

## MSP430FR203x 混合信号微控制器

### 1 器件概述

#### 1.1 特性

- 嵌入式微控制器
  - 频率高达 16MHz 的 16 位精简指令集计算机 (RISC) 架构
  - 3.6V 至 1.8V 的宽电源电压范围 (最低电源电压受限于 SVS 电平, 请参阅 [SVS 规格](#))
- 经优化的低功耗模式 (3V)
  - 工作状态: 126 $\mu$ A/MHz
  - 待机
    - LPM3.5 (具有 VLO): 0.4 $\mu$ A
    - 实时时钟 (RTC) 计数器 (LPM3.5, 采用 32768Hz 晶振): 0.77 $\mu$ A
  - 关断 (LPM4.5): 15nA
- 低功耗铁电 RAM (FRAM)
  - 容量高达 15.5KB 的非易失性存储器
  - 内置错误修正码 (ECC)
  - 可配置的写保护
  - 对程序、常量和存储的统一存储
  - 耐写次数达 10<sup>15</sup> 次
  - 抗辐射和非磁性
- 智能数字外设
  - 红外调制逻辑
  - 两个 16 位定时器, 每个定时器有 3 个捕捉/比较寄存器 (Timer\_A3)
  - 一个仅用作计数器的 16 位 RTC 计数器
  - 16 位循环冗余校验 (CRC)
- 增强型串行通信
  - 增强型 USCI A (eUSCI\_A) 支持 UART、IrDA 和 SPI
  - 增强型 USCI B (eUSCI\_B) 支持 SPI 和 I<sup>2</sup>C
- 高性能模拟
  - 10 通道 10 位模数转换器 (ADC)
    - 1.5V 的内部基准电压
    - 采样与保持 200ksps
- 时钟系统 (CS)
  - 片上 32kHz RC 振荡器 (REFO)
  - 带有锁频环 (FLL) 的片上 16MHz 数控振荡器 (DCO)
    - 室温下的精度为  $\pm 1\%$  (具有片上基准)
  - 片上超低频 10kHz 振荡器 (VLO)
  - 片上高频调制振荡器时钟 (MODCLK)
  - 外部 32kHz 晶振 (XT1)
  - 可编程 MCLK 预分频器 (1 至 128)
  - 通过可编程预分频器 (1、2、4 或 8) 从 MCLK 获得的 SMCLK
- 通用输入/输出和引脚功能
  - 共计 60 个 I/O (64 引脚封装)
  - 16 个中断引脚 (P1 和 P2) 可以将 MCU 从 LPM 唤醒
  - 所有 I/O 均为电容式触控 I/O
- 开发工具和软件
  - 免费的专业开发环境
- 系列成员 (另请参阅 [器件比较](#))
  - MSP430FR2033: 15KB 程序 FRAM + 512B 信息 FRAM + 2KB RAM
  - MSP430FR2032: 8KB 程序 FRAM + 512B 信息 FRAM + 1KB RAM
- 封装选项
  - 64 引脚: LQFP (PM)
  - 56 引脚: TSSOP (G56)
  - 48 引脚: TSSOP (G48)

#### 1.2 应用

- 烟雾或火灾探测器
- 玻璃破裂探测器
- 工业传感器管理
- 系统监测器、低功耗控制器
- 温度传感器或控制器
- 数据存储、数据集成
- 人机界面 (HMI) 控制器

#### 1.3 说明

TI 的 MSP430™ 系列低功耗微控制器种类繁多, 各成员器件配备不同的外设集以满足各类应用的需求的需求。该架构与多种低功耗模式配合使用, 经过优化, 可在便携式测量应用延长电池寿命。此器件具有一个强大的 16 位精简指令集 (RISC) CPU, 使用 16 位寄存器以及常数发生器, 以便获得最高编码效率。DCO 可使器件在不到 10 $\mu$ s 的时间内从低功率模式唤醒并进入工作模式。



有关完整的模块说明，请参阅《MSP430FR4xx 和 MSP430FR2xx 系列器件用户指南》。

#### 器件信息<sup>(1)</sup>

| 器件型号             | 封装         | 封装尺寸 <sup>(2)</sup> |
|------------------|------------|---------------------|
| MSP430FR2033IPM  | LQFP (64)  | 10mm x 10mm         |
| MSP430FR2033IG56 | TSSOP (56) | 14.0mm x 6.1mm      |
| MSP430FR2033IG48 | TSSOP (48) | 12.5mm x 6.1mm      |
| MSP430FR2032IPM  | LQFP (64)  | 10mm x 10mm         |
| MSP430FR2032IG56 | TSSOP (56) | 14.0mm x 6.1mm      |
| MSP430FR2032IG48 | TSSOP (48) | 12.5mm x 6.1mm      |

- (1) 要获得最新的产品、封装和订购信息，请参见封装选项附录（节 9），或者访问德州仪器 (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 9）。

### 1.4 功能方框图

图 1-1 给出了功能框图。

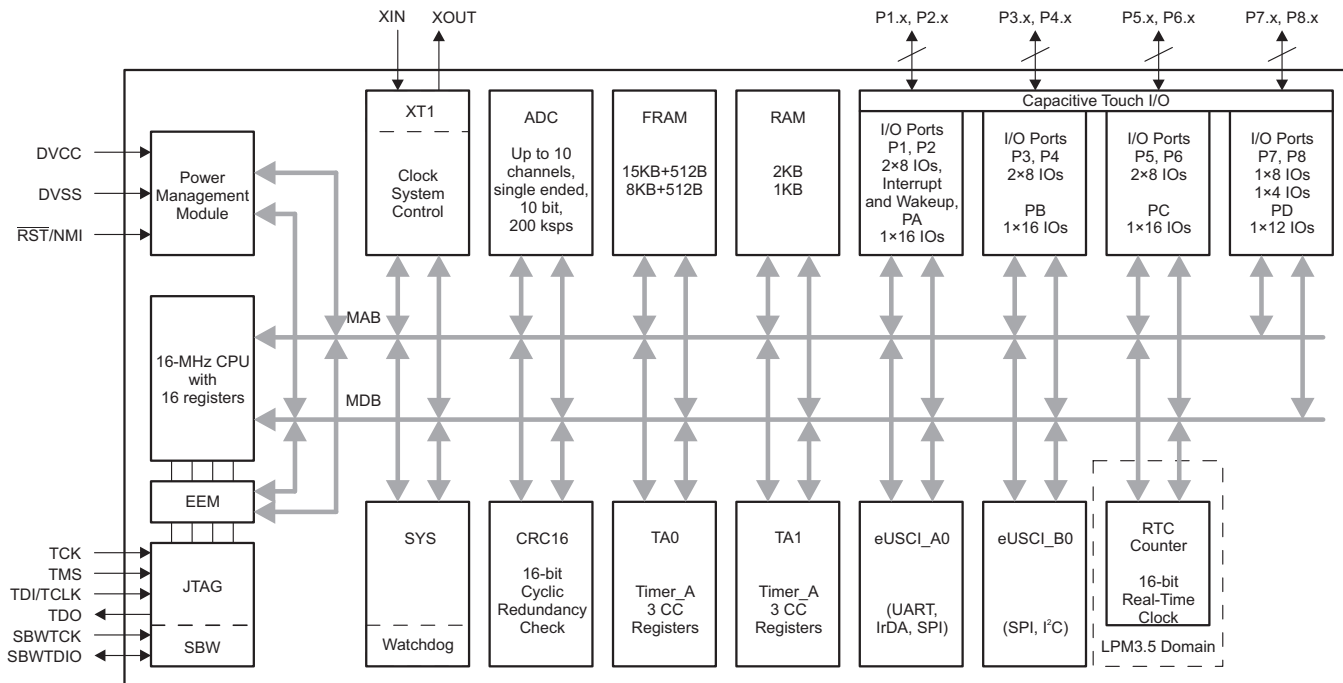


图 1-1. 功能框图

- 该器件具有一对主电源（DVCC 和 DVSS），分别为数字和模拟模块供电。推荐的旁路电容和去耦电容分别为 4.7 $\mu$ F 至 10 $\mu$ F 和 0.1 $\mu$ F，精度为  $\pm$ 5%。
- P1 和 P2 特有引脚中断功能，可将 MCU 从 LPM3.5 模式唤醒。
- 每个 Timer\_A3 均有 3 个 CC 寄存器，不过只有 CCR1 和 CCR2 从外部连接。CCR0 寄存器仅用于内部周期时序和产生中断。
- 在 LPM3.5 模式下，RTC 计数器可继续工作，而其余外设会停止工作。
- 在 TSSOP-56 和 TSSOP-48 封装中，并非所有 I/O 均已打线接合（请参见 Table 4-1）。所有 I/O 均可配置为电容式触摸 I/O。

## 内容

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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。

从修订版本 D 更改为修订版本 E

| Changes from January 22, 2019 to December 9, 2019   | Page |
|---|------|
| <ul style="list-style-type: none"> <li>Changed the note that begins "Supply voltage changes faster than 0.2 V/μs can trigger a BOR reset..." in <a href="#">Section 5.3, Recommended Operating Conditions</a> ..... <a href="#">15</a></li> <li>Added the note that begins "TI recommends that power to the DVCC pin must not exceed the limits..." in <a href="#">Section 5.3, Recommended Operating Conditions</a> ..... <a href="#">15</a></li> <li>Changed the note that begins "A capacitor tolerance of ±20% or better is required..." in <a href="#">Section 5.3, Recommended Operating Conditions</a> ..... <a href="#">15</a></li> <li>Added the note "See <i>MSP430 32-kHz Crystal Oscillators</i> for details on crystal section, layout, and testing" to <a href="#">Table 5-3, XT1 Crystal Oscillator (Low Frequency)</a> ..... <a href="#">22</a></li> <li>Changed the note that begins "Requires external capacitors at both terminals..." in <a href="#">Table 5-3, XT1 Crystal Oscillator (Low Frequency)</a> ..... <a href="#">22</a></li> <li>Added the <math>t_{(int)}</math> parameter in <a href="#">Table 5-8, Digital Inputs</a> ..... <a href="#">24</a></li> <li>Added the <math>t_{TA, cap}</math> parameter in <a href="#">Table 5-10, Timer_A</a> ..... <a href="#">25</a></li> <li>Corrected the test conditions for the <math>R_{I, MUX}</math> parameter in <a href="#">Table 5-17, ADC, Power Supply and Input Range Conditions</a> ..... <a href="#">31</a></li> <li>Added the note that begins "<math>t_{Sample} = \ln(2^{n+1}) \times \tau</math> ..." in <a href="#">Table 5-18, ADC, 10-Bit Timing Parameters</a> ..... <a href="#">31</a></li> </ul> |      |

从修订版本 C 更改为修订版本 D

| Changes from August 30, 2018 to January 21, 2019   | Page |
|--|------|
| <ul style="list-style-type: none"> <li>已通篇将调制振荡器 (MODOSC) 更改为调制振荡器时钟 (MODCLK) ..... <a href="#">1</a></li> <li>Added "or memory corruption" to note (1) in <a href="#">Section 5.1, Absolute Maximum Ratings</a> ..... <a href="#">15</a></li> <li>Added the note that begins "The VLO clock frequency is reduced by..." after <a href="#">Table 5-6, Internal Very-Low-Power Low-Frequency Oscillator (VLO)</a> ..... <a href="#">23</a></li> <li>Added the <math>t_{TA, cap}</math> parameter in <a href="#">Table 5-10, Timer_A</a> ..... <a href="#">25</a></li> <li>Changed the parameter symbol from <math>R_I</math> to <math>R_{I, MUX}</math> in <a href="#">Table 5-17, ADC, Power Supply and Input Range Conditions</a> .. <a href="#">31</a></li> <li>Added the <math>R_{I, Misc}</math> parameter in <a href="#">Table 5-17, ADC, Power Supply and Input Range Conditions</a> ..... <a href="#">31</a></li> <li>Removed ADCDIV from the formula for the <math>t_{CONVERT}</math> TYP value, because ADCCLK is after division, in <a href="#">Table 5-18, ADC, 10-Bit Timing Parameters</a> ..... <a href="#">31</a></li> <li>Added note (2) for <math>R_I</math> calculation in <a href="#">Table 5-18, ADC, 10-Bit Timing Parameters</a> ..... <a href="#">31</a></li> <li>Removed "±3°C" on both temperatures in the note that begins "The device descriptor structure contains..." in <a href="#">Table 5-19, ADC, 10-Bit Linearity Parameters</a> ..... <a href="#">32</a></li> <li>Add "10b" for ADCSSEL bit in <a href="#">Table 6-6, Clock Distribution</a> ..... <a href="#">39</a></li> <li>Added <a href="#">Figure 6-1, Clock Distribution Block Diagram</a> ..... <a href="#">39</a></li> <li>Corrected the spelling of the IRDSSEL bit in the paragraph that begins "The IR functions are controlled by..." in <a href="#">Section 6.9.8, Timers (Timer0_A3, Timer1_A3)</a> ..... <a href="#">44</a></li> <li>Changed two instances of "ADC 1.5-V Reference Temperature" to "ADC 1.5-V Reference Temperature Sensor" in <a href="#">Table 6-29, Device Descriptors</a> ..... <a href="#">62</a></li> </ul> |      |

从修订版本 B 更改为修订版本 C

| Changes from August 15, 2015 to August 29, 2018  | Page |
|--|------|
| <ul style="list-style-type: none"> <li>Updated <a href="#">Section 3.1, Related Products</a> ..... <a href="#">7</a></li> <li>Replaced all notes on <a href="#">Section 5.11, Thermal Characteristics</a> ..... <a href="#">19</a></li> <li>Added note to <math>V_{SVSH-}</math> and <math>V_{SVSH+}</math> parameters in <a href="#">Table 5-1, PMM, SVS and BOR</a> ..... <a href="#">20</a></li> <li>Added the <math>t_{TA, cap}</math> parameter in <a href="#">Table 5-10, Timer_A</a> ..... <a href="#">25</a></li> <li>Updated the link to the BSL user's guide in <a href="#">Section 6.4, Bootloader (BSL)</a> ..... <a href="#">36</a></li> <li>Changed all instances of "bootstrap loader" to "bootloader" throughout document ..... <a href="#">36</a></li> <li>Corrected the ADCINCHx column heading in <a href="#">Table 6-12, ADC Channel Connections</a> ..... <a href="#">45</a></li> </ul> |      |

- 更新了节 8, 器件和文档支持 中的特定于器件的信息和链接 ..... [76](#)

从修订版本 A 更改为修订版本 B

| Changes from December 23, 2014 to August 14, 2015  | Page |
|--|------|
| <ul style="list-style-type: none"> <li>Corrected "10-BIT ADC CHANNELS" column for MSP430FR2032IPM in <a href="#">Table 3-1, Device Comparison</a> ..... <a href="#">7</a></li> <li>Added <math>T_{stg}</math> MIN and MAX values ..... <a href="#">15</a></li> <li>Added <a href="#">Section 5.2, ESD Ratings</a>..... <a href="#">15</a></li> <li>Changed all graphs in <a href="#">Section 5.9, Typical Characteristics, Low-Power Mode Supply Currents</a>, for new measurements ..... <a href="#">18</a></li> <li>Added <math>V_{REF, 1.2V}</math> parameter to <a href="#">Table 5-1, PMM, SVS and BOR</a>..... <a href="#">20</a></li> <li>Added the <math>t_{TA, cap}</math> parameter in <a href="#">Table 5-10, Timer_A</a>..... <a href="#">25</a></li> <li>Changed <math>t_{STE, LEAD}</math> MIN value at 2 V from 40 ns to 50 ns ..... <a href="#">28</a></li> <li>Changed <math>t_{STE, LEAD}</math> MIN value at 3 V from 24 ns to 45 ns ..... <a href="#">28</a></li> <li>Changed <math>t_{VALID, SO}</math> MAX value at 2 V from 55 ns to 65 ns ..... <a href="#">28</a></li> <li>Changed <math>t_{VALID, SO}</math> MAX value at 3 V from 30 ns to 40 ns ..... <a href="#">28</a></li> <li>Changed the <math>f_{ADCOSC}</math> TYP value from 4.5 MHz to 5.0 MHz..... <a href="#">31</a></li> <li>In <a href="#">Table 6-1, Operating Modes</a>, changed the entry for "Power Consumption at 25°C, 3 V" in AM from 100 <math>\mu</math>A/MHz to 126 <math>\mu</math>A/MHz ..... <a href="#">34</a></li> <li>In <a href="#">Table 6-1, Operating Modes</a>, added "with RTC only" to the entry for "Power Consumption at 25°C, 3 V" in LPM3.5 ..... <a href="#">34</a></li> <li>In <a href="#">Table 6-2, Interrupt Sources, Flags, and Vectors</a>, removed "FRAM access time error" (ACCTEIFG) from the "System NMI" row ..... <a href="#">35</a></li> </ul> |      |

从初始发行版更改为修订版本 A

| Changes from October 3, 2014 to December 22, 2014   | Page |
|---|------|
| <ul style="list-style-type: none"> <li>Moved <math>T_{stg}</math> to <a href="#">Absolute Maximum Ratings</a> ..... <a href="#">15</a></li> <li>Added the <math>t_{TA, cap}</math> parameter in <a href="#">Table 5-10, Timer_A</a>..... <a href="#">25</a></li> <li>Changed link to BSL user's guide in <a href="#">Section 6.4, Bootloader (BSL)</a> ..... <a href="#">36</a></li> <li>Added note (1) to <a href="#">Table 6-6</a> ..... <a href="#">39</a></li> <li>Changed the values of ADC Calibration Tag and ADC Calibration Length in the ADC Calibration row..... <a href="#">62</a></li> <li>Added Calibration Tag, Calibration Length, and 1.5-V Reference in the Reference and DCO Calibration row ..... <a href="#">63</a></li> <li>Added row for BSL memory to <a href="#">Table 6-30</a>..... <a href="#">63</a></li> </ul> |      |

### 3 Device Comparison

Table 3-1 summarizes the features of the available family members.

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

| DEVICE           | PROGRAM FRAM + INFORMATION FRAM (BYTES) | SRAM (BYTES) | TA0, TA1               | eUSCI_A | eUSCI_B | 10-BIT ADC CHANNELS | I/O | PACKAGE       |
|------------------|---|--------------|------------------------|---------|---------|---------------------|-----|---------------|
| MSP430FR2033IPM  | 15360 + 512                             | 2048         | 3 × CCR <sup>(3)</sup> | 1       | 1       | 10                  | 60  | PM (LQFP64)   |
| MSP430FR2033IG56 | 15360 + 512                             | 2048         | 3 × CCR <sup>(3)</sup> | 1       | 1       | 8                   | 52  | G56 (TSSOP56) |
| MSP430FR2033IG48 | 15360 + 512                             | 2048         | 3 × CCR <sup>(3)</sup> | 1       | 1       | 8                   | 44  | G48 (TSSOP48) |
| MSP430FR2032IPM  | 8192 + 512                              | 1024         | 3 × CCR <sup>(3)</sup> | 1       | 1       | 10                  | 60  | PM (LQFP64)   |
| MSP430FR2032IG56 | 8192 + 512                              | 1024         | 3 × CCR <sup>(3)</sup> | 1       | 1       | 8                   | 52  | G56 (TSSOP56) |
| MSP430FR2032IG48 | 8192 + 512                              | 1024         | 3 × CCR <sup>(3)</sup> | 1       | 1       | 8                   | 44  | G48 (TSSOP48) |

- (1) For the most current device, package, and ordering information, see the *Package Option Addendum* in [§ 9](#), or see the TI website at [www.ti.com](http://www.ti.com).
- (2) Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at [www.ti.com/packaging](http://www.ti.com/packaging).
- (3) A CCR register is a configurable register that provides internal and external capture or compare inputs, or internal and external PWM outputs.

#### 3.1 Related Products

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

[TI 16-bit and 32-bit microcontrollers](#)

High-performance low-power solutions to enable the autonomous future

[Products for MSP430 ultra-low-power sensing & measurement MCUs](#)

One platform. One ecosystem. Endless possibilities.

[Companion products for MSP430FR2033](#)

Review products that are frequently purchased or used with this product.

[Reference designs for MSP430FR2033](#)

Find reference designs leveraging the best in TI technology to solve your system-level challenges.

## 4 Terminal Configuration and Functions

### 4.1 Pin Diagrams

Figure 4-1 shows the 64-pin PM package.

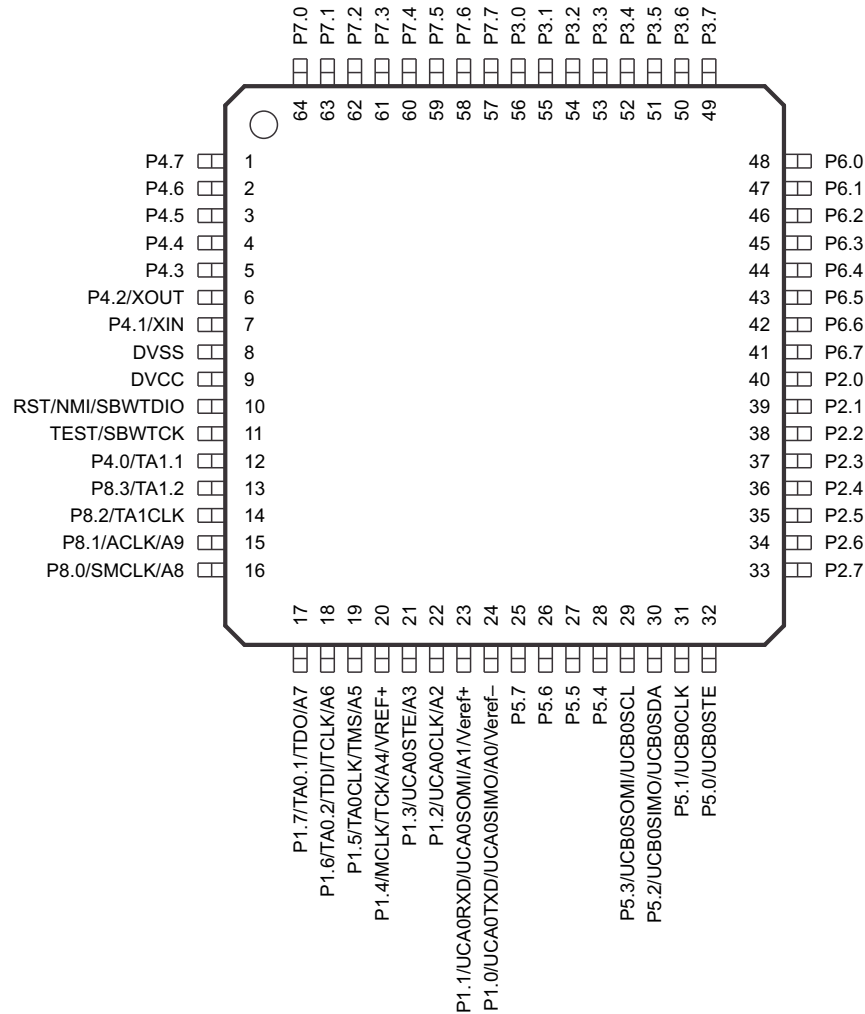


Figure 4-1. 64-Pin PM (LQFP) Designation (Top View)



Figure 4-2 shows the 56-pin G56 package.

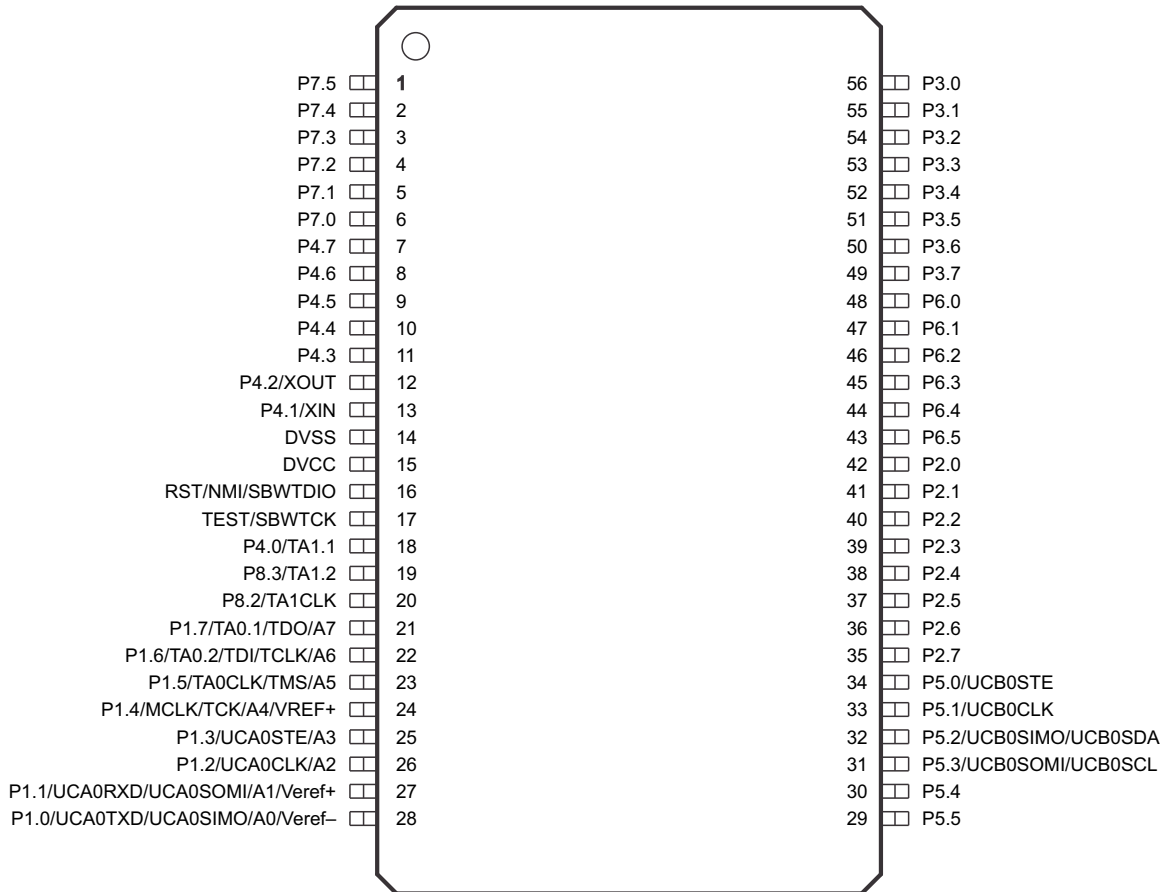
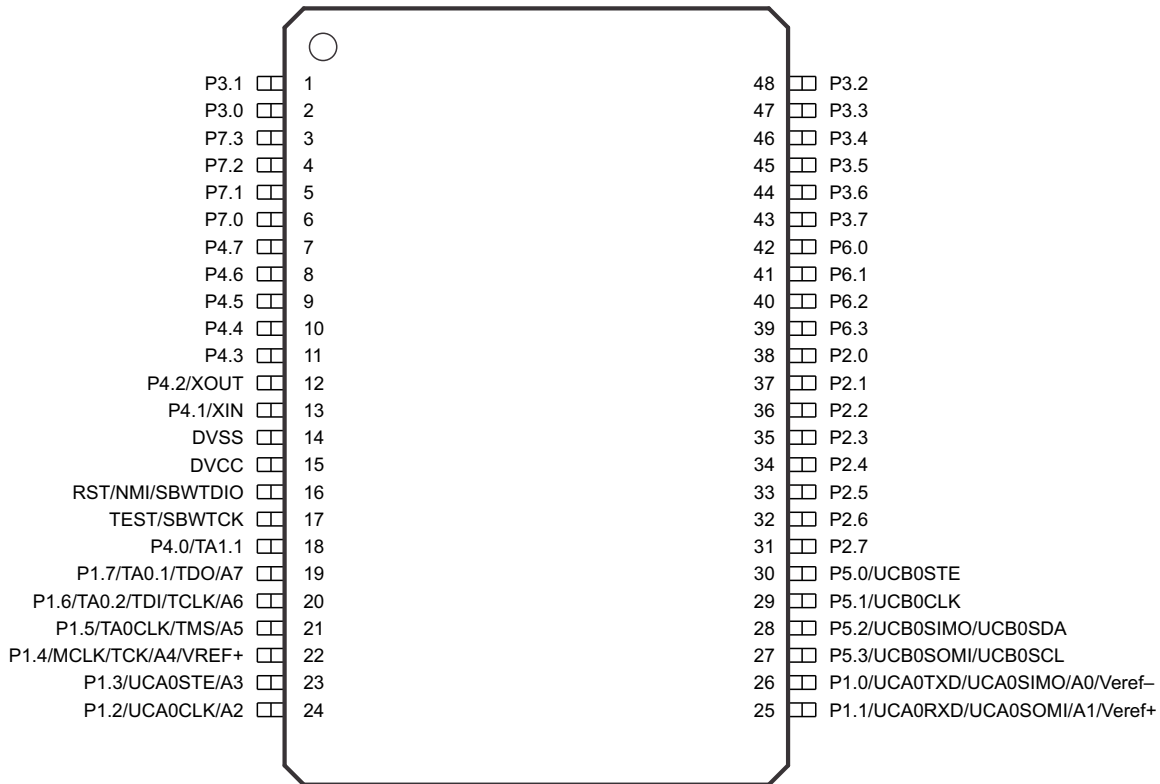


Figure 4-2. 56-Pin DGG (TSSOP) Designation (Top View)

Figure 4-3 shows the 48-pin G48 package.



**Figure 4-3. 48-Pin DGG (TSSOP) Designation (Top View)**

## 4.2 Signal Descriptions

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

**Table 4-1. Signal Descriptions**

| TERMINAL  |                |     |     | I/O | DESCRIPTION   |
|---|----------------|-----|-----|-----|---|
| NAME  | PACKAGE SUFFIX |     |     |     |   |
|   | PM             | G56 | G48 |     |   |
| P4.7  | 1              | 7   | 7   | I/O | General-purpose I/O   |
| P4.6  | 2              | 8   | 8   | I/O | General-purpose I/O   |
| P4.5  | 3              | 9   | 9   | I/O | General-purpose I/O   |
| P4.4  | 4              | 10  | 10  | I/O | General-purpose I/O   |
| P4.3  | 5              | 11  | 11  | I/O | General-purpose I/O   |
| P4.2/XOUT   | 6              | 12  | 12  | I/O | General-purpose I/O<br>Output terminal for crystal oscillator   |
| P4.1/XIN  | 7              | 13  | 13  | I/O | General-purpose I/O<br>Input terminal for crystal oscillator  |
| DVSS  | 8              | 14  | 14  |     | Power ground  |
| DVCC  | 9              | 15  | 15  |     | Power supply  |
| $\overline{\text{RST}}/\text{NMI}/\text{SBWTDIO}$ | 10             | 16  | 16  | I/O | Reset input, active low<br>Nonmaskable interrupt input<br>Spy-Bi-Wire data input/output   |
| TEST/SBWTK  | 11             | 17  | 17  | I   | Test Mode pin – selected digital I/O on JTAG pins<br>Spy-Bi-Wire input clock  |
| P4.0/TA1.1  | 12             | 18  | 18  | I/O | General-purpose I/O<br>Timer TA1 CCR1 capture: CC1A input, compare: Out1 outputs  |
| P8.3/TA1.2 <sup>(1)</sup>                         | 13             | 19  |     | I/O | General-purpose I/O<br>Timer TA1 CCR2 capture: CC1A input, compare: Out2 outputs  |
| P8.2/TA1CLK <sup>(1)</sup>                        | 14             | 20  |     | I/O | General-purpose I/O<br>Timer clock input TACLK for TA1  |
| P8.1/ACLK/A9 <sup>(1)</sup>                       | 15             |     |     | I/O | General-purpose I/O<br>ACLK output<br>Analog input A9   |
| P8.0/SMCLK/A8 <sup>(1)</sup>                      | 16             |     |     | I/O | General-purpose I/O<br>SMCLK output<br>Analog input A8  |
| P1.7/TA0.1/TDO/A7 <sup>(2)</sup>                  | 17             | 21  | 19  | I/O | General-purpose I/O <sup>(2)</sup><br>Timer TA0 CCR1 capture: CC1A input, compare: Out1 outputs<br>Test data output<br>Analog input A7                    |
| P1.6/TA0.2/TDI/TCLK/A6 <sup>(2)</sup>             | 18             | 22  | 20  | I/O | General-purpose I/O <sup>(2)</sup><br>Timer TA0 CCR2 capture: CC1A input, compare: Out2 outputs<br>Test data input or test clock input<br>Analog input A6 |

(1) Any pin that is not bonded out in a smaller package must be initialized by software after reset to achieve the lowest leakage current.

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

Table 4-1. Signal Descriptions (continued)

| TERMINAL                              |                |     |     | I/O | DESCRIPTION   |
|---------------------------------------|----------------|-----|-----|-----|---|
| NAME                                  | PACKAGE SUFFIX |     |     |     |   |
|                                       | PM             | G56 | G48 |     |   |
| P1.5/TA0CLK/TMS/A5 <sup>(2)</sup>     | 19             | 23  | 21  | I/O | General-purpose I/O <sup>(2)</sup><br>Timer clock input TACLK for TA0<br>Test mode select<br>Analog input A5  |
| P1.4/MCLK/TCK/A4/VREF+ <sup>(2)</sup> | 20             | 24  | 22  | I/O | General-purpose I/O <sup>(2)</sup><br>MCLK output<br>Test clock<br>Analog input A4<br>Output of positive reference voltage with ground as reference |
| P1.3/UCA0STE/A3                       | 21             | 25  | 23  | I/O | General-purpose I/O<br>eUSCI_A0 SPI slave transmit enable<br>Analog input A3  |
| P1.2/UCA0CLK/A2                       | 22             | 26  | 24  | I/O | General-purpose I/O<br>eUSCI_A0 SPI clock input/output<br>Analog input A2   |
| P1.1/UCA0RXD/UCA0SOMI/<br>A1/Veref+   | 23             | 27  | 25  | I/O | General-purpose I/O<br>eUSCI_A0 UART receive data<br>eUSCI_A0 SPI slave out/master in<br>Analog input A1, and ADC positive reference                |
| P1.0/UCA0TXD/UCA0SIMO/<br>A0/Veref-   | 24             | 28  | 26  | I/O | General-purpose I/O<br>eUSCI_A0 UART transmit data<br>eUSCI_A0 SPI slave in/master out<br>Analog input A0, and ADC negative reference               |
| P5.7 <sup>(1)</sup>                   | 25             |     |     | I/O | General-purpose I/O   |
| P5.6 <sup>(1)</sup>                   | 26             |     |     | I/O | General-purpose I/O   |
| P5.5 <sup>(1)</sup>                   | 27             | 29  |     | I/O | General-purpose I/O   |
| P5.4 <sup>(1)</sup>                   | 28             | 30  |     | I/O | General-purpose I/O   |
| P5.3/UCB0SOMI/UCB0SCL                 | 29             | 31  | 27  | I/O | General-purpose I/O<br>eUSCI_B0 SPI slave out/master in; eUSCI_B0 I <sup>2</sup> C clock  |
| P5.2/UCB0SIMO/UCB0SDA                 | 30             | 32  | 28  | I/O | General-purpose I/O<br>eUSCI_B0 SPI slave in/master out; eUSCI_B0 I <sup>2</sup> C data   |
| P5.1/UCB0CLK                          | 31             | 33  | 29  | I/O | General-purpose I/O<br>eUSCI_B0 clock input/output  |
| P5.0/UCB0STE                          | 32             | 34  | 30  | I/O | General-purpose I/O<br>eUSCI_B0 slave transmit enable   |
| P2.7                                  | 33             | 35  | 31  | I/O | General-purpose I/O   |
| P2.6                                  | 34             | 36  | 32  | I/O | General-purpose I/O   |
| P2.5                                  | 35             | 37  | 33  | I/O | General-purpose I/O   |
| P2.4                                  | 36             | 38  | 34  | I/O | General-purpose I/O   |
| P2.3                                  | 37             | 39  | 35  | I/O | General-purpose I/O   |
| P2.2                                  | 38             | 40  | 36  | I/O | General-purpose I/O   |
| P2.1                                  | 39             | 41  | 37  | I/O | General-purpose I/O   |

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

| TERMINAL            |                |     |     | I/O | DESCRIPTION         |
|---------------------|----------------|-----|-----|-----|---------------------|
| NAME                | PACKAGE SUFFIX |     |     |     |                     |
|                     | PM             | G56 | G48 |     |                     |
| P2.0                | 40             | 42  | 38  | I/O | General-purpose I/O |
| P6.7 <sup>(1)</sup> | 41             |     |     | I/O | General-purpose I/O |
| P6.6 <sup>(1)</sup> | 42             |     |     | I/O | General-purpose I/O |
| P6.5 <sup>(1)</sup> | 43             | 43  |     | I/O | General-purpose I/O |
| P6.4 <sup>(1)</sup> | 44             | 44  |     | I/O | General-purpose I/O |
| P6.3                | 45             | 45  | 39  | I/O | General-purpose I/O |
| P6.2                | 46             | 46  | 40  | I/O | General-purpose I/O |
| P6.1                | 47             | 47  | 41  | I/O | General-purpose I/O |
| P6.0                | 48             | 48  | 42  | I/O | General-purpose I/O |
| P3.7                | 49             | 49  | 43  | I/O | General-purpose I/O |
| P3.6                | 50             | 50  | 44  | I/O | General-purpose I/O |
| P3.5                | 51             | 51  | 45  | I/O | General-purpose I/O |
| P3.4                | 52             | 52  | 46  | I/O | General-purpose I/O |
| P3.3                | 53             | 53  | 47  | I/O | General-purpose I/O |
| P3.2                | 54             | 54  | 48  | I/O | General-purpose I/O |
| P3.1                | 55             | 55  | 1   | I/O | General-purpose I/O |
| P3.0                | 56             | 56  | 2   | I/O | General-purpose I/O |
| P7.7 <sup>(1)</sup> | 57             |     |     | I/O | General-purpose I/O |
| P7.6 <sup>(1)</sup> | 58             |     |     | I/O | General-purpose I/O |
| P7.5 <sup>(1)</sup> | 59             | 1   |     | I/O | General-purpose I/O |
| P7.4 <sup>(1)</sup> | 60             | 2   |     | I/O | General-purpose I/O |
| P7.3                | 61             | 3   | 3   | I/O | General-purpose I/O |
| P7.2                | 62             | 4   | 4   | I/O | General-purpose I/O |
| P7.1                | 63             | 5   | 5   | I/O | General-purpose I/O |
| P7.0                | 64             | 6   | 6   | I/O | General-purpose I/O |

### 4.3 Pin Multiplexing

Pin multiplexing for these devices is controlled by both register settings and operating modes (for example, if the device is in test mode). For details of the settings for each pin and diagrams of the multiplexed ports, see [Section 6.9.12](#).

### 4.4 Connection of Unused Pins

[Table 4-2](#) shows the correct termination of unused pins.

**Table 4-2. Connection of Unused Pins<sup>(1)</sup>**

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

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

## 5 Specifications

### 5.1 Absolute Maximum Ratings

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

|  | MIN  | MAX                                    | UNIT |
|--|------|--|------|
| Voltage applied at DVCC pin to V <sub>SS</sub>       | -0.3 | 4.1                                    | V    |
| Voltage applied to any pin <sup>(2)</sup>            | -0.3 | V <sub>CC</sub> + 0.3<br>(4.1 Maximum) | V    |
| Diode current at any device pin                      |      | ±2                                     | mA   |
| Maximum junction temperature, T <sub>J</sub>         |      | 85                                     | °C   |
| Storage temperature, T <sub>stg</sub> <sup>(3)</sup> | -40  | 125                                    | °C   |

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

### 5.2 ESD Ratings

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

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

### 5.3 Recommended Operating Conditions

Typical values are specified at V<sub>CC</sub> = 3.3 V and T<sub>A</sub> = 25°C (unless otherwise noted)

|                     |   | MIN  | NOM | MAX               | UNIT |
|---------------------|---|--|-----|-------------------|------|
| V <sub>CC</sub>     | Supply voltage applied at DVCC pin <sup>(1)(2)(3)(4)</sup>  | 1.8  |     | 3.6               | V    |
| V <sub>SS</sub>     | Supply voltage applied at DVSS pin                          |  | 0   |                   | V    |
| T <sub>A</sub>      | Operating free-air temperature                              | -40  |     | 85                | °C   |
| T <sub>J</sub>      | Operating junction temperature                              | -40  |     | 85                | °C   |
| C <sub>DVCC</sub>   | Recommended capacitor at DVCC <sup>(5)</sup>                | 4.7  | 10  |                   | μF   |
| f <sub>SYSTEM</sub> | Processor frequency (maximum MCLK frequency) <sup>(6)</sup> | No FRAM wait states (NWAITSx = 0)                  |     | 8                 | MHz  |
|                     |   | With FRAM wait states (NWAITSx = 1) <sup>(7)</sup> |     | 16 <sup>(8)</sup> |      |
| f <sub>ACLK</sub>   | Maximum ACLK frequency                                      |  |     | 40                | kHz  |
| f <sub>SMCLK</sub>  | Maximum SMCLK frequency                                     |  |     | 16 <sup>(8)</sup> | MHz  |

- (1) Supply voltage changes faster than 0.2 V/μs can trigger a BOR reset even within the recommended supply voltage range. Following the data sheet recommendation for capacitor C<sub>DVCC</sub> limits the slopes accordingly.
- (2) Modules may have a different supply voltage range specification. See the specification of the respective module in this data sheet.
- (3) TI recommends that power to the DVCC pin must not exceed the limits specified in *Recommended Operating Conditions*. Exceeding the specified limits can cause malfunction of the device including erroneous writes to RAM and FRAM.
- (4) The minimum supply voltage is defined by the SVS levels. See the SVS threshold parameters in [Table 5-1](#).
- (5) A capacitor tolerance of ±20% or better is required. A low-ESR ceramic capacitor of 100 nF (minimum) should be placed as close as possible (within a few millimeters) to the respective pin pair.
- (6) Modules may have a different maximum input clock specification. See the specification of the respective module in this data sheet.
- (7) Wait states only occur on actual FRAM accesses (that is, on FRAM cache misses). RAM and peripheral accesses are always executed without wait states.
- (8) If clock sources such as HF crystals or the DCO with frequencies >16 MHz are used, the clock must be divided in the clock system to comply with this operating condition.

#### 5.4 Active Mode Supply Current Into $V_{CC}$ Excluding External Current<sup>(1)</sup>

| PARAMETER             | EXECUTION MEMORY             | TEST CONDITIONS | FREQUENCY ( $f_{MCLK} = f_{SMCLK}$ )    |     |   |     |   |      | UNIT    |
|-----------------------|------------------------------|-----------------|---|-----|---|-----|---|------|---------|
|                       |                              |                 | 1 MHz<br>0 WAIT STATES<br>(NWAITSx = 0) |     | 8 MHz<br>0 WAIT STATES<br>(NWAITSx = 0) |     | 16 MHz<br>1 WAIT STATE<br>(NWAITSx = 1) |      |         |
|                       |                              |                 | TYP                                     | MAX | TYP                                     | MAX | TYP                                     | MAX  |         |
| $I_{AM, FRAM(0\%)}$   | FRAM<br>0% cache hit ratio   | 3 V, 25°C       | 504                                     |     | 2874                                    |     | 3156                                    | 3700 | $\mu A$ |
|                       |                              | 3 V, 85°C       | 516                                     |     | 2919                                    |     | 3205                                    |      |         |
| $I_{AM, FRAM(100\%)}$ | FRAM<br>100% cache hit ratio | 3 V, 25°C       | 209                                     |     | 633                                     |     | 1056                                    | 1298 | $\mu A$ |
|                       |                              | 3 V, 85°C       | 217                                     |     | 647                                     |     | 1074                                    |      |         |
| $I_{AM, RAM}^{(2)}$   | RAM                          | 3 V, 25°C       | 231                                     |     | 809                                     |     | 1450                                    |      | $\mu A$ |

(1) All inputs are tied to 0 V or to  $V_{CC}$ . Outputs do not source or sink any current. Characterized with program executing typical data processing.

$f_{ACLK} = 32786$  Hz,  $f_{MCLK} = f_{SMCLK} = f_{DCO}$  at specified frequency  
Program and data entirely reside in FRAM. All execution is from FRAM.

(2) Program and data reside entirely in RAM. All execution is from RAM. No access to FRAM.

#### 5.5 Active Mode Supply Current Per MHz

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

| PARAMETER         | TEST CONDITIONS   | TYP | UNIT        |
|-------------------|---|-----|-------------|
| $dI_{AM,FRAM}/df$ | Active mode current consumption per MHz, execution from FRAM, no wait states <sup>(1)</sup> | 126 | $\mu A/MHz$ |

(1) All peripherals are turned on in default settings.

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

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

| PARAMETER                                     | $V_{CC}$ | FREQUENCY ( $f_{SMCLK}$ ) |     |       |     |        |     | UNIT    |
|---|----------|---------------------------|-----|-------|-----|--------|-----|---------|
|   |          | 1 MHz                     |     | 8 MHz |     | 16 MHz |     |         |
|   |          | TYP                       | MAX | TYP   | MAX | TYP    | MAX |         |
| $I_{LPM0}$ Low-power mode LPM0 supply current | 2 V      | 158                       |     | 307   |     | 415    |     | $\mu A$ |
|   | 3 V      | 169                       |     | 318   |     | 427    |     |         |

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

(2) Current for watchdog timer clocked by SMCLK included.

$f_{ACLK} = 32786$  Hz,  $f_{MCLK} = 0$  MHz,  $f_{SMCLK}$  at specified frequency.



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

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

| PARAMETER  | $V_{CC}$ | -40°C |     | 25°C |      | 85°C |     | UNIT    |
|--|----------|-------|-----|------|------|------|-----|---------|
|  |          | TYP   | MAX | TYP  | MAX  | TYP  | MAX |         |
| $I_{LPM3,XT1}$ Low-power mode 3, includes SVS <sup>(2)(3)(4)</sup> | 3 V      | 1.13  |     | 1.31 | 1.99 | 3.00 |     | $\mu$ A |
|  | 2 V      | 1.06  |     | 1.21 |      | 2.94 |     |         |
| $I_{LPM3,VLO}$ Low-power mode 3, VLO, excludes SVS <sup>(5)</sup>  | 3 V      | 0.92  |     | 1.00 | 1.75 | 2.89 |     | $\mu$ A |
|  | 2 V      | 0.86  |     | 1.00 |      | 2.75 |     |         |
| $I_{LPM3,RTC}$ Low-power mode 3, RTC, excludes SVS <sup>(6)</sup>  | 3 V      | 1.08  |     | 1.25 |      | 3.04 |     | $\mu$ A |
| $I_{LPM4,SVS}$ Low-power mode 4, includes SVS                      | 3 V      | 0.65  |     | 0.75 |      | 1.88 |     | $\mu$ A |
|  | 2 V      | 0.63  |     | 0.73 |      | 1.85 |     |         |
| $I_{LPM4}$ Low-power mode 4, excludes SVS                          | 3 V      | 0.51  |     | 0.58 |      | 1.51 |     | $\mu$ A |
|  | 2 V      | 0.50  |     | 0.57 |      | 1.49 |     |         |

- (1) All inputs are tied to 0 V or to  $V_{CC}$ . Outputs do not source or sink any current
- (2) Not applicable for devices with HF crystal oscillator only.
- (3) Characterized with a Golledge MS1V-TK/I\_32.768KHZ crystal with a load capacitance chosen to closely match the required load.
- (4) Low-power mode 3, includes SVS test conditions:  
Current for watchdog timer clocked by ACLK and RTC clocked by XT1 included. Current for brownout and SVS included (SVSHE = 1). CPUOFF = 1, SCG0 = 1 SCG1 = 1, OSCOFF = 0 (LPM3),  
 $f_{XT1} = 32768$  Hz,  $f_{ACLK} = f_{XT1}$ ,  $f_{MCLK} = f_{SMCLK} = 0$  MHz
- (5) Low-power mode 3, VLO, excludes SVS test conditions:  
Current for watchdog timer clocked by VLO included. RTC disabled. Current for brownout included. SVS disabled (SVSHE = 0). CPUOFF = 1, SCG0 = 1 SCG1 = 1, OSCOFF = 0 (LPM3),  
 $f_{XT1} = 0$  Hz,  $f_{ACLK} = f_{MCLK} = f_{SMCLK} = 0$  MHz
- (6) RTC periodically wakes up every second with external 32768-Hz as source.

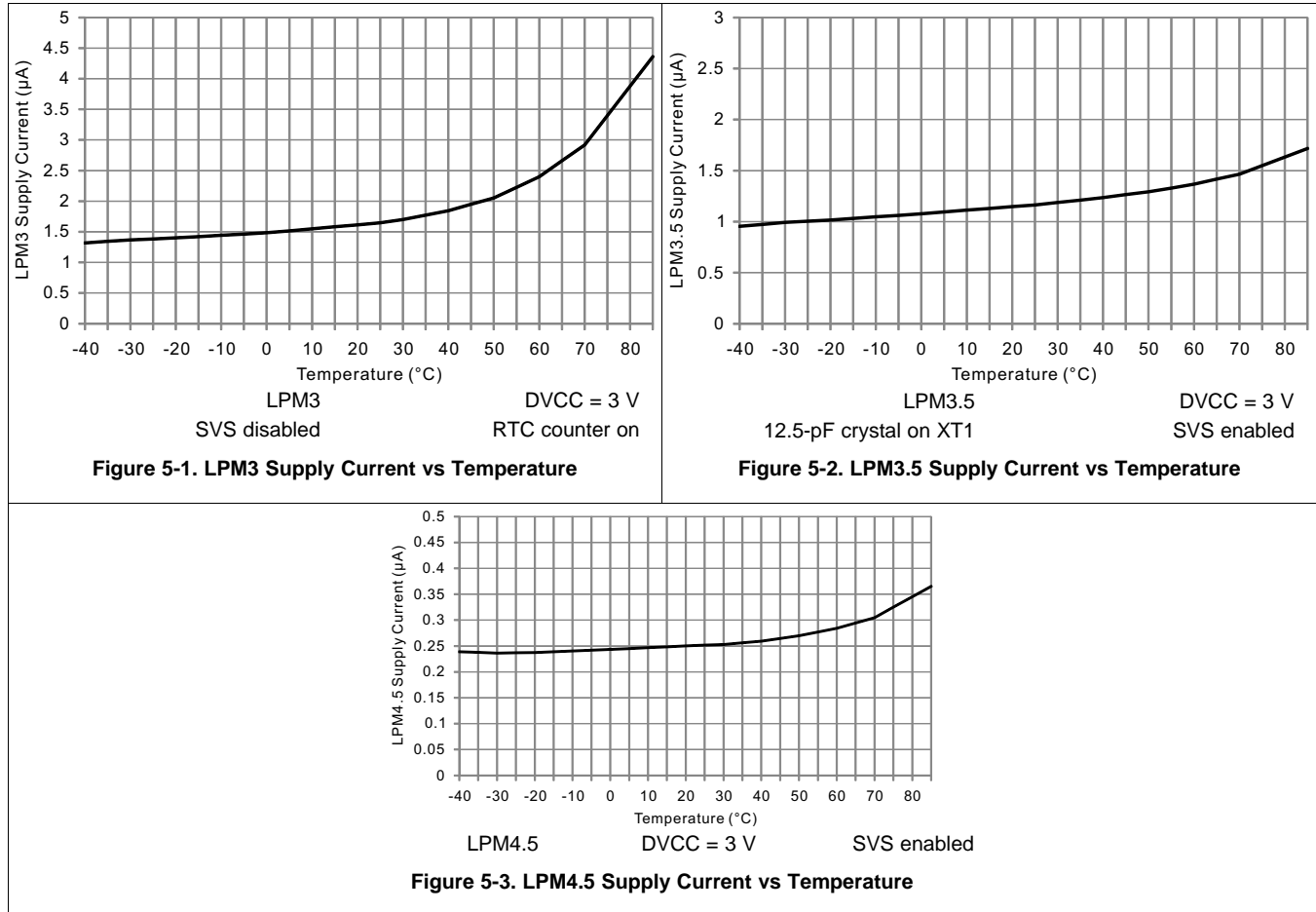
## 5.8 Low-Power Mode LPMx.5 Supply Currents (Into $V_{CC}$ ) Excluding External Current

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

| PARAMETER  | $V_{CC}$ | -40°C |     | 25°C  |       | 85°C  |       | UNIT    |
|--|----------|-------|-----|-------|-------|-------|-------|---------|
|  |          | TYP   | MAX | TYP   | MAX   | TYP   | MAX   |         |
| $I_{LPM3.5,XT1}$ Low-power mode 3.5, includes SVS <sup>(1)(2)(3)</sup><br>(also see <a href="#">Figure 5-2</a> ) | 3 V      | 0.71  |     | 0.77  | 1.25  | 1.06  | 2.06  | $\mu$ A |
|  | 2 V      | 0.66  |     | 0.70  |       | 0.95  |       |         |
| $I_{LPM4.5,SVS}$ Low-power mode 4.5, includes SVS <sup>(4)</sup>   | 3 V      | 0.23  |     | 0.25  | 0.375 | 0.32  | 0.43  | $\mu$ A |
|  | 2 V      | 0.20  |     | 0.20  |       | 0.24  |       |         |
| $I_{LPM4.5}$ Low-power mode 4.5, excludes SVS <sup>(5)</sup>   | 3 V      | 0.010 |     | 0.015 | 0.070 | 0.073 | 0.140 | $\mu$ A |
|  | 2 V      | 0.008 |     | 0.013 |       | 0.060 |       |         |

- (1) Not applicable for devices with HF crystal oscillator only.
- (2) Characterized with a Micro Crystal MS1V-T1K crystal with a load capacitance chosen to closely match the required load.
- (3) Low-power mode 3.5, includes SVS test conditions:  
Current for RTC clocked by XT1 included. Current for brownout and SVS included (SVSHE = 1). Core regulator disabled.  
PMMREGOFF = 1, CPUOFF = 1, SCG0 = 1 SCG1 = 1, OSCOFF = 1 (LPMx.5),  
 $f_{XT1} = 32768$  Hz,  $f_{ACLK} = f_{XT1}$ ,  $f_{MCLK} = f_{SMCLK} = 0$  MHz
- (4) Low-power mode 4.5, includes SVS test conditions:  
Current for brownout and SVS included (SVSHE = 1). Core regulator disabled.  
PMMREGOFF = 1, CPUOFF = 1, SCG0 = 1 SCG1 = 1, OSCOFF = 1 (LPMx.5),  
 $f_{XT1} = 0$  Hz,  $f_{ACLK} = f_{MCLK} = f_{SMCLK} = 0$  MHz
- (5) Low-power mode 4.5, excludes SVS test conditions:  
Current for brownout included. SVS disabled (SVSHE = 0). Core regulator disabled.  
PMMREGOFF = 1, CPUOFF = 1, SCG0 = 1 SCG1 = 1, OSCOFF = 1 (LPMx.5),  
 $f_{XT1} = 0$  Hz,  $f_{ACLK} = f_{MCLK} = f_{SMCLK} = 0$  MHz

### 5.9 Typical Characteristics, Low-Power Mode Supply Currents



## 5.10 Typical Characteristics - Current Consumption Per Module

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

## 5.11 Thermal Characteristics

| THERMAL METRIC <sup>(1)</sup> |  | PACKAGE          | VALUE <sup>(2)</sup> | UNIT |
|-------------------------------|--|------------------|----------------------|------|
| θ <sub>JA</sub>               | Junction-to-ambient thermal resistance, still air    | LQFP-64 (PM)     | 61.7                 | °C/W |
| θ <sub>JC, (TOP)</sub>        | Junction-to-case (top) thermal resistance            |                  | 25.4                 | °C/W |
| θ <sub>JB</sub>               | Junction-to-board thermal resistance                 |                  | 32.7                 | °C/W |
| Ψ <sub>JB</sub>               | Junction-to-board thermal characterization parameter |                  | 32.4                 | °C/W |
| Ψ <sub>JT</sub>               | Junction-to-top thermal characterization parameter   |                  | 2.5                  | °C/W |
| θ <sub>JA</sub>               | Junction-to-ambient thermal resistance, still air    | TSSOP-56 (DGG56) | 62.4                 | °C/W |
| θ <sub>JC, (TOP)</sub>        | Junction-to-case (top) thermal resistance            |                  | 18.7                 | °C/W |
| θ <sub>JB</sub>               | Junction-to-board thermal resistance                 |                  | 31.4                 | °C/W |
| Ψ <sub>JB</sub>               | Junction-to-board thermal characterization parameter |                  | 31.1                 | °C/W |
| Ψ <sub>JT</sub>               | Junction-to-top thermal characterization parameter   |                  | 0.8                  | °C/W |
| θ <sub>JA</sub>               | Junction-to-ambient thermal resistance, still air    | TSSOP-48 (DGG48) | 68.9                 | °C/W |
| θ <sub>JC, (TOP)</sub>        | Junction-to-case (top) thermal resistance            |                  | 23                   | °C/W |
| θ <sub>JB</sub>               | Junction-to-board thermal resistance                 |                  | 35.8                 | °C/W |
| Ψ <sub>JB</sub>               | Junction-to-board thermal characterization parameter |                  | 35.3                 | °C/W |
| Ψ <sub>JT</sub>               | Junction-to-top thermal characterization parameter   |                  | 1.1                  | °C/W |

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

## 5.12 Timing and Switching Characteristics

### 5.12.1 Power Supply Sequencing

Figure 5-4 shows the power supply reset parameters.

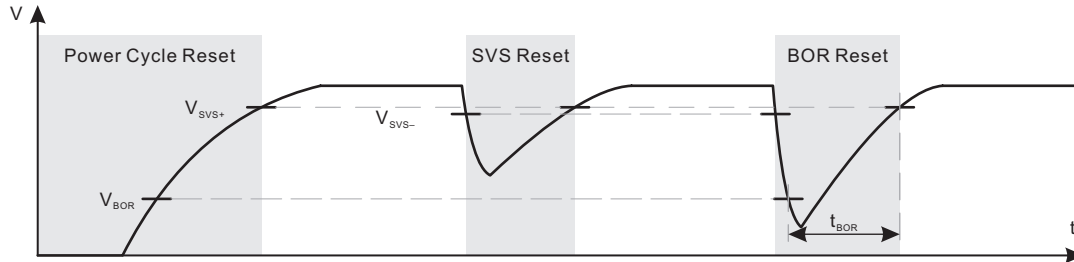


Figure 5-4. Power Cycle, SVS, and BOR Reset Conditions

Table 5-1. PMM, SVS and BOR

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

| PARAMETER           | TEST CONDITIONS                                       | MIN   | TYP   | MAX   | UNIT    |
|---------------------|---|-------|-------|-------|---------|
| $V_{BOR, safe}$     | Safe BOR power-down level <sup>(1)</sup>              | 0.1   |       |       | V       |
| $t_{BOR, safe}$     | Safe BOR reset delay <sup>(2)</sup>                   | 10    |       |       | ms      |
| $I_{SVSH, AM}$      | SVS <sub>H</sub> current consumption, active mode     |       |       | 1.5   | $\mu$ A |
| $I_{SVSH, LPM}$     | SVS <sub>H</sub> current consumption, low-power modes |       | 240   |       | nA      |
| $V_{SVSH-}$         | SVS <sub>H</sub> power-down level <sup>(3)</sup>      | 1.71  | 1.81  | 1.87  | V       |
| $V_{SVSH+}$         | SVS <sub>H</sub> power-up level <sup>(3)</sup>        | 1.76  | 1.88  | 1.99  | V       |
| $V_{SVSH, hys}$     | SVS <sub>H</sub> hysteresis                           |       | 70    |       | mV      |
| $t_{PD, SVSH, AM}$  | SVS <sub>H</sub> propagation delay, active mode       |       |       | 10    | $\mu$ s |
| $t_{PD, SVSH, LPM}$ | SVS <sub>H</sub> propagation delay, low-power modes   |       |       | 100   | $\mu$ s |
| $V_{REF, 1.2V}$     | 1.2-V REF voltage <sup>(4)</sup>                      | 1.158 | 1.200 | 1.242 | V       |

(1) A safe BOR can be correctly generated only if DVCC drops below this voltage before it rises.

(2) When an BOR occurs, a safe BOR can be correctly generated only if DVCC is kept low longer than this period before it reaches  $V_{SVSH+}$ .

(3) For additional information, see the [Dynamic Voltage Scaling Power Solution for MSP430 Devices With Single-Channel LDO Reference Design](#).

(4) This is a characterized result with external 1-mA load to ground from  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ .

## 5.12.2 Reset Timing

**Table 5-2. Wake-Up Times From Low-Power Modes and Reset**

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

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

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

### 5.12.3 Clock Specifications

**Table 5-3. XT1 Crystal Oscillator (Low Frequency)**

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

| PARAMETER         |  | TEST CONDITIONS   | MIN | TYP   | MAX  | UNIT       |
|-------------------|--|---|-----|-------|------|------------|
| $f_{XT1, LF}$     | XT1 oscillator crystal, low frequency                    | LFXTBYPASS = 0  |     | 32768 |      | Hz         |
| $DC_{XT1, LF}$    | XT1 oscillator LF duty cycle                             | Measured at MCLK,<br>$f_{LFXT} = 32768$ Hz  | 30% |       | 70%  |            |
| $f_{XT1, SW}$     | XT1 oscillator logic-level square-wave input frequency   | LFXTBYPASS = 1 <sup>(3)(4)</sup>  |     | 32768 |      | Hz         |
| $DC_{XT1, SW}$    | LFXT oscillator logic-level square-wave input duty cycle | LFXTBYPASS = 1  | 40% |       | 60%  |            |
| $OA_{LFXT}$       | Oscillation allowance for LF crystals <sup>(5)</sup>     | LFXTBYPASS = 0, LFXTDRIVE = {3},<br>$f_{LFXT} = 32768$ Hz, $C_{L,eff} = 12.5$ pF                              |     | 200   |      | k $\Omega$ |
| $C_{L,eff}$       | Integrated effective load capacitance <sup>(6)</sup>     | See <sup>(7)</sup>  |     | 1     |      | pF         |
| $t_{START, LFXT}$ | Start-up time <sup>(8)</sup>                             | $f_{OSC} = 32768$ Hz,<br>LFXTBYPASS = 0, LFXTDRIVE = {3},<br>$T_A = 25^\circ\text{C}$ , $C_{L,eff} = 12.5$ pF |     | 1000  |      | ms         |
| $f_{Fault, LFXT}$ | Oscillator fault frequency <sup>(9)</sup>                | XTS = 0 <sup>(10)</sup>   | 0   |       | 3500 | Hz         |

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

**Table 5-4. DCO FLL, Frequency**

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

| PARAMETER              |   | TEST CONDITIONS                                      | V <sub>CC</sub> | MIN    | TYP | MAX  | UNIT |
|------------------------|---|--|-----------------|--------|-----|------|------|
| f <sub>DCO, FLL</sub>  | FLL lock frequency, 16 MHz, 25°C          | Measured at MCLK, Internal trimmed REFO as reference | 3 V             | -1.0%  |     | 1.0% |      |
|                        | FLL lock frequency, 16 MHz, -40°C to 85°C |  |                 | -2.0%  |     | 2.0% |      |
|                        | FLL lock frequency, 16 MHz, -40°C to 85°C | Measured at MCLK, XT1 crystal as reference           |                 | -0.5%  |     | 0.5% |      |
| f <sub>DUTY</sub>      | Duty cycle                                | Measured at MCLK, XT1 crystal as reference           | 3 V             | 40%    | 50% | 60%  |      |
| Jitter <sub>CC</sub>   | Cycle-to-cycle jitter, 16 MHz             |  |                 | 0.25%  |     |      |      |
| Jitter <sub>long</sub> | Long-term jitter, 16 MHz                  |  |                 | 0.022% |     |      |      |
| t <sub>FLL, lock</sub> | FLL lock time                             |  |                 | 120    |     |      | ms   |

**Table 5-5. REFO**

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

| PARAMETER                            |                                     | TEST CONDITIONS                         | V <sub>CC</sub> | MIN   | TYP   | MAX  | UNIT |
|--------------------------------------|-------------------------------------|---|-----------------|-------|-------|------|------|
| I <sub>REFO</sub>                    | REFO oscillator current consumption | T <sub>A</sub> = 25°C                   | 3 V             |       | 15    |      | μA   |
| f <sub>REFO</sub>                    | REFO calibrated frequency           | Measured at MCLK                        | 3 V             |       | 32768 |      | Hz   |
|                                      | REFO absolute calibrated tolerance  | -40°C to 85°C                           | 1.8 V to 3.6 V  | -3.5% |       | 3.5% |      |
| df <sub>REFO</sub> /dT               | REFO frequency temperature drift    | Measured at MCLK <sup>(1)</sup>         | 3 V             |       | 0.01  |      | %/°C |
| df <sub>REFO</sub> /dV <sub>CC</sub> | REFO frequency supply voltage drift | Measured at MCLK at 25°C <sup>(2)</sup> | 1.8 V to 3.6 V  |       | 1     |      | %/V  |
| f <sub>DC</sub>                      | REFO duty cycle                     | Measured at MCLK                        | 1.8 V to 3.6 V  | 40%   | 50%   | 60%  |      |
| t <sub>START</sub>                   | REFO start-up time                  | 40% to 60% duty cycle                   |                 |       | 50    |      | μs   |

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

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

**Table 5-6. Internal Very-Low-Power Low-Frequency Oscillator (VLO)**

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

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

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

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

**NOTE**

The VLO clock frequency is reduced by 15% (typical) when the device switches from active mode to LPM3 or LPM4, because the reference changes. This lower frequency is not a violation of the VLO specifications (see [Table 5-6](#)).

**Table 5-7. Module Oscillator Clock (MODCLK)**

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

| PARAMETER                             |                                       | V <sub>CC</sub> | MIN | TYP   | MAX | UNIT |
|---------------------------------------|---------------------------------------|-----------------|-----|-------|-----|------|
| f <sub>MODCLK</sub>                   | MODCLK frequency                      | 3 V             | 3.8 | 4.8   | 5.8 | MHz  |
| f <sub>MODCLK</sub> /dT               | MODCLK frequency temperature drift    | 3 V             |     | 0.102 |     | %/°C |
| f <sub>MODCLK</sub> /dV <sub>CC</sub> | MODCLK frequency supply voltage drift | 1.8 V to 3.6 V  |     | 1.02  |     | %/V  |
| f <sub>MODCLK,DC</sub>                | Duty cycle                            | 3 V             | 40% | 50%   | 60% |      |

## 5.12.4 Digital I/Os

**Table 5-8. Digital Inputs**

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

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

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

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

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

**Table 5-9. Digital Outputs**

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

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

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

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



### 5.12.4.1 Digital I/O Typical Characteristics

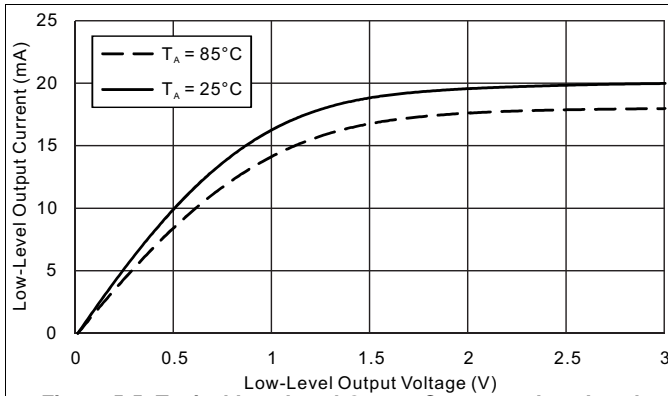


Figure 5-5. Typical Low-Level Output Current vs Low-Level Output Voltage (DVCC = 3 V)

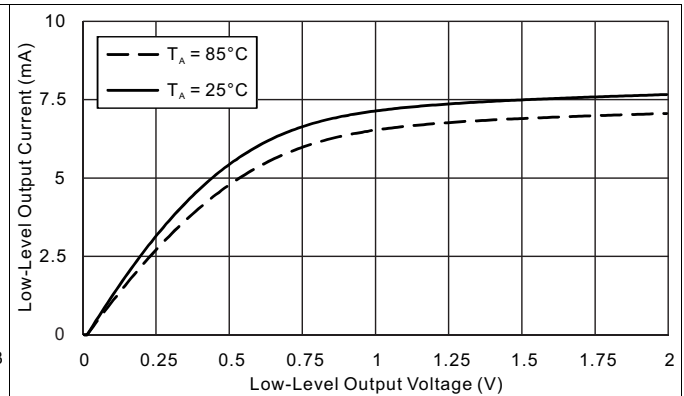


Figure 5-6. Typical Low-Level Output Current vs Low-Level Output Voltage (DVCC = 2 V)

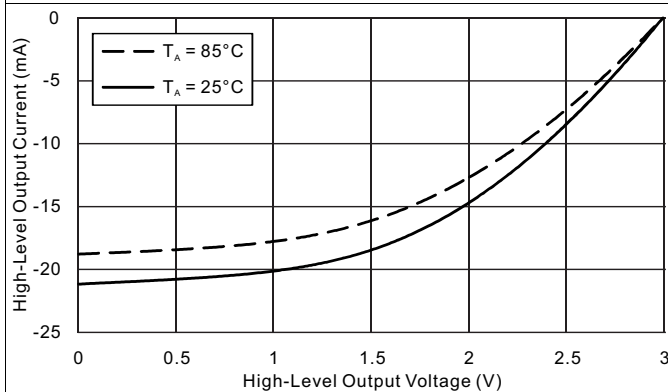


Figure 5-7. Typical High-Level Output Current vs High-Level Output Voltage (DVCC = 3 V)

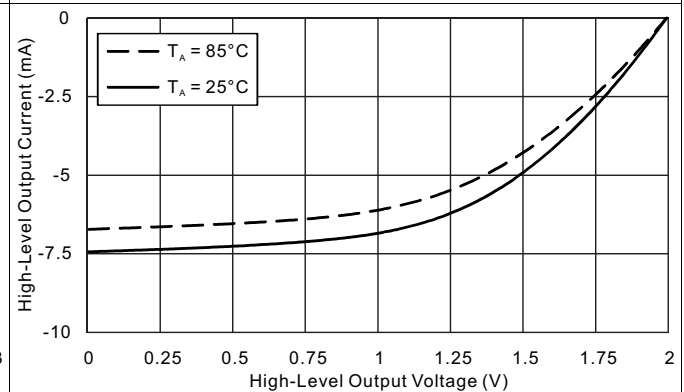


Figure 5-8. Typical High-Level Output Current vs High-Level Output Voltage (DVCC = 2 V)

### 5.12.5 Timer\_A

Table 5-10. Timer\_A Recommended Operating Conditions

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

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

## 5.12.6 eUSCI

**Table 5-11. eUSCI (UART Mode) Recommended Operating Conditions**

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

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

**Table 5-12. eUSCI (UART Mode) Switching Characteristics**

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

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

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

**Table 5-13. eUSCI (SPI Master Mode) Recommended Operating Conditions**

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

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

**Table 5-14. eUSCI (SPI Master Mode) Switching Characteristics**

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

| PARAMETER             |  | TEST CONDITIONS                                    | V <sub>CC</sub> | MIN | MAX | UNIT          |
|-----------------------|--|--|-----------------|-----|-----|---------------|
| t <sub>STE,LEAD</sub> | STE lead time, STE active to clock         | UCSTEM = 1, UCMODEx = 01 or 10                     |                 | 1   |     | UCxCLK cycles |
| t <sub>STE,LAG</sub>  | STE lag time, Last clock to STE inactive   | UCSTEM = 1, UCMODEx = 01 or 10                     |                 | 1   |     | UCxCLK cycles |
| t <sub>SU,MI</sub>    | SOMI input data setup time                 |  | 2 V             | 45  |     | ns            |
|                       |  |  | 3 V             | 35  |     |               |
| t <sub>HD,MI</sub>    | SOMI input data hold time                  |  | 2 V             | 0   |     | ns            |
|                       |  |  | 3 V             | 0   |     |               |
| t <sub>VALID,MO</sub> | SIMO output data valid time <sup>(2)</sup> | UCLK edge to SIMO valid,<br>C <sub>L</sub> = 20 pF | 2 V             |     | 20  | ns            |
|                       |  |  | 3 V             |     | 20  |               |
| t <sub>HD,MO</sub>    | SIMO output data hold time <sup>(3)</sup>  | C <sub>L</sub> = 20 pF                             | 2 V             | 0   |     | ns            |
|                       |  |  | 3 V             | 0   |     |               |

- (1)  $f_{UCxCLK} = 1/2t_{LO/HI}$  with  $t_{LO/HI} = \max(t_{VALID,MO(eUSCI)} + t_{SU,SI(Slave)}, t_{SU,MI(eUSCI)} + t_{VALID,SO(Slave)})$   
 For the slave parameters  $t_{SU,SI(Slave)}$  and  $t_{VALID,SO(Slave)}$ , see the SPI parameters of the attached slave.
- (2) Specifies the time to drive the next valid data to the SIMO output after the output changing UCLK clock edge. See the timing diagrams in [Figure 5-9](#) and [Figure 5-10](#).
- (3) Specifies how long data on the SIMO output is valid after the output changing UCLK clock edge. Negative values indicate that the data on the SIMO output can become invalid before the output changing clock edge observed on UCLK. See the timing diagrams in [Figure 5-9](#) and [Figure 5-10](#).

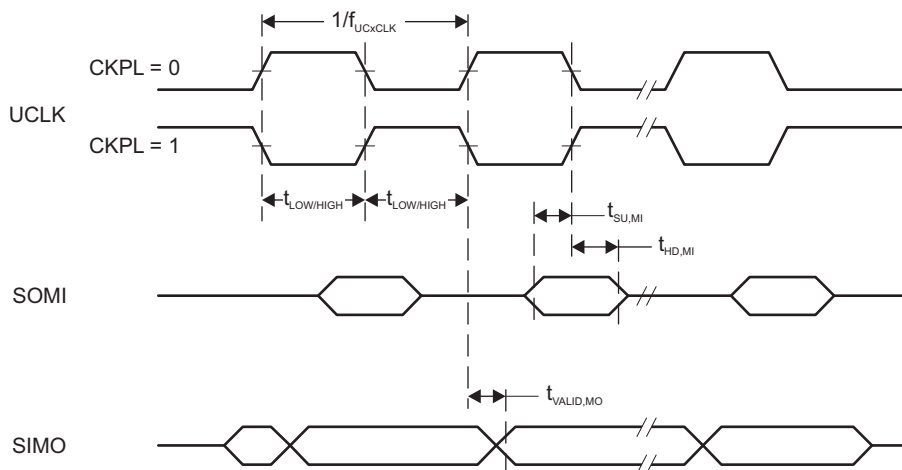


Figure 5-9. SPI Master Mode, CKPH = 0

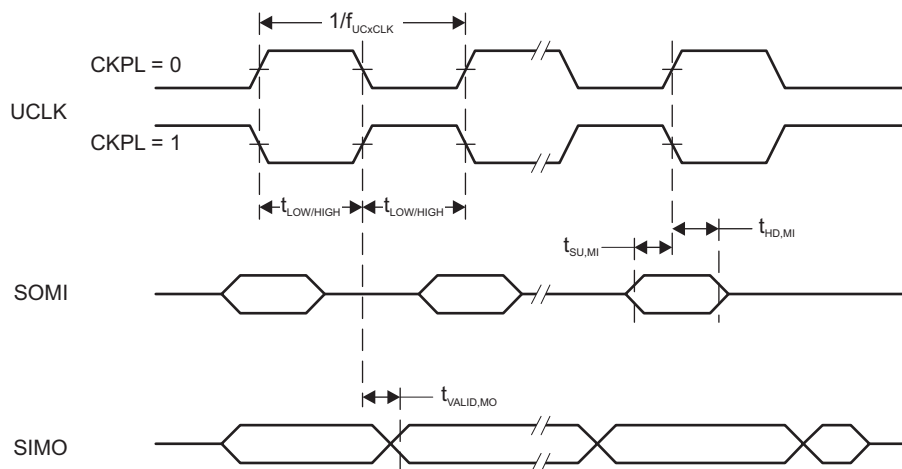


Figure 5-10. SPI Master Mode, CKPH = 1

**Table 5-15. eUSCI (SPI Slave Mode) Switching Characteristics**over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)<sup>(1)</sup>

| PARAMETER             |   | TEST CONDITIONS                                    | V <sub>CC</sub> | MIN | MAX | UNIT |
|-----------------------|---|--|-----------------|-----|-----|------|
| t <sub>STE,LEAD</sub> | STE lead time, STE active to clock                    |  | 2 V             | 55  |     | ns   |
|                       |   |  | 3 V             | 45  |     |      |
| t <sub>STE,LAG</sub>  | STE lag time, Last clock to STE inactive              |  | 2 V             | 20  |     | ns   |
|                       |   |  | 3 V             | 20  |     |      |
| t <sub>STE,ACC</sub>  | STE access time, STE active to SOMI data out          |  | 2 V             |     | 65  | ns   |
|                       |   |  | 3 V             |     | 40  |      |
| t <sub>STE,DIS</sub>  | STE disable time, STE inactive to SOMI high impedance |  | 2 V             |     | 40  | ns   |
|                       |   |  | 3 V             |     | 35  |      |
| t <sub>SU,SI</sub>    | SIMO input data setup time                            |  | 2 V             | 4   |     | ns   |
|                       |   |  | 3 V             | 4   |     |      |
| t <sub>HD,SI</sub>    | SIMO input data hold time                             |  | 2 V             | 12  |     | ns   |
|                       |   |  | 3 V             | 12  |     |      |
| t <sub>VALID,SO</sub> | SOMI output data valid time <sup>(2)</sup>            | UCLK edge to SOMI valid,<br>C <sub>L</sub> = 20 pF | 2 V             |     | 65  | ns   |
|                       |   |  | 3 V             |     | 40  |      |
| t <sub>HD,SO</sub>    | SOMI output data hold time <sup>(3)</sup>             | C <sub>L</sub> = 20 pF                             | 2 V             | 5   |     | ns   |
|                       |   |  | 3 V             | 5   |     |      |

(1)  $f_{UCxCLK} = 1/2t_{LO/HI}$  with  $t_{LO/HI} \geq \max(t_{VALID,MO(Master)} + t_{SU,SI(eUSCI)}, t_{SU,MI(Master)} + t_{VALID,SO(eUSCI)})$ For the master parameters  $t_{SU,MI(Master)}$  and  $t_{VALID,MO(Master)}$ , see the SPI parameters of the attached master.(2) Specifies the time to drive the next valid data to the SOMI output after the output changing UCLK clock edge. See the timing diagrams in [Figure 5-11](#) and [Figure 5-12](#).(3) Specifies how long data on the SOMI output is valid after the output changing UCLK clock edge. See the timing diagrams in [Figure 5-11](#) and [Figure 5-12](#).

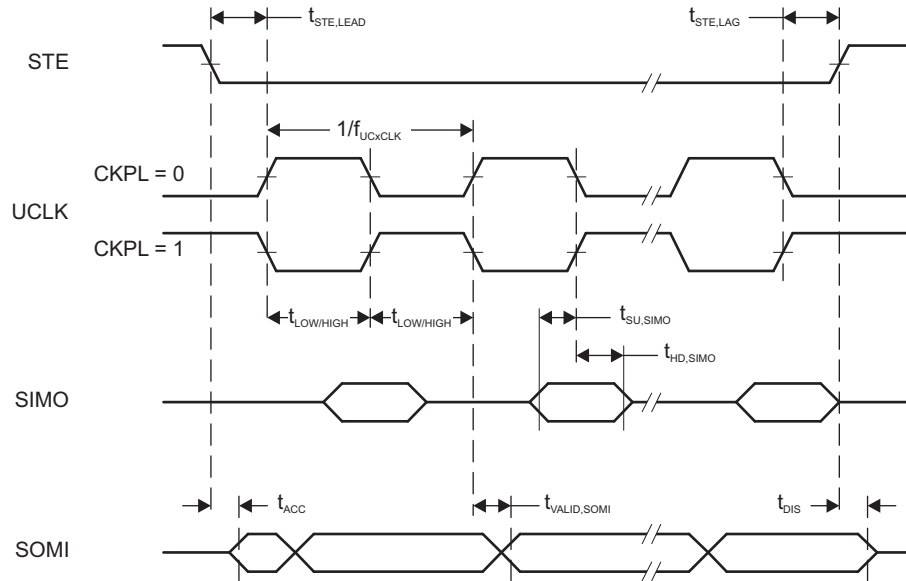


Figure 5-11. SPI Slave Mode, CKPH = 0

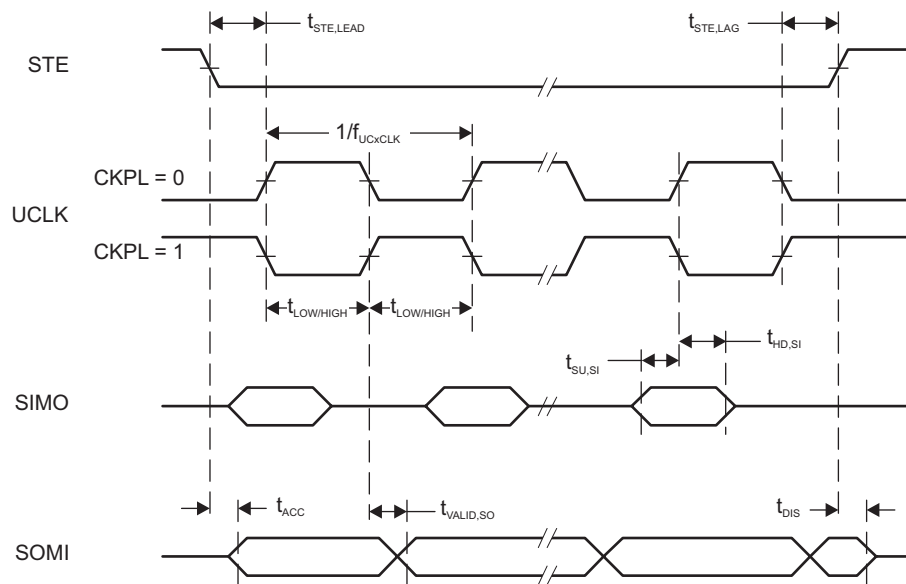
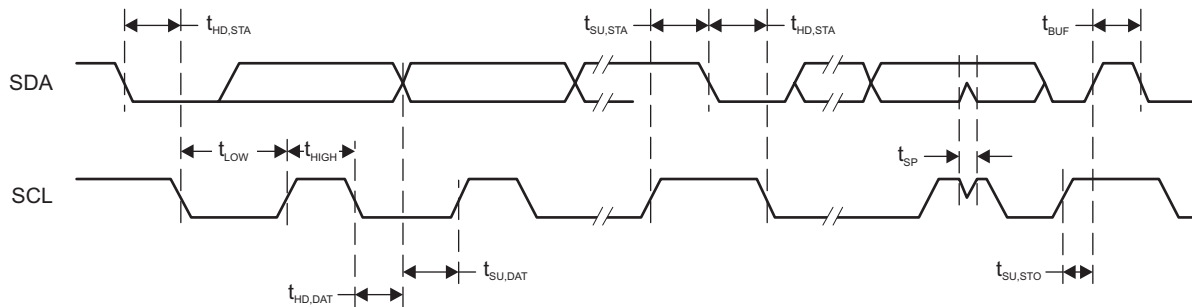


Figure 5-12. SPI Slave Mode, CKPH = 1

**Table 5-16. eUSCI (I<sup>2</sup>C Mode) Switching Characteristics**

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted) (see [Figure 5-13](#))

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



**Figure 5-13. I<sup>2</sup>C Mode Timing**

### 5.12.7 ADC

**Table 5-17. ADC, Power Supply and Input Range Conditions**

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

| PARAMETER           |   | TEST CONDITIONS  | V <sub>CC</sub> | MIN | TYP | MAX              | UNIT |
|---------------------|---|--|-----------------|-----|-----|------------------|------|
| DV <sub>CC</sub>    | ADC supply voltage  |  |                 | 2.0 |     | 3.6              | V    |
| V <sub>(Ax)</sub>   | Analog input voltage range  | All ADC pins   |                 | 0   |     | DV <sub>CC</sub> | V    |
| I <sub>ADC</sub>    | Operating supply current into DV <sub>CC</sub> terminal, reference current not included, repeat-single-channel mode | f <sub>ADCCLK</sub> = 5 MHz, ADCON = 1, REFON = 0, SHT0 = 0, SHT1 = 0, ADCDIV = 0, ADCCONSEQx = 10b                | 2 V             | 185 |     |                  | μA   |
|                     |   |  | 3 V             | 207 |     |                  |      |
| C <sub>I</sub>      | Input capacitance   | Only one terminal Ax can be selected at one time from the pad to the ADC capacitor array, including wiring and pad | 2.2 V           |     | 1.6 | 2.0              | pF   |
| R <sub>I,MUX</sub>  | Input MUX ON resistance   | DV <sub>CC</sub> = 2 V, 0 V ≤ V <sub>Ax</sub> ≤ DV <sub>CC</sub>   |                 |     |     | 2                | kΩ   |
| R <sub>I,Misc</sub> | Input miscellaneous resistance  |  |                 |     | 34  |                  | kΩ   |

**Table 5-18. ADC, 10-Bit Timing Parameters**

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

| PARAMETER            |                                  | TEST CONDITIONS   | V <sub>CC</sub> | MIN  | TYP | MAX  | UNIT |
|----------------------|----------------------------------|---|-----------------|------|-----|------|------|
| f <sub>ADCCLK</sub>  |                                  | For specified performance of ADC linearity parameters   | 2 V to 3.6 V    | 0.45 | 5   | 5.5  | MHz  |
| f <sub>ADCOSC</sub>  | Internal ADC oscillator (MODCLK) | ADCDIV = 0, f <sub>ADCCLK</sub> = f <sub>ADCOSC</sub>   | 2 V to 3.6 V    | 4.5  | 5.0 | 5.5  | MHz  |
| t <sub>CONVERT</sub> | Conversion time                  | REFON = 0, Internal oscillator, 10 ADCCLK cycles, 10-bit mode, f <sub>ADCOSC</sub> = 4.5 MHz to 5.5 MHz   | 2 V to 3.6 V    | 2.18 |     | 2.67 | μs   |
|                      |                                  | External f <sub>ADCCLK</sub> from ACLK, MCLK, or SMCLK, ADCSSEL ≠ 0   | 2 V to 3.6 V    | (1)  |     |      |      |
| t <sub>ADCON</sub>   | Turn-on settling time of the ADC | The error in a conversion started after t <sub>ADCON</sub> is less than ±0.5 LSB, Reference and input signal already settled  |                 |      |     | 100  | ns   |
| t <sub>Sample</sub>  | Sampling time                    | R <sub>S</sub> = 1000 Ω, R <sub>I</sub> <sup>(2)</sup> = 36000 Ω, C <sub>I</sub> = 3.5 pF, approximately 8 Tau (t) are required for an error of less than ±0.5 LSB <sup>(3)</sup> | 2 V             | 1.5  |     |      | μs   |
|                      |                                  |   | 3 V             | 2.0  |     |      |      |

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

 (2)  $R_I = R_{I,MUX} + R_{I,Misc}$ 

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

**Table 5-19. ADC, 10-Bit Linearity Parameters**

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

| PARAMETER                       |   | TEST CONDITIONS  | V <sub>CC</sub> | MIN   | TYP   | MAX  | UNIT  |
|---------------------------------|---|--|-----------------|-------|-------|------|-------|
| E <sub>I</sub>                  | Integral linearity error (10-bit mode)                        | V <sub>DVCC</sub> as reference   | 2.4 V to 3.6 V  | -2    |       | 2    | LSB   |
|                                 | Integral linearity error (8-bit mode)                         |  | 2 V to 3.6 V    | -2    |       | 2    |       |
| E <sub>D</sub>                  | Differential linearity error (10-bit mode)                    | V <sub>DVCC</sub> as reference   | 2.4 V to 3.6 V  | -1    |       | 1    | LSB   |
|                                 | Differential linearity error (8-bit mode)                     |  | 2 V to 3.6 V    | -1    |       | 1    |       |
| E <sub>O</sub>                  | Offset error (10-bit mode)                                    | V <sub>DVCC</sub> as reference   | 2.4 V to 3.6 V  | -6.5  |       | 6.5  | mV    |
|                                 | Offset error (8-bit mode)                                     |  | 2 V to 3.6 V    | -6.5  |       | 6.5  |       |
| E <sub>G</sub>                  | Gain error (10-bit mode)                                      | V <sub>DVCC</sub> as reference   | 2.4 V to 3.6 V  | -2.0  |       | 2.0  | LSB   |
|                                 |   | Internal 1.5-V reference   |                 | -3.0% |       | 3.0% |       |
|                                 | Gain error (8-bit mode)                                       | V <sub>DVCC</sub> as reference   | 2 V to 3.6 V    | -2.0  |       | 2.0  | LSB   |
|                                 |   | Internal 1.5-V reference   |                 | -3.0% |       | 3.0% |       |
| E <sub>T</sub>                  | Total unadjusted error (10-bit mode)                          | V <sub>DVCC</sub> as reference   | 2.4 V to 3.6 V  | -2.0  |       | 2.0  | LSB   |
|                                 |   | Internal 1.5-V reference   |                 | -3.0% |       | 3.0% |       |
|                                 | Total unadjusted error (8-bit mode)                           | V <sub>DVCC</sub> as reference   | 2 V to 3.6 V    | -2.0  |       | 2.0  | LSB   |
|                                 |   | Internal 1.5-V reference   |                 | -3.0% |       | 3.0% |       |
| V <sub>SENSOR</sub>             | See <sup>(1)</sup>  | ADCON = 1, INCH = 0Ch, T <sub>A</sub> = 0°C  | 3 V             |       | 1.013 |      | mV    |
| TC <sub>SENSOR</sub>            | See <sup>(2)</sup>  | ADCON = 1, INCH = 0Ch  | 3 V             |       | 3.35  |      | mV/°C |
| t <sub>SENSOR</sub><br>(sample) | Sample time required if channel 12 is selected <sup>(3)</sup> | ADCON = 1, INCH = 0Ch, Error of conversion result ≤ 1 LSB, AM and all LPM above LPM3 | 3 V             |       | 30    |      | μs    |
|                                 |   | ADCON = 1, INCH = 0Ch, Error of conversion result ≤ 1 LSB, LPM3                      | 3 V             |       | 100   |      |       |

- (1) The temperature sensor offset can vary significantly. TI recommends a single-point calibration to minimize the offset error of the built-in temperature sensor.
- (2) The device descriptor structure contains calibration values for 30°C and 85°C for each of the available reference voltage levels. The sensor voltage can be computed as  $V_{SENSE} = TC_{SENSOR} \times (\text{Temperature, } ^\circ\text{C}) + V_{SENSOR}$ , where TC<sub>SENSOR</sub> and V<sub>SENSOR</sub> can be computed from the calibration values for higher accuracy.
- (3) The typical equivalent impedance of the sensor is 700 kΩ. The sample time required includes the sensor-on time t<sub>SENSOR(on)</sub>.



### 5.12.8 FRAM

**Table 5-20. FRAM**

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

| PARAMETER              |                          | TEST CONDITIONS       | MIN              | MAX | UNIT   |
|------------------------|--------------------------|-----------------------|------------------|-----|--------|
|                        | Read and write endurance |                       | 10 <sup>15</sup> |     | cycles |
| t <sub>Retention</sub> | Data retention duration  | T <sub>J</sub> = 25°C | 100              |     | years  |
|                        |                          | T <sub>J</sub> = 70°C | 40               |     |        |
|                        |                          | T <sub>J</sub> = 85°C | 10               |     |        |

### 5.12.9 Emulation and Debug

**Table 5-21. JTAG and Spy-Bi-Wire Interface Characteristics**

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

| PARAMETER             |  | V <sub>CC</sub> | MIN   | TYP | MAX | UNIT |
|-----------------------|--|-----------------|-------|-----|-----|------|
| f <sub>SBW</sub>      | Spy-Bi-Wire input frequency  | 2 V, 3 V        | 0     |     | 10  | MHz  |
| t <sub>SBW,Low</sub>  | Spy-Bi-Wire low clock pulse duration   | 2 V, 3 V        | 0.028 |     | 15  | μs   |
| t <sub>SBW,En</sub>   | Spy-Bi-Wire enable time (TEST high to acceptance of first clock edge) <sup>(1)</sup> | 2 V, 3 V        |       |     | 110 | μs   |
| t <sub>SBW,Rst</sub>  | Spy-Bi-Wire return to normal operation time  |                 | 15    |     | 100 | μs   |
| f <sub>TCK</sub>      | TCK input frequency, 4-wire JTAG <sup>(2)</sup>                                      | 2 V             | 0     |     | 16  | MHz  |
|                       |  | 3 V             | 0     |     | 16  |      |
| R <sub>internal</sub> | Internal pulldown resistance on TEST   | 2 V, 3 V        | 20    | 35  | 50  | kΩ   |

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

## 6 Detailed Description

### 6.1 CPU

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

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

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

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

### 6.2 Operating Modes

The MSP430 has one active mode and several software selectable low-power modes of operation. An interrupt event can wake up the device from low-power mode LPM0 or LPM3, service the request, and restore back to the low-power mode on return from the interrupt program. Low-power modes LPM3.5 and LPM4.5 disable the core supply to minimize power consumption.

**Table 6-1. Operating Modes**

| MODE                           |                              | AM              | LPM0            | LPM3               | LPM4                    | LPM3.5                     | LPM4.5            |
|--------------------------------|------------------------------|-----------------|-----------------|--------------------|-------------------------|----------------------------|-------------------|
|                                |                              | ACTIVE MODE     | CPU OFF         | STANDBY            | OFF                     | ONLY RTC COUNTER           | SHUTDOWN          |
| Maximum System Clock           |                              | 16 MHz          | 16 MHz          | 40 kHz             | 0                       | 40 kHz                     | 0                 |
| Power Consumption at 25°C, 3 V |                              | 126 $\mu$ A/MHz | 20 $\mu$ A/MHz  | 1.2 $\mu$ A        | 0.6 $\mu$ A without SVS | 0.77 $\mu$ A with RTC only | 13 nA without SVS |
| Wake-up time                   |                              | N/A             | instant         | 10 $\mu$ s         | 10 $\mu$ s              | 150 $\mu$ s                | 150 $\mu$ s       |
| Wake-up events                 |                              | N/A             | All             | All                | I/O                     | RTC Counter, I/O           | I/O               |
| Power                          | Regulator                    | Full Regulation | Full Regulation | Partial Power Down | Partial Power Down      | Partial Power Down         | Power Down        |
|                                | SVS                          | On              | On              | Optional           | Optional                | Optional                   | Optional          |
|                                | Brown Out                    | On              | On              | On                 | On                      | On                         | On                |
| Clock                          | MCLK                         | Active          | Off             | Off                | Off                     | Off                        | Off               |
|                                | SMCLK                        | Optional        | Optional        | Off                | Off                     | Off                        | Off               |
|                                | FLL                          | Optional        | Optional        | Off                | Off                     | Off                        | Off               |
|                                | DCO                          | Optional        | Optional        | Off                | Off                     | Off                        | Off               |
|                                | MODCLK                       | Optional        | Optional        | Off                | Off                     | Off                        | Off               |
|                                | REFO                         | Optional        | Optional        | Optional           | Off                     | Off                        | Off               |
|                                | ACLK                         | Optional        | Optional        | Optional           | Off                     | Off                        | Off               |
|                                | XT1CLK                       | Optional        | Optional        | Optional           | Off                     | Optional                   | Off               |
| Core                           | VLOCLK                       | Optional        | Optional        | Optional           | Off                     | Optional                   | Off               |
|                                | CPU                          | On              | Off             | Off                | Off                     | Off                        | Off               |
|                                | FRAM                         | On              | On              | Off                | Off                     | Off                        | Off               |
|                                | RAM                          | On              | On              | On                 | On                      | Off                        | Off               |
|                                | Backup Memory <sup>(1)</sup> | On              | On              | On                 | On                      | On                         | Off               |

(1) Backup memory contains one 32-byte register in the peripheral memory space. See [Table 6-31](#) and [Table 6-49](#) for its memory allocation.

**Table 6-1. Operating Modes (continued)**

| MODE        |                              | AM          | LPM0     | LPM3       | LPM4       | LPM3.5           | LPM4.5     |
|-------------|------------------------------|-------------|----------|------------|------------|------------------|------------|
|             |                              | ACTIVE MODE | CPU OFF  | STANDBY    | OFF        | ONLY RTC COUNTER | SHUTDOWN   |
| Peripherals | Timer0_A3                    | Optional    | Optional | Optional   | Off        | Off              | Off        |
|             | Timer1_A3                    | Optional    | Optional | Optional   | Off        | Off              | Off        |
|             | WDT                          | Optional    | Optional | Optional   | Off        | Off              | Off        |
|             | eUSCI_A0                     | Optional    | Optional | Off        | Off        | Off              | Off        |
|             | eUSCI_B0                     | Optional    | Optional | Off        | Off        | Off              | Off        |
|             | CRC                          | Optional    | Optional | Off        | Off        | Off              | Off        |
|             | ADC                          | Optional    | Optional | Optional   | Off        | Off              | Off        |
|             | RTC Counter                  | Optional    | Optional | Optional   | Off        | State Held       | Off        |
| I/O         | General Digital Input/Output | On          | Optional | State Held | State Held | Off              | State Held |
|             | Capacitive Touch I/O         | Optional    | Optional | Optional   | Off        | Off              | Off        |

### 6.3 Interrupt Vector Addresses

The interrupt vectors and the power-up start address are in the address range 0FFFFh to 0FF80h. The vector contains the 16-bit address of the appropriate interrupt-handler instruction sequence

**Table 6-2. Interrupt Sources, Flags, and Vectors**

| INTERRUPT SOURCE   | INTERRUPT FLAG  | SYSTEM INTERRUPT | WORD ADDRESS | PRIORITY    |
|--|---|------------------|--------------|-------------|
| <b>System Reset</b><br>Power up, Brownout, Supply supervisor, External reset RST, Watchdog time-out, Key violation, FRAM uncorrectable bit error detection, Software POR, FLL unlock error | SVSHIFG<br>PMMRSTIFG<br>WDTIFG<br>PMMPORIFG, PMMBORIFG<br>SYSRSTIV<br>FLLUNLOCKIFG                | Reset            | FFFEh        | 63, Highest |
| <b>System NMI</b><br>Vacant memory access, JTAG mailbox, FRAM bit error detection  | VMAIFG<br>JMBINIFG, JMBOUTIFG<br>CBDIFG, UBDIFG   | Nonmaskable      | FFFCh        | 62          |
| <b>User NMI</b><br>External NMI, Oscillator Fault  | NMIFG<br>OFIFG  | Nonmaskable      | FFFAh        | 61          |
| Timer0_A3  | TA0CCR0 CCIFG0  | Maskable         | FFF8h        | 60          |
| Timer0_A3  | TA0CCR1 CCIFG1, TA0CCR2 CCIFG2, TA0IFG (TA0IV)  | Maskable         | FFF6h        | 59          |
| Timer1_A3  | TA1CCR0 CCIFG0  | Maskable         | FFF4h        | 58          |
| Timer1_A3  | TA1CCR1 CCIFG1, TA1CCR2 CCIFG2, TA1IFG (TA1IV)  | Maskable         | FFF2h        | 57          |
| RTC Counter  | RTCIFG  | Maskable         | FFF0h        | 56          |
| Watchdog Timer Interval mode   | WDTIFG  | Maskable         | FFEEh        | 55          |
| eUSCI_A0 Receive or Transmit   | UCTXCPITIFG, UCSTTIFG,<br>UCRXIFG, UCTXIFG (UART mode)<br>UCRXIFG, UCTXIFG (SPI mode)<br>(UCA0IV) | Maskable         | FFECh        | 54          |

**Table 6-2. Interrupt Sources, Flags, and Vectors (continued)**

| INTERRUPT SOURCE             | INTERRUPT FLAG   | SYSTEM INTERRUPT | WORD ADDRESS  | PRIORITY   |
|------------------------------|--|------------------|---------------|------------|
| eUSCI_B0 Receive or Transmit | UCB0RXIFG, UCB0TXIFG (SPI mode)<br>UCALIFG, UCNACKIFG,<br>UCSTTIFG, UCSTPIFG,<br>UCRXIFG0, UCTXIFG0,<br>UCRXIFG1, UCTXIFG1,<br>UCRXIFG2, UCTXIFG2,<br>UCRXIFG3, UCTXIFG3,<br>UCCNTIFG, UCBIT9IFG (I <sup>2</sup> C mode)<br>(UCB0IV) | Maskable         | FFEAh         | 53         |
| ADC                          | ADCIFG0, ADCINIFG, ADCLOIFG,<br>ADCHIFG, ADCTOVIFG,<br>ADCOVIFG (ADCIV)  | Maskable         | FFE8h         | 52         |
| P1                           | P1IFG.0 to P1IFG.7 (P1IV)  | Maskable         | FFE6h         | 51         |
| P2                           | P2IFG.0 to P2IFG.7 (P2IV)  | Maskable         | FFE4h         | 50, Lowest |
| Reserved                     | Reserved   | Maskable         | FFE2h to FF8h |            |
| Signatures                   | BSL Signature 2  |                  | 0FF86h        |            |
|                              | BSL Signature 1  |                  | 0FF84h        |            |
|                              | JTAG Signature 2   |                  | 0FF82h        |            |
|                              | JTAG Signature 1   |                  | 0FF80h        |            |

## 6.4 Bootloader (BSL)

The BSL enables users to program the FRAM or RAM using a UART serial interface. Access to the device memory through the BSL is protected by a user-defined password. [Table 6-3](#) lists the BSL pin requirements. BSL entry requires a specific entry sequence on the  $\overline{\text{RST}}/\text{NMI}/\text{SBWTDIO}$  and  $\text{TEST}/\text{SBWTCK}$  pins. For a complete description of the features of the BSL and its implementation, see the [MSP430 FRAM Devices Bootloader \(BSL\) User's Guide](#).

**Table 6-3. BSL Pin Requirements and Functions**

| DEVICE SIGNAL                                     | BSL FUNCTION          |
|---|-----------------------|
| $\overline{\text{RST}}/\text{NMI}/\text{SBWTDIO}$ | Entry sequence signal |
| $\text{TEST}/\text{SBWTCK}$                       | Entry sequence signal |
| P1.0  | Data transmit         |
| P1.1  | Data receive          |
| VCC   | Power supply          |
| VSS   | Ground supply         |

## 6.5 JTAG Standard Interface

The MSP430 family supports the standard JTAG interface which requires four signals for sending and receiving data. The JTAG signals are shared with general-purpose I/O. The  $\text{TEST}/\text{SBWTCK}$  pin is used to enable the JTAG signals. In addition to these signals, the  $\overline{\text{RST}}/\text{NMI}/\text{SBWTDIO}$  is required to interface with MSP430 development tools and device programmers. [Table 6-4](#) lists the JTAG pin requirements. For further details on interfacing to development tools and device programmers, see the [MSP430 Hardware Tools User's Guide](#). For a complete description of the features of the JTAG interface and its implementation, see [MSP430 Programming With the JTAG Interface](#).

**Table 6-4. JTAG Pin Requirements and Function**

| DEVICE SIGNAL          | DIRECTION | JTAG FUNCTION              |
|------------------------|-----------|----------------------------|
| P1.4/MCLK/TCK/A4/VREF+ | IN        | JTAG clock input           |
| P1.5/TA0CLK/TMS/A5     | IN        | JTAG state control         |
| P1.6/TA0.2/TDI/TCLK/A6 | IN        | JTAG data input/TCLK input |
| P1.7/TA0.1/TDO/A7      | OUT       | JTAG data output           |
| TEST/SBWTCK            | IN        | Enable JTAG pins           |
| RST/NMI/SBWDIO         | IN        | External reset             |
| VCC                    |           | Power supply               |
| VSS                    |           | Ground supply              |

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

The MSP430 family supports the 2-wire Spy-Bi-Wire interface. Spy-Bi-Wire can be used to interface with MSP430 development tools and device programmers. [Table 6-5](#) shows the Spy-Bi-Wire interface pin requirements. For further details on interfacing to development tools and device programmers, see the [MSP430 Hardware Tools User's Guide](#).

**Table 6-5. Spy-Bi-Wire Pin Requirements and Functions**

| DEVICE SIGNAL  | DIRECTION | SBW FUNCTION                  |
|----------------|-----------|-------------------------------|
| TEST/SBWTCK    | IN        | Spy-Bi-Wire clock input       |
| RST/NMI/SBWDIO | IN, OUT   | Spy-Bi-Wire data input/output |
| VCC            |           | Power supply                  |
| VSS            |           | Ground supply                 |

## 6.7 FRAM

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

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

## 6.8 Memory Protection

The device features memory protection that can restrict user access and enable write protection:

- Securing the whole memory map to prevent unauthorized access from JTAG port or BSL, by writing JTAG and BSL signatures using the JTAG port, SBW, the BSL, or in-system by the CPU.
- Write protection enabled to prevent unwanted write operation to FRAM contents by setting the control bits in System Configuration register 0. For more detailed information, see the SYS chapter in the [MSP430FR4xx and MSP430FR2xx Family User's Guide](#).

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### NOTE

The FRAM is protected by default on PUC. To write to FRAM during code execution, the application must first clear the corresponding PFWP or DFWP bit in System Configuration Register 0 to unprotect the FRAM.

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## 6.9 Peripherals

Peripherals are connected to the CPU through data, address, and control buses. All peripherals can be handled by using all instructions in the memory map. For complete module description, see the [MSP430FR4xx and MSP430FR2xx Family User's Guide](#).

### 6.9.1 Power Management Module (PMM) and On-chip Reference Voltages

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

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

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

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

A 1.2-V reference voltage can be buffered and output to P1.4/MCLK/TCK/A4/VREF+, when the ADC channel 4 is selected as the function. For more detailed information, see the [MSP430FR4xx and MSP430FR2xx Family User's Guide](#).

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

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

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

All peripherals may have one or several clock sources depending on specific functionality. [Table 6-6](#) shows the clock distribution used in this device.

Table 6-6. Clock Distribution

|                 | CLOCK SOURCE SELECT BITS | MCLK         | SMCLK        | ACLK         | MODCLK     | XT1CLK <sup>(1)</sup> | VLOCLK      | EXTERNAL PIN      |
|-----------------|--------------------------|--------------|--------------|--------------|------------|-----------------------|-------------|-------------------|
| Frequency Range |                          | DC to 16 MHz | DC to 16 MHz | DC to 40 kHz | 5 MHz ±10% | DC to 40 kHz          | 10 kHz ±50% |                   |
| CPU             | N/A                      | Default      |              |              |            |                       |             |                   |
| FRAM            | N/A                      | Default      |              |              |            |                       |             |                   |
| RAM             | N/A                      | Default      |              |              |            |                       |             |                   |
| CRC             | N/A                      | Default      |              |              |            |                       |             |                   |
| I/O             | N/A                      | Default      |              |              |            |                       |             |                   |
| TA0             | TASSEL                   |              | 10b          | 01b          |            |                       |             | 00b (TA0CLK pin)  |
| TA1             | TASSEL                   |              | 10b          | 01b          |            |                       |             | 00b (TA1CLK pin)  |
| eUSCI_A0        | UCSSEL                   |              | 10b or 11b   |              | 01b        |                       |             | 00b (UCA0CLK pin) |
| eUSCI_B0        | UCSSEL                   |              | 10b or 11b   |              | 01b        |                       |             | 00b (UCB0CLK pin) |
| WDT             | WDTSSSEL                 |              | 00b          | 01b          |            |                       | 10b         |                   |
| ADC             | ADCSSSEL                 |              | 10b or 11b   | 01b          | 00b        |                       |             |                   |
| RTC             | RTCSS                    |              | 01b          |              |            | 10b                   | 11b         |                   |

(1) To enable XT1 functionality, configure P4SEL0.1 (XIN) and P4SEL0.2 (XOUT) before configuring the Clock System registers.

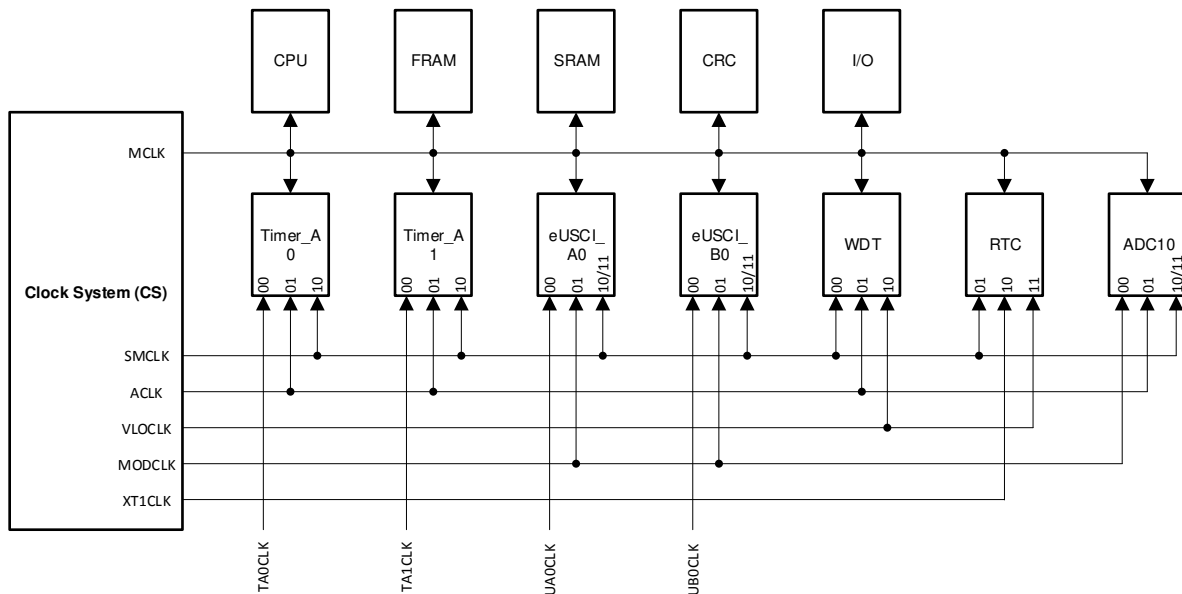


Figure 6-1. Clock Distribution Block Diagram

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

There are up to 60 I/O ports implemented, depending on the package.

- P1, P2, P3, P4, P5, P6, and P7 are full 8-bit ports; P8 has 4 bits implemented.
- All individual I/O bits are independently programmable.
- Any combination of input, output, and interrupt conditions is possible.
- Programmable pullup or pulldown on all ports.
- Edge-selectable interrupt and LPM3.5 and LPM4.5 wake-up input capability is available for P1 and P2.
- Read and write access to port-control registers is supported by all instructions.
- Ports can be accessed byte-wise or word-wise in pairs.
- Capacitive Touch I/O functionality is supported on all pins.

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#### NOTE

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

To prevent any cross currents during start-up of the device, all port pins are high-impedance with Schmitt triggers and module functions disabled. To enable the I/O functions after a BOR reset, the ports must be configured first and then the LOCKLPM5 bit must be cleared. For details, see the *Configuration After Reset* section in the *Digital I/O* chapter of the [MSP430FR4xx and MSP430FR2xx Family User's Guide](#).

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### 6.9.4 Watchdog Timer (WDT)

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

**Table 6-7. WDT Clocks**

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

### 6.9.5 System Module (SYS)

The SYS module handles many of the system functions within the device. These include Power-On Reset (POR) and Power-Up Clear (PUC) handling, NMI source selection and management, reset interrupt vector generators, bootloader entry mechanisms, and configuration management (device descriptors). SYS also includes a data exchange mechanism through SBW called a JTAG mailbox mail box that can be used in the application.

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

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

**Table 6-8. System Module Interrupt Vector Registers (continued)**

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

### 6.9.6 Cyclic Redundancy Check (CRC)

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

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

The eUSCI modules are used for serial data communications. The eUSCI\_A module supports either UART or SPI communications. The eUSCI\_B module supports either SPI or I<sup>2</sup>C communications. Additionally, eUSCI\_A supports automatic baud-rate detection and IrDA.

**Table 6-9. eUSCI Pin Configurations**

|          | PIN  | UART             | SPI  |
|----------|------|------------------|------|
| eUSCI_A0 | P1.0 | TXD              | SIMO |
|          | P1.1 | RXD              | SOMI |
|          | P1.2 | –                | SCLK |
|          | P1.3 | –                | STE  |
|          | PIN  | I <sup>2</sup> C | SPI  |
| eUSCI_B0 | P5.0 | –                | STE  |
|          | P5.1 | –                | SCLK |
|          | P5.2 | SDA              | SIMO |
|          | P5.3 | SCL              | SOMI |

### 6.9.8 Timers (Timer0\_A3, Timer1\_A3)

The Timer0\_A3 and Timer1\_A3 modules are 16-bit timers and counters with three capture/compare registers each. Each timer can support multiple captures or compares, PWM outputs, and interval timing. Each timer has extensive interrupt capabilities. Interrupts may be generated from the counter on overflow conditions and from each of the capture/compare registers. The CCR0 registers on both TA0 and TA1 are not externally connected and can only be used for hardware period timing and interrupt generation. In Up mode, they can be used to set the overflow value of the counter.

**Table 6-10. Timer0\_A3 Signal Connections**

| PORT PIN | DEVICE INPUT SIGNAL                  | MODULE INPUT NAME | MODULE BLOCK | MODULE OUTPUT SIGNAL | DEVICE OUTPUT SIGNAL                                  |
|----------|--------------------------------------|-------------------|--------------|----------------------|---|
| P1.5     | TA0CLK                               | TACLK             | Timer        | N/A                  |   |
|          | ACLK (internal)                      | ACLK              |              |                      |   |
|          | SMCLK (internal)                     | SMCLK             |              |                      |   |
|          | From Capacitive Touch I/O (internal) | INCLK             |              |                      |   |
|          |                                      | CCI0A             | CCR0         | TA0                  |   |
|          |                                      | CCI0B             |              |                      | Timer1_A3 CCI0B input                                 |
|          | DVSS                                 | GND               |              |                      |   |
|          | DVCC                                 | VCC               |              |                      |   |
| P1.7     | TA0.1                                | CCI1A             | CCR1         | TA1                  | TA0.1   |
|          | From RTC (internal)                  | CCI1B             |              |                      | Timer1_A3 CCI1B input                                 |
|          | DVSS                                 | GND               |              |                      |   |
|          | DVCC                                 | VCC               |              |                      |   |
| P1.6     | TA0.2                                | CCI2A             | CCR2         | TA2                  | TA0.2   |
|          | From Capacitive Touch I/O (internal) | CCI2B             |              |                      | Timer1_A3 INCLK<br>Timer1_A3 CCI2B input,<br>IR Input |
|          | DVSS                                 | GND               |              |                      |   |
|          | DVCC                                 | VCC               |              |                      |   |

**Table 6-11. Timer1\_A3 Signal Connections**

| PORT PIN | DEVICE INPUT SIGNAL               | MODULE INPUT NAME | MODULE BLOCK | MODULE OUTPUT SIGNAL | DEVICE OUTPUT SIGNAL |
|----------|-----------------------------------|-------------------|--------------|----------------------|----------------------|
| P8.2     | TA1CLK                            | TACLK             | Timer        | N/A                  |                      |
|          | ACLK (internal)                   | ACLK              |              |                      |                      |
|          | SMCLK (internal)                  | SMCLK             |              |                      |                      |
|          | Timer0_A3 CCR2B output (internal) | INCLK             |              |                      |                      |
|          |                                   | CCI0A             | CCR0         | TA0                  |                      |
|          | Timer0_A3 CCR0B output (internal) | CCI0B             |              |                      |                      |
|          | DVSS                              | GND               |              |                      |                      |
|          | DVCC                              | VCC               |              |                      |                      |
| P4.0     | TA1.1                             | CCI1A             | CCR1         | TA1                  | TA1.1                |
|          | Timer0_A3 CCR1B output (internal) | CCI1B             |              |                      | To ADC trigger       |
|          | DVSS                              | GND               |              |                      |                      |
|          | DVCC                              | VCC               |              |                      |                      |
| P8.3     | TA1.2                             | CCI2A             | CCR2         | TA2                  | TA1.2                |
|          | Timer0_A3 CCR2B output (internal) | CCI2B             |              |                      | IR Input             |
|          | DVSS                              | GND               |              |                      |                      |
|          | DVCC                              | VCC               |              |                      |                      |

The interconnection of Timer0\_A3 and Timer1\_A3 can be used to modulate the eUSCI\_A pin of UCA0TXD/UCA0SIMO in either ASK or FSK mode. This configuration helps an application easily acquire a modulated infrared command for directly driving an external IR diode.

The IR functions are controlled by the following bits in the System Configuration 1 (SYSCFG1) register: IREN (enable), IRPSEL (polarity select), IRMSEL (mode select), IRDSSEL (data select), and IRDATA (data). For more information, see the SYS chapter in the [MSP430FR4xx and MSP430FR2xx Family User's Guide](#).

### 6.9.9 Real-Time Clock (RTC) Counter

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

- Timer0\_A3 CCR1B
- ADC conversion trigger when ADCSHSx bits are set as 01b

### 6.9.10 10-Bit Analog Digital Converter (ADC)

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

The ADC supports 10 external inputs and four internal inputs (see [Table 6-12](#)).

**Table 6-12. ADC Channel Connections**

| ADCINCHx | ADC CHANNELS               | EXTERNAL PIN OUT    |
|----------|----------------------------|---------------------|
| 0        | A0/Vref-                   | P1.0                |
| 1        | A1/Vref+                   | P1.1                |
| 2        | A2                         | P1.2                |
| 3        | A3                         | P1.3                |
| 4        | A4 <sup>(1)</sup>          | P1.4                |
| 5        | A5                         | P1.5                |
| 6        | A6                         | P1.6                |
| 7        | A7                         | P1.7                |
| 8        | A8                         | P8.0 <sup>(2)</sup> |
| 9        | A9                         | P8.1 <sup>(2)</sup> |
| 10       | Not used                   | N/A                 |
| 11       | Not used                   | N/A                 |
| 12       | On-chip temperature sensor | N/A                 |
| 13       | Reference voltage (1.5 V)  | N/A                 |
| 14       | DVSS                       | N/A                 |
| 15       | DVCC                       | N/A                 |

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

(2) P8.0 and P8.1 are only available in the LQFP-64 package.

The A/D conversion can be started by software or a hardware trigger. [Table 6-13](#) shows the trigger sources that are available.

**Table 6-13. ADC Trigger Signal Connections**

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

### 6.9.11 *Embedded Emulation Module (EEM)*

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

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

## 6.9.12 Input/Output Diagrams

### 6.9.12.1 Port P1 Input/Output With Schmitt Trigger

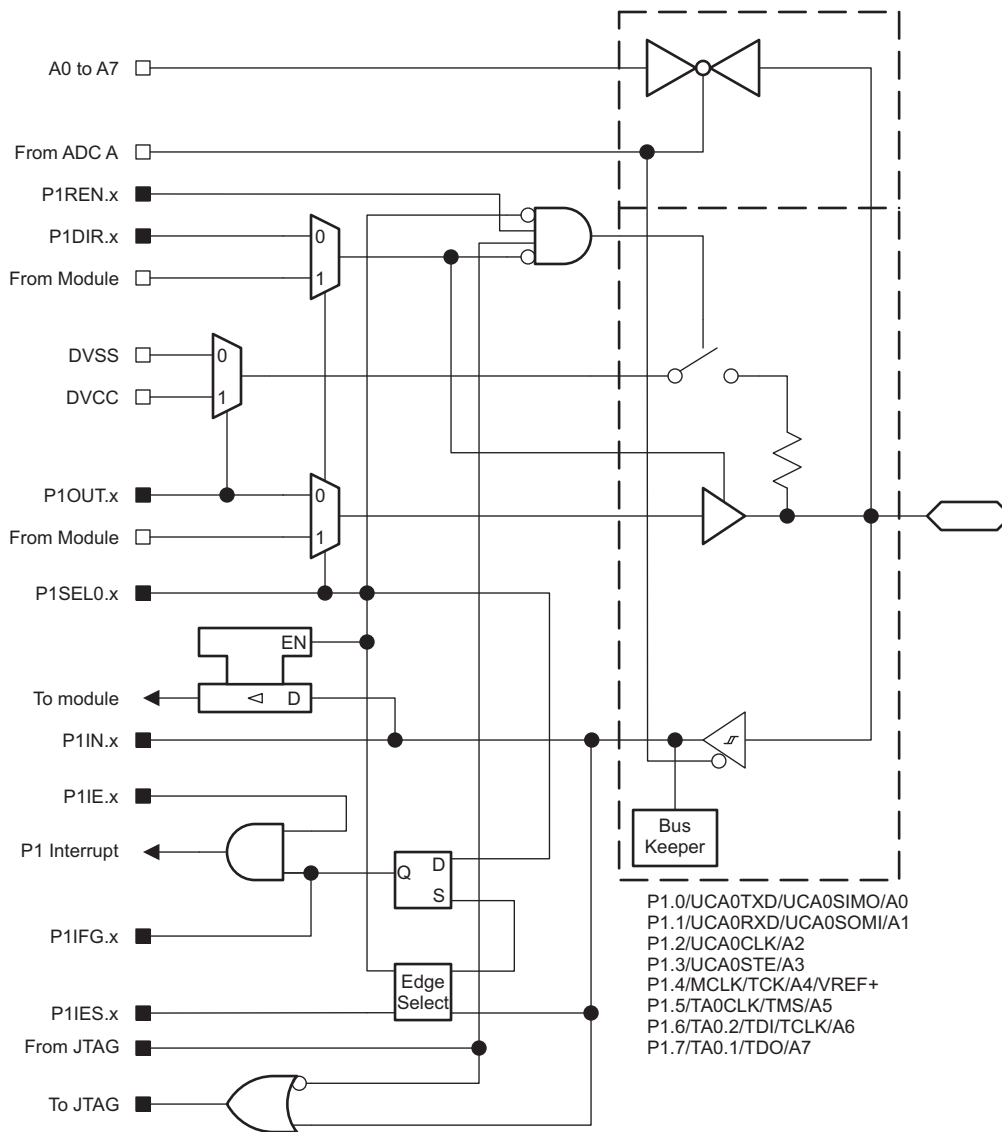


Figure 6-2. Port P1 Input/Output With Schmitt Trigger

**Table 6-14. Port P1 Pin Functions**

| PIN NAME (P1.x)          | x | FUNCTION         | CONTROL BITS AND SIGNALS <sup>(1)</sup> |          |                         |          |
|--------------------------|---|------------------|---|----------|-------------------------|----------|
|                          |   |                  | P1DIR.x                                 | P1SEL0.x | ADCPCTLx <sup>(2)</sup> | JTAG     |
| P1.0/UCA0TXD/UCA0SIMO/A0 | 0 | P1.0 (I/O)       | I: 0; O: 1                              | 0        | 0                       | N/A      |
|                          |   | UCA0TXD/UCA0SIMO | X                                       | 1        | 0                       | N/A      |
|                          |   | A0               | X                                       | X        | 1 (x = 0)               | N/A      |
| P1.1/UCA0RXD/UCA0SOMI/A1 | 1 | P1.1 (I/O)       | I: 0; O: 1                              | 0        | 0                       | N/A      |
|                          |   | UCA0RXD/UCA0SOMI | X                                       | 1        | 0                       | N/A      |
|                          |   | A1               | X                                       | X        | 1 (x = 1)               | N/A      |
| P1.2/UCA0CLK/A2          | 2 | P1.2 (I/O)       | I: 0; O: 1                              | 0        | 0                       | N/A      |
|                          |   | UCA0CLK          | X                                       | 1        | 0                       | N/A      |
|                          |   | A2               | X                                       | X        | 1 (x = 2)               | N/A      |
| P1.3/UCA0STE/A3          | 3 | P1.3 (I/O)       | I: 0; O: 1                              | 0        | 0                       | N/A      |
|                          |   | UCA0STE          | X                                       | 1        | 0                       | N/A      |
|                          |   | A3               | X                                       | X        | 1 (x = 3)               | N/A      |
| P1.4/MCLK/TCK/A4/VREF+   | 4 | P1.4 (I/O)       | I: 0; O: 1                              | 0        | 0                       | Disabled |
|                          |   | VSS              | 0                                       | 1        | 0                       | Disabled |
|                          |   | MCLK             | 1                                       |          |                         |          |
|                          |   | A4, VREF+        | X                                       | X        | 1 (x = 4)               | Disabled |
|                          |   | JTAG TCK         | X                                       | X        | X                       | TCK      |
| P1.5/TA0CLK/TMS/A5       | 5 | P1.5 (I/O)       | I: 0; O: 1                              | 0        | 0                       | Disabled |
|                          |   | TA0CLK           | 0                                       | 1        | 0                       | Disabled |
|                          |   | VSS              | 1                                       |          |                         |          |
|                          |   | A5               | X                                       | X        | 1 (x = 5)               | Disabled |
|                          |   | JTAG TMS         | X                                       | X        | X                       | TMS      |
| P1.6/TA0.2/TDI/TCLK/A6   | 6 | P1.6 (I/O)       | I: 0; O: 1                              | 0        | 0                       | Disabled |
|                          |   | TA0.CCI2A        | 0                                       | 1        | 0                       | Disabled |
|                          |   | TA0.2            | 1                                       |          |                         |          |
|                          |   | A6               | X                                       | X        | 1 (x = 6)               | Disabled |
|                          |   | JTAG TDI/TCLK    | X                                       | X        | X                       | TDI/TCLK |
| P1.7/TA0.1/TDO/A7        | 7 | P1.7 (I/O)       | I: 0; O: 1                              | 0        | 0                       | Disabled |
|                          |   | TA0.CCI1A        | 0                                       | 1        | 0                       | Disabled |
|                          |   | TA0.1            | 1                                       |          |                         |          |
|                          |   | A7               | X                                       | X        | 1 (x = 7)               | Disabled |
|                          |   | JTAG TDO         | X                                       | X        | X                       | TDO      |

(1) X = don't care

(2) Setting the ADCPCTLx bit in SYSCFG2 register disables both the output driver and the input Schmitt trigger to prevent leakage when analog signals are applied.



6.9.12.2 Port P2 Input/Output With Schmitt Trigger

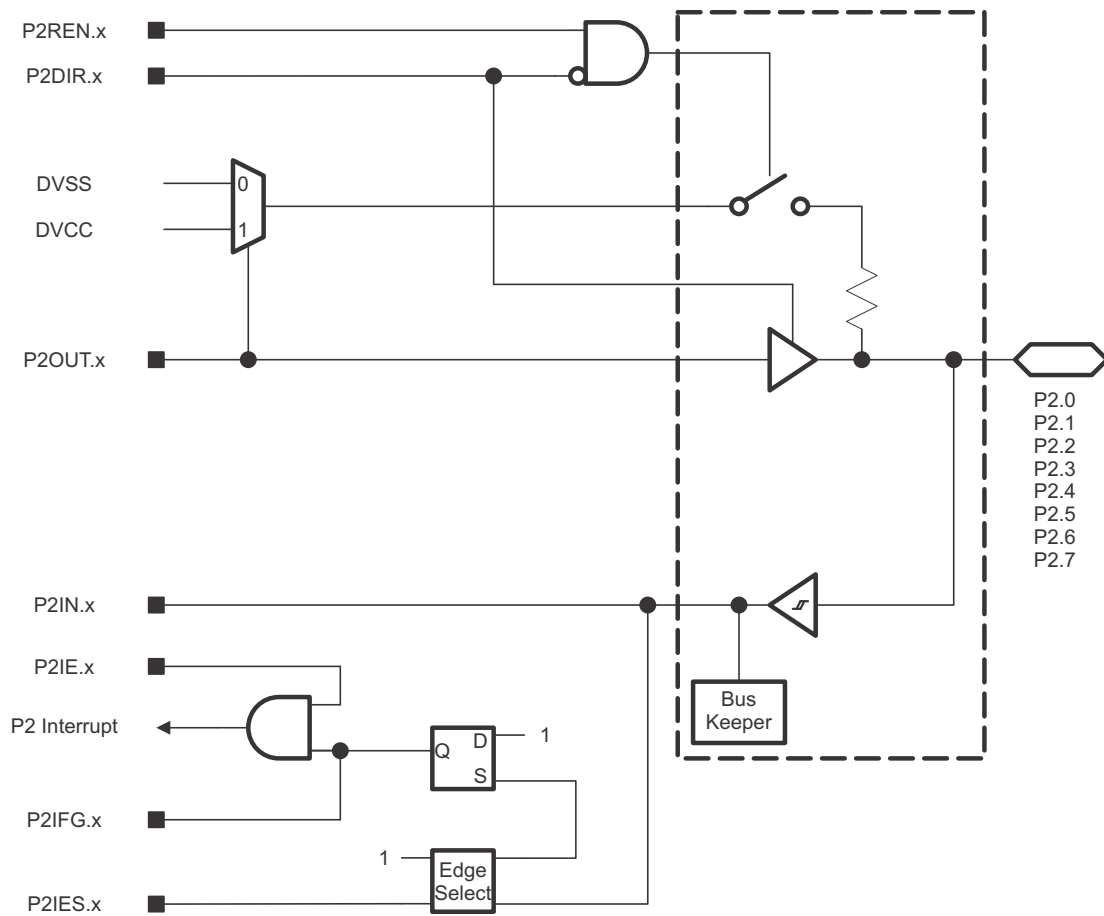


Figure 6-3. Port P2 Input/Output With Schmitt Trigger

Table 6-15. Port P2 Pin Functions

| PIN NAME (P2.x) | x | FUNCTION   | CONTROL BITS AND SIGNALS |
|-----------------|---|------------|--------------------------|
|                 |   |            | P2DIR.x                  |
| P2.0            | 0 | P2.0 (I/O) | I: 0; O: 1               |
| P2.1            | 1 | P2.1 (I/O) | I: 0; O: 1               |
| P2.2            | 2 | P2.2 (I/O) | I: 0; O: 1               |
| P2.3            | 3 | P2.3 (I/O) | I: 0; O: 1               |
| P2.4            | 4 | P2.4 (I/O) | I: 0; O: 1               |
| P2.5            | 5 | P2.5 (I/O) | I: 0; O: 1               |
| P2.6            | 6 | P2.6 (I/O) | I: 0; O: 1               |
| P2.7            | 7 | P2.7 (I/O) | I: 0; O: 1               |

6.9.12.3 Port P3 Input/Output With Schmitt Trigger

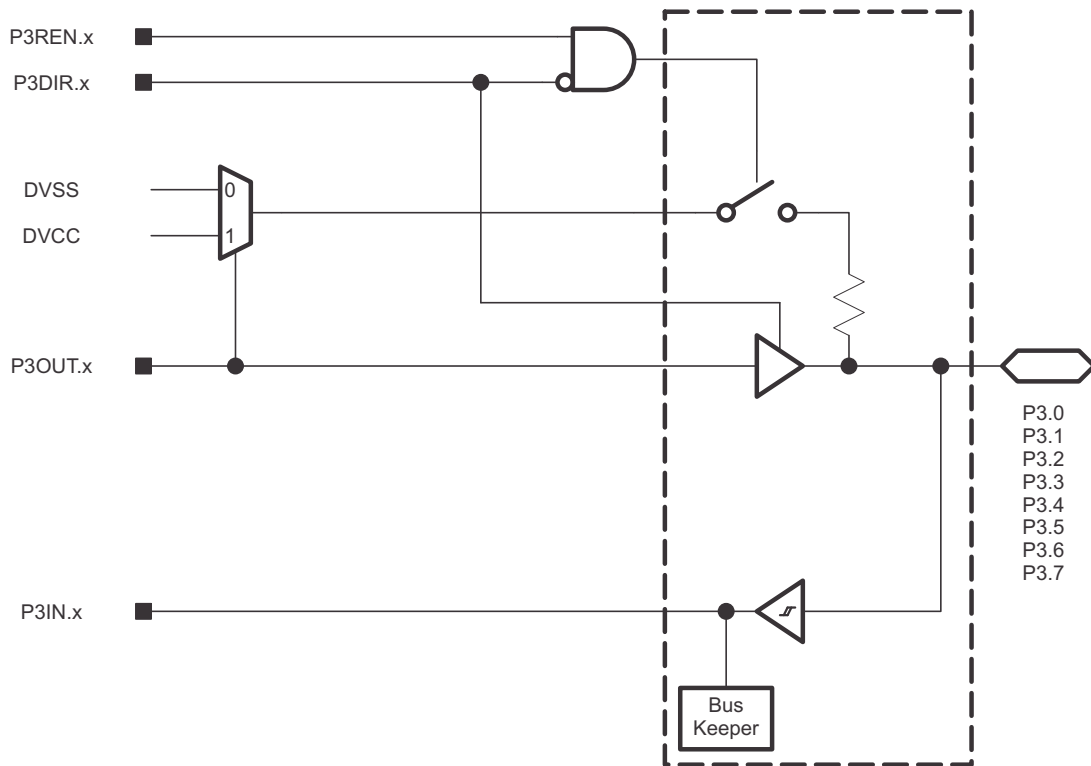


Figure 6-4. Port P3 Input/Output With Schmitt Trigger

Table 6-16. Port P3 Pin Functions

| PIN NAME (P3.x) | x | FUNCTION   | CONTROL BITS AND SIGNALS |
|-----------------|---|------------|--------------------------|
|                 |   |            | P3DIR.x                  |
| P3.0            | 0 | P3.0 (I/O) | I: 0; O: 1               |
| P3.1            | 1 | P3.1 (I/O) | I: 0; O: 1               |
| P3.2            | 2 | P3.2 (I/O) | I: 0; O: 1               |
| P3.3            | 3 | P3.3 (I/O) | I: 0; O: 1               |
| P3.4            | 4 | P3.4 (I/O) | I: 0; O: 1               |
| P3.5            | 5 | P3.5 (I/O) | I: 0; O: 1               |
| P3.6            | 6 | P3.6 (I/O) | I: 0; O: 1               |
| P3.7            | 7 | P3.7 (I/O) | I: 0; O: 1               |

6.9.12.4 Port P4.0 Input/Output With Schmitt Trigger

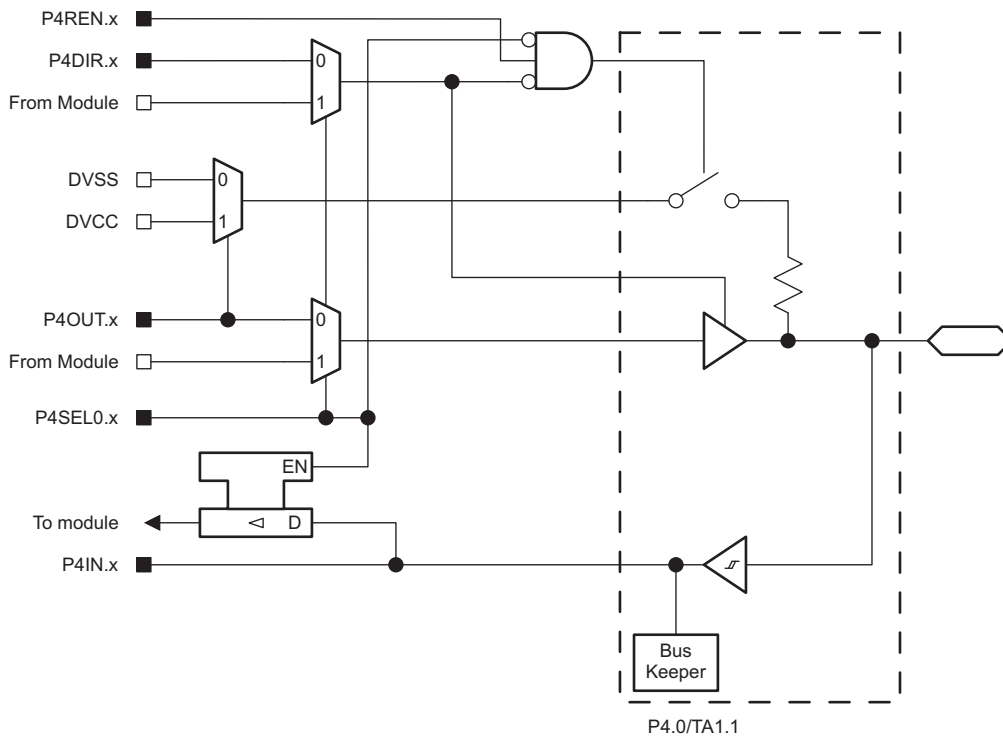


Figure 6-5. Port P4.0 Input/Output With Schmitt Trigger

Table 6-17. Port P4.0 Pin Functions

| PIN NAME (P4.x) | x | FUNCTION   | CONTROL BITS AND SIGNALS |          |
|-----------------|---|------------|--------------------------|----------|
|                 |   |            | P4DIR.x                  | P4SEL0.x |
| P4.0/TA1.1      | 0 | P4.0 (I/O) | I: 0; O: 1               | 0        |
|                 |   | TA1.CCI1A  | 0                        | 1        |
|                 |   | TA1.1      | 1                        |          |

### 6.9.12.5 Port P4.1 and P4.2 Input/Output With Schmitt Trigger

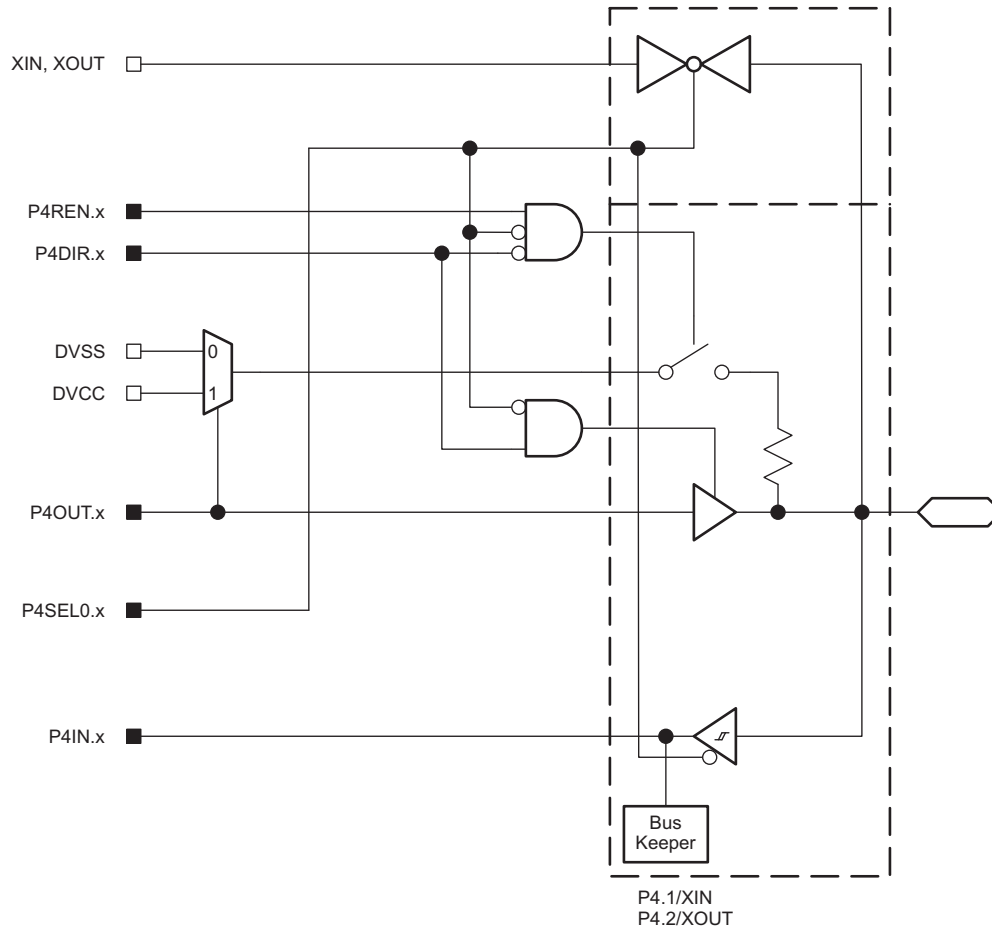


Figure 6-6. Port P4.1 and P4.2 Input/Output With Schmitt Trigger

Table 6-18. Port P4.1 and P4.2 Pin Functions

| PIN NAME (P4.x) | x | FUNCTION   | CONTROL BITS AND SIGNALS <sup>(1)</sup> |          |
|-----------------|---|------------|---|----------|
|                 |   |            | P4DIR.x                                 | P4SEL0.x |
| P4.1/XIN        | 1 | P4.1 (I/O) | I: 0; O: 1                              | 0        |
|                 |   | XIN        | X                                       | 1        |
| P4.2/XOUT       | 2 | P4.2 (I/O) | I: 0; O: 1                              | 0        |
|                 |   | XOUT       | X                                       | 1        |

(1) X = don't care

6.9.12.6 Port 4.3, P4.4, P4.5, P4.6, and P4.7 Input/Output With Schmitt Trigger

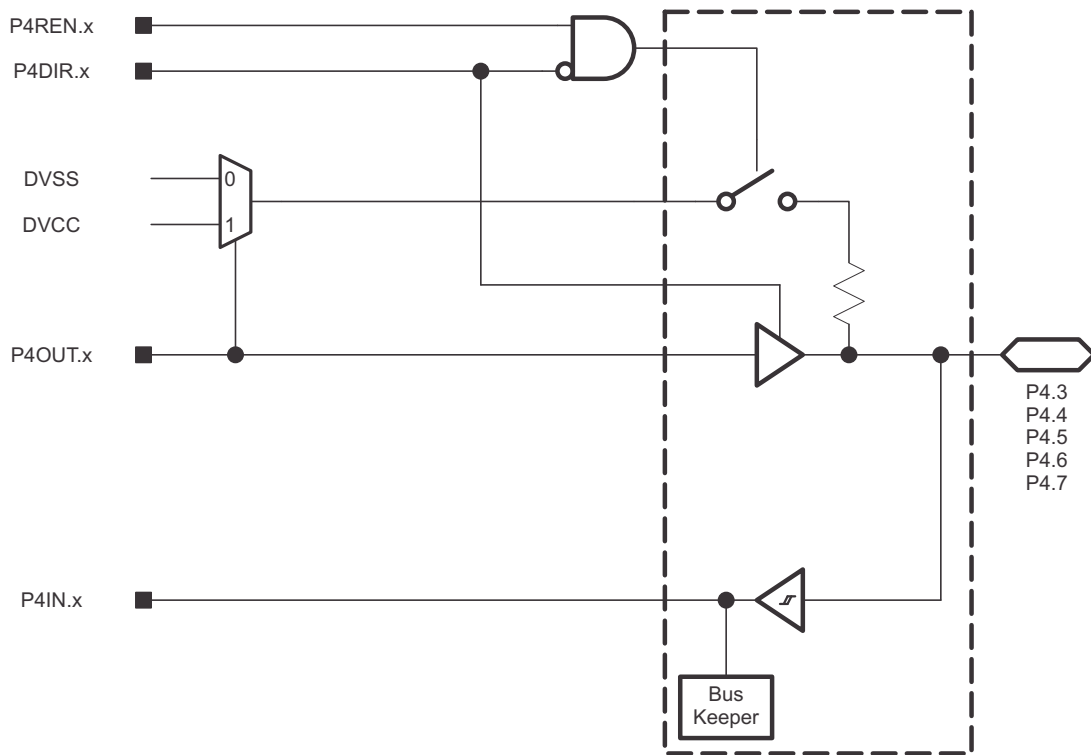


Figure 6-7. Port 4.3, P4.4, P4.5, P4.6, and P4.7 Input/Output With Schmitt Trigger

Table 6-19. Port P4.3, P4.4, P4.5, P4.6, and P4.7 Pin Functions

| PIN NAME (P4.x) | x | FUNCTION   | CONTROL BITS AND SIGNALS |
|-----------------|---|------------|--------------------------|
|                 |   |            | P4DIR.x                  |
| P4.3            | 3 | P4.3 (I/O) | I: 0; O: 1               |
| P4.4            | 4 | P4.4 (I/O) | I: 0; O: 1               |
| P4.5            | 5 | P4.5 (I/O) | I: 0; O: 1               |
| P4.6            | 6 | P4.6 (I/O) | I: 0; O: 1               |
| P4.7            | 7 | P4.7 (I/O) | I: 0; O: 1               |

### 6.9.12.7 Port P5.0, P5.1, P5.2, and P5.3 Input/Output With Schmitt Trigger

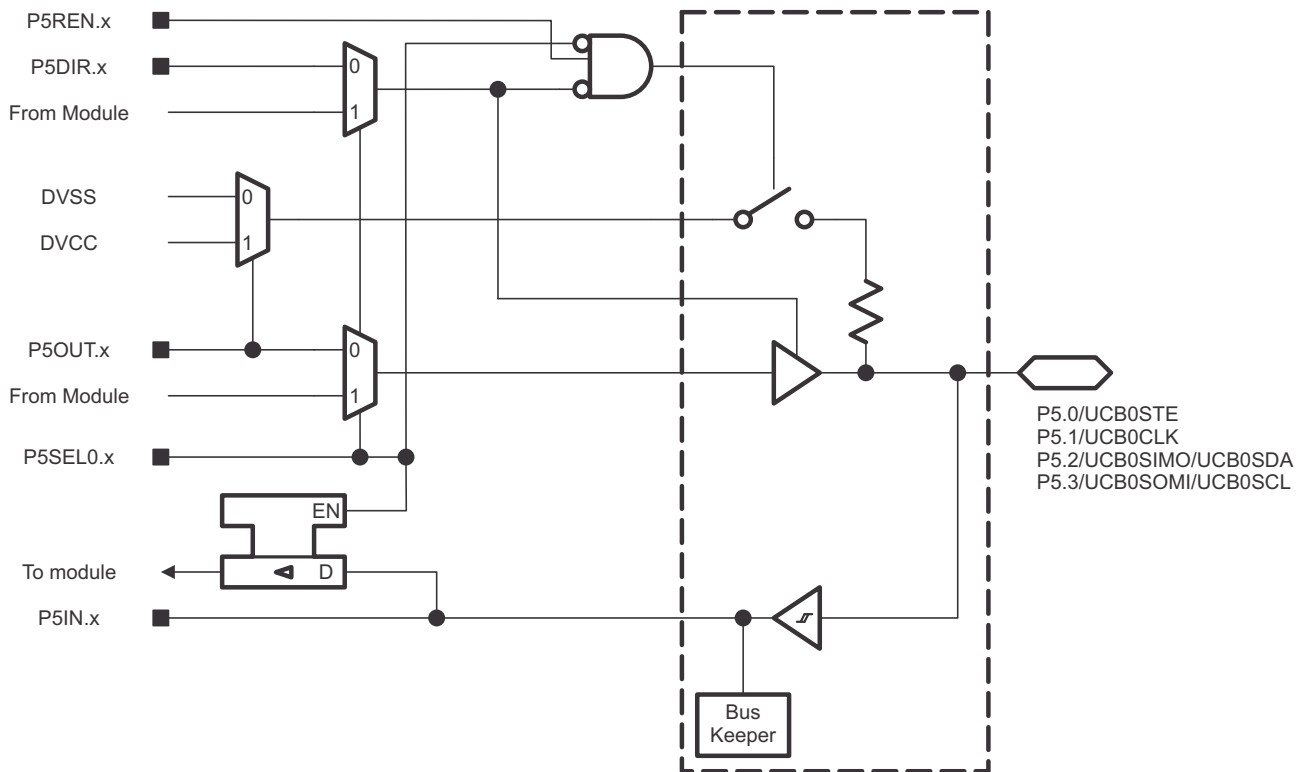


Figure 6-8. Port P5.0, P5.1, P5.2, and P5.3 Input/Output With Schmitt Trigger

Table 6-20. Port P5.0, P5.1, P5.2, and P5.3 Pin Functions

| PIN NAME (P5.x)       | x | FUNCTION         | CONTROL BITS AND SIGNALS |          |
|-----------------------|---|------------------|--------------------------|----------|
|                       |   |                  | P5DIR.x                  | P5SEL0.x |
| P5.0/UCB0STE          | 0 | P5.0 (I/O)       | I: 0; O: 1               | 0        |
|                       |   | UCB0STE          | 0                        | 1        |
| P5.1/UCB0CLK          | 1 | P5.1 (I/O)       | I: 0; O: 1               | 0        |
|                       |   | UCB0CLK          | 0                        | 1        |
| P5.2/UCB0SIMO/UCB0SDA | 2 | P5.2 (I/O)       | I: 0; O: 1               | 0        |
|                       |   | UCB0SIMO/UCB0SDA | 0                        | 1        |
| P5.3/UCB0SOMI/UCB0SCL | 3 | P5.3 (I/O)       | I: 0; O: 1               | 0        |
|                       |   | UCB0SOMI/UCB0SCL | 0                        | 1        |

6.9.12.8 Port P5.4, P5.5, P5.6, and P5.7 Input/Output With Schmitt Trigger

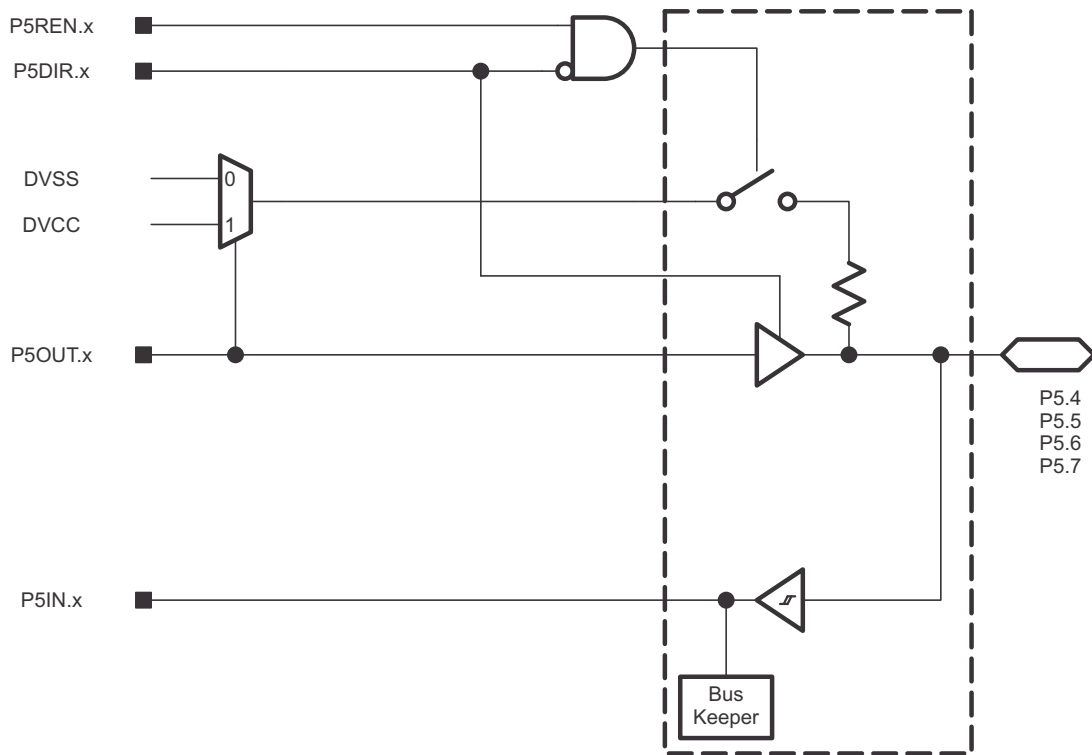


Figure 6-9. Port P5.4, P5.5, P5.6, and P5.7 Input/Output With Schmitt Trigger

Table 6-21. Port P5.4, P5.5, P5.6, and P5.7 Pin Functions

| PIN NAME (P5.x) | x | FUNCTION   | CONTROL BITS AND SIGNALS |
|-----------------|---|------------|--------------------------|
|                 |   |            | P5DIR.x                  |
| P5.4            | 4 | P5.4 (I/O) | I: 0; O: 1               |
| P5.5            | 5 | P5.5 (I/O) | I: 0; O: 1               |
| P5.6            | 6 | P5.6 (I/O) | I: 0; O: 1               |
| P5.7            | 7 | P5.7 (I/O) | I: 0; O: 1               |

6.9.12.9 Port P6.0, P6.1, P6.2, and P6.3 Input/Output With Schmitt Trigger

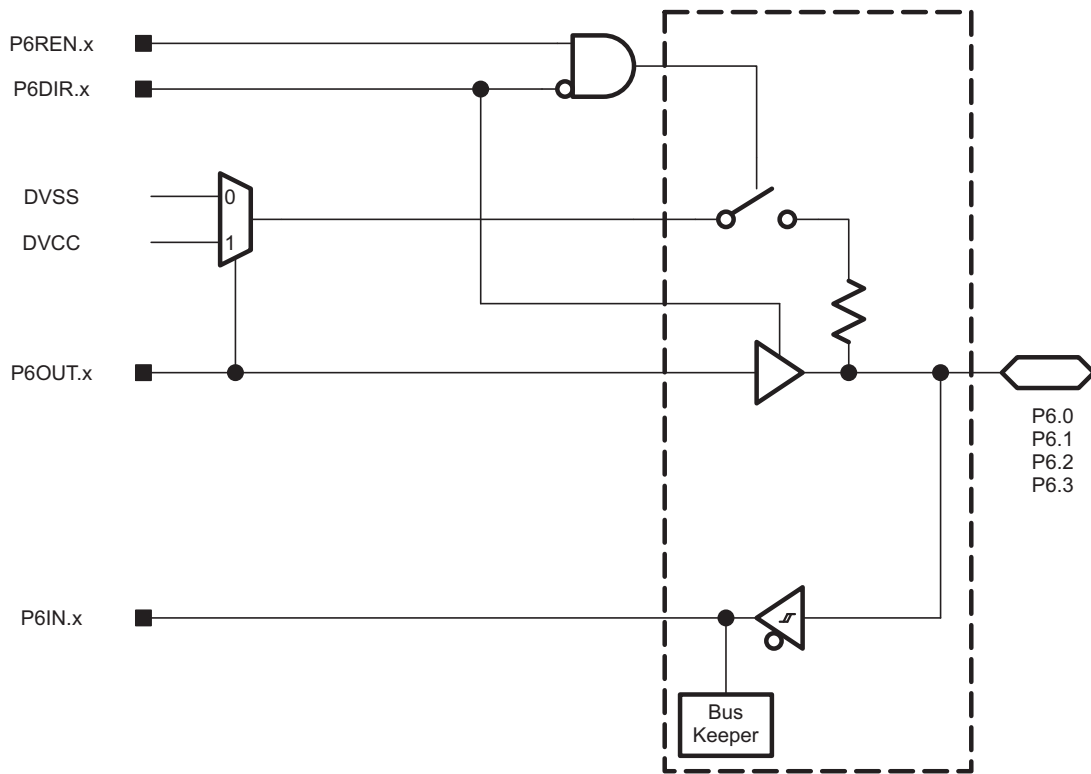


Figure 6-10. Port P6.0, P6.1, P6.2, and P6.3 Input/Output With Schmitt Trigger

Table 6-22. Port P6 Pin Functions

| PIN NAME (P6.x) | x | FUNCTION   | CONTROL BITS AND SIGNALS |
|-----------------|---|------------|--------------------------|
|                 |   |            | P6DIR.x                  |
| P6.0            | 0 | P6.0 (I/O) | I: 0; O: 1               |
| P6.1            | 1 | P6.1 (I/O) | I: 0; O: 1               |
| P6.2            | 2 | P6.2 (I/O) | I: 0; O: 1               |
| P6.3            | 3 | P6.3 (I/O) | I: 0; O: 1               |



6.9.12.10 Port P6.4, P6.5, P6.6, and P6.7 Input/Output With Schmitt Trigger

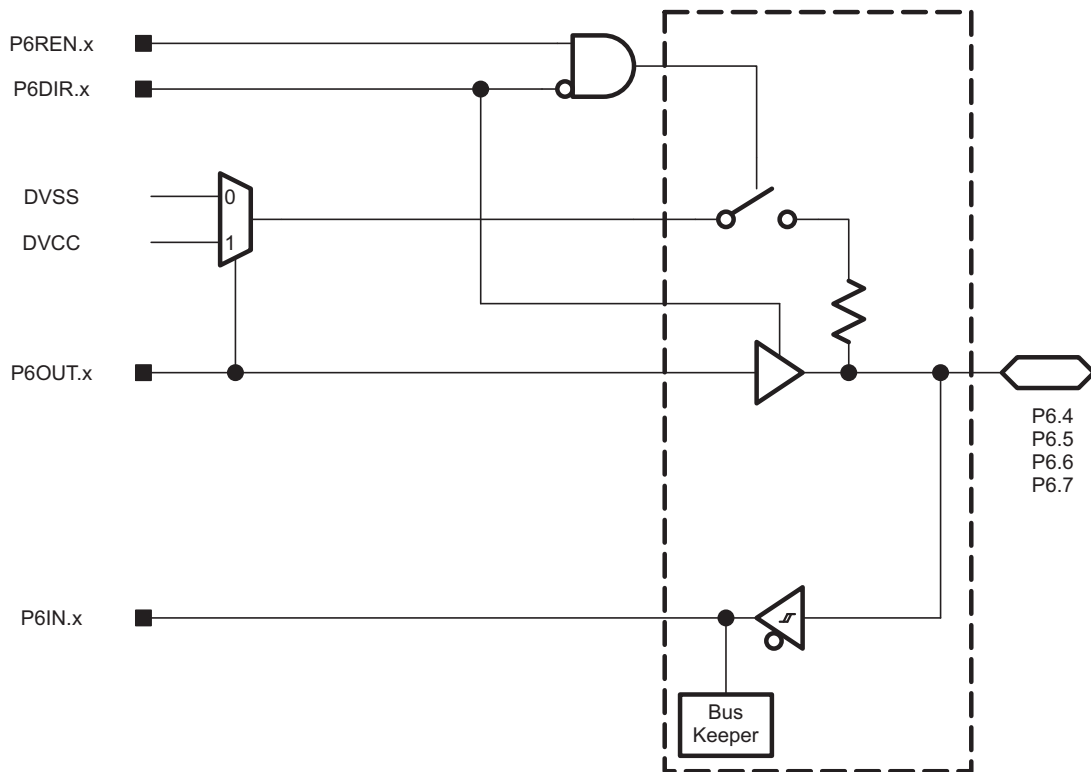


Figure 6-11. Port P6.4, P6.5, P6.6, and P6.7 Input/Output With Schmitt Trigger

Table 6-23. Port P6.4, P6.5, P6.6, and P6.7 Pin Functions

| PIN NAME (P6.x) | x | FUNCTION   | CONTROL BITS AND SIGNALS |
|-----------------|---|------------|--------------------------|
|                 |   |            | P6DIR.x                  |
| P6.4            | 4 | P6.4 (I/O) | I: 0; O: 1               |
| P6.5            | 5 | P6.5 (I/O) | I: 0; O: 1               |
| P6.6            | 6 | P6.6 (I/O) | I: 0; O: 1               |
| P6.7            | 7 | P6.7 (I/O) | I: 0; O: 1               |

6.9.12.11 Port P7.0, P7.1, P7.2, and P7.3 Input/Output With Schmitt Trigger

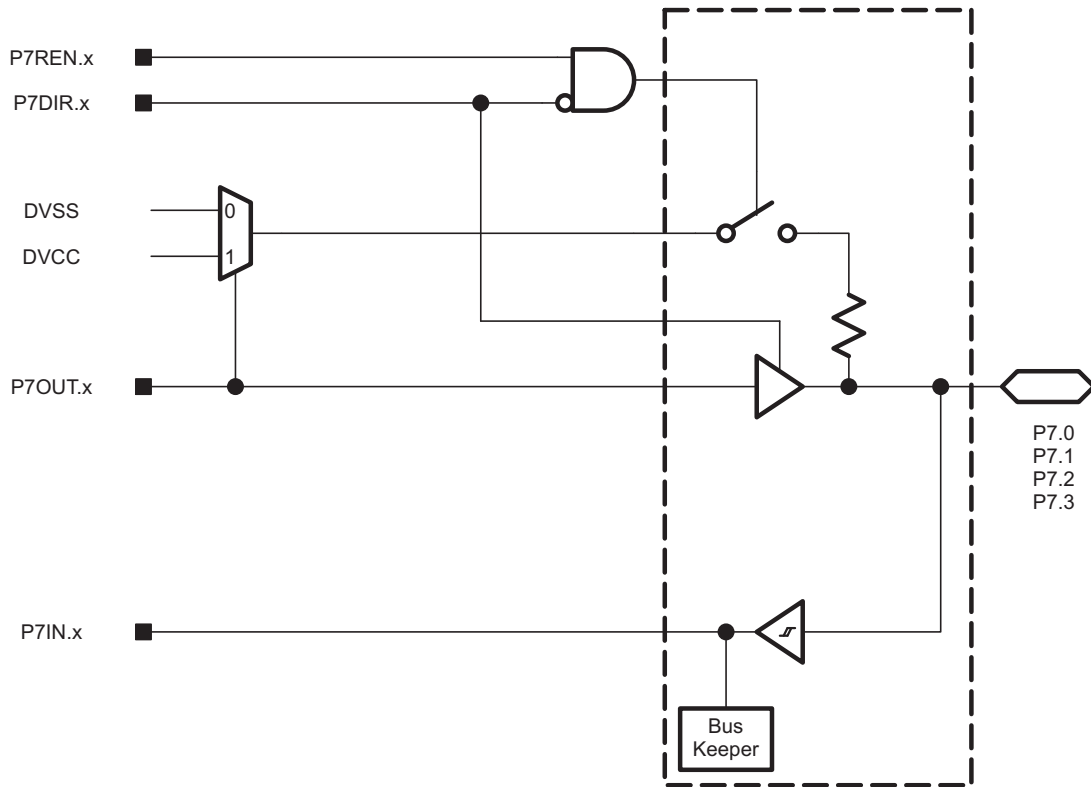


Figure 6-12. Port P7.0, P7.1, P7.2, and P7.3 Input/Output With Schmitt Trigger

Table 6-24. Port P7.0, P7.1, P7.2, and P7.3 Pin Functions

| PIN NAME (P7.x) | x | FUNCTION   | CONTROL BITS AND SIGNALS |
|-----------------|---|------------|--------------------------|
|                 |   |            | P7DIR.x                  |
| P7.0            | 0 | P7.0 (I/O) | I: 0; O: 1               |
| P7.1            | 1 | P7.1 (I/O) | I: 0; O: 1               |
| P7.2            | 2 | P7.2 (I/O) | I: 0; O: 1               |
| P7.3            | 3 | P7.3 (I/O) | I: 0; O: 1               |

6.9.12.12 Port P7.4, P7.5, P7.6, and P7.7 Input/Output With Schmitt Trigger

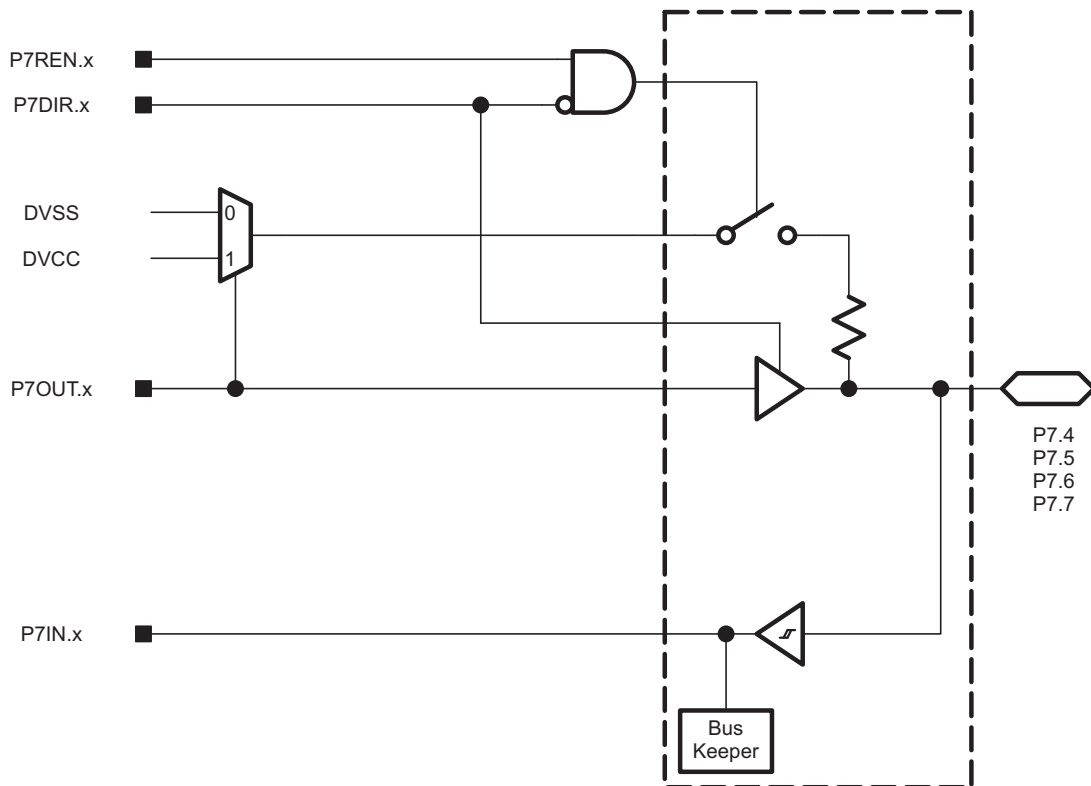


Figure 6-13. Port P7.4, P7.5, P7.6, and P7.7 Input/Output With Schmitt Trigger

Table 6-25. Port P7.4, P7.5, P7.6, and P7.7 Pin Functions

| PIN NAME (P7.x) | x | FUNCTION   | CONTROL BITS AND SIGNALS |
|-----------------|---|------------|--------------------------|
|                 |   |            | P7DIR.x                  |
| P7.4            | 4 | P7.4 (I/O) | I: 0; O: 1               |
| P7.5            | 5 | P7.5 (I/O) | I: 0; O: 1               |
| P7.6            | 6 | P7.6 (I/O) | I: 0; O: 1               |
| P7.7            | 7 | P7.7 (I/O) | I: 0; O: 1               |

### 6.9.12.13 Port P8.0 and P8.1 Input/Output With Schmitt Trigger

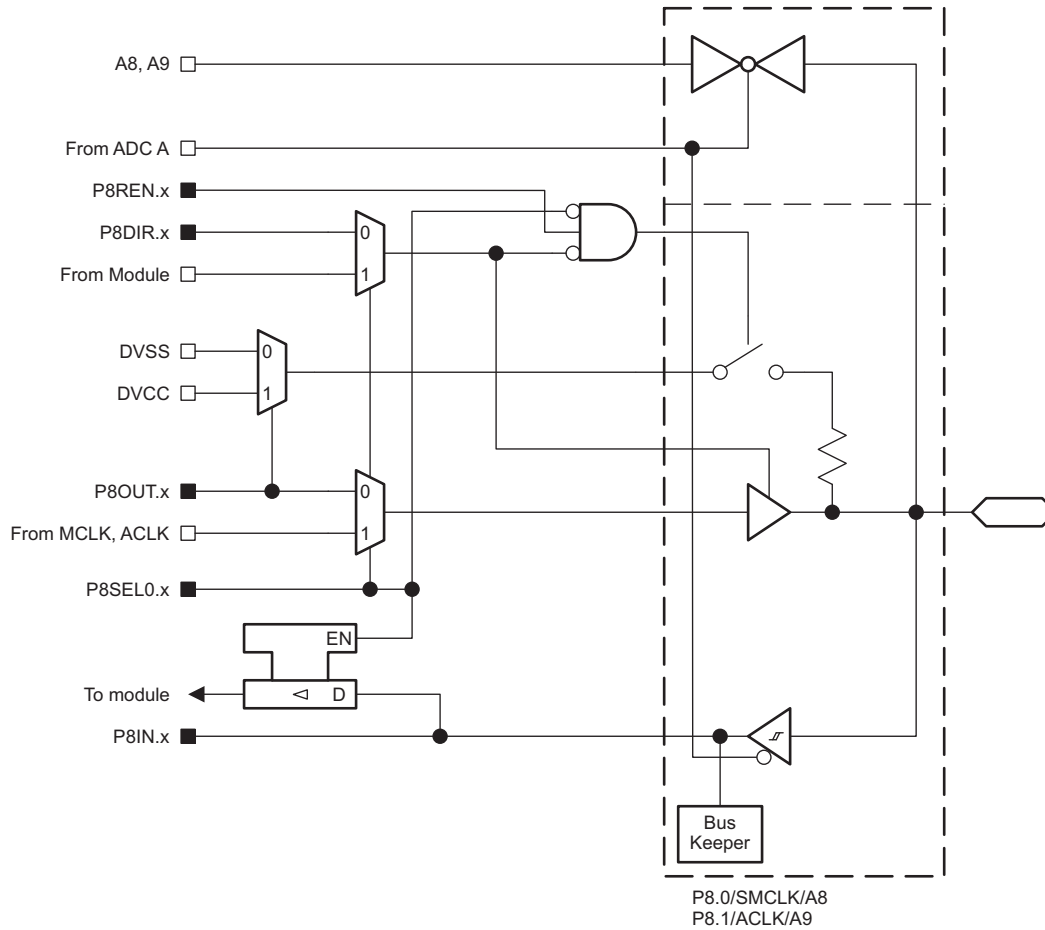


Figure 6-14. Port P8.0 and P8.1 Input/Output With Schmitt Trigger

Table 6-26. Port P8.0 and P8.1 Pin Functions

| PIN NAME (P8.x) | x | FUNCTION   | CONTROL BITS AND SIGNALS <sup>(1)</sup> |          |                         |
|-----------------|---|------------|---|----------|-------------------------|
|                 |   |            | P8DIR.x                                 | P8SEL0.x | ADCPCTLx <sup>(2)</sup> |
| P8.0/SMCLK/A8   | 0 | P8.0 (I/O) | I: 0; O: 1                              | 0        | 0                       |
|                 |   | VSS        | 0                                       | 1        | 0                       |
|                 |   | SMCLK      | 1                                       |          | 0                       |
|                 |   | A8         | X                                       | X        | 1 (x = 8)               |
| P8.1/ACLK/A9    | 1 | P8.1 (I/O) | I: 0; O: 1                              | 0        | 0                       |
|                 |   | VSS        | 0                                       | 1        | 0                       |
|                 |   | ACLK       | 1                                       |          | 0                       |
|                 |   | A9         | X                                       | X        | 1 (x = 9)               |

(1) X = don't care

(2) Setting the ADCPCTLx bit in SYSCFG2 register disables both the output driver and the input Schmitt trigger to prevent leakage when analog signals are applied.

6.9.12.14 Port P8.2 and P8.3 Input/Output With Schmitt Trigger

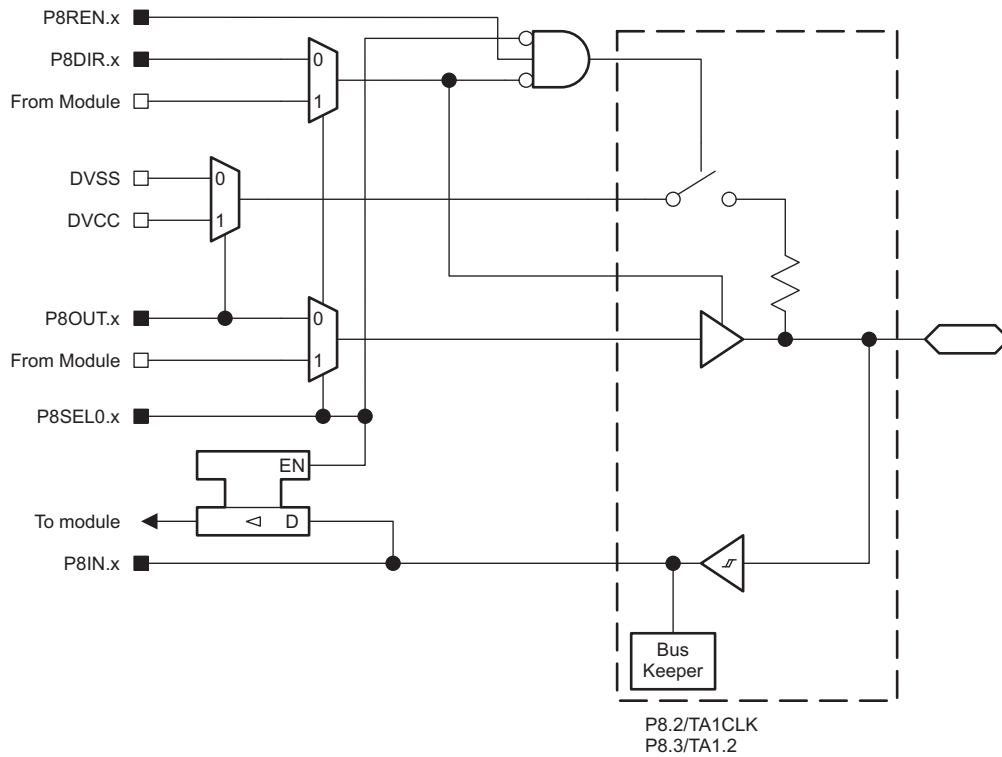


Figure 6-15. Port P8.2 and P8.3 Input/Output With Schmitt Trigger

Table 6-27. Port P8.2 and P8.3 Pin Functions

| PIN NAME (P8.x) | x | FUNCTION   | CONTROL BITS AND SIGNALS |          |
|-----------------|---|------------|--------------------------|----------|
|                 |   |            | P8DIR.x                  | P8SEL0.x |
| P8.2/TA1CLK     | 2 | P8.2 (I/O) | I: 0; O: 1               | 0        |
|                 |   | TA1 CLK    | 0                        | 1        |
|                 |   | VSS        | 1                        |          |
| P8.3/TA1.2      | 3 | P8.3 (I/O) | I: 0; O: 1               | 0        |
|                 |   | TA1.CCI2A  | 0                        | 1        |
|                 |   | TA1.2      | 1                        |          |

## 6.10 Device Descriptors (TLV)

Table 6-28 lists the Device IDs of the MSP430FR203x device variants. Table 6-29 lists the contents of the device descriptor tag-length-value (TLV) structure for MSP430FR203x devices.

**Table 6-28. Device IDs**

| DEVICE       | DEVICE ID |       |
|--------------|-----------|-------|
|              | 1A04h     | 1A05h |
| MSP430FR2033 | 75h       | 82h   |
| MSP430FR2032 | 78h       | 82h   |

**Table 6-29. Device Descriptors**

| DESCRIPTION                                 |   | MSP430FR203x |                |
|---|---|--------------|----------------|
|   |   | ADDRESS      | VALUE          |
| Information Block                           | Info Length                                 | 1A00h        | 06h            |
|   | CRC Length                                  | 1A01h        | 06h            |
|   | CRC Value <sup>(1)</sup>                    | 1A02h        | Per unit       |
|   |   | 1A03h        | Per unit       |
|   | Device ID                                   | 1A04h        | See Table 6-28 |
|   |   | 1A05h        |                |
|   | Hardware Revision                           | 1A06h        | Per unit       |
| Firmware Revision                           | 1A07h                                       | Per unit     |                |
| Die Record                                  | Die Record Tag                              | 1A08h        | 08h            |
|   | Die Record Length                           | 1A09h        | 0Ah            |
|   | Lot Wafer ID                                | 1A0Ah        | Per unit       |
|   |   | 1A0Bh        | Per unit       |
|   |   | 1A0Ch        | Per unit       |
|   |   | 1A0Dh        | Per unit       |
|   | Die X Position                              | 1A0Eh        | Per unit       |
|   |   | 1A0Fh        | Per unit       |
|   | Die Y Position                              | 1A10h        | Per unit       |
|   |   | 1A11h        | Per unit       |
| 1A12h                                       |   | Per unit     |                |
| Test Result                                 | 1A13h                                       | Per unit     |                |
|   | 1A14h                                       | Per unit     |                |
| ADC Calibration                             | ADC Calibration Tag                         | 1A14h        | 11h            |
|   | ADC Calibration Length                      | 1A15h        | 08h            |
|   | ADC Gain Factor                             | 1A16h        | Per unit       |
|   |   | 1A17h        | Per unit       |
|   | ADC Offset                                  | 1A18h        | Per unit       |
|   |   | 1A19h        | Per unit       |
|   | ADC 1.5-V Reference Temperature Sensor 30°C | 1A1Ah        | Per unit       |
|   |   | 1A1Bh        | Per unit       |
| ADC 1.5-V Reference Temperature Sensor 85°C | 1A1Ch                                       | Per unit     |                |
|   | 1A1Dh                                       | Per unit     |                |

(1) The CRC value covers the checksum from 1A04h to 1A77h by applying the CRC-CCITT-16 polynomial of  $x^{16} + x^{12} + x^5 + 1$ .

**Table 6-29. Device Descriptors (continued)**

| DESCRIPTION                   |  | MSP430FR203x |          |
|-------------------------------|--|--------------|----------|
|                               |  | ADDRESS      | VALUE    |
| Reference and DCO Calibration | Calibration Tag  | 1A1Eh        | 12h      |
|                               | Calibration Length   | 1A1Fh        | 04h      |
|                               | 1.5-V Reference Factor                                       | 1A20h        | Per unit |
|                               |  | 1A21h        | Per unit |
|                               | DCO Tap Settings for 16 MHz, Temperature 30°C <sup>(2)</sup> | 1A22h        | Per unit |
| 1A23h                         |  | Per unit     |          |

(2) This value can be directly loaded into DCO bits in CSCTL0 register to get accurate 16-MHz frequency at room temperature, especially when MCU exits from LPM3 and below. TI suggests using a predivider to decrease the frequency, if the temperature drift might result an overshoot beyond 16 MHz.

## 6.11 Memory

Table 6-30 summarizes the memory map of the MSP430FR203x devices.

**Table 6-30. Memory Organization**

|  | ACCESS  | MSP430FR2033                             | MSP430FR2032                            |
|--|---|--|---|
| Memory (FRAM)<br>Main: interrupt vectors and signatures<br>Main: code memory | Read/Write<br>(Optional Write Protect) <sup>(1)</sup> | 15KB<br>FFFFh to FF80h<br>FFFFh to C400h | 8KB<br>FFFFh to FF80h<br>FFFFh to E000h |
| RAM  | Read/Write  | 2KB<br>27FFh to 2000h                    | 1KB<br>23FFh to 2000h                   |
| Information Memory (FRAM)  | Read/Write<br>(Optional Write Protect) <sup>(2)</sup> | 512B<br>19FFh to 1800h                   | 512B<br>19FFh to 1800h                  |
| Bootloader (BSL) Memory (ROM)  | Read only   | 1KB<br>13FFh to 1000h                    | 1KB<br>13FFh to 1000h                   |
| Peripherals  | Read/Write  | 4KB<br>0FFFh to 0000h                    | 4KB<br>0FFFh to 0000h                   |

(1) The Program FRAM can be write protected by setting PFWP bit in SYSCFG0 register. See the SYS chapter in the [MSP430FR4xx and MSP430FR2xx Family User's Guide](#) for more details

(2) The Information FRAM can be write protected by setting DFWP bit in SYSCFG0 register. See the SYS chapter in the [MSP430FR4xx and MSP430FR2xx Family User's Guide](#) for more details

### 6.11.1 Peripheral File Map

Table 6-31 shows the base address and the memory size of the register region for each peripheral, and Table 6-32 through Table 6-50 show all of the available registers for each peripheral and their address offsets.

**Table 6-31. Peripherals Summary**

| MODULE NAME          | BASE ADDRESS | SIZE  | REGISTERS                  |
|----------------------|--------------|-------|----------------------------|
| Special Functions    | 0100h        | 0010h | <a href="#">Table 6-32</a> |
| PMM                  | 0120h        | 0020h | <a href="#">Table 6-33</a> |
| SYS                  | 0140h        | 0030h | <a href="#">Table 6-34</a> |
| CS                   | 0180h        | 0020h | <a href="#">Table 6-35</a> |
| FRAM                 | 01A0h        | 0010h | <a href="#">Table 6-36</a> |
| CRC                  | 01C0h        | 0008h | <a href="#">Table 6-37</a> |
| WDT                  | 01CCh        | 0002h | <a href="#">Table 6-38</a> |
| Port P1, P2          | 0200h        | 0020h | <a href="#">Table 6-39</a> |
| Port P3, P4          | 0220h        | 0020h | <a href="#">Table 6-40</a> |
| Port P5, P6          | 0240h        | 0020h | <a href="#">Table 6-41</a> |
| Port P7, P8          | 0260h        | 0020h | <a href="#">Table 6-42</a> |
| Capacitive Touch I/O | 02E0h        | 0010h | <a href="#">Table 6-43</a> |
| Timer0_A3            | 0300h        | 0030h | <a href="#">Table 6-44</a> |
| Timer1_A3            | 0340h        | 0030h | <a href="#">Table 6-45</a> |
| RTC                  | 03C0h        | 0010h | <a href="#">Table 6-46</a> |
| eUSCI_A0             | 0500h        | 0020h | <a href="#">Table 6-47</a> |
| eUSCI_B0             | 0540h        | 0030h | <a href="#">Table 6-48</a> |
| Backup Memory        | 0660h        | 0020h | <a href="#">Table 6-49</a> |
| ADC                  | 0700h        | 0040h | <a href="#">Table 6-50</a> |



**Table 6-32. Special Function Registers (Base Address: 0100h)**

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

**Table 6-33. PMM Registers (Base Address: 0120h)**

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

**Table 6-34. SYS Registers (Base Address: 0140h)**

| REGISTER DESCRIPTION          | REGISTER  | OFFSET |
|-------------------------------|-----------|--------|
| System control                | SYSCTL    | 00h    |
| Bootloader configuration area | SYSBSLC   | 02h    |
| JTAG mailbox control          | SYSJMBC   | 06h    |
| JTAG mailbox input 0          | SYSJMBI0  | 08h    |
| JTAG mailbox input 1          | SYSJMBI1  | 0Ah    |
| JTAG mailbox output 0         | SYSJMBO0  | 0Ch    |
| JTAG mailbox output 1         | SYSJMBO1  | 0Eh    |
| Bus Error vector generator    | SYSBERRIV | 18h    |
| User NMI vector generator     | SYSUNIV   | 1Ah    |
| System NMI vector generator   | SYSSNIV   | 1Ch    |
| Reset vector generator        | SYSRSTIV  | 1Eh    |
| System configuration 0        | SYSCFG0   | 20h    |
| System configuration 1        | SYSCFG1   | 22h    |
| System configuration 2        | SYSCFG2   | 24h    |

**Table 6-35. CS Registers (Base Address: 0180h)**

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

**Table 6-36. FRAM Registers (Base Address: 01A0h)**

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

**Table 6-37. CRC Registers (Base Address: 01C0h)**

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

**Table 6-38. WDT Registers (Base Address: 01CCh)**

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

**Table 6-39. Port P1, P2 Registers (Base Address: 0200h)**

| REGISTER DESCRIPTION               | REGISTER | OFFSET |
|------------------------------------|----------|--------|
| Port P1 input                      | P1IN     | 00h    |
| Port P1 output                     | P1OUT    | 02h    |
| Port P1 direction                  | P1DIR    | 04h    |
| Port P1 pulling register enable    | P1REN    | 06h    |
| Port P1 selection 0                | P1SEL0   | 0Ah    |
| Port P1 interrupt vector word      | P1IV     | 0Eh    |
| Port P1 interrupt edge select      | P1IES    | 18h    |
| Port P1 interrupt enable           | P1IE     | 1Ah    |
| Port P1 interrupt flag             | P1IFG    | 1Ch    |
| Port P2 input                      | P2IN     | 01h    |
| Port P2 output                     | P2OUT    | 03h    |
| Port P2 direction                  | P2DIR    | 05h    |
| Port P2 pulling register enable    | P2REN    | 07h    |
| Port P2 selection 0 <sup>(1)</sup> | P2SEL0   | 0Bh    |
| Port P2 interrupt vector word      | P2IV     | 1Eh    |
| Port P2 interrupt edge select      | P2IES    | 19h    |
| Port P2 interrupt enable           | P2IE     | 1Bh    |
| Port P2 interrupt flag             | P2IFG    | 1Dh    |

(1) Port P2 selection register does not feature any valid bits. P2SEL0 presents for 16-bit Port A operation with P1SEL0.

**Table 6-40. Port P3, P4 Registers (Base Address: 0220h)**

| REGISTER DESCRIPTION               | REGISTER | OFFSET |
|------------------------------------|----------|--------|
| Port P3 input                      | P3IN     | 00h    |
| Port P3 output                     | P3OUT    | 02h    |
| Port P3 direction                  | P3DIR    | 04h    |
| Port P3 pulling register enable    | P3REN    | 06h    |
| Port P3 selection 0 <sup>(1)</sup> | P3SEL0   | 0Ah    |
| Port P4 input                      | P4IN     | 01h    |
| Port P4 output                     | P4OUT    | 03h    |
| Port P4 direction                  | P4DIR    | 05h    |
| Port P4 pulling register enable    | P4REN    | 07h    |
| Port P4 selection 0                | P4SEL0   | 0Bh    |

(1) Port P3 selection register does not feature any valid bits. P3SEL0 presents for 16-bit Port B operation with P4SEL0.

**Table 6-41. Port P5, P6 Registers (Base Address: 0240h)**

| REGISTER DESCRIPTION               | REGISTER | OFFSET |
|------------------------------------|----------|--------|
| Port P5 input                      | P5IN     | 00h    |
| Port P5 output                     | P5OUT    | 02h    |
| Port P5 direction                  | P5DIR    | 04h    |
| Port P5 pulling register enable    | P5REN    | 06h    |
| Port P5 selection 0                | P5SEL0   | 0Ah    |
| Port P6 input                      | P6IN     | 01h    |
| Port P6 output                     | P6OUT    | 03h    |
| Port P6 direction                  | P6DIR    | 05h    |
| Port P6 pulling register enable    | P6REN    | 07h    |
| Port P6 selection 0 <sup>(1)</sup> | P6SEL0   | 0Bh    |

(1) Port P6 selection register does not feature any valid bits. P6SEL0 presents for 16-bit Port C operation with P5SEL0.

**Table 6-42. Port P7, P8 Registers (Base Address: 0260h)**

| REGISTER DESCRIPTION               | REGISTER | OFFSET |
|------------------------------------|----------|--------|
| Port P7 input                      | P7IN     | 00h    |
| Port P7 output                     | P7OUT    | 02h    |
| Port P7 direction                  | P7DIR    | 04h    |
| Port P7 pulling register enable    | P7REN    | 06h    |
| Port P7 selection 0 <sup>(1)</sup> | P7SEL0   | 0Ah    |
| Port P8 input                      | P8IN     | 01h    |
| Port P8 output                     | P8OUT    | 03h    |
| Port P8 direction                  | P8DIR    | 05h    |
| Port P8 pulling register enable    | P8REN    | 07h    |
| Port P8 selection 0                | P8SEL0   | 0Bh    |

(1) Port P7 selection register does not feature any valid bits. P7SEL0 presents for 16-bit Port D operation with P8SEL0.

**Table 6-43. Capacitive Touch I/O Registers (Base Address: 02E0h)**

| REGISTER DESCRIPTION           | REGISTER   | OFFSET |
|--------------------------------|------------|--------|
| Capacitive Touch I/O 0 control | CAPTIO0CTL | 0Eh    |

**Table 6-44. Timer0\_A3 Registers (Base Address: 0300h)**

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

**Table 6-45. Timer1\_A3 Registers (Base Address: 0340h)**

| REGISTER DESCRIPTION       | REGISTER | OFFSET |
|----------------------------|----------|--------|
| TA1 control                | TA1CTL   | 00h    |
| Capture/compare control 0  | TA1CCTL0 | 02h    |
| Capture/compare control 1  | TA1CCTL1 | 04h    |
| Capture/compare control 2  | TA1CCTL2 | 06h    |
| TA1 counter register       | TA1R     | 10h    |
| Capture/compare register 0 | TA1CCR0  | 12h    |
| Capture/compare register 1 | TA1CCR1  | 14h    |
| Capture/compare register 2 | TA1CCR2  | 16h    |
| TA1 expansion register 0   | TA1EX0   | 20h    |
| TA1 interrupt vector       | TA1IV    | 2Eh    |

**Table 6-46. RTC Registers (Base Address: 03C0h)**

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

**Table 6-47. eUSCI\_A0 Registers (Base Address: 0500h)**

| REGISTER DESCRIPTION          | REGISTER    | OFFSET |
|-------------------------------|-------------|--------|
| eUSCI_A control word 0        | UCA0CTLW0   | 00h    |
| eUSCI_A control word 1        | UCA0CTLW1   | 02h    |
| eUSCI_A control rate 0        | UCA0BR0     | 06h    |
| eUSCI_A control rate 1        | UCA0BR1     | 07h    |
| eUSCI_A modulation control    | UCA0MCTLW   | 08h    |
| eUSCI_A status                | UCA0STAT    | 0Ah    |
| eUSCI_A receive buffer        | UCA0RXBUF   | 0Ch    |
| eUSCI_A transmit buffer       | UCA0TXBUF   | 0Eh    |
| eUSCI_A LIN control           | UCA0ABCTL   | 10h    |
| eUSCI_A IrDA transmit control | IUCA0IRTCTL | 12h    |
| eUSCI_A IrDA receive control  | IUCA0IRRCTL | 13h    |
| eUSCI_A interrupt enable      | UCA0IE      | 1Ah    |
| eUSCI_A interrupt flags       | UCA0IFG     | 1Ch    |
| eUSCI_A interrupt vector word | UCA0IV      | 1Eh    |

**Table 6-48. eUSCI\_B0 Registers (Base Address: 0540h)**

| REGISTER DESCRIPTION           | REGISTER   | OFFSET |
|--------------------------------|------------|--------|
| eUSCI_B control word 0         | UCB0CTLW0  | 00h    |
| eUSCI_B control word 1         | UCB0CTLW1  | 02h    |
| eUSCI_B bit rate 0             | UCB0BR0    | 06h    |
| eUSCI_B bit rate 1             | UCB0BR1    | 07h    |
| eUSCI_B status word            | UCB0STATW  | 08h    |
| eUSCI_B byte counter threshold | UCB0TBCNT  | 0Ah    |
| eUSCI_B receive buffer         | UCB0RXBUF  | 0Ch    |
| eUSCI_B transmit buffer        | UCB0TXBUF  | 0Eh    |
| eUSCI_B I2C own address 0      | UCB0I2COA0 | 14h    |

**Table 6-48. eUSCI\_B0 Registers (Base Address: 0540h) (continued)**

| REGISTER DESCRIPTION          | REGISTER    | OFFSET |
|-------------------------------|-------------|--------|
| eUSCI_B I2C own address 1     | UCB0I2COA1  | 16h    |
| eUSCI_B I2C own address 2     | UCB0I2COA2  | 18h    |
| eUSCI_B I2C own address 3     | UCB0I2COA3  | 1Ah    |
| eUSCI_B receive address       | UCB0ADDRX   | 1Ch    |
| eUSCI_B address mask          | UCB0ADDMASK | 1Eh    |
| eUSCI_B I2C slave address     | UCB0I2CSA   | 20h    |
| eUSCI_B interrupt enable      | UCB0IE      | 2Ah    |
| eUSCI_B interrupt flags       | UCB0IFG     | 2Ch    |
| eUSCI_B interrupt vector word | UCB0IV      | 2Eh    |

**Table 6-49. Backup Memory Registers (Base Address: 0660h)**

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

**Table 6-50. ADC Registers (Base Address: 0700h)**

| REGISTER DESCRIPTION                 | REGISTER | OFFSET |
|--------------------------------------|----------|--------|
| ADC control register 0               | ADCCTL0  | 00h    |
| ADC control register 1               | ADCCTL1  | 02h    |
| ADC control register 2               | ADCCTL2  | 04h    |
| ADC window comparator low threshold  | ADCLO    | 06h    |
| ADC window comparator high threshold | ADCHI    | 08h    |
| ADC memory control register 0        | ADCMCTL0 | 0Ah    |
| ADC conversion memory register       | ADCMEM0  | 12h    |
| ADC interrupt enable                 | ADCIE    | 1Ah    |
| ADC interrupt flags                  | ADCIFG   | 1Ch    |
| ADC interrupt vector word            | ADCIV    | 1Eh    |

## 6.12 Identification

### 6.12.1 Revision Identification

The device revision information is shown as part of the top-side marking on the device package. The device-specific errata sheet describes these markings. For links to the errata sheets for the devices in this data sheet, see [节 8.4](#).

The hardware revision is also stored in the Device Descriptor structure in the Info Block section. For details on this value, see the "Hardware Revision" entries in [Section 6.10](#).

### 6.12.2 Device Identification

The device type can be identified from the top-side marking on the device package. The device-specific errata sheet describes these markings. For links to the errata sheets for the devices in this data sheet, see [节 8.4](#).

A device identification value is also stored in the Device Descriptor structure in the Info Block section. For details on this value, see the "Device ID" entries in [Section 6.10](#).

### 6.12.3 JTAG Identification

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

## 7 Applications, Implementation, and Layout

### NOTE

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

### 7.1 Device Connection and Layout Fundamentals

This section discusses the recommended guidelines when designing with the MSP430FR413x devices. These guidelines are to make sure that the device has proper connections for powering, programming, debugging, and optimum analog performance.

#### 7.1.1 Power Supply Decoupling and Bulk Capacitors

TI recommends connecting a combination of a 10- $\mu$ F plus a 100-nF low-ESR ceramic decoupling capacitor to the DVCC and DVSS pins. Higher-value capacitors may be used but can impact supply rail ramp-up time. Decoupling capacitors must be placed as close as possible to the pins that they decouple (within a few millimeters).

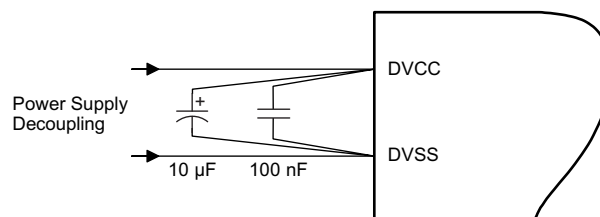


Figure 7-1. Power Supply Decoupling

#### 7.1.2 External Oscillator

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

It is also possible to apply digital clock signals to the XIN input pin that meet the specifications of the respective oscillator if the appropriate XT1BYPASS mode is selected. In this case, the associated XOUT pin can be used for other purposes. If they are left unused, they must be terminated according to [Section 4.4](#).

Figure 7-2 shows a typical connection diagram.

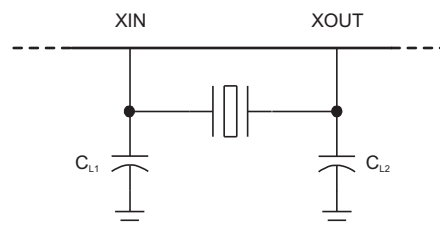


Figure 7-2. Typical Crystal Connection

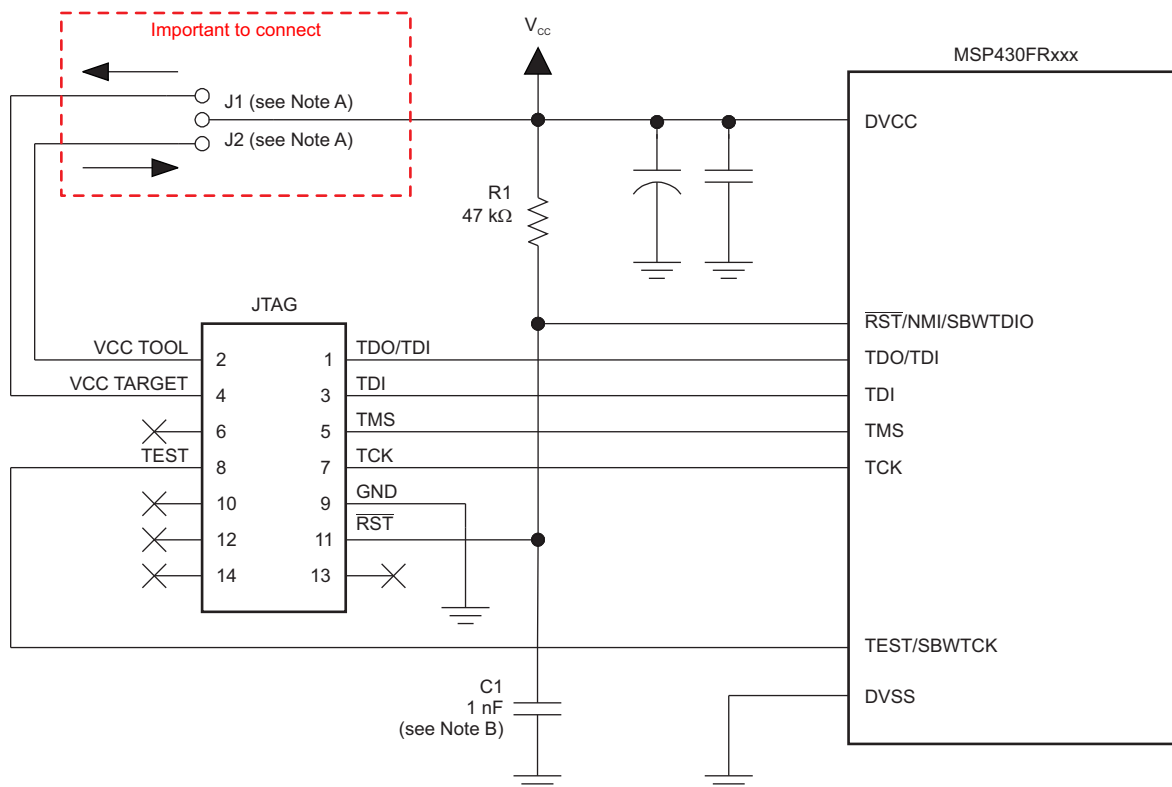
See [MSP430 32-kHz Crystal Oscillators](#) for more information on selecting, testing, and designing a crystal oscillator with the MSP430 devices.

### 7.1.3 JTAG

With the proper connections, the debugger and a hardware JTAG interface (such as the MSP-FET or MSP-FET430UIF) can be used to program and debug code on the target board. In addition, the connections also support the MSP-GANG production programmers, thus providing an easy way to program prototype boards, if desired. [Figure 7-3](#) shows the connections between the 14-pin JTAG connector and the target device required to support in-system programming and debugging for 4-wire JTAG communication. [Figure 7-4](#) shows the connections for 2-wire JTAG mode (Spy-Bi-Wire).

The connections for the MSP-FET and MSP-FET430UIF interface modules and the MSP-GANG are identical. Both can supply VCC to the target board (through pin 2). In addition, the MSP-FET and MSP-FET430UIF interface modules and MSP-GANG have a VCC sense feature that, if used, requires an alternate connection (pin 4 instead of pin 2). The VCC-sense feature senses the local VCC present on the target board (that is, a battery or other local power supply) and adjusts the output signals accordingly. [Figure 7-3](#) and [Figure 7-4](#) show a jumper block that supports both scenarios of supplying VCC to the target board. If this flexibility is not required, the desired VCC connections may be hard-wired to eliminate the jumper block. Pins 2 and 4 must not be connected at the same time.

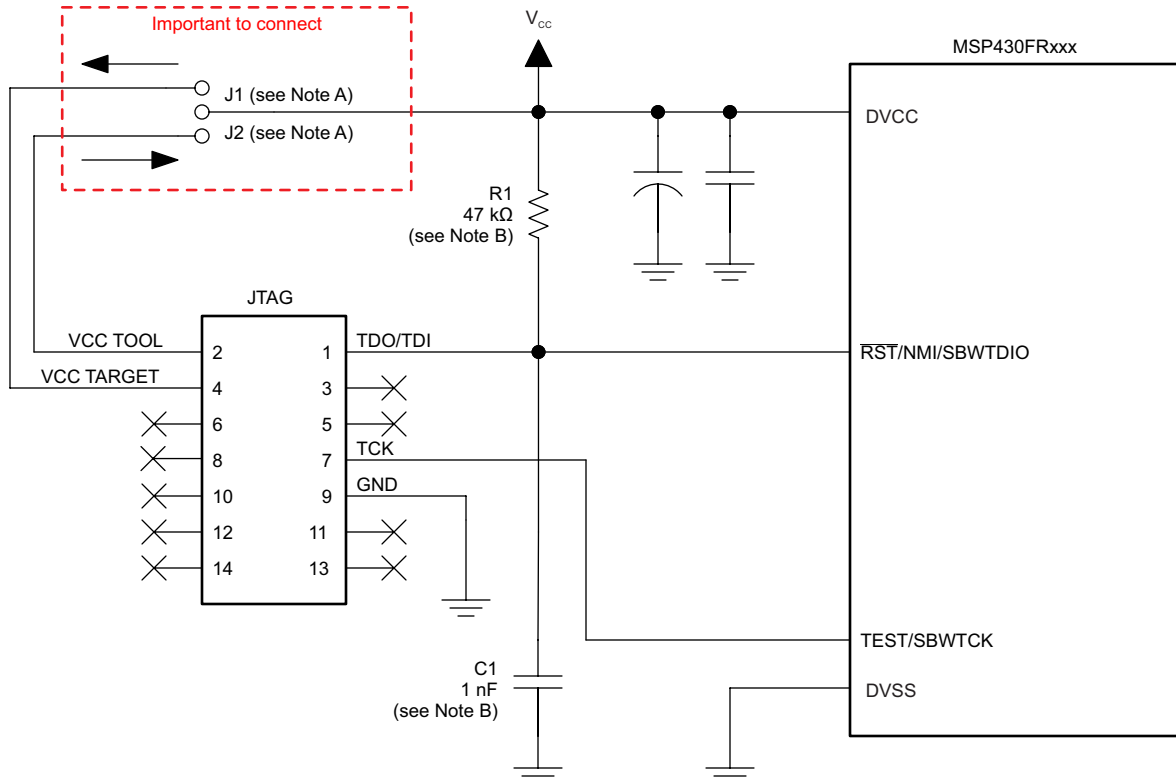
For additional design information regarding the JTAG interface, see the [MSP430 Hardware Tools User's Guide](#).



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

**Figure 7-3. Signal Connections for 4-Wire JTAG Communication**





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

**Figure 7-4. Signal Connections for 2-Wire JTAG Communication (Spy-Bi-Wire)**

### 7.1.4 Reset

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

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

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

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

See the [MSP430FR4xx and MSP430FR2xx Family User's Guide](#) for more information on the referenced control registers and bits.

### 7.1.5 Unused Pins

For details on the connection of unused pins, see [Section 4.4](#).

## 7.1.6 General Layout Recommendations

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

## 7.1.7 Do's and Don'ts

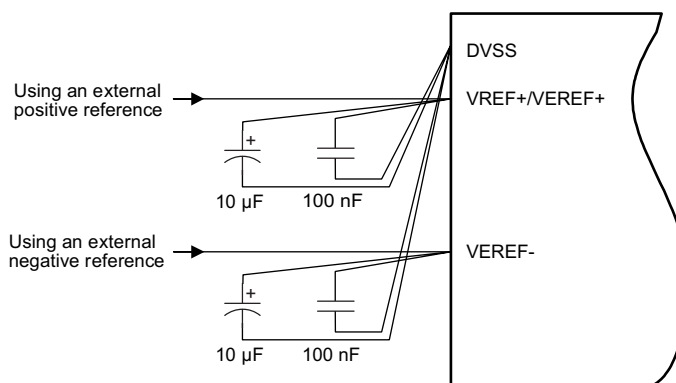
During power up, power down, and device operation, DVCC must not exceed the limits specified in [Section 5.1, Absolute Maximum Ratings](#). Exceeding the specified limits may cause malfunction of the device including erroneous writes to RAM and FRAM.

## 7.2 Peripheral- and Interface-Specific Design Information

### 7.2.1 ADC Peripheral

#### 7.2.1.1 Partial Schematic

[Figure 7-5](#) shows the recommended circuit for external reference inputs to the ADC.



**Figure 7-5. ADC Grounding and Noise Considerations**

#### 7.2.1.2 Design Requirements

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

Ground loops are formed when return current from the ADC flows through paths that are common with other analog or digital circuitry. If care is not taken, this current can generate small unwanted offset voltages that can add to or subtract from the reference or input voltages of the ADC. The general guidelines in [Section 7.1.1](#) combined with the connections shown in [Section 7.2.1.1](#) prevent this.

In addition to grounding, ripple and noise spikes on the power-supply lines that are caused by digital switching or switching power supplies can corrupt the conversion result. TI recommends a noise-free design using separate analog and digital ground planes with a single-point connection to achieve high accuracy.

[Figure 7-5](#) shows the recommended decoupling circuit when an external voltage reference is used. The internal reference module has a maximum drive current as described in the sections *ADC Pin Enable* and *1.2-V Reference Settings* of the [MSP430FR4xx and MSP430FR2xx Family User's Guide](#).

The reference voltage must be a stable voltage for accurate measurements. The capacitor values that are selected in the general guidelines filter out the high- and low-frequency ripple before the reference voltage enters the device. In this case, the 10- $\mu$ F capacitor is used to buffer the reference pin and filter any low-frequency ripple. A bypass capacitor of 100 nF is used to filter out any high-frequency noise.

### 7.2.1.3 Layout Guidelines

Components that are shown in the partial schematic (see [Figure 7-5](#)) should be placed as close as possible to the respective device pins to avoid long traces, because they add additional parasitic capacitance, inductance, and resistance on the signal.

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

## 8 器件和文档支持

### 8.1 开始使用

有关可帮助您开发的 MSP430 系列器件、工具和库的介绍，请参阅 [MSP430™ 超低功耗感应和测量 MCU 概述](#)。

### 8.2 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。提供了解读完整器件名称的图例。

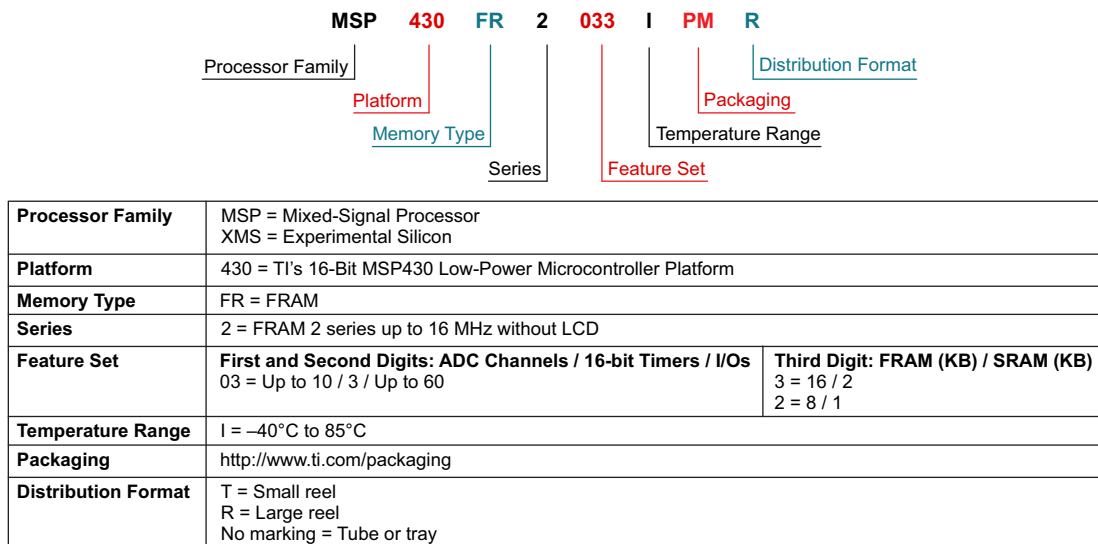


图 8-1. 器件命名规则

### 8.3 工具和软件

表 8-1 列出了 MSP430FR203x 微控制器所 调试 调控功能。请参阅《适用于 MSP430™ MCU 的 Code Composer Studio™ IDE》用户指南，以了解有关可用 功能的详细信息。

表 8-1. 硬件 特性

| MSP430 架构 | 四线制 JTAG | 两线制 JTAG | 断点 (N) | 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 |
|-----------|----------|----------|--------|------|------|---------|-------|-------------|
| MSP430Xv2 | 有        | 有        | 3      | 有    | 是    | 否       | 否     | 否           |

#### 设计套件与评估模块

##### MSP430FR4133 LaunchPad 开发套件

MSP-EXP430FR4133 LaunchPad 开发套件是适用于 MSP430FR4133 微控制器的简单易用的评估模块 (EVM)。它包含在基于 FRAM 的 MSP430 超低功耗 (ULP) 微控制器 (MCU) 平台上进行开发所需的全部资源，包括用于编程、调试和能量测量的板载仿真。

##### 适用于 MSP430FR2x/4x MCU 的 MSP-TS430PM64D 目标开发板

MSP-TS430PM64D 是一款独立的 64 引脚 ZIF 插座目标板，用于通过 JTAG 接口或 Spy Bi-Wire (2 线 JTAG) 协议对 MSP430 MCU 系统内置器件进行编程和调试。

##### 适用于 MSP430FR2x/4x MCU 的 MSP-FET430U64D 目标开发板 (64 引脚) 和 MSP-FET 编程器捆绑包

MSP-FET430U64D 是一款捆绑套件，包含 MSP-FET 仿真器和 MSP-TS430PM64D 64 引脚 ZIF 插座目标板，用于通过 JTAG 接口或 Spy Bi-Wire (2 线式 JTAG) 协议对 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、数据表以及其他设计资源，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。

##### MSP430FR413x、MSP430FR203x 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 超低功耗微控制器的 FRAM 嵌入式软件实用程序

TI FRAM 实用程序软件旨在用作不断扩充的嵌入式软件实用程序集合，其中的实用程序充分利用了 FRAM 的超低功耗和近乎无限次的写入寿命。这些实用程序适用于 MSP430FRxx FRAM 微控制器并提供示例代码，以帮助开始进行应用程序开发。

## MSP430 Touch Pro GUI

MSP430 Touch Pro 工具是基于 PC 的工具，可用于检验电容式触控按钮、滑块和滚轮设计。此工具可接收并显示 CapTouch 传感器数据，帮助用户快速轻松地评估、诊断和调整按钮、滑块和滚轮设计。

## MSP430 触控电源设计器 GUI

使用 MSP430 电容式触控电源设计器，可以计算给定的 MSP430 电容式触控系统的估计平均电流消耗。通过输入系统参数（如工作电压、频率、按钮数量和按钮选通时间），用户可以在数分钟内估计给定的器件系列的指定电容式触控配置的功耗。

## 适用于 MSP 微控制器的数字信号处理 (DSP) 库

数字信号处理库是一组经高度优化的函数，可针对 MSP430 和 MSP432 微控制器对定点数执行许多常见的信号处理运算。该函数集通常用于以要求完成实时密集处理转换，从而以最低能耗实现高精度的应用。针对定点数学对 MSP 固有硬件的最佳利用可以极大地提高性能。

## MSP 驱动程序库

MSP 驱动程序库的抽象 API 提供易用的函数调用，无需直接操纵 MSP430 硬件的位与字节。完整的文档通过具有帮助意义的 API 指南交付，其中包括有关每个函数调用和经过验证的参数的详细信息。开发人员可使用驱动程序库函数以尽可能低的费用编写全部项目。

## MSP EnergyTrace 技术

适用于 MSP430 微控制器的 EnergyTrace 技术是基于电能的代码分析工具，适用于测量和显示应用的电能系统配置并帮助优化应用以实现超低功耗。

## ULP（超低功耗）Advisor

ULP Advisor™ 软件是一款辅助工具，旨在指导开发人员编写更为高效的代码，从而充分利用 MSP430 和 MSP432 微控制器独特功能。ULP Advisor 的目标人群是微控制器的资深开发者和开发新手，可以根据详尽的 ULP 检验表检查代码，以便最大限度地减少应用程序的能耗。在编译时，ULP Advisor 会提供通知和备注以突出显示代码中可以进一步优化的区域，进而实现更低功耗。

## 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。

## 适用于 MSP430 的浮点数学库

TI 在低功耗和低成本微控制器领域锐意创新，为您提供 MSPMATHLIB。该标量函数的浮点数学库能够利用我们的器件的智能外设，其速度最高可为标准 MSP430 数学函数的 26 倍。Mathlib 能够轻松集成到您的设计中。该运算库免费使用并集成在 Code Composer Studio IDE 和 IAR Embedded Workbench IDE 中。

## 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。

## 8.4 文档支持

以下文档描述了 MSP430FR203x 微控制器。[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 8.5）。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

#### 《MSP430FR2033 器件勘误表》

介绍了这款器件所有芯片修订版本的功能规格的已知例外情况。

#### 《MSP430FR2032 器件勘误表》

介绍了这款器件所有芯片修订版本的功能规格的已知例外情况。

### 用户指南

#### 《MSP430FR4xx 和 MSP430FR2xx 系列用户指南》

可说明。

#### 《MSP430 FRAM 器件引导加载程序 (BSL) 用户指南》

MSP430 MCU 上的引导加载程序 (BSL) 允许用户在原型设计、投产和维护等各阶段与 MSP430 MCU 中的嵌入式存储器进行通信。可编程存储器 (FRAM 存储器) 和数据存储器 (RAM) 均可按要求予以修改。

### 《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 FRAM 技术 – 操作方法和最佳实践

FRAM 采用非易失性存储器技术，行为与 SRAM 类似，支持大量新应用，还改变了固件的设计方式。该应用程序报告从嵌入式软件开发方面概述了 FRAM 技术在 MSP430 中的使用方法和最佳实践。其中介绍了如何按照应用程序特定的代码、常量、数据空间要求实施存储器布局以及如何使用 FRAM 优化应用程序的能耗。

### 《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。

### 《MSP430 系统级 ESD 注意事项》

随着芯片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。

## 8.5 相关链接

表 8-2 列出了快速访问链接。类别包括技术文档、支持与社区资源、工具和软件，以及申请样片或购买产品的快速链接。

表 8-2. 相关链接

| 器件           | 产品文件夹                 | 立即订购                  | 技术文档                  | 工具和软件                 | 支持和社区                 |
|--------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| MSP430FR2033 | <a href="#">请单击此处</a> | <a href="#">请单击此处</a> | <a href="#">请单击此处</a> | <a href="#">请单击此处</a> | <a href="#">请单击此处</a> |
| MSP430FR2032 | <a href="#">请单击此处</a> | <a href="#">请单击此处</a> | <a href="#">请单击此处</a> | <a href="#">请单击此处</a> | <a href="#">请单击此处</a> |



## 8.6 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。

## 8.7 商标

MSP430, MSP430Ware, ULP Advisor, 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.

## 8.8 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。

## 8.9 Glossary

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

## 9 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。如需获取此数据表的浏览器版本，请查阅左侧的导航栏。

**PACKAGING INFORMATION**

| Orderable Device  | Status<br>(1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan<br>(2) | Lead finish/<br>Ball material<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples                 |
|-------------------|---------------|--------------|-----------------|------|-------------|-----------------|--------------------------------------|----------------------|--------------|-------------------------|-------------------------|
| MSP430FR2032IG48  | ACTIVE        | TSSOP        | DGG             | 48   | 40          | RoHS & Green    | NIPDAU                               | Level-3-260C-168 HR  | -40 to 85    | FR2032                  | <a href="#">Samples</a> |
| MSP430FR2032IG48R | ACTIVE        | TSSOP        | DGG             | 48   | 2000        | RoHS & Green    | NIPDAU                               | Level-3-260C-168 HR  | -40 to 85    | FR2032                  | <a href="#">Samples</a> |
| MSP430FR2032IG56  | ACTIVE        | TSSOP        | DGG             | 56   | 35          | RoHS & Green    | NIPDAU                               | Level-3-260C-168 HR  | -40 to 85    | FR2032                  | <a href="#">Samples</a> |
| MSP430FR2032IG56R | ACTIVE        | TSSOP        | DGG             | 56   | 2000        | RoHS & Green    | NIPDAU                               | Level-3-260C-168 HR  | -40 to 85    | FR2032                  | <a href="#">Samples</a> |
| MSP430FR2032IPMR  | ACTIVE        | LQFP         | PM              | 64   | 1000        | RoHS & Green    | NIPDAU                               | Level-3-260C-168 HR  | -40 to 85    | FR2032                  | <a href="#">Samples</a> |
| MSP430FR2033IG48  | ACTIVE        | TSSOP        | DGG             | 48   | 40          | RoHS & Green    | NIPDAU                               | Level-3-260C-168 HR  | -40 to 85    | FR2033                  | <a href="#">Samples</a> |
| MSP430FR2033IG48R | ACTIVE        | TSSOP        | DGG             | 48   | 2000        | RoHS & Green    | NIPDAU                               | Level-3-260C-168 HR  | -40 to 85    | FR2033                  | <a href="#">Samples</a> |
| MSP430FR2033IG56  | ACTIVE        | TSSOP        | DGG             | 56   | 35          | RoHS & Green    | NIPDAU                               | Level-3-260C-168 HR  | -40 to 85    | FR2033                  | <a href="#">Samples</a> |
| MSP430FR2033IG56R | ACTIVE        | TSSOP        | DGG             | 56   | 2000        | RoHS & Green    | NIPDAU                               | Level-3-260C-168 HR  | -40 to 85    | FR2033                  | <a href="#">Samples</a> |
| MSP430FR2033IPM   | ACTIVE        | LQFP         | PM              | 64   | 160         | RoHS & Green    | NIPDAU                               | Level-3-260C-168 HR  | -40 to 85    | FR2033                  | <a href="#">Samples</a> |
| MSP430FR2033IPMR  | ACTIVE        | LQFP         | PM              | 64   | 1000        | RoHS & Green    | NIPDAU                               | Level-3-260C-168 HR  | -40 to 85    | FR2033                  | <a href="#">Samples</a> |

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

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

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

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

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

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

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

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

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

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

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

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

(6) Lead finish/Ball material - Orderable Devices 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.

**Important Information and Disclaimer:**The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

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**TAPE AND REEL INFORMATION**

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


\*All dimensions are nominal

| Device            | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|-------------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| MSP430FR2032IG48R | TSSOP        | DGG             | 48   | 2000 | 330.0              | 24.4               | 8.6     | 13.0    | 1.8     | 12.0    | 24.0   | Q1            |
| MSP430FR2032IG56R | TSSOP        | DGG             | 56   | 2000 | 330.0              | 24.4               | 8.6     | 15.6    | 1.8     | 12.0    | 24.0   | Q1            |
| MSP430FR2032IPMR  | LQFP         | PM              | 64   | 1000 | 330.0              | 24.4               | 13.0    | 13.0    | 2.1     | 16.0    | 24.0   | Q2            |
| MSP430FR2033IG48R | TSSOP        | DGG             | 48   | 2000 | 330.0              | 24.4               | 8.6     | 13.0    | 1.8     | 12.0    | 24.0   | Q1            |
| MSP430FR2033IG56R | TSSOP        | DGG             | 56   | 2000 | 330.0              | 24.4               | 8.6     | 15.6    | 1.8     | 12.0    | 24.0   | Q1            |
| MSP430FR2033IPMR  | LQFP         | PM              | 64   | 1000 | 330.0              | 24.4               | 13.0    | 13.0    | 2.1     | 16.0    | 24.0   | Q2            |

**TAPE AND REEL BOX DIMENSIONS**


\*All dimensions are nominal

| Device            | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|-------------------|--------------|-----------------|------|------|-------------|------------|-------------|
| MSP430FR2032IG48R | TSSOP        | DGG             | 48   | 2000 | 350.0       | 350.0      | 43.0        |
| MSP430FR2032IG56R | TSSOP        | DGG             | 56   | 2000 | 350.0       | 350.0      | 43.0        |
| MSP430FR2032IPMR  | LQFP         | PM              | 64   | 1000 | 350.0       | 350.0      | 43.0        |
| MSP430FR2033IG48R | TSSOP        | DGG             | 48   | 2000 | 350.0       | 350.0      | 43.0        |
| MSP430FR2033IG56R | TSSOP        | DGG             | 56   | 2000 | 350.0       | 350.0      | 43.0        |
| MSP430FR2033IPMR  | LQFP         | PM              | 64   | 1000 | 350.0       | 350.0      | 43.0        |

**TUBE**


\*All dimensions are nominal

| Device           | Package Name | Package Type | Pins | SPQ | L (mm) | W (mm) | T (μm) | B (mm) |
|------------------|--------------|--------------|------|-----|--------|--------|--------|--------|
| MSP430FR2032IG48 | DGG          | TSSOP        | 48   | 40  | 530    | 11.89  | 3600   | 4.9    |
| MSP430FR2032IG56 | DGG          | TSSOP        | 56   | 35  | 530    | 11.89  | 3600   | 4.9    |
| MSP430FR2033IG48 | DGG          | TSSOP        | 48   | 40  | 530    | 11.89  | 3600   | 4.9    |
| MSP430FR2033IG56 | DGG          | TSSOP        | 56   | 35  | 530    | 11.89  | 3600   | 4.9    |

**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) |
|-----------------|--------------|--------------|------|-----|-------------------|----------------------|--------|--------|---------|---------|---------|---------|
| MSP430FR2033IPM | PM           | LQFP         | 64   | 160 | 8 x 20            | 150                  | 315    | 135.9  | 7620    | 15.2    | 13.1    | 13      |



# PM0064A



# PACKAGE OUTLINE

LQFP - 1.6 mm max height

PLASTIC QUAD FLATPACK



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.

# EXAMPLE BOARD LAYOUT

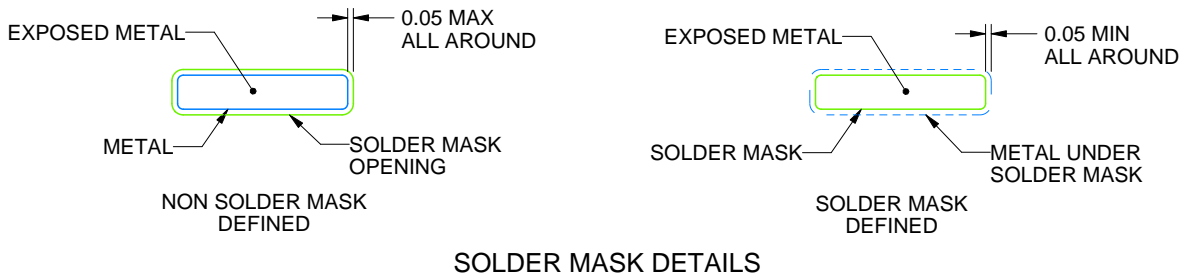
PM0064A

LQFP - 1.6 mm max height

PLASTIC QUAD FLATPACK



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:8X



SOLDER MASK DETAILS

4215162/A 03/2017

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



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.

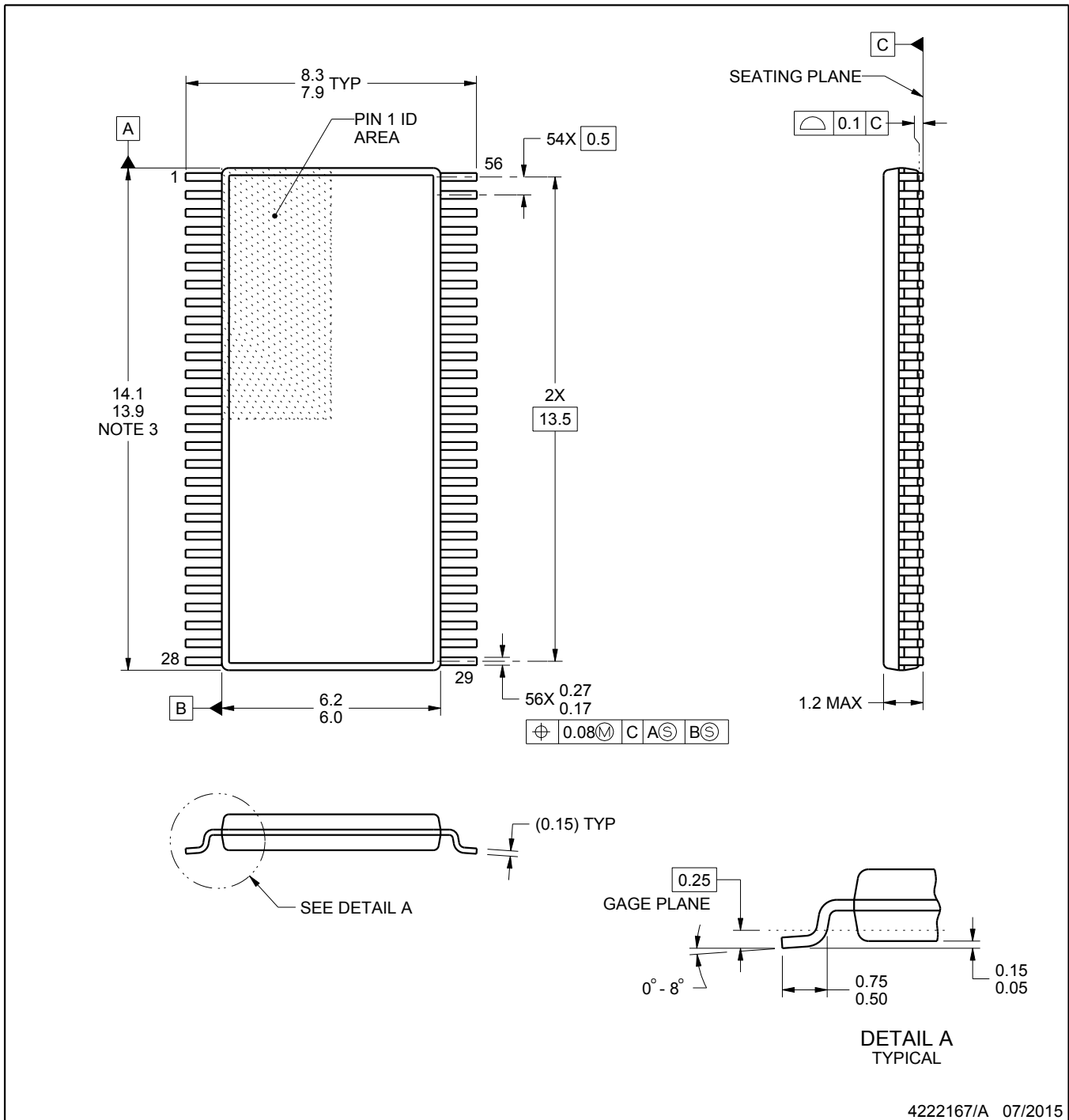
# DGG0056A



# PACKAGE OUTLINE

## TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



4222167/A 07/2015

### 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 MO-153.

# EXAMPLE BOARD LAYOUT

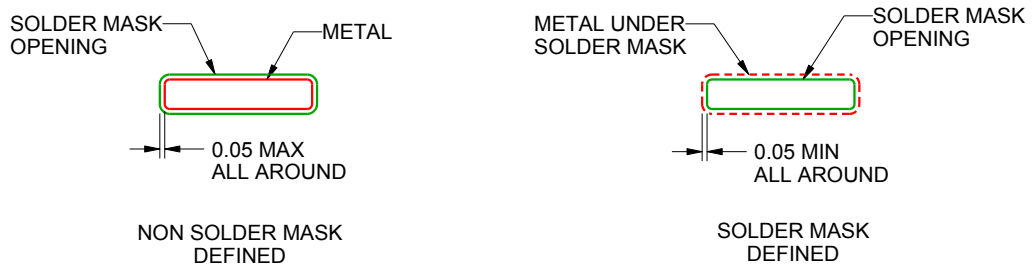
DGG0056A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE  
SCALE:6X



SOLDER MASK DETAILS

4222167/A 07/2015

NOTES: (continued)

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

# EXAMPLE STENCIL DESIGN

DGG0056A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



SOLDER PASTE EXAMPLE  
BASED ON 0.125 mm THICK STENCIL  
SCALE:6X

4222167/A 07/2015

NOTES: (continued)

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

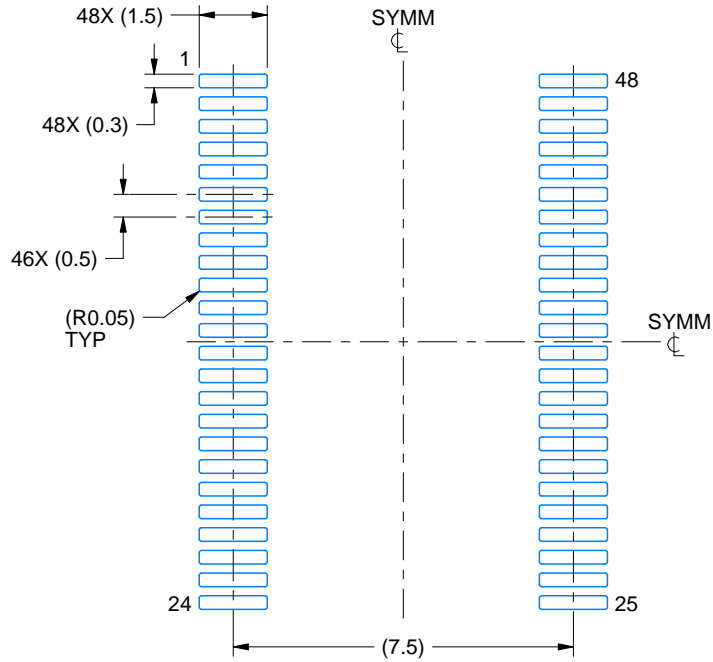


# EXAMPLE BOARD LAYOUT

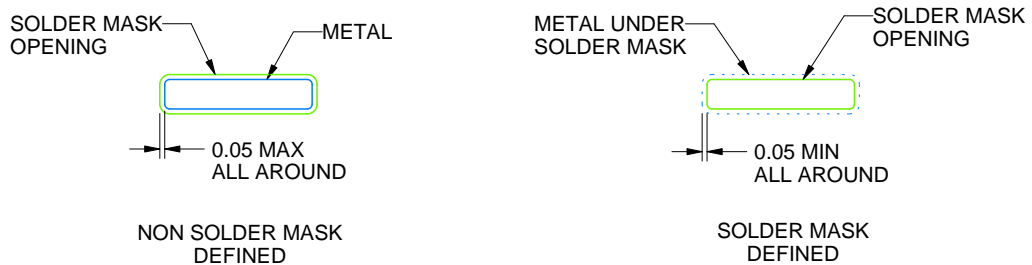
DGG0048A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE  
SCALE:6X



SOLDER MASK DETAILS

4214859/B 11/2020

NOTES: (continued)

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

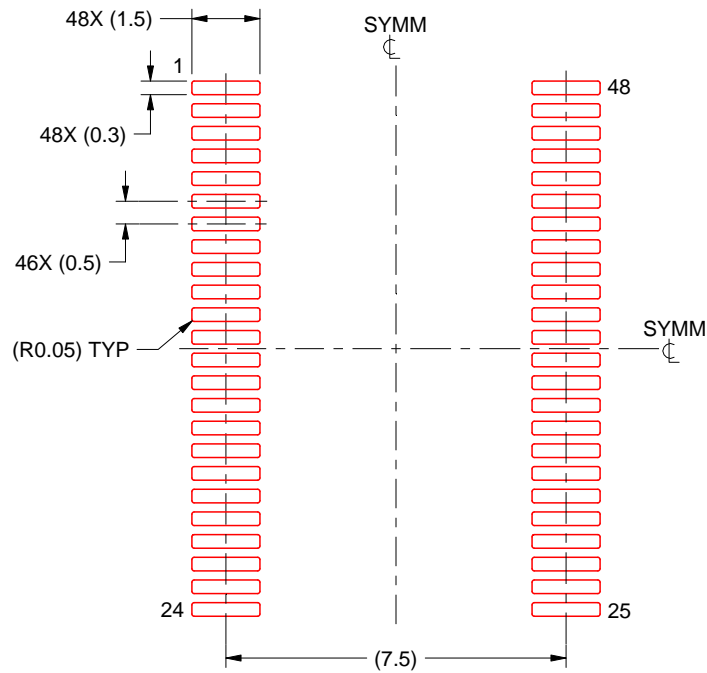


# EXAMPLE STENCIL DESIGN

DGG0048A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



SOLDER PASTE EXAMPLE  
BASED ON 0.125 mm THICK STENCIL  
SCALE:6X

4214859/B 11/2020

NOTES: (continued)

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

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

PLASTIC SMALL-OUTLINE PACKAGE

48 PINS SHOWN



- NOTES: A. All linear dimensions are in millimeters.  
 B. This drawing is subject to change without notice.  
 C. Body dimensions do not include mold protrusion not to exceed 0,15.  
 D. Falls within JEDEC MO-153

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