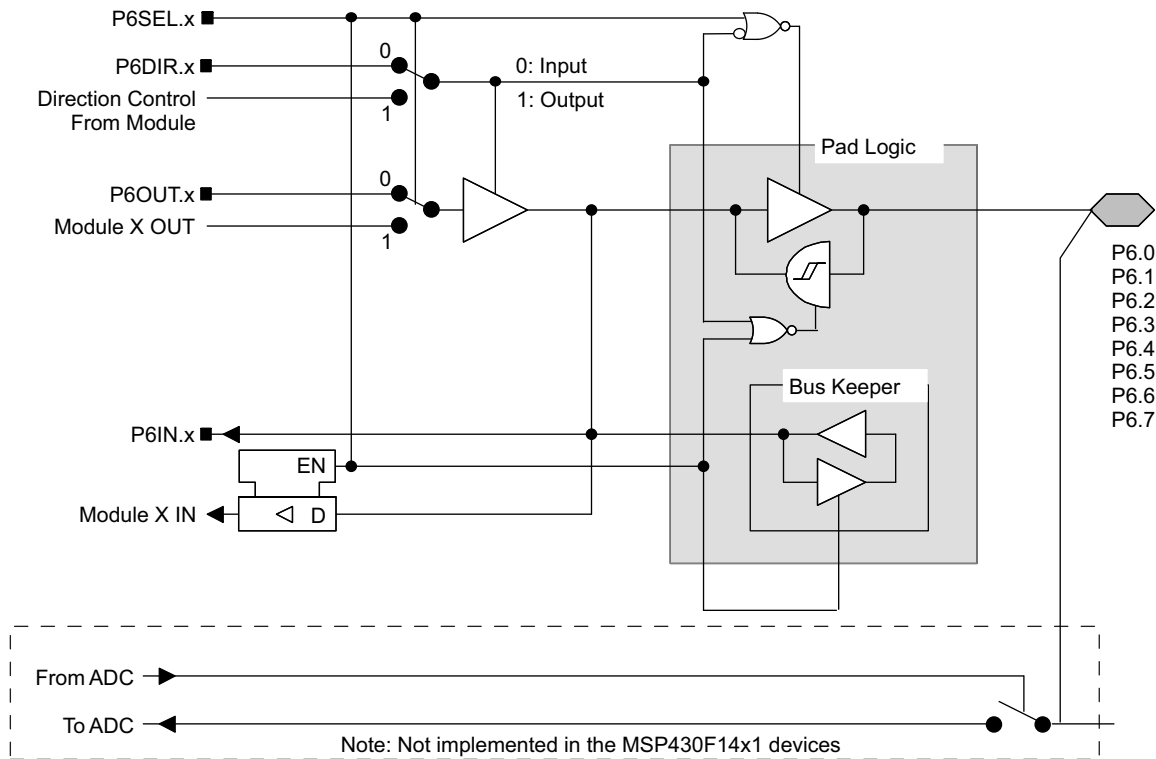
Figure 6-22. Port P5 (P5.2) Diagram



NOTE: UART mode: The UART clock can only be an input. If UART mode and UART function are selected, P5.3/UCLK1 is always an input.  
SPI slave mode: The clock applied to UCLK1 is used to shift data in and out.  
SPI master mode: The clock to shift data in and out is supplied to connected devices on pin P5.3/UCLK1 (in slave mode).

Figure 6-23. Port P5 (P5.3) Diagram

## 6.9.6 Port P6, Input/Output With Schmitt Trigger



NOTE: Analog signals applied to digital gates can cause current flow from the positive to the negative terminal. The throughput current flows if the analog signal is in the range of transitions 0→1 or 1→0. The value of the throughput current depends on the driving capability of the gate. For MSP430 MCUs, the current is approximately 100  $\mu$ A. Use P6SEL.x = 1 to prevent throughput current. P6SEL.x should be set, even if the signal at the pin is not being used by the ADC12.

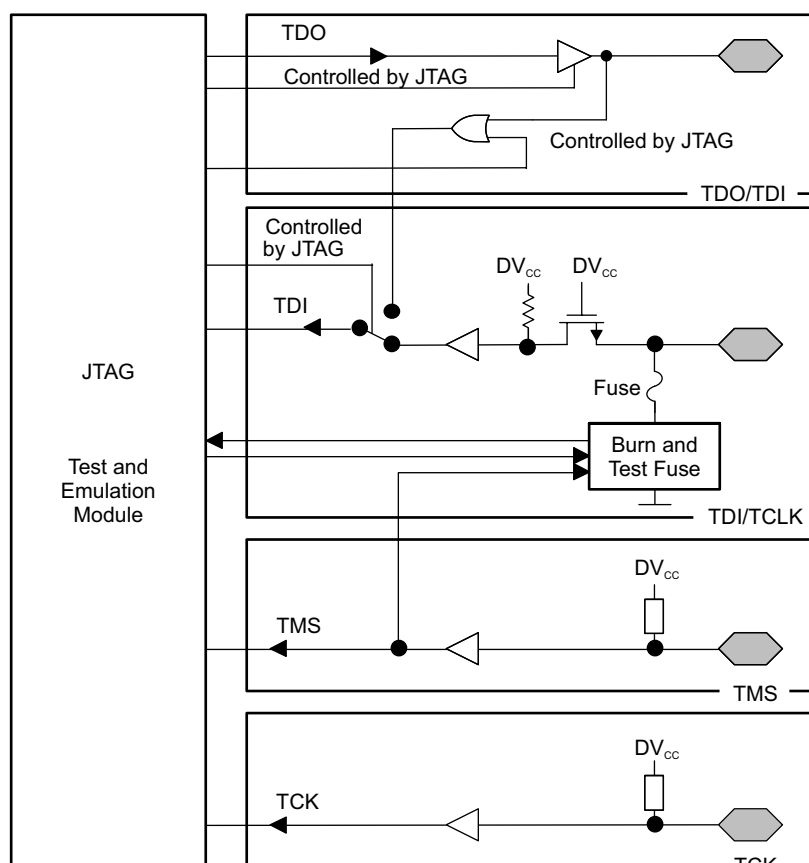
**Figure 6-24. Port P6 (P6.0 to P6.7) Diagram**

**Table 6-23. Port P6 (P6.0 to P6.7) Pin Functions<sup>(1)</sup>**

| PnSel.x | PnDIR.x | DIRECTION<br>CONTROL FROM<br>MODULE | PnOUT.x | MODULE X OUT     | PnIN.x | MODULE X IN |
|---------|---------|-------------------------------------|---------|------------------|--------|-------------|
| P6Sel.0 | P6DIR.0 | P6DIR.0                             | P6OUT.0 | DV <sub>SS</sub> | P6IN.0 | unused      |
| P6Sel.1 | P6DIR.1 | P6DIR.1                             | P6OUT.1 | DV <sub>SS</sub> | P6IN.1 | unused      |
| P6Sel.2 | P6DIR.2 | P6DIR.2                             | P6OUT.2 | DV <sub>SS</sub> | P6IN.2 | unused      |
| P6Sel.3 | P6DIR.3 | P6DIR.3                             | P6OUT.3 | DV <sub>SS</sub> | P6IN.3 | unused      |
| P6Sel.4 | P6DIR.4 | P6DIR.4                             | P6OUT.4 | DV <sub>SS</sub> | P6IN.4 | unused      |
| P6Sel.5 | P6DIR.5 | P6DIR.5                             | P6OUT.5 | DV <sub>SS</sub> | P6IN.5 | unused      |
| P6Sel.6 | P6DIR.6 | P6DIR.6                             | P6OUT.6 | DV <sub>SS</sub> | P6IN.6 | unused      |
| P6Sel.7 | P6DIR.7 | P6DIR.7                             | P6OUT.7 | DV <sub>SS</sub> | P6IN.7 | unused      |

(1) The signal at pins P6.x/Ax is used by the 12-bit ADC module.

### 6.9.7 Port JTAG (TMS, TCK, TDI/TCLK, TDO/TDI), Input/Output With Schmitt Trigger



During programming activity and during blowing of the fuse, the TDO/TDI pin is used to apply the test input data for JTAG circuitry.

**Figure 6-25. JTAG (TMS, TCK, TDI/TCLK, TDO/TDI) Diagram**

## 7 器件和文档支持

### 7.1 入门和后续步骤

有关 MSP430 系列器件以及有助于开发的工具和库的更多信息，请访问[入门](#)页面。

### 7.2 器件命名规则

为了标示产品开发周期所处的阶段，TI 为所有 MSP MCU 器件的部件号分配了前缀。每个 MSP MCU 商用系列产品成员都具有以下两个前缀之一：MSP 或 XMS。这些前缀代表了产品开发的发展阶段，即从工程原型 (XMS) 直到完全合格的生产器件 (MSP)。

**XMS** - 实验器件，不一定代表最终器件的电气规格

**MSP** - 完全合格的生产器件

XMS 器件在供货时附带如下免责声明：

“开发中的产品用于内部评估用途。”

MSP 器件的特性已经全部明确，并且器件的质量和可靠性已经完全论证。TI 的标准保修证书对该器件适用。

预测显示原型器件 (XMS) 的故障率大于标准生产器件。由于这些器件的预计最终使用故障率尚不确定，德州仪器 (TI) 建议不要将它们用于任何生产系统。请仅使用合格的生产器件。

TI 器件的命名规则还包括一个带有器件系列名称的后缀。此后缀表示温度范围、封装类型和配送形式。[图 7-1](#) 提供了解读完整器件名称的图例。

|                                      |                                                                                                                                |                                                                                                                                                                                             |
|--------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>MSP 430 F 5 438 A I ZQW T -EP</b> |                                                                                                                                |                                                                                                                                                                                             |
| Processor Family                     | MCU Platform                                                                                                                   | Optional: Additional Features                                                                                                                                                               |
| Device Type                          | Series                                                                                                                         | Optional: Tape and Reel                                                                                                                                                                     |
| Feature Set                          | Optional: Temperature Range                                                                                                    | Packaging                                                                                                                                                                                   |
| Optional: A = Revision               |                                                                                                                                |                                                                                                                                                                                             |
| <b>Processor Family</b>              | CC = Embedded RF Radio<br>MSP = Mixed-Signal Processor<br>XMS = Experimental Silicon<br>PMS = Prototype Device                 |                                                                                                                                                                                             |
| <b>MCU Platform</b>                  | 430 = MSP430 low-power microcontroller platform                                                                                |                                                                                                                                                                                             |
| <b>Device Type</b>                   | <b>Memory Type</b><br>C = ROM<br>F = Flash<br>FR = FRAM<br>G = Flash or FRAM (Value Line)<br>L = No Nonvolatile Memory         | <b>Specialized Application</b><br>AFE = Analog Front End<br>BQ = Contactless Power<br>CG = ROM Medical<br>FE = Flash Energy Meter<br>FG = Flash Medical<br>FW = Flash Electronic Flow Meter |
| <b>Series</b>                        | 1 = Up to 8 MHz<br>2 = Up to 16 MHz<br>3 = Legacy<br>4 = Up to 16 MHz with LCD                                                 | 5 = Up to 25 MHz<br>6 = Up to 25 MHz with LCD<br>0 = Low-Voltage Series                                                                                                                     |
| <b>Feature Set</b>                   | Various levels of integration within a series                                                                                  |                                                                                                                                                                                             |
| <b>Optional: A = Revision</b>        | N/A                                                                                                                            |                                                                                                                                                                                             |
| <b>Optional: Temperature Range</b>   | S = 0°C to 50°C<br>C = 0°C to 70°C<br>I = -40°C to 85°C<br>T = -40°C to 105°C                                                  |                                                                                                                                                                                             |
| <b>Packaging</b>                     | <a href="http://www.ti.com/packaging">http://www.ti.com/packaging</a>                                                          |                                                                                                                                                                                             |
| <b>Optional: Tape and Reel</b>       | T = Small reel<br>R = Large reel<br>No markings = Tube or tray                                                                 |                                                                                                                                                                                             |
| <b>Optional: Additional Features</b> | -EP = Enhanced Product (-40°C to 105°C)<br>-HT = Extreme Temperature Parts (-55°C to 150°C)<br>-Q1 = Automotive Q100 Qualified |                                                                                                                                                                                             |

NOTE: 该图不代表可用 特性 和选项的完整列表，也不表示所有这些 特性 和选项都可用于给定的器件或系列。

图 7-1. 器件命名规则 – 部件号解码器

## 7.3 工具和软件

表 7-1 列出了 MSP430F14x、MSP430F14x1 和 MSP430F13x 微控制器支持的调试特性。关于可用特性的详细信息，请参见《适用于 MSP430 的 Code Composer Studio 用户指南》。

表 7-1. 硬件 特性

| MSP430 架构 | 四线制 JTAG | 两线制 JTAG | 断点 | 范围断点 | 时钟控制 | 状态序列发生器 | 跟踪缓冲器 | LPMx.5 调试支持 |
|-----------|----------|----------|----|------|------|---------|-------|-------------|
| MSP430    | 是        | 否        | 3  | 是    | 否    | 否       | 否     | 否           |

### 设计套件与评估模块

**64 引脚目标开发板和 MSP-FET 编程器捆绑包 - MSP430F1x、MSP430F2x、MSP430F4x MCU** MSP-FET430U64 是一款强大的闪存仿真工具，它包含在 MSP430 MCU 上快速开始应用开发所需的硬件和软件。它包含 ZIF 插座目标板 (MSP-TS430PM64) 和 USB 调试接口 (MSP-FET)，用于通过 JTAG 接口对 MSP430 系统内置器件进行编程和调试。只需使用几个按键即可在数秒钟内擦除闪存并对其进行编程。由于 MSP430 闪存的功耗极低，因此无需外部电源。

**MSP-TS430PM64 - 适用于 MSP430F1x、MSP430F2x、MSP430F4x MCU 的 64 引脚目标开发板** MSP-TS430PM64 是一个独立的 ZIF 插座目标板，用于通过 JTAG 接口对 MSP430 MCU 系统内置器件进行编程和调试。

### 软件

**MSP430Ware™ 软件** MSP430Ware 软件集合了所有 MSP430 器件的代码示例、产品说明书以及其他设计资源，打包提供给用户。除了提供已有 MSP430 MCU 设计资源的完整集合外，MSP430Ware 软件还包含名为 MSP 驱动程序库的高级 API。借助该库可以轻松地对 MSP430 硬件进行编程。MSP430Ware 软件以 CCS 组件或独立软件包两种形式提供。

**MSP430F13x、MSP430F14x、MSP430F15x、MSP430F16x 代码示例** 根据不同应用需求配置各集成外设的每个 MSP 器件均具备相应的 C 代码示例。

**适用于 MSP 低功耗微控制器的引导加载程序 (BSL)** 引导加载程序 (BSL) 是内置到 MSP 低功耗微控制器中的应用程序。借助该应用程序，用户可以与器件通信，以便从其存储器中读取数据或向其中写入数据。该功能主要用于在原型设计、最终生产和服务期间对器件进行编程。可编程存储器（闪存）和数据存储器 (RAM) 可根据需要进行修改。

**适用于 MSP 的定点数学库** MSP IQmath 和 Qmath 库是为 C 语言开发者提供的一套经过高度优化的高精度数学运算函数集合，能够将浮点算法无缝嵌入 MSP430 和 MSP432 器件的定点代码中。这些例程通常用于计算密集型实时应用，而优化的执行速度、高精度以及超低能耗通常是影响这些实时应用的关键因素。与使用浮点数学算法编写的同等代码相比，使用 IQmath 和 Qmath 库可以大幅提高执行速度并显著降低能耗。

### 开发工具

**适用于 MSP 微控制器的 Code Composer Studio™ 集成开发环境** Code Composer Studio (CCS) 集成开发环境 (IDE) 支持所有 MSP 微控制器器件。CCS 包含一整套用于开发和调试嵌入式应用的嵌入式软件实用程序。CCS 包含了优化的 C/C++ 编译器、源代码编辑器、项目构建环境、调试器、描述器以及其他众多功能。

**命令行编程器** MSP Flasher 是一款基于 shell 的开源接口，可使用 JTAG 或 Spy-Bi-Wire (SBW) 通信通过 FET 编程器或 eZ430 对 MSP 微控制器进行编程。MSP Flasher 可用于将二进制文件 (.txt 或 .hex 文件) 直接下载到 MSP 微控制器，而无需使用 IDE。

**MSP MCU 编程器和调试器** MSP-FET 是一款强大的仿真开发工具（通常称为调试探针），可帮助用户在 MSP 低功耗微控制器 (MCU) 中快速开发应用。创建 MCU 软件通常需要将生成的二进制程序下载到 MSP 器件中，从而进行验证和调试。

**MSP-GANG 生产编程器** MSP Gang 编程器是一款 MSP430 或 MSP432 器件编程器，可同时对多达八个完全相同的 MSP430 或 MSP432 闪存或 FRAM 器件进行编程。MSP Gang 编程器可使用标准的 RS-232 或 USB 连接与主机 PC 相连并提供灵活的编程选项，允许用户完全自定义流程。

## 7.4 文档支持

以下文档对 MSP430F14x、MSP430F14x1 和 MSP430F13x MCU 进行了介绍。[www.ti.com.cn](http://www.ti.com.cn) 网站上提供了这些文档的副本。

### 接收文档更新通知

要接收文档更新通知（包括芯片勘误表），请转至 [ti.com.cn](http://ti.com.cn) 上您的器件对应的产品文件夹（关于产品文件夹的链接，请参见节 7.5）。请单击右上角的“通知我”按钮。点击注册后，即可收到产品信息更改每周摘要（如有）。有关更改的详细信息，请查阅已修订文档的修订历史记录。

## 勘误

《[MSP430F149 器件勘误表](#)》 介绍功能规格的已知例外情况。

《[MSP430F1491 器件勘误表](#)》 介绍功能规格的已知例外情况。

《[MSP430F148 器件勘误表](#)》 介绍功能规格的已知例外情况。

《[MSP430F1481 器件勘误表](#)》 介绍功能规格的已知例外情况。

《[MSP430F147 器件勘误表](#)》 介绍功能规格的已知例外情况。

《[MSP430F1471 器件勘误表](#)》 介绍功能规格的已知例外情况。

《[MSP430F135 器件勘误表](#)》 介绍功能规格的已知例外情况。

《[MSP430F133 器件勘误表](#)》 介绍功能规格的已知例外情况。

## 用户指南

《[MSP430x1xx 系列用户指南](#)》 该器件系列提供的所有模块和外设的详细说明。

《[MSP430 闪存器件引导加载程序 \(BSL\) 用户指南](#)》 MSP430™ 引导加载程序 (BSL) 允许用户在原型设计、最终生产和服务阶段与 MSP430 微控制器 (MCU) 中的嵌入式存储器进行通信。可编程存储器（闪存）和数据存储器 (RAM) 可根据需要进行修改。

《[通过 JTAG 接口对 MSP430 进行编程](#)》 此文档介绍了使用 JTAG 通信端口擦除、编程和验证基于 MSP430 闪存和 FRAM 的微控制器系列的存储器模块所需的功能。此外，该文档还介绍了如何编程所有 MSP430 器件上均具备的 JTAG 访问安全保险丝。此文档介绍了使用标准四线制 JTAG 接口和两线制 JTAG 接口（也称为 Spy-Bi-Wire (SBW)）的器件访问。

《[MSP430 硬件工具用户指南](#)》 此手册介绍了 TI MSP-FET430 闪存仿真工具 (FET) 的硬件。FET 是针对 MSP430 超低功耗微控制器的程序开发工具。文中对提供的接口类型，即并行端口接口和 USB 接口进行了说明。

## 应用报告

《**MSP430 32kHz 晶体振荡器**》 选择合适的晶体、正确的负载电路和适当的电路板布局是实现稳定的晶体振荡器的关键。该应用报告总结了晶体振荡器的功能，介绍了用于选择合适的晶体以实现 MSP430 超低功耗运行的参数。此外，还给出了正确电路板布局的提示和示例。此外，为了确保振荡器在大规模生产后能够稳定运行，还可能需要进行一些振荡器测试，该文档中提供了有关这些测试的详细信息。

《**适用于 MSP430™ MCU 的软件编码技术**》 该应用报告介绍了 MSP430 MCU 编程人员感兴趣的软件技术和相关主题。

《**对 MSP ADC 进行一般过采样以获得更高分辨率**》 多个 MSP430 超低功耗微控制器都可以提供用以将物理量转换成数字的 ADC，这是一种广泛用于大量应用的函数。但是，有时客户设计要求的分辨率会高于所选 MSP 可提供的 ADC 分辨率。该应用报告介绍了如何通过加入过采样方式来提高 ADC 分辨率，使其超过当前可实现的位数。

《**MSP430 系统级 ESD 注意事项**》 随着硅晶技术向更低电压方向发展以及设计具有成本效益的超低功耗组件的需求的出现，系统级 ESD 要求变得越来越苛刻。该应用报告介绍了三个不同的 ESD 主题，旨在帮助电路板设计人员和 OEM 理解并设计出稳健耐用的系统级设计。

## 7.5 相关链接

表 7-2 列出了快速访问链接。类别包括技术文档、支持和社区资源、工具和软件，以及立即购买的快速链接。

表 7-2. 相关链接

| 部件          | 产品文件夹                | 立即订购                 | 技术文档                 | 工具和软件                | 支持和社区                |
|-------------|----------------------|----------------------|----------------------|----------------------|----------------------|
| MSP430F149  | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> |
| MSP430F1491 | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> |
| MSP430F148  | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> |
| MSP430F1481 | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> |
| MSP430F147  | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> |
| MSP430F1471 | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> |
| MSP430F135  | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> |

## 7.6 社区资源

下列链接提供到 TI 社区资源的连接。链接的内容由各个分销商“按照原样”提供。这些内容并不构成 TI 技术规范，并且不一定反映 TI 的观点；请参见 TI 的《使用条款》。

### TI E2E™ 社区

TI 的工程师交流 (E2E) 社区。此社区的创建目的是为了促进工程师之间协作。在 [e2e.ti.com](http://e2e.ti.com) 中，您可以提问、共享知识、拓展思路，在同领域工程师的帮助下解决问题。

### TI 嵌入式处理器维基网页

德州仪器 (TI) 嵌入式处理器维基网页。此网站的建立是为了帮助开发人员熟悉德州仪器 (TI) 的嵌入式处理器，并且也为了促进与这些器件相关的硬件和软件的总体知识的创新和增长。

## 7.7 商标

MSP430, MSP430Ware, 适用于 MSP 微控制器的 Code Composer Studio, E2E are trademarks of Texas Instruments.

All other trademarks are the property of their respective owners.

## 7.8 静电放电警告



ESD 可能会损坏该集成电路。德州仪器 (TI) 建议通过适当的预防措施处理所有集成电路。如果不遵守正确的处理措施和安装程序，可能会损坏集成电路。

ESD 的损坏小至导致微小的性能降级，大至整个器件故障。精密的集成电路可能更容易受到损坏，这是因为非常细微的参数更改都可能会导致器件与其发布的规格不相符。

## 7.9 出口管制提示

接收方同意：如果美国或其他适用法律限制或禁止将通过非披露义务的披露方获得的任何产品或技术数据（其中包括软件）（见美国、欧盟和其他出口管理条例之定义）、或者其他适用国家条例限制的任何受管制产品或此项技术的任何直接产品出口或再出口至任何目的地，那么在没有事先获得美国商务部和其他相关政府机构授权的情况下，接收方不得在知情的情况下，以直接或间接的方式将其出口。

## 7.10 术语表

**TI 术语表** 这份术语表列出并解释术语、缩写和定义。

## 8 机械、封装和可订购信息

以下页面包含机械、封装和可订购信息。这些信息是指定器件的最新可用数据。数据如有变更，恕不另行通知，且不会对此文档进行修订。如需获取此产品说明书的浏览器版本，请查看左侧的导航栏。

## PACKAGING INFORMATION

| Orderable<br>part number        | Status<br>(1) | Material type<br>(2) | Package   Pins  | Package qty   Carrier      | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6) |
|---------------------------------|---------------|----------------------|-----------------|----------------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| <a href="#">MSP430F133IPAG</a>  | Active        | Production           | TQFP (PAG)   64 | 160   JEDEC<br>TRAY (10+1) | Yes         | NIPDAU                               | Level-4-260C-72 HR                | -40 to 85    | M430F133            |
| <a href="#">MSP430F133IPM</a>   | Active        | Production           | LQFP (PM)   64  | 160   JEDEC<br>TRAY (10+1) | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 85    | M430F133            |
| <a href="#">MSP430F133IPMR</a>  | Active        | Production           | LQFP (PM)   64  | 1000   LARGE T&R           | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 85    | M430F133            |
| <a href="#">MSP430F133IRTD</a>  | Active        | Production           | VQFN (RTD)   64 | 250   SMALL T&R            | Yes         | SN                                   | Level-3-260C-168 HR               | -40 to 85    | M430F133            |
| <a href="#">MSP430F135IPAG</a>  | Active        | Production           | TQFP (PAG)   64 | 160   JEDEC<br>TRAY (10+1) | Yes         | NIPDAU                               | Level-4-260C-72 HR                | -40 to 85    | M430F135<br>REV #   |
| <a href="#">MSP430F135IPM</a>   | Active        | Production           | LQFP (PM)   64  | 160   JEDEC<br>TRAY (10+1) | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 85    | M430F135<br>REV #   |
| <a href="#">MSP430F135IPMR</a>  | Active        | Production           | LQFP (PM)   64  | 1000   LARGE T&R           | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 85    | M430F135<br>REV #   |
| <a href="#">MSP430F135IRTD</a>  | Active        | Production           | VQFN (RTD)   64 | 2500   LARGE T&R           | Yes         | SN                                   | Level-3-260C-168 HR               | -40 to 85    | M430F135            |
| <a href="#">MSP430F135IRTD</a>  | Active        | Production           | VQFN (RTD)   64 | 250   SMALL T&R            | Yes         | SN                                   | Level-3-260C-168 HR               | -40 to 85    | M430F135            |
| <a href="#">MSP430F1471IPM</a>  | Active        | Production           | LQFP (PM)   64  | 160   JEDEC<br>TRAY (10+1) | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 85    | M430F1471<br>REV #  |
| <a href="#">MSP430F1471IPMR</a> | Active        | Production           | LQFP (PM)   64  | 1000   LARGE T&R           | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 85    | M430F1471<br>REV #  |
| <a href="#">MSP430F1471IRTD</a> | Active        | Production           | VQFN (RTD)   64 | 250   SMALL T&R            | Yes         | SN                                   | Level-3-260C-168 HR               | -40 to 85    | M430F1471           |
| <a href="#">MSP430F147IPAG</a>  | Active        | Production           | TQFP (PAG)   64 | 160   JEDEC<br>TRAY (10+1) | Yes         | NIPDAU                               | Level-4-260C-72 HR                | -40 to 85    | M430F147<br>REV #   |
| <a href="#">MSP430F147IPM</a>   | Active        | Production           | LQFP (PM)   64  | 160   JEDEC<br>TRAY (10+1) | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 85    | M430F147<br>REV #   |
| <a href="#">MSP430F147IPMR</a>  | Active        | Production           | LQFP (PM)   64  | 1000   LARGE T&R           | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 85    | M430F147<br>REV #   |
| <a href="#">MSP430F147IRTD</a>  | Active        | Production           | VQFN (RTD)   64 | 2500   LARGE T&R           | Yes         | SN                                   | Level-3-260C-168 HR               | -40 to 85    | M430F147            |
| <a href="#">MSP430F147IRTD</a>  | Active        | Production           | VQFN (RTD)   64 | 250   SMALL T&R            | Yes         | SN                                   | Level-3-260C-168 HR               | -40 to 85    | M430F147            |
| <a href="#">MSP430F1481IPM</a>  | Active        | Production           | LQFP (PM)   64  | 160   JEDEC<br>TRAY (10+1) | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 85    | M430F1481           |
| <a href="#">MSP430F1481IPMR</a> | Active        | Production           | LQFP (PM)   64  | 1000   LARGE T&R           | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 85    | M430F1481           |
| <a href="#">MSP430F1481IRTD</a> | Active        | Production           | VQFN (RTD)   64 | 250   SMALL T&R            | Yes         | SN                                   | Level-3-260C-168 HR               | -40 to 85    | M430F1481           |

| Orderable part number           | Status<br>(1) | Material type<br>(2) | Package   Pins  | Package qty   Carrier   | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6) |
|---------------------------------|---------------|----------------------|-----------------|-------------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| <a href="#">MSP430F148IPAG</a>  | Active        | Production           | TQFP (PAG)   64 | 160   JEDEC TRAY (10+1) | Yes         | NIPDAU                               | Level-4-260C-72 HR                | -40 to 85    | M430F148            |
| <a href="#">MSP430F148IPM</a>   | Active        | Production           | LQFP (PM)   64  | 160   JEDEC TRAY (10+1) | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 85    | M430F148<br>REV #   |
| <a href="#">MSP430F148IPMR</a>  | Active        | Production           | LQFP (PM)   64  | 1000   LARGE T&R        | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 85    | M430F148<br>REV #   |
| <a href="#">MSP430F148IRTDR</a> | Active        | Production           | VQFN (RTD)   64 | 2500   LARGE T&R        | Yes         | SN                                   | Level-3-260C-168 HR               | -40 to 85    | M430F148            |
| <a href="#">MSP430F148IRTD</a>  | Active        | Production           | VQFN (RTD)   64 | 250   SMALL T&R         | Yes         | SN                                   | Level-3-260C-168 HR               | -40 to 85    | M430F148            |
| <a href="#">MSP430F149IPM</a>   | Active        | Production           | LQFP (PM)   64  | 160   JEDEC TRAY (10+1) | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 85    | M430F1491           |
| <a href="#">MSP430F149IPMR</a>  | Active        | Production           | LQFP (PM)   64  | 1000   LARGE T&R        | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 85    | M430F1491           |
| <a href="#">MSP430F149IRTDR</a> | Active        | Production           | VQFN (RTD)   64 | 2500   LARGE T&R        | Yes         | SN                                   | Level-3-260C-168 HR               | -40 to 85    | M430F1491           |
| <a href="#">MSP430F149IRTD</a>  | Active        | Production           | VQFN (RTD)   64 | 250   SMALL T&R         | Yes         | SN                                   | Level-3-260C-168 HR               | -40 to 85    | M430F1491           |
| <a href="#">MSP430F149IPAG</a>  | Active        | Production           | TQFP (PAG)   64 | 160   JEDEC TRAY (10+1) | Yes         | NIPDAU                               | Level-4-260C-72 HR                | -40 to 85    | M430F149<br>REV #   |
| <a href="#">MSP430F149IPAGR</a> | Active        | Production           | TQFP (PAG)   64 | 1500   LARGE T&R        | Yes         | NIPDAU                               | Level-4-260C-72 HR                | -40 to 85    | M430F149<br>REV #   |
| <a href="#">MSP430F149IPM</a>   | Active        | Production           | LQFP (PM)   64  | 160   JEDEC TRAY (5+1)  | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 85    | M430F149<br>REV #   |
| <a href="#">MSP430F149IPMR</a>  | Active        | Production           | LQFP (PM)   64  | 1000   LARGE T&R        | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 85    | M430F149<br>REV #   |
| <a href="#">MSP430F149IRTDR</a> | Active        | Production           | VQFN (RTD)   64 | 2500   LARGE T&R        | Yes         | SN                                   | Level-3-260C-168 HR               | -40 to 85    | M430F149            |
| <a href="#">MSP430F149IRTD</a>  | Active        | Production           | VQFN (RTD)   64 | 250   SMALL T&R         | Yes         | SN                                   | Level-3-260C-168 HR               | -40 to 85    | M430F149            |

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

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

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

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

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

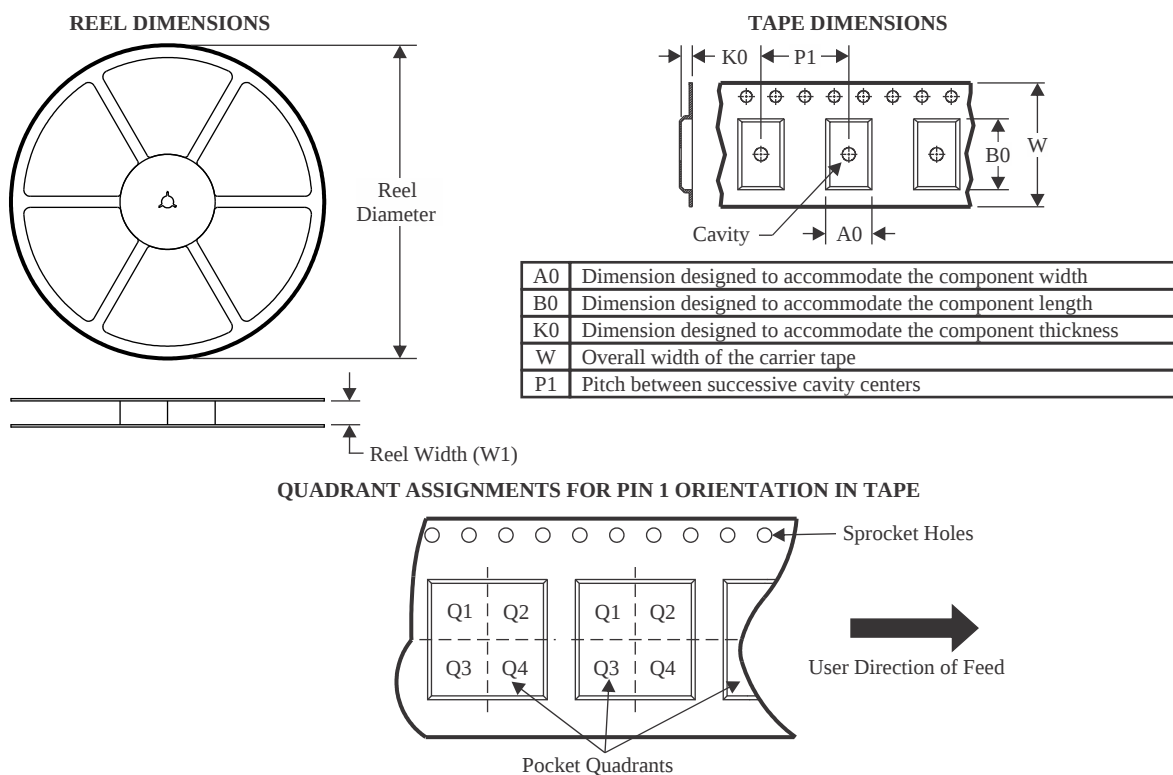
<sup>(6)</sup> **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

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

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## TAPE AND REEL INFORMATION

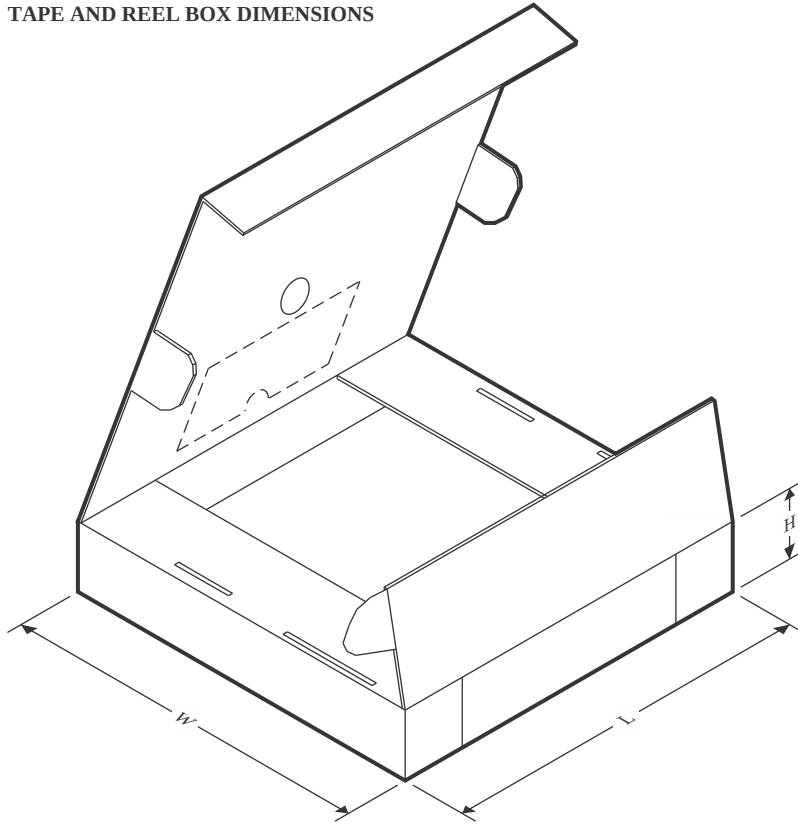


\*All dimensions are nominal

| Device          | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|-----------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| MSP430F133IPMR  | LQFP         | PM              | 64   | 1000 | 330.0              | 24.4               | 13.0    | 13.0    | 2.1     | 16.0    | 24.0   | Q2            |
| MSP430F133IRTD  | VQFN         | RTD             | 64   | 250  | 180.0              | 16.4               | 9.3     | 9.3     | 1.5     | 12.0    | 16.0   | Q2            |
| MSP430F135IPMR  | LQFP         | PM              | 64   | 1000 | 330.0              | 24.4               | 13.0    | 13.0    | 2.1     | 16.0    | 24.0   | Q2            |
| MSP430F135IRTD  | VQFN         | RTD             | 64   | 2500 | 330.0              | 16.4               | 9.3     | 9.3     | 1.5     | 12.0    | 16.0   | Q2            |
| MSP430F135IRTD  | VQFN         | RTD             | 64   | 250  | 180.0              | 16.4               | 9.3     | 9.3     | 1.5     | 12.0    | 16.0   | Q2            |
| MSP430F1471IPMR | LQFP         | PM              | 64   | 1000 | 330.0              | 24.4               | 13.0    | 13.0    | 2.1     | 16.0    | 24.0   | Q2            |
| MSP430F1471IRTD | VQFN         | RTD             | 64   | 250  | 180.0              | 16.4               | 9.3     | 9.3     | 1.5     | 12.0    | 16.0   | Q2            |
| MSP430F147IPMR  | LQFP         | PM              | 64   | 1000 | 330.0              | 24.4               | 13.0    | 13.0    | 2.1     | 16.0    | 24.0   | Q2            |
| MSP430F147IRTD  | VQFN         | RTD             | 64   | 2500 | 330.0              | 16.4               | 9.3     | 9.3     | 1.5     | 12.0    | 16.0   | Q2            |
| MSP430F147IRTD  | VQFN         | RTD             | 64   | 250  | 180.0              | 16.4               | 9.3     | 9.3     | 1.5     | 12.0    | 16.0   | Q2            |
| MSP430F1481IPMR | LQFP         | PM              | 64   | 1000 | 330.0              | 24.4               | 13.0    | 13.0    | 2.1     | 16.0    | 24.0   | Q2            |
| MSP430F1481IRTD | VQFN         | RTD             | 64   | 250  | 180.0              | 16.4               | 9.3     | 9.3     | 1.5     | 12.0    | 16.0   | Q2            |
| MSP430F148IPMR  | LQFP         | PM              | 64   | 1000 | 330.0              | 24.4               | 13.0    | 13.0    | 2.1     | 16.0    | 24.0   | Q2            |
| MSP430F148IRTD  | VQFN         | RTD             | 64   | 2500 | 330.0              | 16.4               | 9.3     | 9.3     | 1.5     | 12.0    | 16.0   | Q2            |
| MSP430F148IRTD  | VQFN         | RTD             | 64   | 250  | 180.0              | 16.4               | 9.3     | 9.3     | 1.5     | 12.0    | 16.0   | Q2            |
| MSP430F1491IPMR | LQFP         | PM              | 64   | 1000 | 330.0              | 24.4               | 13.0    | 13.0    | 2.1     | 16.0    | 24.0   | 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 |
|------------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| MSP430F1491IRTDR | VQFN         | RTD             | 64   | 2500 | 330.0              | 16.4               | 9.3     | 9.3     | 1.5     | 12.0    | 16.0   | Q2            |
| MSP430F1491IRTDI | VQFN         | RTD             | 64   | 250  | 180.0              | 16.4               | 9.3     | 9.3     | 1.5     | 12.0    | 16.0   | Q2            |
| MSP430F149IPAGR  | TQFP         | PAG             | 64   | 1500 | 330.0              | 24.4               | 13.0    | 13.0    | 1.5     | 16.0    | 24.0   | Q2            |
| MSP430F149IPMR   | LQFP         | PM              | 64   | 1000 | 330.0              | 24.4               | 13.0    | 13.0    | 2.1     | 16.0    | 24.0   | Q2            |
| MSP430F149IRTDR  | VQFN         | RTD             | 64   | 2500 | 330.0              | 16.4               | 9.3     | 9.3     | 1.5     | 12.0    | 16.0   | Q2            |
| MSP430F149IRTDI  | VQFN         | RTD             | 64   | 250  | 180.0              | 16.4               | 9.3     | 9.3     | 1.5     | 12.0    | 16.0   | Q2            |

## TAPE AND REEL BOX DIMENSIONS



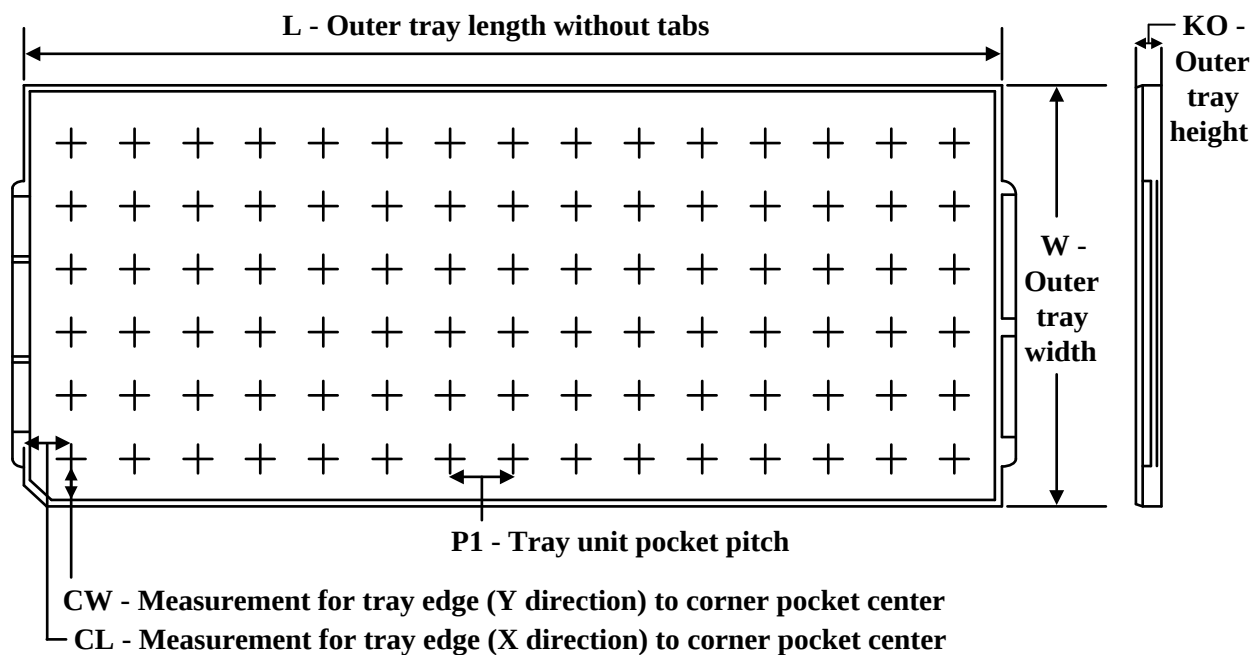
\*All dimensions are nominal

| Device          | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|-----------------|--------------|-----------------|------|------|-------------|------------|-------------|
| MSP430F133IPMR  | LQFP         | PM              | 64   | 1000 | 336.6       | 336.6      | 41.3        |
| MSP430F133IRTD  | VQFN         | RTD             | 64   | 250  | 210.0       | 185.0      | 35.0        |
| MSP430F135IPMR  | LQFP         | PM              | 64   | 1000 | 336.6       | 336.6      | 41.3        |
| MSP430F135IRTD  | VQFN         | RTD             | 64   | 2500 | 356.0       | 356.0      | 35.0        |
| MSP430F135IRTD  | VQFN         | RTD             | 64   | 250  | 210.0       | 185.0      | 35.0        |
| MSP430F1471IPMR | LQFP         | PM              | 64   | 1000 | 336.6       | 336.6      | 41.3        |
| MSP430F1471IRTD | VQFN         | RTD             | 64   | 250  | 210.0       | 185.0      | 35.0        |
| MSP430F1471IPMR | LQFP         | PM              | 64   | 1000 | 336.6       | 336.6      | 41.3        |
| MSP430F1471IRTD | VQFN         | RTD             | 64   | 2500 | 356.0       | 356.0      | 35.0        |
| MSP430F1471IRTD | VQFN         | RTD             | 64   | 250  | 210.0       | 185.0      | 35.0        |
| MSP430F1481IPMR | LQFP         | PM              | 64   | 1000 | 336.6       | 336.6      | 41.3        |
| MSP430F1481IRTD | VQFN         | RTD             | 64   | 250  | 210.0       | 185.0      | 35.0        |
| MSP430F1481IPMR | LQFP         | PM              | 64   | 1000 | 336.6       | 336.6      | 41.3        |
| MSP430F1481IRTD | VQFN         | RTD             | 64   | 2500 | 356.0       | 356.0      | 35.0        |
| MSP430F1481IRTD | VQFN         | RTD             | 64   | 250  | 210.0       | 185.0      | 35.0        |
| MSP430F1491IPMR | LQFP         | PM              | 64   | 1000 | 336.6       | 336.6      | 41.3        |
| MSP430F1491IRTD | VQFN         | RTD             | 64   | 2500 | 356.0       | 356.0      | 35.0        |
| MSP430F1491IRTD | VQFN         | RTD             | 64   | 250  | 210.0       | 185.0      | 35.0        |

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| Device          | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|-----------------|--------------|-----------------|------|------|-------------|------------|-------------|
| MSP430F149IPAGR | TQFP         | PAG             | 64   | 1500 | 350.0       | 350.0      | 43.0        |
| MSP430F149IPMR  | LQFP         | PM              | 64   | 1000 | 336.6       | 336.6      | 41.3        |
| MSP430F149IRTDR | VQFN         | RTD             | 64   | 2500 | 356.0       | 356.0      | 35.0        |
| MSP430F149IRTD  | VQFN         | RTD             | 64   | 250  | 210.0       | 185.0      | 35.0        |

## TRAY



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

\*All dimensions are nominal

| Device         | Package Name | Package Type | Pins | SPQ | Unit array matrix | Max temperature (°C) | L (mm) | W (mm) | K0 (μm) | P1 (mm) | CL (mm) | CW (mm) |
|----------------|--------------|--------------|------|-----|-------------------|----------------------|--------|--------|---------|---------|---------|---------|
| MSP430F133IPAG | PAG          | TQFP         | 64   | 160 | 8 x 20            | 150                  | 315    | 135.9  | 7620    | 15.2    | 13.1    | 13      |
| MSP430F133IPM  | PM           | LQFP         | 64   | 160 | 8 X 20            | 150                  | 315    | 135.9  | 7620    | 15.2    | 13.1    | 13      |
| MSP430F133IPM  | PM           | LQFP         | 64   | 160 | 8 x 20            | 150                  | 315    | 135.9  | 7620    | 15.2    | 13.1    | 13      |
| MSP430F135IPAG | PAG          | TQFP         | 64   | 160 | 8 x 20            | 150                  | 315    | 135.9  | 7620    | 15.2    | 13.1    | 13      |
| MSP430F135IPM  | PM           | LQFP         | 64   | 160 | 8 X 20            | 150                  | 315    | 135.9  | 7620    | 15.2    | 13.1    | 13      |
| MSP430F135IPM  | PM           | LQFP         | 64   | 160 | 8 x 20            | 150                  | 315    | 135.9  | 7620    | 15.2    | 13.1    | 13      |
| MSP430F1471IPM | PM           | LQFP         | 64   | 160 | 8 x 20            | 150                  | 315    | 135.9  | 7620    | 15.2    | 13.1    | 13      |
| MSP430F1471IPM | PM           | LQFP         | 64   | 160 | 8 X 20            | 150                  | 315    | 135.9  | 7620    | 15.2    | 13.1    | 13      |
| MSP430F147IPAG | PAG          | TQFP         | 64   | 160 | 8 x 20            | 150                  | 315    | 135.9  | 7620    | 15.2    | 13.1    | 13      |
| MSP430F147IPM  | PM           | LQFP         | 64   | 160 | 8 X 20            | 150                  | 315    | 135.9  | 7620    | 15.2    | 13.1    | 13      |
| MSP430F147IPM  | PM           | LQFP         | 64   | 160 | 8 x 20            | 150                  | 315    | 135.9  | 7620    | 15.2    | 13.1    | 13      |
| MSP430F1481IPM | PM           | LQFP         | 64   | 160 | 8 x 20            | 150                  | 315    | 135.9  | 7620    | 15.2    | 13.1    | 13      |
| MSP430F1481IPM | PM           | LQFP         | 64   | 160 | 8 X 20            | 150                  | 315    | 135.9  | 7620    | 15.2    | 13.1    | 13      |
| MSP430F148IPAG | PAG          | TQFP         | 64   | 160 | 8 x 20            | 150                  | 315    | 135.9  | 7620    | 15.2    | 13.1    | 13      |
| MSP430F148IPM  | PM           | LQFP         | 64   | 160 | 8 x 20            | 150                  | 315    | 135.9  | 7620    | 15.2    | 13.1    | 13      |
| MSP430F148IPM  | PM           | LQFP         | 64   | 160 | 8 X 20            | 150                  | 315    | 135.9  | 7620    | 15.2    | 13.1    | 13      |
| MSP430F1491IPM | PM           | LQFP         | 64   | 160 | 8 X 20            | 150                  | 315    | 135.9  | 7620    | 15.2    | 13.1    | 13      |

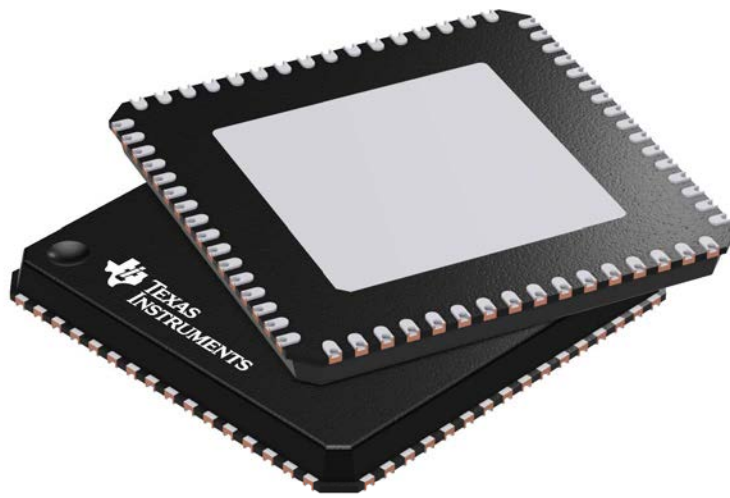
| Device          | Package Name | Package Type | Pins | SPQ | Unit array matrix | Max temperature (°C) | L (mm) | W (mm) | K0 (µm) | P1 (mm) | CL (mm) | CW (mm) |
|-----------------|--------------|--------------|------|-----|-------------------|----------------------|--------|--------|---------|---------|---------|---------|
| MSP430F1491IPM  | PM           | LQFP         | 64   | 160 | 8 x 20            | 150                  | 315    | 135.9  | 7620    | 15.2    | 13.1    | 13      |
| MSP430F149IPAG  | PAG          | TQFP         | 64   | 160 | 8 x 20            | 150                  | 315    | 135.9  | 7620    | 15.2    | 13.1    | 13      |
| MSP430F149IPM   | PM           | LQFP         | 64   | 160 | 8 x 20            | 150                  | 315    | 135.9  | 7620    | 15.2    | 13.1    | 13      |
| MSP430F149IPM   | PM           | LQFP         | 64   | 160 | 8 X 20            | 150                  | 315    | 135.9  | 7620    | 15.2    | 13.1    | 13      |
| MSP430F149IPMG4 | PM           | LQFP         | 64   | 160 | 8 X 20            | 150                  | 315    | 135.9  | 7620    | 15.2    | 13.1    | 13      |
| MSP430F149IPMG4 | PM           | LQFP         | 64   | 160 | 8 x 20            | 150                  | 315    | 135.9  | 7620    | 15.2    | 13.1    | 13      |

## GENERIC PACKAGE VIEW

**RTD 64**

**VQFNP - 0.9 mm max height**

PLASTIC QUAD FLATPACK - NO LEAD

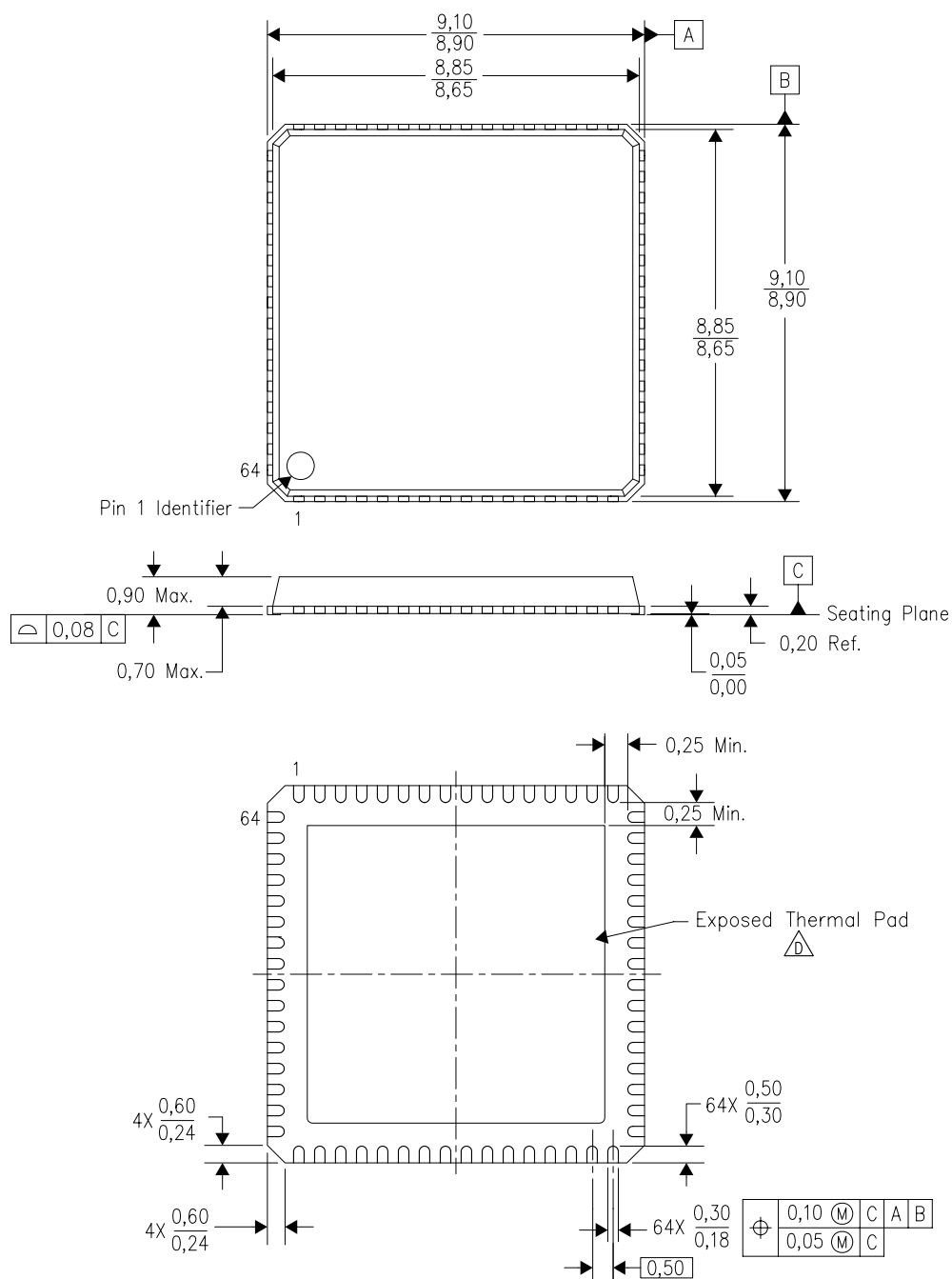


Images above are just a representation of the package family, actual package may vary.  
Refer to the product data sheet for package details.

4205146/D

RTD (S-PVQFN-N64)

PLASTIC QUAD FLATPACK NO-LEAD



4205146/C 12/10

- 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. QFN (Quad Flatpack No-Lead) Package configuration.
  - The package thermal pad must be soldered to the board for thermal and mechanical performance. See the Product Data Sheet for details regarding the exposed thermal pad dimensions.

RTD (S-PVQFN-N64)

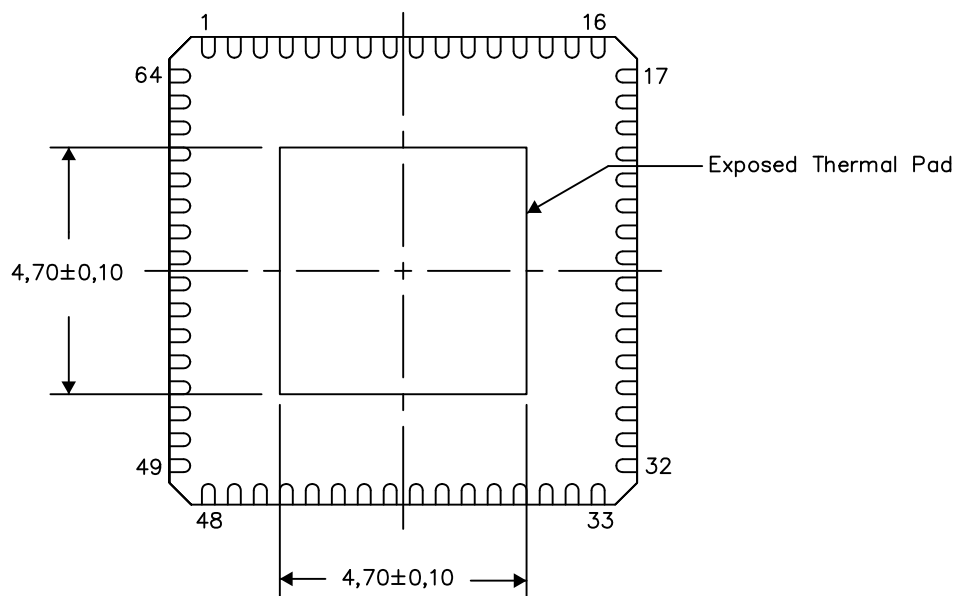
PLASTIC QUAD FLATPACK NO-LEAD

## THERMAL INFORMATION

This package incorporates an exposed thermal pad that is designed to be attached directly to an external heatsink. The thermal pad must be soldered directly to the printed circuit board (PCB). After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For information on the Quad Flatpack No-Lead (QFN) package and its advantages, refer to Application Report, QFN/SON PCB Attachment, Texas Instruments Literature No. SLUA271. This document is available at [www.ti.com](http://www.ti.com).

The exposed thermal pad dimensions for this package are shown in the following illustration.



Bottom View

Exposed Thermal Pad Dimensions

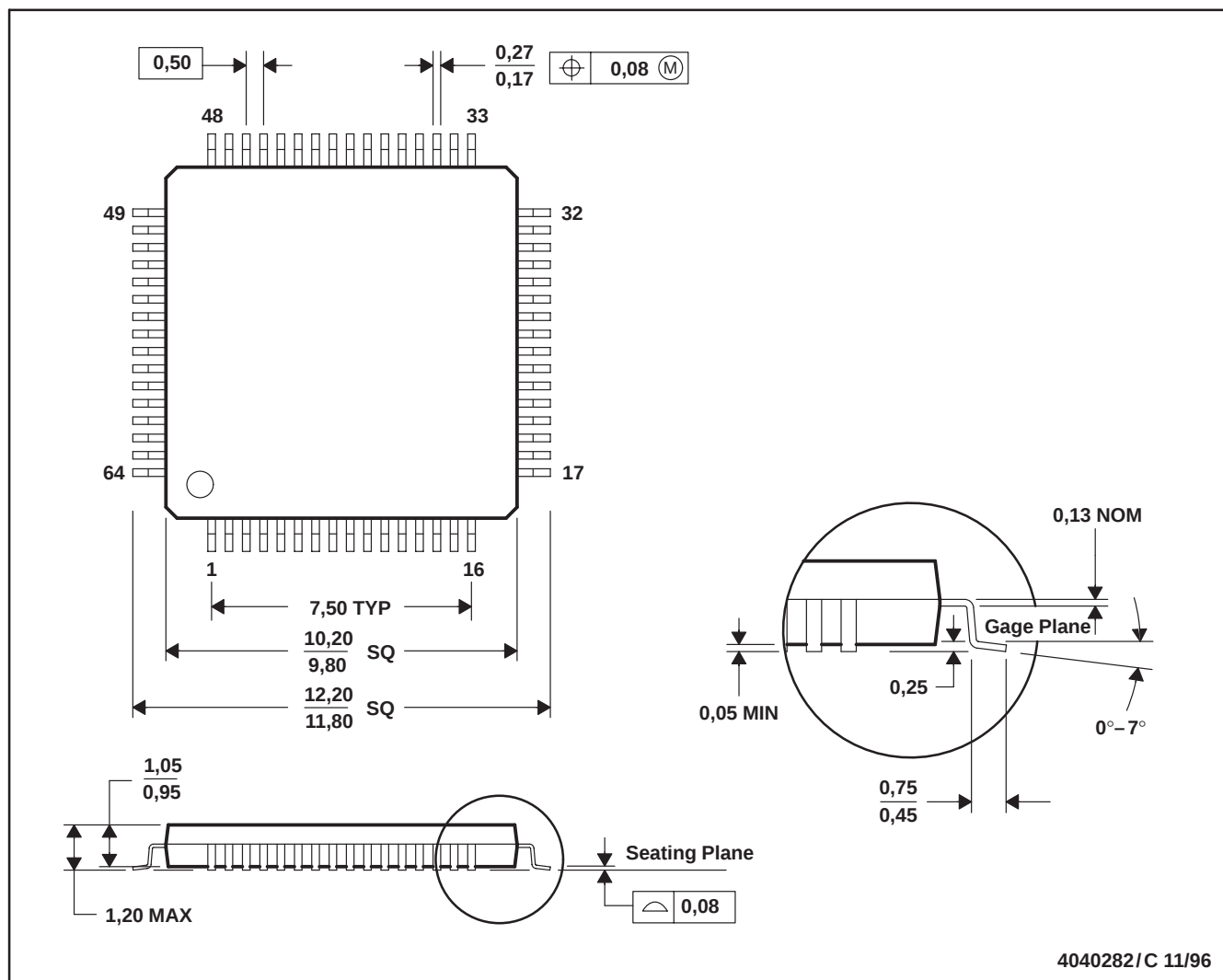
4206338-3/F 09/14

NOTE: A. All linear dimensions are in millimeters

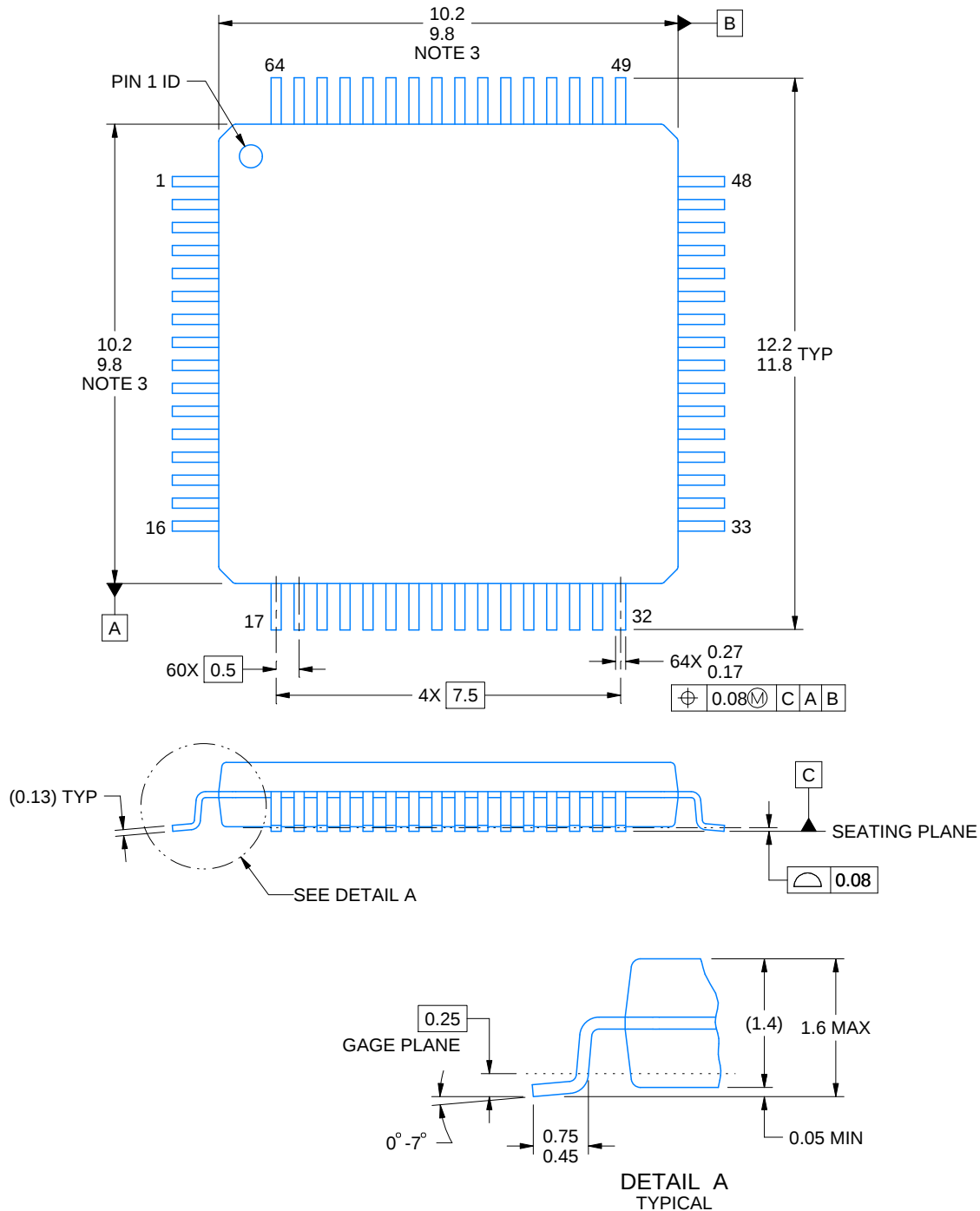
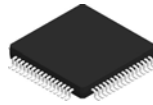


## PAG (S-PQFP-G64)

## PLASTIC QUAD FLATPACK



- NOTES: A. All linear dimensions are in millimeters.  
 B. This drawing is subject to change without notice.  
 C. Falls within JEDEC MS-026



4215162/A 03/2017

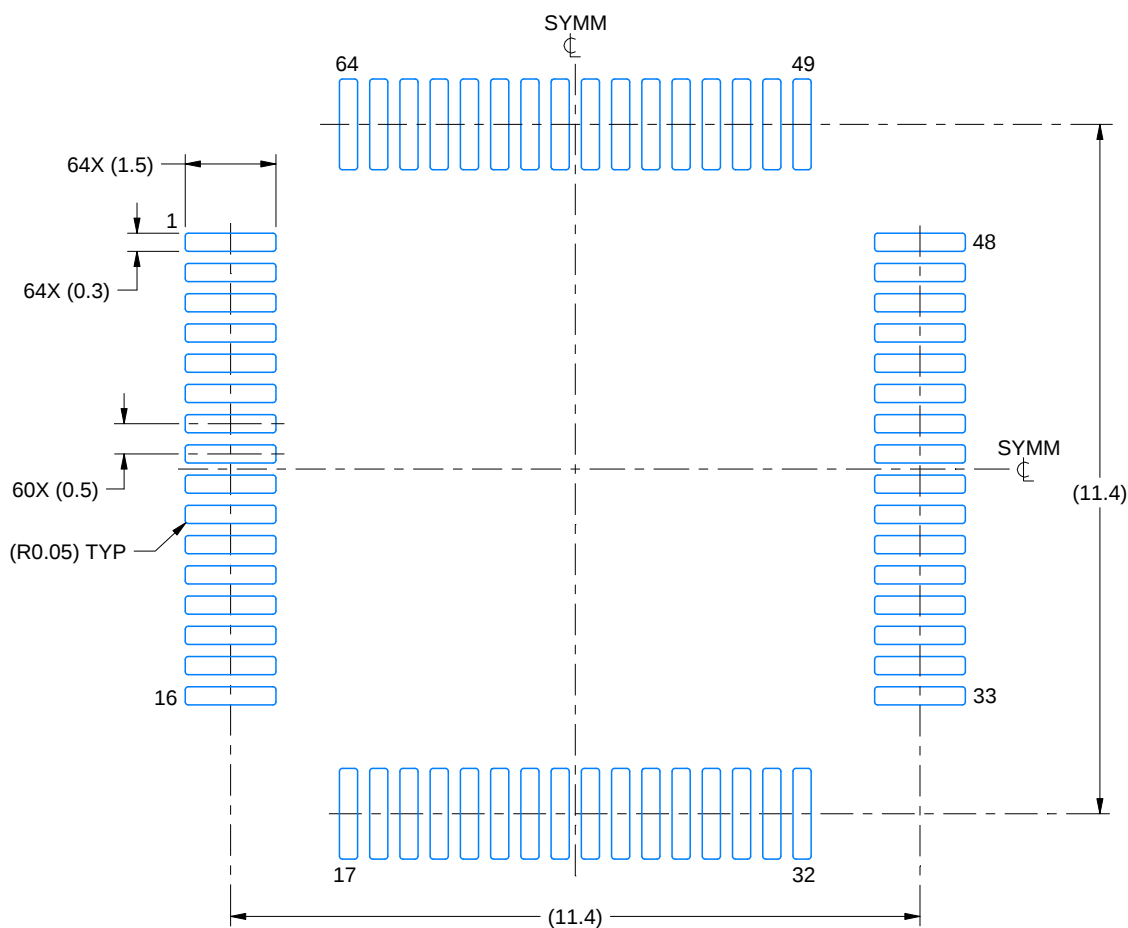
## NOTES:

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. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. Reference JEDEC registration MS-026.

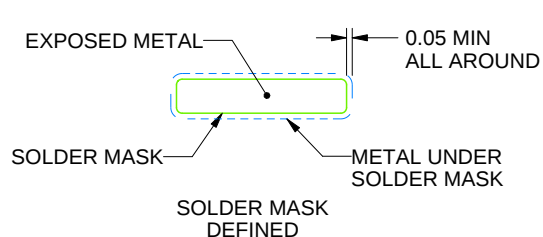
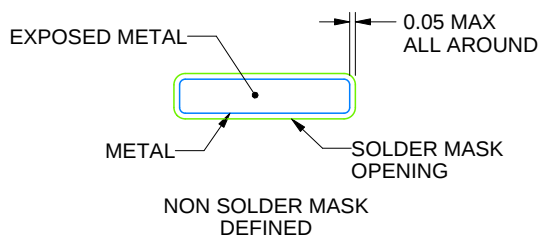
**PM0064A**

**LQFP - 1.6 mm max height**

## PLASTIC QUAD FLATPACK



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:8X



## SOLDER MASK DETAILS

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NOTES: (continued)

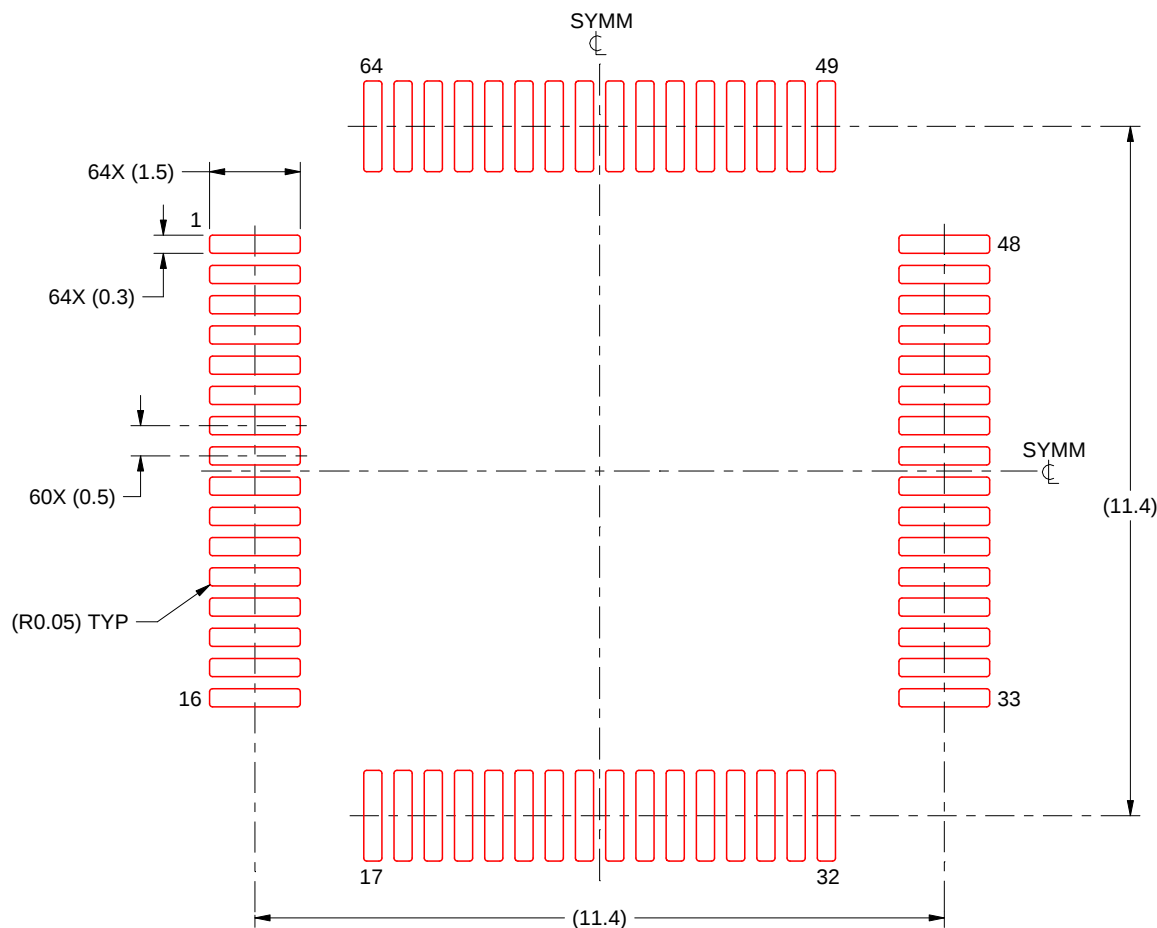
5. Publication IPC-7351 may have alternate designs.
6. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
7. For more information, see Texas Instruments literature number SLMA004 ([www.ti.com/lit/slma004](http://www.ti.com/lit/slma004)).

# EXAMPLE STENCIL DESIGN

PM0064A

LQFP - 1.6 mm max height

PLASTIC QUAD FLATPACK



SOLDER PASTE EXAMPLE  
 BASED ON 0.125 mm THICK STENCIL  
 SCALE:8X

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NOTES: (continued)

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

## 重要通知和免责声明

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