



## MSP430FE42x ミクスト・シグナル・マイクロコントローラ

### 1 デバイスの概要

#### 1.1 特長

- 低い電源電圧範囲: 2.7V~3.6V
- 超低消費電力
  - アクティブ・モード: 1MHz、3Vで400μA
  - スタンバイ・モード: 1.6μA
  - オフ・モード(RAM内容の保持):0.1μA
- 5つの省電力モード
- スタンバイ・モードから6μs以内にウェークアップ
- 周波数ロック・ループ、FLL+
- 16ビットRISCアーキテクチャ、命令サイクル・タイム 125ns
- 単相エネルギー測定用の信号処理を内蔵、アナログ・フロント・エンドと温度センサを搭載(ESP430CE1)
- 16ビットのTimer\_A (3つのキャプチャ/コンペア・レジスタ付き)
- 128セグメント用のLCDドライバを搭載
- シリアル通信インターフェイス(USART)、非同期UART または同期SPIをソフトウェアで選択可能
- ブラウンアウト検出器
- 電源電圧スーパーバイザとモニタ、プログラムにより検出レベルを設定可能
- シリアル・オンボード・プログラミング、外部のプログラミング電圧不要、セキュリティ・ヒューズによるプログラム可能なコード保護
- ブートローダー(BSL)
- ファミリー製品:
  - MSP430FE423  
8KB + 256Bのフラッシュ・メモリ、256BのRAM
  - MSP430FE425  
16KB + 256Bのフラッシュ・メモリ、512BのRAM
  - MSP430FE427  
32KB + 256Bのフラッシュ・メモリ、1KBのRAM
- 64ピンのクワッド・フラット・パック(LQFP)で供給
- モジュールの完全な説明については、『[MSP430x4xx ファミリー・ユーザーズ・ガイド](#)』を参照

#### 1.2 アプリケーション

- 2線式および3線式の単相メータ
- 改ざん防止メータ

#### 1.3 概要

TI MSP430™ファミリの超低消費電力マイクロコントローラは複数のデバイスで構成され、それぞれが各種のアプリケーションを対象とする異なるペリフェラルを搭載しています。このアーキテクチャは5つの低消費電力モードを持ち、携帯用測定器用途でバッテリー駆動時間を延長するよう最適化されています。このデバイスには、強力な16ビットRISC CPU、16ビット・レジスタ、およびコンスタント・ジェネレータが搭載されており、コード効率が最大限に発揮されます。デジタル制御発振器(DCO)により、デバイスは低消費電力モードからアクティブ・モードへ6μs以内にウェークアップできます。

MSP430FE42xシリーズは、3つの独立した16ビットのシグマ・デルタADCと、内蔵の信号プロセッサ・コアを持つマイクロコントローラ構成であり、2線式および3線式の両方の構成で単相エネルギーを測定、計算するため使用されます。また、16ビットのタイマ、128セグメントのLCDドライブ機能、14本のI/Oピンも搭載されています。

代表的なアプリケーションは、変更を加えることのできない堅牢なメータなど、2線式および3線式の単相計測です。



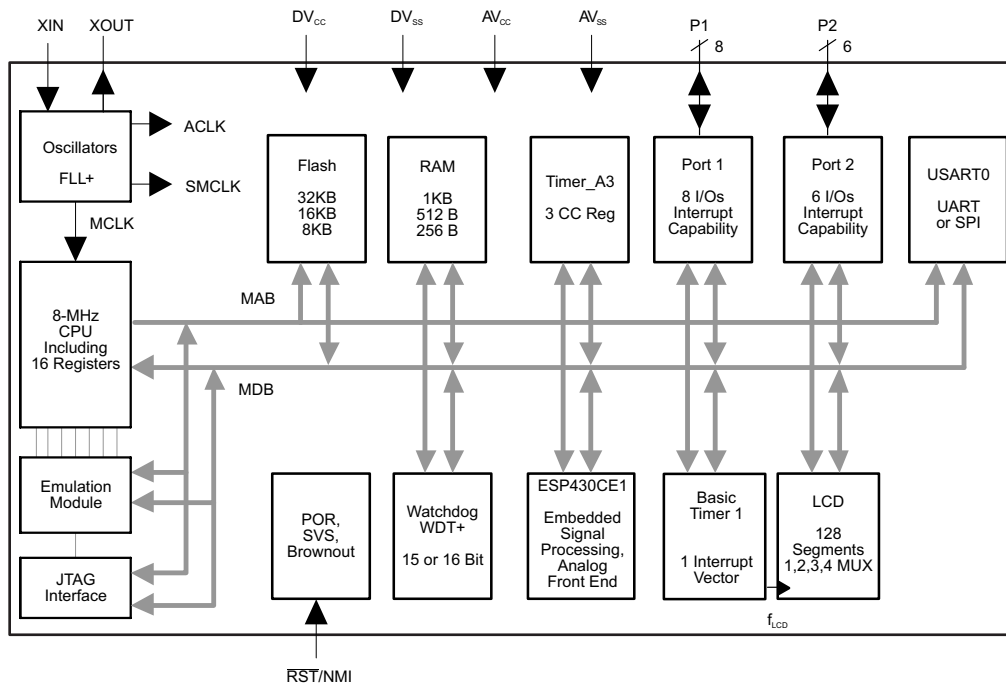
製品情報<sup>(1)</sup>

| 型番             | パッケージ     | 本体サイズ <sup>(2)</sup> |
|----------------|-----------|----------------------|
| MSP430FE427IPM | LQFP (64) | 10mm×10mm            |
| MSP430FE425IPM | LQFP (64) | 10mm×10mm            |
| MSP430FE423IPM | LQFP (64) | 10mm×10mm            |

- (1) 提供中の全デバイスに関する最新の製品、パッケージ、および注文情報については 8 の「付録: パッケージ・オプション」または [www.ti.com](http://www.ti.com) の TI Web サイトを参照してください。
- (2) ここに記載されているサイズは概略です。許容公差を含めたパッケージの寸法については、8 の「メカニカル・データ」を参照してください。

## 1.4 機能ブロック図

機能ブロック図を、図 1-1 に示します。



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図 1-1. MSP430FE42x のブロック図

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## 2 改訂履歴

資料番号末尾の英字は改訂を表しています。その改訂履歴は英語版に準じています。

| 2008年10月16日発行分から2016年11月14日発行分への変更                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Page                                                                                                                                                                                                                                         |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"> <li>ドキュメント全体を通してフォーマットと編成を変更、セクション番号の追加も含む .....</li> <li>Added <a href="#">Section 3</a> .....</li> <li>Added <a href="#">Section 5</a> and moved all electrical and timing specifications to it .....</li> <li>Added <a href="#">Section 5.2, ESD Ratings</a>.....</li> <li>Changed the MAX value of the <math>I_{LPM3}</math> parameter at 85°C from 2.6 to 3.5 <math>\mu</math>A in <a href="#">Section 5.4, Supply Current Into <math>AV_{CC}</math> and <math>DV_{CC}</math> Excluding External Current</a> .....</li> <li>Added <a href="#">Section 5.5, Thermal Resistance Characteristics, PM Package (LQFP-64)</a> .....</li> <li>Changed all cases of "bootstrap loader" to "bootloader".....</li> <li>Changed the value of the <math>\overline{\text{Port/LCD}}</math> column in <a href="#">Table 6-14, Port P1 (P1.2 to P1.7) Pin Functions</a> .....</li> <li>Changed the value of the <math>\overline{\text{Port/LCD}}</math> column in <a href="#">Table 6-15, Port P2 (P2.0 and P2.1) Pin Functions</a>.....</li> <li><a href="#">7</a>、「デバイスおよびドキュメントのサポート」を追加 .....</li> <li><a href="#">8</a>、「メカニカル、パッケージ、および注文情報」を追加.....</li> </ul> | <a href="#">1</a><br><a href="#">5</a><br><a href="#">10</a><br><a href="#">10</a><br><a href="#">11</a><br><a href="#">12</a><br><a href="#">38</a><br><a href="#">46</a><br><a href="#">47</a><br><a href="#">52</a><br><a href="#">58</a> |

### 3 Device Comparison

Table 3-1 summarizes the available family members.

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

| DEVICE     | FLASH (KB) | RAM (B) | FREQUENCY (MHz) | BSL  | ESP430 | I/O | PACKAGE |
|------------|------------|---------|-----------------|------|--------|-----|---------|
| MSP430F427 | 32         | 1K      | 8               | UART | 1      | 14  | PM 64   |
| MSP430F425 | 16         | 512     | 8               | UART | 1      | 14  | PM 64   |
| MSP430F423 | 8          | 256     | 8               | UART | 1      | 14  | PM 64   |

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

(2) Package drawings, thermal data, and symbolization are available at [www.ti.com/packaging](http://www.ti.com/packaging).

#### 3.1 Related Products

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

**TI Microcontrollers Product Selection** TI's low-power and-high performance MCUs, with wired and wireless connectivity options, are optimized for a broad range of applications.

**Products for MSP430 Ultra-Low-Power Microcontrollers** One platform. One ecosystem. Endless possibilities. Enabling the connected world with innovations in ultra-low-power microcontrollers with advanced peripherals for precise sensing and measurement.

**Products for MSP430F2x/4x Ultra-Low-Power Microcontrollers** MSP430F2x/4x microcontrollers (MCUs) from the MSP ultra-low-power MCU series are general-purpose 16-bit microcontrollers used for a wide range of applications including consumer electronics, data logging applications, portable medical instruments, and low-power metering. MSP430F4x MCUs feature an integrated LCD controller, while select MSP430F2x devices feature extended temperature ranges.

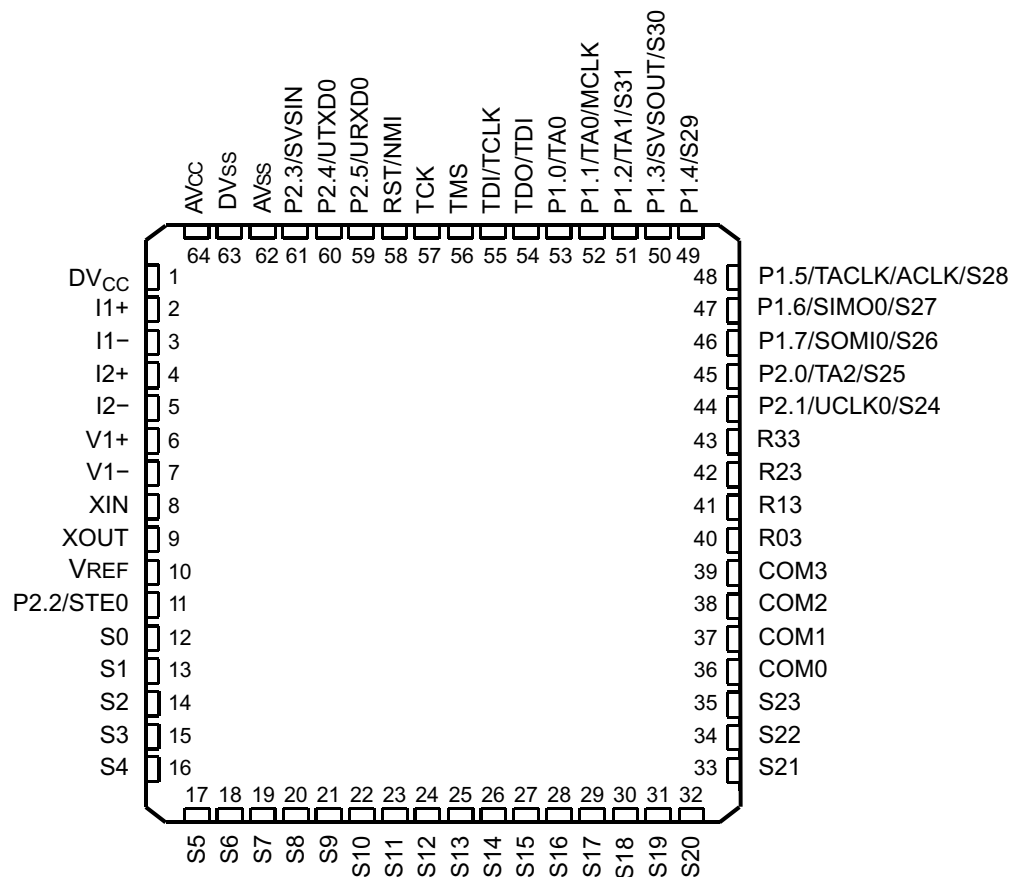
**Companion Products for MSP430FE427** Review products that are frequently purchased or used with this product.

**Reference Designs** The TI Designs Reference Design Library is a robust reference design library that spans analog, embedded processor, and connectivity. Created by TI experts to help you jump start your system design, all TI Designs include schematic or block diagrams, BOMs, and design files to speed your time to market.

## 4 Terminal Configuration and Functions

### 4.1 Pin Diagram

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



NOTE: TI recommends leaving all unused analog inputs open.

**Figure 4-1. 64-Pin PM Package (Top View)**

## 4.2 Signal Descriptions

Table 4-1 describes the signals for all device variants

**Table 4-1. Terminal Functions**

| SIGNAL NAME      | PIN NO. | I/O | DESCRIPTION                                                                                             |
|------------------|---------|-----|---------------------------------------------------------------------------------------------------------|
| DVCC             | 1       |     | Digital supply voltage, positive terminal                                                               |
| I1+              | 2       | I   | Current 1 positive analog input, internal connection to SD16 channel 0 A0+ <sup>(1)</sup>               |
| I1–              | 3       | I   | Current 1 negative analog input, internal connection to SD16 channel 0 A0– <sup>(1)</sup>               |
| I2+              | 4       | I   | Current 2 positive analog input, internal connection to SD16 channel 1 A0+ <sup>(1)</sup>               |
| I2–              | 5       | I   | Current 2 negative analog input, internal connection to SD16 channel 1 A0– <sup>(1)</sup>               |
| V1+              | 6       | I   | Voltage 1 positive analog input, internal connection to SD16 channel 2 A0+ <sup>(1)</sup>               |
| V1–              | 7       | I   | Voltage 1 negative analog input, internal connection to SD16 channel 2 A0– <sup>(1)</sup>               |
| XIN              | 8       | I   | Input port for crystal oscillator XT1. Standard or watch crystals can be connected.                     |
| XOUT             | 9       | O   | Output terminal of crystal oscillator XT1                                                               |
| V <sub>REF</sub> | 10      | I/O | Input for an external reference voltage, internal reference voltage output (can be used as mid-voltage) |
| P2.2/STE0        | 11      | I/O | General-purpose digital I/O<br>Slave transmit enable for USART0 in SPI mode                             |
| S0               | 12      | O   | LCD segment output 0                                                                                    |
| S1               | 13      | O   | LCD segment output 1                                                                                    |
| S2               | 14      | O   | LCD segment output 2                                                                                    |
| S3               | 15      | O   | LCD segment output 3                                                                                    |
| S4               | 16      | O   | LCD segment output 4                                                                                    |
| S5               | 17      | O   | LCD segment output 5                                                                                    |
| S6               | 18      | O   | LCD segment output 6                                                                                    |
| S7               | 19      | O   | LCD segment output 7                                                                                    |
| S8               | 20      | O   | LCD segment output 8                                                                                    |
| S9               | 21      | O   | LCD segment output 9                                                                                    |
| S10              | 22      | O   | LCD segment output 10                                                                                   |
| S11              | 23      | O   | LCD segment output 11                                                                                   |
| S12              | 24      | O   | LCD segment output 12                                                                                   |
| S13              | 25      | O   | LCD segment output 13                                                                                   |
| S14              | 26      | O   | LCD segment output 14                                                                                   |
| S15              | 27      | O   | LCD segment output 15                                                                                   |
| S16              | 28      | O   | LCD segment output 16                                                                                   |
| S17              | 29      | O   | LCD segment output 17                                                                                   |
| S18              | 30      | O   | LCD segment output 18                                                                                   |
| S19              | 31      | O   | LCD segment output 19                                                                                   |
| S20              | 32      | O   | LCD segment output 20                                                                                   |
| S21              | 33      | O   | LCD segment output 21                                                                                   |
| S22              | 34      | O   | LCD segment output 22                                                                                   |
| S23              | 35      | O   | LCD segment output 23                                                                                   |
| COM0             | 36      | O   | Common output, COM0–COM3 are used for LCD backplanes.                                                   |
| COM1             | 37      | O   | Common output, COM0–COM3 are used for LCD backplanes.                                                   |
| COM2             | 38      | O   | Common output, COM0–COM3 are used for LCD backplanes.                                                   |
| COM3             | 39      | O   | Common output, COM0–COM3 are used for LCD backplanes.                                                   |
| R03              | 40      | I   | Input port of fourth positive (lowest) analog LCD level (V5)                                            |
| R13              | 41      | I   | Input port of third most positive analog LCD level (V4 or V3)                                           |
| R23              | 42      | I   | Input port of second most positive analog LCD level (V2)                                                |

(1) TI recommends open connection for all unused analog inputs.

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

| SIGNAL NAME         | PIN NO. | I/O | DESCRIPTION                                                                                                                                                        |
|---------------------|---------|-----|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| R33                 | 43      | O   | Output port of most positive analog LCD level (V1)                                                                                                                 |
| P2.1/UCLK0/S24      | 44      | I/O | General-purpose digital I/O<br>External clock input for USART0 in UART or SPI mode, or clock output for USART0 in SPI mode<br>LCD segment output 24 <sup>(2)</sup> |
| P2.0/TA2/S25        | 45      | I/O | General-purpose digital I/O<br>Timer_A Capture: CCI2A input, Compare: Out2 output<br>LCD segment output 25 <sup>(2)</sup>                                          |
| P1.7/SOMI0/S26      | 46      | I/O | General-purpose digital I/O<br>Slave out/master in for USART0 in SPI mode<br>LCD segment output 26 <sup>(2)</sup>                                                  |
| P1.6/SIMO0/S27      | 47      | I/O | General-purpose digital I/O<br>Slave in/master out for USART0 in SPI mode<br>LCD segment output 27 <sup>(2)</sup>                                                  |
| P1.5/TACLK/ACLK/S28 | 48      | I/O | General-purpose digital I/O<br>Timer_A and SD16 clock signal TACLK input<br>ACLK output (divided by 1, 2, 4, or 8)<br>LCD segment output 28 <sup>(2)</sup>         |
| P1.4/S29            | 49      | I/O | General-purpose digital I/O<br>LCD segment output 29 <sup>(2)</sup>                                                                                                |
| P1.3/SVSOUT/S30     | 50      | I/O | General-purpose digital I/O<br>SVS: output of SVS comparator<br>LCD segment output 30 <sup>(2)</sup>                                                               |
| P1.2/TA1/S31        | 51      | I/O | General-purpose digital I/O<br>Timer_A, Capture: CCI1A, CCI1B input, Compare: Out1 output<br>LCD segment output 31 <sup>(2)</sup>                                  |
| P1.1/TA0/MCLK       | 52      | I/O | General-purpose digital I/O<br>Timer_A, Capture: CCI0B input. Note: TA0 is only an input on this pin.<br>MCLK output<br>BSL receive                                |
| P1.0/TA0            | 53      | I/O | General-purpose digital I/O<br>Timer_A, Capture: CCI0A input, Compare: Out0 output<br>BSL transmit                                                                 |
| TDO/TDI             | 54      | I/O | Test data output port, TDO/TDI data output or programming data input terminal                                                                                      |
| TDI/TCLK            | 55      | I   | Test data input or test clock input. The device protection fuse is connected to TDI.                                                                               |
| TMS                 | 56      | I   | Test mode select. TMS is used as an input port for device programming and test.                                                                                    |
| TCK                 | 57      | I   | Test clock. TCK is the clock input port for device programming and test.                                                                                           |
| RST/NMI             | 58      | I   | Reset input or nonmaskable interrupt input port                                                                                                                    |
| P2.5/URXD0          | 59      | I/O | General-purpose digital I/O<br>Receive data in for USART0 in UART mode                                                                                             |
| P2.4/UTXD0          | 60      | I/O | General-purpose digital I/O<br>Transmit data out for USART0 in UART mode                                                                                           |

(2) LCD function selected automatically when applicable LCD module control bits are set, not with PxSEL bits.

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

| SIGNAL NAME      | PIN NO. | I/O | DESCRIPTION                                                                                                                                           |
|------------------|---------|-----|-------------------------------------------------------------------------------------------------------------------------------------------------------|
| P2.3/SVSIN       | 61      | I/O | General-purpose digital I/O<br>Analog input to brownout, supply voltage supervisor                                                                    |
| AV <sub>SS</sub> | 62      |     | Analog supply voltage, negative terminal. Supplies SD16, SVS, brownout, oscillator, and LCD resistive divider circuitry.                              |
| DV <sub>SS</sub> | 63      |     | Digital supply voltage, negative terminal                                                                                                             |
| AV <sub>CC</sub> | 64      |     | Analog supply voltage, positive terminal. Supplies SD16, SVS, brownout, oscillator, and LCD resistive divider circuitry. Do not power up before DVCC. |

## 5 Specifications

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

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

|                                           |                     | MIN  | MAX            | UNIT |
|-------------------------------------------|---------------------|------|----------------|------|
| Voltage applied at $V_{CC}$ to $V_{SS}$   |                     | −0.3 | 4.1            | V    |
| Voltage applied to any pin <sup>(2)</sup> |                     | −0.3 | $V_{CC} + 0.3$ | V    |
| Diode current at any device terminal      |                     |      | ±2             | mA   |
| Storage temperature range, $T_{stg}$      | 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 TDI/TCLK 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  |      |

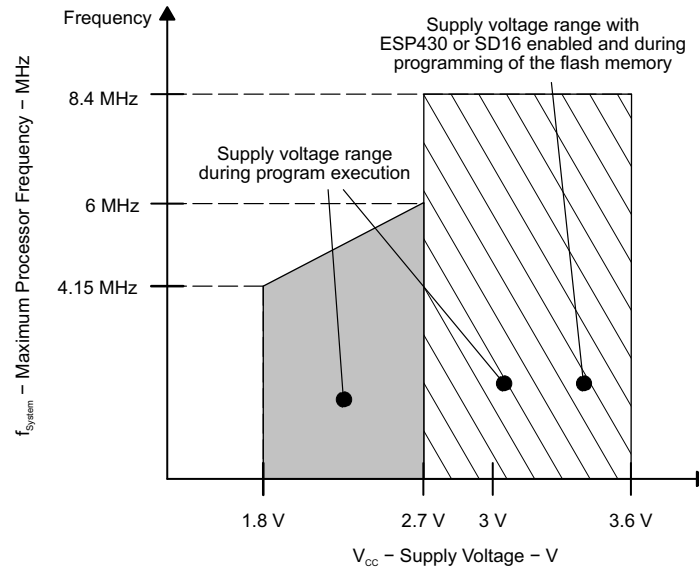
- (1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process. Pins listed as ±1000 V may actually have higher performance.
- (2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process. Pins listed as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

### 5.3 Recommended Operating Conditions

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

|                                                                                                        |                                                                  |                   | MIN  | NOM    | MAX  | UNIT |
|--------------------------------------------------------------------------------------------------------|------------------------------------------------------------------|-------------------|------|--------|------|------|
| $V_{CC}$ Supply voltage during program execution <sup>(1)</sup> ( $AV_{CC} = DV_{CC} = V_{CC}$ )       | ESP430 and SD16 disabled                                         |                   | 1.8  |        | 3.6  | V    |
|                                                                                                        | SVS enabled, PORON = 1 <sup>(2)</sup> , ESP430 and SD16 disabled |                   | 2.0  |        | 3.6  |      |
|                                                                                                        | ESP430 or SD16 enabled or during programming of flash memory     |                   | 2.7  |        | 3.6  |      |
| $V_{SS}$ Supply voltage ( $AV_{SS} = DV_{SS} = V_{SS}$ )                                               |                                                                  |                   | 0    |        | 0    | V    |
| $T_A$ Operating free-air temperature range                                                             |                                                                  |                   | −40  |        | 85   | °C   |
| $f_{(LFXT1)}$ LFXT1 crystal frequency <sup>(3)</sup>                                                   | LF selected, XTS_FLL = 0                                         | Watch crystal     |      | 32.768 |      | kHz  |
|                                                                                                        | XT1 selected, XTS_FLL = 1                                        | Ceramic resonator | 450  |        | 8000 |      |
|                                                                                                        | XT1 selected, XTS_FLL = 1                                        | Crystal           | 1000 |        | 8000 |      |
| $f_{(System)}$ Processor frequency (signal MCLK) <sup>(4)</sup> (also see <a href="#">Figure 5-1</a> ) | $V_{CC} = 2.7$ V                                                 |                   | DC   |        | 8.4  | MHz  |
|                                                                                                        | $V_{CC} = 3.6$ V                                                 |                   | DC   |        | 8.4  |      |

- (1) TI recommends powering  $AV_{CC}$  and  $DV_{CC}$  from the same source. A maximum difference of 0.3 V between  $AV_{CC}$  and  $DV_{CC}$  can be tolerated during power up and operation.
- (2) The minimum operating supply voltage is defined according to the trip point where POR is going active by decreasing the supply voltage. POR is going inactive when the supply voltage is raised above the minimum supply voltage plus the hysteresis of the SVS circuitry.
- (3) In LF mode, the LFXT1 oscillator requires a watch crystal.
- (4) For frequencies above 8 MHz, MCLK is sourced by the built-in oscillator (DCO and FLL+).



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

#### 5.4 Supply Current Into AV<sub>CC</sub> and DV<sub>CC</sub> Excluding External Current<sup>(1)</sup>

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

| PARAMETER           |                                                                                                                                                                                                                  | T <sub>A</sub> | V <sub>CC</sub> | MIN | TYP | MAX | UNIT |
|---------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|-----------------|-----|-----|-----|------|
| I <sub>(AM)</sub>   | Active mode (AM)<br>f <sub>(MCLK)</sub> = f <sub>(SMCLK)</sub> = f <sub>(DCO)</sub> = 1 MHz,<br>f <sub>(ACLK)</sub> = 32768 Hz, XTS_FLL = 0,<br>program executes in flash                                        | –40°C to 85°C  | 3 V             |     | 400 | 500 | μA   |
| I <sub>(LPM0)</sub> | Low-power mode 0 or 1 (LPM0 or LPM1) <sup>(2)</sup><br>f <sub>(MCLK)</sub> = f <sub>(SMCLK)</sub> = f <sub>(DCO)</sub> = 1 MHz,<br>f <sub>(ACLK)</sub> = 32768 Hz, XTS_FLL = 0,<br>FN_8 = FN_4 = FN_3 = FN_2 = 0 | –40°C to 85°C  | 3 V             |     | 130 | 150 | μA   |
| I <sub>(LPM2)</sub> | Low-power mode 2 (LPM2) <sup>(2)</sup>                                                                                                                                                                           | –40°C to 85°C  | 3 V             |     | 10  | 22  | μA   |
| I <sub>(LPM3)</sub> | Low-power mode 3 (LPM3) <sup>(2)</sup>                                                                                                                                                                           | –40°C          | 3 V             |     | 1.5 | 2.0 | μA   |
|                     |                                                                                                                                                                                                                  | 25°C           |                 |     | 1.6 | 2.1 |      |
|                     |                                                                                                                                                                                                                  | 60°C           |                 |     | 1.7 | 2.2 |      |
|                     |                                                                                                                                                                                                                  | 85°C           |                 |     | 2.0 | 3.5 |      |
| I <sub>(LPM4)</sub> | Low-power mode 4 (LPM4) <sup>(2)</sup>                                                                                                                                                                           | –40°C          | 3 V             |     | 0.1 | 0.5 | μA   |
|                     |                                                                                                                                                                                                                  | 25°C           |                 |     | 0.1 | 0.5 |      |
|                     |                                                                                                                                                                                                                  | 85°C           |                 |     | 0.8 | 2.5 |      |

(1) All inputs are tied to 0 V or V<sub>CC</sub>. Outputs do not source or sink any current. The current consumption in LPM2, LPM3, and LPM4 are measured with active Basic Timer1 and LCD (ACLK selected). The current consumption of the ESP430CE1 and the SVS module are specified in their respective sections. LPMx currents measured with WDT+ disabled. The currents are characterized with a KDS Daishinku DT-38 (6 pF) crystal.

(2) Current consumption for brownout is included.

Current consumption of active mode versus system frequency:

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

Current consumption of active mode versus supply voltage:

$$I_{(AM)} = I_{(AM)} [3 \text{ V}] + 170 \text{ } \mu\text{A/V} \times (V_{\text{CC}} - 3 \text{ V})$$

## 5.5 Thermal Resistance Characteristics, PM Package (LQFP64)

| PARAMETER                                                                       | VALUE | UNIT |
|---------------------------------------------------------------------------------|-------|------|
| $R\theta_{JA}$ Junction-to-ambient thermal resistance, still air <sup>(1)</sup> | 55.7  | °C/W |
| $R\theta_{JC(TOP)}$ Junction-to-case (top) thermal resistance <sup>(2)</sup>    | 16.7  | °C/W |
| $R\theta_{JB}$ Junction-to-board thermal resistance <sup>(3)</sup>              | 27.1  | °C/W |
| $\Psi_{JB}$ Junction-to-board thermal characterization parameter                | 26.8  | °C/W |
| $\Psi_{JT}$ Junction-to-top thermal characterization parameter                  | 0.8   | °C/W |

- (1) The junction-to-ambient thermal resistance under natural convection is obtained in a simulation on a JEDEC-standard, High-K board, as specified in JESD51-7, in an environment described in JESD51-2a.
- (2) The junction-to-case (top) thermal resistance is obtained by simulating a cold plate test on the package top. No specific JEDEC-standard test exists, but a close description can be found in the ANSI SEMI standard G30-88.
- (3) The junction-to-board thermal resistance is obtained by simulating in an environment with a ring cold plate fixture to control the PCB temperature, as described in JESD51-8.

## 5.6 Schmitt-Trigger Inputs – Ports (P1 and P2), $\overline{RST}/NMI$ , JTAG (TCK, TMS, TDI/TCLK, TDO/TDI)

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

| PARAMETER                                                  | $V_{CC}$ | MIN  | MAX  | UNIT |
|------------------------------------------------------------|----------|------|------|------|
| $V_{IT+}$ Positive-going input threshold voltage           | 3 V      | 1.5  | 1.98 | V    |
| $V_{IT-}$ Negative-going input threshold voltage           | 3 V      | 0.9  | 1.3  | V    |
| $V_{hys}$ Input voltage hysteresis ( $V_{IT+} - V_{IT-}$ ) | 3 V      | 0.45 | 1    | V    |

## 5.7 Inputs P1.x, P2.x, TAx

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

| PARAMETER                                                       | TEST CONDITIONS                                                                          | $V_{CC}$ | MIN | MAX | UNIT  |
|-----------------------------------------------------------------|------------------------------------------------------------------------------------------|----------|-----|-----|-------|
| $t_{(int)}$ External interrupt timing                           | Port P1, P2: P1.x to P2.x, external trigger signal for the interrupt flag <sup>(1)</sup> | 3 V      | 1.5 |     | cycle |
| $t_{(cap)}$ Timer_A capture timing                              | TAx                                                                                      | 3 V      | 50  |     | ns    |
| $f_{(TAext)}$ Timer_A clock frequency externally applied to pin | TAxCLK, INCLK $t_{(H)} = t_{(L)}$                                                        | 3 V      |     | 10  | MHz   |
| $f_{(TAint)}$ Timer_A clock frequency                           | SMCLK or ACLK signal selected                                                            | 3 V      |     | 10  | MHz   |

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

## 5.8 Leakage Current – Ports (P1 and P2)<sup>(1)</sup>

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

| PARAMETER                                 | TEST CONDITIONS                     | $V_{CC}$ | MIN | MAX | UNIT |
|-------------------------------------------|-------------------------------------|----------|-----|-----|------|
| $I_{lk}(P1.x)$ Leakage current, Port P1.x | Port 1: $V_{(P1.x)}$ <sup>(2)</sup> | 3 V      |     | ±50 | nA   |
| $I_{lk}(P2.x)$ Leakage current, Port P2.x | Port 2: $V_{(P2.x)}$ <sup>(2)</sup> | 3 V      |     | ±50 | nA   |

- (1) The leakage current is measured with  $V_{SS}$  or  $V_{CC}$  applied to the corresponding pins, unless otherwise noted.
- (2) The port pin must be selected as input.

## 5.9 Outputs – Ports (P1 and P2)

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

| PARAMETER                                 | TEST CONDITIONS                               | V <sub>CC</sub> | MIN                    | MAX                    | UNIT |
|-------------------------------------------|-----------------------------------------------|-----------------|------------------------|------------------------|------|
| V <sub>OH</sub> High-level output voltage | I <sub>OH(max)</sub> = –1.5 mA <sup>(1)</sup> | 3 V             | V <sub>CC</sub> – 0.25 | V <sub>CC</sub>        | V    |
|                                           | I <sub>OH(max)</sub> = –6 mA <sup>(2)</sup>   | 3 V             | V <sub>CC</sub> – 0.6  | V <sub>CC</sub>        |      |
| V <sub>OL</sub> Low-level output voltage  | I <sub>OL(max)</sub> = 1.5 mA <sup>(1)</sup>  | 3 V             | V <sub>SS</sub>        | V <sub>SS</sub> + 0.25 | V    |
|                                           | I <sub>OL(max)</sub> = 6 mA <sup>(2)</sup>    | 3 V             | V <sub>SS</sub>        | V <sub>SS</sub> + 0.6  |      |

- (1) The maximum total current, I<sub>OH(max)</sub> and I<sub>OL(max)</sub>, for all outputs combined, should not exceed ±12 mA to satisfy the maximum specified voltage drop.
- (2) The maximum total current, I<sub>OH(max)</sub> and I<sub>OL(max)</sub>, for all outputs combined, should not exceed ±48 mA to satisfy the maximum specified voltage drop.

## 5.10 Output Frequency

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

| PARAMETER                                                              | TEST CONDITIONS                                                                                          | MIN                                                       | TYP            | MAX                   | UNIT |
|------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------|-----------------------------------------------------------|----------------|-----------------------|------|
| f <sub>(Px.y)</sub> Output frequency<br>(1 ≤ x ≤ 2, 0 ≤ y ≤ 7)         | C <sub>L</sub> = 20 F, I <sub>L</sub> = ±1.5 mA, V <sub>CC</sub> = 3 V                                   | DC                                                        |                | 12                    | MHz  |
| f <sub>(ACLK)</sub> ,<br>f <sub>(MCLK)</sub> ,<br>f <sub>(SMCLK)</sub> | C <sub>L</sub> = 20 pF, V <sub>CC</sub> = 3 V                                                            |                                                           |                | 12                    | MHz  |
| t <sub>(Xdc)</sub> Duty cycle of output frequency                      | P1.5/TACLK/ACLK/S28,<br>C <sub>L</sub> = 20 pF, V <sub>CC</sub> = 3 V                                    | f <sub>ACLK</sub> = f <sub>LFXT1</sub> = f <sub>XT1</sub> | 40%            | 60%                   |      |
|                                                                        |                                                                                                          | f <sub>ACLK</sub> = f <sub>LFXT1</sub> = f <sub>LF</sub>  | 30%            | 70%                   |      |
|                                                                        |                                                                                                          | f <sub>ACLK</sub> = f <sub>LFXT1</sub>                    | 50%            |                       |      |
|                                                                        | P1.1/TA0/MCLK, C <sub>L</sub> = 20 pF, V <sub>CC</sub> = 3 V,<br>f <sub>MCLK</sub> = f <sub>DCOCLK</sub> |                                                           | 50% –<br>15 ns | 50%<br>50% +<br>15 ns |      |

## 5.11 Typical Characteristics – Ports P1 and P2

Figure 5-2 through Figure 5-5 show the typical output currents of Ports P1 and P2. One output loaded at a time.

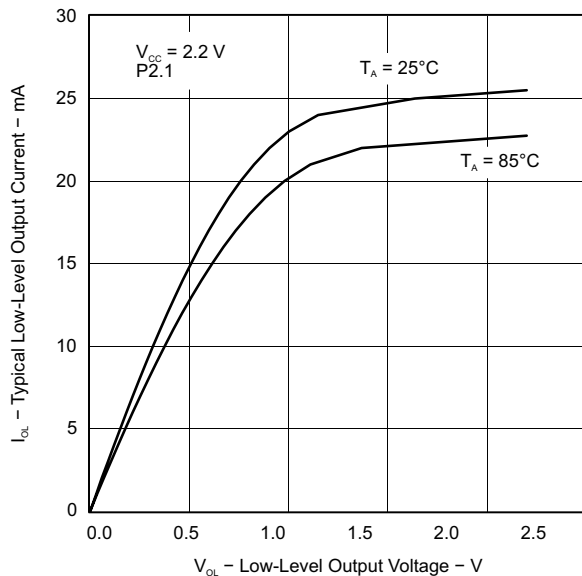


Figure 5-2. Typical Low-Level Output Current vs Low-Level Output Voltage

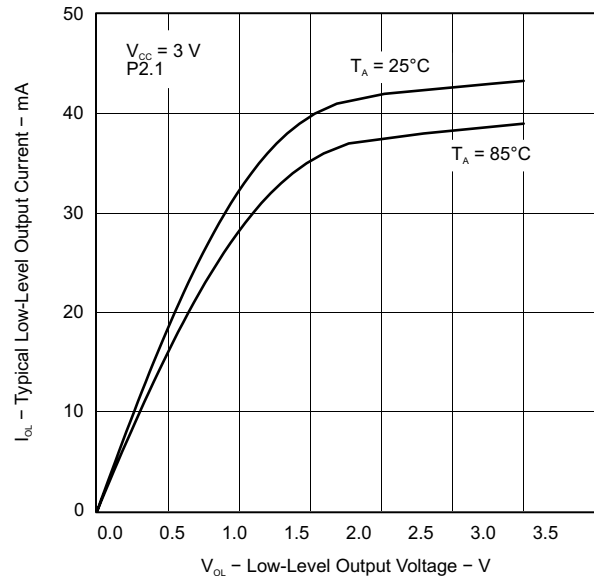


Figure 5-3. Typical Low-Level Output Current vs Low-Level Output Voltage

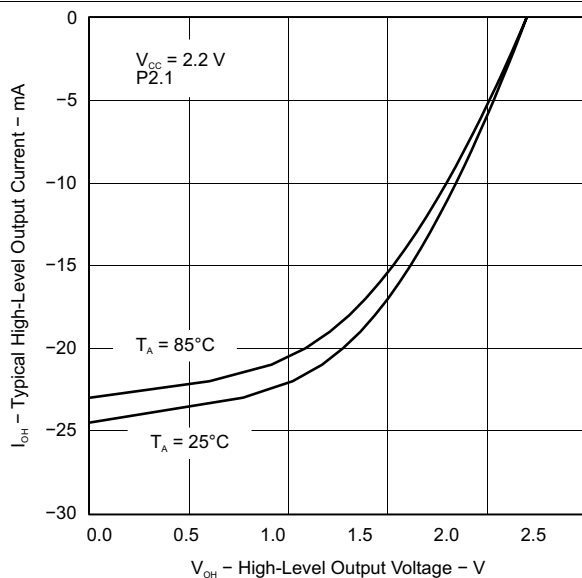


Figure 5-4. Typical High-Level Output Current vs High-Level Output Voltage

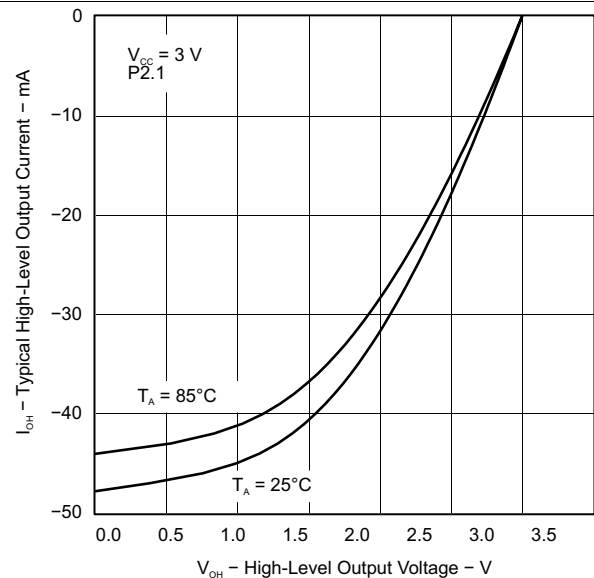


Figure 5-5. Typical High-Level Output Current vs High-Level Output Voltage

## 5.12 Wake-up Time From LPM3

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

| PARAMETER                | TEST CONDITIONS | MIN                   | MAX | UNIT |
|--------------------------|-----------------|-----------------------|-----|------|
| $t_{d(LPM3)}$ Delay time | f = 1 MHz       | V <sub>CC</sub> = 3 V | 6   | μs   |
|                          | f = 2 MHz       |                       | 6   |      |
|                          | f = 3 MHz       |                       | 6   |      |

## 5.13 RAM

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

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

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

## 5.14 LCD

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

| PARAMETER                            | TEST CONDITIONS                                   | MIN                                                            | TYP | MAX                     | UNIT |
|--------------------------------------|---------------------------------------------------|----------------------------------------------------------------|-----|-------------------------|------|
| V <sub>(33)</sub>                    | Voltage at R33                                    | 2.5                                                            |     | V <sub>CC</sub> + 0.2   | V    |
| V <sub>(23)</sub>                    | Voltage at R23                                    | $\frac{[V_{(33)} - V_{(03)}] \times 2}{3 + V_{(03)}}$          |     |                         |      |
| V <sub>(13)</sub>                    | Voltage at R13                                    | $\frac{[V_{(33)} - V_{(03)}] \times 1}{3 + V_{(03)}}$          |     |                         |      |
| V <sub>(33) - V<sub>(03)</sub></sub> | Voltage at R33 to R03                             | 2.5                                                            |     | V <sub>CC</sub> + 0.2   |      |
| I <sub>(R03)</sub>                   | R03 = V <sub>SS</sub>                             | No load at all segment and common lines, V <sub>CC</sub> = 3 V |     | ±20                     | nA   |
| I <sub>(R13)</sub>                   | R13 = V <sub>CC</sub> / 3                         |                                                                |     | ±20                     |      |
| I <sub>(R23)</sub>                   | R23 = 2 × V <sub>CC</sub> / 3                     |                                                                |     | ±20                     |      |
| V <sub>(Sxx0)</sub>                  | I <sub>(Sxx)</sub> = -3 μA, V <sub>CC</sub> = 3 V | V <sub>(03)</sub>                                              |     | V <sub>(03)</sub> - 0.1 | V    |
| V <sub>(Sxx1)</sub>                  |                                                   | V <sub>(13)</sub>                                              |     | V <sub>(13)</sub> - 0.1 |      |
| V <sub>(Sxx2)</sub>                  |                                                   | V <sub>(23)</sub>                                              |     | V <sub>(23)</sub> - 0.1 |      |
| V <sub>(Sxx3)</sub>                  |                                                   | V <sub>(33)</sub>                                              |     | V <sub>(33)</sub> + 0.1 |      |

## 5.15 USART0<sup>(1)</sup>

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

| PARAMETER                             | TEST CONDITIONS                            | MIN | TYP | MAX | UNIT |
|---------------------------------------|--------------------------------------------|-----|-----|-----|------|
| t <sub>(t)</sub> USART0 deglitch time | 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>(t)</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>(t)</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.

## 5.16 POR, BOR<sup>(1)</sup>

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

| PARAMETER         | TEST CONDITIONS                                                                                             | MIN | TYP                       | MAX  | UNIT          |
|-------------------|-------------------------------------------------------------------------------------------------------------|-----|---------------------------|------|---------------|
| $t_{d(BOR)}$      |                                                                                                             |     |                           | 2000 | $\mu\text{s}$ |
| $V_{CC(start)}$   | $dV_{CC}/dt \leq 3 \text{ V/s}$ (see Figure 5-6)                                                            |     | $0.7 \times V_{(B\_IT-)}$ |      | V             |
| $V_{(B\_IT-)}$    | $dV_{CC}/dt \leq 3 \text{ V/s}$ (see Figure 5-6 through Figure 5-8)                                         |     | 1.71                      |      | V             |
| $V_{hys(B\_IT-)}$ | $dV_{CC}/dt \leq 3 \text{ V/s}$ (see Figure 5-6)                                                            | 70  | 130                       | 180  | mV            |
| $t_{(reset)}$     | Pulse duration needed at $\overline{\text{RST/NMI}}$ pin to accept reset internally, $V_{CC} = 3 \text{ V}$ | 2   |                           |      | $\mu\text{s}$ |

- (1) The current consumption of the brownout module is already included in the  $I_{CC}$  current consumption data. The voltage level  $V_{(B\_IT-)} + V_{hys(B\_IT-)} \leq 1.8 \text{ V}$ .
- (2) During power up, the CPU begins code execution following a period of  $t_{d(BOR)}$  after  $V_{CC} = V_{(B\_IT-)} + V_{hys(B\_IT-)}$ . The default FLL+ settings must not be changed until  $V_{CC} \geq V_{CC(min)}$ , where  $V_{CC(min)}$  is the minimum supply voltage for the desired operating frequency. See the [MSP430x4xx Family User's Guide](#) for more information on the brownout and SVS circuit.

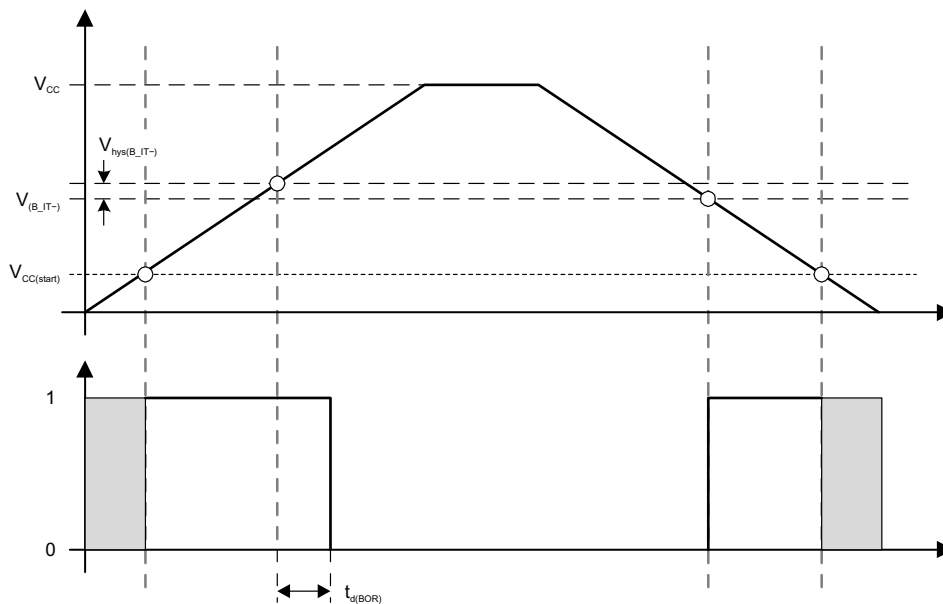


Figure 5-6. POR and BOR vs Supply Voltage

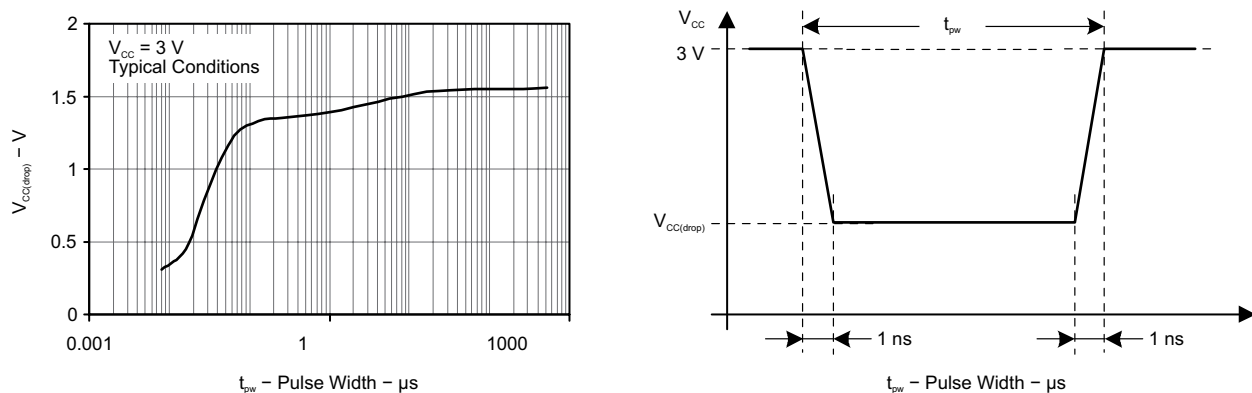
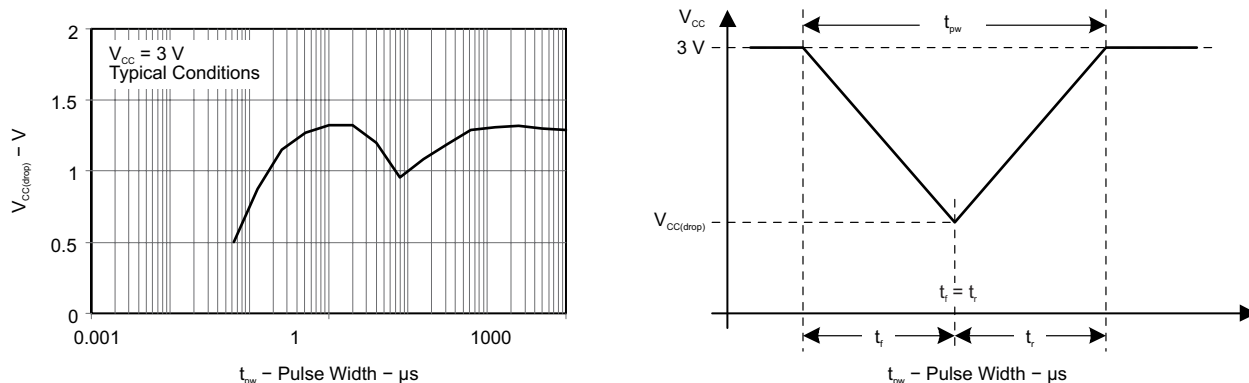


Figure 5-7.  $V_{CC(drop)}$  Level With a Rectangular Voltage Drop to Generate a POR/Brownout Signal



**Figure 5-8.  $V_{CC(drop)}$  Level With a Triangular Voltage Drop to Generate a POR or BOR Signal**

## 5.17 SVS (Supply Voltage Supervisor and Monitor)<sup>(1)</sup>

over recommended operating free-air temperature range (unless otherwise noted) (also see [Figure 5-10](#))

| PARAMETER                            | TEST CONDITIONS                                                                                 |               | MIN                            | TYP                | MAX                            | UNIT |
|--------------------------------------|-------------------------------------------------------------------------------------------------|---------------|--------------------------------|--------------------|--------------------------------|------|
| t <sub>(SVSR)</sub>                  | dV <sub>CC</sub> /dt > 30 V/ms (see <a href="#">Figure 5-9</a> )                                |               | 5                              |                    | 150                            | μs   |
|                                      | dV <sub>CC</sub> /dt ≤ 30 V/ms                                                                  |               |                                |                    | 2000                           |      |
| t <sub>d</sub> (SVSon)               | SVS on, switch from VLD = 0 to VLD ≠ 0, V <sub>CC</sub> = 3 V                                   |               | 20                             |                    | 150                            | 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 5-9</a> )                          |               |                                | 1.55               | 1.7                            | V    |
| V <sub>hys</sub> (SVS_IT–)           | V <sub>CC</sub> /dt ≤ 3 V/s (see <a href="#">Figure 5-9</a> )                                   | VLD = 1       | 70                             | 120                | 155                            | mV   |
|                                      |                                                                                                 | VLD = 2 to 14 | V <sub>(SVS_IT–)</sub> × 0.004 |                    | V <sub>(SVS_IT–)</sub> × 0.008 |      |
|                                      | V <sub>CC</sub> /dt ≤ 3 V/s (see <a href="#">Figure 5-9</a> ), external voltage applied on P2.3 | VLD = 15      | 4.4                            |                    | 10.4                           | mV   |
| V <sub>(SVS_IT–)</sub>               | V <sub>CC</sub> /dt ≤ 3 V/s (see <a href="#">Figure 5-9</a> )                                   | VLD = 1       | 1.8                            | 1.9                | 2.05                           | V    |
|                                      |                                                                                                 | VLD = 2       | 1.94                           | 2.1                | 2.25                           |      |
|                                      |                                                                                                 | VLD = 3       | 2.05                           | 2.2                | 2.37                           |      |
|                                      |                                                                                                 | VLD = 4       | 2.14                           | 2.3                | 2.48                           |      |
|                                      |                                                                                                 | VLD = 5       | 2.24                           | 2.4                | 2.6                            |      |
|                                      |                                                                                                 | VLD = 6       | 2.33                           | 2.5                | 2.71                           |      |
|                                      |                                                                                                 | VLD = 7       | 2.46                           | 2.65               | 2.86                           |      |
|                                      |                                                                                                 | VLD = 8       | 2.58                           | 2.8                | 3                              |      |
|                                      |                                                                                                 | VLD = 9       | 2.69                           | 2.9                | 3.13                           |      |
|                                      |                                                                                                 | VLD = 10      | 2.83                           | 3.05               | 3.29                           |      |
|                                      |                                                                                                 | VLD = 11      | 2.94                           | 3.2                | 3.42                           |      |
|                                      |                                                                                                 | VLD = 12      | 3.11                           | 3.35               | 3.61 <sup>(3)</sup>            |      |
|                                      |                                                                                                 | VLD = 13      | 3.24                           | 3.5                | 3.76 <sup>(3)</sup>            |      |
|                                      |                                                                                                 | VLD = 14      | 3.43                           | 3.7 <sup>(3)</sup> | 3.99 <sup>(3)</sup>            |      |
|                                      | V <sub>CC</sub> /dt ≤ 3 V/s (see <a href="#">Figure 5-9</a> ), external voltage applied on P2.3 | VLD = 15      | 1.1                            | 1.2                | 1.3                            |      |
| I <sub>CC</sub> (SVS) <sup>(1)</sup> | VLD ≠ 0, V <sub>CC</sub> = 2.2 V or 3 V                                                         |               |                                | 10                 | 15                             | μA   |

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

(2)  $t_{\text{settle}}$  is the settling time that the comparator o/p must have a stable level after VLD is switched from VLD  $\neq$  0 to a different VLD value between 2 and 15. The overdrive is assumed to be  $> 50 \text{ mV}$ .

(3) The recommended operating voltage range is limited to  $3.6 \text{ V}$ .

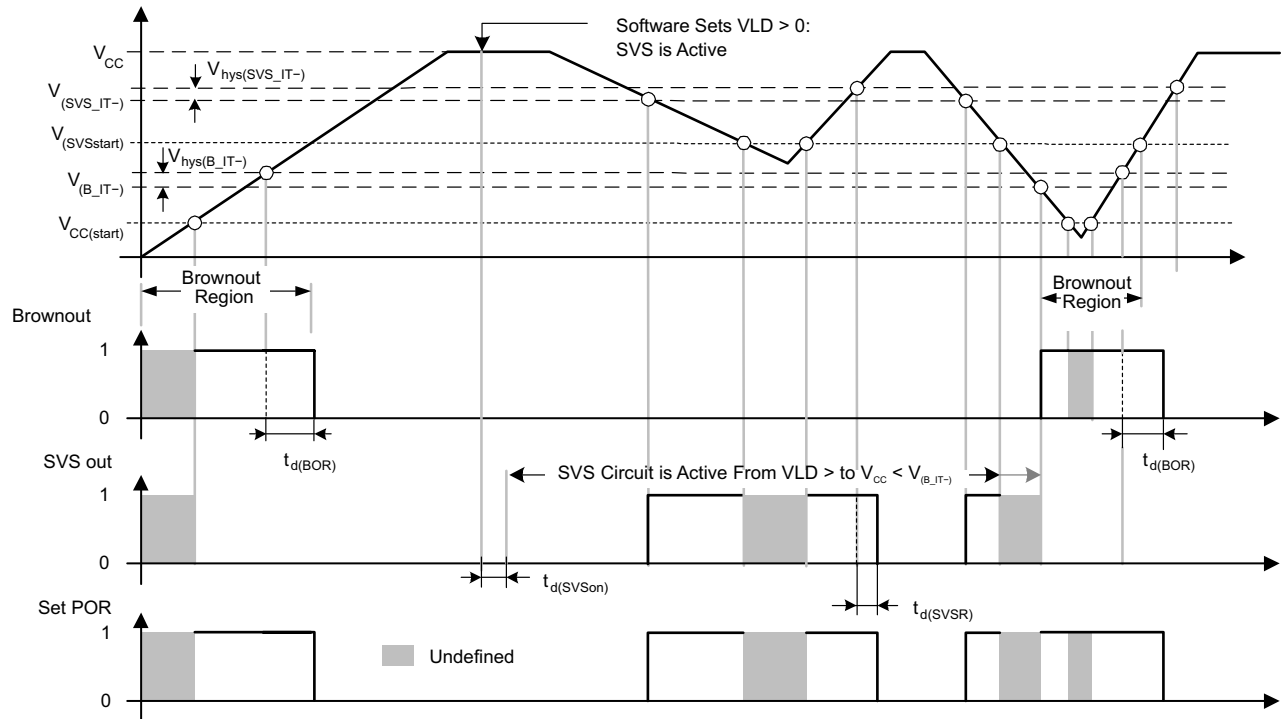
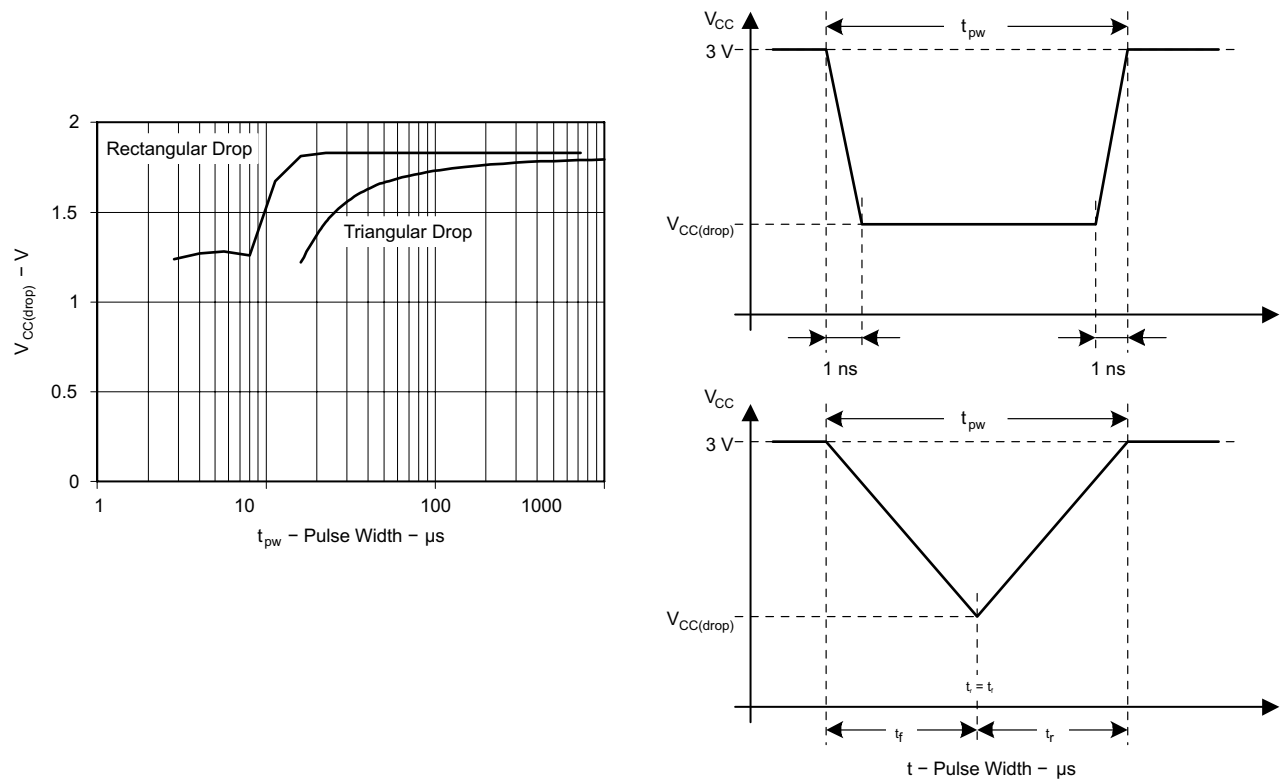


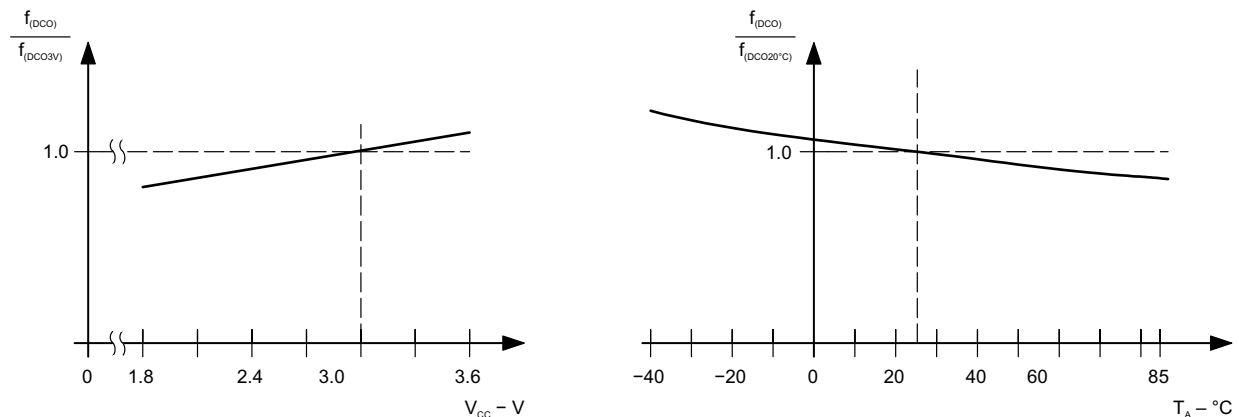
Figure 5-9. SVS Reset (SVSR) vs Supply Voltage

Figure 5-10.  $V_{CC(drop)}$  With a Rectangular Voltage Drop and a Triangular Voltage Drop to Generate an SVS Signal

## 5.18 DCO

over recommended operating free-air temperature range (unless otherwise noted) (also see [Figure 5-11](#) through [Figure 5-13](#))

| PARAMETER               | TEST CONDITIONS                                                                                                                                                         | V <sub>CC</sub> | MIN  | TYP  | MAX  | UNIT |
|-------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|------|------|------|------|
| f <sub>(DCOCLK)</sub>   | N <sub>(DCO)</sub> = 01Eh, FN_8 = FN_4 = FN_3 = FN_2 = 0, D = 2, DCOPLUS = 0, f <sub>Crystal</sub> = 32.768 kHz                                                         | 3 V             |      | 1    |      | MHz  |
| f <sub>(DCO = 2)</sub>  | FN_8 = FN_4 = FN_3 = FN_2 = 0, DCOPLUS = 1                                                                                                                              | 3 V             | 0.3  | 0.7  | 1.3  | MHz  |
| f <sub>(DCO = 27)</sub> | FN_8 = FN_4 = FN_3 = FN_2 = 0, DCOPLUS = 1                                                                                                                              | 3 V             | 2.7  | 6.1  | 11.3 | MHz  |
| f <sub>(DCO = 2)</sub>  | FN_8 = FN_4 = FN_3 = FN_2 = 1, DCOPLUS = 1                                                                                                                              | 3 V             | 0.8  | 1.5  | 2.5  | MHz  |
| f <sub>(DCO = 27)</sub> | FN_8 = FN_4 = FN_3 = FN_2 = 1, DCOPLUS = 1                                                                                                                              | 3 V             | 6.5  | 12.1 | 20   | MHz  |
| f <sub>(DCO = 2)</sub>  | FN_8 = FN_4 = 0, FN_3 = 1, FN_2 = x, DCOPLUS = 1                                                                                                                        | 3 V             | 1.3  | 2.2  | 3.5  | MHz  |
| f <sub>(DCO = 27)</sub> | FN_8 = FN_4 = 0, FN_3 = 1, FN_2 = x, DCOPLUS = 1                                                                                                                        | 3 V             | 10.3 | 17.9 | 28.5 | MHz  |
| f <sub>(DCO = 2)</sub>  | FN_8 = 0, FN_4 = 1, FN_3 = FN_2 = x, DCOPLUS = 1                                                                                                                        | 3 V             | 2.1  | 3.4  | 5.2  | MHz  |
| f <sub>(DCO = 27)</sub> | FN_8 = 0, FN_4 = 1, FN_3 = FN_2 = x, DCOPLUS = 1                                                                                                                        | 3 V             | 16   | 26.6 | 41   | MHz  |
| f <sub>(DCO = 2)</sub>  | FN_8 = 1, FN_4 = 1 = FN_3 = FN_2 = x, DCOPLUS = 1                                                                                                                       | 3 V             | 4.2  | 6.3  | 9.2  | MHz  |
| f <sub>(DCO = 27)</sub> | FN_8 = 1, FN_4 = 1 = FN_3 = FN_2 = x, DCOPLUS = 1                                                                                                                       | 3 V             | 30   | 46   | 70   | MHz  |
| S <sub>n</sub>          | Step size (ratio) between adjacent DCO taps:<br>S <sub>n</sub> = f <sub>DCO(Tap n+1)</sub> /f <sub>DCO(Tap n)</sub> (see <a href="#">Figure 5-12</a> for taps 21 to 27) | 1 < TAP ≤ 20    | 1.06 |      | 1.11 |      |
|                         |                                                                                                                                                                         | TAP = 27        | 1.07 |      | 1.17 |      |
| D <sub>t</sub>          | Temperature drift, N <sub>(DCO)</sub> = 01Eh, FN_8 = FN_4 = FN_3 = FN_2 = 0, D = 2, DCOPLUS = 0                                                                         | 3 V             | –0.2 | –0.3 | –0.4 | %/°C |
| D <sub>V</sub>          | Drift with V <sub>CC</sub> variation, N <sub>(DCO)</sub> = 01Eh, FN_8 = FN_4 = FN_3 = FN_2 = 0, D = 2, DCOPLUS = 0                                                      |                 | 0    | 5    | 15   | %/V  |



**Figure 5-11. DCO Frequency vs Supply Voltage V<sub>CC</sub> and vs Ambient Temperature**

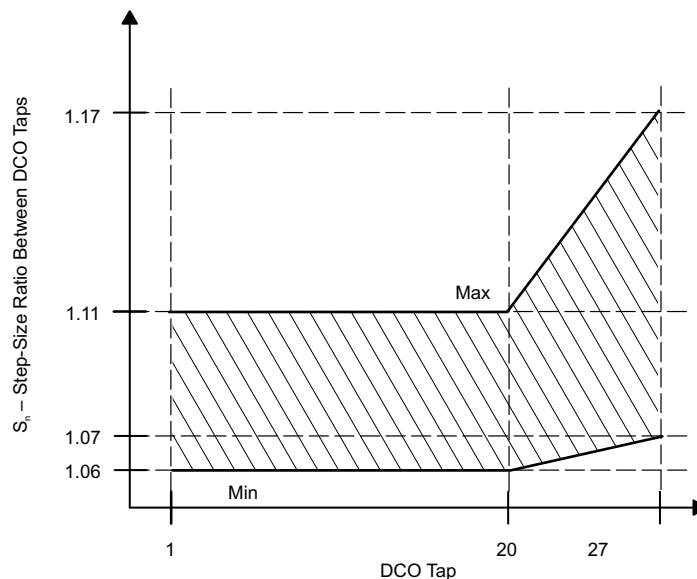


Figure 5-12. DCO Tap Step Size

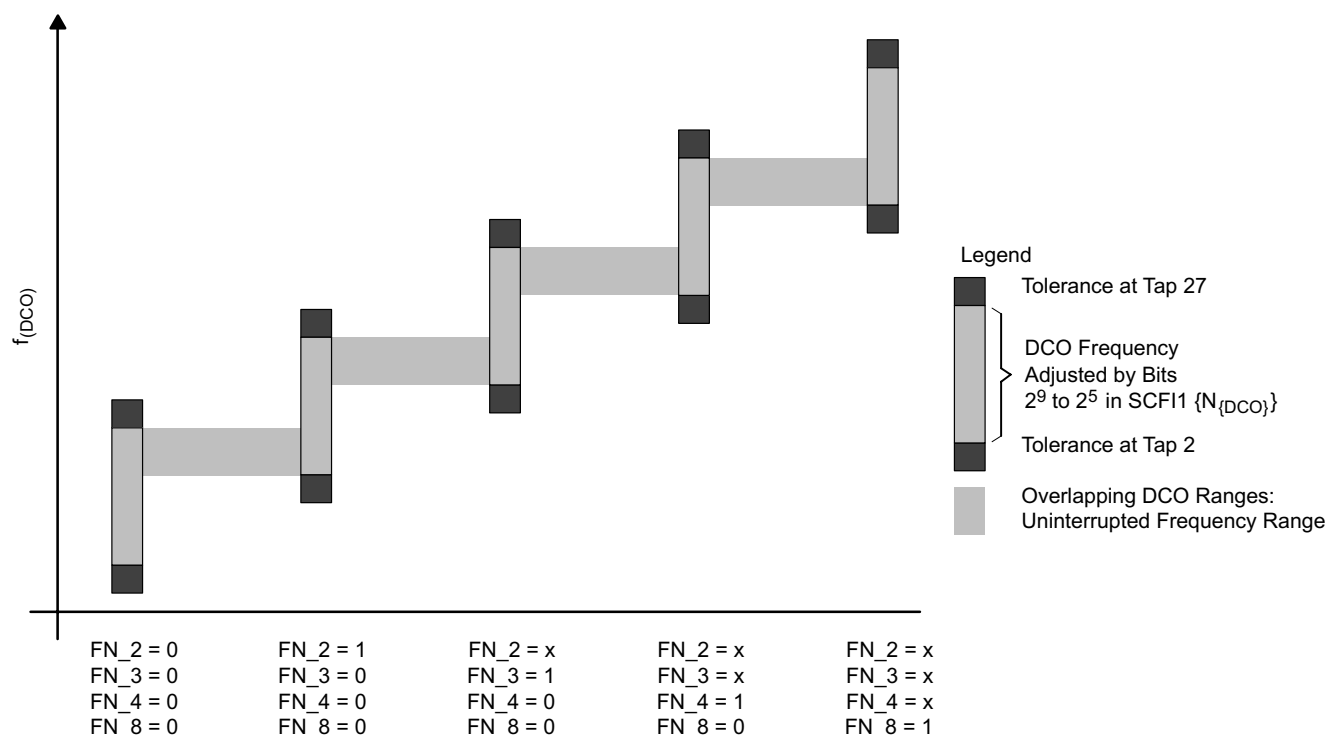


Figure 5-13. Five Overlapping DCO Ranges Controlled by FN\_x Bits

## 5.19 Crystal Oscillator, LFXT1 Oscillator<sup>(1) (2)</sup>

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

| PARAMETER         |                                              | TEST CONDITIONS | V <sub>CC</sub> | MIN                   | TYP | MAX                   | UNIT |
|-------------------|----------------------------------------------|-----------------|-----------------|-----------------------|-----|-----------------------|------|
| C <sub>XIN</sub>  | Integrated input capacitance <sup>(3)</sup>  | OSCCAPx = 0h    | 3 V             |                       | 0   |                       | pF   |
|                   |                                              | OSCCAPx = 1h    |                 |                       | 10  |                       |      |
|                   |                                              | OSCCAPx = 2h    |                 |                       | 14  |                       |      |
|                   |                                              | OSCCAPx = 3h    |                 |                       | 18  |                       |      |
| C <sub>XOUT</sub> | Integrated output capacitance <sup>(3)</sup> | OSCCAPx = 0h    | 3 V             |                       | 0   |                       | pF   |
|                   |                                              | OSCCAPx = 1h    |                 |                       | 10  |                       |      |
|                   |                                              | OSCCAPx = 2h    |                 |                       | 14  |                       |      |
|                   |                                              | OSCCAPx = 3h    |                 |                       | 18  |                       |      |
| V <sub>IL</sub>   | Input levels at XIN <sup>(4)</sup>           |                 | 2.2 V,<br>3 V   | V <sub>SS</sub>       |     | 0.2 × V <sub>CC</sub> | V    |
| V <sub>IH</sub>   |                                              |                 |                 | 0.8 × V <sub>CC</sub> |     | V <sub>CC</sub>       |      |

- (1) The parasitic capacitance from the package and board may be estimated to be 2 pF. The effective load capacitor for the crystal is  $(C_{XIN} \times C_{XOUT}) / (C_{XIN} + C_{XOUT})$ . This is independent of XTS\_FLL.
- (2) To improve EMI on the low-power LFXT1 oscillator, particularly in the LF mode (32 kHz), the following guidelines should be observed.
  - Keep the trace between the device and the crystal as short as possible.
  - Design a good ground plane around the oscillator pins.
  - Prevent crosstalk from other clock or data lines into oscillator pins XIN and XOUT.
  - Avoid running PCB traces underneath or adjacent to the XIN and XOUT pins.
  - Use assembly materials and processes that avoid any parasitic load on the oscillator XIN and XOUT pins.
  - If conformal coating is used, ensure that it does not induce capacitive or resistive leakage between the oscillator pins.
  - Do not route the XOUT line to the JTAG header to support the serial programming adapter as shown in other documentation. This signal is no longer required for the serial programming adapter.
- (3) TI recommends external capacitance for precision real-time clock applications; OSCCAPx = 0h.
- (4) Applies only when using an external logic-level clock source. XTS\_FLL must be set. Not applicable when using a crystal or resonator.

## 5.20 ESP430CE1, SD16 and ESP430 Power Supply and Operating Conditions

over recommended operating free-air temperature range (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> , AV <sub>SS</sub> = DV <sub>SS</sub> = 0 V                                 |                 | 2.7 |      | 3.6  | V    |
| I <sub>ESP430CE1</sub> Total digital and analog supply current when ESP430 and SD16 active (I <sub>AVCC</sub> + I <sub>DVCC</sub> ) | SD16LP = 0, f <sub>MCLK</sub> = 4 MHz, f <sub>SD16</sub> = f <sub>MCLK</sub> / 4, SD16REFON = 1, SD16VMIDON = 0 | 3 V             |     | 2.0  | 2.6  | mA   |
|                                                                                                                                     | GAIN(V): 1, GAIN(I1): 1, I2: off                                                                                |                 |     | 2.4  | 3.3  |      |
|                                                                                                                                     | GAIN(V): 1, GAIN(I1): 32, I2: off                                                                               |                 |     | 2.7  | 3.6  |      |
|                                                                                                                                     | GAIN(V): 1, GAIN(I1): 1, GAIN(I2): 1                                                                            |                 |     | 3.4  | 4.9  |      |
|                                                                                                                                     | GAIN(V): 1, GAIN(I1): 32, GAIN(I2): 32                                                                          |                 |     | 1.5  | 2.1  |      |
|                                                                                                                                     | SD16LP = 1, f <sub>MCLK</sub> = 2 MHz, f <sub>SD16</sub> = f <sub>MCLK</sub> / 4, SD16REFON = 1, SD16VMIDON = 0 |                 |     | 1.6  | 2.1  |      |
|                                                                                                                                     | GAIN(V): 1, GAIN(I1): 1, I2: off                                                                                |                 |     | 2.1  | 2.8  |      |
|                                                                                                                                     | GAIN(V): 1, GAIN(I1): 32, I2: off                                                                               |                 |     | 2.2  | 3.0  |      |
|                                                                                                                                     | GAIN(V): 1, GAIN(I1): 1, GAIN(I2): 1                                                                            |                 |     |      |      |      |
|                                                                                                                                     | GAIN(V): 1, GAIN(I1): 32, GAIN(I2): 32                                                                          |                 |     |      |      |      |
| I <sub>SD16</sub> Analog supply current: 1 active SD16 channel including internal reference (ESP430 disabled)                       | SD16LP = 0, f <sub>SD16</sub> = 1 MHz, SD16OSR = 256                                                            | 3 V             |     | 650  | 950  | μA   |
|                                                                                                                                     | GAIN: 1, 2                                                                                                      |                 |     | 730  | 1100 |      |
|                                                                                                                                     | GAIN: 4, 8, 16                                                                                                  |                 |     | 1050 | 1550 |      |
|                                                                                                                                     | GAIN: 32                                                                                                        |                 |     | 620  | 930  |      |
|                                                                                                                                     | SD16LP = 1, f <sub>SD16</sub> = 0.5 MHz, SD16OSR = 256                                                          |                 |     | 700  | 1060 |      |
|                                                                                                                                     | GAIN: 1                                                                                                         |                 |     |      |      |      |
|                                                                                                                                     | GAIN: 32                                                                                                        |                 |     |      |      |      |
| f <sub>MAINS</sub> Mains frequency range                                                                                            |                                                                                                                 |                 | 33  |      | 80   | Hz   |
| f <sub>SD16</sub> Analog front-end input clock frequency                                                                            | SD16LP = 0 (low-power mode disabled)                                                                            |                 |     | 1    |      | MHz  |
|                                                                                                                                     | SD16LP = 1 (low-power mode enabled)                                                                             |                 |     | 0.5  |      |      |

## 5.21 ESP430CE1, SD16 Input Range<sup>(1)</sup>

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

| PARAMETER                                                                                 | TEST CONDITIONS                           | V <sub>CC</sub> | MIN                  | TYP  | MAX              | UNIT |
|-------------------------------------------------------------------------------------------|-------------------------------------------|-----------------|----------------------|------|------------------|------|
| V <sub>ID</sub> Differential input voltage range for specified performance <sup>(2)</sup> | SD16GAINx = 1, SD16REFON = 1              |                 |                      | ±500 |                  | mV   |
|                                                                                           | SD16GAINx = 2, SD16REFON = 1              |                 |                      | ±250 |                  |      |
|                                                                                           | SD16GAINx = 4, SD16REFON = 1              |                 |                      | ±125 |                  |      |
|                                                                                           | SD16GAINx = 8, SD16REFON = 1              |                 |                      | ±62  |                  |      |
|                                                                                           | SD16GAINx = 16, SD16REFON = 1             |                 |                      | ±31  |                  |      |
|                                                                                           | SD16GAINx = 32, SD16REFON = 1             |                 |                      | ±15  |                  |      |
|                                                                                           |                                           |                 |                      |      |                  |      |
| Z <sub>I</sub> Input impedance (one input pin to AV <sub>SS</sub> )                       | f <sub>SD16</sub> = 1 MHz, SD16GAINx = 1  | 3 V             |                      | 200  |                  | kΩ   |
|                                                                                           | f <sub>SD16</sub> = 1 MHz, SD16GAINx = 32 |                 |                      | 75   |                  |      |
| Z <sub>ID</sub> Differential input impedance (IN+ to IN-)                                 | f <sub>SD16</sub> = 1 MHz, SD16GAINx = 1  | 3 V             | 300                  | 400  |                  | kΩ   |
|                                                                                           | f <sub>SD16</sub> = 1 MHz, SD16GAINx = 32 |                 | 100                  | 150  |                  |      |
| V <sub>I</sub> Absolute input voltage range                                               |                                           |                 | AV <sub>SS</sub> – 1 |      | AV <sub>CC</sub> | V    |
| V <sub>IC</sub> Common-mode input voltage range                                           |                                           |                 | AV <sub>SS</sub> – 1 |      | AV <sub>CC</sub> | V    |

(1) All parameters pertain to each SD16 channel.

(2) The analog input range depends on the reference voltage applied to V<sub>REF</sub>. If V<sub>REF</sub> is sourced externally, 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. The analog input range should not exceed 80% of V<sub>FSR+</sub> or V<sub>FSR-</sub>.

## 5.22 ESP430CE1, SD16 Performance

 $f_{SD16} = 1 \text{ MHz}$ ,  $SD16OSRx = 256$ ,  $SD16REFON = 1$ , over operating free-air temperature range (unless otherwise noted)

| PARAMETER            |                                      | TEST CONDITIONS                                                                                      |                                   | V <sub>CC</sub> | MIN         | TYP   | MAX   | UNIT       |
|----------------------|--------------------------------------|------------------------------------------------------------------------------------------------------|-----------------------------------|-----------------|-------------|-------|-------|------------|
| SINAD                | Signal-to-noise + distortion ratio   | SD16GAINx = 1, signal amplitude = 500 mV                                                             | f <sub>IN</sub> = 50 Hz or 100 Hz | 3 V             | 83.5        | 85    |       | dB         |
|                      |                                      | SD16GAINx = 2, signal amplitude = 250 mV                                                             |                                   |                 | 81.5        | 84    |       |            |
|                      |                                      | SD16GAINx = 4, signal amplitude = 125 mV                                                             |                                   |                 | 76          | 79.5  |       |            |
|                      |                                      | SD16GAINx = 8, signal amplitude = 62 mV                                                              |                                   |                 | 73          | 76.5  |       |            |
|                      |                                      | SD16GAINx = 16, signal amplitude = 31 mV                                                             |                                   |                 | 69          | 73    |       |            |
|                      |                                      | SD16GAINx = 32, signal amplitude = 15 mV                                                             |                                   |                 | 62          | 69    |       |            |
| G                    | Nominal gain                         | SD16GAINx = 1                                                                                        |                                   | 3 V             | 0.97        | 1.00  | 1.02  |            |
|                      |                                      | SD16GAINx = 2                                                                                        |                                   |                 | 1.90        | 1.96  | 2.02  |            |
|                      |                                      | SD16GAINx = 4                                                                                        |                                   |                 | 3.76        | 3.86  | 3.96  |            |
|                      |                                      | SD16GAINx = 8                                                                                        |                                   |                 | 7.36        | 7.62  | 7.84  |            |
|                      |                                      | SD16GAINx = 16                                                                                       |                                   |                 | 14.56       | 15.04 | 15.52 |            |
|                      |                                      | SD16GAINx = 32                                                                                       |                                   |                 | 27.20       | 28.35 | 29.76 |            |
| E <sub>OS</sub>      | Offset error                         | SD16GAINx = 1                                                                                        |                                   | 3 V             | ±0.2        |       |       | %FSR       |
|                      |                                      | SD16GAINx = 32                                                                                       |                                   |                 | ±1.5        |       |       |            |
| dE <sub>OS</sub> /dT | Offset error temperature coefficient | SD16GAINx = 1                                                                                        |                                   | 3 V             | ±4    ±20   |       |       | ppm FSR/°C |
|                      |                                      | SD16GAINx = 32                                                                                       |                                   |                 | ±20    ±100 |       |       |            |
| CMRR                 | Common-mode rejection ratio          | SD16GAINx = 1, Common-mode input signal: V <sub>ID</sub> = 500 mV, f <sub>IN</sub> = 50 Hz or 100 Hz |                                   | 3 V             | >90         |       |       | dB         |
|                      |                                      | SD16GAINx = 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      | SD16GAINx = 1, V <sub>CC</sub> = 3 V ±100 mV, f <sub>VCC</sub> = 50 Hz                               |                                   | 3 V             | >80         |       |       | dB         |
| XT                   | Crosstalk                            |                                                                                                      |                                   | 3 V             | <−100       |       |       | dB         |

## 5.23 ESP430CE1, SD16 Temperature Sensor<sup>(1)</sup>

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

| PARAMETER                                                   | TEST CONDITIONS                                     | V <sub>CC</sub> | MIN  | TYP  | MAX  | UNIT |
|-------------------------------------------------------------|-----------------------------------------------------|-----------------|------|------|------|------|
| TC <sub>Sensor</sub><br>Sensor temperature coefficient      |                                                     |                 | 1.18 | 1.32 | 1.46 | mV/K |
| V <sub>Offset,sensor</sub><br>Sensor offset voltage         |                                                     |                 | -100 |      | 100  | mV   |
| V <sub>Sensor</sub><br>Sensor output voltage <sup>(2)</sup> | Temperature sensor voltage at T <sub>A</sub> = 85°C | 3 V             | 435  | 475  | 515  | mV   |
|                                                             | Temperature sensor voltage at T <sub>A</sub> = 25°C |                 | 355  | 395  | 435  |      |
|                                                             | Temperature sensor voltage at T <sub>A</sub> = 0°C  |                 | 320  | 360  | 400  |      |

(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 or production test, no TC<sub>Sensor</sub> or V<sub>Offset,sensor</sub>.

## 5.24 ESP430CE1, SD16 Built-in Voltage Reference

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

| PARAMETER         |                                                                | TEST CONDITIONS                                                 | V <sub>CC</sub> | MIN  | TYP  | MAX  | UNIT  |
|-------------------|----------------------------------------------------------------|-----------------------------------------------------------------|-----------------|------|------|------|-------|
| V <sub>REF</sub>  | Internal reference voltage                                     | SD16REFON = 1, SD16VMIDON = 0                                   | 3 V             | 1.14 | 1.20 | 1.26 | V     |
| I <sub>REF</sub>  | Reference supply current                                       | SD16REFON = 1, SD16VMIDON = 0                                   | 3 V             |      | 175  | 260  | μA    |
| TC                | Temperature coefficient                                        | SD16REFON = 1, SD16VMIDON = 0 <sup>(1)</sup>                    | 3 V             |      | 20   | 50   | ppm/K |
| C <sub>REF</sub>  | V <sub>REF</sub> load capacitance                              | SD16REFON = 1 SD16VMIDON = 0 <sup>(2)</sup>                     |                 |      | 100  |      | nF    |
| I <sub>LOAD</sub> | V <sub>REF(I)</sub> maximum load current                       | SD16REFON = 0, SD16VMIDON = 0                                   | 3 V             |      |      | ±200 | nA    |
| t <sub>ON</sub>   | Turnon time                                                    | SD16REFON = 0 → 1, SD16VMIDON = 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> | SD16REFON = 1, SD16VMIDON = 0, V <sub>CC</sub> = 2.5 V to 3.6 V |                 |      | 200  |      | 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, TI recommends a capacitance of at least 100 nF to reduce any reference voltage noise.

## 5.25 ESP430CE1, SD16 Reference Output Buffer

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

| PARAMETER             | TEST CONDITIONS                                                | V <sub>CC</sub>                                                 | MIN | TYP | MAX | UNIT |
|-----------------------|----------------------------------------------------------------|-----------------------------------------------------------------|-----|-----|-----|------|
| V <sub>REF,BUF</sub>  | Reference buffer output voltage                                | SD16REFON = 1, SD16VMIDON = 1                                   | 3 V | 1.2 |     | V    |
| I <sub>REF,BUF</sub>  | Reference supply and reference output buffer quiescent current | SD16REFON = 1, SD16VMIDON = 1                                   | 3 V | 385 | 600 | A    |
| C <sub>REF(O)</sub>   | Required load capacitance on V <sub>REF</sub>                  | SD16REFON = 1, SD16VMIDON = 1                                   |     | 470 |     | nF   |
| I <sub>LOAD,Max</sub> | Maximum load current on V <sub>REF</sub>                       | SD16REFON = 1, SD16VMIDON = 1                                   | 3 V |     | ±1  | mA   |
|                       | Maximum voltage variation versus load current                  | I <sub>LOAD</sub>   = 0 to 1 mA                                 | 3 V | −15 | +15 | mV   |
| t <sub>ON</sub>       | Turnon time                                                    | SD16REFON = 0 → 1, SD16VMIDON = 0,<br>C <sub>REF</sub> = 100 nF | 3 V | 100 |     | μs   |

## 5.26 ESP430CE1, SD16 External Reference Input

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

| PARAMETER           |               | TEST CONDITIONS | V <sub>CC</sub> | MIN | TYP  | MAX | UNIT |
|---------------------|---------------|-----------------|-----------------|-----|------|-----|------|
| V <sub>REF(I)</sub> | Input voltage | SD16REFON = 0   | 3 V             | 1.0 | 1.25 | 1.5 | V    |
| I <sub>REF(I)</sub> | Input current | SD16REFON = 0   | 3 V             |     |      | 50  | nA   |

## 5.27 ESP430CE1, Active Energy Measurement Test Conditions and Accuracy<sup>(1)</sup>

$T_A = 25^\circ\text{C}$ , input conditions (unless otherwise noted):  $I_B = 6\text{ A}$ ,  $I_{MAX} = n \times I_B = 60\text{ A}$ ,  $n = 10$ ,  $V_N = 230\text{ V}$ ,  $f_{MAINS} = 50\text{ Hz}$

| PARAMETER                       | TEST CONDITIONS                                                     | $V_{CC}$ | TYP          | UNIT |
|---------------------------------|---------------------------------------------------------------------|----------|--------------|------|
| Maximum error <sup>(2)(3)</sup> | $I = 0.05 \times I_B$ , $V = V_N$ , $PF = 1.0$                      | 3 V      | $\pm 0.17\%$ |      |
|                                 | $I = 0.1 \times I_B$ to $I_{MAX}$ , $V = V_N$ , $PF = 1.0$          |          | $\pm 0.18\%$ |      |
|                                 | $I = 0.1 \times I_B$ , $V = V_N$ , $PF = 0.5$ lagging               |          | $\pm 0.19\%$ |      |
|                                 | $I = 0.2 \times I_B$ to $I_{MAX}$ , $V = V_N$ , $PF = 0.5$ lagging  |          | $\pm 0.27\%$ |      |
|                                 | $I = 0.1 \times I_B$ , $V = V_N$ , $PF = 0.8$ leading               |          | $\pm 0.15\%$ |      |
|                                 | $I = 0.2 \times I_B$ to $I_{MAX}$ , $V = V_N$ , $PF = 0.8$ leading  |          | $\pm 0.24\%$ |      |
|                                 | $I = 0.2 \times I_B$ to $I_{MAX}$ , $V = V_N$ , $PF = 0.25$ lagging |          | $\pm 0.38\%$ |      |

(1)

- $f_{ACLK} = 32768\text{ Hz}$  (watch crystal)
- $f_{MCLK} = 4.194\text{ MHz}$  (FLL+)
- $f_{SD16} = f_{MCLK} / 4 = 1.049\text{ MHz}$
- Single-point calibration at  $I = 10\text{ A}$  and  $PF = 0.5$  lagging
- Measurements according to IEC1036

(2) Measurements performed using complete hardware solution. Error shown contain temperature dependencies of all components including the MSP430FE42x, crystal, and discrete components.

- (3) I1 SD16GAIN x = 1 or 4: CT part number = T60404-E4624-X101 (Vacuumschmelze)  
I1 SD16GAINx = 8: shunt part number = A-H2-R005-F1-K2-0.1 (Isabellenhütte Heusler GmbH KG)  
I1 SD16GAINx = 32: shunt part number = BVO-M-R0002-5.0 (Isabellenhütte Heusler GmbH KG)

## 5.28 ESP430CE1, Active Energy Measurement Test Conditions and Accuracy<sup>(1)</sup>

$T_A = 25^\circ\text{C}$ , input conditions (unless otherwise noted):  $I_B = 10\text{ A}$ ,  $I_{MAX} = n \times I_B = 60\text{ A}$ ,  $n = 6$ ,  $V_N = 230\text{ V}$ ,  $f_{MAINS} = 50\text{ Hz}$

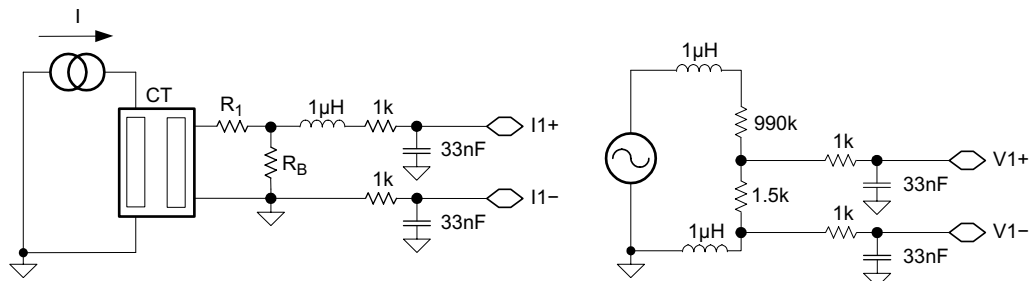
| PARAMETER                       | TEST CONDITIONS                                                     | $V_{CC}$ | TYP          | UNIT |
|---------------------------------|---------------------------------------------------------------------|----------|--------------|------|
| Maximum error <sup>(2)(3)</sup> | $I = 0.05 \times I_B$ , $V = V_N$ , $PF = 1.0$                      | 3 V      | $\pm 0.11\%$ |      |
|                                 | $I = 0.1 \times I_B$ to $I_{MAX}$ , $V = V_N$ , $PF = 1.0$          |          | $\pm 0.18\%$ |      |
|                                 | $I = 0.1 \times I_B$ , $V = V_N$ , $PF = 0.5$ lagging               |          | $\pm 0.45\%$ |      |
|                                 | $I = 0.2 \times I_B$ to $I_{MAX}$ , $V = V_N$ , $PF = 0.5$ lagging  |          | $\pm 0.33\%$ |      |
|                                 | $I = 0.1 \times I_B$ , $V = V_N$ , $PF = 0.8$ leading               |          | $\pm 0.10\%$ |      |
|                                 | $I = 0.2 \times I_B$ to $I_{MAX}$ , $V = V_N$ , $PF = 0.8$ leading  |          | $\pm 0.18\%$ |      |
|                                 | $I = 0.2 \times I_B$ to $I_{MAX}$ , $V = V_N$ , $PF = 0.25$ lagging |          | $\pm 0.51\%$ |      |

(1)

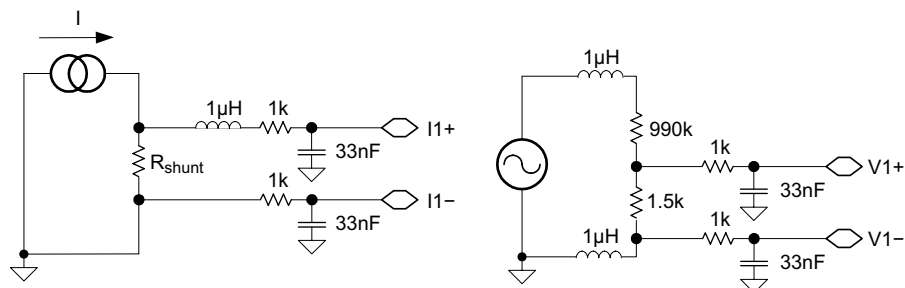
- $f_{ACLK} = 32768\text{ Hz}$  (watch crystal)
- $f_{MCLK} = 4.194\text{ MHz}$  (FLL+)
- $f_{SD16} = f_{MCLK} / 4 = 1.049\text{ MHz}$
- Single-point calibration at  $I = 10\text{ A}$  and  $PF = 0.5$  lagging
- Measurements according to IEC1036

(2) Measurements performed using complete hardware solution. Error shown contain temperature dependencies of all components including the MSP430FE42x, crystal, and discrete components.

- (3) I1 SD16GAIN x = 1 or 4: CT part number = T60404-E4624-X101 (Vacuumschmelze)  
I1 SD16GAINx = 8: shunt part number = A-H2-R005-F1-K2-0.1 (Isabellenhütte Heusler GmbH KG)  
I1 SD16GAINx = 32: shunt part number = BVO-M-R0002-5.0 (Isabellenhütte Heusler GmbH KG)



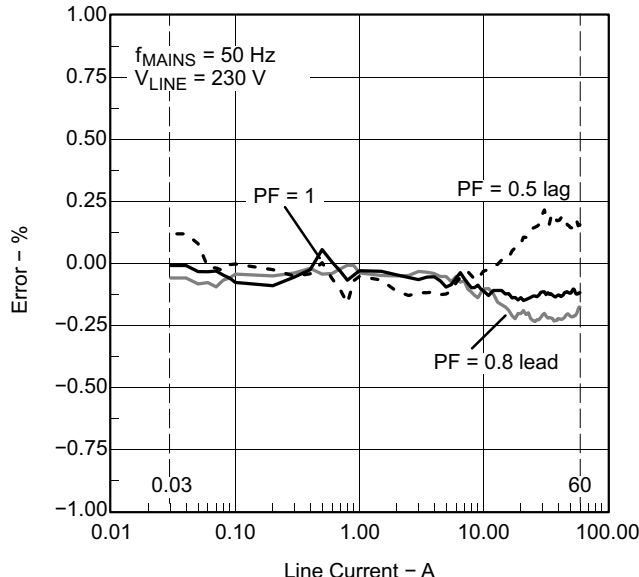
**Figure 5-14. Energy Measurement Test Circuitry (SD16GAINx = 1 or 4)**



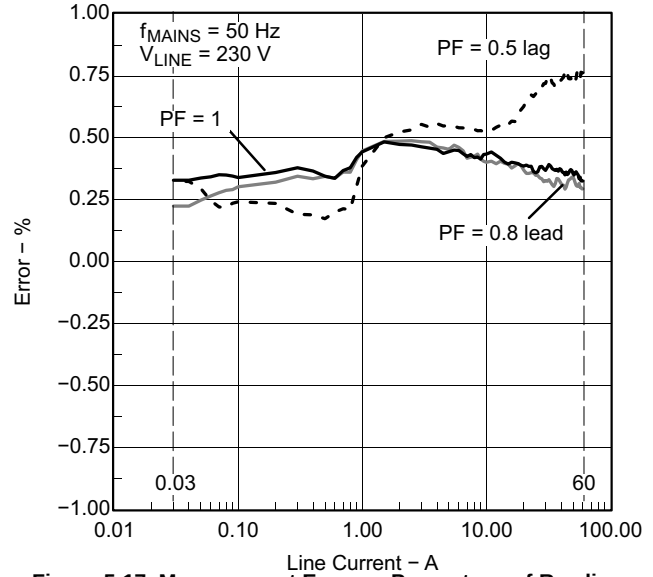
**Figure 5-15. Energy Measurement Test Circuitry (SD16GAINx = 8 or 32)**

## 5.29 ESP430CE1 Typical Characteristics (I1 SD16GAINx = 1)

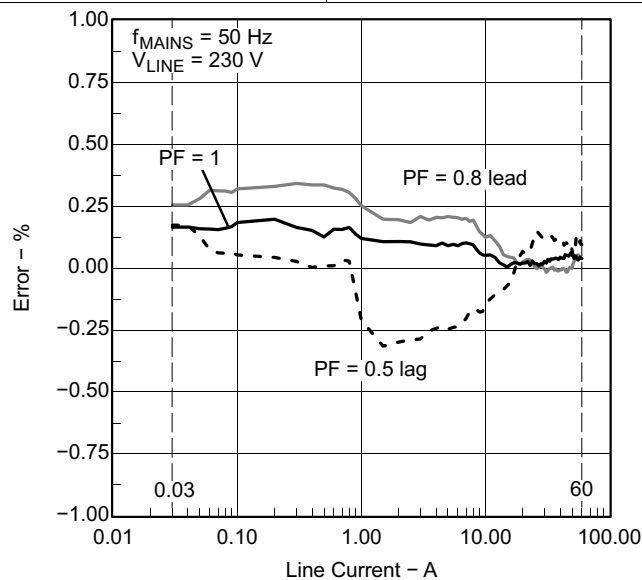
Results corrected for typical phase error of CT used ( $-40^{\circ}\text{C}$  to  $25^{\circ}\text{C}$ :  $-0.7^{\circ}$ ;  $25^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ :  $+0.5^{\circ}$ ). See [Figure 5-14](#) for test circuitry: CT part number = T60404-E4624-X101 (Vacuumschmelze),  $R_1 = 0\ \Omega$ ,  $R_B = 12.4\ \Omega$



**Figure 5-16. Measurement Error as Percentage of Reading ( $T_A = 25^{\circ}\text{C}$ )**



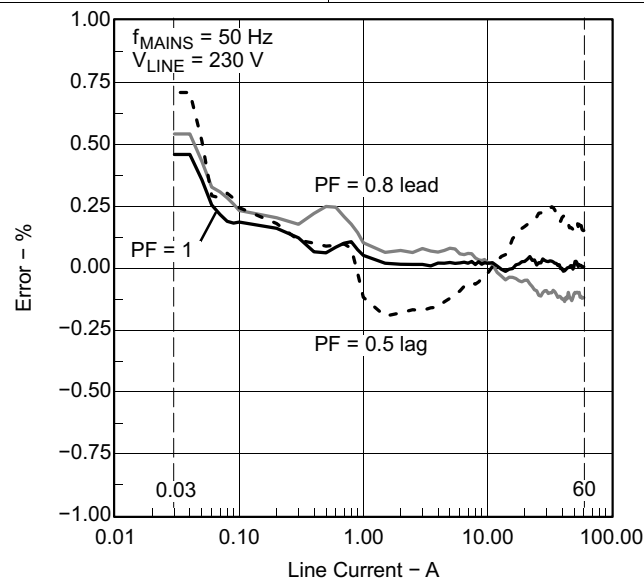
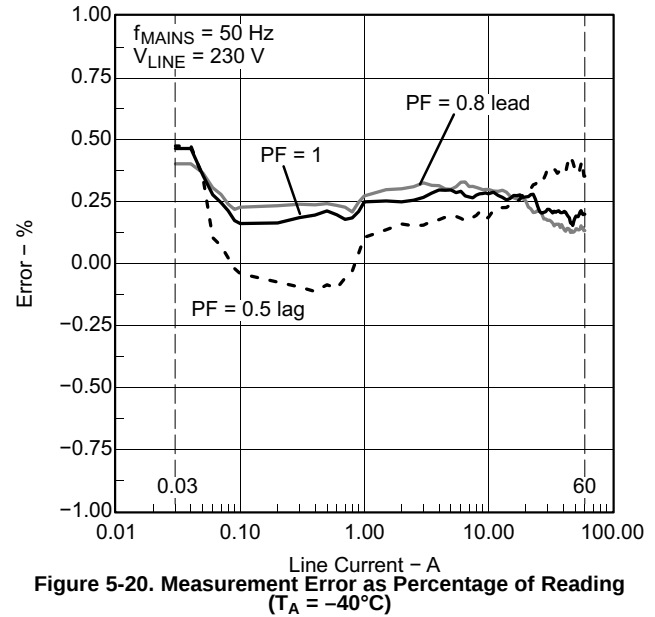
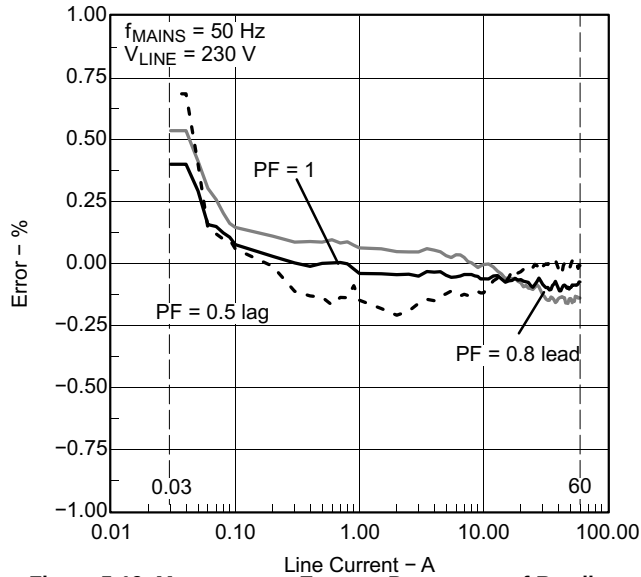
**Figure 5-17. Measurement Error as Percentage of Reading ( $T_A = -40^{\circ}\text{C}$ )**



**Figure 5-18. Measurement Error as Percentage of Reading ( $T_A = 85^{\circ}\text{C}$ )**

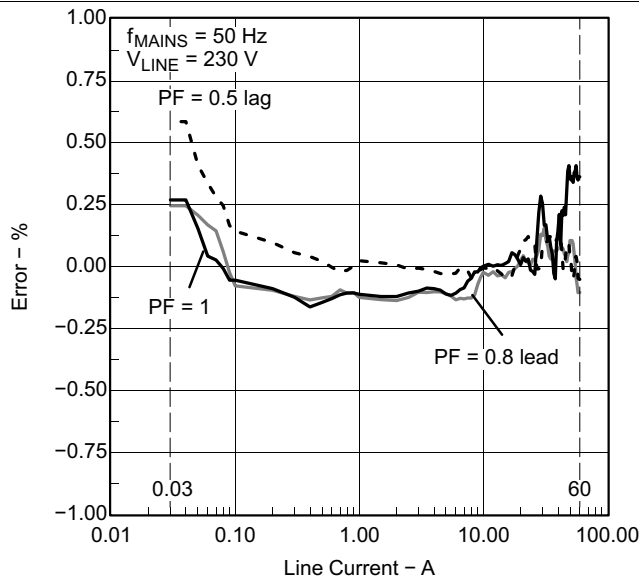
### 5.30 ESP430CE1 Typical Characteristics (I1 SD16GAINx = 4)

Results corrected for typical phase error of CT used ( $-40^{\circ}\text{C}$  to  $25^{\circ}\text{C}$ :  $-0.7^{\circ}$ ;  $25^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ :  $+0.5^{\circ}$ ). See [Figure 5-14](#) for test circuitry: CT part number = T60404-E4624-X101 (Vacuumschmelze),  $R_1 = 9.36\ \Omega$ ,  $R_B = 3.16\ \Omega$

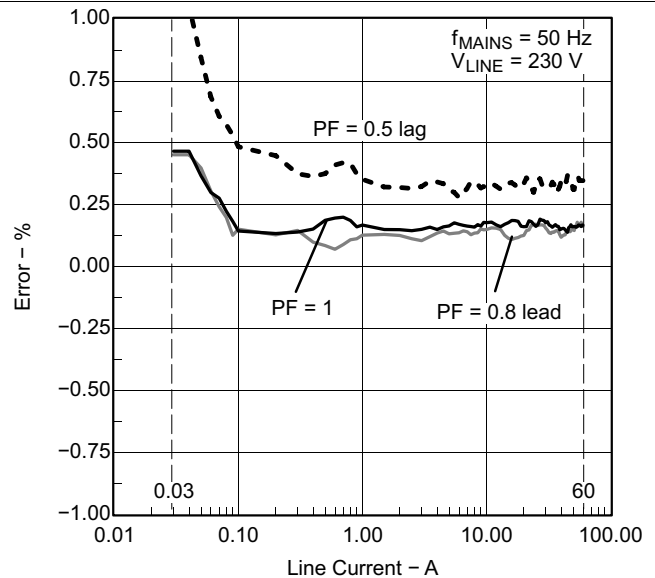


### 5.31 ESP430CE1 Typical Characteristics (I1 SD16GAINx = 8)

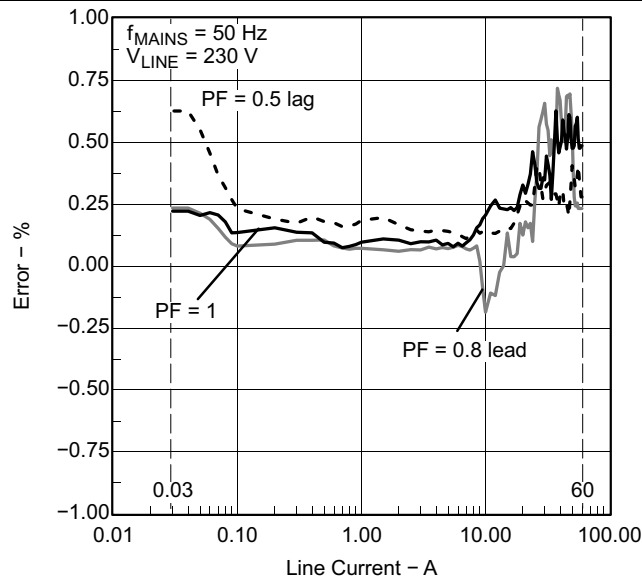
See [Figure 5-15](#) for test circuitry: shunt part number = A-H2-R005-F1-K2-0.1 (Isabellenhütte Heusler GmbH KG)



**Figure 5-22. Measurement Error as Percentage of Reading**  
( $T_A = 25^\circ\text{C}$ )



**Figure 5-23. Measurement Error as Percentage of Reading**  
( $T_A = -40^\circ\text{C}$ )



**Figure 5-24. Measurement Error as Percentage of Reading**  
( $T_A = 85^\circ\text{C}$ )

### 5.32 ESP430CE1 Typical Characteristics (I1 SD16GAINx = 32)

See [Figure 5-15](#) for test circuitry: shunt part number = BVO-M-R0002-5.0 (Isabellenhütte Heusler GmbH KG)

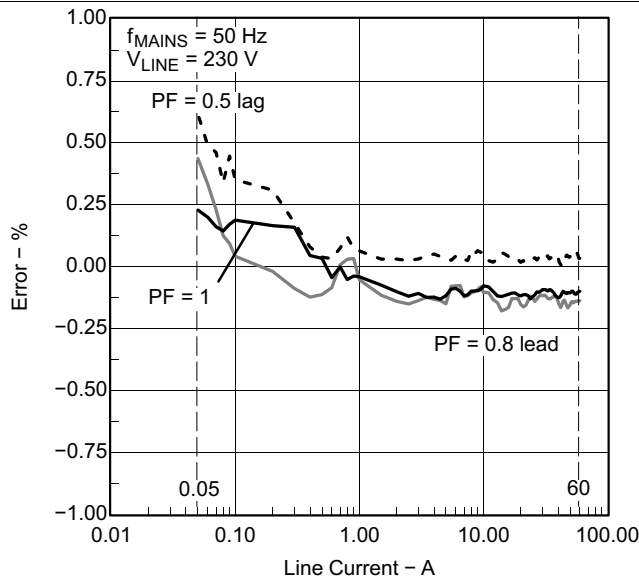


Figure 5-25. Measurement Error as Percentage of Reading ( $T_A = 25^\circ\text{C}$ )

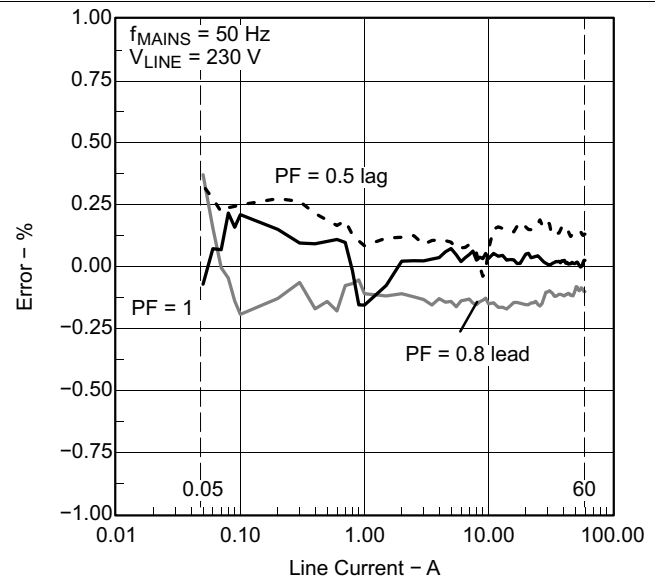


Figure 5-26. Measurement Error as Percentage of Reading ( $T_A = -40^\circ\text{C}$ )

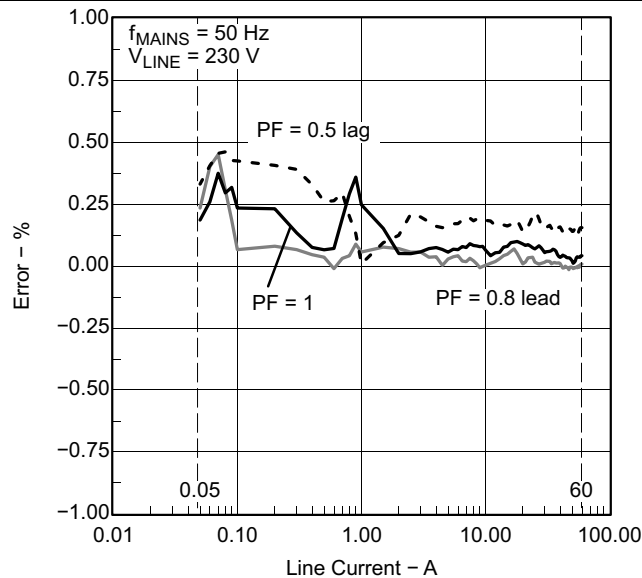


Figure 5-27. Measurement Error as Percentage of Reading ( $T_A = 85^\circ\text{C}$ )

### 5.33 Flash Memory

over recommended operating free-air temperature range (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                    |                       |                 | 2.7             |                 | 3.6 | V                |
| f <sub>FTG</sub>           | Flash timing generator frequency                    |                       |                 | 257             |                 | 476 | kHz              |
| I <sub>PGM</sub>           | Supply current from DV <sub>CC</sub> during program |                       | 2.7 V, 3.6 V    |                 | 3               | 5   | mA               |
| I <sub>ERASE</sub>         | Supply current from DV <sub>CC</sub> during erase   |                       | 2.7 V, 3.6 V    |                 | 3               | 7   | mA               |
| t <sub>CPT</sub>           | Cumulative program time                             | See <sup>(1)</sup>    | 2.7 V, 3.6 V    |                 |                 | 10  | ms               |
| t <sub>CMErase</sub>       | Cumulative mass erase time                          | See <sup>(2)</sup>    | 2.7 V, 3.6 V    | 200             |                 |     | 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>(3)</sup>    |                 |                 | 35              |     | t <sub>FTG</sub> |
| t <sub>Block, 0</sub>      | Block program time for first byte or word           |                       |                 |                 | 30              |     |                  |
| t <sub>Block, 1–63</sub>   | Block program time for each additional byte or word |                       |                 |                 | 21              |     |                  |
| t <sub>Block, End</sub>    | Block program end-sequence wait time                |                       |                 |                 | 6               |     |                  |
| t <sub>Mass Erase</sub>    | Mass erase time                                     |                       |                 |                 | 5297            |     |                  |
| t <sub>Seg Erase</sub>     | Segment erase time                                  |                       |                 |                 | 4819            |     |                  |

- (1) The cumulative program time must not be exceeded when writing to a 64-byte flash block. This parameter applies to all programming methods: individual word or byte write mode and block write mode.
- (2) The mass erase duration generated by the flash timing generator is at least 11.1 ms ( = 5297 × (1 / f<sub>FTG,max</sub>) = 5297 × (1 / 476 kHz)). To achieve the required cumulative mass erase time, the mass erase operation of the flash controller can be repeated until this time is met (a worst case minimum of 19 cycles is required).
- (3) These values are hardwired into the state machine of the flash controller (t<sub>FTG</sub> = 1 / f<sub>FTG</sub>).

### 5.34 JTAG Interface

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

| PARAMETER             |                                                  | TEST CONDITIONS    | V <sub>CC</sub> | MIN | TYP | MAX | UNIT |
|-----------------------|--------------------------------------------------|--------------------|-----------------|-----|-----|-----|------|
| f <sub>TCK</sub>      | TCK input frequency                              | See <sup>(1)</sup> | 2.2 V           | 0   |     | 5   | MHz  |
|                       |                                                  |                    | 3V              | 0   |     | 10  |      |
| R <sub>Internal</sub> | Internal pullup resistance on TMS, TCK, TDI/TCLK | See <sup>(2)</sup> | 2.2 V, 3 V      | 25  | 60  | 90  | kΩ   |

- (1) f<sub>TCK</sub> may be restricted to meet the timing requirements of the module selected.
- (2) TMS, TDI/TCLK, and TCK pullup resistors are implemented in all versions.

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

over recommended operating free-air temperature range (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 TDI/TCLK for fuse-blow       |                       | 6   | 7   | V    |
| I <sub>FB</sub>     | Supply current into TDI/TCLK during fuse blow |                       |     | 100 | mA   |
| t <sub>FB</sub>     | Time to blow fuse                             |                       |     | 1   | ms   |

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

## 6 Detailed Description

### 6.1 CPU

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

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

Four of the registers, R0 to R3, are dedicated as program counter, stack pointer, status register, and constant generator, respectively. The remaining registers are general-purpose registers (see [Figure 6-1](#)).

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

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

**Figure 6-1. CPU Registers**

## 6.2 Instruction Set

The instruction set consists of the original 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 and destination       | ADD R4,R5 | $R4 + R5 \rightarrow R5$                  |
| Single operand, destination only            | CALL R8   | $PC \rightarrow (TOS), R8 \rightarrow PC$ |
| Relative jump, unconditional or conditional | JNE       | Jump-on-equal bit = 0                     |

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

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

(1) S = source, D = destination

## 6.3 Operating Modes

The MSP430FE42x has 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 available to modules.
  - FLL+ loop control remains active.
- Low-power mode 1 (LPM1)
  - CPU is disabled.
  - ACLK and SMCLK remain active, MCLK available to modules.
  - FLL+ loop control is disabled.
- Low-power mode 2 (LPM2)
  - CPU is disabled.
  - MCLK, FLL+ loop control, and DCOCLK are disabled.
  - DC generator of the DCO remains enabled.
  - ACLK remains active.
- Low-power mode 3 (LPM3)
  - CPU is disabled.
  - MCLK, FLL+ loop control, and DCOCLK are disabled.
  - DC generator of the DCO is disabled.
  - ACLK remains active.
- Low-power mode 4 (LPM4)
  - CPU is disabled.
  - ACLK is disabled.
  - MCLK, FLL+ loop control, and DCOCLK are disabled.
  - DC generator of the DCO is disabled.
  - Crystal oscillator is stopped.

## 6.4 Interrupt Vector Addresses

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

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

| INTERRUPT SOURCE                                                                         | INTERRUPT FLAG                                                          | SYSTEM INTERRUPT                                               | WORD ADDRESS | PRIORITY    |
|------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|----------------------------------------------------------------|--------------|-------------|
| Power up<br>External reset<br>Watchdog<br>Flash memory<br>PC out of range <sup>(1)</sup> | WDTIFG<br>KEYV <sup>(2)</sup>                                           | Reset                                                          | 0FFFEh       | 15, highest |
| NMI oscillator fault<br>Flash memory access violation                                    | NMIIFG <sup>(2)</sup><br>OFIFG <sup>(2)</sup><br>ACCVIFG <sup>(2)</sup> | (Non)maskable <sup>(3)</sup><br>(Non)maskable<br>(Non)maskable | 0FFFCh       | 14          |
| ESP430                                                                                   | MBCTL_OUTxIFG,<br>MBCTL_INxIFG <sup>(2)(4)</sup>                        | Maskable                                                       | 0FFFAh       | 13          |
| SD16                                                                                     | SD16CCTLx SD16OVIFG,<br>SD16CCTLx SD16IFG <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                                                                                 | TACCR0 CCIFG <sup>(4)</sup>                                             | Maskable                                                       | 0FFECCh      | 6           |
| Timer_A3                                                                                 | TACCR1 and TACCR2<br>CCIFGs, and TACTL TAIFG <sup>(2)(4)</sup>          | Maskable                                                       | 0FFEAh       | 5           |
| I/O port P1 (8 flags)                                                                    | P1IFG.0 to P1IFG.7 <sup>(2)(4)</sup>                                    | Maskable                                                       | 0FFE8h       | 4           |
|                                                                                          |                                                                         |                                                                | 0FFE6h       | 3           |
|                                                                                          |                                                                         |                                                                | 0FFE4h       | 2           |
| I/O port P2 (8 flags)                                                                    | P2IFG.0 to P2IFG.7 <sup>(2)(4)</sup>                                    | Maskable                                                       | 0FFE2h       | 1           |
| Basic Timer1                                                                             | BTIFG                                                                   | Maskable                                                       | 0FFE0h       | 0, lowest   |

(1) A reset is generated if the CPU tries to fetch instructions from within the module register memory address range (0h–01FFh) or from within unused address ranges (0600h–0BFFh).

(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 in the lowest address space. Special-function register bits not allocated to a functional purpose are not physically present in the device. This arrangement provides simple software access.

### 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 shows the Interrupt Enable Register 1, and Table 6-4 describes the bit fields.

**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 Description**

| BITS | 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                                                                                                         |
| 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 shows the Interrupt Enable Register 2, and Table 6-5 describes the bit fields.

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

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

**Table 6-5. Interrupt Enable Register 2 Description**

| BITS | FIELD | TYPE | RESET | DESCRIPTION                   |
|------|-------|------|-------|-------------------------------|
| 7    | BTIE  | RW   | 0h    | Basic Timer1 interrupt enable |

Figure 6-4 shows the Interrupt Flag Register 1, and Table 6-6 describes the bit fields.

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

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

**Table 6-6. Interrupt Flag Register 1 Description**

| BITS | FIELD   | TYPE | RESET | DESCRIPTION                                                                                                                                                                         |
|------|---------|------|-------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7    | UTXIFG0 | RW   | 1h    | USART0: UART and SPI transmit flag                                                                                                                                                  |
| 6    | URXIFG0 | RW   | 0h    | USART0: UART and SPI receive flag                                                                                                                                                   |
| 4    | NMIIFG  | RW   | 0h    | Set by the $\overline{\text{RST}}$ /NMI pin                                                                                                                                         |
| 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 $V_{CC}$ power on or a reset condition at the $\overline{\text{RST}}$ /NMI pin in reset mode. |

Figure 6-5 shows the Interrupt Flag Register 2, and Table 6-7 describes the bit fields.

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

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

**Table 6-7. Interrupt Flag Register 2 Description**

| BITS | FIELD | TYPE | RESET | DESCRIPTION                 |
|------|-------|------|-------|-----------------------------|
| 7    | BTIFG | RW   | 0h    | Basic Timer1 interrupt flag |

Figure 6-6 shows the Module Enable Register 1, and Table 6-8 describes the bit fields.

**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 6-8. Module Enable Register 1 Description**

| BITS | 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 |

Module Enable Register 2 is not defined for the MSP430FE42x MCUs.

## 6.6 Memory Organization

Table 6-9 summarizes the memory map of the MSP430FE42x MCUs.

**Table 6-9. Memory Organization**

|                    |           | MSP430FE423   | MSP430FE425   | MSP430FE427   |
|--------------------|-----------|---------------|---------------|---------------|
| Memory             | Size      | 8KB           | 16KB          | 32KB          |
| Interrupt vector   | Flash     | 0FFFFh–0FFE0h | 0FFFFh–0FFE0h | 0FFFFh–0FFE0h |
| Code memory        | Flash     | 0FFFFh–0E000h | 0FFFFh–0C000h | 0FFFFh–08000h |
| Information memory | Size      | 256 Byte      | 256 Byte      | 256 Byte      |
|                    |           | 010FFh–01000h | 010FFh–01000h | 010FFh–01000h |
| Boot memory        | Size      | 1KB           | 1KB           | 1KB           |
|                    |           | 0FFFh–0C00h   | 0FFFh–0C00h   | 0FFFh–0C00h   |
| RAM                | Size      | 256 Byte      | 512 Byte      | 1KB           |
|                    |           | 02FFh–0200h   | 03FFh–0200h   | 05FFh–0200h   |
| Peripherals        | 16-bit    | 01FFh–0100h   | 01FFh–0100h   | 01FFh–0100h   |
|                    | 8-bit     | 0FFh–010h     | 0FFh–010h     | 0FFh–010h     |
|                    | 8-bit SFR | 0Fh–00h       | 0Fh–00h       | 0Fh–00h       |

## 6.7 Bootloader (BSL)

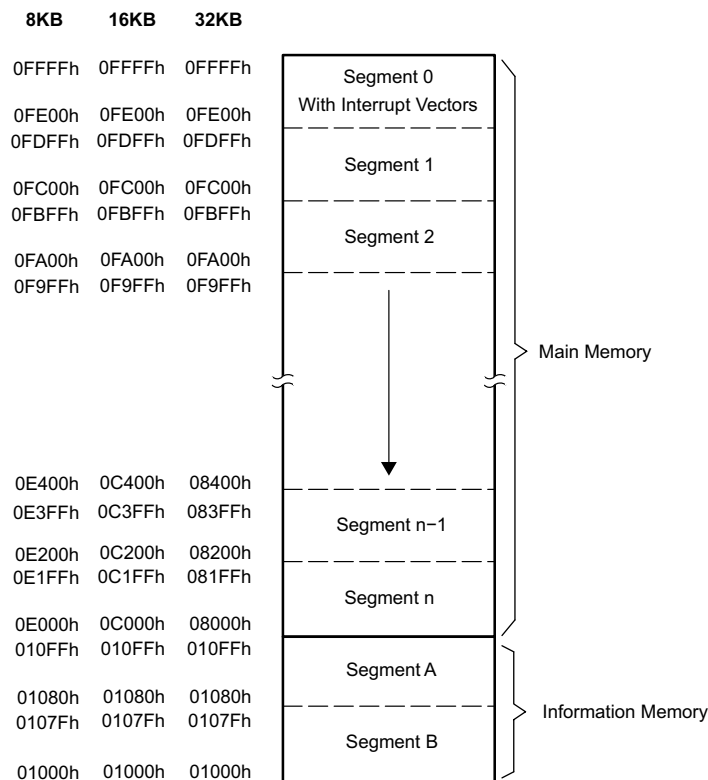
The MSP430 bootloader (BSL) enables users to program the flash memory or RAM using a UART serial interface. Access to the MSP430 memory through the BSL is protected by user-defined password. For complete description of the features of the BSL and its implementation, see [MSP430 Programming With the Bootloader \(BSL\)](#).

| BSL FUNCTION  | PM PACKAGE PINS |
|---------------|-----------------|
| Data transmit | 53 - P1.0       |
| Data receiver | 52 - P1.1       |

## 6.8 Flash Memory

The flash memory (see [Figure 6-7](#)) can be programmed using the JTAG port, the bootloader, or in system by the CPU. The CPU can perform single-byte and single-word writes to the flash memory. Features of the flash memory include:

- Flash memory has n segments of main memory and two segments of information memory (A and B) of 128 bytes each. Each segment in main memory is 512 bytes in size.
- Segments 0 to n may be erased in one step, or each segment may be individually erased.
- Segments A and B can be erased individually, or as a group with segments 0 to n. Segments A and B are also called *information memory*.
- New devices may have some bytes programmed in the information memory (needed for test during manufacturing). The user should perform an erase of the information memory before the first use.



**Figure 6-7. Flash Memory Map**

## 6.9 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 [MSP430x4xx Family User's Guide](#).

### 6.9.1 Oscillator and System Clock

The clock system is supported by the FLL+ module that includes support for a 32768-Hz watch crystal oscillator, an internal digitally controlled oscillator (DCO), and a high-frequency crystal oscillator. The FLL+ clock module is designed to meet the requirements of both low system cost and low power consumption. The FLL+ features digital frequency locked loop (FLL) hardware that, in conjunction with a digital modulator, stabilizes the DCO frequency to a programmable multiple of the watch crystal frequency. The internal DCO provides a fast turnon clock source and stabilizes in less than 6  $\mu$ s. The FLL+ module provides the following clock signals:

- Auxiliary clock (ACLK), sourced from a 32768-Hz watch crystal or a high-frequency crystal
- Main clock (MCLK), the system clock used by the CPU
- Sub-Main clock (SMCLK), the subsystem clock used by the peripheral modules
- ACLK/n, the buffered output of ACLK, ACLK/2, ACLK/4, or ACLK/8

### 6.9.2 Brownout, Supply Voltage Supervisor (SVS)

The brownout circuit provides the proper internal reset signal to the device during power on and power off. The SVS circuitry detects if the supply voltage drops below a user-selectable level and supports both supply voltage supervision (the device is automatically reset) and supply voltage monitoring (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 ensure that the default FLL+ 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  $V_{CC(min)}$ .

### 6.9.3 Digital I/O

Two I/O ports are implemented: ports P1 and P2 (only six P2 I/O signals are available on external pins).

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

---

#### NOTE

Six bits of port P2 (P2.0 to P2.5) are available on external pins, but all control and data bits for port P2 are implemented.

---

### 6.9.4 Basic Timer1

The Basic Timer1 has two independent 8-bit timers that can be cascaded to form a 16-bit timer/counter. Both timers can be read and written by software. The Basic Timer1 can be used to generate periodic interrupts and clock for the LCD module.

### 6.9.5 LCD Drive

The LCD driver generates the segment and common signals required to drive an LCD display. The LCD controller has dedicated data memory to hold segment drive information. Common and segment signals are generated as defined by the mode. Static, 2-mux, 3-mux, and 4-mux LCDs are supported by this peripheral.

### 6.9.6 Watchdog Timer (WDT+)

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

### 6.9.7 Timer\_A3

Timer\_A3 is a 16-bit timer and counter with three capture/compare registers. Timer\_A3 can support multiple capture/compares, PWM outputs, and interval timing (see [Table 6-10](#)). 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 6-10. Timer\_A3 Signal Connections**

| INPUT PIN NUMBER | DEVICE INPUT SIGNAL       | MODULE INPUT NAME | MODULE BLOCK | MODULE OUTPUT SIGNAL | OUTPUT PIN NUMBER |
|------------------|---------------------------|-------------------|--------------|----------------------|-------------------|
| 48 - P1.5        | TACLK                     | TACLK             | Timer        | NA                   |                   |
|                  | ACLK                      | ACLK              |              |                      |                   |
|                  | SMCLK                     | SMCLK             |              |                      |                   |
| 48 - P1.5        | $\overline{\text{TACLK}}$ | INCLK             |              |                      |                   |
| 53 - P1.0        | TA0                       | CCI0A             | CCR0         | TA0                  | 53 - P1.0         |
| 52 - P1.1        | TA0                       | CCI0B             |              |                      |                   |
|                  | DV <sub>SS</sub>          | GND               |              |                      |                   |
|                  | DV <sub>CC</sub>          | V <sub>CC</sub>   |              |                      |                   |
| 51 - P1.2        | TA1                       | CCI1A             | CCR1         | TA1                  | 51 - P1.2         |
| 51 - P1.2        | TA1                       | CCI1B             |              |                      |                   |
|                  | DV <sub>SS</sub>          | GND               |              |                      |                   |
|                  | DV <sub>CC</sub>          | V <sub>CC</sub>   |              |                      |                   |
| 45 - P2.0        | TA2                       | CCI2A             | CCR2         | TA2                  | 45 - P2.0         |
|                  | ACLK (internal)           | CCI2B             |              |                      |                   |
|                  | DV <sub>SS</sub>          | GND               |              |                      |                   |
|                  | DV <sub>CC</sub>          | V <sub>CC</sub>   |              |                      |                   |

### 6.9.8 USART0

The MSP430FE42x devices have one hardware universal synchronous/asynchronous receive transmit (USART0) peripheral module that is used for serial data communication. The USART supports synchronous SPI (3- or 4-pin) and asynchronous UART communication protocols, using double-buffered transmit and receive channels.

### 6.9.9 ESP430CE1

The ESP430CE1 module integrates a hardware multiplier, three independent 16-bit Sigma-Delta ADCs (SD16) and an embedded signal processor (ESP430). The ESP430CE1 module measures 2- or 3-wire single-phase energy and automatically calculates parameters which are made available to the MSP430 CPU. The module can be calibrated and initialized to accurately calculate energy, power factor, and other values for a wide range of metering sensor configurations.

## 6.9.10 Peripheral File Map

Table 6-11 and Table 6-12 list the peripheral registers with their addresses.

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

| MODULE                             | REGISTER NAME                          | ACRONYM | ADDRESS |
|------------------------------------|----------------------------------------|---------|---------|
| Watchdog                           | Watchdog timer control                 | WDTCTL  | 0120h   |
| Timer_A3                           | Timer0_A interrupt vector              | TA0IV   | 012Eh   |
|                                    | Timer0_A control                       | TACTL0  | 0160h   |
|                                    | Capture/compare control 0              | TACCTL0 | 0162h   |
|                                    | Capture/compare control 1              | TACCTL1 | 0164h   |
|                                    | Capture/compare control 2              | TACCTL2 | 0166h   |
|                                    | Reserved                               |         | 0168h   |
|                                    | Reserved                               |         | 016Ah   |
|                                    | Reserved                               |         | 016Ch   |
|                                    | Reserved                               |         | 016Eh   |
|                                    | Timer_A counter                        | TA0R    | 0170h   |
|                                    | Capture/compare 0                      | TACCR0  | 0172h   |
|                                    | Capture/compare 1                      | TACCR1  | 0174h   |
|                                    | Capture/compare 2                      | TACCR2  | 0176h   |
|                                    | Reserved                               |         | 0178h   |
|                                    | Reserved                               |         | 017Ah   |
|                                    | Reserved                               |         | 017Ch   |
|                                    | Reserved                               |         | 017Eh   |
| Hardware Multiplier <sup>(1)</sup> | 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                              | Flash control 3                        | FCTL3   | 012Ch   |
|                                    | Flash control 2                        | FCTL2   | 012Ah   |
|                                    | Flash control 1                        | FCTL1   | 0128h   |

(1) This module is contained within ESP430CE1. Registers are not accessible when ESP430 is active. ESP430 must be disabled or suspended to allow CPU access to these modules.

**Table 6-11. Peripherals With Word Access (continued)**

| MODULE                                                        | REGISTER NAME               | ACRONYM   | ADDRESS |
|---------------------------------------------------------------|-----------------------------|-----------|---------|
| SD16 <sup>(1)</sup><br>(also see <a href="#">Table 6-12</a> ) | General control             | SD16CTL   | 0100h   |
|                                                               | Channel 0 control           | SD16CCTL0 | 0102h   |
|                                                               | Channel 1 control           | SD16CCTL1 | 0104h   |
|                                                               | Channel 2 control           | SD16CCTL2 | 0106h   |
|                                                               | Reserved                    |           | 0108h   |
|                                                               | Reserved                    |           | 010Ah   |
|                                                               | Reserved                    |           | 010Ch   |
|                                                               | Reserved                    |           | 010Eh   |
|                                                               | Interrupt vector word       | SD16IV    | 0110h   |
|                                                               | Channel 0 conversion memory | SD16MEM0  | 0112h   |
|                                                               | Channel 1 conversion memory | SD16MEM1  | 0114h   |
|                                                               | Channel 2 conversion memory | SD16MEM2  | 0116h   |
|                                                               | Reserved                    |           | 0118h   |
|                                                               | Reserved                    |           | 011Ah   |
|                                                               | Reserved                    |           | 011Ch   |
|                                                               | Reserved                    |           | 011Eh   |
| ESP430 (ESP430CE1)                                            | ESP430 control              | ESPCTL    | 0150h   |
|                                                               | Mailbox control             | MBCTL     | 0152h   |
|                                                               | Mailbox in 0                | MBIN0     | 0154h   |
|                                                               | Mailbox in 1                | MBIN1     | 0156h   |
|                                                               | Mailbox out 0               | MBOUT0    | 0158h   |
|                                                               | Mailbox out 1               | MBOUT1    | 015Ah   |
|                                                               | ESP430 return value 0       | RET0      | 01C0h   |
|                                                               | ⋮                           | ⋮         | ⋮       |
|                                                               | ESP430 return value 31      | RET31     | 01FEh   |

**Table 6-12. Peripherals With Byte Access**

| MODULE                                                        | REGISTER NAME           | ACRONYM    | ADDRESS |
|---------------------------------------------------------------|-------------------------|------------|---------|
| SD16 <sup>(1)</sup><br>(also see <a href="#">Table 6-11</a> ) | Channel 0 input control | SD16INCTL0 | 0B0h    |
|                                                               | Channel 1 input control | SD16INCTL1 | 0B1h    |
|                                                               | Channel 2 input control | SD16INCTL2 | 0B2h    |
|                                                               | Reserved                |            | 0B3h    |
|                                                               | Reserved                |            | 0B4h    |
|                                                               | Reserved                |            | 0B5h    |
|                                                               | Reserved                |            | 0B6h    |
|                                                               | Reserved                |            | 0B7h    |
|                                                               | Channel 0 preload       | SD16PRE0   | 0B8h    |
|                                                               | Channel 1 preload       | SD16PRE1   | 0B9h    |
|                                                               | Channel 2 preload       | SD16PRE2   | 0BAh    |
|                                                               | Reserved                |            | 0BBh    |
|                                                               | Reserved                |            | 0BCh    |
|                                                               | Reserved                |            | 0BDh    |
|                                                               | Reserved                |            | 0BEh    |
|                                                               | Reserved                |            | 0BFh    |

(1) This module is contained within ESP430CE1. Registers are not accessible when ESP430 is active. ESP430 must be disabled or suspended to allow CPU access to these modules.

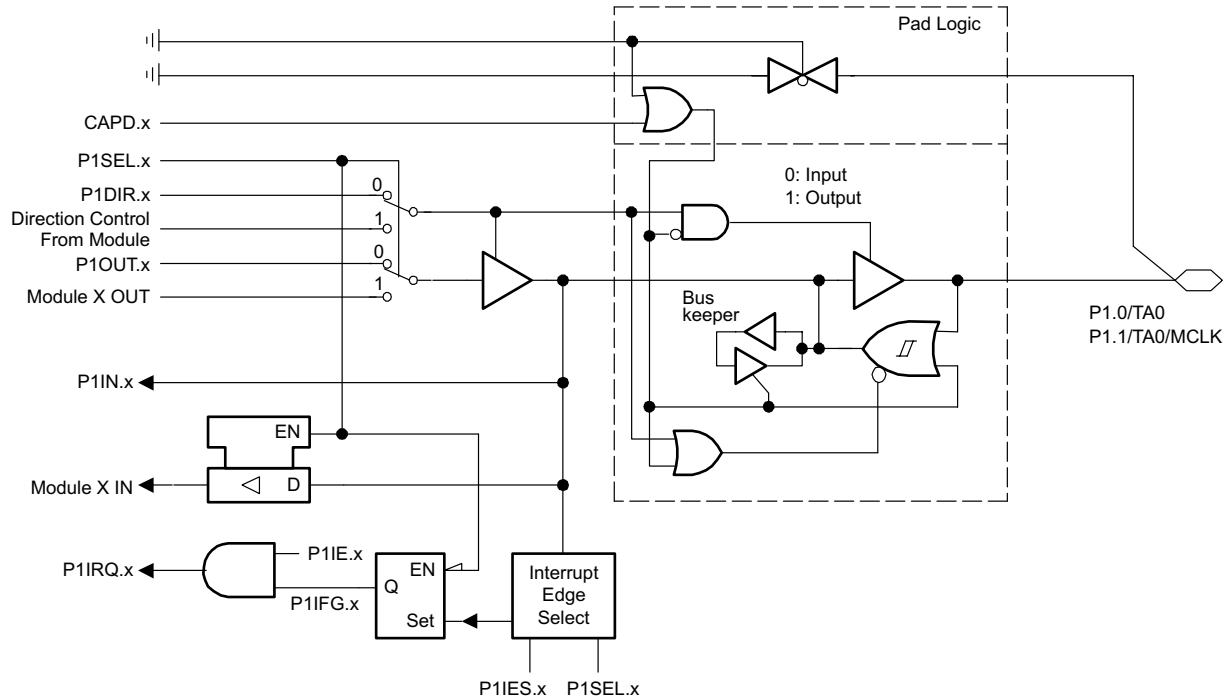
**Table 6-12. Peripherals With Byte Access (continued)**

| MODULE            | REGISTER NAME                     | ACRONYM  | ADDRESS |
|-------------------|-----------------------------------|----------|---------|
| LCD               | LCD memory 20                     | LCDM20   | 0A4h    |
|                   | ⋮                                 | ⋮        | ⋮       |
|                   | LCD memory 16                     | LCDM16   | 0A0h    |
|                   | LCD memory 15                     | LCDM15   | 09Fh    |
|                   | ⋮                                 | ⋮        | ⋮       |
|                   | LCD memory 1                      | LCDM1    | 091h    |
|                   | LCD control and mode              | LCDCTL   | 090h    |
| USART0            | Transmit buffer                   | U0TXBUF  | 077h    |
|                   | Receive buffer                    | U0RXBUF  | 076h    |
|                   | Baud rate 1                       | U0BR1    | 075h    |
|                   | Baud rate 0                       | U0BR0    | 074h    |
|                   | Modulation control                | U0MCTL   | 073h    |
|                   | Receive control                   | U0RCTL   | 072h    |
|                   | Transmit control                  | U0TCTL   | 071h    |
|                   | USART control                     | U0CTL    | 070h    |
| Brownout, SVS     | SVS control register              | SVSCTL   | 056h    |
| FLL+ Clock        | FLL+ control 1                    | FLL_CTL1 | 054h    |
|                   | FLL+ control 0                    | FLL_CTL0 | 053h    |
|                   | System clock frequency control    | SCFQCTL  | 052h    |
|                   | System clock frequency integrator | SCFI1    | 051h    |
|                   | System clock frequency integrator | SCFI0    | 050h    |
| Basic Timer1      | BT counter 2                      | BTCNT2   | 047h    |
|                   | BT counter 1                      | BTCNT1   | 046h    |
|                   | BT control                        | BTCTL    | 040h    |
| Port P2           | Port P2 selection                 | P2SEL    | 02Eh    |
|                   | Port P2 interrupt enable          | P2IE     | 02Dh    |
|                   | Port P2 interrupt-edge select     | P2IES    | 02Ch    |
|                   | Port P2 interrupt flag            | P2IFG    | 02Bh    |
|                   | Port P2 direction                 | P2DIR    | 02Ah    |
|                   | Port P2 output                    | P2OUT    | 029h    |
|                   | Port P2 input                     | P2IN     | 028h    |
| Port P1           | Port P1 selection                 | P1SEL    | 026h    |
|                   | Port P1 interrupt enable          | P1IE     | 025h    |
|                   | Port P1 interrupt-edge select     | P1IES    | 024h    |
|                   | Port P1 interrupt flag            | P1IFG    | 023h    |
|                   | Port P1 direction                 | P1DIR    | 022h    |
|                   | Port P1 output                    | P1OUT    | 021h    |
|                   | Port P1 input                     | P1IN     | 020h    |
| Special Functions | SFR module enable 2               | ME2      | 005h    |
|                   | SFR module enable 1               | ME1      | 004h    |
|                   | SFR interrupt flag 2              | IFG2     | 003h    |
|                   | SFR interrupt flag 1              | IFG1     | 002h    |
|                   | SFR interrupt enable 2            | IE2      | 001h    |
|                   | SFR interrupt enable 1            | IE1      | 000h    |

## 6.10 Input/Output Diagrams

### 6.10.1 Port P1 (P1.0 and P1.1) Input/Output With Schmitt Trigger

Figure 6-8 shows the port diagram. Table 6-13 summarizes the selection of the port function.



NOTE:  $0 \leq x \leq 1$ . Port function is active if CAPD.x = 0.

### Figure 6-8. Port P1 (P1.0 and P1.1) Diagram

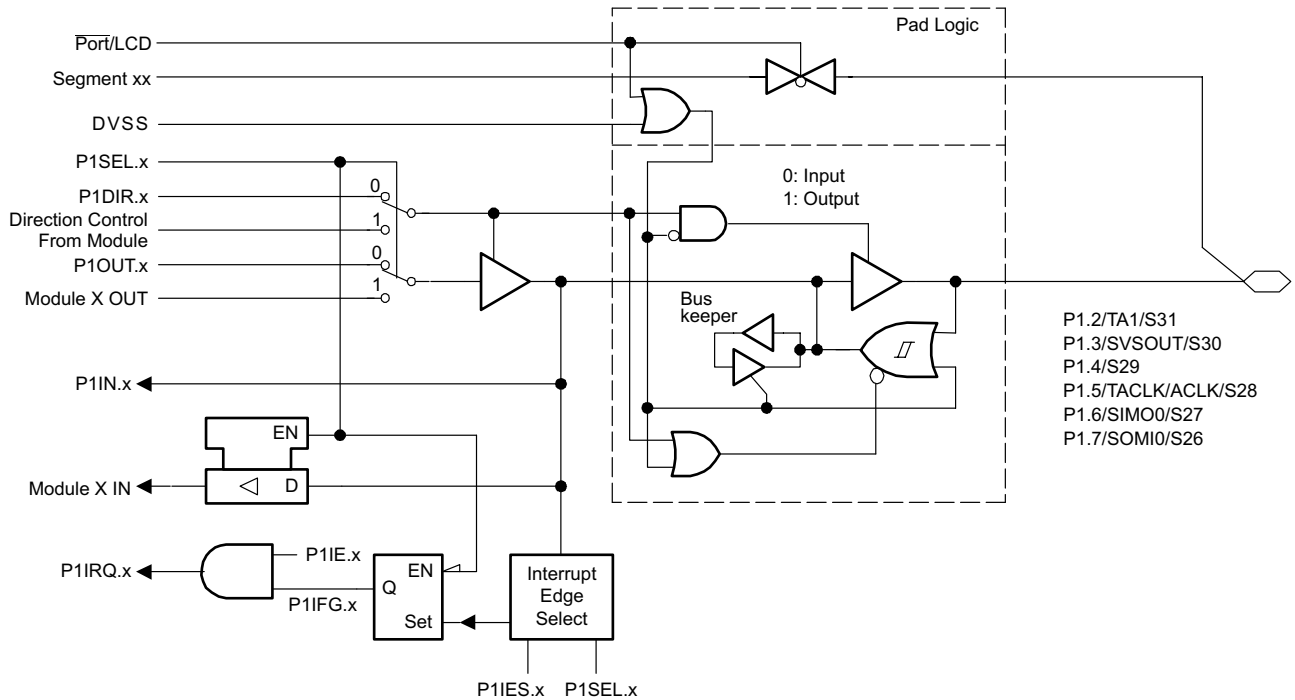
### Table 6-13. Port P1 (P1.0 and P1.1) Pin Function

| P1SEL.x | PnDIR.x | DIRECTION<br>CONTROL<br>FROM<br>MODULE | P1OUT.x | MODULE X<br>OUT          | P1IN.x | MODULE X<br>IN       | P1IE.x | P1IFG.x | P1IES.x | CAPD.x |
|---------|---------|----------------------------------------|---------|--------------------------|--------|----------------------|--------|---------|---------|--------|
| P1SEL.0 | P1DIR.0 | P1DIR.0                                | P1OUT.0 | Out0 Sig. <sup>(1)</sup> | P1IN.0 | CC10A <sup>(1)</sup> | P1IE.0 | P1IFG.0 | P1IES.0 | DVSS   |
| P1SEL.1 | P1DIR.1 | P1DIR.1                                | P1OUT.1 | MCLK                     | P1IN.1 | CC10B <sup>(1)</sup> | P1IE.1 | P1IFG.1 | P1IES.1 | DVSS   |

(1) Timer\_A3

### 6.10.2 Port P1 (P1.2 to P1.7) Input/Output With Schmitt Trigger

Figure 6-9 shows the port diagram. Table 6-14 summarizes the selection of the port function.



NOTE:  $2 \leq x \leq 7$ . Port function is active if  $\overline{\text{Port/LCD}} = 0$ .

Figure 6-9. Port P1 (P1.2 to P1.7) Diagram

Table 6-14. Port P1 (P1.2 to P1.7) Pin Functions

| P1SEL.x | P1DIR.x | DIRECTION CONTROL FROM MODULE | P1OUT.x | MODULE X OUT             | P1IN.x | MODULE X IN             | P1IE.x | P1IFG.x | P1IES.x | $\overline{\text{Port/LCD}}$      | SEGMENT |
|---------|---------|-------------------------------|---------|--------------------------|--------|-------------------------|--------|---------|---------|-----------------------------------|---------|
| P1SEL.2 | P1DIR.2 | P1DIR.2                       | P1OUT.2 | Out1 Sig. <sup>(1)</sup> | P1IN.2 | CCI1A†                  | P1IE.2 | P1IFG.2 | P1IES.2 | 0: LCDPx < 05h,<br>1: LCDPx ≥ 05h | S31     |
| P1SEL.3 | P1DIR.3 | P1DIR.3                       | P1OUT.3 | SVSOUT                   | P1IN.3 | unused                  | P1IE.3 | P1IFG.3 | P1IES.3 |                                   | S30     |
| P1SEL.4 | P1DIR.4 | P1DIR.4                       | P1OUT.4 | DVSS                     | P1IN.4 | unused                  | P1IE.4 | P1IFG.4 | P1IES.4 |                                   | S29     |
| P1SEL.5 | P1DIR.5 | P1DIR.5                       | P1OUT.5 | ACLK                     | P1IN.5 | TACLK <sup>(1)</sup>    | P1IE.5 | P1IFG.5 | P1IES.5 |                                   | S28     |
| P1SEL.6 | P1DIR.6 | DCM_SIMO                      | P1OUT.6 | SIMO0(o) <sup>(2)</sup>  | P1IN.6 | SIMO0(i) <sup>(2)</sup> | P1IE.6 | P1IFG.6 | P1IES.6 | 0: LCDPx < 04h,<br>1: LCDPx ≥ 04h | S27     |
| P1SEL.7 | P1DIR.7 | DCM_SOMI                      | P1OUT.7 | SOMI0(o) <sup>(2)</sup>  | P1IN.7 | SOMI0(i) <sup>(2)</sup> | P1IE.7 | P1IFG.7 | P1IES.7 |                                   | S26     |

(1) Timer\_A3

(2) USART0 (also see Figure 6-10)

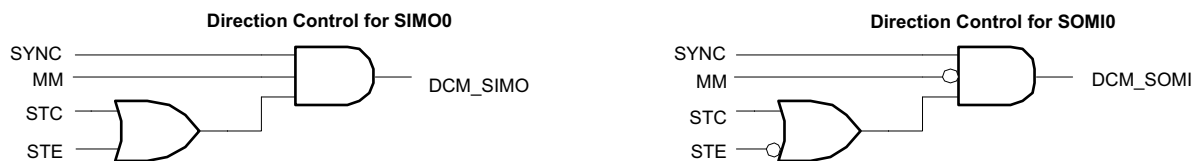
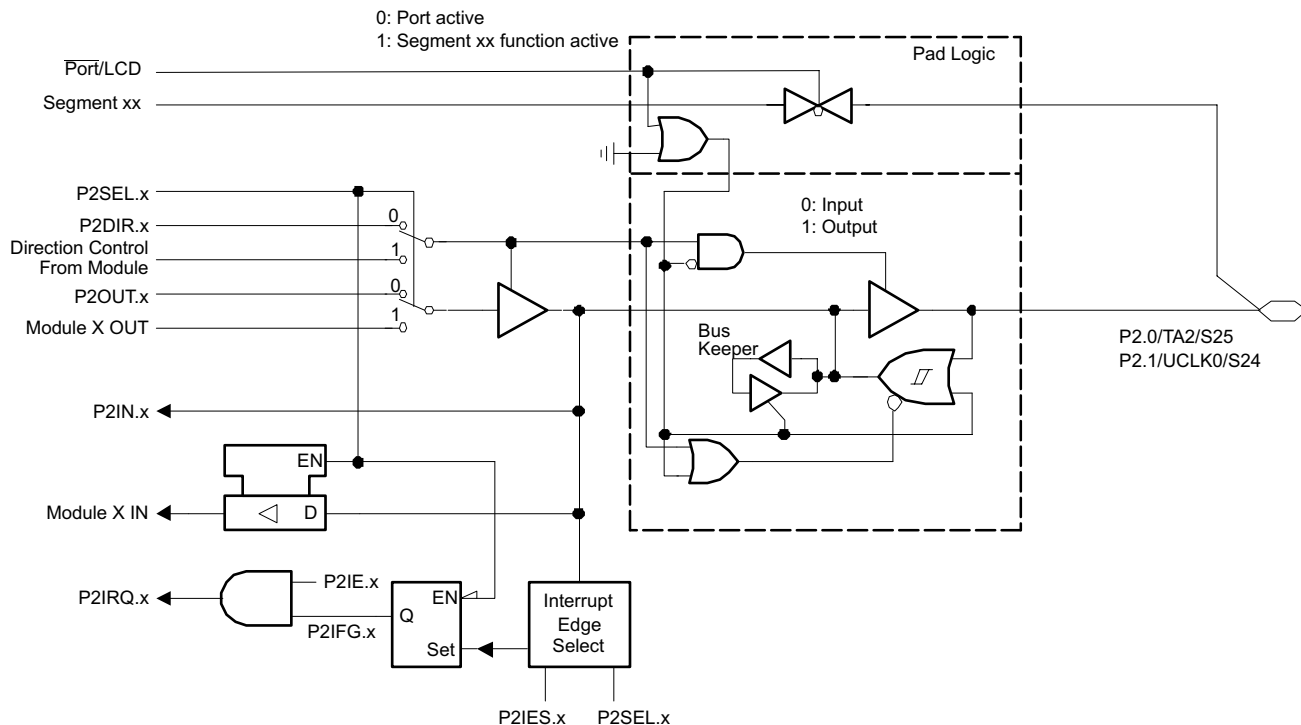


Figure 6-10. Direction Control for SIMO0 and SOMI0

### 6.10.3 Port P2 (P2.0 and P2.1) Input/Output With Schmitt Trigger

Figure 6-11 shows the port diagram. Table 6-15 summarizes the selection of the port function.



NOTE:  $0 \leq x \leq 1$ . Port function is active if  $\overline{\text{Port/LCD}} = 0$ .

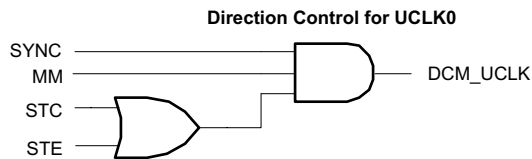
**Figure 6-11. Port P2 (P2.0 and P2.1) Diagram**

**Table 6-15. Port P2 (P2.0 and P2.1) Pin Functions**

| P2SEL.x | P2DIR.x | DIRECTION CONTROL FROM MODULE | P2OUT.x | MODULE X OUT             | P2IN.x | MODULE X IN             | P2IE.x | P2IFG.x | P2IES.x | $\overline{\text{Port/LCD}}$      | SEGMENT |
|---------|---------|-------------------------------|---------|--------------------------|--------|-------------------------|--------|---------|---------|-----------------------------------|---------|
| P2SEL.0 | P2DIR.0 | P2DIR.0                       | P2OUT.0 | Out2 Sig. <sup>(1)</sup> | P2IN.0 | CCI2A <sup>(1)</sup>    | P2IE.0 | P2IFG.0 | P2IES.0 | 0: LCDPx < 04h,<br>1: LCDPx ≥ 04h | S25     |
| P2SEL.1 | P2DIR.1 | DCM_UCLK                      | P2OUT.1 | UCLK0(o) <sup>(2)</sup>  | P2IN.1 | UCLK0(i) <sup>(2)</sup> | P2IE.1 | P2IFG.1 | P2IES.1 |                                   | S24     |

(1) Timer\_A3

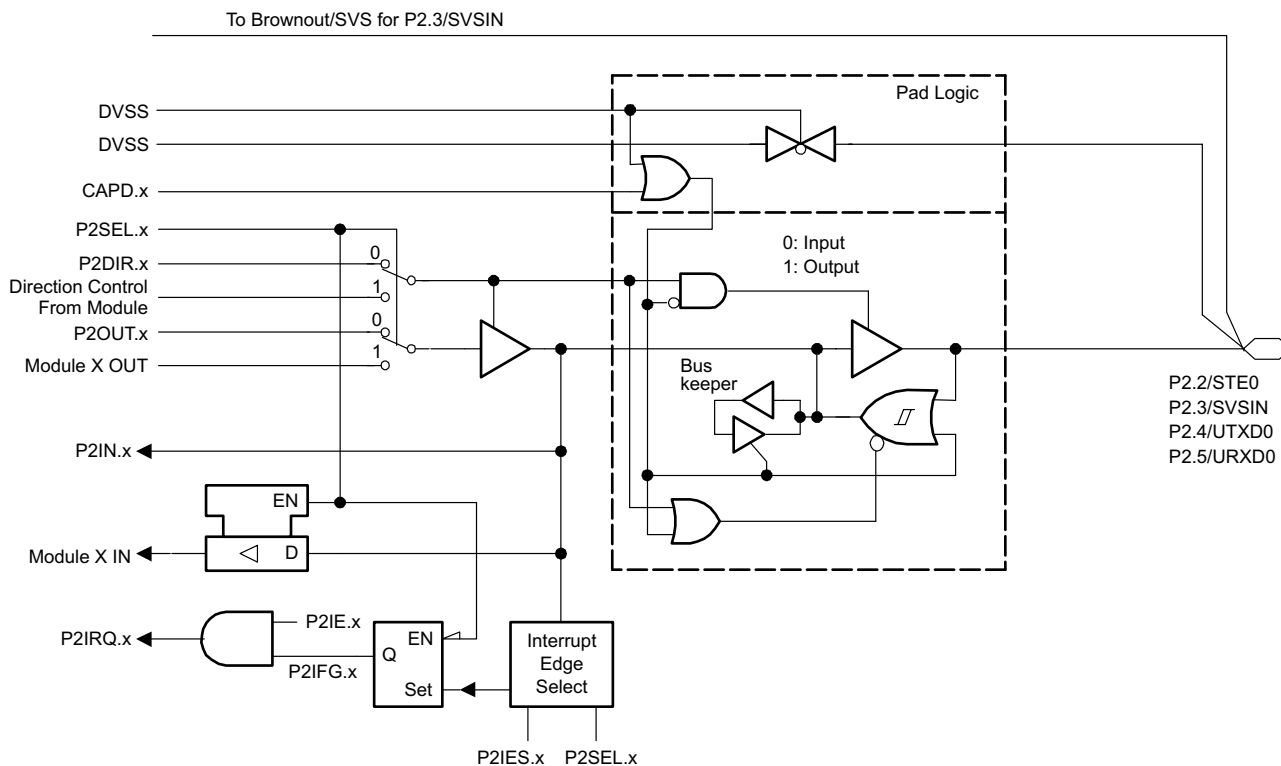
(2) USART0 (also see Figure 6-12)



**Figure 6-12. Direction Control for UCLK0**

#### 6.10.4 Port P2 (P2.2 to P2.5) Input/Output With Schmitt Trigger

Figure 6-13 shows the port diagram. Table 6-16 summarizes the selection of the port function.



NOTE:  $2 \leq x \leq 5$ . Port function is active if CAPD.x = 0

**Figure 6-13. Port P2 (P2.2 to P2.5) Diagram**

**Table 6-16. Port P2 (P2.2 to P2.5) Pin Functions**

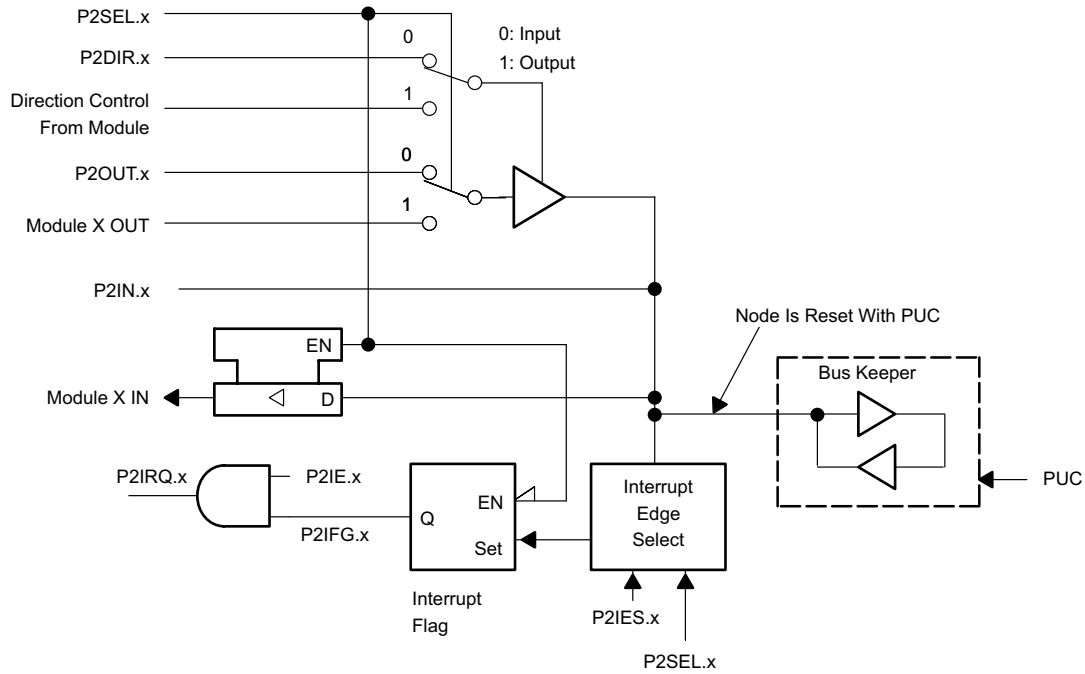
| P2SEL.x | P2DIR.x | DIRECTION CONTROL FROM MODULE | P2OUT.x | MODULE X OUT         | P2IN.x | MODULE X IN          | P2IE.x | P2IFG.x | P2IES.x | CAPD.x                |
|---------|---------|-------------------------------|---------|----------------------|--------|----------------------|--------|---------|---------|-----------------------|
| P2SEL.2 | P2DIR.2 | DVSS                          | P2OUT.2 | DVSS                 | P2IN.2 | STE0 <sup>(1)</sup>  | P2IE.2 | P2IFG.2 | P2IES.2 | DVSS                  |
| P2SEL.3 | P2DIR.3 | P2DIR.3                       | P2OUT.3 | DVSS                 | P2IN.3 | Unused               | P2IE.3 | P2IFG.3 | P2IES.3 | SVSCTL<br>VLD = 1111b |
| P2SEL.4 | P2DIR.4 | DVCC                          | P2OUT.4 | UTXD0 <sup>(1)</sup> | P2IN.4 | Unused               | P2IE.4 | P2IFG.4 | P2IES.4 | DVSS                  |
| P2SEL.5 | P2DIR.5 | DVSS                          | P2OUT.5 | DVSS                 | P2IN.5 | URXD0 <sup>(1)</sup> | P2IE.5 | P2IFG.5 | P2IES.5 | DVSS                  |

(1) USART0

### 6.10.5 Port P2 (P2.6 and P2.7) Unbonded GPIOs

Unbonded GPIOs P2.6 and P2.7 can be used as interrupt flags. Only software can affect the interrupt flags. They work as software interrupts.

Figure 6-14 shows the port diagram. Table 6-17 summarizes the selection of the port function.



NOTE: x = Bit/identifier, 6 or 7 for Port P2 without external pins

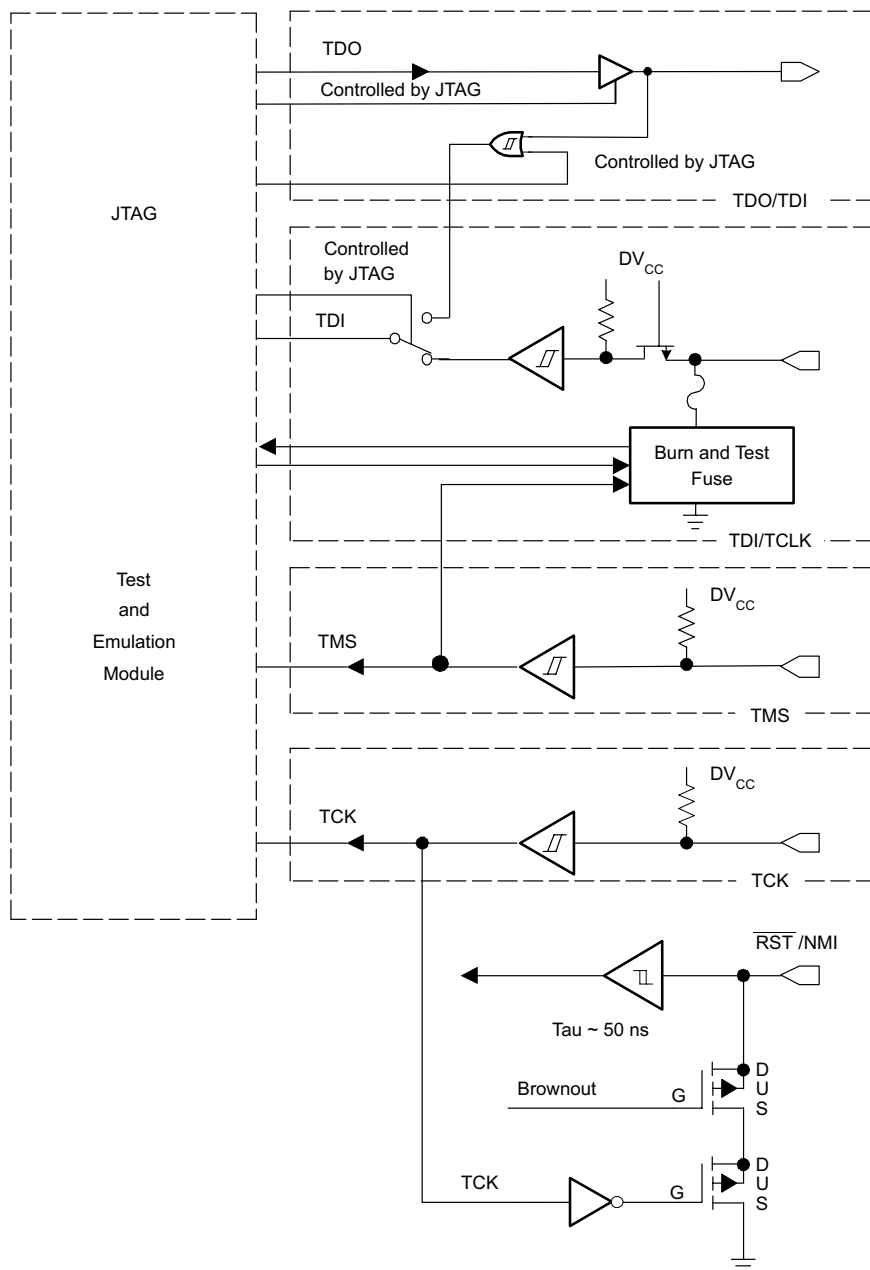
### Figure 6-14. Port P2 (P2.6 and P2.7) Diagram

### Table 6-17. Port P2 (P2.6 and P2.7) Pin Functions

| P2SEL.x | P2DIR.x | DIRECTION<br>CONTROL<br>FROM<br>MODULE | P2OUT.x | MODULE X<br>OUT | P2IN.x | MODULE X<br>IN | P2IE.x | P2IFG.x | P2IES.x |
|---------|---------|----------------------------------------|---------|-----------------|--------|----------------|--------|---------|---------|
| P2SEL.6 | P2DIR.6 | P2DIR.6                                | P2OUT.6 | DVSS            | P2IN.6 | Unused         | P2IE.6 | P2IFG.6 | P2IES.6 |
| P2SEL.7 | P2DIR.7 | P2DIR.7                                | P2OUT.7 | DVSS            | P2IN.7 | Unused         | P2IE.7 | P2IFG.7 | P2IES.7 |

### 6.10.6 JTAG Pins TMS, TCK, TDI/TCLK, TDO/TDI, Input/Output With Schmitt-Trigger or Output

Figure 6-15 shows the port diagram.



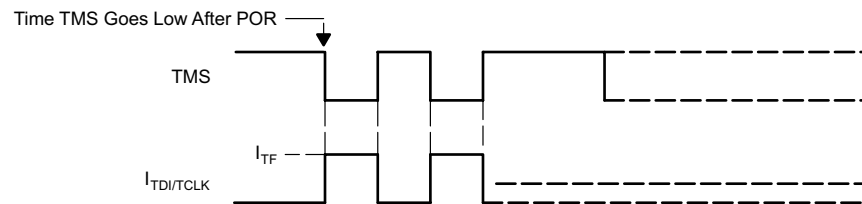
### Figure 6-15. JTAG Pins Diagram

### 6.10.7 JTAG Fuse Check Mode

MSP430 devices that have the fuse on the TDI/TCLK terminal have a fuse check mode that tests the continuity of the fuse the first time the JTAG port is accessed after a power-on reset (POR). When activated, a fuse check current ( $I_{TF}$ ) of 1.8 mA at 3 V can flow from the TDI/TCLK pin to ground if the fuse is not burned. Care must be taken to avoid accidentally activating the fuse check mode and increasing overall system power consumption.

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

The fuse check current flows only when the fuse check mode is active and the TMS pin is in a low state (see [Figure 6-16](#)). Therefore, the additional current flow can be prevented by holding the TMS pin high (default condition). The JTAG pins are terminated internally and therefore do not require external termination.



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

## 7 デバイスおよびドキュメントのサポート

### 7.1 使い始めと次の手順

MSP430ファミリのデバイス、および開発に役立つツールやライブラリの詳細については、「[使い始め](#)」ページを参照してください。

### 7.2 デバイスの項目表記

製品開発サイクルの段階を示すために、TIでは MSP430 MCU デバイスとサポート・ツールのすべての型番に接頭辞が割り当てられています。MSP430 MCU 商用ファミリの各番号には、MSP、PMS、XMS のいずれかの接頭辞があります。TIでは、サポート・ツールに使用可能な3つの接頭辞指定子のうち、MSPおよびMSPXの2つを推奨しています。これらの接頭辞は、エンジニアリング・プロトタイプ(デバイスではXMS、ツールではMSPX)から、完全に認定済みの量産版デバイスとツール(デバイスではMSP、ツールではMSP)まで、製品開発の段階を表しています。

デバイス開発の段階は次のとおりです。

**XMS** - 実験段階のデバイスで、デバイスの最終的な電氣的仕様を表しているとは限りません。

**MSP** - 完全に認定済みの量産版デバイスです。

サポート・ツール開発の段階は次のとおりです。

**MSPX** - TIの社内認定テストが完了していない開発サポート製品です。

**MSP** - 完全に認定済みの開発サポート製品です。

XMSデバイスとMSPX開発サポート・ツールは、次の免責事項付きで出荷されます。

「開発中の製品は、社内での評価用です。」

MSPデバイスとMSP開発サポート・ツールの特性は完全に明確化されており、デバイスの品質と信頼性が十分に示されています。TIの標準保証が適用されます。

プロトタイプ・デバイス(XMS)は標準の量産デバイスよりも故障率が高いことが予想されます。これらのデバイスは、予測される最終使用時の故障率が未定義であるため、TIはそれらのデバイスを量産システムで使用しないよう推奨しています。認定された量産デバイスのみを使用する必要があります。

TIデバイスの項目表記には、デバイス・ファミリ名の接尾辞も含まれます。この接尾辞は、パッケージの種類 (例: PZP) と温度範囲 (例: T) を示しています。[図 7-1](#) に、任意のファミリ・メンバについて、完全なデバイス名を読み取るための凡例を示します。

|                                      |                                                                                                                                |                                                                                                                                                                                                                                         |
|--------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <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>BT = Preprogrammed with <i>Bluetooth</i><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 Series = Up to 8 MHz<br>2 Series = Up to 16 MHz<br>3 Series = Legacy<br>4 Series = Up to 16 MHz with LCD                     | 5 Series = Up to 25 MHz<br>6 Series = Up to 25 MHz with LCD<br>0 = Low-Voltage Series                                                                                                                                                   |
| <b>Feature Set</b>                   | Various Levels of Integration Within a Series                                                                                  |                                                                                                                                                                                                                                         |
| <b>Optional: A = Revision</b>        | N/A                                                                                                                            |                                                                                                                                                                                                                                         |
| <b>Optional: Temperature Range</b>   | S = 0°C to 50°C<br>C = 0°C to 70°C<br>I = –40°C to 85°C<br>T = –40°C to 105°C                                                  |                                                                                                                                                                                                                                         |
| <b>Packaging</b>                     | <a href="http://www.ti.com/packaging">http://www.ti.com/packaging</a>                                                          |                                                                                                                                                                                                                                         |
| <b>Optional: Tape and Reel</b>       | T = Small Reel<br>R = Large Reel<br>No Markings = Tube or Tray                                                                 |                                                                                                                                                                                                                                         |
| <b>Optional: Additional Features</b> | -EP = Enhanced Product (–40°C to 105°C)<br>-HT = Extreme Temperature Parts (–55°C to 150°C)<br>-Q1 = Automotive Q100 Qualified |                                                                                                                                                                                                                                         |

NOTE: この図は、利用可能な機能とオプションの完全なリストではなく、与えられたデバイスまたはファミリについてこれらの機能とオプションのすべてが利用できることを示すものでもありません。

図 7-1. デバイスの項目表記 - 型番の読み方

## 7.3 ツールとソフトウェア

MSP430FE42xマイクロコントローラによりサポートされるデバッグ機能の一覧を、表 7-1に示します。利用可能な機能の詳細については、『[MSP430用Code Composer Studio ユーザー・ガイド](#)』を参照してください。

表 7-1. ハードウェアの特長

| MSP430アーキテクチャ | 4線式JTAG | 2線式JTAG | ブレーク・ポイント (N) | 範囲ブレーク・ポイント | クロック制御 | 状態シーケンサ | トレース・バッファ |
|---------------|---------|---------|---------------|-------------|--------|---------|-----------|
| MSP430        | ○       | ×       | 3             | ×           | グローバル  | ×       | ×         |

### 設計キットと評価モジュール

#### 64ピンのターゲット開発ボードとMSP-FETプログラマのバンドル: **MSP430F1x, MSP430F2x, MSP430F4x MCU**

MSP-FET430U64 は、強力なフラッシュ・エミュレーション・ツールで、MSP430 MCU 向けのアプリケーション開発をすぐに開始するために必要なハードウェアとソフトウェアが含まれています。この中には、ZIFソケット・ターゲット・ボード (MSP-TS430PM64) とUSBデバッグ・インターフェイス (MSP-FET) が含まれており、JTAG インターフェイス、またはピンを削減できるSpy-Bi-Wire (2線式のJTAG) プロトコルによる、イン・システムでのMSP430のプログラムとデバッグに使用できます。フラッシュ・メモリは、数回のキー操作により、数秒で消去およびプログラムできます。また、MSP430のフラッシュは消費電力が非常に低いため、外部電源は不要です。

### ソフトウェア

**MSP430x41x, MSP430F42xのサンプル・コード** C サンプル・コードは、各種のアプリケーションで使用するそれぞれのペリフェラルを設定します。またすべての MSP デバイスで使用できます。

**静電容量式タッチ・ソフトウェア・ライブラリ** MSP430 MCU で静電容量式タッチ機能を有効にするための、無償のCライブラリです。MSP430 MCU バージョンのライブラリには、ROおよびRC方式を含む、いくつかの静電容量式タッチ機能の実装が含まれています。

**MSPWareソフトウェア** MSPWareソフトウェアは、すべてのMSPデバイス用のサンプル・コード、データシート、その他の設計リソースを、1つの便利なパッケージとしてまとめたものです。既存のMSP設計リソースの完全なコレクションに加えて、MSPWareソフトウェアにはMSPドライバ・ライブラリと呼ばれる高レベルのAPIも含まれています。このライブラリにより、MSPハードウェアを簡単にプログラムできます。MSPWareソフトウェアはCCSのコンポーネントとして、またはスタンドアロンのパッケージとして入手できます。

**MSPドライバ・ライブラリ** MSPドライバ・ライブラリの抽象化されたAPIには、使いやすい関数呼び出しが含まれているため、MSP430ハードウェアのビットやバイトを直接操作する煩雑さから解放されます。使いやすいAPIガイドにより包括的な技術資料が参照でき、それぞれの関数呼び出しと、認識されるパラメータの詳細が記載されています。開発者は、ドライバ・ライブラリの関数を使用して、最小限のオーバーヘッドで完全なプロジェクトを作成できます。

**MSP EnergyTraceテクノロジー** MSP430マイクロコントローラ用のEnergyTraceテクノロジーは、エネルギーを基準としたコード解析ツールで、アプリケーションのエネルギー・プロファイルを測定して表示し、消費電力が極めて低くなるよう最適化するのに役立ちます。

**ULP (超低消費電力) Advisor** ULP Advisor™ソフトウェアは、MSPおよびMSP432マイクロコントローラの超低消費電力機能を十分に活用できる、最も効率的なコードを開発者が作成できるよう手引きするツールです。ULP Advisorはマイクロコントローラに熟練した開発者と、新しい開発者の両方を対象としており、包括的なULPチェックリストを使用してコードをチェックし、アプリケーションのエネルギー消費を最小化するため役立ちます。ビルド時に、消費電力低減のためさらに最適化が可能なコードの部分を明らかにするため通知と注釈を出力します。

**MSP用の固定小数点算術ライブラリ** MSP IQmathおよびQmathライブラリは、Cプログラマ向けの高度に最適化された高精度の算術関数のコレクションで、浮動小数点アルゴリズムをMSP430およびMSP432デバイスの固定小数点コード・ヘシームレスに移行できます。これらのルーチンは通常、最適な実行速度、高精度、超低消費電力が重視される、演算集中型のリアルタイム・アプリケーションで使用されます。IQmathライブラリとQmathライブラリを使用すると、浮動小数点演算を使用して記述した同等のコードに比べて、実行速度を大幅に高速化するとともに、消費電力の大幅な削減が可能です。

## 開発ツール

**Code Composer Studio™: MSPマイクロコントローラ用の統合開発環境** Code Composer Studio (CCS)は、すべてのMSPマイクロコントローラ・デバイスをサポートする統合開発環境(IDE)です。CCSは、組み込みアプリケーションの開発とデバッグに使用される、組み込み用ソフトウェア・ユーティリティのスイートです。CCSには、最適化C/C++コンパイラ、ソース・コード・エディタ、プロジェクトのビルド環境、デバッグ、プロファイラなど、多数の機能が含まれています。

**MSPWareソフトウェア** MSPWareソフトウェアは、すべてのMSPデバイス用のサンプル・コード、データシート、その他の設計リソースを、1つの便利なパッケージとしてまとめたものです。既存のMSP設計リソースの完全なコレクションに加えて、MSPWareソフトウェアにはMSPドライバ・ライブラリと呼ばれる高レベルのAPIも含まれています。このライブラリにより、MSPハードウェアを簡単にプログラムできます。MSPWareソフトウェアはCCSのコンポーネントとして、またはスタンドアロンのパッケージとして入手できます。

**コマンドライン・プログラマ** MSP Flasher は、FETプログラマまたは eZ430 を経由し、JTAG または Spy-Bi-Wire (SBW) 通信を使用して MSP マイクロコントローラをプログラムするための、オープン・ソースでシェルスクリプトのインターフェイスです。MSP Flasher は、IDE を使用せずにバイナリ・ファイル (.txt または .hex) を MSP マイクロコントローラへ直接ダウンロードできます。

**MSP MCUプログラマおよびデバッグ** MSP-FETは強力なエミュレーション開発ツールで、多くの場合にデバッグ・プローブと呼ばれます。ユーザーはこのツールを使用して、MSPの低消費電力MCUのアプリケーション開発をすぐに始めることができます。MCUのソフトウェアを作成する場合は通常、結果として得られたバイナリ・プログラムをMSPデバイスにダウンロードし、検証とデバッグを行う必要があります。

**MSP-GANG量産プログラマ** MSP Gang プログラマは MSP430 または MSP432 用のデバイス・プログラマで、8 つまでの同一の MSP430 または MSP432 のフラッシュまたは FRAM デバイスを同時にプログラムできます。MSP Gang プログラマは、標準の RS-232 または USB 接続を使用してホストPC と接続し、柔軟なプログラミング・オプションが用意されているため、ユーザーはプロセスを完全にカスタマイズ可能です。

## 7.4 ドキュメントのサポート

以下のドキュメントには、MSP430FE42x MCU についての解説が記載されています。これらのドキュメントのコピーは、[www.ti.com](http://www.ti.com) で入手できます。

### ドキュメントの更新通知を受け取る方法

ドキュメント更新の通知を、シリコンの正誤表も含めて受け取るには、[ti.com](http://ti.com) でお使いのデバイスの製品フォルダへ移動します(製品フォルダへのリンクについては、7.5を参照してください)。右上の隅にある「通知を受け取る」ボタンをクリックします。これによって登録が行われ、変更された製品情報の概要を毎週受け取ることができます。変更の詳細については、修正されたドキュメントに含まれている改訂履歴をご覧ください。

### 正誤表

『**MSP430FE427デバイス正誤表**』このデバイスにおけるシリコンの各リビジョンについて、機能仕様に関する既知の例外が記載されています。

『**MSP430FE425デバイス正誤表**』このデバイスにおけるシリコンの各リビジョンについて、機能仕様に関する既知の例外が記載されています。

『**MSP430FE423デバイス正誤表**』このデバイスにおけるシリコンの各リビジョンについて、機能仕様に関する既知の例外が記載されています。

### ユーザー・ガイド

『**MSP430x4xxファミリ・ユーザー・ガイド**』このデバイス・ファミリで利用可能なすべてのモジュールとペリフェラルについての詳細情報です。

『**ESP430CE1、ESP430CE1A、ESP430CE1Bペリフェラル・モジュール・ユーザー・ガイド**』ESP430CE1/1A/1B モジュールには、SD16、ハードウェア・マルチプライヤ、およびESP430組み込みプロセッサ・エンジンが内蔵されており、単相エネルギー計測アプリケーションで使用できます。

『**MSP430用Code Composer Studio v6.1 ユーザー・ガイド**』 このマニュアルは、TI Code Composer Studio IDE v6.1 (CCS v6.1)をMSP430超低消費電力マイクロコントローラで使用方法について解説しています。このマニュアルはCode Composer Studio IDEの Windows®バージョンのみを対象とします。Linux®バージョンの内容はほぼ同じであるため、別の記載はありません。

『**MSP430用IAR Embedded Workbenchバージョン3+ ユーザー・ガイド**』 このマニュアルは、IAR Embedded Workbench (EW430)をMSP430超低消費電力マイクロコントローラで使用方法について解説しています。

『**JTAGインターフェイスによるMSP430のプログラミング**』 このドキュメントでは、JTAG通信ポートを使用してMSP430のフラッシュ・ベースおよびFRAMベースのマイクロコントローラ・ファミリのメモリ・モジュールを消去、プログラム、検証するために必要な機能について解説しています。さらに、すべてのMSP430デバイスで利用可能なJTAGアクセス・セキュリティ・ヒューズのプログラム方法についても解説しています。このドキュメントには、標準の4線式JTAGインターフェイスと2線式JTAGインターフェイスの両方を使用してデバイスにアクセスする方法が解説されています。2線式JTAGインターフェイスはSpy-Bi-Wire (SBW)とも呼ばれます。

『**MSP430ハードウェア・ツール ユーザー・ガイド**』 このマニュアルには、TI MSP-FET430フラッシュ・エミュレーション・ツール(FET)のハードウェアについて解説されています。FETは、MSP430超低消費電力マイクロコントローラ用のプログラム開発ツールです。利用可能なインターフェイスとして、パラレル・ポート・インターフェイスとUSBインターフェイスの両方について解説されています。

#### アプリケーション・レポート

『**MSP430 32kHz水晶発振器**』 適切な水晶、正しい負荷回路、および適切な基板レイアウトの選択は、安定した水晶発振器のため重要です。このアプリケーション・レポートでは、水晶発振器の機能について要約し、MSP430の超低消費電力動作の適切な水晶を選択するためのパラメータについて説明します。また、正しい基板レイアウトについてのヒントや例も紹介しています。このドキュメントには、量産時の安定した発振器の動作を保証するために行うことができる、発振器のテストについての詳細情報も記載されています。

『**MSP430 システム・レベルESDの考慮事項**』 シリコン・テクノロジーがますます低電圧化し、コスト効率に優れ非常に消費電力の低いコンポーネントを設計する必要性が高まっていくにつれ、システム・レベルESDの要求はますます高くなりつつあります。このアプリケーション・レポートでは、基板設計者とOEMが堅牢なシステム・レベルのデザインを理解し設計できるよう、3種類の異なるESDトピックについて扱います。

『**MSP430とセグメントLCDを使用する設計**』 セグメント液晶ディスプレイ(LCD)は、スマート・メータから電氣的シェルフ・ラベル(ESL)や医療機器までの広範なアプリケーションで、ユーザーに情報を提示するため必要となります。MSP430™マイクロコントローラ・ファミリの中には、低電力のLCDドライバ回路を内蔵し、MSP430 MCUでセグメントLCDガラスを直接制御できるものもあります。このアプリケーション・ノートは以下の項目の補助的な説明を記載しています。セグメントLCDの動作、MSP430 MCUファミリにおける各種LCDモジュールの様々な機能、LCDハードウェアをレイアウトするコツ、効率的で使いやすいLCDドライバ・ソフトウェアの書き方のガイド、デバイス選択に役立つ、様々なLCD機能を含んだMSP430デバイスの製品ラインの概要。

『**MSP430のフラッシュ・データの保持について**』 幅広い製品ラインの一部であるMSP430マイクロコントローラ・ファミリには、読み取り専用メモリ(ROM)ベースおよびフラッシュ・ベース両方のデバイスがあります。MSP430フラッシュを理解することは、効率的で堅牢、かつ信頼できるシステムを設計するのに極めて重要です。データの保持は、フラッシュの信頼性の主要な要素の1つです。このアプリケーション・レポートでは、MSP430フラッシュのデータ保持について詳細に検討され、温度の影響が最重要とされています。

『**3V MSP430と5V回路とのインターフェイス**』 3VのMSP430x1xxおよびMSP430x4xxマイクロコントローラ・ファミリを、5Vまたはそれ以上の電源電圧を持つ回路と接続する方法について説明します。入力、出力、I/Oインターフェイスを示し、説明します。必要に応じて、ワーストケースの設計用の数式も説明されています。両方の電圧を生成するシンプルな電源もいくつか示します。

『**MSP430FE42x(A)/FE42x2による電子的なワット時メータの実装**』 このレポートには、MSP430FE42x(A)/FE42x2デバイスを使用して電子的なワット時メータを実装する方法が示されています。MSP430FE42x(A)およびMSP430FE42x2デバイスを使用するためのガイドラインや推奨事項も含まれています。また、リファレンス・ボードと、そのハードウェア詳細、およびソフトウェアの例も含まれています。

『**MSP430を使用した効率的な乗除**』 ハードウェア・マルチプライヤがない場合、乗除演算で多数の命令サイクルが必要になります(特にC言語の場合)。このレポートでは、ハードウェア・マルチプライヤを必要とせず、シフトと加算命令のみで乗除演算を可能とする手法について解説します。このアプリケーション・レポートで解説している方法は、ホーナー法に基づくものです。

## 7.5 関連リンク

表 7-2 に、クイック・アクセス・リンクの一覧を示します。カテゴリには、技術資料、サポートおよびコミュニティ・リソース、ツールとソフトウェア、およびサンプル注文またはご購入へのクイック・アクセスが含まれます。

表 7-2. 関連リンク

| 製品          | プロダクト・フォルダ              | サンプルとご購入                | 技術資料                    | ツールとソフトウェア              | サポートとコミュニティ             |
|-------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|
| MSP430FE427 | <a href="#">ここをクリック</a> | <a href="#">ここをクリック</a> | <a href="#">ここをクリック</a> | <a href="#">ここをクリック</a> | <a href="#">ここをクリック</a> |
| MSP430FE425 | <a href="#">ここをクリック</a> | <a href="#">ここをクリック</a> | <a href="#">ここをクリック</a> | <a href="#">ここをクリック</a> | <a href="#">ここをクリック</a> |
| MSP430FE423 | <a href="#">ここをクリック</a> | <a href="#">ここをクリック</a> | <a href="#">ここをクリック</a> | <a href="#">ここをクリック</a> | <a href="#">ここをクリック</a> |

## 7.6 Community Resources

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

### TI E2E™ Community

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

### TI Embedded Processors Wiki

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

## 7.7 商標

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Linux is a registered trademark of Linus Torvalds.

Windows is a registered trademark of Microsoft Corporation.

## 7.8 静電気放電に関する注意事項



すべての集積回路は、適切なESD保護方法を用いて、取扱いと保存を行うようにして下さい。

静電気放電はわずかな性能の低下から完全なデバイスの故障に至るまで、様々な損傷を与えます。高精度の集積回路は、損傷に対して敏感であり、極めてわずかなパラメータの変化により、デバイスに規定された仕様に適合しなくなる場合があります。

## 7.9 Export Control Notice

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## 7.10 用語集

**TI 用語集** この用語集には、用語や略語の一覧および定義が記載されています。

## 8 メカニカル、パッケージ、および注文情報

以下のページには、メカニカル、パッケージ、および注文情報が記載されています。これらの情報は、指定のデバイスに対して提供されている最新のデータです。このデータは予告なく変更されることがあり、ドキュメントが改訂される場合もあります。本データシートのブラウザ版を使用されている場合は、画面左側の説明をご覧ください。

## PACKAGING INFORMATION

| Orderable part number           | Status<br>(1) | Material type<br>(2) | Package   Pins | Package qty   Carrier   | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6) |
|---------------------------------|---------------|----------------------|----------------|-------------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| <a href="#">MSP430FE423IPM</a>  | Active        | Production           | LQFP (PM)   64 | 160   JEDEC TRAY (10+1) | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 85    | M430FE423           |
| MSP430FE423IPM.B                | Active        | Production           | LQFP (PM)   64 | 160   JEDEC TRAY (10+1) | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 85    | M430FE423           |
| <a href="#">MSP430FE423IPMR</a> | Active        | Production           | LQFP (PM)   64 | 1000   LARGE T&R        | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 85    | M430FE423           |
| MSP430FE423IPMR.B               | Active        | Production           | LQFP (PM)   64 | 1000   LARGE T&R        | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 85    | M430FE423           |
| <a href="#">MSP430FE425IPM</a>  | Active        | Production           | LQFP (PM)   64 | 160   JEDEC TRAY (10+1) | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 85    | M430FE425           |
| MSP430FE425IPM.B                | Active        | Production           | LQFP (PM)   64 | 160   JEDEC TRAY (10+1) | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 85    | M430FE425           |
| <a href="#">MSP430FE425IPMR</a> | Active        | Production           | LQFP (PM)   64 | 1000   LARGE T&R        | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 85    | M430FE425           |
| MSP430FE425IPMR.B               | Active        | Production           | LQFP (PM)   64 | 1000   LARGE T&R        | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 85    | M430FE425           |
| <a href="#">MSP430FE427IPM</a>  | Active        | Production           | LQFP (PM)   64 | 160   JEDEC TRAY (10+1) | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 85    | M430FE427           |
| MSP430FE427IPM.B                | Active        | Production           | LQFP (PM)   64 | 160   JEDEC TRAY (10+1) | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 85    | M430FE427           |
| <a href="#">MSP430FE427IPMR</a> | Active        | Production           | LQFP (PM)   64 | 1000   LARGE T&R        | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 85    | M430FE427           |
| MSP430FE427IPMR.B               | Active        | Production           | LQFP (PM)   64 | 1000   LARGE T&R        | Yes         | NIPDAU                               | Level-3-260C-168 HR               | -40 to 85    | M430FE427           |

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

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

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

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

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

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

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

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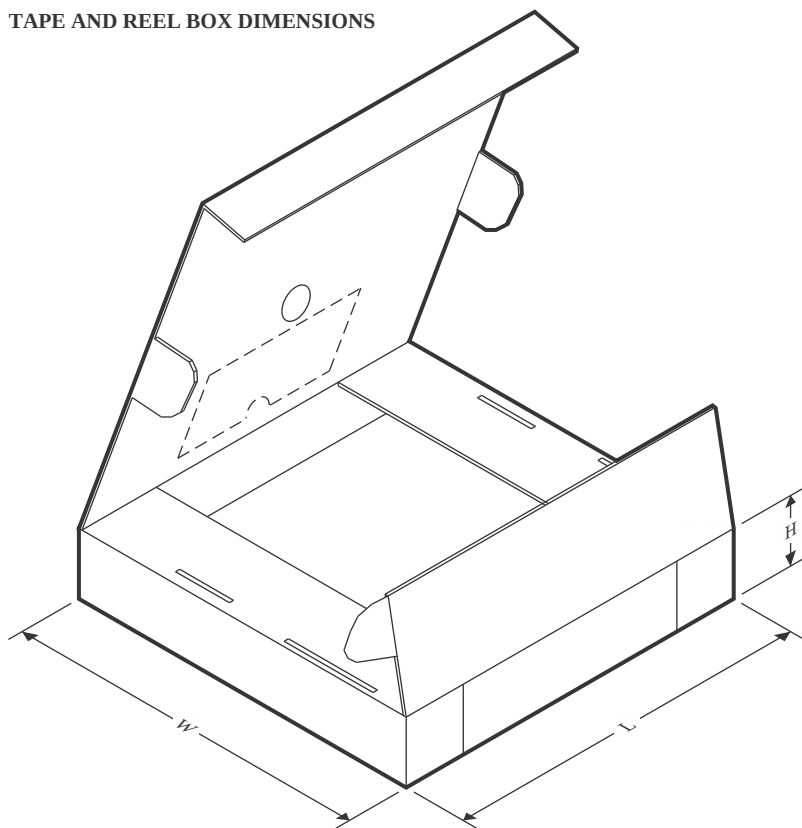
## TAPE AND REEL INFORMATION



\*All dimensions are nominal

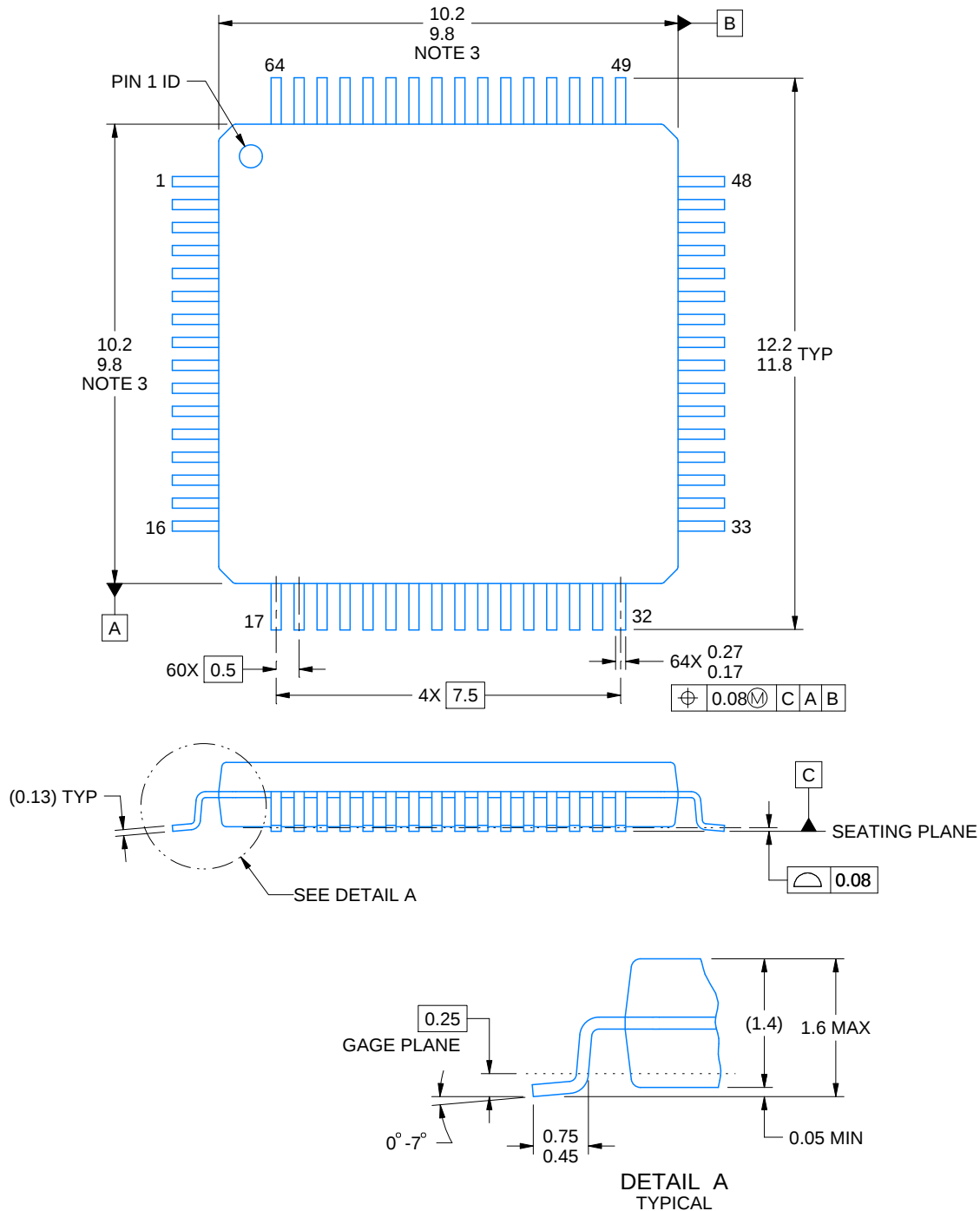
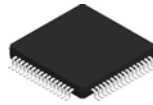
| Device          | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|-----------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| MSP430FE423IPMR | LQFP         | PM              | 64   | 1000 | 330.0              | 24.4               | 12.5    | 12.5    | 2.2     | 16.0    | 24.0   | Q2            |
| MSP430FE425IPMR | LQFP         | PM              | 64   | 1000 | 330.0              | 24.4               | 12.5    | 12.5    | 2.2     | 16.0    | 24.0   | Q2            |
| MSP430FE427IPMR | LQFP         | PM              | 64   | 1000 | 330.0              | 24.4               | 13.0    | 13.0    | 2.1     | 16.0    | 24.0   | Q2            |
| MSP430FE427IPMR | LQFP         | PM              | 64   | 1000 | 330.0              | 24.4               | 12.5    | 12.5    | 2.2     | 16.0    | 24.0   | Q2            |

## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

| Device          | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|-----------------|--------------|-----------------|------|------|-------------|------------|-------------|
| MSP430FE423IPMR | LQFP         | PM              | 64   | 1000 | 336.6       | 336.6      | 41.3        |
| MSP430FE425IPMR | LQFP         | PM              | 64   | 1000 | 336.6       | 336.6      | 41.3        |
| MSP430FE427IPMR | LQFP         | PM              | 64   | 1000 | 350.0       | 350.0      | 43.0        |
| MSP430FE427IPMR | LQFP         | PM              | 64   | 1000 | 336.6       | 336.6      | 41.3        |



4215162/A 03/2017

## NOTES:

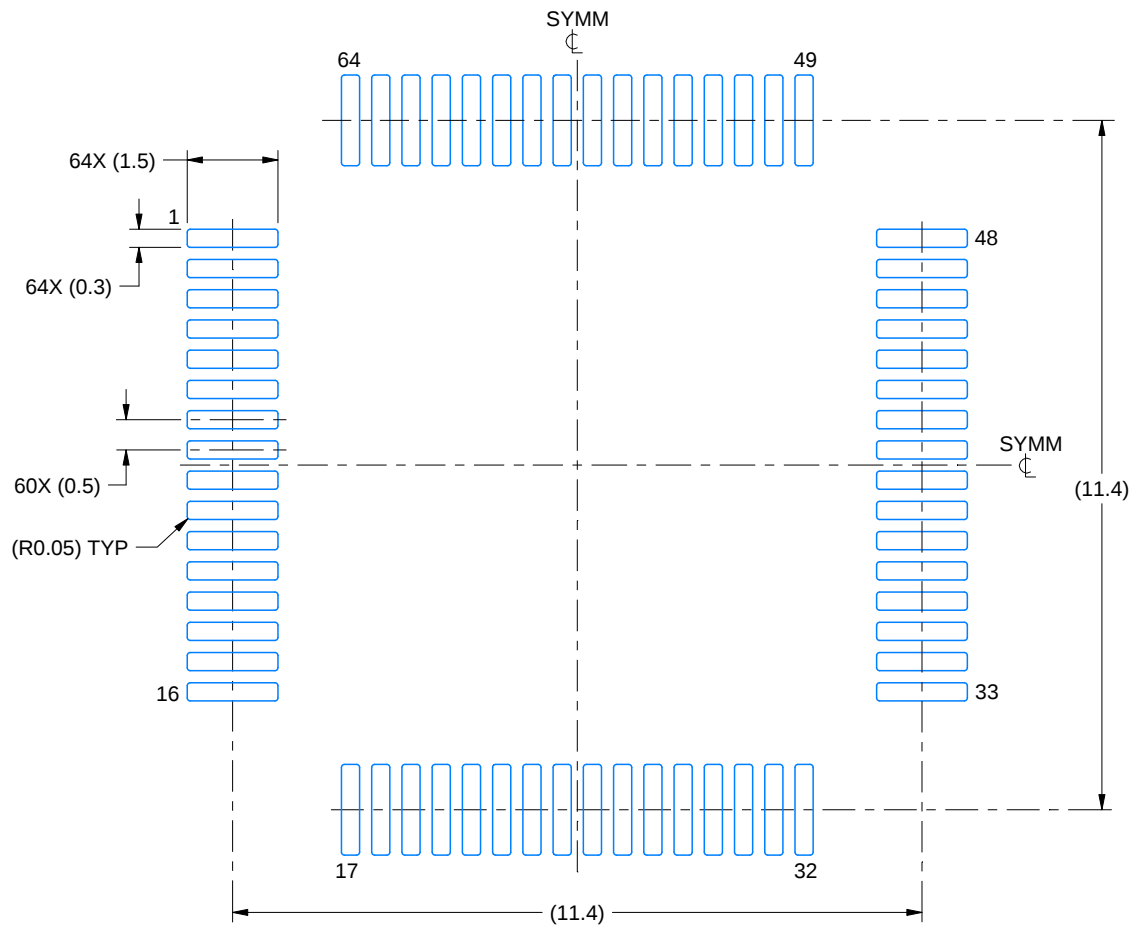
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. Reference JEDEC registration MS-026.

# EXAMPLE BOARD LAYOUT

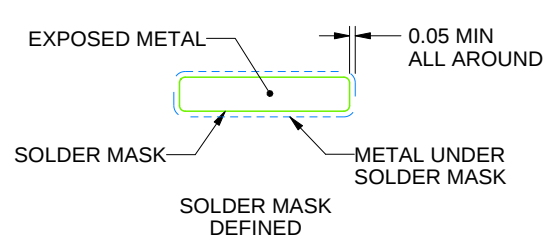
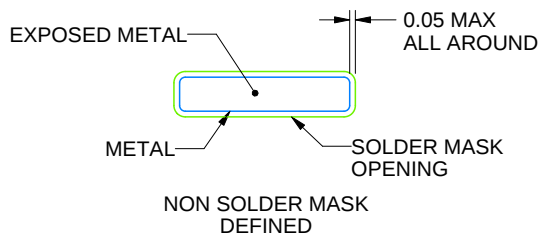
PM0064A

LQFP - 1.6 mm max height

PLASTIC QUAD FLATPACK



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:8X



SOLDER MASK DETAILS

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NOTES: (continued)

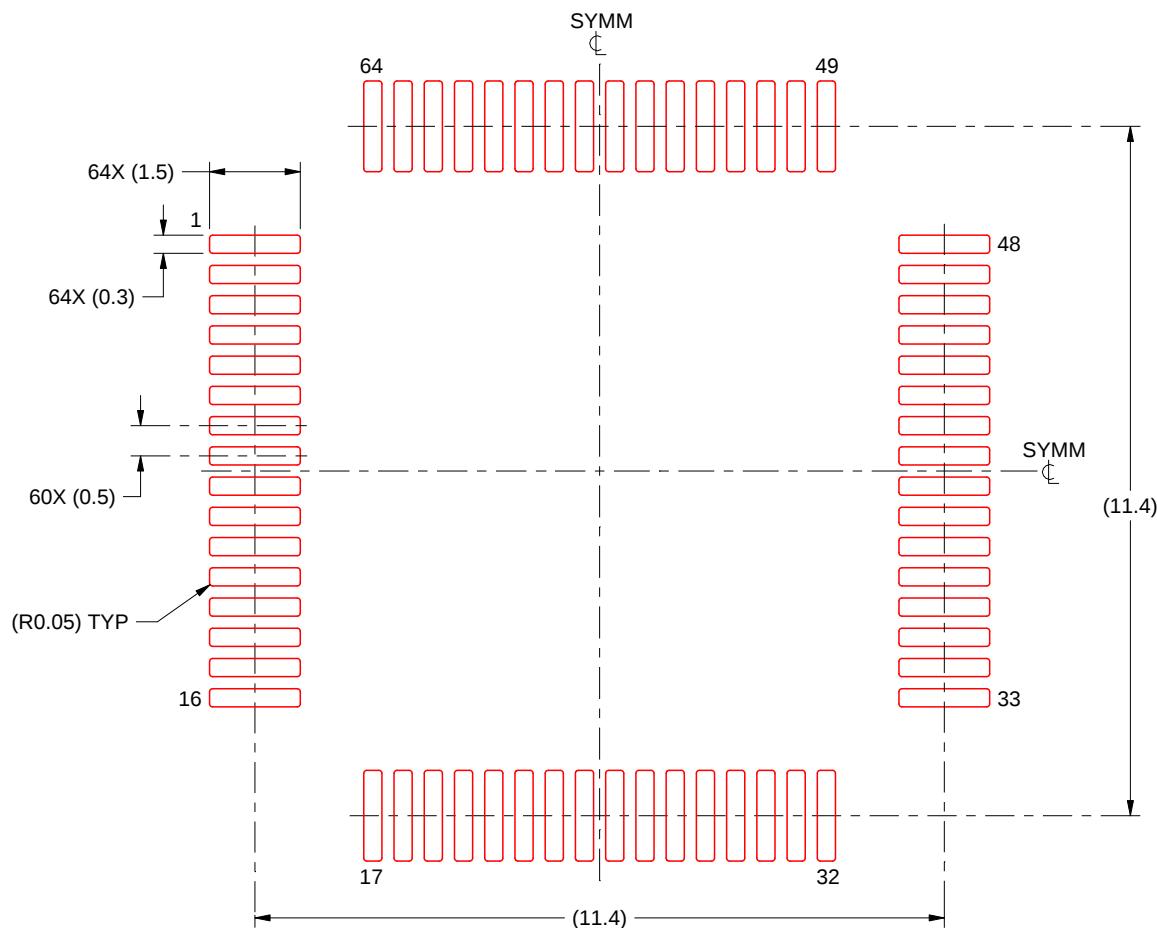
5. Publication IPC-7351 may have alternate designs.
6. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
7. For more information, see Texas Instruments literature number SLMA004 ([www.ti.com/lit/slma004](http://www.ti.com/lit/slma004)).

# EXAMPLE STENCIL DESIGN

PM0064A

LQFP - 1.6 mm max height

PLASTIC QUAD FLATPACK



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

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NOTES: (continued)

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

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