

# MSP430AFE2x3、MSP430AFE2x2、MSP430AFE2x1 混合信号微控制器

## 1 器件概述

### 1.1 特性

- 低电源电压范围：1.8V 至 3.6V
- 超低功耗
  - 激活模式：220 $\mu$ A（在 1MHz 频率和 2.2V 电压条件下）
  - 待机模式：0.5 $\mu$ A
  - 关闭模式（RAM 保持）：0.1 $\mu$ A
- 5 种省电模式
- 可在不到 1 $\mu$ s 的时间内超快速地从待机模式唤醒
- 16 位精简指令集 (RISC) 架构, 高达 12MHz 系统时钟
- 基本时钟模块配置
  - 带有两个已校准频率的高达 12MHz 的内部频率
  - 内部超低功耗低频 (LF) 振荡器
  - 高达 16MHz 的高频 (HF) 晶振
  - 谐振器
- 外部数字时钟源
- 多达三个具有差分 PGA 输入的 24 位  $\Sigma$ - $\Delta$  模数转换器 (ADC)
- 具有 3 个捕获/比较寄存器的 16 位 Timer\_A
- 串行通信接口 (USART)，可用软件来选择异步 UART 或同步 SPI
- 16 位硬件乘法器
- 欠压检测器
- 具有可编程电平检测功能的电源电压监控器和监视器
- 串行板上编程，无需从外部进行电压编程，利用安全熔丝实现可编程代码保护
- 片上仿真模块
- [器件比较](#) 汇总了可用的产品系列成员
- 如需完整的模块说明，请参阅 [《MSP430x2xx 系列用户指南》](#)

### 1.2 应用

- 单相电表
- 数字电源监控
- 传感器 应用

### 1.3 说明

TI MSP 系列超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。该架构与五种低功耗模式配合使用，是延长便携式测量应用电池寿命的最优选择。该器件采用一个强大的 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。数控振荡器 (DCO) 可使该器件在不到 1 $\mu$ s 的时间内实现从低功率模式唤醒至激活模式。

MSP430AFE2x3 器件是超低功耗混合信号微控制器，集成了三个独立的 24 位  $\Sigma$ - $\Delta$  ADC、一个 16 位计时器、一个 16 位硬件乘法器、USART 通信接口、看门狗计时器和 11 个 I/O 引脚。

MSP430AFE2x2 器件与 MSP430AFE2x3 基本相同，唯一的差异是前者仅集成了两个 24 位  $\Sigma$ - $\Delta$  ADC。

MSP430AFE2x1 器件与 MSP430AFE2x3 基本相同，唯一的差异是前者仅集成了一个 24 位  $\Sigma$ - $\Delta$  ADC。

器件信息<sup>(1)</sup>

| 器件型号            | 封装         | 封装尺寸          |
|-----------------|------------|---------------|
| MSP430AFE253IPW | TSSOP (24) | 7.8mm × 4.4mm |

(1) 有关更多信息，请参阅 [节 8 机械、封装和可订购信息](#)。



## 1.4 功能框图

图 1-1 给出了功能框图。

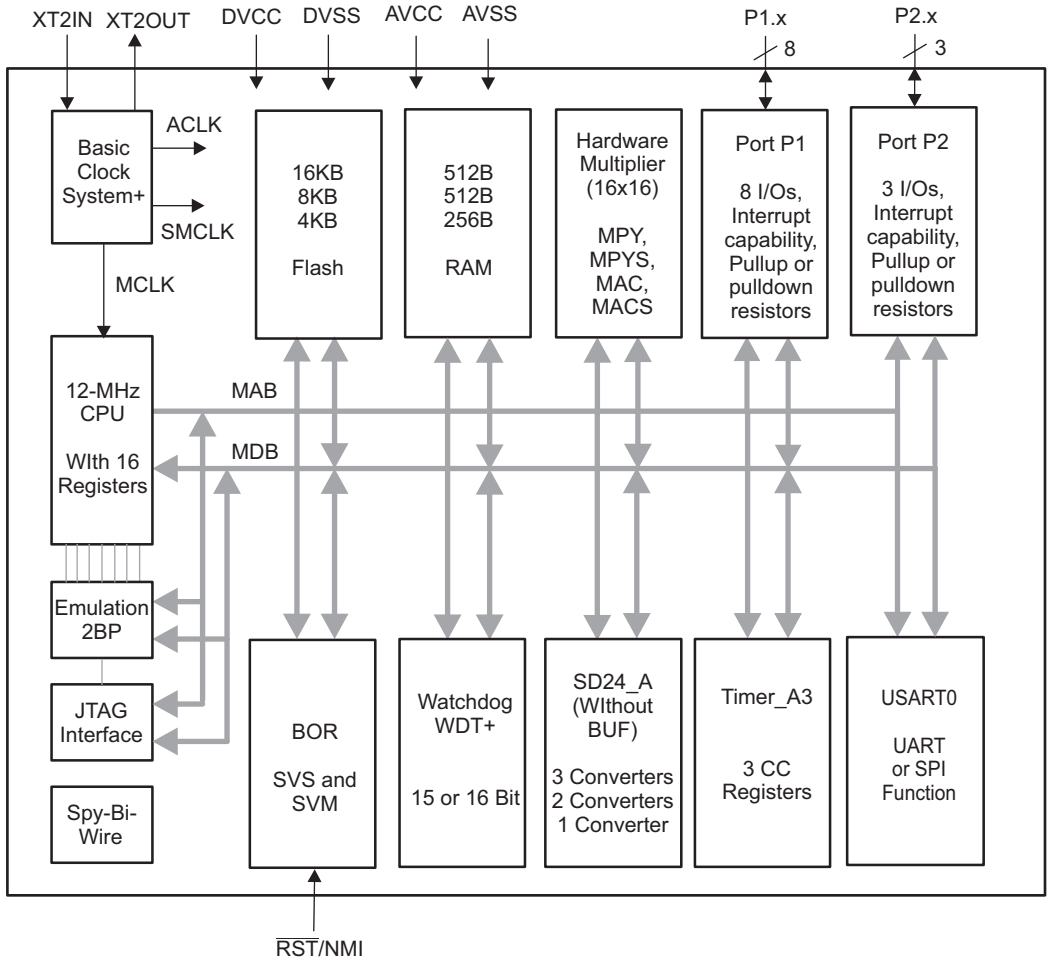


图 1-1. 功能框图

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## 2 修订历史记录

注：之前版本的页码可能与当前版本有所不同。

| Changes from March 21, 2011 to June 11, 2018                                                                    | Page               |
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| • 通篇更改文档格式，其中包括添加章节编号 .....                                                                                     | <a href="#">1</a>  |
| • 添加了节 <a href="#">1.2</a> 应用.....                                                                              | <a href="#">1</a>  |
| • 添加了节 <a href="#">1.4</a> 功能框图，并将功能框图移到此部分 .....                                                               | <a href="#">2</a>  |
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### 3 Device Comparison

Table 3-1 summarizes the available family members.

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

| DEVICE          | FLASH<br>(KB) | SRAM<br>(Byte) | EEM | SD24_A<br>CONVERTERS | 16-BIT<br>MPY | Timer_A <sup>(2)</sup> | USART<br>(UART,<br>SPI) | CLOCKS          | I/O | PACKAGE  |
|-----------------|---------------|----------------|-----|----------------------|---------------|------------------------|-------------------------|-----------------|-----|----------|
| MSP430AFE253IPW | 16            | 512            | 1   | 3                    | 1             | 3                      | 1                       | HF, DCO,<br>VLO | 11  | 24-TSSOP |
| MSP430AFE233IPW | 8             | 512            | 1   | 3                    | 1             | 3                      | 1                       | HF, DCO,<br>VLO | 11  | 24-TSSOP |
| MSP430AFE223IPW | 4             | 256            | 1   | 3                    | 1             | 3                      | 1                       | HF, DCO,<br>VLO | 11  | 24-TSSOP |
| MSP430AFE252IPW | 16            | 512            | 1   | 2                    | 1             | 3                      | 1                       | HF, DCO,<br>VLO | 11  | 24-TSSOP |
| MSP430AFE232IPW | 8             | 512            | 1   | 2                    | 1             | 3                      | 1                       | HF, DCO,<br>VLO | 11  | 24-TSSOP |
| MSP430AFE222IPW | 4             | 256            | 1   | 2                    | 1             | 3                      | 1                       | HF, DCO,<br>VLO | 11  | 24-TSSOP |
| MSP430AFE251IPW | 16            | 512            | 1   | 1                    | 1             | 3                      | 1                       | HF, DCO,<br>VLO | 11  | 24-TSSOP |
| MSP430AFE231IPW | 8             | 512            | 1   | 1                    | 1             | 3                      | 1                       | HF, DCO,<br>VLO | 11  | 24-TSSOP |
| MSP430AFE221IPW | 4             | 256            | 1   | 1                    | 1             | 3                      | 1                       | HF, DCO,<br>VLO | 11  | 24-TSSOP |

(1) For the most current package and ordering information, see the *Package Option Addendum* in 节 8, or see the TI website at [www.ti.com](http://www.ti.com).

(2) Each number in the sequence represents an instantiation of Timer\_A with its associated number of capture compare registers and PWM output generators available. For example, a number sequence of 3, 5 would represent two instantiations of Timer\_A, the first instantiation having 3 and the second instantiation having 5 capture compare registers and PWM output generators, respectively.

#### 3.1 Related Products

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

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

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

**Companion Products for MSP430AFE253** Review products that are frequently purchased or used in conjunction with this product.

**Reference Designs for MSP430AFE253** TI reference designs leverage the best in TI technology – from analog and power management to embedded processors. All designs include a schematic, test data, and design files. Search and download designs at [ti.com/tidesigns](http://ti.com/tidesigns).

## 4 Terminal Configuration and Functions

### 4.1 Pin Diagrams

Figure 4-1 shows the pinout of the MSP430AFE2x3 devices in the 24-pin PW (TSSOP) package.

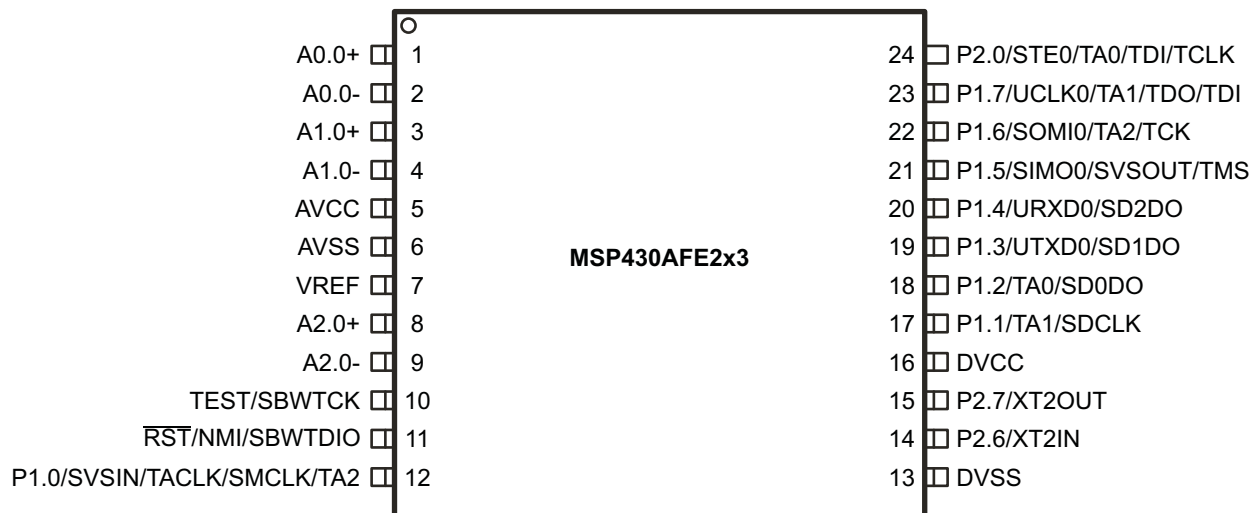
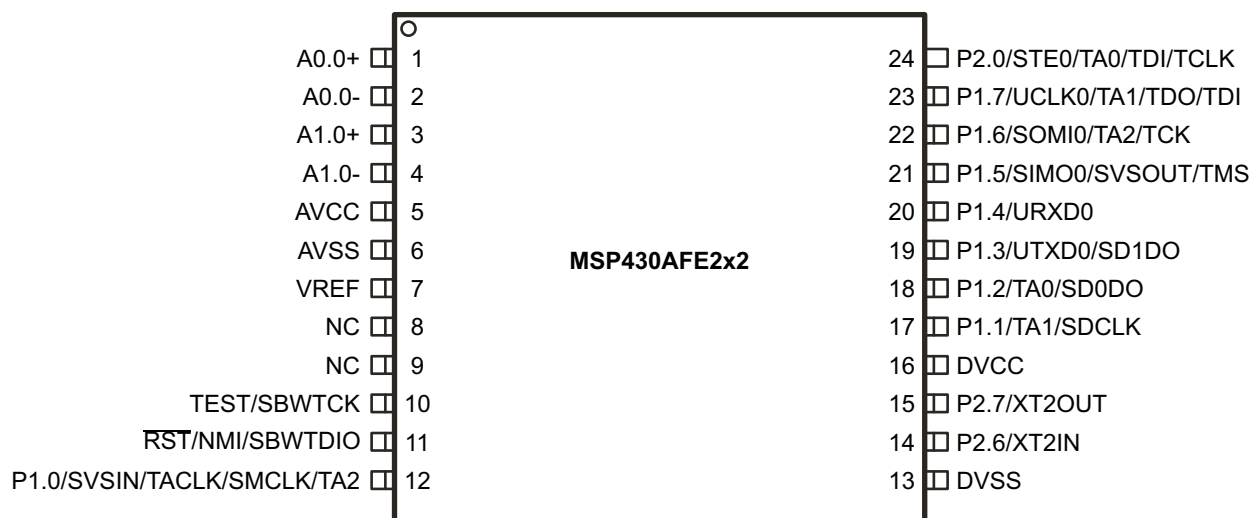


Figure 4-1. 24-Pin PW Package (Top View), MSP430AFE2x3

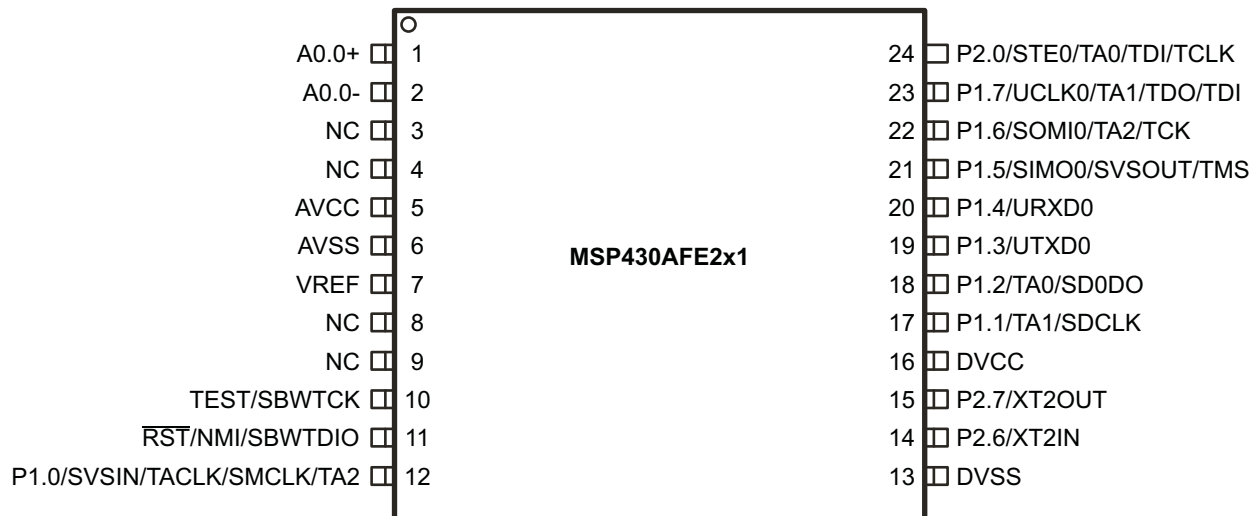
Figure 4-2 shows the pinout of the MSP430AFE2x2 devices in the 24-pin PW (TSSOP) package.



NOTE: Connect NC pins to analog ground (AVSS)

Figure 4-2. 24-Pin PW Package (Top View), MSP430AFE2x2

Figure 4-3 shows the pinout of the MSP430AFE2x1 devices in the 24-pin PW (TSSOP) package.



NOTE: Connect NC pins to analog ground (AVSS)

**Figure 4-3. 24-Pin PW Package (Top View), MSP430AFE2x1**

## 4.2 Signal Descriptions

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

**Table 4-1. Terminal Functions**

| TERMINAL                   |     | I/O | DESCRIPTION                                                                                                                                                                    |
|----------------------------|-----|-----|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| NAME                       | NO. |     |                                                                                                                                                                                |
| A0.0+                      | 1   | I   | SD24_A positive analog input A0.0 <sup>(1)</sup>                                                                                                                               |
| A0.0-                      | 2   | I   | SD24_A negative analog input A0.0 <sup>(1)</sup>                                                                                                                               |
| A1.0+                      | 3   | I   | SD24_A positive analog input A1.0 (not available on MSP430AFE2x1) <sup>(1)</sup>                                                                                               |
| A1.0-                      | 4   | I   | SD24_A negative analog input A1.0 (not available on MSP430AFE2x1) <sup>(1)</sup>                                                                                               |
| AVCC                       | 5   |     | Analog supply voltage, positive terminal. Must not power up prior to DVCC.                                                                                                     |
| AVSS                       | 6   |     | Analog supply voltage, negative terminal                                                                                                                                       |
| VREF                       | 7   | I/O | Input for an external reference voltage<br>output for internal reference voltage (can be used as mid-voltage)                                                                  |
| A2.0+                      | 8   | I   | SD24_A positive analog input A2.0 (not available on MSP430AFE2x2 and MSP430AFE2x1) <sup>(1)</sup>                                                                              |
| A2.0-                      | 9   | I   | SD24_A negative analog input A2.0 (not available on MSP430AFE2x2 and MSP430AFE2x1) <sup>(1)</sup>                                                                              |
| TEST/SBWTCK                | 10  | I   | Selects test mode for JTAG pins on P1.5 to P1.7 and P2.0.<br>The device protection fuse is connected to TEST.<br>Spy-Bi-Wire test clock input for device programming and test. |
| RST/NMI/SBWDIO             | 11  | I   | Reset or nonmaskable interrupt input<br>Spy-Bi-Wire test data input/output for device programming and test.                                                                    |
| P1.0/SVSIN/TACLK/SMCLK/TA2 | 12  | I/O | General-purpose digital I/O pin<br>Analog input to supply voltage supervisor<br>Timer_A3, clock signal TACLK input<br>SMCLK signal output<br>Timer_A3, compare: Out2 Output    |
| DVSS                       | 13  |     | Digital supply voltage, negative terminal                                                                                                                                      |
| P2.6/XT2IN                 | 14  | I/O | Input terminal of crystal oscillator<br>General-purpose digital I/O pin                                                                                                        |
| P2.7/XT2OUT                | 15  | I/O | Output terminal of crystal oscillator<br>General-purpose digital I/O pin                                                                                                       |

(1) TI recommends shorting unused analog input pairs and connecting them to analog ground.

**Table 4-1. Terminal Functions (continued)**

| TERMINAL               |     | I/O | DESCRIPTION                                                                                                                                                                                                                                    |
|------------------------|-----|-----|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| NAME                   | NO. |     |                                                                                                                                                                                                                                                |
| DVCC                   | 16  |     | Digital supply voltage, positive terminal.                                                                                                                                                                                                     |
| P1.1/TA1/SDCLK         | 17  | I/O | General-purpose digital I/O pin<br>Timer_A3, capture: CCI1A and CCI1B inputs, compare: Out1 output<br>SD24_A bit stream clock output                                                                                                           |
| P1.2/TA0/SD0DO         | 18  | I/O | General-purpose digital I/O pin<br>Timer_A3, capture: CCI0A and CCI0B inputs, compare: Out0 output<br>SD24_A bit stream data output for channel 0                                                                                              |
| P1.3/UTXD0/SD1DO       | 19  | I/O | General-purpose digital I/O pin<br>Transmit data out - USART0 in UART mode<br>SD24_A bit stream data output for channel 1 (not available on MSP430AFE2x1)                                                                                      |
| P1.4/URXD0/SD2DO       | 20  | I/O | General-purpose digital I/O pin<br>Receive data in - USART0 in UART mode<br>SD24_A bit stream data output for channel 2 (not available on MSP430AFE2x2 and MSP430AFE2x1)                                                                       |
| P1.5/SIMO0/SVSOUT/TMS  | 21  | I/O | General-purpose digital I/O<br>Slave in/master out of USART0 in SPI mode<br>SVS: output of SVS comparator<br>JTAG test mode select. TMS is used as an input port for device programming and test.                                              |
| P1.6/SOMI0/TA2/TCK     | 22  | I/O | General-purpose digital I/O pin<br>Slave out/master in of USART0 in SPI mode<br>Timer_A3, compare: Out2 output<br>JTAG test clock. TCK is the clock input port for device programming and test.                                                |
| P1.7/UCLK0/TA1/TDO/TDI | 23  | I/O | General-purpose digital I/O pin<br>External clock input - USART0 in UART or SPI mode, clock output - USART0/SPI mode.<br>Timer_A3, compare: Out1 output<br>JTAG test data output port. TDO/TDI data output or programming data input terminal. |
| P2.0/STE0/TA0/TDI/TCLK | 24  | I/O | General-purpose digital I/O pin<br>Slave transmit enable - USART0 in SPI mode.<br>Timer_A3, compare: Out0 output<br>JTAG test data input or test clock input for device programming and test.                                                  |

## 5 Specifications

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

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

|                                           |                     | MIN  | MAX            | UNIT |
|-------------------------------------------|---------------------|------|----------------|------|
| Voltage applied at $V_{CC}$ to $V_{SS}$   |                     | −0.3 | 4.1            | V    |
| Voltage applied to any pin <sup>(2)</sup> |                     | −0.3 | $V_{CC} + 0.3$ | V    |
| Diode current at any device terminal      |                     | −2   | 2              | mA   |
| Storage temperature, $T_{stg}$            | Unprogrammed device | −55  | 150            | °C   |
|                                           | Programmed device   | −40  | 85             |      |

- (1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) All voltages referenced to  $V_{SS}$ . The JTAG fuse-blow voltage,  $V_{FB}$ , is allowed to exceed the absolute maximum rating. The voltage is applied to the TEST pin when blowing the JTAG fuse.

### 5.2 ESD Ratings

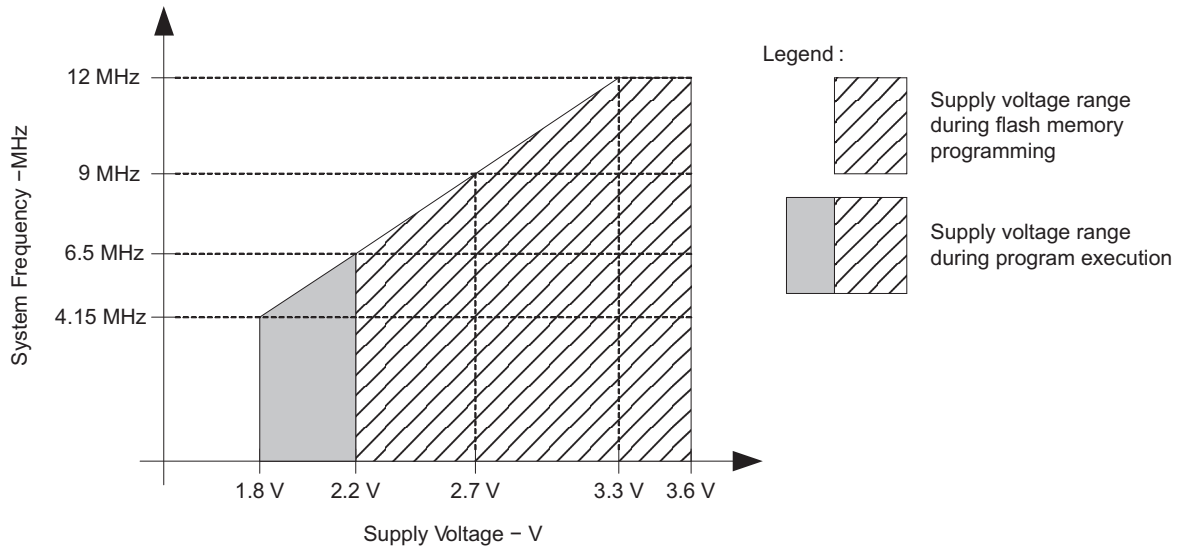
|                                     |                                                                                | VALUE | UNIT |
|-------------------------------------|--------------------------------------------------------------------------------|-------|------|
| $V_{(ESD)}$ Electrostatic discharge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

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

### 5.3 Recommended Operating Conditions<sup>(1)(2)</sup>

|                     |                                                                                                  |                                                |                                         | MIN | NOM | MAX  | UNIT |
|---------------------|--------------------------------------------------------------------------------------------------|------------------------------------------------|-----------------------------------------|-----|-----|------|------|
| V <sub>CC</sub>     | Supply voltage                                                                                   | AVCC = DVCC = V <sub>CC</sub> <sup>(1)</sup>   | During program execution <sup>(3)</sup> | 1.8 |     | 3.6  | V    |
|                     |                                                                                                  |                                                | During program or erase of flash memory | 2.2 |     | 3.6  |      |
| V <sub>SS</sub>     | Supply voltage                                                                                   | AVSS = DVSS = V <sub>SS</sub>                  |                                         |     | 0   |      | V    |
| T <sub>A</sub>      | Operating free-air temperature                                                                   |                                                |                                         | −40 |     | 85   | °C   |
| f <sub>SYSTEM</sub> | Processor frequency (maximum MCLK frequency) <sup>(1)(2)</sup> (see <a href="#">Figure 5-1</a> ) | V <sub>CC</sub> = 1.8 V, Duty cycle = 50% ±10% |                                         | dc  |     | 4.15 | MHz  |
|                     |                                                                                                  | V <sub>CC</sub> = 2.7 V, Duty cycle = 50% ±10% |                                         | dc  |     | 9    |      |
|                     |                                                                                                  | V <sub>CC</sub> ≥ 3.3 V, Duty cycle = 50% ±10% |                                         | dc  |     | 12   |      |

- (1) The MSP430 CPU is clocked directly with MCLK. Both the high and low phases of MCLK must not exceed the pulse duration of the specified maximum frequency.
- (2) Modules might have a different maximum input clock specification. See the specification of the respective module in this data sheet.
- (3) The operating voltage range for SD24\_A is 2.5 V to 3.6 V



- Minimum processor frequency is defined by system clock. Flash program or erase operations require a minimum  $V_{CC}$  of 2.2 V.
- If high frequency crystal used is above 12 MHz and selected to source CPU clock then MCLK divider should be programmed appropriately to run CPU below 8 MHz.

**Figure 5-1. Operating Area**

## 5.4 Thermal Resistance Characteristics for PW-24 Package

| THERMAL METRIC <sup>(1)</sup> (2) |                                                      | VALUE <sup>(3)</sup> | UNIT |
|-----------------------------------|------------------------------------------------------|----------------------|------|
| $R_{\theta JA}$                   | Junction-to-ambient thermal resistance, still air    | 76.4                 | °C/W |
| $R_{\theta JC(TOP)}$              | Junction-to-case (top) thermal resistance            | 21.1                 | °C/W |
| $R_{\theta JC(BOT)}$              | Junction-to-case (bottom) thermal resistance         | 31.7                 | °C/W |
| $R_{\theta JB}$                   | Junction-to-board thermal resistance                 | 31.1                 | °C/W |
| $\Psi_{JB}$                       | Junction-to-board thermal characterization parameter | 1.0                  | °C/W |
| $\Psi_{JT}$                       | Junction-to-top thermal characterization parameter   | N/A                  | °C/W |

- For more information about traditional and new thermal metrics, see [Semiconductor and IC Package Thermal Metrics](#).
- These values are based on a JEDEC-defined 2S2P system (with the exception of the Theta JC [ $R_{\theta JC}$ ] value, which is based on a JEDEC-defined 1S0P system) and will change based on environment and application. For more information, see these EIA/JEDEC standards:
  - JESD51-2, *Integrated Circuits Thermal Test Method Environmental Conditions - Natural Convection (Still Air)*
  - JESD51-3, *Low Effective Thermal Conductivity Test Board for Leaded Surface Mount Packages*
  - JESD51-7, *High Effective Thermal Conductivity Test Board for Leaded Surface Mount Packages*
  - JESD51-9, *Test Boards for Area Array Surface Mount Package Thermal Measurements*
- N/A = Not applicable

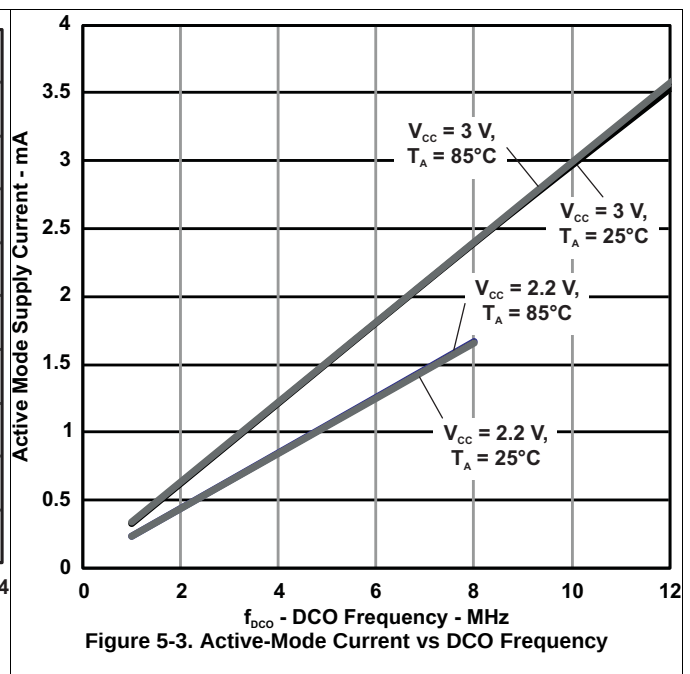
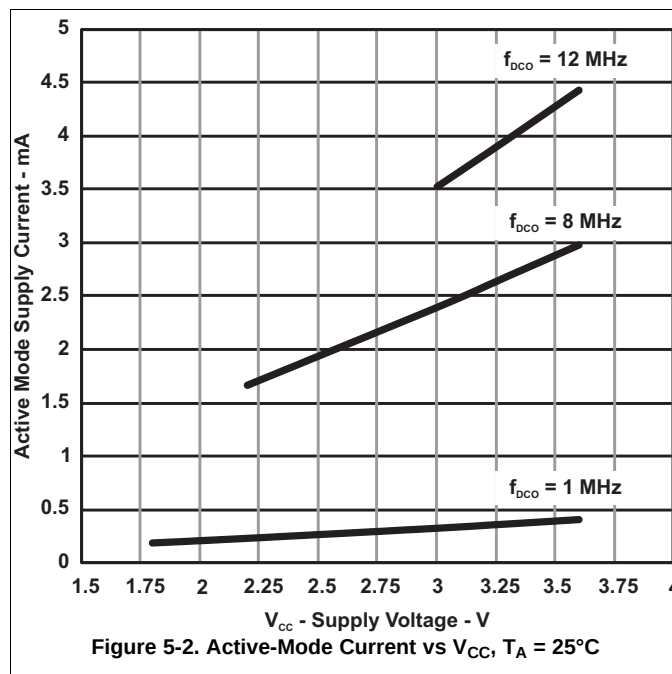
## 5.5 Active Mode Supply Current (Into DVCC and AVCC) Excluding External Current<sup>(1)</sup>

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

| PARAMETER                                                        | TEST CONDITIONS                                                                                                                                                                                                                           | V <sub>CC</sub> | MIN | TYP | MAX | UNIT |
|------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|-----|-----|-----|------|
| I <sub>AM</sub> , 1MHz<br>Active mode (AM)<br>current at 1 MHz   | f <sub>DCO</sub> = f <sub>MCLK</sub> = f <sub>SMCLK</sub> = DCO default frequency<br>(approximately 1 MHz),<br>f <sub>ACLK</sub> = f <sub>VLO</sub> = 12 kHz,<br>Program executes in flash,<br>CPUOFF = 0, SCG0 = 0, SCG1 = 0, OSCOFF = 0 | 2.2 V           |     | 220 |     | μA   |
|                                                                  |                                                                                                                                                                                                                                           | 3 V             |     | 350 |     |      |
| I <sub>AM</sub> , 12MHz<br>Active mode (AM)<br>current at 12 MHz | f <sub>DCO</sub> = f <sub>MCLK</sub> = f <sub>SMCLK</sub> = 12 MHz,<br>f <sub>ACLK</sub> = f <sub>VLO</sub> = 12 kHz,<br>Program executes in flash,<br>CPUOFF = 0, SCG0 = 0, SCG1 = 0, OSCOFF = 0                                         | 3.3 V           |     | 4.0 | 4.5 | mA   |

(1) All inputs are tied to 0 V or V<sub>CC</sub>. Outputs do not source or sink any current.

## 5.6 Typical Characteristics – Active-Mode Supply Current (Into DVCC and AVCC)



## 5.7 Low-Power-Mode Supply Currents (Into $V_{CC}$ ) Excluding External Current<sup>(1)</sup>

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

| PARAMETER                                                     | TEST CONDITIONS                                                                                                                                                                | $T_A$ | $V_{CC}$ | MIN | TYP | MAX | UNIT    |
|---------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|----------|-----|-----|-----|---------|
| $I_{LPM0}$ Low-power mode 0 (LPM0) current <sup>(2)</sup>     | $f_{MCLK} = 0$ MHz,<br>$f_{SMCLK} = f_{DCO} =$ DCO default frequency (approximately 1 MHz),<br>$f_{ACLK} = f_{VLO} = 12$ kHz,<br>CPUOFF = 1, SCG0 = 0, SCG1 = 0,<br>OSCOFF = 0 | 25°C  | 2.2 V    |     | 65  |     | $\mu$ A |
| $I_{LPM2}$ Low-power mode 2 (LPM2) current <sup>(3)</sup>     | $f_{MCLK} = f_{SMCLK} = 0$ MHz,<br>$f_{DCO} =$ DCO default frequency (approximately 1 MHz),<br>$f_{ACLK} = f_{VLO} = 12$ kHz,<br>CPUOFF = 1, SCG0 = 0, SCG1 = 1,<br>OSCOFF = 0 | 25°C  | 2.2 V    |     | 22  |     | $\mu$ A |
| $I_{LPM3,VLO}$ Low-power mode 3 (LPM3) current <sup>(3)</sup> | $f_{DCO} = f_{MCLK} = f_{SMCLK} = 0$ MHz,<br>$f_{ACLK} = f_{VLO} = 12$ kHz,<br>CPUOFF = 1, SCG0 = 1, SCG1 = 1,<br>OSCOFF = 0                                                   | 25°C  | 2.2 V    |     | 0.5 | 1.0 | $\mu$ A |
| $I_{LPM4}$ Low-power mode 4 (LPM4) current <sup>(4)</sup>     | $f_{DCO} = f_{MCLK} = f_{SMCLK} = 0$ MHz,<br>$f_{ACLK} = f_{VLO} = 0$ Hz,<br>CPUOFF = 1, SCG0 = 1, SCG1 = 1,<br>OSCOFF = 1                                                     | 25°C  | 2.2 V    |     | 0.1 | 0.7 | $\mu$ A |
|                                                               |                                                                                                                                                                                | 85°C  |          |     | 1.1 | 2.5 |         |

- (1) All inputs are tied to 0 V or  $V_{CC}$ . Outputs do not source or sink any current.  
(2) Current for brownout and WDT clocked by SMCLK included.  
(3) Current for brownout and WDT clocked by ACLK included.  
(4) Current for brownout included.

## 5.8 Typical Characteristics – LPM4 Current

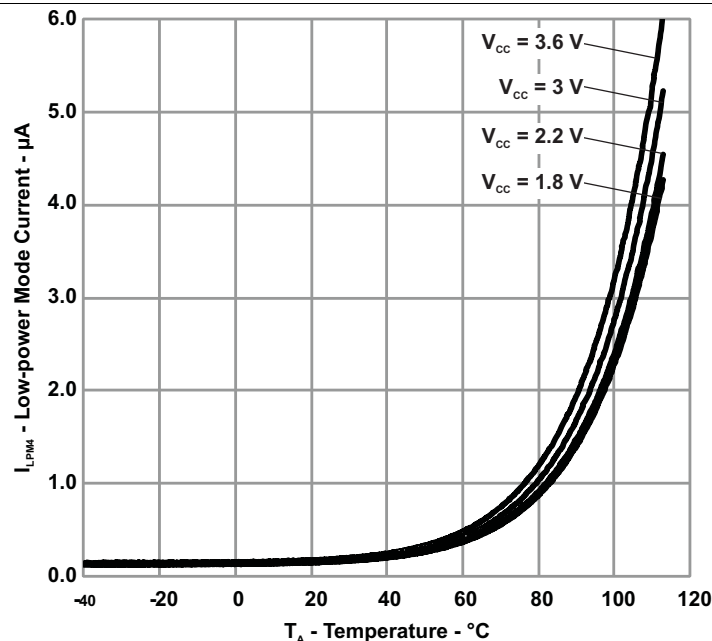


Figure 5-4.  $I_{LPM4}$  -- LPM4 Current vs Temperature

## 5.9 Schmitt-Trigger Inputs (Ports Px and $\overline{\text{RST/NMI}}$ )

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                             |                                                                                                    |                 | 0.45 V <sub>CC</sub> |     | 0.75 V <sub>CC</sub> | V    |
|                                                                                     |                                                                                                    | 3 V             | 1.35                 |     | 2.25                 |      |
| V <sub>IT-</sub> Negative-going input threshold voltage                             |                                                                                                    |                 | 0.25 V <sub>CC</sub> |     | 0.55 V <sub>CC</sub> | V    |
|                                                                                     |                                                                                                    | 3 V             | 0.75                 |     | 1.65                 |      |
| V <sub>hys</sub> Input voltage hysteresis (V <sub>IT+</sub> – V <sub>IT-</sub> )    |                                                                                                    | 3 V             | 0.3                  |     | 1.0                  | V    |
| R <sub>Pull</sub> Pullup or pulldown resistor (not $\overline{\text{RST/NMI}}$ pin) | For pullup: V <sub>IN</sub> = V <sub>SS</sub> ,<br>For pulldown: V <sub>IN</sub> = V <sub>CC</sub> | 3 V             | 20                   | 35  | 50                   | kΩ   |
| C <sub>I</sub> Input capacitance                                                    | V <sub>IN</sub> = V <sub>SS</sub> or V <sub>CC</sub>                                               |                 |                      | 5   |                      | pF   |

## 5.10 Leakage Current (Ports Px)

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

| PARAMETER                                             | TEST CONDITIONS                   | V <sub>CC</sub> | MIN | MAX | UNIT |
|-------------------------------------------------------|-----------------------------------|-----------------|-----|-----|------|
| I <sub>lkg(Px,y)</sub> High-impedance leakage current | See <sup>(1)</sup> <sup>(2)</sup> | 3 V             |     | ±50 | nA   |

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

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

## 5.11 Outputs (Ports Px)

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>OH(max)</sub> = –6 mA <sup>(1)</sup> | 3 V             |     | V <sub>CC</sub> – 0.2 |     | V    |
| V <sub>OL</sub> Low-level output voltage  | I <sub>OL(max)</sub> = 6 mA <sup>(1)</sup>  | 3 V             |     | V <sub>SS</sub> + 0.2 |     | V    |

(1) The maximum total current (I<sub>OH(max)</sub> and I<sub>OL(max)</sub>) for all outputs combined cannot exceed ±48 mA to hold the maximum voltage drop specified.

## 5.12 Output Frequency (Ports Px)

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

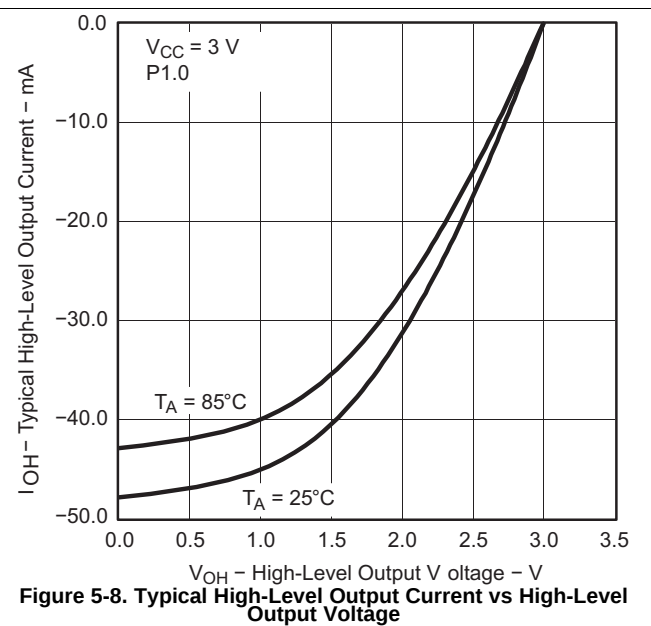
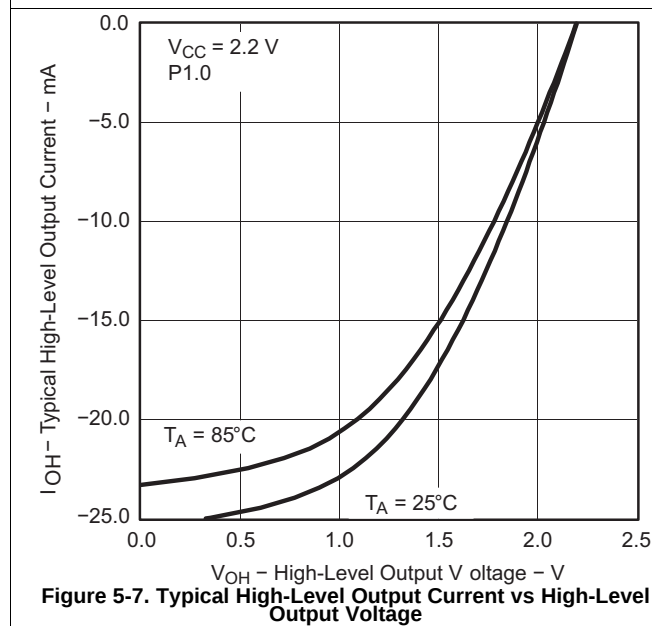
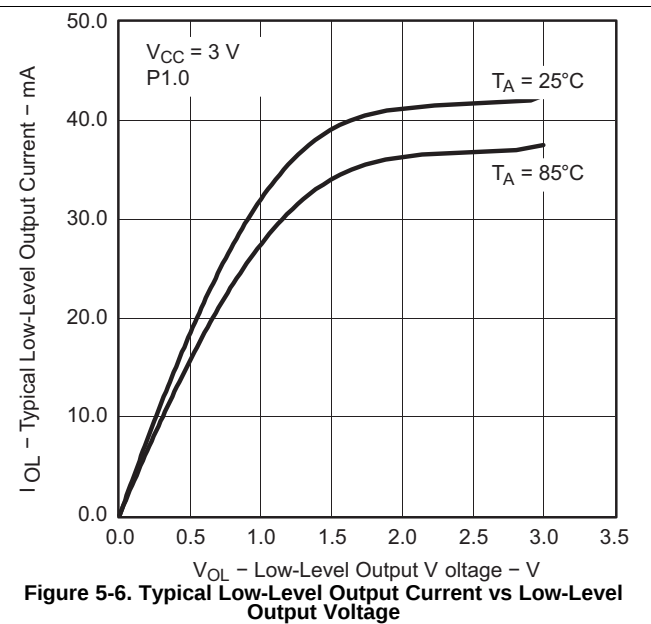
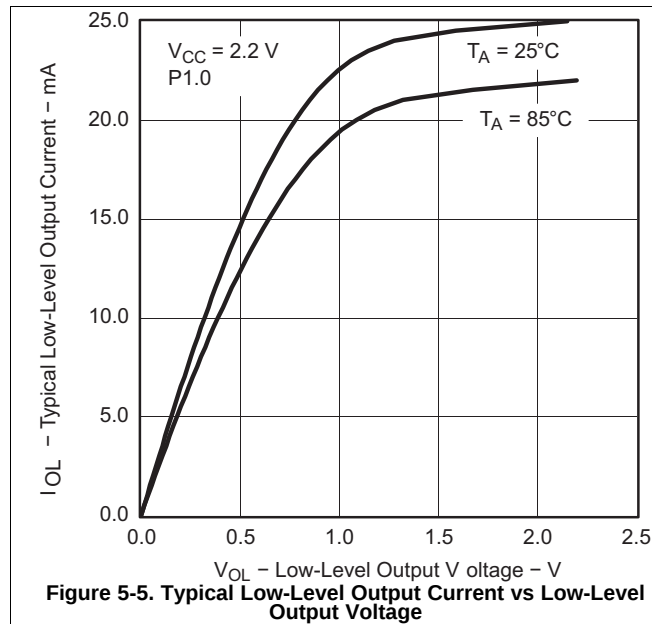
| PARAMETER                                           | TEST CONDITIONS                                                                   | V <sub>CC</sub> | MIN | TYP | MAX | UNIT |
|-----------------------------------------------------|-----------------------------------------------------------------------------------|-----------------|-----|-----|-----|------|
| f <sub>Px,y</sub> Port output frequency (with load) | Px.y, C <sub>L</sub> = 20 pF, R <sub>L</sub> = 1 kΩ <sup>(1)</sup> <sup>(2)</sup> | 3 V             |     | 12  |     | MHz  |
| f <sub>Port_CLK</sub> Clock output frequency        | Px.y, C <sub>L</sub> = 20 pF <sup>(2)</sup>                                       | 3 V             |     | 16  |     | MHz  |

(1) A resistive divider with two 0.5-kΩ resistors between V<sub>CC</sub> and V<sub>SS</sub> is used as load. The output is connected to the center tap of the divider.

(2) The output voltage reaches at least 10% and 90% V<sub>CC</sub> at the specified toggle frequency.

## 5.13 Typical Characteristics – Outputs

One output loaded at a time.



## 5.14 POR, BOR<sup>(1)(2)</sup>

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

| PARAMETER               | TEST CONDITIONS                                                                              | V <sub>CC</sub> | MIN | TYP                           | MAX | UNIT |
|-------------------------|----------------------------------------------------------------------------------------------|-----------------|-----|-------------------------------|-----|------|
| V <sub>CC(start)</sub>  | See Figure 5-9                                                                               |                 |     | 0.7 ×<br>V <sub>(B_IT-)</sub> |     | V    |
| V <sub>(B_IT-)</sub>    | See Figure 5-9 through Figure 5-11                                                           |                 |     | 1.42                          |     | V    |
| V <sub>hys(B_IT-)</sub> | See Figure 5-9                                                                               |                 |     | 120                           |     | mV   |
| t <sub>d(BOR)</sub>     | See Figure 5-9                                                                               |                 |     | 2000                          |     | μs   |
| t <sub>(reset)</sub>    | Pulse duration needed at $\overline{\text{RST}}/\text{NMI}$ pin to accepted reset internally | 3 V             | 2   |                               |     | μs   |

- (1) The current consumption of the brownout module is already included in the I<sub>CC</sub> current consumption data. The voltage level V<sub>(B\_IT-)</sub> + V<sub>hys(B\_IT-)</sub> is ≤ 1.8 V.
- (2) During power up, the CPU begins code execution following a period of t<sub>d(BOR)</sub> after V<sub>CC</sub> = V<sub>(B\_IT-)</sub> + V<sub>hys(B\_IT-)</sub>. The default DCO settings must not be changed until V<sub>CC</sub> ≥ V<sub>CC(min)</sub>, where V<sub>CC(min)</sub> is the minimum supply voltage for the desired operating frequency.

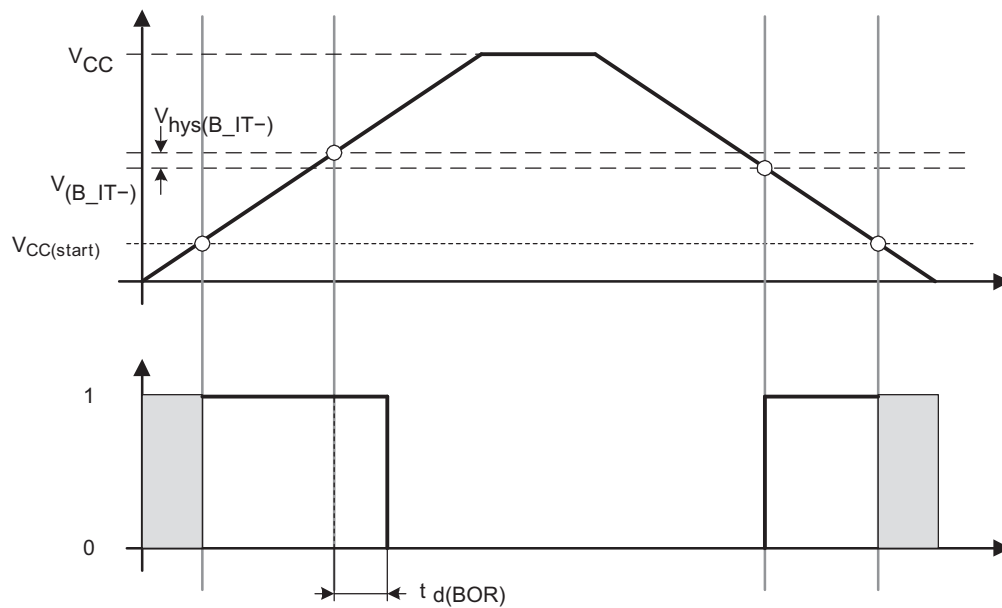
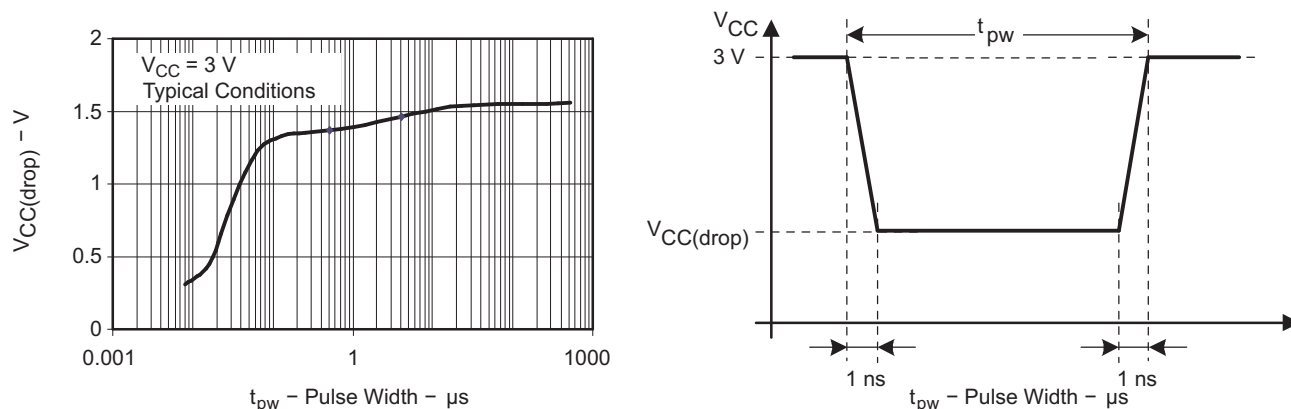
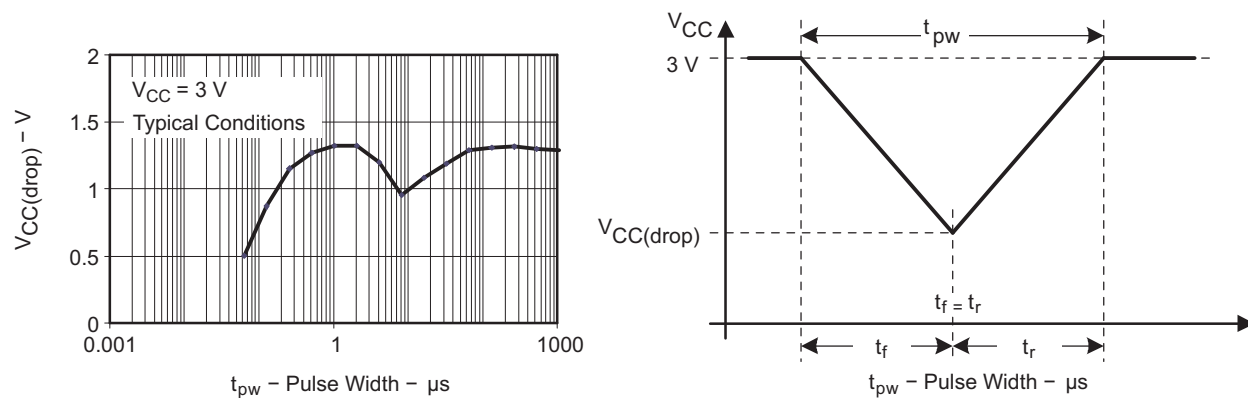


Figure 5-9. POR, BOR vs Supply Voltage

## 5.15 Typical Characteristics – POR, BOR



**Figure 5-10.  $V_{CC(drop)}$  Level With a Square Voltage Drop to Generate a POR or BOR Signal**



**Figure 5-11.  $V_{CC(drop)}$  Level With a Triangular Voltage Drop to Generate a POR or BOR Signal**

## 5.16 Supply Voltage Supervisor (SVS), Supply Voltage Monitor (SVM)<sup>(1)</sup>

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

| PARAMETER                           | TEST CONDITIONS                                                                                   |               | MIN                | TYP | MAX                 | UNIT |     |
|-------------------------------------|---------------------------------------------------------------------------------------------------|---------------|--------------------|-----|---------------------|------|-----|
| t <sub>(SVSR)</sub>                 | dV <sub>CC</sub> /dt > 30 V/ms (see <a href="#">Figure 5-12</a> )                                 |               | 100                |     |                     | μs   |     |
|                                     | dV <sub>CC</sub> /dt ≤ 30 V/ms                                                                    |               | 2000               |     |                     |      |     |
| t <sub>d(SVSON)</sub>               | SVS on, switch from VLD = 0 to VLD ≠ 0, V <sub>CC</sub> =3 V                                      |               | 100                |     |                     | μs   |     |
| t <sub>settle</sub>                 | VLD ≠ 0 <sup>(2)</sup>                                                                            |               | 12                 |     |                     | μs   |     |
| V <sub>(SVSstart)</sub>             | VLD ≠ 0, V <sub>CC</sub> /dt ≤ 3 V/s (see <a href="#">Figure 5-12</a> )                           |               | 1.55               | 1.7 |                     | V    |     |
| V <sub>hys(SVS_IT-)</sub>           | V <sub>CC</sub> /dt ≤ 3 V/s (see <a href="#">Figure 5-12</a> )                                    | VLD = 1       | 120                |     |                     | mV   |     |
|                                     |                                                                                                   | VLD = 2 to 14 | 15                 |     |                     |      |     |
|                                     | V <sub>CC</sub> /dt ≤ 3 V/s (see <a href="#">Figure 5-12</a> ), external voltage applied on SVSIN |               | VLD = 15           | 10  |                     |      |     |
| V <sub>(SVS_IT-)</sub>              | V <sub>CC</sub> /dt ≤ 3V/s (see <a href="#">Figure 5-12</a> )                                     | VLD = 1       | 1.8                | 1.9 | 2.05                | V    |     |
|                                     |                                                                                                   | VLD = 2       | 2.1                |     |                     |      |     |
|                                     |                                                                                                   | VLD = 3       | 2.2                |     |                     |      |     |
|                                     |                                                                                                   | VLD = 4       | 2.3                |     |                     |      |     |
|                                     |                                                                                                   | VLD = 5       | 2.24               | 2.4 | 2.6                 |      |     |
|                                     |                                                                                                   | VLD = 6       | 2.5                |     |                     |      |     |
|                                     |                                                                                                   | VLD = 7       | 2.65               |     |                     |      |     |
|                                     |                                                                                                   | VLD = 8       | 2.8                |     |                     |      |     |
|                                     |                                                                                                   | VLD = 9       | 2.69               | 2.9 | 3.13                |      |     |
|                                     |                                                                                                   | VLD = 10      | 3.05               |     |                     |      |     |
|                                     |                                                                                                   | VLD = 11      | 3.2                |     |                     |      |     |
|                                     |                                                                                                   | VLD = 12      | 3.35               |     |                     |      |     |
|                                     |                                                                                                   | VLD = 13      | 3.24               | 3.5 | 3.76 <sup>(3)</sup> |      |     |
|                                     |                                                                                                   | VLD = 14      | 3.7 <sup>(3)</sup> |     |                     |      |     |
|                                     | V <sub>CC</sub> /dt ≤ 3 V/s (see <a href="#">Figure 5-12</a> ), external voltage applied on SVSIN |               | VLD = 15           | 1.1 | 1.2                 |      | 1.3 |
| I <sub>CC(SVS)</sub> <sup>(1)</sup> | VLD ≠ 0, V <sub>CC</sub> = 3 V                                                                    |               | 12                 |     |                     | 17   | μA  |

(1) The current consumption of the SVS module is not included in the  $I_{\text{CC}}$  current consumption data.

(2)  $t_{\text{settle}}$  is the settling time that the comparator operational amplifier needs to have a stable level after VLD is switched from  $\text{VLD} \neq 0$  to a different VLD value between 2 and 15. The overdrive is assumed to be greater than 50 mV.

(3) The recommended operating voltage range is limited to 3.6 V.

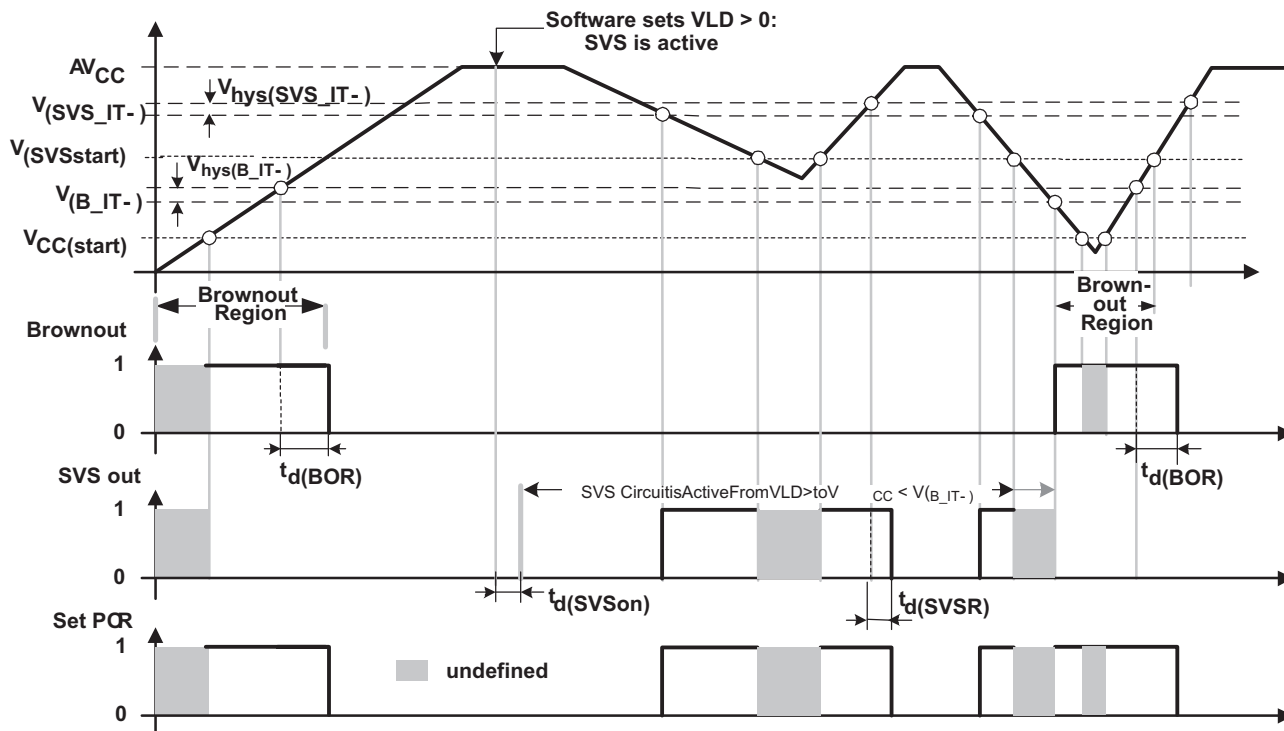


Figure 5-12. SVS Reset (SVSR) vs Supply Voltage

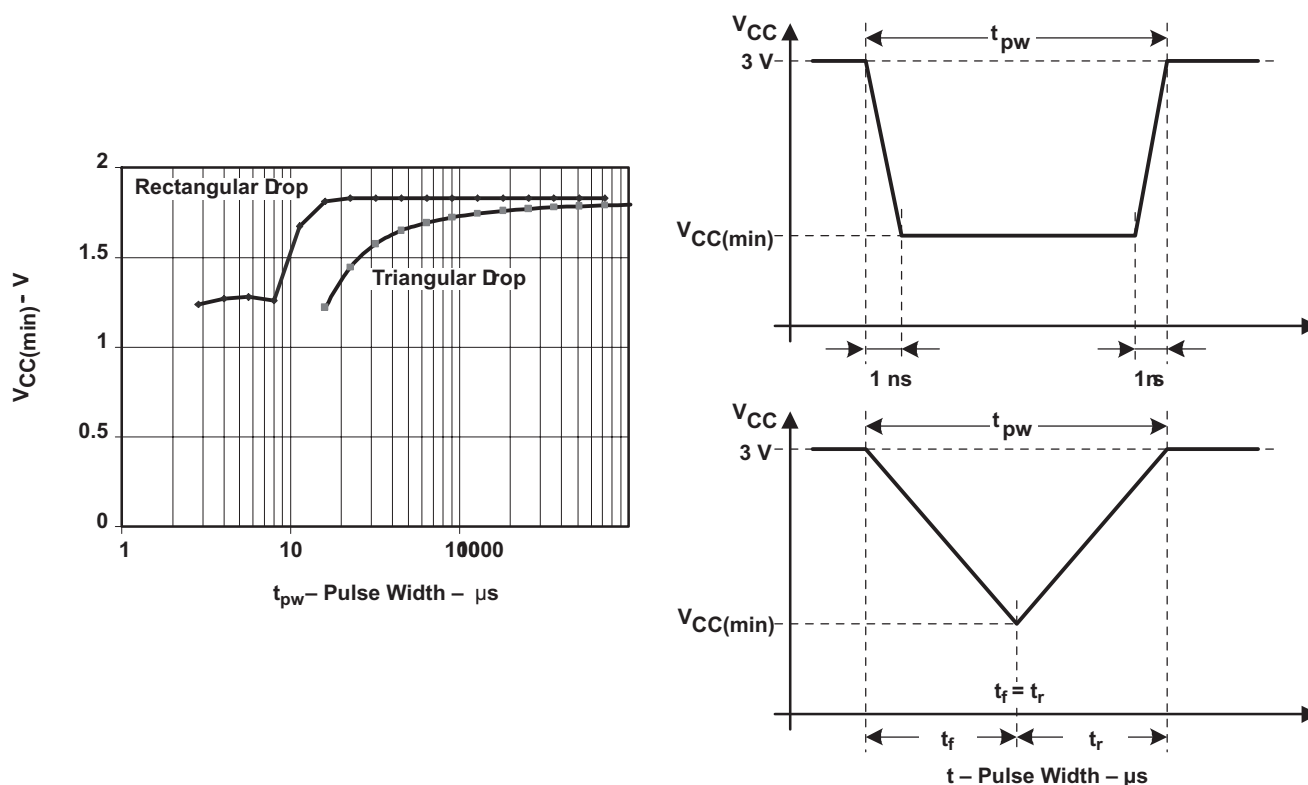


Figure 5-13.  $V_{CC(min)}$  With a Square Voltage Drop and a Triangular Voltage Drop to Generate an SVS

## 5.17 Main DCO Characteristics

- All ranges selected by RSELx overlap with RSELx + 1: RSELx = 0 overlaps RSELx = 1, ... RSELx = 14 overlaps RSELx = 15.
- DCO control bits DCOx have a step size as defined by parameter S<sub>DCO</sub>.
- Modulation control bits MODx select how often f<sub>DCO(RSEL,DCO+1)</sub> is used within the period of 32 DCOCLK cycles. The frequency f<sub>DCO(RSEL,DCO)</sub> is used for the remaining cycles. The frequency is an average equal to:

$$f_{\text{average}} = \frac{32 \times f_{\text{DCO(RSEL,DCO)}} \times f_{\text{DCO(RSEL,DCO+1)}}}{\text{MOD} \times f_{\text{DCO(RSEL,DCO)}} + (32 - \text{MOD}) \times f_{\text{DCO(RSEL,DCO+1)}}}$$

## 5.18 DCO Frequency

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

| PARAMETER              |                                              | TEST CONDITIONS                                                              | V <sub>CC</sub> | MIN  | TYP   | MAX  | UNIT  |
|------------------------|----------------------------------------------|------------------------------------------------------------------------------|-----------------|------|-------|------|-------|
| V <sub>CC</sub>        | Supply voltage range                         | RSELx < 14                                                                   |                 | 1.8  |       | 3.6  | V     |
|                        |                                              | RSELx = 14                                                                   |                 | 2.2  |       | 3.6  |       |
|                        |                                              | RSELx = 15                                                                   |                 | 3.0  |       | 3.6  |       |
| f <sub>DCO(0,0)</sub>  | DCO frequency (0, 0)                         | RSELx = 0, DCOx = 0, MODx = 0                                                | 3.3 V           | 0.06 | 0.10  | 0.14 | MHz   |
| f <sub>DCO(0,3)</sub>  | DCO frequency (0, 3)                         | RSELx = 0, DCOx = 3, MODx = 0                                                | 3.3 V           |      | 0.12  |      | MHz   |
| f <sub>DCO(1,3)</sub>  | DCO frequency (1, 3)                         | RSELx = 1, DCOx = 3, MODx = 0                                                | 3.3 V           |      | 0.15  |      | MHz   |
| f <sub>DCO(2,3)</sub>  | DCO frequency (2, 3)                         | RSELx = 2, DCOx = 3, MODx = 0                                                | 3.3 V           |      | 0.21  |      | MHz   |
| f <sub>DCO(3,3)</sub>  | DCO frequency (3, 3)                         | RSELx = 3, DCOx = 3, MODx = 0                                                | 3.3 V           |      | 0.30  |      | MHz   |
| f <sub>DCO(4,3)</sub>  | DCO frequency (4, 3)                         | RSELx = 4, DCOx = 3, MODx = 0                                                | 3.3 V           |      | 0.41  |      | MHz   |
| f <sub>DCO(5,3)</sub>  | DCO frequency (5, 3)                         | RSELx = 5, DCOx = 3, MODx = 0                                                | 3.3 V           |      | 0.58  |      | MHz   |
| f <sub>DCO(6,3)</sub>  | DCO frequency (6, 3)                         | RSELx = 6, DCOx = 3, MODx = 0                                                | 3.3 V           |      | 0.80  |      | MHz   |
| f <sub>DCO(7,3)</sub>  | DCO frequency (7, 3)                         | RSELx = 7, DCOx = 3, MODx = 0                                                | 3.3 V           |      | 1.15  |      | MHz   |
| f <sub>DCO(8,3)</sub>  | DCO frequency (8, 3)                         | RSELx = 8, DCOx = 3, MODx = 0                                                | 3.3 V           |      | 1.60  |      | MHz   |
| f <sub>DCO(9,3)</sub>  | DCO frequency (9, 3)                         | RSELx = 9, DCOx = 3, MODx = 0                                                | 3.3 V           |      | 2.30  |      | MHz   |
| f <sub>DCO(10,3)</sub> | DCO frequency (10, 3)                        | RSELx = 10, DCOx = 3, MODx = 0                                               | 3.3 V           |      | 3.40  |      | MHz   |
| f <sub>DCO(11,3)</sub> | DCO frequency (11, 3)                        | RSELx = 11, DCOx = 3, MODx = 0                                               | 3.3 V           |      | 4.25  |      | MHz   |
| f <sub>DCO(12,3)</sub> | DCO frequency (12, 3)                        | RSELx = 12, DCOx = 3, MODx = 0                                               | 3.3 V           |      | 5.80  |      | M Hz  |
| f <sub>DCO(13,3)</sub> | DCO frequency (13, 3)                        | RSELx = 13, DCOx = 3, MODx = 0                                               | 3.3 V           |      | 7.80  |      | MHz   |
| f <sub>DCO(14,3)</sub> | DCO frequency (14, 3)                        | RSELx = 14, DCOx = 3, MODx = 0                                               | 3.3 V           | 8.6  | 11.25 | 13.9 | MHz   |
| f <sub>DCO(15,3)</sub> | DCO frequency (15, 3)                        | RSELx = 15, DCOx = 3, MODx = 0                                               | 3.3 V           |      | 15.30 |      | MHz   |
| f <sub>DCO(15,7)</sub> | DCO frequency (15, 7)                        | RSELx = 15, DCOx = 7, MODx = 0                                               | 3.3 V           |      | 21.00 |      | MHz   |
| S <sub>RSEL</sub>      | Frequency step between range RSEL and RSEL+1 | S <sub>RSEL</sub> = f <sub>DCO(RSEL+1,DCO)</sub> /f <sub>DCO(RSEL,DCO)</sub> | 3.3 V           |      | 1.35  |      | ratio |
| S <sub>DCO</sub>       | Frequency step between tap DCO and DCO+1     | S <sub>DCO</sub> = f <sub>DCO(RSEL,DCO+1)</sub> /f <sub>DCO(RSEL,DCO)</sub>  | 3.3 V           |      | 1.08  |      | ratio |
|                        | Duty cycle                                   | Measured at SMCLK output                                                     | 3.3 V           |      | 50    |      | %     |

## 5.19 Calibrated DCO Frequencies – Tolerance

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

| PARAMETER                                        | TEST CONDITIONS                                                                   | T <sub>A</sub> | V <sub>CC</sub> | MIN   | TYP | MAX   | UNIT |
|--------------------------------------------------|-----------------------------------------------------------------------------------|----------------|-----------------|-------|-----|-------|------|
| 8-MHz tolerance over temperature <sup>(1)</sup>  | BCSCTL1 = CALBC1_8MHZ,<br>DCOCTL = CALDCO_8MHZ,<br>calibrated at 30°C and 3.3 V   | 0°C to 85°C    | 3.3 V           | 7.76  | 8   | 8.24  | MHz  |
| 8-MHz tolerance over V <sub>CC</sub>             | BCSCTL1 = CALBC1_8MHZ,<br>DCOCTL = CALDCO_8MHZ,<br>calibrated at 30°C and 3.3 V   | 30°C           | 2.7 V to 3.6 V  | 7.76  | 8   | 8.24  | MHz  |
| 8-MHz tolerance overall                          | BCSCTL1 = CALBC1_8MHZ,<br>DCOCTL = CALDCO_8MHZ,<br>calibrated at 30°C and 3.3 V   | –40°C to 85°C  | 2.7 V to 3.6 V  | 7.52  | 8   | 8.48  | MHz  |
| 12-MHz tolerance over temperature <sup>(1)</sup> | BCSCTL1 = CALBC1_12MHZ,<br>DCOCTL = CALDCO_12MHZ,<br>calibrated at 30°C and 3.3 V | 0°C to 85°C    | 3.3 V           | 11.64 | 12  | 12.36 | MHz  |
| 12-MHz tolerance over V <sub>CC</sub>            | BCSCTL1 = CALBC1_12MHZ,<br>DCOCTL = CALDCO_12MHZ,<br>calibrated at 30°C and 3.3 V | 30°C           | 3.3 V to 3.6 V  | 11.64 | 12  | 12.36 | MHz  |
| 12-MHz tolerance overall                         | BCSCTL1 = CALBC1_12MHZ,<br>DCOCTL = CALDCO_12MHZ,<br>calibrated at 30°C and 3.3 V | –40°C to 85°C  | 3.3 V to 3.6 V  | 11.28 | 12  | 12.72 | MHz  |

(1) This is the frequency change from the measured frequency at 30°C over temperature.

## 5.20 Wake-up Times From Lower-Power Modes (LPM3, LPM4)

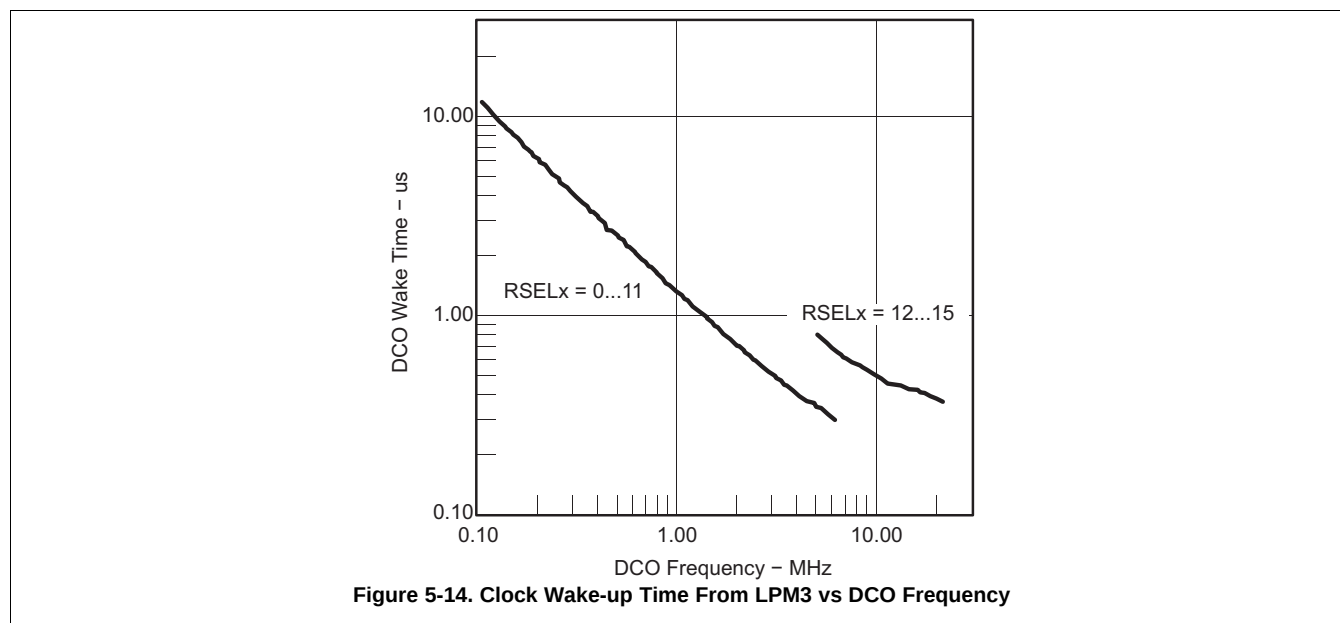
over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)

| PARAMETER                                                                       | TEST CONDITIONS                                                | V <sub>CC</sub> | MIN | TYP                                             | MAX | UNIT |
|---------------------------------------------------------------------------------|----------------------------------------------------------------|-----------------|-----|-------------------------------------------------|-----|------|
| t <sub>DCO,LPM3/4</sub> DCO clock wake-up time from LPM3 or LPM4 <sup>(1)</sup> | f <sub>DCO</sub> = DCO default frequency (approximately 1 MHz) | 3 V             |     | 1.5                                             |     | μs   |
| t <sub>CPU,LPM3/4</sub> CPU wake-up time from LPM3 or LPM4 <sup>(2)</sup>       |                                                                |                 |     | 1 / f <sub>MCLK</sub> + t <sub>DCO,LPM3/4</sub> |     | μs   |

(1) The DCO clock wake-up time is measured from the edge of an external wake-up signal (for example, a port interrupt) to the first clock edge observable externally on a clock pin (MCLK or SMCLK).

(2) Parameter applicable only if DCOCLK is used for MCLK.

## 5.21 Typical Characteristics – DCO Clock Wake-up Time



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

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

| PARAMETER                                                                             | T <sub>A</sub> | V <sub>CC</sub> | MIN | TYP | MAX | UNIT |
|---------------------------------------------------------------------------------------|----------------|-----------------|-----|-----|-----|------|
| f <sub>VLO</sub> VLO frequency                                                        | –40°C to 85°C  | 3 V             | 4   | 12  | 22  | kHz  |
| df <sub>VLO</sub> /dT VLO frequency temperature drift <sup>(1)</sup>                  | –40°C to 85°C  | 3 V             |     | 0.5 |     | %/°C |
| df <sub>VLO</sub> /dV <sub>CC</sub> VLO frequency supply voltage drift <sup>(2)</sup> | 25°C           | 1.8 V to 3.6 V  |     | 4   |     | %/V  |

(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)

## 5.23 Crystal Oscillator (XT2)<sup>(1)</sup>

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

| PARAMETER                                                                                 | TEST CONDITIONS                                                                   | V <sub>CC</sub> | MIN | TYP  | MAX | UNIT |
|-------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|-----------------|-----|------|-----|------|
| f <sub>XT2,HF0</sub> XT2 oscillator crystal frequency, HF mode 0                          | XT2OFF = 0, XT2Sx = 0                                                             | 1.8 V to 3.6 V  | 0.4 |      | 1   | MHz  |
| f <sub>XT2,HF1</sub> XT2 oscillator crystal frequency, HF mode 1                          | XT2OFF = 0, XT2Sx = 1                                                             | 1.8 V to 3.6 V  | 1   |      | 4   | MHz  |
| f <sub>XT2,HF2</sub> XT2 oscillator crystal frequency, HF mode 2                          | XT2OFF = 0, XT2Sx = 2                                                             | 1.8 V to 2.2 V  | 2   |      | 10  | MHz  |
|                                                                                           |                                                                                   | 2.2 V to 3.0 V  | 2   |      | 12  |      |
|                                                                                           |                                                                                   | 3.0 V to 3.6 V  | 2   |      | 16  |      |
| f <sub>XT2,HF,logic</sub> XT2 oscillator logic-level square-wave input frequency, HF mode | XT2OFF = 0, XT2Sx = 3                                                             | 1.8 V to 2.2 V  | 0.4 |      | 10  | MHz  |
|                                                                                           |                                                                                   | 2.2 V to 3.0 V  | 0.4 |      | 12  |      |
|                                                                                           |                                                                                   | 3.0 V to 3.6 V  | 0.4 |      | 16  |      |
| OA <sub>HF</sub> Oscillation allowance for HF crystals (see Figure 5-15)                  | XT2OFF = 0, XT2Sx = 0<br>f <sub>XT2,HF</sub> = 1 MHz, C <sub>L,eff</sub> = 15 pF  |                 |     | 2700 |     | Ω    |
|                                                                                           | XT2OFF = 0, XT2Sx = 1<br>f <sub>XT2,HF</sub> = 4 MHz, C <sub>L,eff</sub> = 15 pF  |                 |     | 800  |     |      |
|                                                                                           | XT2OFF = 0, XT2Sx = 2<br>f <sub>XT2,HF</sub> = 16 MHz, C <sub>L,eff</sub> = 15 pF |                 |     | 300  |     |      |
| C <sub>L,eff</sub> Integrated effective load capacitance, HF mode <sup>(2)</sup>          | XT2OFF = 0 <sup>(3)</sup>                                                         |                 |     | 1    |     | pF   |
| Duty cycle                                                                                | XT2OFF = 0, Measured at P1.0/SVSIN/TACLK/SMCLK/TA2, f <sub>XT2,HF</sub> = 10 MHz  | 3 V             | 40  | 50   | 60  | %    |
|                                                                                           | XT2OFF = 0, Measured at P1.0/SVSIN/TACLK/SMCLK/TA2, f <sub>XT2,HF</sub> = 16 MHz  |                 | 40  | 50   | 60  |      |
| f <sub>Fault,HF</sub> Oscillator fault frequency <sup>(4)</sup>                           | XT2OFF = 0, XT2Sx = 3 <sup>(5)</sup>                                              | 3 V             | 30  |      | 300 | kHz  |

(1) To improve EMI on the XT2 oscillator, observe the following guidelines:

- Keep the trace between the device and the crystal as short as possible.
- Design a good ground plane around the oscillator pins.
- Prevent crosstalk from other clock or data lines into oscillator pins XT2IN and XT2OUT.
- Avoid running PCB traces underneath or adjacent to the XT2IN and XT2OUT pins.
- Use assembly materials and processes that avoid any parasitic load on the oscillator XT2IN and XT2OUT pins.
- If conformal coating is used, make sure that it does not induce capacitive or resistive leakage between the oscillator pins.

(2) Includes parasitic bond and package capacitance (approximately 2 pF per pin). Because the PCB adds additional capacitance, TI recommends verifying the correct load by measuring the ACLK frequency. For a correct setup, the effective load capacitance should always match the specification of the used crystal.

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

(4) Frequencies below the MIN specification set the fault flag, frequencies above the MAX specification do not set the fault flag, and frequencies in between might set the flag.

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

## 5.24 Typical Characteristics – XT2 Oscillator

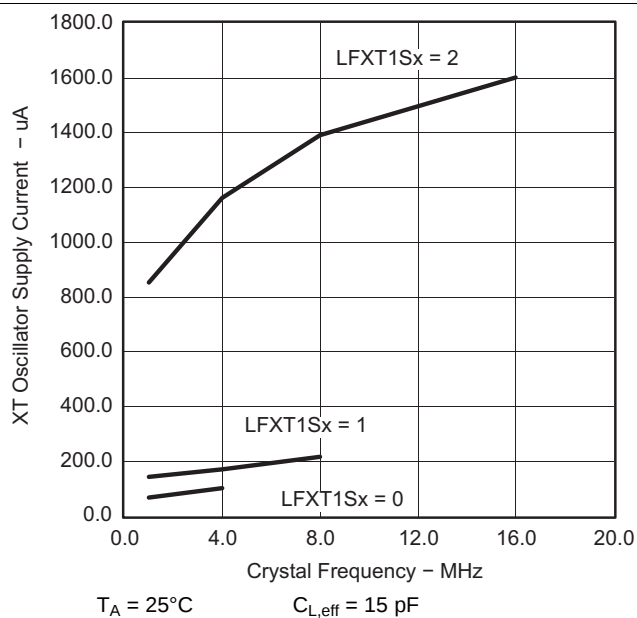


Figure 5-15. XT2 Oscillator Supply Current vs Crystal Frequency

## 5.25 SD24\_A, Power Supply

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 |
|-------------------|-----------------------------------------------------------------------------|----------------------------------------------------------------------------------|----------------|-----------------|------|------|------|------|
| AV <sub>CC</sub>  | Analog supply voltage                                                       | AV <sub>CC</sub> = DV <sub>CC</sub><br>AV <sub>SS</sub> = DV <sub>SS</sub> = 0 V |                |                 | 2.5  |      | 3.6  | V    |
| I <sub>SD24</sub> | Analog supply current: 1 active SD24_A channel including internal reference | SD24LP = 0, f <sub>SD24</sub> = 1 MHz,<br>SD24OSR = 256                          | GAIN: 1, 2     | 3 V             |      | 800  | 1100 | μA   |
|                   |                                                                             |                                                                                  | GAIN: 4, 8, 16 |                 |      | 900  |      |      |
|                   |                                                                             |                                                                                  | GAIN: 32       |                 |      | 1200 |      |      |
|                   |                                                                             | SD24LP = 1, f <sub>SD24</sub> = 0.5 MHz,<br>SD24OSR = 256                        | GAIN: 1        |                 |      | 800  |      |      |
|                   |                                                                             |                                                                                  | GAIN: 32       |                 |      | 900  |      |      |
|                   |                                                                             |                                                                                  |                |                 |      |      |      |      |
| f <sub>SD24</sub> | Analog front-end input clock frequency                                      | SD24LP = 0 (low-power mode disabled)                                             |                | 3 V             | 0.03 | 1    | 1.1  | MHz  |
|                   |                                                                             | SD24LP = 1 (low-power mode enabled)                                              |                |                 | 0.03 | 0.5  |      |      |

## 5.26 SD24\_A, Input Range<sup>(1)</sup>

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

| PARAMETER           |                                                                           | TEST CONDITIONS            | V <sub>CC</sub> | MIN                | TYP | MAX                | UNIT |
|---------------------|---------------------------------------------------------------------------|----------------------------|-----------------|--------------------|-----|--------------------|------|
| V <sub>ID,FSR</sub> | Differential full-scale input voltage range                               | Bipolar mode, SD24UNI = 0  |                 | $-V_{REF} / 2GAIN$ |     | $+V_{REF} / 2GAIN$ | mV   |
|                     |                                                                           | Unipolar mode, SD24UNI = 1 |                 | 0                  |     | $+V_{REF} / 2GAIN$ |      |
| V <sub>ID</sub>     | Differential input voltage range for specified performance <sup>(2)</sup> | SD24REFON = 1              |                 | SD24GAINx = 1      |     | ±500               | mV   |
|                     |                                                                           |                            |                 | SD24GAINx = 2      |     | ±250               |      |
|                     |                                                                           |                            |                 | SD24GAINx = 4      |     | ±125               |      |
|                     |                                                                           |                            |                 | SD24GAINx = 8      |     | ±62                |      |
|                     |                                                                           |                            |                 | SD24GAINx = 16     |     | ±31                |      |
|                     |                                                                           |                            |                 | SD24GAINx = 32     |     | ±15                |      |
| Z <sub>I</sub>      | Input impedance (one input pin to AVSS)                                   | f <sub>SD24</sub> = 1 MHz  | 3 V             | SD24GAINx = 1      |     | 200                | kΩ   |
|                     |                                                                           |                            |                 | SD24GAINx = 32     |     | 75                 |      |
| Z <sub>ID</sub>     | Differential input impedance (IN+ to IN-)                                 | f <sub>SD24</sub> = 1 MHz  | 3 V             | SD24GAINx = 1      |     | 300                | kΩ   |
|                     |                                                                           |                            |                 | SD24GAINx = 32     |     | 100                |      |
| V <sub>I</sub>      | Absolute input voltage range                                              |                            |                 | AVSS – 1           |     | AVCC               | V    |
| V <sub>IC</sub>     | Common-mode input voltage range                                           |                            |                 | AVSS – 1           |     | AVCC               | V    |

(1) All parameters pertain to each SD24\_A channel.

(2) The full-scale range is defined by V<sub>FSR+</sub> = +(V<sub>REF</sub> / 2) / GAIN and V<sub>FSR–</sub> = –(V<sub>REF</sub> / 2) / GAIN. If V<sub>REF</sub> is sourced externally, the analog input range cannot exceed 80% of V<sub>FSR+</sub> or V<sub>FSR–</sub>; that is, V<sub>ID</sub> = 0.8 × V<sub>FSR–</sub> to 0.8 × V<sub>FSR+</sub>. If V<sub>REF</sub> is sourced internally, the given V<sub>ID</sub> ranges apply.

## 5.27 SD24\_A, Performance

$f_{SD24} = 1$  MHz, SD24OSRx = 256, SD24REFON = 1, 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       |
|----------------------------------------------|------------------------------------------------------------------------------------------------------|-----------------|-----|-------|------|------------|
| G Nominal gain                               | SD24GAINx = 1                                                                                        | 3 V             |     | 1     |      |            |
|                                              | SD24GAINx = 2                                                                                        |                 |     | 1.96  |      |            |
|                                              | SD24GAINx = 4                                                                                        |                 |     | 3.86  |      |            |
|                                              | SD24GAINx = 8                                                                                        |                 |     | 7.62  |      |            |
|                                              | SD24GAINx = 16                                                                                       |                 |     | 15.04 |      |            |
|                                              | SD24GAINx = 32                                                                                       |                 |     | 28.35 |      |            |
| E <sub>OS</sub> Offset error                 | SD24GAINx = 1                                                                                        | 3 V             |     |       | ±0.2 | %FSR       |
|                                              | SD24GAINx = 32                                                                                       |                 |     |       | ±1.5 |            |
| ΔEOS/ΔT Offset error temperature coefficient | SD24GAINx = 1                                                                                        | 3 V             |     | ±4    | ±20  | ppm FSR/°C |
|                                              | SD24GAINx = 32                                                                                       |                 |     | ±20   | ±100 |            |
| CMRR Common-mode rejection ratio             | SD24GAINx = 1, Common-mode input signal: V <sub>ID</sub> = 500 mV, f <sub>IN</sub> = 50 Hz or 100 Hz | 3 V             |     | >90   |      | dB         |
|                                              | SD24GAINx = 32, Common-mode input signal: V <sub>ID</sub> = 16 mV, f <sub>IN</sub> = 50 Hz or 100 Hz |                 |     | >75   |      |            |
| AC PSRR AC power supply rejection ratio      | SD24GAINx = 1, V <sub>CC</sub> = 3 V ±100 mV, f <sub>VCC</sub> = 50 Hz                               | 3 V             |     | >80   |      | dB         |
| XT Crosstalk                                 | SD24GAINx = 1, V <sub>ID</sub> = 500 mV, f <sub>IN</sub> = 50 Hz or 100 Hz                           | 3 V             |     | <-100 |      | dB         |

## 5.28 SD24\_A, Temperature Sensor and Built-In V<sub>CC</sub> Sense

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  |
|---------------------------------------------------------------------------------|----------------------------------------------------------|-----------------|------|-------------------------|------|-------|
| TC <sub>Sensor</sub> Sensor temperature coefficient                             |                                                          |                 | 1.18 | 1.32                    | 1.46 | mV/°C |
| V <sub>Offset,sensor</sub> Sensor offset voltage                                |                                                          |                 | -100 |                         | 100  | mV    |
| V <sub>Sensor</sub> Sensor output voltage <sup>(1)(2)</sup>                     | Temperature sensor voltage at T <sub>A</sub> = 85°C      | 3 V             | 420  | 475                     | 515  | mV    |
|                                                                                 | Temperature sensor voltage at T <sub>A</sub> = 30°C      |                 | 350  | 402                     | 442  |       |
| V <sub>CC,Sense</sub> V <sub>CC</sub> divider at input 5                        | f <sub>SD24</sub> = 1 MHz, SD24OSRx = 256, SD24REFON = 1 |                 |      | V <sub>CC</sub> /1<br>1 |      | V     |
| R <sub>Source,VCC</sub> Source resistance of V <sub>CC</sub> divider at input 5 |                                                          |                 |      | 20                      |      | kΩ    |

(1) The following formula can be used to calculate the temperature sensor output voltage:

$$V_{\text{Sensor,typ}} = TC_{\text{Sensor}} (273 + T [^{\circ}\text{C}]) + V_{\text{Offset,sensor}} [\text{mV}]$$

(2) Results based on characterization and/or production test, not TC<sub>Sensor</sub> or V<sub>Offset,sensor</sub>. Measured with f<sub>SD24</sub> = 1 MHz, SD24OSRx = 256, SD24REFON = 1.

## 5.29 SD24\_A, Built-In Voltage Reference

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>REF</sub> Internal reference voltage                          | SD24REFON = 1, SD24VMIDON = 0                                   | 3 V             | 1.14 | 1.2 | 1.26 | V      |
| I <sub>REF</sub> Reference supply current                            | SD24REFON = 1, SD24VMIDON = 0                                   | 3 V             |      | 200 | 320  | μA     |
| TC Temperature coefficient                                           | SD24REFON = 1, SD24VMIDON = 0 <sup>(1)</sup>                    | 3 V             |      | 18  | 50   | ppm/°C |
| C <sub>REF</sub> V <sub>REF</sub> load capacitance                   | SD24REFON = 1, SD24VMIDON = 0 <sup>(2)</sup>                    |                 |      | 100 |      | nF     |
| I <sub>LOAD</sub> V <sub>REF(I)</sub> maximum load current           | SD24REFON = 1, SD24VMIDON = 0                                   | 3 V             |      |     | ±200 | nA     |
| t <sub>ON</sub> Turn-on time                                         | SD24REFON = 0→1, SD24VMIDON = 0, C <sub>REF</sub> = 100 nF      | 3 V             |      | 5   |      | ms     |
| DC PSR DC power supply rejection ΔV <sub>REF</sub> /ΔV <sub>CC</sub> | SD24REFON = 1, SD24VMIDON = 0, V <sub>CC</sub> = 2.5 V to 3.6 V |                 |      | 100 |      | μV/V   |

(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) There is no capacitance required on V<sub>REF</sub>. However, a capacitance of at least 100 nF is recommended to reduce any reference voltage noise.

### 5.30 SD24\_A, Reference Output Buffer

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>REF, BUF</sub>  | Reference buffer output voltage                              | SD24REFON = 1, SD24VMIDON = 1                                | 3 V             |     | 1.2 |     | V    |
| I <sub>REF, BUF</sub>  | Reference supply + reference output buffer quiescent current | SD24REFON = 1, SD24VMIDON = 1                                | 3 V             |     | 430 | 650 | μA   |
| C <sub>REF(O)</sub>    | Required load capacitance on VREF                            | SD24REFON = 1, SD24VMIDON = 1                                |                 | 470 |     |     | nF   |
| I <sub>LOAD, Max</sub> | Maximum load current on VREF                                 | SD24REFON = 1, SD24VMIDON = 1                                | 3 V             |     |     | ±1  | mA   |
|                        | Maximum voltage variation vs load current                    | I <sub>LOAD</sub>   = 0 to 1 mA                              | 3 V             | –15 |     | +15 | mV   |
| t <sub>ON</sub>        | Turnon time                                                  | SD24REFON = 0→1, SD24VMIDON = 0→1, C <sub>REF</sub> = 470 nF | 3 V             |     | 100 |     | μs   |

### 5.31 SD24\_A, External Reference Input

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>REF(I)</sub> | Input voltage range | SD24REFON = 0   | 3 V             | 1.0 | 1.25 | 1.5 | V    |
| I <sub>REF(I)</sub> | Input current       | SD24REFON = 0   | 3 V             |     |      | 50  | nA   |

### 5.32 USART0

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

| PARAMETER          |                                      | TEST CONDITIONS                            | MIN | TYP | MAX | UNIT |
|--------------------|--------------------------------------|--------------------------------------------|-----|-----|-----|------|
| f <sub>USART</sub> | USART clock frequency                |                                            |     |     | 8   | MHz  |
| t <sub>(τ)</sub>   | USART0: deglitch time <sup>(1)</sup> | V <sub>CC</sub> = 3 V, SYNC = 0, UART mode | 150 | 280 | 500 | ns   |

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

### 5.33 Timer\_A3

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>TA</sub>      | Timer_A3 clock frequency | SMCLK, Duty cycle = 50% ±10% |                 |     | f <sub>SYSTEM</sub> |     | MHz  |
| t <sub>TA, cap</sub> | Timer_A3, capture timing | TA0, TA1                     | 3 V             | 20  |                     |     | ns   |

## 5.34 Flash Memory

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

| PARAMETER                                                                    | TEST CONDITIONS       | V <sub>CC</sub> | MIN             | TYP             | MAX | UNIT             |
|------------------------------------------------------------------------------|-----------------------|-----------------|-----------------|-----------------|-----|------------------|
| V <sub>CC(PGM/ERASE)</sub> Program and erase supply voltage                  |                       |                 | 2.2             |                 | 3.6 | V                |
| f <sub>FTG</sub> Flash timing generator frequency                            |                       |                 | 257             |                 | 476 | kHz              |
| I <sub>PGM</sub> Supply current from V <sub>CC</sub> during program          |                       | 2.2 V, 3.6 V    |                 | 1               | 5   | mA               |
| I <sub>ERASE</sub> Supply current from V <sub>CC</sub> during erase          |                       | 2.2 V, 3.6 V    |                 | 1               | 7   | mA               |
| t <sub>CPT</sub> Cumulative program time <sup>(1)</sup>                      |                       | 2.2 V, 3.6 V    |                 |                 | 10  | ms               |
| t <sub>CMErase</sub> Cumulative mass erase time                              |                       | 2.2 V, 3.6 V    | 20              |                 |     | ms               |
| Program and erase endurance                                                  |                       |                 | 10 <sup>4</sup> | 10 <sup>5</sup> |     | cycles           |
| t <sub>Retention</sub> Data retention duration                               | T <sub>J</sub> = 25°C |                 | 100             |                 |     | years            |
| t <sub>Word</sub> Word or byte program time                                  | See <sup>(2)</sup>    |                 |                 | 30              |     | t <sub>FTG</sub> |
| t <sub>Block, 0</sub> Block program time for first byte or word              | See <sup>(2)</sup>    |                 |                 | 25              |     | t <sub>FTG</sub> |
| t <sub>Block, 1-63</sub> Block program time for each additional byte or word | See <sup>(2)</sup>    |                 |                 | 18              |     | t <sub>FTG</sub> |
| t <sub>Block, End</sub> Block program end-sequence wait time                 | See <sup>(2)</sup>    |                 |                 | 6               |     | t <sub>FTG</sub> |
| t <sub>Mass Erase</sub> Mass erase time                                      | See <sup>(2)</sup>    |                 |                 | 10593           |     | t <sub>FTG</sub> |
| t <sub>Seg Erase</sub> Segment erase time                                    | See <sup>(2)</sup>    |                 |                 | 4819            |     | t <sub>FTG</sub> |

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

(2) These values are hardwired into the state machine of the flash controller (t<sub>FTG</sub> = 1 / f<sub>FTG</sub>).

## 5.35 RAM

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

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

(1) This parameter defines the minimum supply voltage V<sub>CC</sub> when the data in RAM remains unchanged. No program execution should happen during this supply voltage condition.

### 5.36 JTAG and Spy-Bi-Wire Interface

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

| PARAMETER             |                                                                                       | V <sub>CC</sub> | MIN   | TYP | MAX | UNIT |
|-----------------------|---------------------------------------------------------------------------------------|-----------------|-------|-----|-----|------|
| f <sub>SBW</sub>      | Spy-Bi-Wire input frequency                                                           | 3 V             | 0     |     | 20  | MHz  |
| t <sub>SBW,Low</sub>  | Spy-Bi-Wire low clock pulse duration                                                  | 3 V             | 0.025 |     | 15  | μs   |
| t <sub>SBW,En</sub>   | Spy-Bi-Wire enable time (TEST high to acceptance of first clock edge <sup>(1)</sup> ) | 3 V             |       |     | 1   | μs   |
| t <sub>SBW,Ret</sub>  | Spy-Bi-Wire return to normal operation time                                           | 3 V             | 15    |     | 100 | μs   |
| f <sub>TCK</sub>      | TCK input frequency <sup>(2)</sup>                                                    | 3 V             | 0     |     | 10  | MHz  |
| R <sub>Internal</sub> | Internal pulldown resistance on TEST                                                  | 3 V             | 25    | 60  | 90  | kΩ   |

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

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

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

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

- (1) After the fuse is blown, no further access to the JTAG Test, Spy-Bi-Wire, or emulation features is possible, and JTAG is switched to bypass mode.

## 6 Detailed Description

### 6.1 CPU

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

The CPU is integrated with 16 registers that provide reduced instruction execution time. The register-to-register operation execution time is one cycle of the CPU clock. Four of the registers, R0 to R3, are dedicated as program counter, stack pointer, status register, and constant generator respectively. The remaining registers are general-purpose registers (see [Figure 6-1](#)).

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

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

Figure 6-1. CPU Registers

## 6.2 Instruction Set

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

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

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

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

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

(1) S = source

(2) D = destination

## 6.3 Operating Modes

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

Software can configure the following operating modes:

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

## 6.4 Interrupt Vector Addresses

The interrupt vectors and the power-up starting address are in the address range of 0FFFFh to 0FFE0h (see [Table 6-3](#)). The vector contains the 16-bit address of the appropriate interrupt handler instruction sequence.

If the reset vector (at address 0FFFEh) contains 0FFFFh (for example, if flash is not programmed), the CPU goes into LPM4 immediately after power up.

**Table 6-3. Interrupt Vector Addresses**

| INTERRUPT SOURCE                                                                                | INTERRUPT FLAG                                                      | SYSTEM INTERRUPT                                  | WORD ADDRESS | PRIORITY    |
|-------------------------------------------------------------------------------------------------|---------------------------------------------------------------------|---------------------------------------------------|--------------|-------------|
| Power up<br>External reset<br>Watchdog<br>Flash key violation<br>PC out-of-range <sup>(1)</sup> | PORIFG<br>RSTIFG<br>WDTIFG<br>KEYV <sup>(2)</sup>                   | Reset                                             | 0FFFEh       | 15, highest |
| NMI<br>Oscillator fault<br>Flash memory access violation                                        | NMIIFG<br>OFIFG<br>ACCVIFG <sup>(2) (3)</sup>                       | (Non)maskable,<br>(Non)maskable,<br>(Non)maskable | 0FFFCCh      | 14          |
|                                                                                                 |                                                                     |                                                   | 0FFFAh       | 13          |
| SD24_A                                                                                          | SD24CTLx SD24OVIFG,<br>SD24CTLx SD24IFG <sup>(2) (4)</sup>          | Maskable                                          | 0FFF8h       | 12          |
|                                                                                                 |                                                                     |                                                   | 0FFF6h       | 11          |
| Watchdog Timer                                                                                  | WDTIFG                                                              | Maskable                                          | 0FFF4h       | 10          |
| USART0 Receive                                                                                  | URXIFG0                                                             | Maskable                                          | 0FFF2h       | 9           |
| USART0 Transmit                                                                                 | UTXIFG0                                                             | Maskable                                          | 0FFF0h       | 8           |
|                                                                                                 |                                                                     |                                                   | 0FFEEh       | 7           |
| Timer_A3                                                                                        | TA0CCR0 CCIFG <sup>(4)</sup>                                        | Maskable                                          | 0FFECCh      | 6           |
| Timer_A3                                                                                        | TA0CCR1 CCIFG,<br>TA0CCR2 CCIFG,<br>TA0CTL TAIFG <sup>(2) (4)</sup> | Maskable                                          | 0FFEAh       | 5           |
| I/O Port P1 (eight flags)                                                                       | P1IFG.0 to P1IFG.7 <sup>(2) (4)</sup>                               | Maskable                                          | 0FFE8h       | 4           |
|                                                                                                 |                                                                     |                                                   | 0FFE6h       | 3           |
|                                                                                                 |                                                                     |                                                   | 0FFE4h       | 2           |
| I/O Port P2 (three flags)                                                                       | P2IFG.0 to P2IFG.2 <sup>(2) (4)</sup>                               | Maskable                                          | 0FFE2h       | 1           |
|                                                                                                 |                                                                     |                                                   | 0FFE0h       | 0, lowest   |

(1) A reset is generated if the CPU tries to fetch instructions from within the module register memory address range (0h to 01FFh) or from within unused address range.

(2) Multiple source flags

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

(4) Interrupt flags are in the module.

## 6.5 Special Function Registers

Most interrupt and module enable bits are collected into the lowest address space. Special function register bits not allocated to a functional purpose are not physically present in the device. Simple software access is provided with this arrangement.

### Legend

|                                                                                   |                                                         |
|-----------------------------------------------------------------------------------|---------------------------------------------------------|
| rw                                                                                | Bit can be read and written.                            |
| rw-0, rw-1                                                                        | Bit can be read and written. It is reset or set by PUC. |
| rw-(0), rw-(1)                                                                    | Bit can be read and written. It is reset or set by POR. |
|  | SFR bit is not present in device.                       |

**Figure 6-2. Interrupt Enable Register 1 (Address 00h)**

| 7      | 6      | 5      | 4     | 3 | 2 | 1    | 0     |
|--------|--------|--------|-------|---|---|------|-------|
| UTXIE0 | URXIE0 | ACCVIE | NMIIE |   |   | OFIE | WDTIE |
| rw-0   | rw-0   | rw-0   | rw-0  |   |   | rw-0 | rw-0  |

**Table 6-4. Interrupt Enable Register 1 Field Descriptions**

| Bit | Field  | Type | Reset | Description                                                                                                                            |
|-----|--------|------|-------|----------------------------------------------------------------------------------------------------------------------------------------|
| 7   | UTXIE0 | RW   | 0h    | USART0: UART and SPI transmit interrupt enable                                                                                         |
| 6   | URXIE0 | RW   | 0h    | USART0: UART and SPI receive interrupt enable                                                                                          |
| 5   | ACCVIE | RW   | 0h    | Flash access violation interrupt enable                                                                                                |
| 4   | NMIIE  | RW   | 0h    | (Non)maskable interrupt enable                                                                                                         |
| 3-2 | Unused |      |       |                                                                                                                                        |
| 1   | OFIE   | RW   | 0h    | Oscillator fault interrupt enable                                                                                                      |
| 0   | WDTIE  | RW   | 0h    | Watchdog timer interrupt enable. Inactive if watchdog mode is selected. Active if watchdog timer is configured in interval timer mode. |

**Figure 6-3. Interrupt Enable Register 2 (Address 01h)**

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
|   |   |   |   |   |   |   |   |

**Figure 6-4. Interrupt Flag Register 1 (Address 02h)**

| 7       | 6       | 5 | 4      | 3      | 2      | 1     | 0      |
|---------|---------|---|--------|--------|--------|-------|--------|
| UTXIFG0 | URXIFG0 |   | NMIIFG | RSTIFG | PORIFG | OFIFG | WDTIFG |
| rw-1    | rw-0    |   | rw-0   | rw-(0) | rw-(1) | rw-1  | rw-(0) |

**Table 6-5. Interrupt Flag Register 1 Field Descriptions**

| Bit | Field   | Type | Reset | Description                                                                                                                                                                            |
|-----|---------|------|-------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7   | UTXIFG0 | RW   | 1h    | USART0: UART and SPI transmit interrupt flag                                                                                                                                           |
| 6   | URXIFG0 | RW   | 0h    | USART0: UART and SPI receive interrupt flag                                                                                                                                            |
| 5   | Unused  |      |       |                                                                                                                                                                                        |
| 4   | NMIIFG  | RW   | 0h    | Set by $\overline{\text{RST}}$ /NMI pin                                                                                                                                                |
| 3   | RSTIFG  | RW   | 0h    | Power-on reset interrupt flag. Set on V <sub>CC</sub> power up.                                                                                                                        |
| 2   | PORIFG  | RW   | 1h    | External reset interrupt flag. Set on a reset condition at $\overline{\text{RST}}$ /NMI pin in reset mode. Reset on V <sub>CC</sub> power up.                                          |
| 1   | OFIFG   | RW   | 1h    | Flag set on oscillator fault                                                                                                                                                           |
| 0   | WDTIFG  | RW   | 0h    | Set on watchdog timer overflow (in watchdog mode) or security key violation. Reset on V <sub>CC</sub> power-up or a reset condition at $\overline{\text{RST}}$ /NMI pin in reset mode. |

**Figure 6-5. Interrupt Flag Register 2 (Address 03h)**

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
|   |   |   |   |   |   |   |   |

**Figure 6-6. Module Enable Register 1 (Address 04h)**

| 7     | 6               | 5 | 4 | 3 | 2 | 1 | 0 |
|-------|-----------------|---|---|---|---|---|---|
| UTXE0 | URXE0<br>USPIE0 |   |   |   |   |   |   |
| rw-0  | rw-0            |   |   |   |   |   |   |

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

| Bit | Field           | Type | Reset | Description                                                                      |
|-----|-----------------|------|-------|----------------------------------------------------------------------------------|
| 7   | UTXE0           | RW   | 0h    | USART0: UART mode transmit enable                                                |
| 6   | URXE0<br>USPIE0 | RW   | 0h    | USART0: UART mode receive enable<br>USART0: SPI mode transmit and receive enable |
| 5-0 | Unused          |      |       |                                                                                  |

**Figure 6-7. Module Enable Register 2 (Address 05h)**

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
|   |   |   |   |   |   |   |   |

## 6.6 Memory Organization

Table 6-7 summarizes the memory map of all device variants.

Table 6-7. Memory Organization

|                        |           | MSP430AFE22x   | MSP430AFE23x   | MSP430AFE25x   |
|------------------------|-----------|----------------|----------------|----------------|
| Memory                 | Size      | 4KB            | 8KB            | 16KB           |
| Main: interrupt vector | Flash     | FFFFh to FFE0h | FFFFh to FFE0h | FFFFh to FFE0h |
| Main: code memory      | Flash     | FFFFh to F000h | FFFFh to E000h | FFFFh to C000h |
| Information memory     | Size      | 256 Byte       | 256 Byte       | 256 Byte       |
|                        | Flash     | 10FFh to 1000h | 10FFh to 1000h | 10FFh to 1000h |
| RAM                    | Size      | 256 bytes      | 512 bytes      | 512 bytes      |
|                        |           | 02FFh to 0200h | 03FFh to 0200h | 03FFh to 0200h |
| Peripherals            | 16-bit    | 01FFh to 0100h | 01FFh to 0100h | 01FFh to 0100h |
|                        | 8-bit     | 00FFh to 0010h | 00FFh to 0010h | 00FFh to 0010h |
|                        | 8-bit SFR | 000Fh to 0000h | 000Fh to 0000h | 000Fh to 0000h |

## 6.7 Flash Memory

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

- Flash memory has  $n$  segments of main memory and four segments of information memory (A to D) of 64 bytes each. Each segment in main memory is 512 bytes in size.
- Segments 0 to  $n$  may be erased in one step, or each segment may be individually erased.
- Segments A to D can be erased individually, or as a group with segments 0 to  $n$ . Segments A to D are also called *information memory*.
- Segment A contains calibration data. After reset, segment A is protected against programming and erasing. It can be unlocked, but do not erase this segment if the device-specific calibration data is required.

## 6.8 Peripherals

Peripherals are connected to the CPU through data, address, and control buses. Peripherals can be managed using all instructions. For complete module descriptions, see the [MSP430x2xx Family User's Guide](#).

## 6.9 Oscillator and System Clock

The clock system is supported by the Basic Clock module that includes support for an internal digitally controlled oscillator (DCO), a high-frequency crystal oscillator, and an internal very-low-power low-frequency oscillator (VLO). The clock module is designed to meet the requirements of both low system cost and low power consumption. The internal DCO provides a fast turnon clock source and stabilizes in less than 1  $\mu$ s. The clock module provides the following clock signals:

- Auxiliary clock (ACLK), sourced from the VLO
- Main clock (MCLK), the system clock used by the CPU
- Sub-Main clock (SMCLK), the subsystem clock used by the peripheral modules

Table 6-8 lists the addresses of the available DCO calibration data.

**Table 6-8. DCO Calibration Data**  
(Provided From Factory in Flash Information Memory Segment A)

| DCO FREQUENCY | CALIBRATION REGISTER | SIZE | ADDRESS |
|---------------|----------------------|------|---------|
| 8 MHz         | CALBC1_8MHZ          | byte | 010FDh  |
|               | CALDCO_8MHZ          | byte | 010FCh  |
| 12 MHz        | CALBC1_12MHZ         | byte | 010FBh  |
|               | CALDCO_12MHZ         | byte | 010FAh  |

## 6.10 Brownout, Supply Voltage Supervisor

The brownout circuit is implemented to provide the proper internal reset signal to the device during power on and power off. The supply voltage supervisor (SVS) circuitry detects if supply voltage drops below a user-selectable level and supports both supply voltage supervision (the device is automatically reset) and supply voltage monitoring (SVM) (the device is not automatically reset).

The CPU begins code execution after the brownout circuit releases the device reset. However,  $V_{CC}$  may not have ramped to  $V_{CC(min)}$  at that time. The user must make sure that the default DCO settings are not changed until  $V_{CC}$  reaches  $V_{CC(min)}$ . If desired, the SVS circuit can be used to determine when  $V_{CC}$  reaches  $V_{CC(min)}$ .

## 6.11 Digital I/O

Two I/O ports are implemented: 8-bit port P1 and 3-bit port P2.

- All individual I/O bits are independently programmable.
- Any combination of input, output, and interrupt condition is possible.
- Edge-selectable interrupt input capability for all eight bits of port P1 and three bits of port P2.
- Read and write access to port-control registers is supported by all instructions.
- Each I/O has an individually programmable pullup or pulldown resistor.

Because there are only three I/O pins implemented from port P2, bits [5:1] of all port P2 registers read as 0, and write data is ignored.

## 6.12 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 disabled or configured as an interval timer and can generate interrupts at selected time intervals.

## 6.13 Timer\_A3

Timer\_A3 is a 16-bit timer/counter with three capture/compare registers. Timer\_A3 can support multiple capture/compares, PWM outputs, and interval timing (see [Table 6-9](#)). Timer\_A3 also has extensive interrupt capabilities. Interrupts may be generated from the counter on overflow conditions and from each of the capture/compare registers.

**Table 6-9. Timer\_A3 Signal Connections**

| INPUT PIN NUMBER | DEVICE INPUT SIGNAL       | MODULE INPUT NAME | MODULE BLOCK | MODULE OUTPUT SIGNAL | OUTPUT PIN NUMBER |
|------------------|---------------------------|-------------------|--------------|----------------------|-------------------|
| 24-PIN PW        |                           |                   |              |                      | 24-PIN PW         |
| 12 - P1.0        | TACLK                     | TACLK             | Timer        | NA                   |                   |
|                  | ACLK                      | ACLK              |              |                      |                   |
|                  | SMCLK                     | SMCLK             |              |                      |                   |
| 12 - P1.0        | $\overline{\text{TACLK}}$ | INCLK             |              |                      |                   |
| 18 - P1.2        | TA0                       | CCI0A             | CCR0         | TA0                  | 18 - P1.2         |
| 18 - P1.2        | TA0                       | CCI0B             |              |                      | 24 - P2.0         |
|                  | DVSS                      | GND               |              |                      |                   |
|                  | DVCC                      | VCC               |              |                      |                   |
| 17 - P1.1        | TA1                       | CCI1A             | CCR1         | TA1                  | 17 - P1.1         |
| 17 - P1.1        | TA1                       | CCI1B             |              |                      | 23 - P1.7         |
|                  | DVSS                      | GND               |              |                      |                   |
|                  | DVCC                      | VCC               |              |                      |                   |
|                  | DVSS                      | CCI2A             | CCR2         | TA2                  | 12 - P1.0         |
|                  | ACLK (internal)           | CCI2B             |              |                      | 22 - P1.6         |
|                  | DVSS                      | GND               |              |                      |                   |
|                  | DVCC                      | VCC               |              |                      |                   |

## 6.14 USART0

The MSP430AFE2xx devices have one hardware universal synchronous/asynchronous receive transmit (USART0) peripheral module that is used for serial data communication. The USART0 module supports synchronous SPI (3-pin or 4-pin) and asynchronous UART communication protocols, using double-buffered transmit and receive channels. The maximum operational frequency for the USART0 module is 8 MHz.

## 6.15 Hardware Multiplier

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

## 6.16 SD24\_A

The SD24\_A module integrates up to three independent 24-bit sigma-delta ADCs. Each channel is designed with fully differential analog input pair and programmable gain amplifier input stage. In addition to external analog inputs, an internal VCC sense and temperature sensor are also available.

## 6.17 Peripheral File Map

[Table 6-10](#) lists the peripheral registers with word access. [Table 6-11](#) lists the peripheral registers with byte access. Some registers are included in both tables.

**Table 6-10. Peripherals With Word Access**

| PERIPHERAL                                    | REGISTER NAME                          | ACRONYM   | ADDRESS |
|-----------------------------------------------|----------------------------------------|-----------|---------|
| Timer_A3                                      | Capture/compare register 2             | TACCR2    | 0176h   |
|                                               | Capture/compare register 1             | TACCR1    | 0174h   |
|                                               | Capture/compare register 0             | TACCR0    | 0172h   |
|                                               | Timer_A register                       | TAR       | 0170h   |
|                                               | Capture/compare control 2              | TACCTL2   | 0166h   |
|                                               | Capture/compare control 1              | TACCTL1   | 0164h   |
|                                               | Capture/compare control 0              | TACCTL0   | 0162h   |
|                                               | Timer_A control                        | TACTL     | 0160h   |
|                                               | Timer_A interrupt vector               | TAIV      | 012Eh   |
| Hardware Multiplier                           | Sum extend                             | SUMEXT    | 013Eh   |
|                                               | Result high word                       | RESHI     | 013Ch   |
|                                               | Result low word                        | RESLO     | 013Ah   |
|                                               | Second operand                         | OP2       | 0138h   |
|                                               | Multiply signed + accumulate/operand 1 | MACS      | 0136h   |
|                                               | Multiply + accumulate/operand 1        | MAC       | 0134h   |
|                                               | Multiply signed/operand 1              | MPYS      | 0132h   |
|                                               | Multiply unsigned/operand 1            | MPY       | 0130h   |
| Flash Memory                                  | Flash control 3                        | FCTL3     | 012Ch   |
|                                               | Flash control 2                        | FCTL2     | 012Ah   |
|                                               | Flash control 1                        | FCTL1     | 0128h   |
| Watchdog Timer+                               | Watchdog/timer control                 | WDTCTL    | 0120h   |
| SD24_A (also see <a href="#">Table 6-11</a> ) | General Control                        | SD24CTL   | 0100h   |
|                                               | Channel 0 Control                      | SD24CCTL0 | 0102h   |
|                                               | Channel 1Control                       | SD24CCTL1 | 0104h   |
|                                               | Channel 2 Control                      | SD24CCTL2 | 0106h   |
|                                               | Channel 0 conversion memory            | SD24MEM0  | 0110h   |
|                                               | Channel 1 conversion memory            | SD24MEM1  | 0112h   |
|                                               | Channel 2 conversion memory            | SD24MEM2  | 0114h   |
|                                               | SD24 Interrupt vector word register    | SD24IV    | 01AEh   |

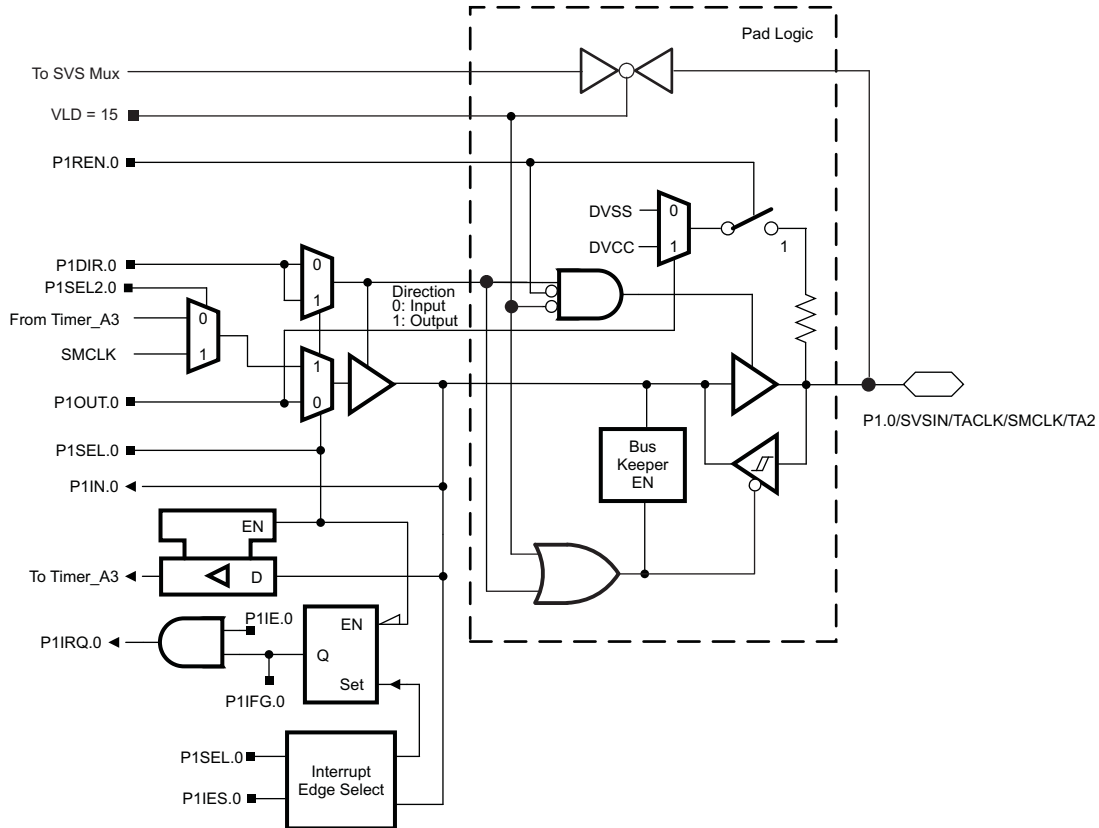
**Table 6-11. Peripherals With Byte Access**

| PERIPHERAL                                    | REGISTER NAME                                   | ACRONYM    | ADDRESS |
|-----------------------------------------------|-------------------------------------------------|------------|---------|
| SD24_A (also see <a href="#">Table 6-10</a> ) | Channel 0 Input Control                         | SD24INCTL0 | 00B0h   |
|                                               | Channel 1 Input Control                         | SD24INCTL1 | 00B1h   |
|                                               | Channel 2 Input Control                         | SD24INCTL2 | 00B2h   |
|                                               | Channel 0 Preload                               | SD24PRE0   | 00B8h   |
|                                               | Channel 1 Preload                               | SD24PRE1   | 00B9h   |
|                                               | Channel 2 Preload                               | SD24PRE2   | 00BAh   |
|                                               | Reserved (Internal SD24_A Configuration 1)      | SD24CONF1  | 00BFh   |
| USART0                                        | Transmit buffer                                 | U0TXBUF    | 0077h   |
|                                               | Receive buffer                                  | U0RXBUF    | 0076h   |
|                                               | Baud rate                                       | U0BR1      | 0075h   |
|                                               | Baud rate                                       | U0BR0      | 0074h   |
|                                               | Modulation control                              | U0MCTL     | 0073h   |
|                                               | Receive control                                 | U0RCTL     | 0072h   |
|                                               | Transmit control                                | U0TCTL     | 0071h   |
|                                               | USART control                                   | U0CTL      | 0070h   |
| Basic Clock System+                           | Basic clock system control 3                    | BCSCTL3    | 0053h   |
|                                               | Basic clock system control 2                    | BCSCTL2    | 0058h   |
|                                               | Basic clock system control 1                    | BCSCTL1    | 0057h   |
|                                               | DCO clock frequency control                     | DCOCTL     | 0056h   |
| Brownout, SVS                                 | SVS control register (reset by brownout signal) | SVSCTL     | 0055h   |
| Port P2                                       | Port P2 selection 2                             | P2SEL2     | 0042h   |
|                                               | Port P2 resistor enable                         | P2REN      | 002Fh   |
|                                               | Port P2 selection                               | P2SEL      | 002Eh   |
|                                               | Port P2 interrupt enable                        | P2IE       | 002Dh   |
|                                               | Port P2 interrupt edge select                   | P2IES      | 002Ch   |
|                                               | Port P2 interrupt flag                          | P2IFG      | 002Bh   |
|                                               | Port P2 direction                               | P2DIR      | 002Ah   |
|                                               | Port P2 output                                  | P2OUT      | 0029h   |
|                                               | Port P2 input                                   | P2IN       | 0028h   |
| Port P1                                       | Port P1 selection 2 register                    | P1SEL2     | 0041h   |
|                                               | Port P1 resistor enable                         | P1REN      | 0027h   |
|                                               | Port P1 selection                               | P1SEL      | 0026h   |
|                                               | Port P1 interrupt enable                        | P1IE       | 0025h   |
|                                               | Port P1 interrupt edge select                   | P1IES      | 0024h   |
|                                               | Port P1 interrupt flag                          | P1IFG      | 0023h   |
|                                               | Port P1 direction                               | P1DIR      | 0022h   |
|                                               | Port P1 output                                  | P1OUT      | 0021h   |
|                                               | Port P1 input                                   | P1IN       | 0020h   |
| Special Function                              | SFR module enable 2                             | ME2        | 0005h   |
|                                               | SFR module enable 1                             | ME1        | 0004h   |
|                                               | SFR interrupt flag 2                            | IFG2       | 0003h   |
|                                               | SFR interrupt flag 1                            | IFG1       | 0002h   |
|                                               | SFR interrupt enable 2                          | IE2        | 0001h   |
|                                               | SFR interrupt enable 1                          | IE1        | 0000h   |

## 6.18 I/O Port Schematics

### 6.18.1 Port P1 Pin Schematic: P1.0 Input/Output With Schmitt Trigger

Figure 6-8 shows the port schematic. Table 6-12 summarizes the selection of the pin functions.



**Figure 6-8. Port P1 (P1.0) Schematic**

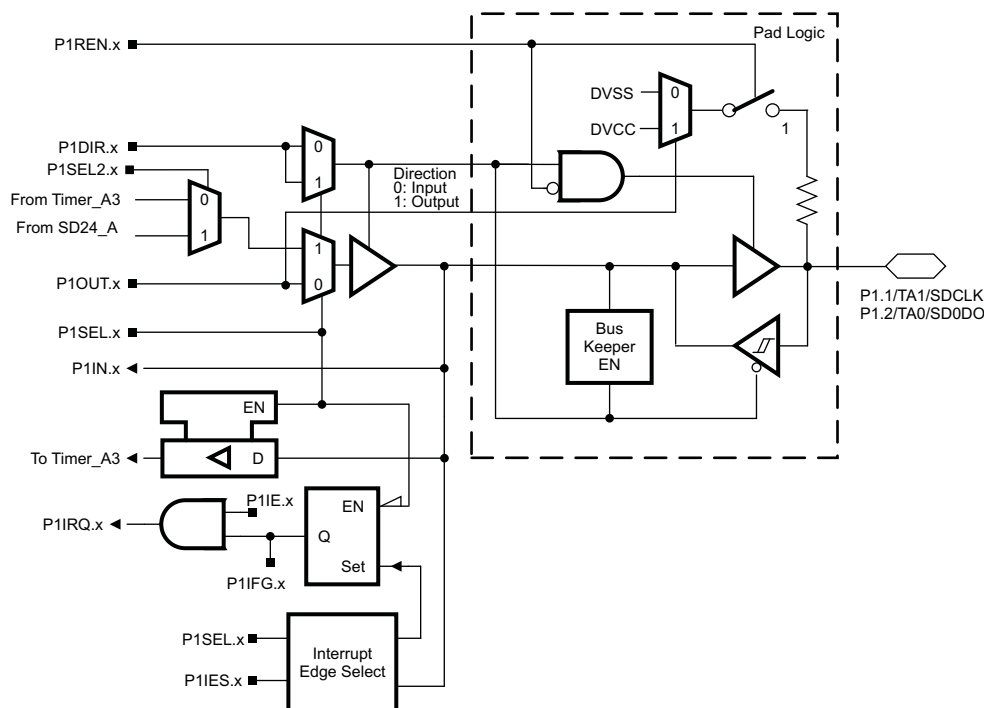
**Table 6-12. Port P1 (P1.0) Pin Functions**

| PIN NAME (P1.x)            | x | FUNCTION         | CONTROL BITS OR SIGNALS <sup>(1)</sup> |         |          |
|----------------------------|---|------------------|----------------------------------------|---------|----------|
|                            |   |                  | P1DIR.x                                | P1SEL.x | P1SEL2.x |
| P1.0/SVSIN/TACLK/SMCLK/TA2 | 0 | P1.0 (I/O)       | I: 0, O: 1                             | 0       | X        |
|                            |   | SVSIN (VLD = 15) | X                                      | X       | X        |
|                            |   | Timer_A3.TACLK   | 0                                      | 1       | 0        |
|                            |   | SMCLK            | 1                                      | 1       | 1        |
|                            |   | Timer_A3.TA2     | 1                                      | 1       | 0        |

(1) X = don't care

## 6.18.2 Port P1 Pin Schematic: P1.1 and P1.2 Input/Output With Schmitt Trigger

Figure 6-9 shows the port schematic. Table 6-13 summarizes the selection of the pin functions.



**Figure 6-9. Port P1 (P1.1 and P1.2) Schematic**

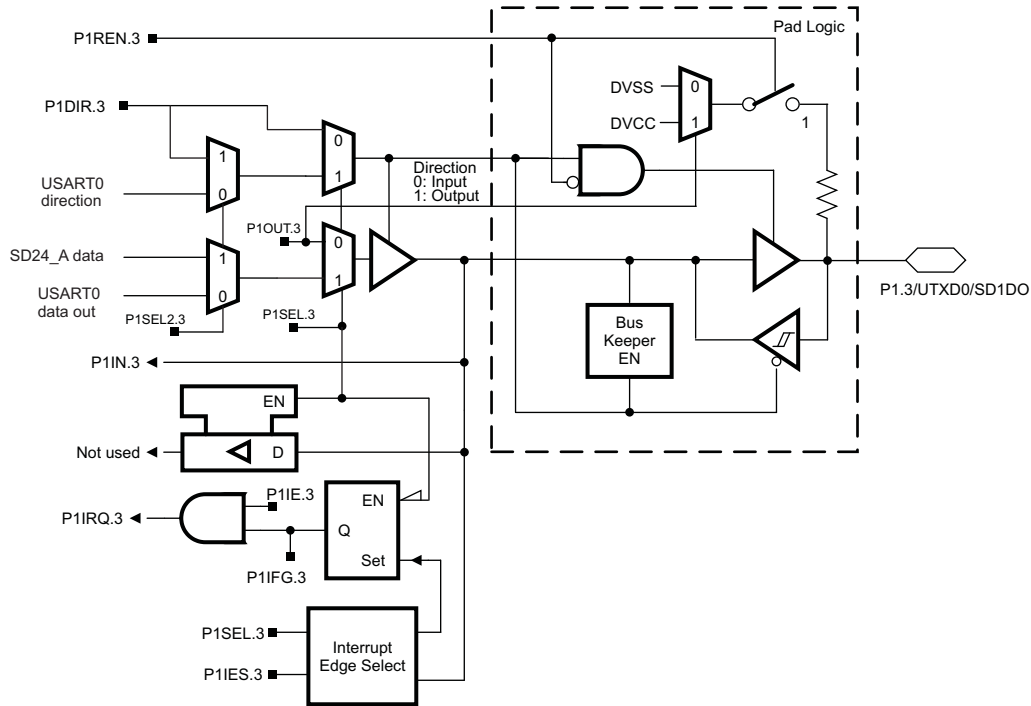
**Table 6-13. Port P1 (P1.1 and P1.2) Pin Functions**

| PIN NAME (P1.x) | x | FUNCTION                 | CONTROL BITS / SIGNAL <sup>(1)</sup> |         |          |
|-----------------|---|--------------------------|--------------------------------------|---------|----------|
|                 |   |                          | P1DIR.x                              | P1SEL.x | P1SEL2.x |
| P1.1/TA1/SDCLK  | 1 | P1.1 (I/O)               | I: 0, O: 1                           | 0       | X        |
|                 |   | Timer_A3.CCI1A and CCI1B | 0                                    | 1       | 0        |
|                 |   | Timer_A3.TA1             | 1                                    | 1       | 0        |
|                 |   | SDCLK                    | 1                                    | 1       | 1        |
| P1.2/TA0/SD0DO  | 2 | P1.2 (I/O)               | I: 0, O: 1                           | 0       | X        |
|                 |   | Timer_A3.CCI0A and CCI0B | 0                                    | 1       | 0        |
|                 |   | Timer_A3.TA0             | 1                                    | 1       | 0        |
|                 |   | SD0DO                    | 1                                    | 1       | 1        |

(1) X = don't care

### 6.18.3 Port P1 Pin Schematic: P1.3 Input/Output With Schmitt Trigger

Figure 6-10 shows the port schematic. Table 6-14 summarizes the selection of the pin functions.



**Figure 6-10. Port P1 (P1.3) Schematic**

**Table 6-14. Port P1 (P1.3) Pin Functions**

| PIN NAME (P1.x)  | x | FUNCTION   | CONTROL BITS OR SIGNALS <sup>(1)</sup> |         |          |
|------------------|---|------------|----------------------------------------|---------|----------|
|                  |   |            | P1DIR.x                                | P1SEL.x | P1SEL2.x |
| P1.3/UTXD0/SD1DO | 3 | P1.3 (I/O) | I: 0, O: 1                             | 0       | X        |
|                  |   | UTXD0      | X                                      | 1       | 0        |
|                  |   | SD1DO      | 1                                      | 1       | 1        |

(1) X = don't care

#### 6.18.4 Port P1 Pin Schematic: P1.4 Input/Output With Schmitt Trigger

Figure 6-11 shows the port schematic. Table 6-15 summarizes the selection of the pin functions.

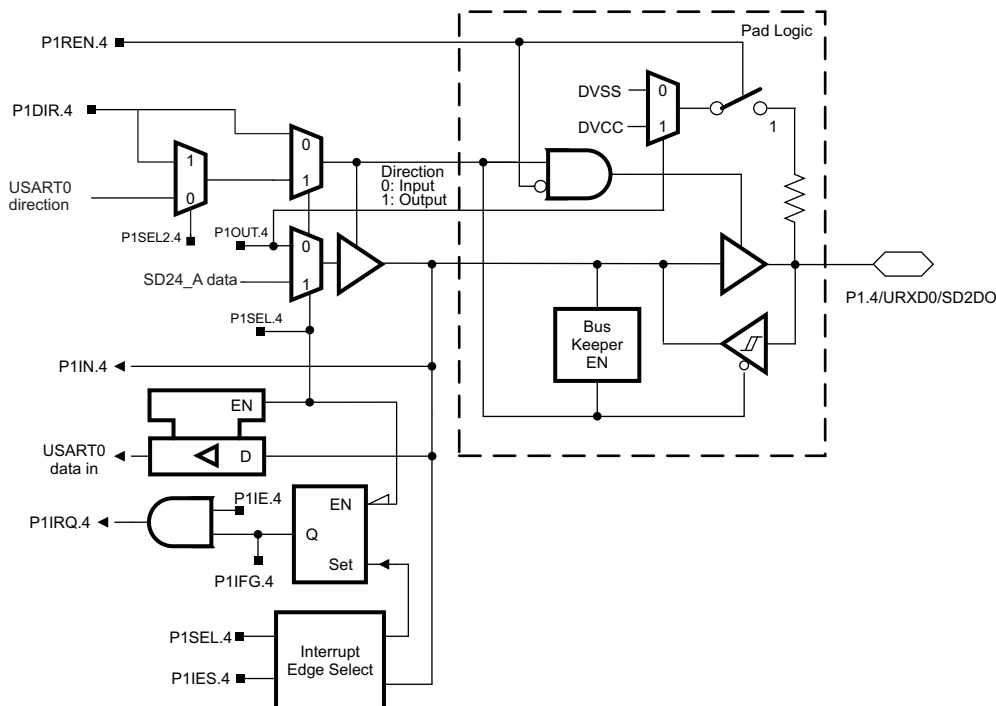


Figure 6-11. Port P1 (P1.4) Schematic

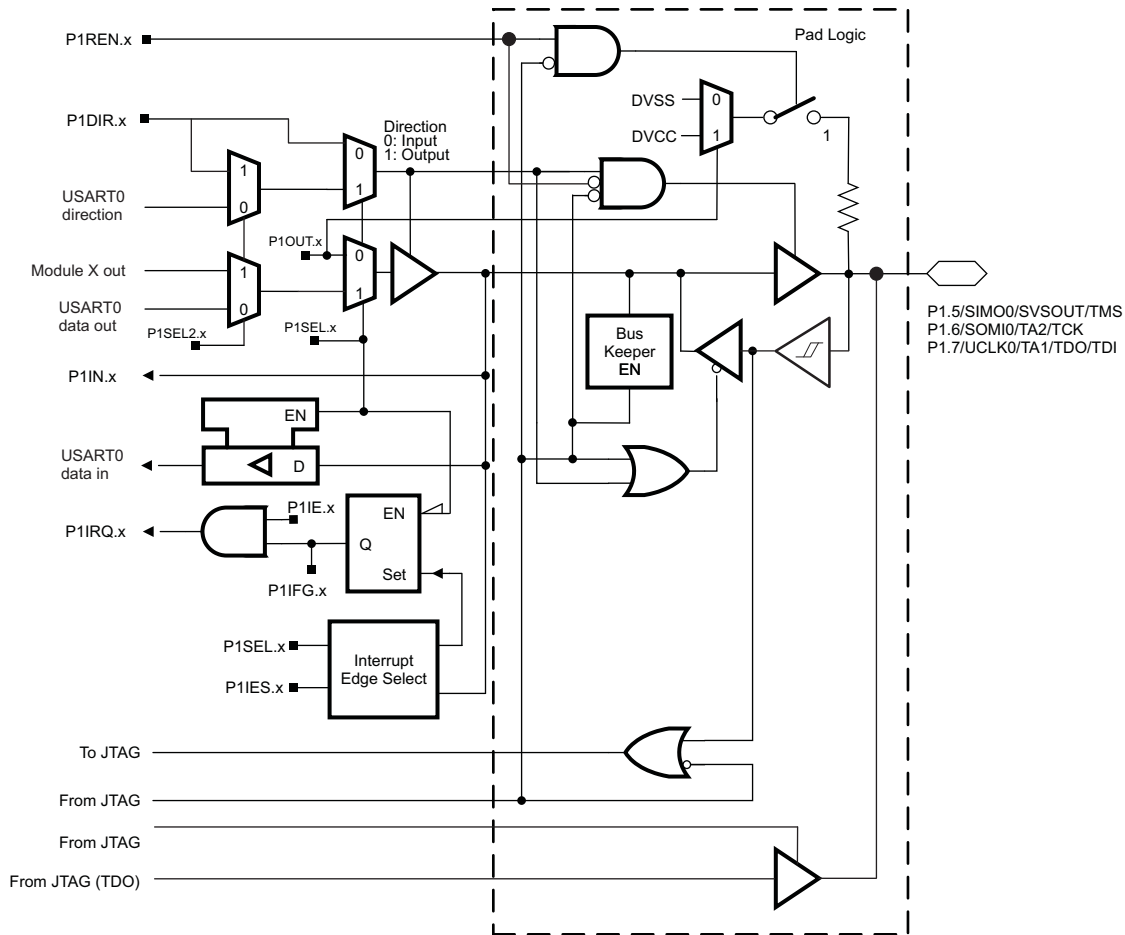
Table 6-15. Port P1 (P1.4) Pin Functions

| PIN NAME (P1.x)  | x | FUNCTION   | CONTROL BITS OR SIGNALS <sup>(1)</sup> |         |          |
|------------------|---|------------|----------------------------------------|---------|----------|
|                  |   |            | P1DIR.x                                | P1SEL.x | P1SEL2.x |
| P1.4/URXD0/SD2DO | 4 | P1.4 (I/O) | I: 0, O: 1                             | 0       | X        |
|                  |   | URXD0      | X                                      | 1       | 0        |
|                  |   | SD2DO      | 1                                      | 1       | 1        |

(1) X = don't care

### 6.18.5 Port P1 Pin Schematic: P1.5 to P1.7 Input/Output With Schmitt Trigger

Figure 6-12 shows the port schematic. Table 6-16 summarizes the selection of the pin functions.



**Figure 6-12. Port P1 (P1.5 to P1.7) Schematic**

**Table 6-16. Port P1 (P1.5 to P1.7) Pin Functions**

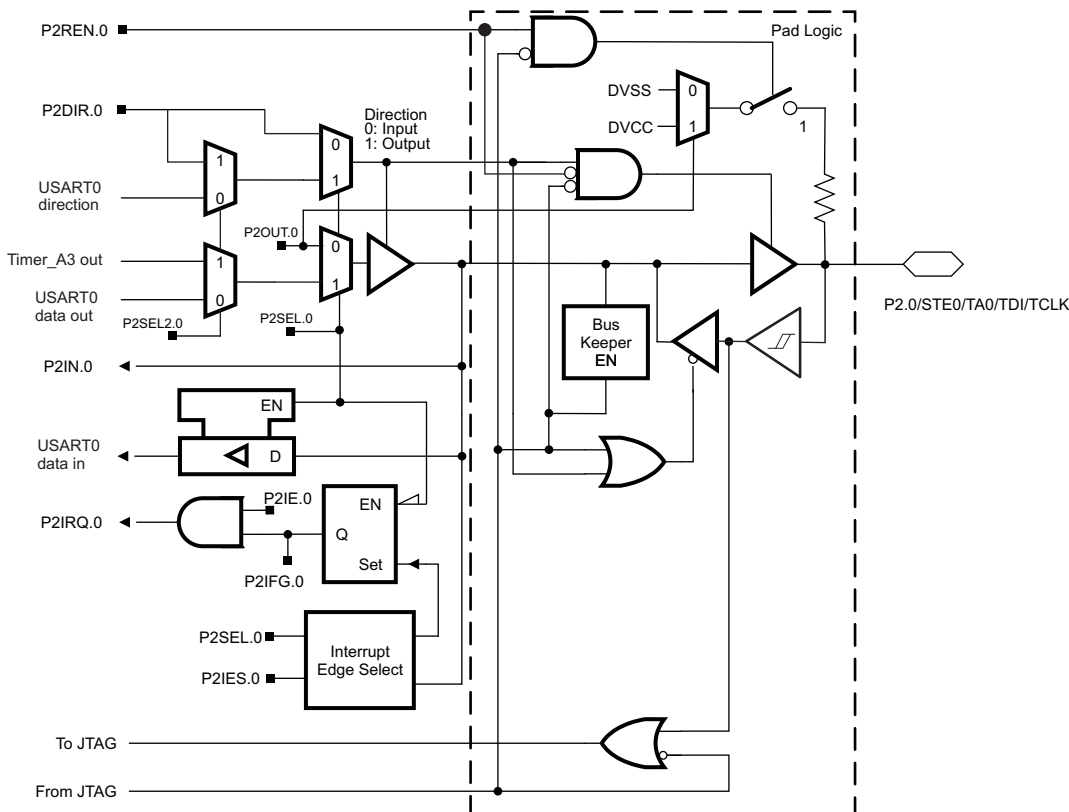
| PIN NAME (P1.x)        | x | FUNCTION     | CONTROL BITS OR SIGNALS <sup>(1)</sup> |         |          |                          |
|------------------------|---|--------------|----------------------------------------|---------|----------|--------------------------|
|                        |   |              | P1DIR.x                                | P1SEL.x | P1SEL2.x | JTAG Mode <sup>(2)</sup> |
| P1.5/SIMO0/SVSOUT/TMS  | 5 | P1.5 (I/O)   | I: 0; O: 1                             | 0       | X        | 0                        |
|                        |   | SIMO0        | X                                      | 1       | 0        | 0                        |
|                        |   | SVSOUT       | 1                                      | 1       | 1        | 0                        |
|                        |   | TMS          | X                                      | X       | X        | 1                        |
| P1.6/SOMI0/TA2/TCK     | 6 | P1.6 (I/O)   | I: 0; O: 1                             | 0       | X        | 0                        |
|                        |   | SOMI0        | X                                      | 1       | 0        | 0                        |
|                        |   | Timer_A3.TA2 | 1                                      | 1       | 1        | 0                        |
|                        |   | TCK          | X                                      | X       | X        | 1                        |
| P1.7/UCLK0/TA1/TDO/TDI | 7 | P1.7 (I/O)   | I: 0; O: 1                             | 0       | X        | 0                        |
|                        |   | UCLK0        | X                                      | 1       | 0        | 0                        |
|                        |   | Timer_A3.TA1 | 1                                      | 1       | 1        | 0                        |
|                        |   | TDO/TDI      | X                                      | X       | X        | 1                        |

(1) X = don't care

(2) JTAG Mode is not a register bit but signal generated internally when the 4-wire JTAG option is selected in the IDE.

## 6.18.6 Port P2 Pin Schematic: P2.0 Input/Output With Schmitt Trigger

Figure 6-13 shows the port schematic. Table 6-17 summarizes the selection of the pin functions.



**Figure 6-13. Port P2 (P2.0) Schematic**

**Table 6-17. Port P2 (P2.0) Pin Functions**

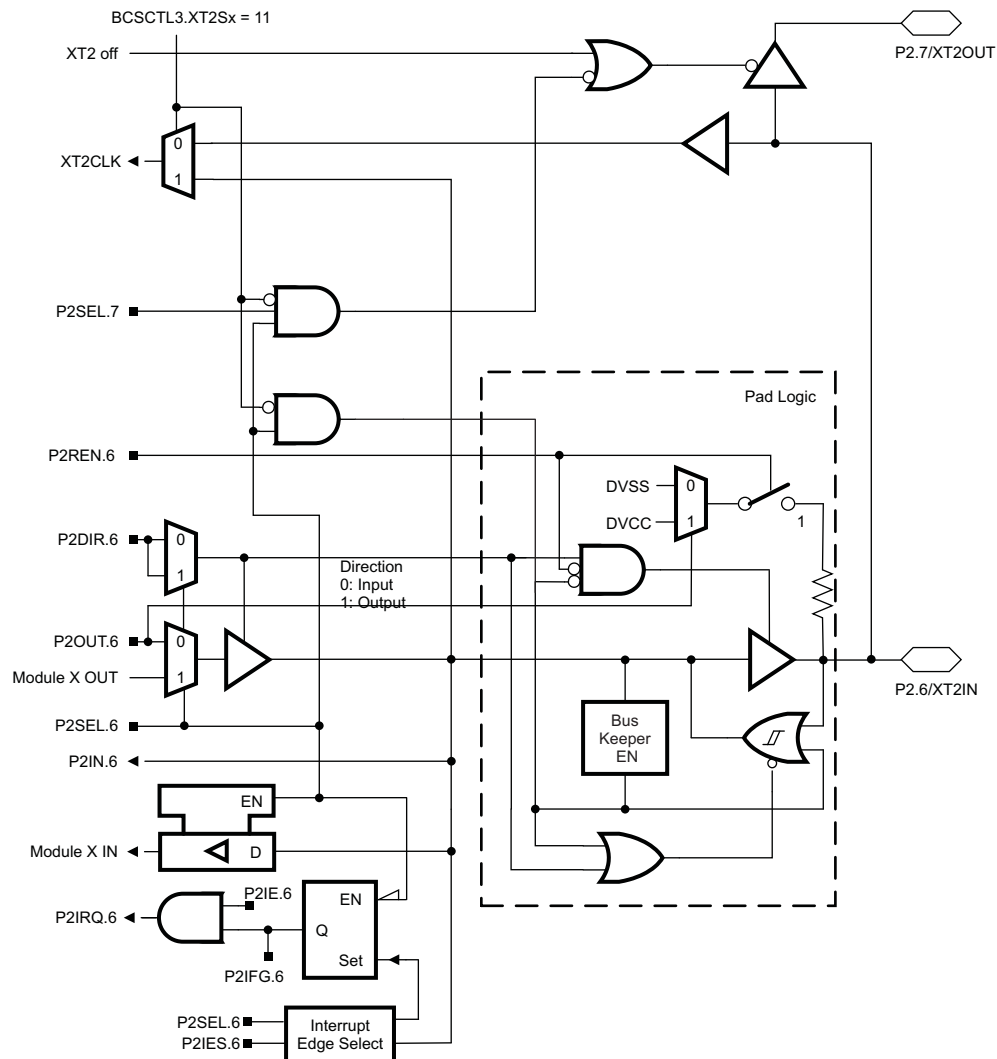
| PIN NAME (P2.x)        | x | FUNCTION     | CONTROL BITS OR SIGNALS <sup>(1)</sup> |         |          |                          |
|------------------------|---|--------------|----------------------------------------|---------|----------|--------------------------|
|                        |   |              | P2DIR.x                                | P2SEL.x | P2SEL2.x | JTAG Mode <sup>(2)</sup> |
| P2.0/STE0/TA0/TDI/TCLK | 0 | P2.0 (I/O)   | I: 0; O: 1                             | 0       | X        | 0                        |
|                        |   | STE0         | X                                      | 1       | 0        | 0                        |
|                        |   | Timer_A3.TA0 | 1                                      | 1       | 1        | 0                        |
|                        |   | TDI/TCLK     | X                                      | X       | X        | 1                        |

(1) X = don't care

(2) JTAG Mode is not a register bit but signal generated internally when the 4-wire JTAG option is selected in the IDE.

### 6.18.7 Port P2 Pin Schematic: P2.6, Input/Output With Schmitt Trigger

Figure 6-14 shows the port schematic. Table 6-18 summarizes the selection of the pin functions.



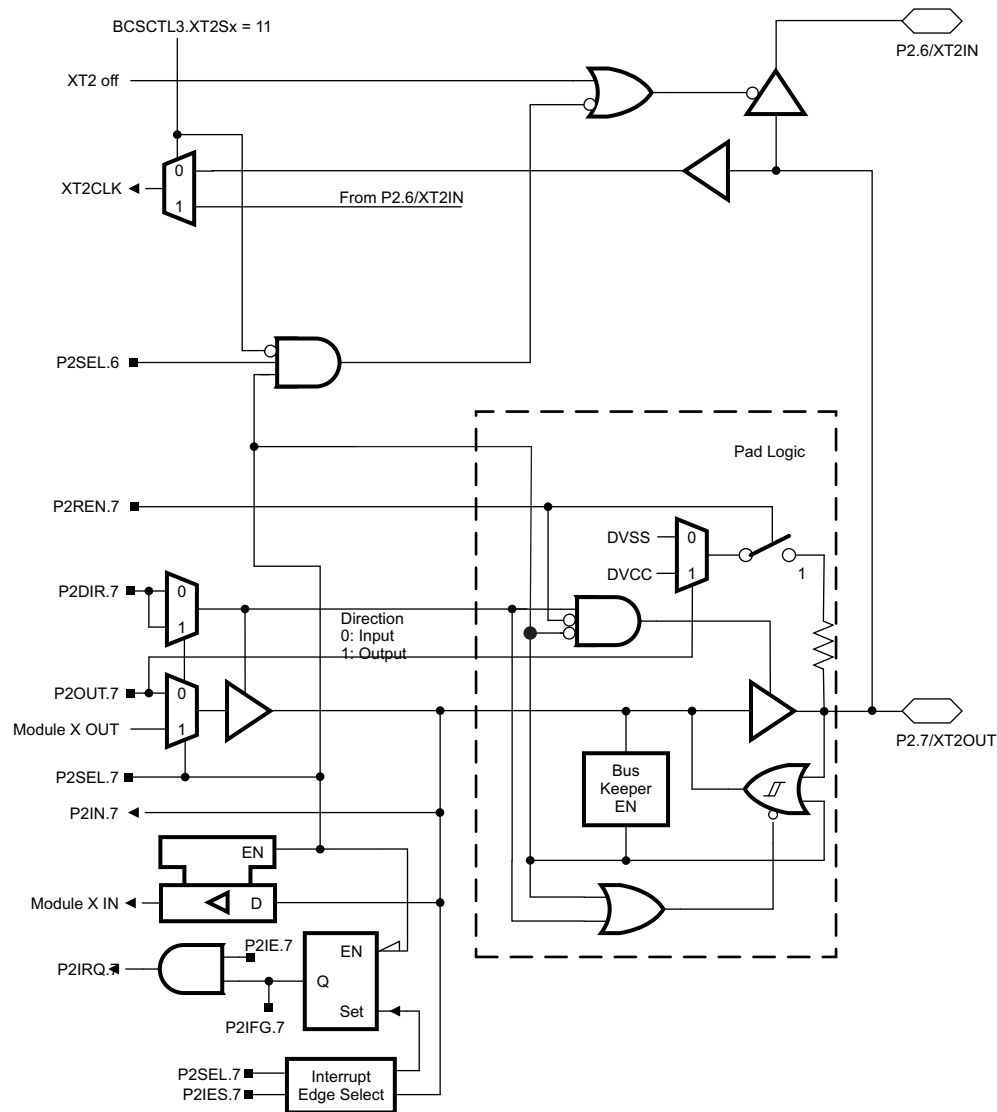
### Figure 6-14. Port P2 (P2.6) Schematic

### Table 6-18. Port P2 (P2.6) Pin Functions

| Pin Name (P2.x) | x | FUNCTION        | CONTROL BITS OR SIGNALS |         |
|-----------------|---|-----------------|-------------------------|---------|
|                 |   |                 | P2DIR.6                 | P2SEL.6 |
| P2.6/XT2IN      | 6 | P2.6 (I/O)      | I: 0; O: 1              | 0       |
|                 |   | XT2IN (default) | 0                       | 1       |

#### 6.18.8 Port P2 Pin Schematic: P2.7, Input/Output With Schmitt Trigger

Figure 6-15 shows the port schematic. Table 6-19 summarizes the selection of the pin functions.



### Figure 6-15. Port P2 (P2.7) Schematic

### Table 6-19. Port P2 (P2.7) Pin Functions

| PIN NAME (P2.x) | x | FUNCTION         | CONTROL BITS OR SIGNALS |         |
|-----------------|---|------------------|-------------------------|---------|
|                 |   |                  | P2DIR.7                 | P2SEL.7 |
| P2.7/XT2OUT     | 7 | P2.7 (I/O)       | I: 0, O: 1              | 0       |
|                 |   | XT2OUT (default) | 0                       | 1       |

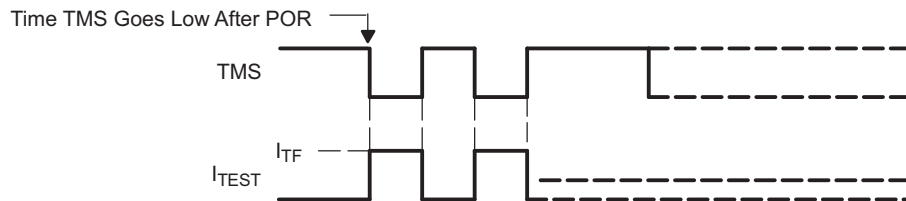
### 6.18.9 JTAG Fuse Check Mode

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

When the TEST pin is again taken low after a test or programming session, the fuse check mode and sense currents are terminated.

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

The fuse check current flow only when the fuse check mode is active and the TMS pin is in a low state (see Figure 6-16). Therefore, the additional current flow can be prevented by holding the TMS pin high (default condition).



**Figure 6-16. Fuse Check Mode Current**

#### NOTE

The CODE and RAM data protection is ensured if the JTAG fuse is blown.

## 7 器件和文档支持

### 7.1 使用入门

要获得 MSP430™ 系列器件以及有助于开发工作的工具和库的更多信息，请访问[概述页面](#)。

### 7.2 Device Nomenclature

To designate the stages in the product development cycle, TI assigns prefixes to the part numbers of all MSP430 MCU devices and support tools. Each MSP430 MCU commercial family member has one of three prefixes: MSP, PMS, or XMS (for example, MSP430F5438A). TI recommends two of three possible prefix designators for its support tools: MSP and MSPX. These prefixes represent evolutionary stages of product development from engineering prototypes (with XMS for devices and MSPX for tools) through fully qualified production devices and tools (with MSP for devices and MSP for tools).

Device development evolutionary flow:

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

**PMS** – Final silicon die that conforms to the electrical specifications for the device but has not completed quality and reliability verification

**MSP** – Fully qualified production device

Support tool development evolutionary flow:

**MSPX** – Development-support product that has not yet completed TI's internal qualification testing.

**MSP** – Fully-qualified development-support product

XMS and PMS devices and MSPX development-support tools are shipped against the following disclaimer:

"Developmental product is intended for internal evaluation purposes."

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

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

TI device nomenclature also includes a suffix with the device family name. This suffix indicates the package type (for example, PZP) and temperature range (for example, T). [图 7-1](#) provides a legend for reading the complete device name for any family member.

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

图 7-1. Device Nomenclature

### 7.3 工具与软件

所有 MSP 微控制器均受多种软件和硬件开发工具的支持。相关工具由 TI 以及多家第三方供应商提供。可从[低功耗 MCU 开发套件和软件](#)获取全部信息。

表 7-1 列出了 MSP430AFE2xx MCU 的调试功能。关于可用特性的详细信息，请参见《[适用于 MSP430 的 Code Composer Studio 用户指南](#)》。

表 7-1. 硬件调试 特性

| MSP430 架构 | 4 线 JTAG | 2 线 JTAG | 断点 (N) | 范围断点 | 时钟控制 | 状态序列发生器 | 跟踪缓冲器 |
|-----------|----------|----------|--------|------|------|---------|-------|
| MSP430    | 有        | 有        | 2      | 否    | 是    | 否       | 否     |

#### 设计套件与评估模块

**MSP-TS430PW24 - 适用于 MSP430AFEx MCU 的 24 引脚目标开发板** MSP-TS430PW24 是一款独立的 ZIF 插座目标板，用于通过 JTAG 接口或 Spy-Bi-Wire（双线制 JTAG）协议对 MSP430 MCU 系统内置器件进行编程和调试。

**MSP430AFE253 嵌入式计量（分项计量表）EVM** 该嵌入式计量（分项计量表/电表）EVM 基于 MSP430AFE253 而设计。该 EVM 可直接连接至市电（或直流电源）和负载。该 EVM 会测量负载的电气参数且测量结果可从 UART 端口处读取。该 EVM 配备了内置电源和独立的串行连接，方便用户快速开始在嵌入式计量应用中评估 MSP430AFE253。

#### 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。

**MSP430AFE2x3、MSP430AFE2x2、MSP430AFE2x1 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 的定点数学库** TI 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的实时应用，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 MSP 微控制器的数字信号处理 (DSP) 库** 该数字信号处理库是一组经高度优化的函数，可针对 MSP430 微控制器对定点数字执行许多常见的信号处理操作。这种功能集通常用于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。该库可针对定点数学对 MSP 系列固有硬件进行最佳利用，从而极大地提高性能。

#### 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) 是一种集成开发环境 (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。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。

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

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

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

## 7.4 文档支持

以下文档对 MSP430AFE2xx MCU 进行了介绍。[www.ti.com.cn](http://www.ti.com.cn) 网站上提供了这些文档的副本。

### 接收文档更新通知

要接收文档更新通知（包括芯片勘误表），请转至 [ti.com.cn](http://ti.com.cn) 上您的器件对应的产品文件夹（关于产品文件夹的链接，请参见节 7.5）。请单击右上角的“通知我”按钮。点击后，您将每周定期收到已更改的产品信息（如果有的话）。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

《MSP430AFE253 器件勘误表》 介绍功能规格的已知例外情况。

《MSP430AFE252 器件勘误表》 介绍功能规格的已知例外情况。

《MSP430AFE251 器件勘误表》 介绍功能规格的已知例外情况。

《MSP430AFE233 器件勘误表》 介绍功能规格的已知例外情况。

《MSP430AFE232 器件勘误表》 介绍功能规格的已知例外情况。

《MSP430AFE231 器件勘误表》 介绍功能规格的已知例外情况。

《MSP430AFE223 器件勘误表》 介绍功能规格的已知例外情况。

《MSP430AFE222 器件勘误表》 介绍功能规格的已知例外情况。

《MSP430AFE221 器件勘误表》 介绍功能规格的已知例外情况。

### 用户指南

《MSP430x2xx 系列用户指南》 详细介绍了该器件系列提供的模块和外设。

《使用引导加载程序 (BSL) 对 MSP430 进行编程》 MSP430 引导加载程序 (bootloader, 简称 BSL, 以前称为 bootstrap loader) 允许用户在原型设计、最终生产和投用阶段与 MSP430 微控制器中的嵌入式存储器进行通信。可编程存储器 (闪存) 和数据存储器 (RAM) 能够按照要求进行变更。不要将此处的引导加载程序与某些数字信号处理器 (DSP) 中将外部存储器中的程序代码 (和数据) 自动加载到 DSP 内部存储器的引导装载程序混为一谈。

《通过 JTAG 接口对 MSP430 进行编程》 本文档介绍了使用 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，该文档还描述了如何设定所有 MSP430 器件提供的 JTAG 访问安全熔丝。本文档介绍了使用标准 4 线 JTAG 接口和 2 线 JTAG 接口（也称为 Spy-Bi-Wire (SBW)）访问 MCU。

《**MSP430 硬件工具用户指南**》 本手册介绍了 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。对提供的接口类型，即并行端口接口和 USB 接口进行了说明。

## 应用报告

**MSP430 32kHz 晶体振荡器** 对于稳定的晶体振荡器，选择合适的晶振、正确的负载电路和适当的电路板布局布线至关重要。该应用报告总结了晶体振荡器的功能，介绍了为实现 MSP430 超低功耗运行而选择正确晶体的参数。此外，还给出了正确电路板布局布线的提示和示例。本文档还包含与可能振荡器测试相关的详细信息以确保大批量生产中的稳定振荡器运行。

《**MSP430 系统级 ESD 注意事项**》 系统级 ESD 对于低电压下的硅晶技术以及经济高效型和超低功耗组件的需求日益增加。该应用报告提出了三项不同的 ESD 主题，旨在帮助电路板设计人员和 OEM 理解并设计出稳健耐用的系统级设计。

## 7.5 相关链接

表 7-2 列出了快速访问链接。类别包括技术文档、支持和社区资源、工具和软件以及申请样片或购买产品的快速访问链接。

表 7-2. 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                |
|--------------|----------------------|----------------------|----------------------|----------------------|----------------------|
| MSP430AFE253 | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> |
| MSP430AFE252 | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> |
| MSP430AFE251 | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> |
| MSP430AFE233 | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> |
| MSP430AFE232 | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> |
| MSP430AFE231 | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> |
| MSP430AFE223 | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> |
| MSP430AFE222 | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> |
| MSP430AFE221 | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> | <a href="#">单击此处</a> |

## 7.6 社区资源

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

### TI E2E™ 社区

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

### TI 嵌入式处理器维基网页

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

## 7.7 商标

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

All other trademarks are the property of their respective owners.

## 7.8 静电放电警告



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

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

## 7.9 术语表

**TI 术语表** 这份术语表列出并解释术语、缩写和定义。

## 8 机械、封装和可订购信息

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

## PACKAGING INFORMATION

| Orderable Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package<br>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                 |
|------------------|---------------|--------------|--------------------|------|----------------|-----------------|--------------------------------------|----------------------|--------------|-------------------------|-------------------------|
| MSP4301103IPWR   | ACTIVE        | TSSOP        | PW                 | 24   | 2000           | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | 430AFE253               | <a href="#">Samples</a> |
| MSP430AFE221IPW  | ACTIVE        | TSSOP        | PW                 | 24   | 60             | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | 430AFE221               | <a href="#">Samples</a> |
| MSP430AFE221IPWR | ACTIVE        | TSSOP        | PW                 | 24   | 2000           | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | 430AFE221               | <a href="#">Samples</a> |
| MSP430AFE222IPW  | ACTIVE        | TSSOP        | PW                 | 24   | 60             | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | 430AFE222               | <a href="#">Samples</a> |
| MSP430AFE222IPWR | ACTIVE        | TSSOP        | PW                 | 24   | 2000           | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | 430AFE222               | <a href="#">Samples</a> |
| MSP430AFE223IPW  | ACTIVE        | TSSOP        | PW                 | 24   | 60             | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | 430AFE223               | <a href="#">Samples</a> |
| MSP430AFE223IPWR | ACTIVE        | TSSOP        | PW                 | 24   | 2000           | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | 430AFE223               | <a href="#">Samples</a> |
| MSP430AFE231IPW  | ACTIVE        | TSSOP        | PW                 | 24   | 60             | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | 430AFE231               | <a href="#">Samples</a> |
| MSP430AFE231IPWR | ACTIVE        | TSSOP        | PW                 | 24   | 2000           | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | 430AFE231               | <a href="#">Samples</a> |
| MSP430AFE232IPW  | ACTIVE        | TSSOP        | PW                 | 24   | 60             | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | 430AFE232               | <a href="#">Samples</a> |
| MSP430AFE232IPWR | ACTIVE        | TSSOP        | PW                 | 24   | 2000           | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | 430AFE232               | <a href="#">Samples</a> |
| MSP430AFE233IPW  | ACTIVE        | TSSOP        | PW                 | 24   | 60             | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | 430AFE233               | <a href="#">Samples</a> |
| MSP430AFE233IPWR | ACTIVE        | TSSOP        | PW                 | 24   | 2000           | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | 430AFE233               | <a href="#">Samples</a> |
| MSP430AFE251IPW  | ACTIVE        | TSSOP        | PW                 | 24   | 60             | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | 430AFE251               | <a href="#">Samples</a> |
| MSP430AFE251IPWR | ACTIVE        | TSSOP        | PW                 | 24   | 2000           | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | 430AFE251               | <a href="#">Samples</a> |
| MSP430AFE252IPW  | ACTIVE        | TSSOP        | PW                 | 24   | 60             | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | 430AFE252               | <a href="#">Samples</a> |
| MSP430AFE252IPWR | ACTIVE        | TSSOP        | PW                 | 24   | 2000           | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | 430AFE252               | <a href="#">Samples</a> |
| MSP430AFE253IPW  | ACTIVE        | TSSOP        | PW                 | 24   | 60             | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | 430AFE253               | <a href="#">Samples</a> |
| MSP430AFE253IPWR | ACTIVE        | TSSOP        | PW                 | 24   | 2000           | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | 430AFE253               | <a href="#">Samples</a> |

<sup>(1)</sup> The marketing status values are defined as follows:

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

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

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

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

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

<sup>(2)</sup> **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  $\leq 1000$ ppm threshold. Antimony trioxide based flame retardants must also meet the  $\leq 1000$ ppm threshold requirement.

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

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

<sup>(5)</sup> 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.

<sup>(6)</sup> 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.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

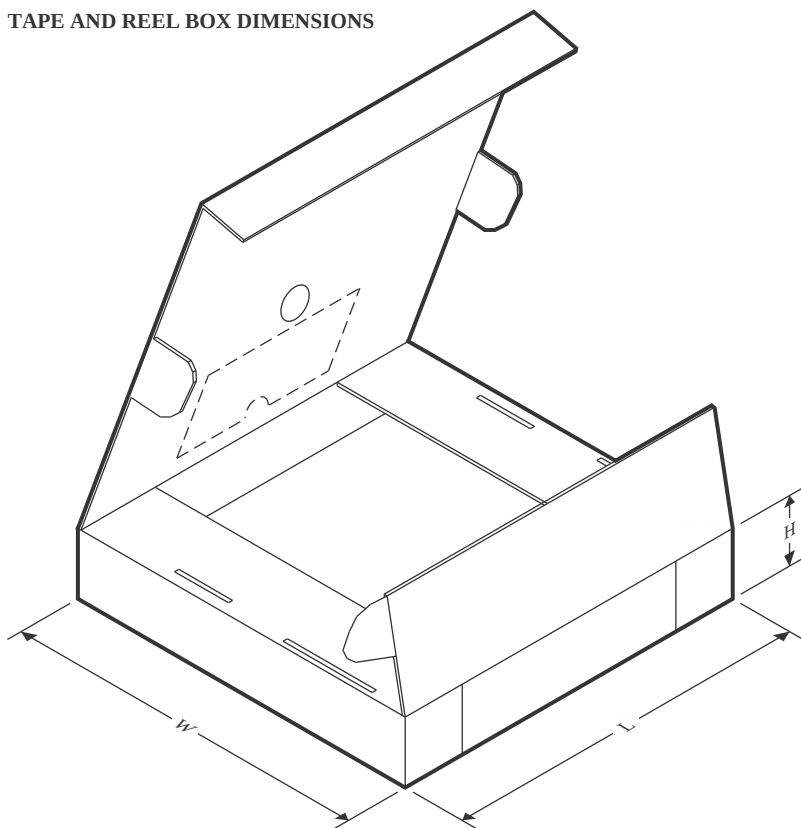
## TAPE AND REEL INFORMATION



\*All dimensions are nominal

| Device           | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|------------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| MSP430AFE221IPWR | TSSOP        | PW              | 24   | 2000 | 330.0              | 16.4               | 6.95    | 8.3     | 1.6     | 8.0     | 16.0   | Q1            |
| MSP430AFE222IPWR | TSSOP        | PW              | 24   | 2000 | 330.0              | 16.4               | 6.95    | 8.3     | 1.6     | 8.0     | 16.0   | Q1            |
| MSP430AFE223IPWR | TSSOP        | PW              | 24   | 2000 | 330.0              | 16.4               | 6.95    | 8.3     | 1.6     | 8.0     | 16.0   | Q1            |
| MSP430AFE231IPWR | TSSOP        | PW              | 24   | 2000 | 330.0              | 16.4               | 6.95    | 8.3     | 1.6     | 8.0     | 16.0   | Q1            |
| MSP430AFE232IPWR | TSSOP        | PW              | 24   | 2000 | 330.0              | 16.4               | 6.95    | 8.3     | 1.6     | 8.0     | 16.0   | Q1            |
| MSP430AFE233IPWR | TSSOP        | PW              | 24   | 2000 | 330.0              | 16.4               | 6.95    | 8.3     | 1.6     | 8.0     | 16.0   | Q1            |
| MSP430AFE251IPWR | TSSOP        | PW              | 24   | 2000 | 330.0              | 16.4               | 6.95    | 8.3     | 1.6     | 8.0     | 16.0   | Q1            |
| MSP430AFE252IPWR | TSSOP        | PW              | 24   | 2000 | 330.0              | 16.4               | 6.95    | 8.3     | 1.6     | 8.0     | 16.0   | Q1            |

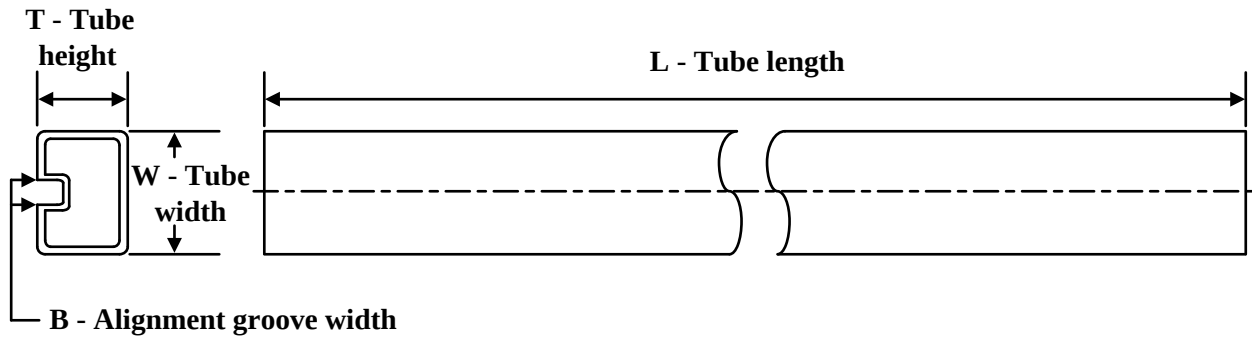
## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

| Device           | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|------------------|--------------|-----------------|------|------|-------------|------------|-------------|
| MSP430AFE221IPWR | TSSOP        | PW              | 24   | 2000 | 350.0       | 350.0      | 43.0        |
| MSP430AFE222IPWR | TSSOP        | PW              | 24   | 2000 | 350.0       | 350.0      | 43.0        |
| MSP430AFE223IPWR | TSSOP        | PW              | 24   | 2000 | 350.0       | 350.0      | 43.0        |
| MSP430AFE231IPWR | TSSOP        | PW              | 24   | 2000 | 350.0       | 350.0      | 43.0        |
| MSP430AFE232IPWR | TSSOP        | PW              | 24   | 2000 | 350.0       | 350.0      | 43.0        |
| MSP430AFE233IPWR | TSSOP        | PW              | 24   | 2000 | 350.0       | 350.0      | 43.0        |
| MSP430AFE251IPWR | TSSOP        | PW              | 24   | 2000 | 350.0       | 350.0      | 43.0        |
| MSP430AFE252IPWR | TSSOP        | PW              | 24   | 2000 | 350.0       | 350.0      | 43.0        |

## TUBE



\*All dimensions are nominal

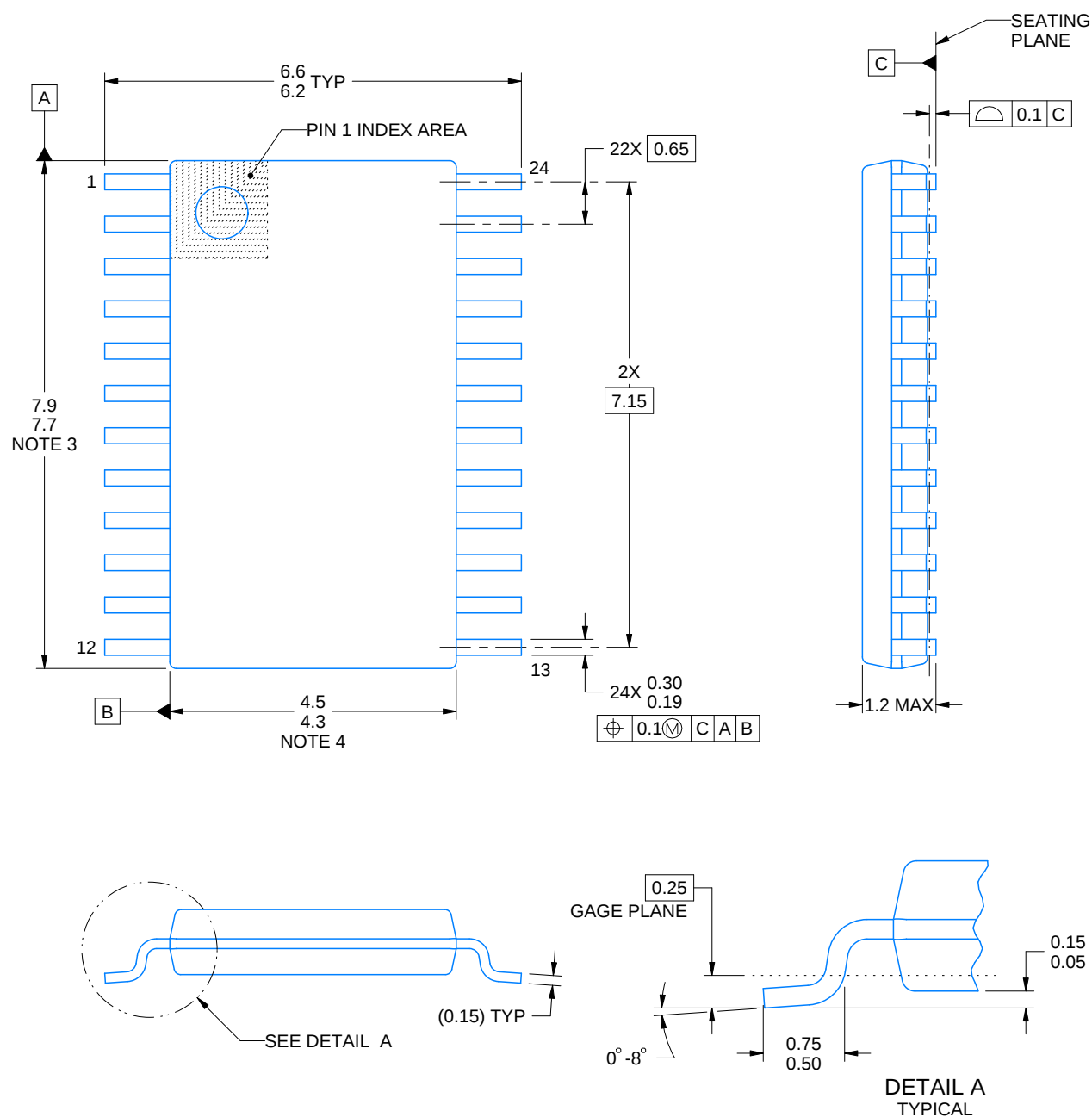
| Device          | Package Name | Package Type | Pins | SPQ | L (mm) | W (mm) | T (μm) | B (mm) |
|-----------------|--------------|--------------|------|-----|--------|--------|--------|--------|
| MSP430AFE221IPW | PW           | TSSOP        | 24   | 60  | 530    | 10.2   | 3600   | 3.5    |
| MSP430AFE222IPW | PW           | TSSOP        | 24   | 60  | 530    | 10.2   | 3600   | 3.5    |
| MSP430AFE223IPW | PW           | TSSOP        | 24   | 60  | 530    | 10.2   | 3600   | 3.5    |
| MSP430AFE231IPW | PW           | TSSOP        | 24   | 60  | 530    | 10.2   | 3600   | 3.5    |
| MSP430AFE232IPW | PW           | TSSOP        | 24   | 60  | 530    | 10.2   | 3600   | 3.5    |
| MSP430AFE233IPW | PW           | TSSOP        | 24   | 60  | 530    | 10.2   | 3600   | 3.5    |
| MSP430AFE251IPW | PW           | TSSOP        | 24   | 60  | 530    | 10.2   | 3600   | 3.5    |
| MSP430AFE252IPW | PW           | TSSOP        | 24   | 60  | 530    | 10.2   | 3600   | 3.5    |
| MSP430AFE253IPW | PW           | TSSOP        | 24   | 60  | 530    | 10.2   | 3600   | 3.5    |



PW0024A

## TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



4220208/A 02/2017

NOTES:

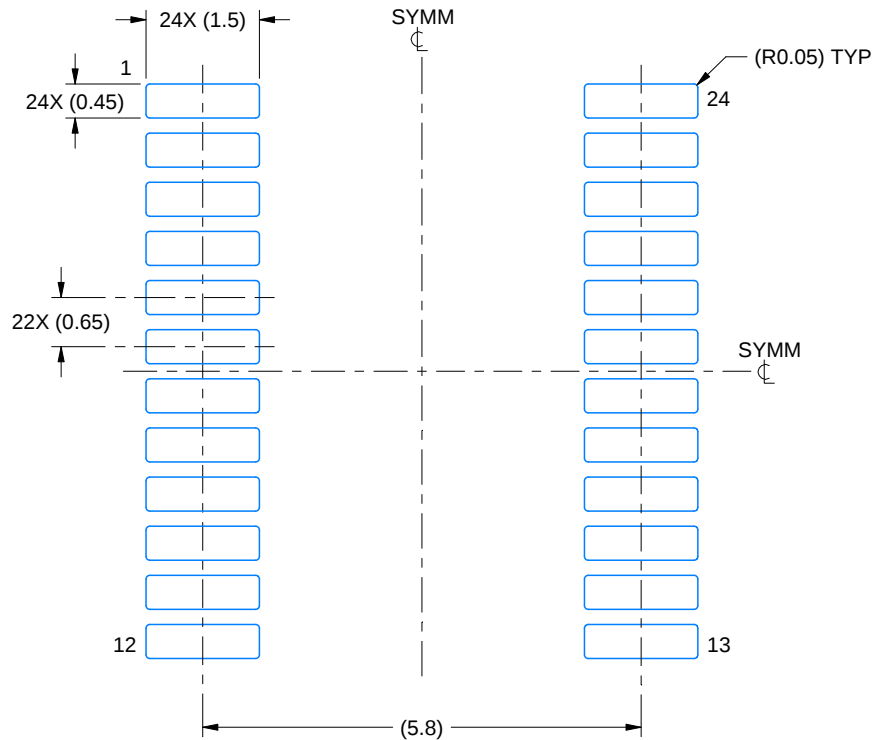
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
5. Reference JEDEC registration MO-153.

# EXAMPLE BOARD LAYOUT

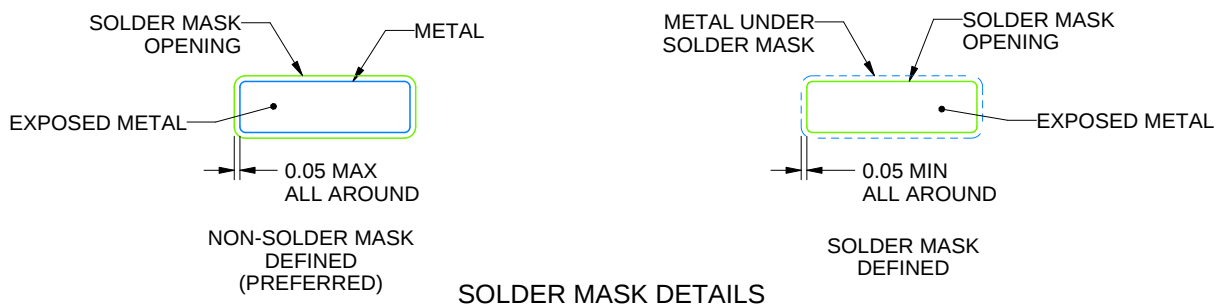
PW0024A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE: 10X



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NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

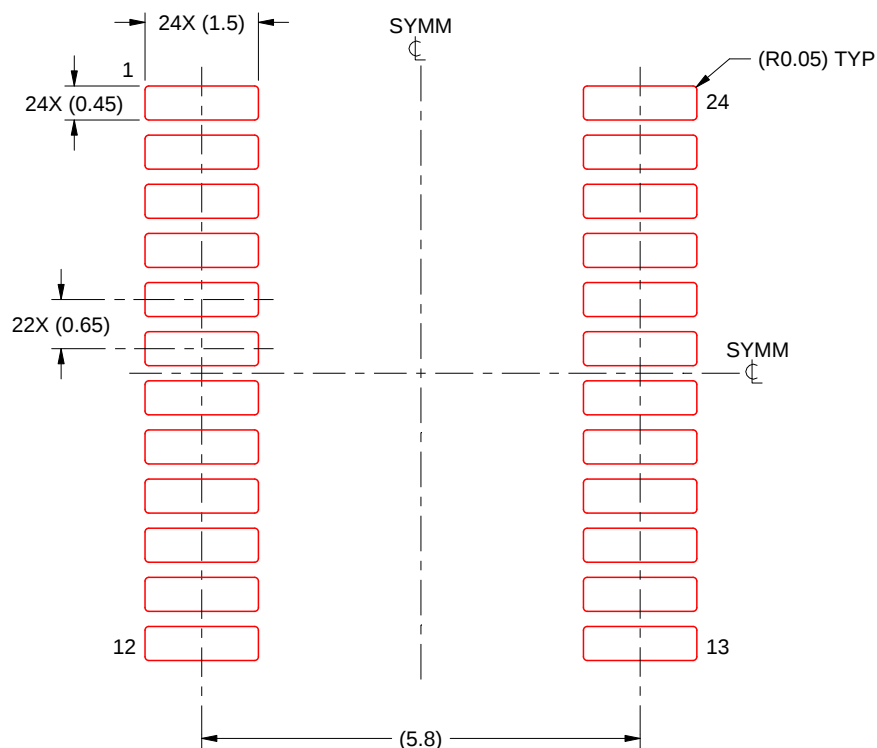
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

# EXAMPLE STENCIL DESIGN

PW0024A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



SOLDER PASTE EXAMPLE  
BASED ON 0.125 mm THICK STENCIL  
SCALE: 10X

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NOTES: (continued)

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

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