

## MIXED SIGNAL MICROCONTROLLER

### FEATURES

- **Low Supply Voltage Range: 1.8 V to 3.6 V**
- **Ultra-Low Power Consumption**
  - Active Mode: 250  $\mu$ A at 1 MHz, 2.2 V
  - Standby Mode: 0.7  $\mu$ A
  - Off Mode (RAM Retention): 0.1  $\mu$ A
- **Ultra-Fast Wake-Up From Standby Mode in Less Than 1  $\mu$ s**
- **16-Bit RISC Architecture, 62.5-ns Instruction Cycle Time**
- **Basic Clock Module Configurations**
  - Internal Frequencies up to 16 MHz With Four Calibrated Frequencies to  $\pm 1\%$
  - 32-kHz Crystal
  - High-Frequency Crystal up to 16 MHz
  - Resonator
  - External Digital Clock Source
- **16-Bit Timer\_A With Three Capture/Compare Registers**
- **On-Chip Comparator for Analog Signal Compare Function or Slope Analog-to-Digital (A/D) Conversion**
- **Brownout Detector**
- **Serial Onboard Programming, No External Programming Voltage Needed, Programmable Code Protection by Security Fuse**
- **Bootstrap Loader**
- **On Chip Emulation Module**
- **Family Members:**
  - **MSP430F2101**
    - 1KB + 256B Flash Memory
    - 128B RAM
  - **MSP430F2111**
    - 2KB + 256B Flash Memory
    - 128B RAM
  - **MSP430F2121**
    - 4KB + 256B Flash Memory
    - 256B RAM
  - **MSP430F2131**
    - 8KB + 256B Flash Memory
    - 256B RAM
- **Available in a 20-Pin Plastic Small-Outline Wide Body (SOWB) Package, 20-Pin Plastic Small-Outline Thin (TSSOP) Package, 20-Pin TVSOP Package, and 24-Pin QFN Package**
- **For Complete Module Descriptions, See the MSP430x2xx Family User's Guide ([SLAU144](#))**

### DESCRIPTION

The Texas Instruments MSP430 family of ultra-low-power microcontrollers consist of several devices featuring different sets of peripherals targeted for various applications. The architecture, combined with five low-power modes, is optimized to achieve extended battery life in portable measurement applications. The device features a powerful 16-bit RISC CPU, 16-bit registers, and constant generators that contribute to maximum code efficiency. The digitally controlled oscillator (DCO) allows wake-up from low-power modes to active mode in less than 1  $\mu$ s.

The MSP430x21x1 series is an ultra-low-power mixed signal microcontroller with a built-in 16-bit timer, versatile analog comparator, and sixteen I/O pins.

Typical applications include sensor systems that capture analog signals, convert them to digital values, and then process the data for display or for transmission to a host system. Stand-alone RF sensor front end is another area of application. The analog comparator provides slope A/D conversion capability.



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

**Table 1. Available Options**

| $T_A$          | PACKAGED DEVICES               |                                 |                                  |                                |
|----------------|--------------------------------|---------------------------------|----------------------------------|--------------------------------|
|                | PLASTIC<br>20-PIN SOWB<br>(DW) | PLASTIC<br>20-PIN TSSOP<br>(PW) | PLASTIC<br>20-PIN TVSOP<br>(DGV) | PLASTIC<br>24-PIN QFN<br>(RGE) |
| -40°C to 85°C  | MSP430F2101IDW                 | MSP430F2101IPW                  | MSP430F2101IDGV                  | MSP430F2101IRGE                |
|                | MSP430F2111IDW                 | MSP430F2111IPW                  | MSP430F2111IDGV                  | MSP430F2111IRGE                |
|                | MSP430F2121IDW                 | MSP430F2121IPW                  | MSP430F2121IDGV                  | MSP430F2121IRGE                |
|                | MSP430F2131IDW                 | MSP430F2131IPW                  | MSP430F2131IDGV                  | MSP430F2131IRGE                |
| -40°C to 105°C | MSP430F2101TDW                 | MSP430F2101TPW                  | MSP430F2101TDGV                  | MSP430F2101TRGE                |
|                | MSP430F2111TDW                 | MSP430F2111TPW                  | MSP430F2111TDGV                  | MSP430F2111TRGE                |
|                | MSP430F2121TDW                 | MSP430F2121TPW                  | MSP430F2121TDGV                  | MSP430F2121TRGE                |
|                | MSP430F2131TDW                 | MSP430F2131TPW                  | MSP430F2131TDGV                  | MSP430F2131TRGE                |

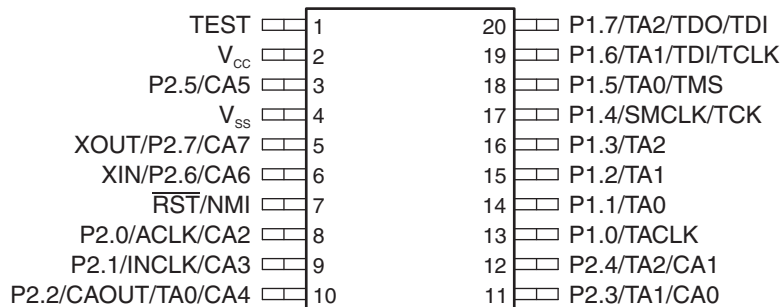
### Development Tool Support

All MSP430 microcontrollers include an Embedded Emulation Module (EEM) that allows advanced debugging and programming through easy-to-use development tools. Recommended hardware options include:

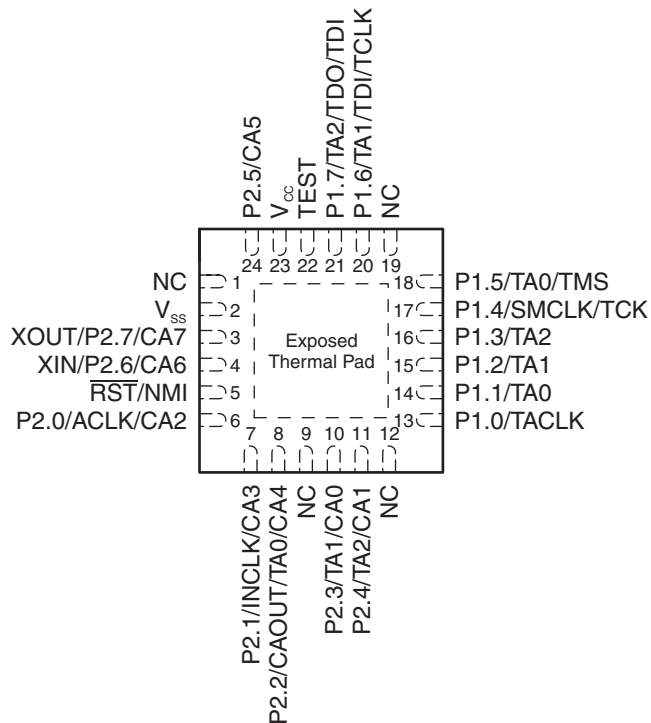
- Debugging and Programming Interface with Target Board
  - MSP-FET430U28 (PW package)
- Debugging and Programming Interface
  - MSP-FET430UIF (USB)
  - MSP-FET430PIF (Parallel Port)
- Target Board
  - MSP-TS430PW28 (PW package)
- Production Programmer
  - MSP-GANG430

## Device Pinout

**DW, PW, or DGV PACKAGE  
(TOP VIEW)**

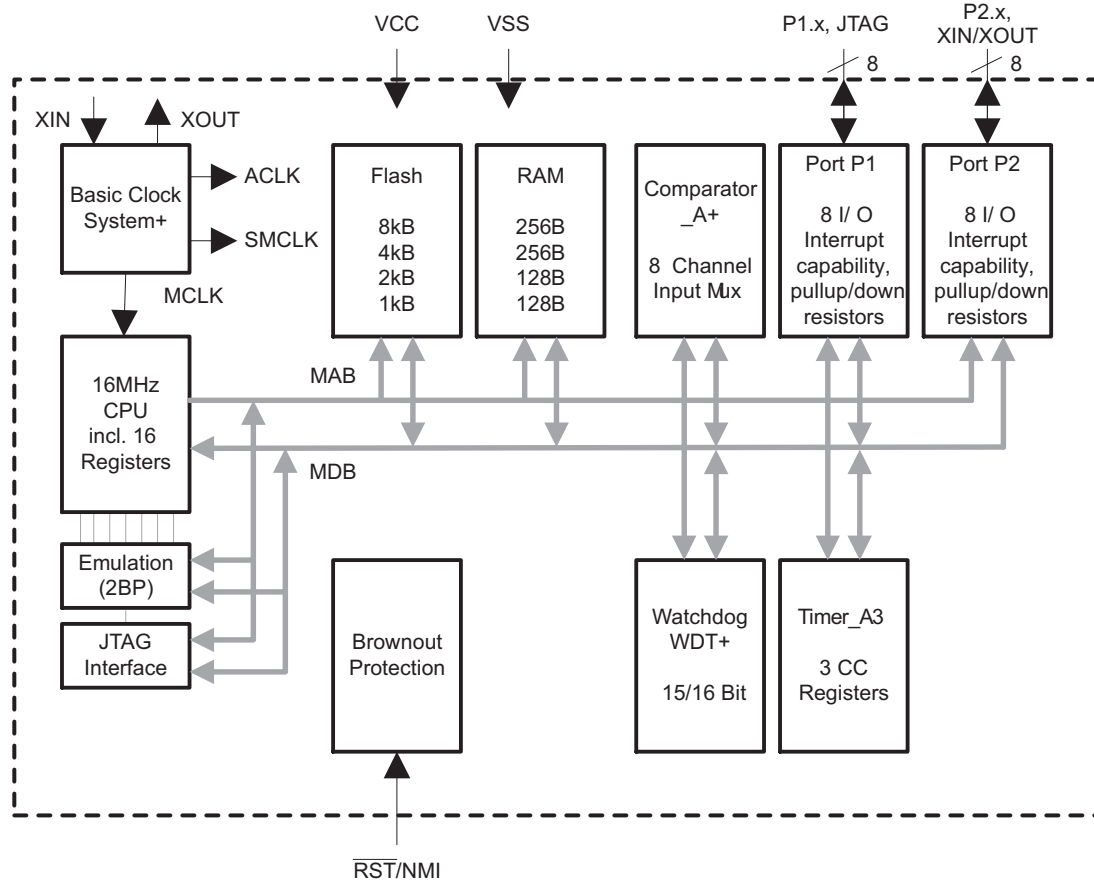


**RGE PACKAGE  
(TOP VIEW)**



- A. NC = Not internally connected
- B. Exposed thermal pad connection to V<sub>SS</sub> recommended.

## Functional Block Diagram



NOTE: See port schematics section for detailed I/O information.

**Table 2. Terminal Functions**

| TERMINAL                        |                         |     | I/O | DESCRIPTION                                                                                                                     |
|---------------------------------|-------------------------|-----|-----|---------------------------------------------------------------------------------------------------------------------------------|
| NAME                            | NO.                     |     |     |                                                                                                                                 |
|                                 | DW,<br>PW,<br>or<br>DGV | RGE |     |                                                                                                                                 |
| P1.0/TACLK                      | 13                      | 13  | I/O | General-purpose digital I/O pin<br>Timer_A, clock signal TACLK input                                                            |
| P1.1/TA                         | 14                      | 14  | I/O | General-purpose digital I/O pin<br>Timer_A, capture: CCI0A input, compare: Out0 output/BSL transmit                             |
| P1.2/TA1                        | 15                      | 15  | I/O | General-purpose digital I/O pin<br>Timer_A, capture: CCI1A input, compare: Out1 output                                          |
| P1.3/TA2                        | 16                      | 16  | I/O | General-purpose digital I/O pin<br>Timer_A, capture: CCI2A input, compare: Out2 output                                          |
| P1.4/SMCLK/TCK                  | 17                      | 17  | I/O | General-purpose digital I/O pin / SMCLK signal output<br>Test Clock input for device programming and test                       |
| P1.5/TA/TMS                     | 18                      | 18  | I/O | General-purpose digital I/O pin / Timer_A, compare: Out0 output<br>Test Mode Select input for device programming and test       |
| P1.6/TA1/TDI/TCLK               | 19                      | 20  | I/O | General-purpose digital I/O pin / Timer_A, compare: Out1 output<br>Test Data Input or Test Clock Input for programming and test |
| P1.7/TA2/TDO/TDI <sup>(1)</sup> | 20                      | 21  | I/O | General-purpose digital I/O pin / Timer_A, compare: Out2 output<br>Test Data Output or Test Data Input for programming and test |
| P2.0/ACLK/CA2                   | 8                       | 6   | I/O | General-purpose digital I/O pin / ACLK output<br>Comparator_A+, CA2 input                                                       |
| P2.1/INCLK/CA3                  | 9                       | 7   | I/O | General-purpose digital I/O pin / Timer_A, clock signal at INCLK<br>Comparator_A+, CA3 input                                    |
| P2.2/CAOUT/TA/CA4               | 10                      | 8   | I/O | General-purpose digital I/O pin<br>Timer_A, capture: CCI0B input/BSL receive<br>Comparator_A+, output / CA4 input               |
| P2.3/CA0/TA1                    | 11                      | 10  | I/O | General-purpose digital I/O pin / Timer_A, compare: Out1 output<br>Comparator_A+, CA0 input                                     |
| P2.4/CA1/TA2                    | 12                      | 11  | I/O | General-purpose digital I/O pin / Timer_A, compare: Out2 output<br>Comparator_A+, CA1 input                                     |
| P2.5/CA5                        | 3                       | 24  | I/O | General-purpose digital I/O pin<br>Comparator_A+, CA5 input                                                                     |
| XIN/P2.6/CA6                    | 6                       | 4   | I/O | Input terminal of crystal oscillator<br>General-purpose digital I/O pin<br>Comparator_A+, CA6 input                             |
| XOUT/P2.7/CA7 <sup>(2)</sup>    | 5                       | 3   | I/O | Output terminal of crystal oscillator<br>General-purpose digital I/O pin<br>Comparator_A+, CA7 input                            |
| RST/NMI                         | 7                       | 5   | I   | Reset or nonmaskable interrupt input                                                                                            |
| TEST                            | 1                       | 22  | I   | Selects test mode for JTAG pins on Port1. The device protection fuse is connected to TEST.                                      |
| V <sub>CC</sub>                 | 2                       | 23  |     | Supply voltage                                                                                                                  |
| V <sub>SS</sub>                 | 4                       | 2   |     | Ground reference                                                                                                                |
| QFN Pad                         | NA                      | Pad | NA  | QFN package thermal pad. Connect to V <sub>SS</sub> .                                                                           |

(1) TDO or TDI is selected via JTAG instruction.

(2) If XOUT/P2.7/CA7 is used as an input, excess current will flow until P2SEL.7 is cleared. This is due to the oscillator output driver connection to this pad after reset.

## SHORT-FORM DESCRIPTION

### 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.

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

### Instruction Set

The instruction set consists of 51 instructions with three formats and seven address modes. Each instruction can operate on word and byte data. [Table 3](#) shows examples of the three types of instruction formats; [Table 4](#) shows the address modes.

|                          |           |
|--------------------------|-----------|
| 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       |

**Table 3. Instruction Word Formats**

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

**Table 4. Address Mode Descriptions**

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

(1) S = source

(2) D = destination

## Operating Modes

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

The following six operating modes can be configured by software:

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

## Interrupt Vector Addresses

The interrupt vectors and the power-up starting address are located in the address range of 0xFFFF to 0xFFC0. The vector contains the 16-bit address of the appropriate interrupt handler instruction sequence.

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

**Table 5. Interrupt Vector Addresses**

| INTERRUPT SOURCE                                                                                | INTERRUPT FLAG                                    | SYSTEM INTERRUPT                                   | WORD ADDRESS     | PRIORITY        |
|-------------------------------------------------------------------------------------------------|---------------------------------------------------|----------------------------------------------------|------------------|-----------------|
| Power-up<br>External reset<br>Watchdog<br>Flash key violation<br>PC out of range <sup>(2)</sup> | PORIFG<br>RSTIFG<br>WDTIFG<br>KEYV <sup>(1)</sup> | Reset                                              | 0xFFFFE          | 31, highest     |
| NMI<br>Oscillator fault<br>Flash memory access violation                                        | NMIIFG<br>OFIFG<br>ACCVIFG <sup>(1)(3)</sup>      | (non)-maskable<br>(non)-maskable<br>(non)-maskable | 0xFFFFC          | 30              |
|                                                                                                 |                                                   |                                                    | 0xFFFFA          | 29              |
|                                                                                                 |                                                   |                                                    | 0xFFFF8          | 28              |
| Comparator_A+                                                                                   | CAIFG                                             | maskable                                           | 0xFFFF6          | 27              |
| Watchdog Timer+                                                                                 | WDTIFG                                            | maskable                                           | 0xFFFF4          | 26              |
| Timer_A3                                                                                        | TACCR0 CCIFG <sup>(4)</sup>                       | maskable                                           | 0xFFFF2          | 25              |
| Timer_A3                                                                                        | TACCR2, TACCR1 CCIFG,<br>TAIFG <sup>(1)(4)</sup>  | maskable                                           | 0xFFFF0          | 24              |
|                                                                                                 |                                                   |                                                    | 0xFFEE           | 23              |
|                                                                                                 |                                                   |                                                    | 0xFFEC           | 22              |
|                                                                                                 |                                                   |                                                    | 0xFFEA           | 21              |
|                                                                                                 |                                                   |                                                    | 0xFFE8           | 20              |
| I/O port P2 (eight flags)                                                                       | P2IFG.0 to P2IFG.7 <sup>(1)(4)</sup>              | maskable                                           | 0xFFE6           | 19              |
| I/O port P1 (eight flags)                                                                       | P1IFG.0 to P1IFG.7 <sup>(1)(4)</sup>              | maskable                                           | 0xFFE4           | 18              |
|                                                                                                 |                                                   |                                                    | 0xFFE2           | 17              |
|                                                                                                 |                                                   |                                                    | 0xFFE0           | 16              |
| See <sup>(5)</sup>                                                                              |                                                   |                                                    | 0xFFDE           | 15              |
| See <sup>(6)</sup>                                                                              |                                                   |                                                    | 0xFFDC to 0xFFC0 | 14 to 0, lowest |

(1) Multiple source flags

(2) A reset is generated if the CPU tries to fetch instructions from within the module register memory address range (0x0000 to 0x01FF) or from within unused address range.

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

(4) Interrupt flags are located in the module.

(5) This location is used as bootstrap loader security key (BSLSKEY).

A value of 0xAA55 at this location disables the BSL completely.

A value of 0x0 disables the erasure of the flash if an invalid password is supplied.

(6) The interrupt vectors at addresses 0xFFDC to 0xFFC0 are not used in this device and can be used for regular program code if necessary.

## Special Function Registers

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

### Legend

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

**Table 6. Interrupt Enable 1**

| Address | 7 | 6 | 5      | 4     | 3 | 2 | 1    | 0     |
|---------|---|---|--------|-------|---|---|------|-------|
| 00h     |   |   | ACCVIE | NMIIE |   |   | OFIE | WDTIE |
|         |   |   | rw-0   | rw-0  |   |   | rw-0 | rw-0  |

|        |                                                                                                                                        |
|--------|----------------------------------------------------------------------------------------------------------------------------------------|
| WDTIE  | Watchdog timer interrupt enable. Inactive if watchdog mode is selected. Active if watchdog timer is configured in interval timer mode. |
| OFIE   | Oscillator fault interrupt enable                                                                                                      |
| NMIIE  | (Non)maskable interrupt enable                                                                                                         |
| ACCVIE | Flash access violation interrupt enable                                                                                                |

**Table 7. Interrupt Enable 2**

| Address | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---------|---|---|---|---|---|---|---|---|
| 01h     |   |   |   |   |   |   |   |   |

**Table 8. Interrupt Flag Register 1**

| Address | 7 | 6 | 5 | 4      | 3      | 2      | 1     | 0      |
|---------|---|---|---|--------|--------|--------|-------|--------|
| 02h     |   |   |   | NMIIFG | RSTIFG | PORIFG | OFIFG | WDTIFG |
|         |   |   |   | rw-0   | rw-(0) | rw-(1) | rw-1  | rw-(0) |

|        |                                                                                                                                                                                           |
|--------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| WDTIFG | Set on watchdog timer overflow (in watchdog mode) or security key violation.<br>Reset on V <sub>CC</sub> power-up or a reset condition at $\overline{\text{RST}}$ /NMI pin in reset mode. |
| OFIFG  | Flag set on oscillator fault                                                                                                                                                              |
| RSTIFG | External reset interrupt flag. Set on a reset condition at $\overline{\text{RST}}$ /NMI pin in reset mode. Reset on V <sub>CC</sub> power up.                                             |
| PORIFG | Power-on reset interrupt flag. Set on V <sub>CC</sub> power up.                                                                                                                           |
| NMIIFG | Set via $\overline{\text{RST}}$ /NMI pin                                                                                                                                                  |

**Table 9. Interrupt Flag Register 2**

| Address | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---------|---|---|---|---|---|---|---|---|
| 03h     |   |   |   |   |   |   |   |   |

## Memory Organization

**Table 10. Memory Organization**

|                        |           | MSP430F2101      | MSP430F2111      | MSP430F2121      | MSP430F2131      |
|------------------------|-----------|------------------|------------------|------------------|------------------|
| Memory                 | Size      | 1 KB Flash       | 2 KB Flash       | 4 KB Flash       | 8 KB Flash       |
| Main: interrupt vector | Flash     | 0xFFFF to 0xFFE0 | 0xFFFF to 0xFFE0 | 0xFFFF to 0xFFE0 | 0xFFFF to 0xFFE0 |
| Main: code memory      | Flash     | 0xFFFF to 0xFC00 | 0xFFFF to 0xF800 | 0xFFFF to 0xF000 | 0xFFFF to 0xE000 |
| Information memory     | Size      | 256 Byte         | 256 Byte         | 256 Byte         | 256 Byte         |
|                        | Flash     | 0x10FF to 0x1000 | 0x10FF to 0x1000 | 0x10FF to 0x1000 | 0x10FF to 0x1000 |
| Boot memory            | Size      | 1 KB             | 1 KB             | 1 KB             | 1 KB             |
|                        | ROM       | 0x0FFF to 0x0C00 | 0x0FFF to 0x0C00 | 0x0FFF to 0x0C00 | 0x0FFF to 0x0C00 |
| RAM                    | Size      | 128 B            | 128 B            | 256 Byte         | 256 Byte         |
|                        |           | 0x027F to 0x0200 | 0x027F to 0x0200 | 0x02FF to 0x0200 | 0x02FF to 0x0200 |
| Peripherals            | 16-bit    | 0x01FF to 0x0100 | 0x01FF to 0x0100 | 0x01FF to 0x0100 | 0x01FF to 0x0100 |
|                        | 8-bit     | 0x0FF to 0x010   | 0x0FF to 0x010   | 0x0FF to 0x010   | 0x0FF to 0x010   |
|                        | 8-bit SFR | 0x0F to 0x00     | 0x0F to 0x00     | 0x0F to 0x00     | 0x0F to 0x00     |

## Bootstrap Loader (BSL)

The MSP430 bootstrap loader (BSL) enables users to program the flash memory or RAM using a UART serial interface. Access to the MSP430 memory via the BSL is protected by user-defined password. A bootstrap loader security key is provided at address 0FFDEh to disable the BSL completely or to disable the erasure of the flash if an invalid password is supplied. For complete description of the features of the BSL and its implementation, see the *MSP430 Programming Via the Bootstrap Loader User's Guide*, literature number [SLAU319](#).

**Table 11. BSL Keys**

| BSLKEY          | DESCRIPTION                                                |
|-----------------|------------------------------------------------------------|
| 00000h          | Erase of flash disabled if an invalid password is supplied |
| 0AA55h          | BSL disabled                                               |
| any other value | BSL enabled                                                |

**Table 12. BSL Function Pins**

| BSL FUNCTION  | DW, PW, DGV PACKAGE PINS | RGE PACKAGE PINS |
|---------------|--------------------------|------------------|
| Data transmit | 14 - P1.1                | 14 - P1.1        |
| Data receive  | 10 - P2.2                | 8 - P2.2         |

## Flash Memory

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

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

## Peripherals

Peripherals are connected to the CPU through data, address, and control buses and can be handled using all instructions. For complete module descriptions, see the *MSP430x2xx Family User's Guide* ([SLAU144](#)).

## Oscillator and System Clock

The clock system is supported by the basic clock module that includes support for a 32768-Hz watch crystal oscillator, an internal digitally-controlled oscillator (DCO), and a high-frequency crystal oscillator. The basic clock module is designed to meet the requirements of both low system cost and low power consumption. The internal DCO provides a fast turn-on clock source and stabilizes in less than 1  $\mu$ s. The basic clock module provides the following clock signals:

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

**Table 13. DCO Calibration Data, Provided From Factory In Flash Info Memory Segment A**

| DCO FREQUENCY | CALIBRATION REGISTER | SIZE | ADDRESS |
|---------------|----------------------|------|---------|
| 1 MHz         | CALBC1_1MHZ          | byte | 0x010FF |
|               | CALBC0_1MHZ          | byte | 0x010FE |
| 8 MHz         | CALBC1_8MHZ          | byte | 0x010FD |
|               | CALBC0_8MHZ          | byte | 0x010FC |
| 12 MHz        | CALBC1_12MHZ         | byte | 0x010FB |
|               | CALBC0_12MHZ         | byte | 0x010FA |
| 16 MHz        | CALBC1_16MHZ         | byte | 0x010F9 |
|               | CALBC0_16MHZ         | byte | 0x010F8 |

## Brownout

The brownout circuit is implemented to provide the proper internal reset signal to the device during power on and power off.

## Digital I/O

There are two 8-bit I/O ports implemented—ports P1 and P2.

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

## Watchdog Timer (WDT+)

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

## Comparator\_A+

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

## Timer\_A3

Timer\_A3 is a 16-bit timer/counter with three capture/compare registers. Timer\_A3 can support multiple capture/compares, PWM outputs, and interval timing. 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 14. Timer\_A3 Signal Connections**

| INPUT PIN NUMBER |           | DEVICE INPUT SIGNAL | MODULE INPUT NAME | MODULE BLOCK | MODULE OUTPUT SIGNAL | OUTPUT PIN NUMBER |           |
|------------------|-----------|---------------------|-------------------|--------------|----------------------|-------------------|-----------|
| DW, PW, DGV      | RGE       |                     |                   |              |                      | DW, PW, DGV       | RGE       |
| 13 - P1.0        | 13 - P1.0 | TACLK               | TACLK             | Timer        | NA                   |                   |           |
|                  |           | ACLK                | ACLK              |              |                      |                   |           |
|                  |           | SMCLK               | SMCLK             |              |                      |                   |           |
| 9 - P2.1         | 7 - P2.1  | INCLK               | INCLK             |              |                      |                   |           |
| 14 - P1.1        | 14 - P1.1 | TA                  | CCI0A             | CCR0         | TA                   | 14 - P1.1         | 14 - P1.1 |
| 10 - P2.2        | 8 - P2.2  | TA                  | CCI0B             |              |                      | 18 - P1.5         | 18 - P1.5 |
|                  |           | VSS                 | GND               |              |                      |                   |           |
|                  |           | VCC                 | VCC               |              |                      |                   |           |
| 15 - P1.2        | 15 - P1.2 | TA1                 | CCI1A             | CCR1         | TA1                  | 11 - P2.3         | 10 - P2.3 |
|                  |           | CAOUT (internal)    | CCI1B             |              |                      | 15 - P1.2         | 15 - P1.2 |
|                  |           | VSS                 | GND               |              |                      | 19 - P1.6         | 20 - P1.6 |
|                  |           | VCC                 | VCC               |              |                      |                   |           |
| 16 - P1.3        | 16 - P1.3 | TA2                 | CCI2A             | CCR2         | TA2                  | 12 - P2.4         | 11 - P2.4 |
|                  |           | ACLK (internal)     | CCI2B             |              |                      | 16 - P1.3         | 16 - P1.3 |
|                  |           | VSS                 | GND               |              |                      | 20 - P1.7         | 21 - P1.7 |
|                  |           | VCC                 | VCC               |              |                      |                   |           |

## Peripheral File Map

**Table 15. Peripherals With Word Access**

| MODULE          | REGISTER NAME             | SHORT NAME | ADDRESS OFFSET |
|-----------------|---------------------------|------------|----------------|
| Timer_A         | Capture/compare register  | TACCR2     | 0x0176         |
|                 | Capture/compare register  | TACCR1     | 0x0174         |
|                 | Capture/compare register  | TACCR0     | 0x0172         |
|                 | Timer_A3 register         | TAR        | 0x0170         |
|                 | Capture/compare control   | TACCTL2    | 0x0166         |
|                 | Capture/compare control   | TACCTL1    | 0x0164         |
|                 | Capture/compare control   | TACCTL0    | 0x0162         |
|                 | Timer_A3 control          | TACTL      | 0x0160         |
|                 | Timer_A3 interrupt vector | TAIV       | 0x012E         |
| Flash Memory    | Flash control 3           | FCTL3      | 0x012C         |
|                 | Flash control 2           | FCTL2      | 0x012A         |
|                 | Flash control 1           | FCTL1      | 0x0128         |
| Watchdog Timer+ | Watchdog/timer control    | WDTCTL     | 0x0120         |

**Table 16. Peripherals With Byte Access**

| MODULE           | REGISTER NAME                 | SHORT NAME | ADDRESS OFFSET |
|------------------|-------------------------------|------------|----------------|
| Comparator_A+    | Comparator_A port disable     | CAPD       | 0x005B         |
|                  | Comparator_A control 2        | CACTL2     | 0x005A         |
|                  | Comparator_A control 1        | CACTL1     | 0x0059         |
| Basic Clock      | Basic clock system control 3  | BCSCTL3    | 0x0053         |
|                  | Basic clock system control 2  | BCSCTL2    | 0x0058         |
|                  | Basic clock system control 1  | BCSCTL1    | 0x0057         |
|                  | DCO clock frequency control   | DCOCTL     | 0x0056         |
| Port P2          | Port P2 resistor enable       | P2REN      | 0x002F         |
|                  | Port P2 selection             | P2SEL      | 0x002E         |
|                  | Port P2 interrupt enable      | P2IE       | 0x002D         |
|                  | Port P2 interrupt edge select | P2IES      | 0x002C         |
|                  | Port P2 interrupt flag        | P2IFG      | 0x002B         |
|                  | Port P2 direction             | P2DIR      | 0x002A         |
|                  | Port P2 output                | P2OUT      | 0x0029         |
|                  | Port P2 input                 | P2IN       | 0x0028         |
| Port P1          | Port P1 resistor enable       | P1REN      | 0x0027         |
|                  | Port P1 selection             | P1SEL      | 0x0026         |
|                  | Port P1 interrupt enable      | P1IE       | 0x0025         |
|                  | Port P1 interrupt edge select | P1IES      | 0x0024         |
|                  | Port P1 interrupt flag        | P1IFG      | 0x0023         |
|                  | Port P1 direction             | P1DIR      | 0x0022         |
|                  | Port P1 output                | P1OUT      | 0x0021         |
|                  | Port P1 input                 | P1IN       | 0x0020         |
| Special Function | SFR interrupt flag 2          | IFG2       | 0x0003         |
|                  | SFR interrupt flag 1          | IFG1       | 0x0002         |
|                  | SFR interrupt enable 2        | IE2        | 0x0001         |
|                  | SFR interrupt enable 1        | IE1        | 0x0000         |

**Absolute Maximum Ratings<sup>(1)</sup>**

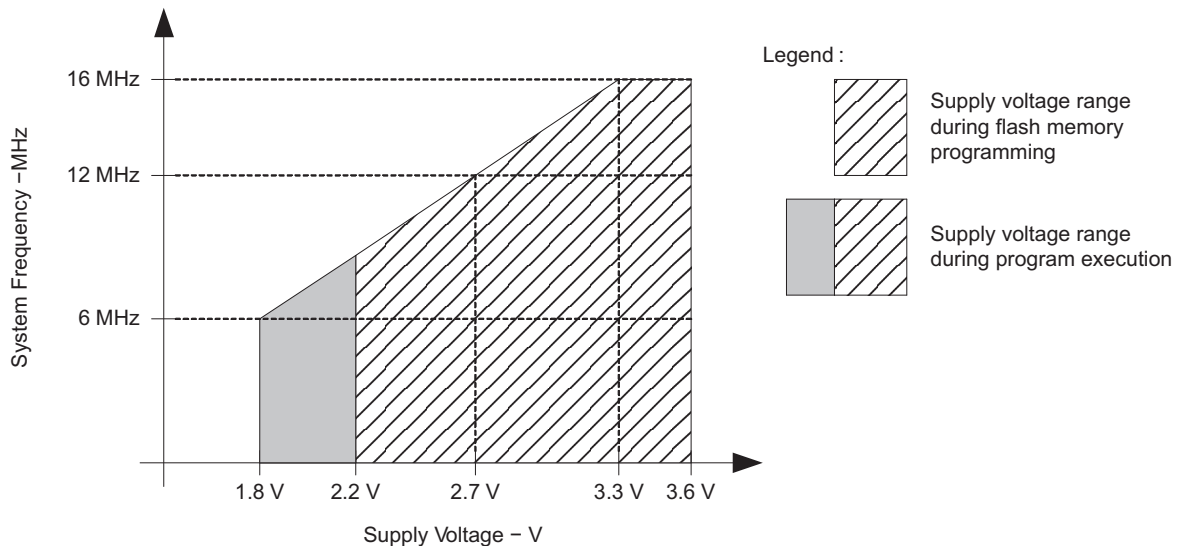
|                                               |                     |                               |
|-----------------------------------------------|---------------------|-------------------------------|
| Voltage applied at $V_{CC}$ to $V_{SS}$       |                     | -0.3 V to 4.1 V               |
| Voltage applied to any pin <sup>(2)</sup>     |                     | -0.3 V to ( $V_{CC} + 0.3$ V) |
| Diode current at any device terminal          |                     | $\pm 2$ mA                    |
| Storage temperature, $T_{stg}$ <sup>(3)</sup> | Unprogrammed device | -55°C to 150°C                |
|                                               | Programmed device   | -55°C to 150°C                |

- (1) Stresses beyond those listed under *absolute maximum ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *recommended operating conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) All voltages referenced to  $V_{SS}$ . The JTAG fuse-blow voltage,  $V_{FB}$ , is allowed to exceed the absolute maximum rating. The voltage is applied to the TEST pin when blowing the JTAG fuse.
- (3) Higher temperature may be applied during board soldering process according to the current JEDEC J-STD-020 specification with peak reflow temperatures not higher than classified on the device label on the shipping boxes or reels.

**Recommended Operating Conditions<sup>(1)</sup>**

|              |                                                                                  |                                                  | MIN | NOM | MAX | UNIT |
|--------------|----------------------------------------------------------------------------------|--------------------------------------------------|-----|-----|-----|------|
| $V_{CC}$     | Supply voltage, $AV_{CC} = DV_{CC} = V_{CC}$                                     | During program execution                         | 1.8 |     | 3.6 | V    |
|              |                                                                                  | During flash memory programming                  | 2.2 |     | 3.6 |      |
| $V_{SS}$     | Supply voltage, $AV_{SS} = DV_{SS} = V_{SS}$                                     |                                                  |     | 0   |     | V    |
| $T_A$        | Operating free-air temperature                                                   | I version                                        | -40 |     | 85  | °C   |
|              |                                                                                  | T version                                        | -40 |     | 105 |      |
| $f_{SYSTEM}$ | Processor frequency (maximum MCLK frequency) <sup>(2)(1)</sup><br>(see Figure 1) | $V_{CC} = 1.8$ V, Duty cycle = 50% $\pm 10\%$    | 0   |     | 6   | MHz  |
|              |                                                                                  | $V_{CC} = 2.7$ V, Duty cycle = 50% $\pm 10\%$    | 0   |     | 12  |      |
|              |                                                                                  | $V_{CC} \geq 3.3$ V, Duty cycle = 50% $\pm 10\%$ | 0   |     | 16  |      |

- (1) Modules might have a different maximum input clock specification. See the specification of the respective module in this data sheet.
- (2) The MSP430 CPU is clocked directly with MCLK. Both the high and low phase of MCLK must not exceed the pulse width of the specified maximum frequency.



NOTE: Minimum processor frequency is defined by system clock. Flash program or erase operations require a minimum  $V_{CC}$  of 2.2 V.

**Figure 1. Operating Area**

## Active Mode Supply Current (into DV<sub>CC</sub> + AV<sub>CC</sub>) Excluding External Current

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

| PARAMETER                                                 | TEST CONDITIONS                                                                                                                                                                                                                                         | T <sub>A</sub> | V <sub>CC</sub> | MIN | TYP | MAX | UNIT |
|-----------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|-----------------|-----|-----|-----|------|
| I <sub>AM,1MHz</sub> Active mode (AM) current (1 MHz)     | f <sub>DCO</sub> = f <sub>MCLK</sub> = f <sub>SMCLK</sub> = 1 MHz,<br>f <sub>ACLK</sub> = 32768 Hz,<br>Program executes in flash,<br>BCSCTL1 = CALBC1_1MHZ,<br>DCOCTL = CALDCO_1MHZ,<br>CPUOFF = 0, SCG0 = 0, SCG1 = 0,<br>OSCOFF = 0                   |                | 2.2 V           |     | 250 | 300 | μA   |
|                                                           |                                                                                                                                                                                                                                                         |                | 3 V             |     | 350 | 410 |      |
| I <sub>AM,1MHz</sub> Active mode (AM) current (1 MHz)     | f <sub>DCO</sub> = f <sub>MCLK</sub> = f <sub>SMCLK</sub> = 1 MHz,<br>f <sub>ACLK</sub> = 32768 Hz,<br>Program executes in RAM,<br>BCSCTL1 = CALBC1_1MHZ,<br>DCOCTL = CALDCO_1MHZ,<br>CPUOFF = 0, SCG0 = 0, SCG1 = 0,<br>OSCOFF = 0                     |                | 2.2 V           |     | 200 |     | μA   |
|                                                           |                                                                                                                                                                                                                                                         |                | 3 V             |     | 300 |     |      |
| I <sub>AM,4kHz</sub> Active mode (AM) current (4 kHz)     | f <sub>MCLK</sub> = f <sub>SMCLK</sub> = f <sub>ACLK</sub> = 32768 Hz / 8 = 4096 Hz,<br>f <sub>DCO</sub> = 0 Hz,<br>Program executes in flash,<br>SELMx = 11, SELS = 1,<br>DIVMx = DIVSx = DIVAx = 11,<br>CPUOFF = 0, SCG0 = 1, SCG1 = 0,<br>OSCOFF = 0 | -40°C to 85°C  | 2.2 V           |     | 2   | 5   | μA   |
|                                                           |                                                                                                                                                                                                                                                         | 105°C          |                 |     |     | 6   |      |
|                                                           |                                                                                                                                                                                                                                                         | -40°C to 85°C  | 3 V             |     | 3   | 9   |      |
|                                                           |                                                                                                                                                                                                                                                         | 105°C          |                 |     |     | 9   |      |
| I <sub>AM,100kHz</sub> Active mode (AM) current (100 kHz) | f <sub>MCLK</sub> = f <sub>SMCLK</sub> = f <sub>DCO(0, 0)</sub> ≈ 100 kHz,<br>f <sub>ACLK</sub> = 0 Hz,<br>Program executes in flash,<br>RSELx = 0, DCOx = 0, CPUOFF = 0,<br>SCG0 = 0, SCG1 = 0, OSCOFF = 1                                             |                | 2.2 V           |     | 60  | 85  | μA   |
|                                                           |                                                                                                                                                                                                                                                         |                | 3 V             |     | 72  | 95  |      |

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

(2) The currents are characterized with a Micro Crystal CC4V-T1A SMD crystal with a load capacitance of 9 pF. The internal and external load capacitance is chosen to closely match the required 9 pF.

## Typical Characteristics - Active-Mode Supply Current (Into V<sub>CC</sub>)

### ACTIVE-MODE CURRENT

vs

SUPPLY VOLTAGE

T<sub>A</sub> = 25°C

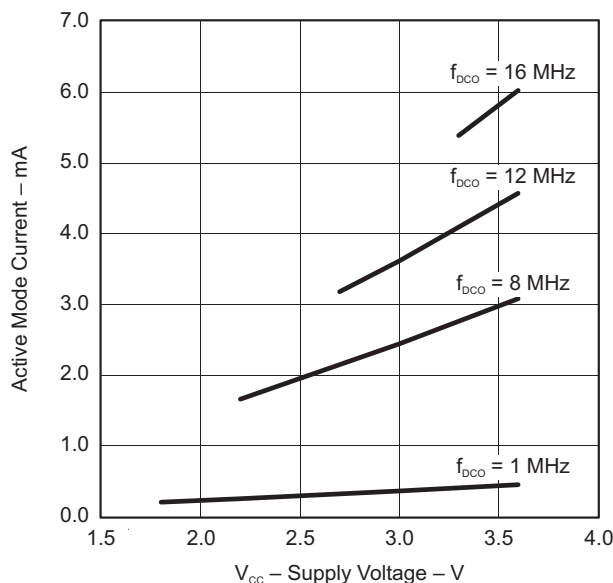


Figure 2.

### ACTIVE-MODE CURRENT

vs

DCO FREQUENCY

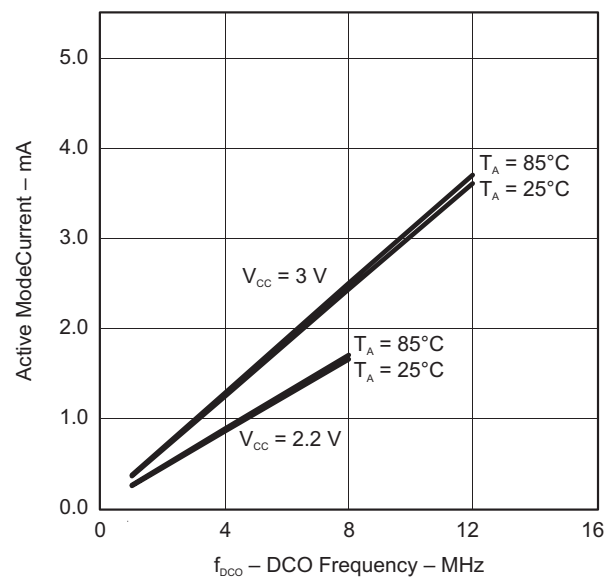


Figure 3.

## Low-Power-Mode Supply Currents (Into $V_{CC}$ ) Excluding External Current <sup>(1)(2)</sup>

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

| PARAMETER                                                        | TEST CONDITIONS                                                                                                                                                                     | $T_A$         | $V_{CC}$  | MIN | TYP | MAX | UNIT    |
|------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|-----------|-----|-----|-----|---------|
| $I_{LPM0,1MHz}$ Low-power mode 0 (LPM0) current <sup>(3)</sup>   | $f_{MCLK} = 0$ MHz,<br>$f_{SMCLK} = f_{DCO} = 1$ MHz,<br>$f_{ACLK} = 32768$ Hz,<br>BCSCTL1 = CALBC1_1MHz,<br>DCOCTL = CALDCO_1MHz,<br>CPUOFF = 1, SCG0 = 0, SCG1 = 0,<br>OSCOFF = 0 |               | 2.2 V     |     | 65  | 80  | $\mu A$ |
|                                                                  |                                                                                                                                                                                     |               | 3 V       |     | 85  | 100 |         |
| $I_{LPM0,100kHz}$ Low-power mode 0 (LPM0) current <sup>(3)</sup> | $f_{MCLK} = 0$ MHz,<br>$f_{SMCLK} = f_{DCO}(0, 0) \approx 100$ kHz,<br>$f_{ACLK} = 0$ Hz,<br>RSELX = 0, DCOX = 0,<br>CPUOFF = 1, SCG0 = 0, SCG1 = 0,<br>OSCOFF = 1                  |               | 2.2 V     |     | 37  | 48  | $\mu A$ |
|                                                                  |                                                                                                                                                                                     |               | 3 V       |     | 41  | 52  |         |
| $I_{LPM2}$ Low-power mode 2 (LPM2) current <sup>(4)</sup>        | $f_{MCLK} = f_{SMCLK} = 0$ MHz,<br>$f_{DCO} = 1$ MHz, $f_{ACLK} = 32768$ Hz,<br>BCSCTL1 = CALBC1_1MHz,<br>DCOCTL = CALDCO_1MHz,<br>CPUOFF = 1, SCG0 = 0, SCG1 = 1,<br>OSCOFF = 0    | -40°C to 85°C | 2.2 V     |     | 22  | 29  | $\mu A$ |
|                                                                  |                                                                                                                                                                                     | 105°C         |           |     |     | 31  |         |
|                                                                  |                                                                                                                                                                                     | -40°C to 85°C | 3 V       |     | 25  | 32  |         |
|                                                                  |                                                                                                                                                                                     | 105°C         |           |     |     | 34  |         |
| $I_{LPM3,LFX1}$ Low-power mode 3 (LPM3) current <sup>(4)</sup>   | $f_{DCO} = f_{MCLK} = f_{SMCLK} = 0$ MHz,<br>$f_{ACLK} = 32768$ Hz,<br>CPUOFF = 1, SCG0 = 1, SCG1 = 1,<br>OSCOFF = 0                                                                | -40°C         | 2.2 V     |     | 0.7 | 1.2 | $\mu A$ |
|                                                                  |                                                                                                                                                                                     | 25°C          |           |     | 0.7 | 1   |         |
|                                                                  |                                                                                                                                                                                     | 85°C          |           |     | 1.6 | 2.3 |         |
|                                                                  |                                                                                                                                                                                     | 105°C         |           |     | 3   | 6   |         |
|                                                                  |                                                                                                                                                                                     | -40°C         | 3 V       |     | 0.9 | 1.2 |         |
|                                                                  |                                                                                                                                                                                     | 25°C          |           |     | 0.9 | 1.2 |         |
|                                                                  |                                                                                                                                                                                     | 85°C          |           |     | 1.6 | 2.8 |         |
|                                                                  |                                                                                                                                                                                     | 105°C         |           |     | 3   | 7   |         |
| $I_{LPM4}$ Low-power mode 4 (LPM4) current <sup>(5)</sup>        | $f_{DCO} = f_{MCLK} = f_{SMCLK} = 0$ MHz,<br>$f_{ACLK} = 0$ Hz,<br>CPUOFF = 1, SCG0 = 1, SCG1 = 1,<br>OSCOFF = 1                                                                    | -40°C         | 2.2 V/3 V |     | 0.1 | 0.5 | $\mu A$ |
|                                                                  |                                                                                                                                                                                     | 25°C          |           |     | 0.1 | 0.5 |         |
|                                                                  |                                                                                                                                                                                     | 85°C          |           |     | 0.8 | 1.9 |         |
|                                                                  |                                                                                                                                                                                     | 105°C         |           |     | 2   | 4   |         |

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

(2) The currents are characterized with a Micro Crystal CC4V-T1A SMD crystal with a load capacitance of 9 pF. The internal and external load capacitance is chosen to closely match the required 9 pF.

(3) Current for brownout and WDT clocked by SMCLK included.

(4) Current for brownout and WDT clocked by ACLK included.

(5) Current for brownout included.

## Schmitt-Trigger Inputs (Ports P1, P2)

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

| PARAMETER                                                                        | TEST CONDITIONS                                                                                    | V <sub>CC</sub> | MIN                  | TYP | MAX                  | UNIT |
|----------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------|-----------------|----------------------|-----|----------------------|------|
| V <sub>IT+</sub> Positive-going input threshold voltage                          |                                                                                                    |                 | 0.45 V <sub>CC</sub> |     | 0.75 V <sub>CC</sub> | V    |
|                                                                                  |                                                                                                    | 2.2 V           | 1                    |     | 1.65                 |      |
|                                                                                  |                                                                                                    | 3 V             | 1.35                 |     | 2.25                 |      |
| V <sub>IT-</sub> Negative-going input threshold voltage                          |                                                                                                    |                 | 0.25 V <sub>CC</sub> |     | 0.55 V <sub>CC</sub> | V    |
|                                                                                  |                                                                                                    | 2.2 V           | 0.55                 |     | 1.20                 |      |
|                                                                                  |                                                                                                    | 3 V             | 0.75                 |     | 1.65                 |      |
| V <sub>hys</sub> Input voltage hysteresis (V <sub>IT+</sub> - V <sub>IT-</sub> ) |                                                                                                    | 2.2 V           | 0.2                  |     | 1                    | V    |
|                                                                                  |                                                                                                    | 3 V             | 0.3                  |     | 1                    |      |
| R <sub>Pull</sub> Pullup/pulldown resistor                                       | For pullup: V <sub>IN</sub> = V <sub>SS</sub> ,<br>For pulldown: V <sub>IN</sub> = V <sub>CC</sub> |                 | 20                   | 35  | 50                   | kΩ   |
| C <sub>I</sub> Input capacitance                                                 | V <sub>IN</sub> = V <sub>SS</sub> or V <sub>CC</sub>                                               |                 |                      | 5   |                      | pF   |

## Inputs (Ports P1, P2)

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

| PARAMETER                                    | TEST CONDITIONS                                                                              | V <sub>CC</sub> | MIN | MAX | UNIT |
|----------------------------------------------|----------------------------------------------------------------------------------------------|-----------------|-----|-----|------|
| t <sub>(int)</sub> External interrupt timing | Port P1, P2: P1.x to P2.x, External trigger pulse width to set interrupt flag <sup>(1)</sup> | 2.2 V/3 V       | 20  |     | ns   |

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

## Leakage Current (Ports P1, P2)

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

| PARAMETER                                             | TEST CONDITIONS | V <sub>CC</sub> | MIN | MAX | UNIT |
|-------------------------------------------------------|-----------------|-----------------|-----|-----|------|
| I <sub>lkg(Px.y)</sub> High-impedance leakage current | (1) (2)         | 2.2 V/3 V       |     | ±50 | nA   |

- (1) The leakage current is measured with V<sub>SS</sub> or V<sub>CC</sub> applied to the corresponding pin(s), unless otherwise noted.  
(2) The leakage of the digital port pins is measured individually. The port pin is selected for input and the pullup/pulldown resistor is disabled.

## Outputs (Ports P1, P2)

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

| PARAMETER                                 | TEST CONDITIONS                               | V <sub>CC</sub> | MIN                    | MAX                    | UNIT |
|-------------------------------------------|-----------------------------------------------|-----------------|------------------------|------------------------|------|
| V <sub>OH</sub> High-level output voltage | I <sub>OH(max)</sub> = -1.5 mA <sup>(1)</sup> | 2.2 V           | V <sub>CC</sub> - 0.25 | V <sub>CC</sub>        | V    |
|                                           | I <sub>OH(max)</sub> = -6 mA <sup>(2)</sup>   |                 | V <sub>CC</sub> - 0.6  | V <sub>CC</sub>        |      |
|                                           | I <sub>OH(max)</sub> = -1.5 mA <sup>(1)</sup> | 3 V             | V <sub>CC</sub> - 0.25 | V <sub>CC</sub>        |      |
|                                           | I <sub>OH(max)</sub> = -6 mA <sup>(2)</sup>   |                 | 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>  | 2.2 V           | V <sub>SS</sub>        | V <sub>SS</sub> + 0.25 | V    |
|                                           | I <sub>OL(max)</sub> = 6 mA <sup>(2)</sup>    |                 | V <sub>SS</sub>        | V <sub>SS</sub> + 0.6  |      |
|                                           | I <sub>OL(max)</sub> = 1.5 mA <sup>(1)</sup>  | 3 V             | V <sub>SS</sub>        | V <sub>SS</sub> + 0.25 |      |
|                                           | I <sub>OL(max)</sub> = 6 mA <sup>(2)</sup>    |                 | 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 hold the maximum voltage drop specified.

(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 hold the maximum voltage drop specified.

## Output Frequency (Ports P1, P2)

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

| PARAMETER                                           | TEST CONDITIONS                                                             | V <sub>CC</sub> | MIN | MAX | UNIT |
|-----------------------------------------------------|-----------------------------------------------------------------------------|-----------------|-----|-----|------|
| f <sub>PX,Y</sub> Port output frequency (with load) | P1.4/SMCLK, C <sub>L</sub> = 20 pF, R <sub>L</sub> = 1 kΩ <sup>(1)(2)</sup> | 2.2 V           |     | 10  | MHz  |
|                                                     |                                                                             | 3 V             |     | 12  |      |
| f <sub>Port_CLK</sub> Clock output frequency        | P2.0/ACLK, P1.4/SMCLK, C <sub>L</sub> = 20 pF <sup>(2)</sup>                | 2.2 V           |     | 12  | MHz  |
|                                                     |                                                                             | 3 V             |     | 16  |      |

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

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

## Typical Characteristics - Outputs

One output loaded at a time.

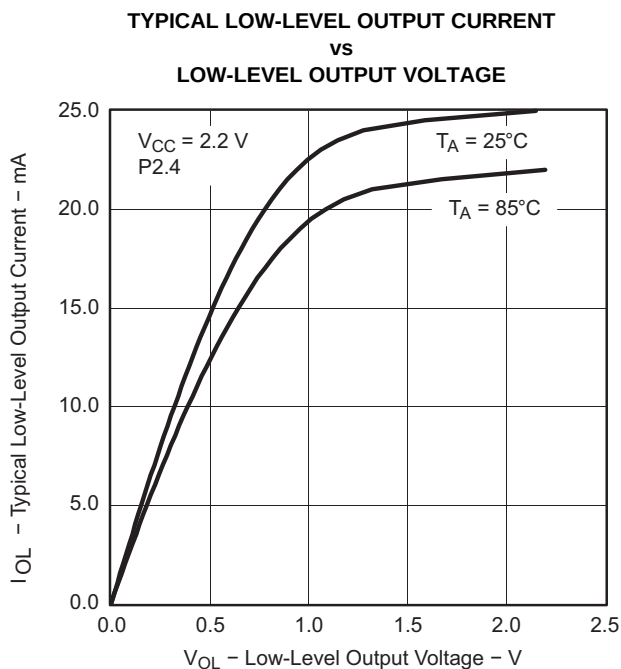


Figure 4.

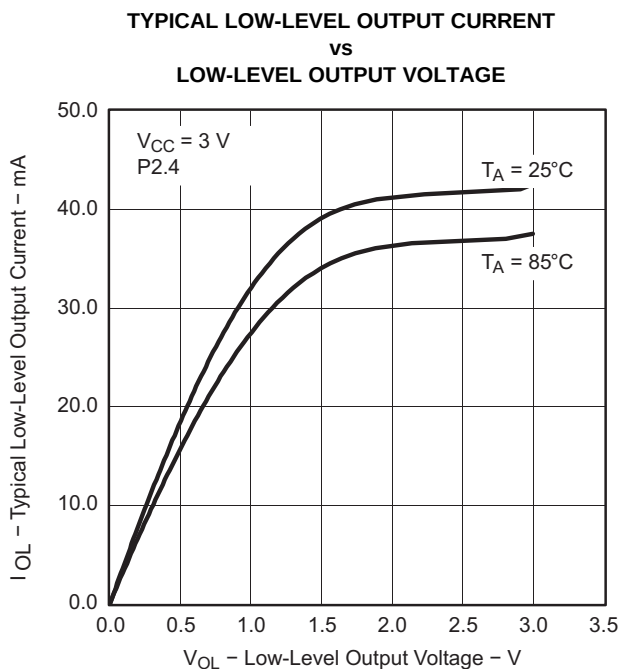


Figure 5.

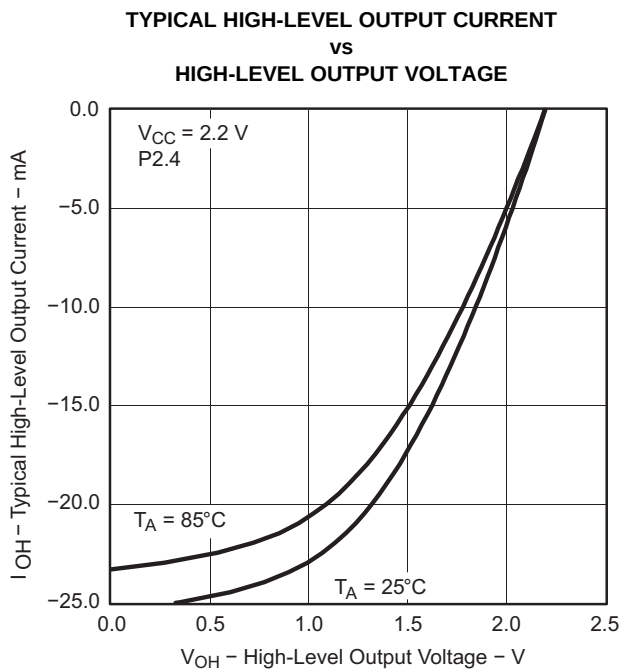


Figure 6.

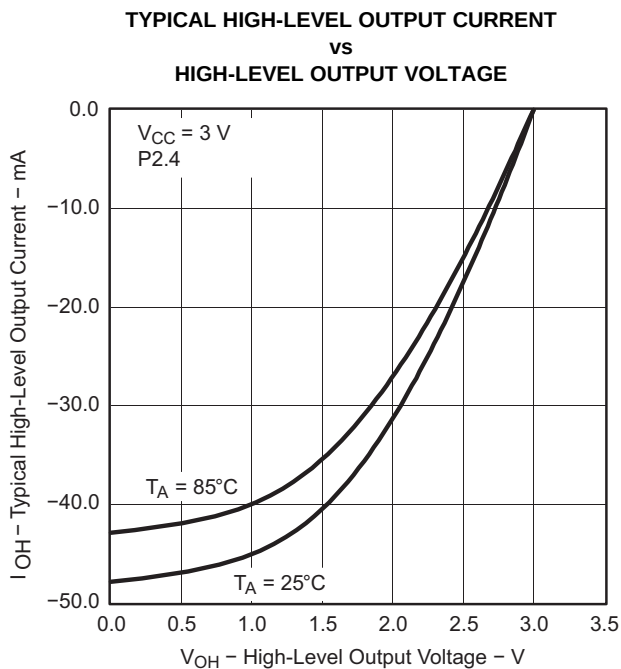


Figure 7.

## POR/Brownout Reset (BOR)<sup>(1)(2)</sup>

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

| PARAMETER               | TEST CONDITIONS                                                 | T <sub>A</sub> | V <sub>CC</sub> | MIN | TYP                        | MAX  | UNIT |
|-------------------------|-----------------------------------------------------------------|----------------|-----------------|-----|----------------------------|------|------|
| V <sub>CC(start)</sub>  | See Figure 8                                                    |                |                 |     | 0.7 × V <sub>(B_IT-)</sub> |      | V    |
| V <sub>(B_IT-)</sub>    | See Figure 8 through Figure 10                                  |                |                 |     |                            | 1.71 | V    |
| V <sub>hys(B_IT-)</sub> | See Figure 8                                                    | -40°C to 85°C  |                 | 70  | 130                        | 180  | mV   |
|                         |                                                                 | 105°C          |                 | 70  | 130                        | 210  |      |
| t <sub>d(BOR)</sub>     | See Figure 8                                                    |                |                 |     |                            | 2000 | μs   |
| t <sub>(reset)</sub>    | Pulse length needed at RST/NMI pin to accepted reset internally |                | 2.2 V/3 V       | 2   |                            |      | μs   |

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

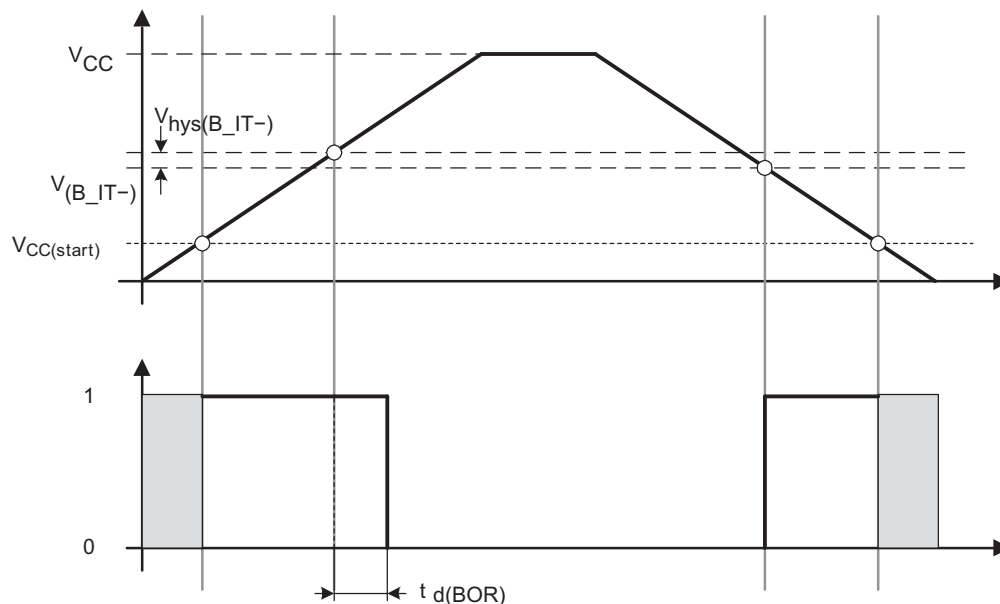


Figure 8. POR/Brownout Reset (BOR) vs Supply Voltage

## Typical Characteristics - POR/Brownout Reset (BOR)

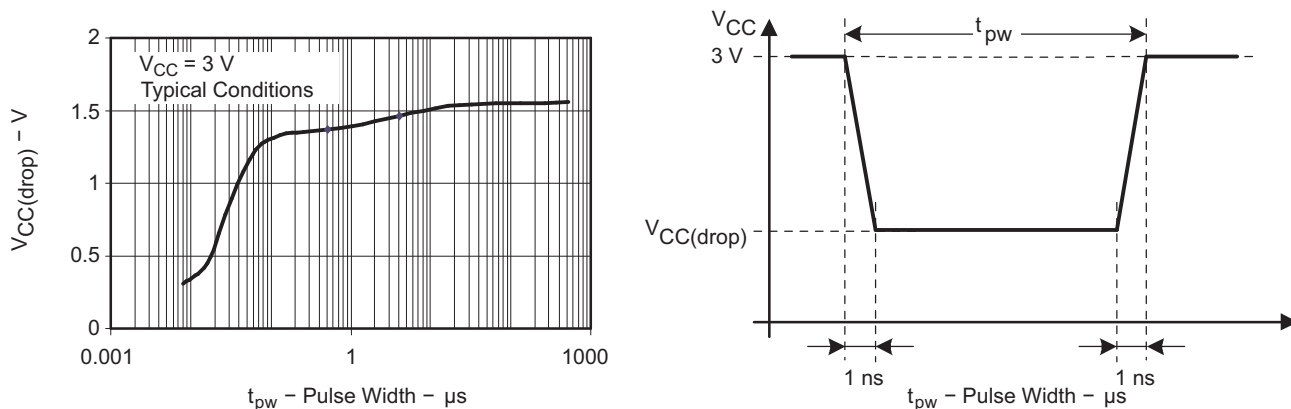


Figure 9.  $V_{CC(drop)}$  Level With a Square Voltage Drop to Generate a POR/Brownout Signal

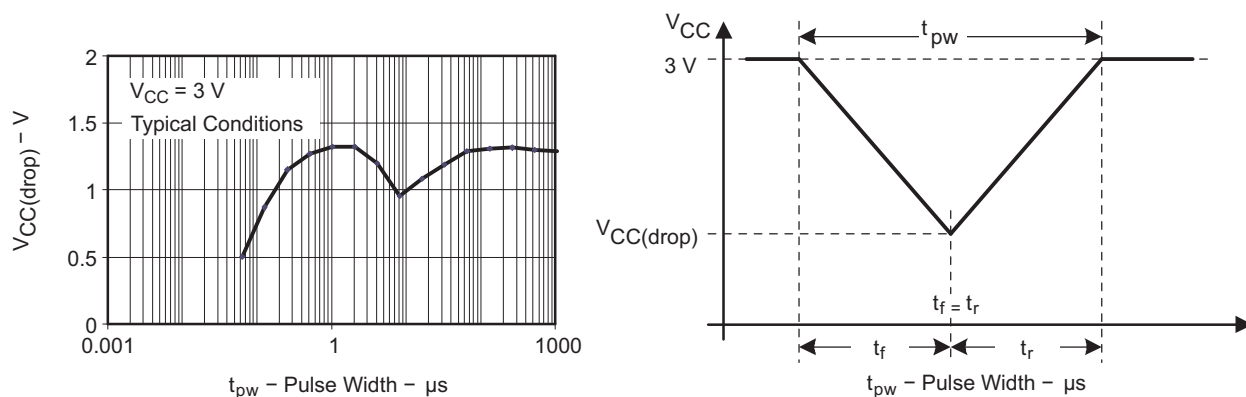


Figure 10.  $V_{CC(drop)}$  Level With a Triangle Voltage Drop to Generate a POR/Brownout Signal

## Main DCO Characteristics

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

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

## DCO Frequency

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

| PARAMETER              |                                              | TEST CONDITIONS                                                               | V <sub>CC</sub> | MIN  | TYP  | MAX  | UNIT  |
|------------------------|----------------------------------------------|-------------------------------------------------------------------------------|-----------------|------|------|------|-------|
| V <sub>CC</sub>        | Supply voltage range                         | RSELx < 14                                                                    |                 | 1.8  |      | 3.6  | V     |
|                        |                                              | RSELx = 14                                                                    |                 | 2.2  |      | 3.6  |       |
|                        |                                              | RSELx = 15                                                                    |                 | 3.0  |      | 3.6  |       |
| f <sub>DCO(0,0)</sub>  | DCO frequency (0, 0)                         | RSELx = 0, DCOx = 0, MODx = 0                                                 | 2.2 V/3 V       | 0.06 |      | 0.14 | MHz   |
| f <sub>DCO(0,3)</sub>  | DCO frequency (0, 3)                         | RSELx = 0, DCOx = 3, MODx = 0                                                 | 2.2 V/3 V       | 0.07 |      | 0.17 | MHz   |
| f <sub>DCO(1,3)</sub>  | DCO frequency (1, 3)                         | RSELx = 1, DCOx = 3, MODx = 0                                                 | 2.2 V/3 V       | 0.10 |      | 0.20 | MHz   |
| f <sub>DCO(2,3)</sub>  | DCO frequency (2, 3)                         | RSELx = 2, DCOx = 3, MODx = 0                                                 | 2.2 V/3 V       | 0.14 |      | 0.28 | MHz   |
| f <sub>DCO(3,3)</sub>  | DCO frequency (3, 3)                         | RSELx = 3, DCOx = 3, MODx = 0                                                 | 2.2 V/3 V       | 0.20 |      | 0.40 | MHz   |
| f <sub>DCO(4,3)</sub>  | DCO frequency (4, 3)                         | RSELx = 4, DCOx = 3, MODx = 0                                                 | 2.2 V/3 V       | 0.28 |      | 0.54 | MHz   |
| f <sub>DCO(5,3)</sub>  | DCO frequency (5, 3)                         | RSELx = 5, DCOx = 3, MODx = 0                                                 | 2.2 V/3 V       | 0.39 |      | 0.77 | MHz   |
| f <sub>DCO(6,3)</sub>  | DCO frequency (6, 3)                         | RSELx = 6, DCOx = 3, MODx = 0                                                 | 2.2 V/3 V       | 0.54 |      | 1.06 | MHz   |
| f <sub>DCO(7,3)</sub>  | DCO frequency (7, 3)                         | RSELx = 7, DCOx = 3, MODx = 0                                                 | 2.2 V/3 V       | 0.80 |      | 1.50 | MHz   |
| f <sub>DCO(8,3)</sub>  | DCO frequency (8, 3)                         | RSELx = 8, DCOx = 3, MODx = 0                                                 | 2.2 V/3 V       | 1.10 |      | 2.10 | MHz   |
| f <sub>DCO(9,3)</sub>  | DCO frequency (9, 3)                         | RSELx = 9, DCOx = 3, MODx = 0                                                 | 2.2 V/3 V       | 1.60 |      | 3.00 | MHz   |
| f <sub>DCO(10,3)</sub> | DCO frequency (10, 3)                        | RSELx = 10, DCOx = 3, MODx = 0                                                | 2.2 V/3 V       | 2.50 |      | 4.30 | MHz   |
| f <sub>DCO(11,3)</sub> | DCO frequency (11, 3)                        | RSELx = 11, DCOx = 3, MODx = 0                                                | 2.2 V/3 V       | 3.00 |      | 5.50 | MHz   |
| f <sub>DCO(12,3)</sub> | DCO frequency (12, 3)                        | RSELx = 12, DCOx = 3, MODx = 0                                                | 2.2 V/3 V       | 4.30 |      | 7.30 | MHz   |
| f <sub>DCO(13,3)</sub> | DCO frequency (13, 3)                        | RSELx = 13, DCOx = 3, MODx = 0                                                | 2.2 V/3 V       | 6.00 |      | 9.60 | MHz   |
| f <sub>DCO(14,3)</sub> | DCO frequency (14, 3)                        | RSELx = 14, DCOx = 3, MODx = 0                                                | 2.2 V/3 V       | 8.60 |      | 13.9 | MHz   |
| f <sub>DCO(15,3)</sub> | DCO frequency (15, 3)                        | RSELx = 15, DCOx = 3, MODx = 0                                                | 3 V             | 12.0 |      | 18.5 | MHz   |
| f <sub>DCO(15,7)</sub> | DCO frequency (15, 7)                        | RSELx = 15, DCOx = 7, MODx = 0                                                | 3 V             | 16.0 |      | 26.0 | MHz   |
| S <sub>RSEL</sub>      | Frequency step between range RSEL and RSEL+1 | S <sub>RSEL</sub> = f <sub>DCO(RSEL+1,DCO)</sub> / f <sub>DCO(RSEL,DCO)</sub> | 2.2 V/3 V       |      |      | 1.55 | ratio |
| S <sub>DCO</sub>       | Frequency step between tap DCO and DCO+1     | S <sub>DCO</sub> = f <sub>DCO(RSEL,DCO+1)</sub> / f <sub>DCO(RSEL,DCO)</sub>  | 2.2 V/3 V       | 1.05 | 1.08 | 1.12 | ratio |
|                        | Duty cycle                                   | Measured at P1.4/SMCLK                                                        | 2.2 V/3 V       | 40   | 50   | 60   | %     |

## Calibrated DCO Frequencies - Tolerance at Calibration

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

| PARAMETER                                        | TEST CONDITIONS                                                        | T <sub>A</sub> | V <sub>CC</sub> | MIN   | TYP  | MAX   | UNIT |
|--------------------------------------------------|------------------------------------------------------------------------|----------------|-----------------|-------|------|-------|------|
| Frequency tolerance at calibration               |                                                                        | 25°C           | 3 V             | -1    | ±0.2 | +1    | %    |
| f <sub>CAL(1MHz)</sub> 1-MHz calibration value   | BCSCTL1 = CALBC1_1MHZ,<br>DCOCTL = CALDCO_1MHZ,<br>Gating time: 5 ms   | 25°C           | 3 V             | 0.990 | 1    | 1.010 | MHz  |
| f <sub>CAL(8MHz)</sub> 8-MHz calibration value   | BCSCTL1 = CALBC1_8MHZ,<br>DCOCTL = CALDCO_8MHZ,<br>Gating time: 5 ms   | 25°C           | 3 V             | 7.920 | 8    | 8.080 | MHz  |
| f <sub>CAL(12MHz)</sub> 12-MHz calibration value | BCSCTL1 = CALBC1_12MHZ,<br>DCOCTL = CALDCO_12MHZ,<br>Gating time: 5 ms | 25°C           | 3 V             | 11.88 | 12   | 12.12 | MHz  |
| f <sub>CAL(16MHz)</sub> 16-MHz calibration value | BCSCTL1 = CALBC1_16MHZ,<br>DCOCTL = CALDCO_16MHZ,<br>Gating time: 2 ms | 25°C           | 3 V             | 15.84 | 16   | 16.16 | MHz  |

## Calibrated DCO Frequencies - Tolerance Over Temperature 0°C to 85°C

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

| PARAMETER                                        | TEST CONDITIONS                                                        | T <sub>A</sub> | V <sub>CC</sub> | MIN   | TYP  | MAX   | UNIT |
|--------------------------------------------------|------------------------------------------------------------------------|----------------|-----------------|-------|------|-------|------|
| 1-MHz tolerance over temperature                 |                                                                        | 0°C to 85°C    | 3 V             | -2.5  | ±0.5 | +2.5  | %    |
| 8-MHz tolerance over temperature                 |                                                                        | 0°C to 85°C    | 3 V             | -2.5  | ±1   | +2.5  | %    |
| 12-MHz tolerance over temperature                |                                                                        | 0°C to 85°C    | 3 V             | -2.5  | ±1   | +2.5  | %    |
| 16-MHz tolerance over temperature                |                                                                        | 0°C to 85°C    | 3 V             | -3    | ±2   | +3    | %    |
| f <sub>CAL(1MHz)</sub> 1-MHz calibration value   | BCSCTL1 = CALBC1_1MHZ,<br>DCOCTL = CALDCO_1MHZ,<br>Gating time: 5 ms   | 0°C to 85°C    | 2.2 V           | 0.97  | 1    | 1.03  | MHz  |
|                                                  |                                                                        |                | 3 V             | 0.975 | 1    | 1.025 |      |
|                                                  |                                                                        |                | 3.6 V           | 0.97  | 1    | 1.03  |      |
| f <sub>CAL(8MHz)</sub> 8-MHz calibration value   | BCSCTL1 = CALBC1_8MHZ,<br>DCOCTL = CALDCO_8MHZ,<br>Gating time: 5 ms   | 0°C to 85°C    | 2.2 V           | 7.76  | 8    | 8.4   | MHz  |
|                                                  |                                                                        |                | 3 V             | 7.8   | 8    | 8.2   |      |
|                                                  |                                                                        |                | 3.6 V           | 7.6   | 8    | 8.24  |      |
| f <sub>CAL(12MHz)</sub> 12-MHz calibration value | BCSCTL1 = CALBC1_12MHZ,<br>DCOCTL = CALDCO_12MHZ,<br>Gating time: 5 ms | 0°C to 85°C    | 2.2 V           | 11.7  | 12   | 12.3  | MHz  |
|                                                  |                                                                        |                | 3 V             | 11.7  | 12   | 12.3  |      |
|                                                  |                                                                        |                | 3.6 V           | 11.7  | 12   | 12.3  |      |
| f <sub>CAL(16MHz)</sub> 16-MHz calibration value | BCSCTL1 = CALBC1_16MHZ,<br>DCOCTL = CALDCO_16MHZ,<br>Gating time: 2 ms | 0°C to 85°C    | 3 V             | 15.52 | 16   | 16.48 | MHz  |
|                                                  |                                                                        |                | 3.6 V           | 15    | 16   | 16.48 |      |

## Calibrated DCO Frequencies - Tolerance Over Supply Voltage $V_{CC}$

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

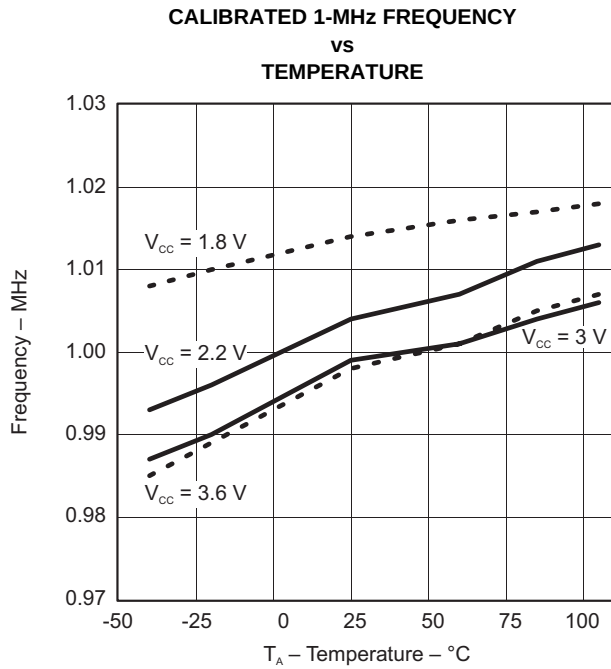
| PARAMETER                                 | TEST CONDITIONS                                                        | $T_A$ | $V_{CC}$       | MIN   | TYP | MAX   | UNIT |
|-------------------------------------------|------------------------------------------------------------------------|-------|----------------|-------|-----|-------|------|
| 1-MHz tolerance over $V_{CC}$             |                                                                        | 25°C  | 1.8 V to 3.6 V | -3    | ±2  | +3    | %    |
| 8-MHz tolerance over $V_{CC}$             |                                                                        | 25°C  | 1.8 V to 3.6 V | -3    | ±2  | +3    | %    |
| 12-MHz tolerance over $V_{CC}$            |                                                                        | 25°C  | 2.2 V to 3.6 V | -3    | ±2  | +3    | %    |
| 16-MHz tolerance over $V_{CC}$            |                                                                        | 25°C  | 3 V to 3.6 V   | -3    | ±2  | +3    | %    |
| $f_{CAL(1MHz)}$ 1-MHz calibration value   | BCSCTL1 = CALBC1_1MHZ,<br>DCOCTL = CALDCO_1MHZ,<br>Gating time: 5 ms   | 25°C  | 1.8 V to 3.6 V | 0.97  | 1   | 1.03  | MHz  |
| $f_{CAL(8MHz)}$ 8-MHz calibration value   | BCSCTL1 = CALBC1_8MHZ,<br>DCOCTL = CALDCO_8MHZ,<br>Gating time: 5 ms   | 25°C  | 1.8 V to 3.6 V | 7.76  | 8   | 8.24  | MHz  |
| $f_{CAL(12MHz)}$ 12-MHz calibration value | BCSCTL1 = CALBC1_12MHZ,<br>DCOCTL = CALDCO_12MHZ,<br>Gating time: 5 ms | 25°C  | 2.2 V to 3.6 V | 11.64 | 12  | 12.36 | MHz  |
| $f_{CAL(16MHz)}$ 16-MHz calibration value | BCSCTL1 = CALBC1_16MHZ,<br>DCOCTL = CALDCO_16MHZ,<br>Gating time: 2 ms | 25°C  | 3 V to 3.6 V   | 15    | 16  | 16.48 | MHz  |

## Calibrated DCO Frequencies - Overall Tolerance

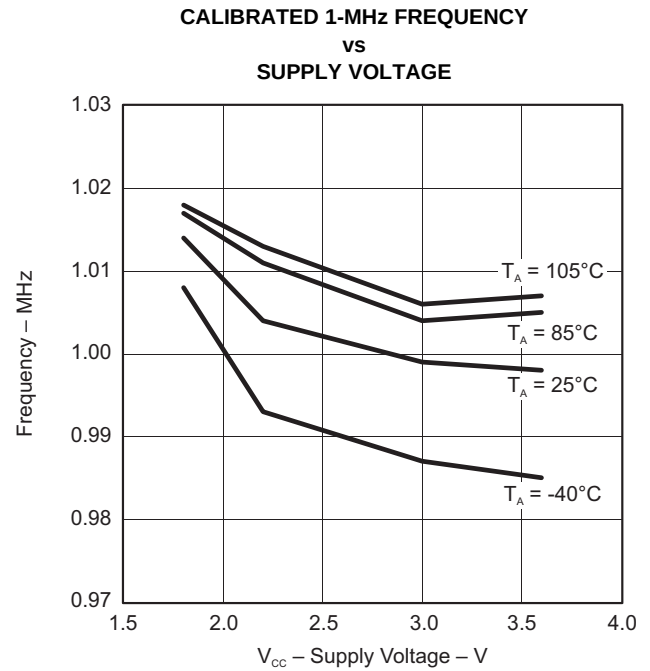
over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)

| PARAMETER                                 | TEST CONDITIONS                                                        | $T_A$                                 | $V_{CC}$       | MIN  | TYP | MAX  | UNIT |
|-------------------------------------------|------------------------------------------------------------------------|---------------------------------------|----------------|------|-----|------|------|
| 1-MHz tolerance overall                   |                                                                        | I: -40°C to 85°C<br>T: -40°C to 105°C | 1.8 V to 3.6 V | -5   | ±2  | +5   | %    |
| 8-MHz tolerance overall                   |                                                                        | I: -40°C to 85°C<br>T: -40°C to 105°C | 1.8 V to 3.6 V | -5   | ±2  | +5   | %    |
| 12-MHz tolerance overall                  |                                                                        | I: -40°C to 85°C<br>T: -40°C to 105°C | 2.2 V to 3.6 V | -5   | ±2  | +5   | %    |
| 16-MHz tolerance overall                  |                                                                        | I: -40°C to 85°C<br>T: -40°C to 105°C | 3 V to 3.6 V   | -6   | ±3  | +6   | %    |
| $f_{CAL(1MHz)}$ 1-MHz calibration value   | BCSCTL1 = CALBC1_1MHZ,<br>DCOCTL = CALDCO_1MHZ,<br>Gating time: 5 ms   | I: -40°C to 85°C<br>T: -40°C to 105°C | 1.8 V to 3.6 V | 0.95 | 1   | 1.05 | MHz  |
| $f_{CAL(8MHz)}$ 8-MHz calibration value   | BCSCTL1 = CALBC1_8MHZ,<br>DCOCTL = CALDCO_8MHZ,<br>Gating time: 5 ms   | I: -40°C to 85°C<br>T: -40°C to 105°C | 1.8 V to 3.6 V | 7.6  | 8   | 8.4  | MHz  |
| $f_{CAL(12MHz)}$ 12-MHz calibration value | BCSCTL1 = CALBC1_12MHZ,<br>DCOCTL = CALDCO_12MHZ,<br>Gating time: 5 ms | I: -40°C to 85°C<br>T: -40°C to 105°C | 2.2 V to 3.6 V | 11.4 | 12  | 12.6 | MHz  |
| $f_{CAL(16MHz)}$ 16-MHz calibration value | BCSCTL1 = CALBC1_16MHZ,<br>DCOCTL = CALDCO_16MHZ,<br>Gating time: 2 ms | I: -40°C to 85°C<br>T: -40°C to 105°C | 3 V to 3.6 V   | 15   | 16  | 17   | MHz  |

# **Typical Characteristics - Calibrated 1-MHz DCO Frequency**



**Figure 11.**



**Figure 12.**

## Wake-Up From Lower-Power Modes (LPM3/4)

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

| PARAMETER                                                                 | TEST CONDITIONS                                  | V <sub>CC</sub> | MIN | TYP                                             | MAX | UNIT          |
|---------------------------------------------------------------------------|--------------------------------------------------|-----------------|-----|-------------------------------------------------|-----|---------------|
| $t_{\text{DCO,LPM3/4}}$ DCO clock wake-up time from LPM3/4 <sup>(1)</sup> | BCSCTL1 = CALBC1_1MHZ,<br>DCOCTL = CALDCO_1MHZ   | 2.2 V/3 V       |     |                                                 | 2   | $\mu\text{s}$ |
|                                                                           | BCSCTL1 = CALBC1_8MHZ,<br>DCOCTL = CALDCO_8MHZ   |                 |     |                                                 | 1.5 |               |
|                                                                           | BCSCTL1 = CALBC1_12MHZ,<br>DCOCTL = CALDCO_12MHZ |                 |     |                                                 | 1   |               |
|                                                                           | BCSCTL1 = CALBC1_16MHZ,<br>DCOCTL = CALDCO_16MHZ | 3 V             |     |                                                 | 1   |               |
| $t_{\text{CPU,LPM3/4}}$ CPU wake-up time from LPM3/4 <sup>(2)</sup>       |                                                  |                 |     | $1 / f_{\text{MCLK}} + t_{\text{Clock,LPM3/4}}$ |     |               |

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

## Typical Characteristics - DCO Clock Wake-Up Time From LPM3/4

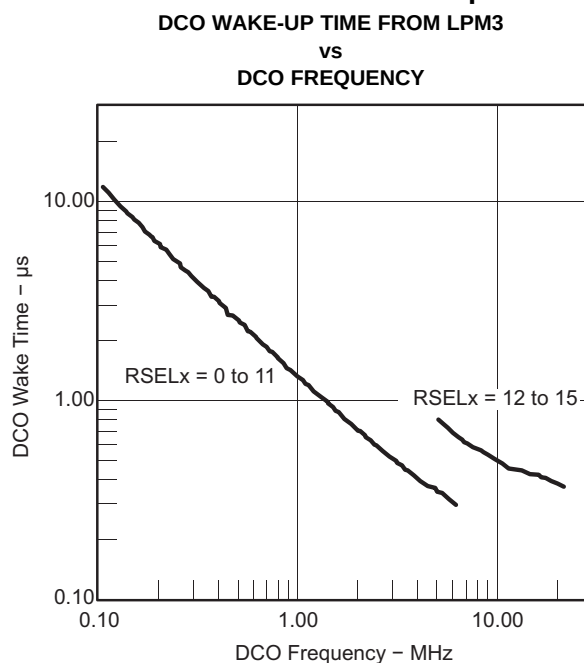


Figure 13.

## Crystal Oscillator LFXT1, Low-Frequency Mode<sup>(1)</sup>

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

| PARAMETER                   | TEST CONDITIONS                                                   | V <sub>CC</sub>                                                                    | MIN            | TYP   | MAX   | UNIT  |    |
|-----------------------------|-------------------------------------------------------------------|------------------------------------------------------------------------------------|----------------|-------|-------|-------|----|
| f <sub>LFXT1,LF</sub>       | LFXT1 oscillator crystal frequency, LF mode 0, 1                  | XTS = 0, LFXT1Sx = 0 or 1                                                          | 1.8 V to 3.6 V | 32768 |       | Hz    |    |
| f <sub>LFXT1,LF,logic</sub> | LFXT1 oscillator logic level square wave input frequency, LF mode | XTS = 0, LFXT1Sx = 3                                                               | 1.8 V to 3.6 V | 10000 | 32768 | 50000 | Hz |
| O <sub>A,LF</sub>           | Oscillation allowance for LF crystals                             | XTS = 0, LFXT1Sx = 0, f <sub>LFXT1,LF</sub> = 32768 Hz, C <sub>L,eff</sub> = 6 pF  |                | 500   |       | kΩ    |    |
|                             |                                                                   | XTS = 0, LFXT1Sx = 0, f <sub>LFXT1,LF</sub> = 32768 Hz, C <sub>L,eff</sub> = 12 pF |                | 200   |       |       |    |
| C <sub>L,eff</sub>          | Integrated effective load capacitance, LF mode <sup>(2)</sup>     | XTS = 0, XCAPx = 0                                                                 |                | 1     |       | pF    |    |
|                             |                                                                   | XTS = 0, XCAPx = 1                                                                 |                | 5.5   |       |       |    |
|                             |                                                                   | XTS = 0, XCAPx = 2                                                                 |                | 8.5   |       |       |    |
|                             |                                                                   | XTS = 0, XCAPx = 3                                                                 |                | 11    |       |       |    |
|                             | Duty cycle, LF mode                                               | XTS = 0, Measured at P2.0/ACLK, f <sub>LFXT1,LF</sub> = 32768 Hz                   | 2.2 V/3 V      | 30    | 50    | 70    | %  |
| f <sub>Fault,LF</sub>       | Oscillator fault frequency, LF mode <sup>(3)</sup>                | XTS = 0, LFXT1Sx = 3 <sup>(4)</sup>                                                | 2.2 V/3 V      | 10    | 10000 |       | Hz |

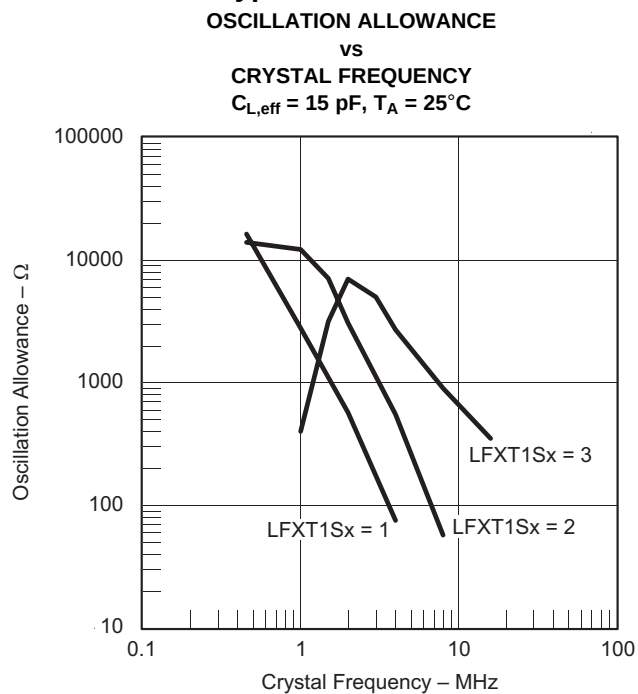
- (1) To improve EMI on the XT1 oscillator, the following guidelines should be observed.
  - (a) Keep the trace between the device and the crystal as short as possible.
  - (b) Design a good ground plane around the oscillator pins.
  - (c) Prevent crosstalk from other clock or data lines into oscillator pins XIN and XOUT.
  - (d) Avoid running PCB traces underneath or adjacent to the XIN and XOUT pins.
  - (e) Use assembly materials and praxis to avoid any parasitic load on the oscillator XIN and XOUT pins.
  - (f) If conformal coating is used, ensure that it does not induce capacitive/resistive leakage between the oscillator pins.
  - (g) 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.
- (2) Includes parasitic bond and package capacitance (approximately 2 pF per pin).  
Because the PCB adds additional capacitance, it is recommended to verify the correct load by measuring the ACLK frequency. For a correct setup, the effective load capacitance should always match the specification of the crystal that is used.
- (3) Frequencies below the MIN specification set the fault flag. Frequencies above the MAX specification do not set the fault flag. Frequencies in between might set the flag.
- (4) Measured with logic-level input frequency but also applies to operation with crystals.

**Crystal Oscillator LFXT1, High-Frequency Mode<sup>(1)</sup>**

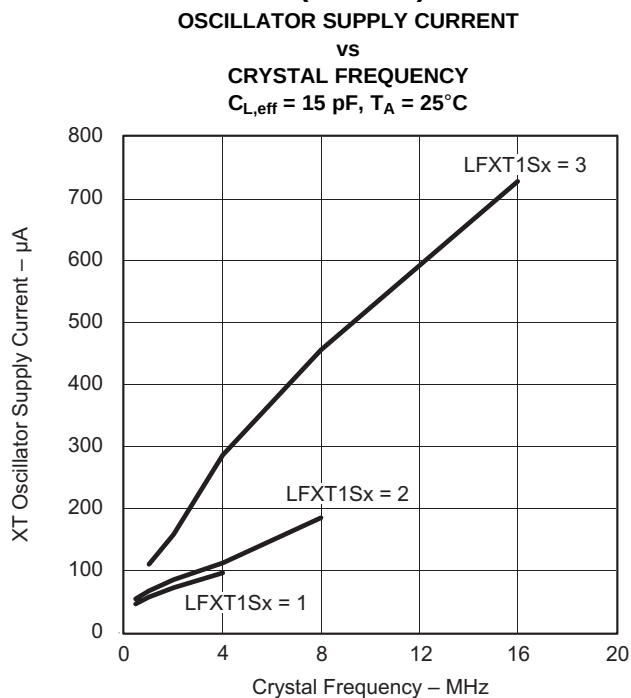
| PARAMETER                   |                                                                                                      | TEST CONDITIONS                                                                  | V <sub>CC</sub> | MIN | TYP  | MAX | UNIT |
|-----------------------------|------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|-----------------|-----|------|-----|------|
| f <sub>LFXT1,HF0</sub>      | LFXT1 oscillator crystal frequency, HF mode 0                                                        | XTS = 1, LFXT1Sx = 0                                                             | 1.8 V to 3.6 V  | 0.4 |      | 1   | MHz  |
| f <sub>LFXT1,HF1</sub>      | LFXT1 oscillator crystal frequency, HF mode 1                                                        | XTS = 1, LFXT1Sx = 1                                                             | 1.8 V to 3.6 V  | 1   |      | 4   | MHz  |
| f <sub>LFXT1,HF2</sub>      | LFXT1 oscillator crystal frequency, HF mode 2                                                        | XTS = 1, LFXT1Sx = 2                                                             | 1.8 V to 3.6 V  | 2   |      | 10  | MHz  |
|                             |                                                                                                      |                                                                                  | 2.2 V to 3.6 V  | 2   |      | 12  |      |
|                             |                                                                                                      |                                                                                  | 3 V to 3.6 V    | 2   |      | 16  |      |
| f <sub>LFXT1,HF,logic</sub> | LFXT1 oscillator logic-level square-wave input frequency, HF mode                                    | XTS = 1, LFXT1Sx = 3                                                             | 1.8 V to 3.6 V  | 0.4 |      | 10  | MHz  |
|                             |                                                                                                      |                                                                                  | 2.2 V to 3.6 V  | 0.4 |      | 12  |      |
|                             |                                                                                                      |                                                                                  | 3 V to 3.6 V    | 0.4 |      | 16  |      |
| O <sub>AHF</sub>            | Oscillation allowance for HF crystals (see <a href="#">Figure 14</a> and <a href="#">Figure 15</a> ) | XTS = 1, LFXT1Sx = 0, f <sub>LFXT1,HF</sub> = 1 MHz, C <sub>L,eff</sub> = 15 pF  |                 |     | 2700 |     | Ω    |
|                             |                                                                                                      | XTS = 1, LFXT1Sx = 1, f <sub>LFXT1,HF</sub> = 4 MHz, C <sub>L,eff</sub> = 15 pF  |                 |     | 800  |     |      |
|                             |                                                                                                      | XTS = 1, LFXT1Sx = 2, f <sub>LFXT1,HF</sub> = 16 MHz, C <sub>L,eff</sub> = 15 pF |                 |     | 300  |     |      |
| C <sub>L,eff</sub>          | Integrated effective load capacitance, HF mode <sup>(2)</sup>                                        | XTS = 1 <sup>(3)</sup>                                                           |                 |     | 1    |     | pF   |
|                             | Duty cycle, HF mode                                                                                  | XTS = 1, Measured at P2.0/ACLK, f <sub>LFXT1,HF</sub> = 10 MHz                   | 2.2 V/3 V       | 40  | 50   | 60  | %    |
|                             |                                                                                                      | XTS = 1, Measured at P2.0/ACLK, f <sub>LFXT1,HF</sub> = 16 MHz                   |                 | 40  | 50   | 60  |      |
| f <sub>Fault,HF</sub>       | Oscillator fault frequency <sup>(4)</sup>                                                            | XTS = 1, LFXT1Sx = 3 <sup>(5)</sup>                                              | 2.2 V/3 V       | 30  |      | 300 | kHz  |

- (1) To improve EMI on the XT2 oscillator the following guidelines should be observed:
  - (a) Keep the trace between the device and the crystal as short as possible.
  - (b) Design a good ground plane around the oscillator pins.
  - (c) Prevent crosstalk from other clock or data lines into oscillator pins XIN and XOUT.
  - (d) Avoid running PCB traces underneath or adjacent to the XIN and XOUT pins.
  - (e) Use assembly materials and praxis to avoid any parasitic load on the oscillator XIN and XOUT pins.
  - (f) If conformal coating is used, ensure that it does not induce capacitive/resistive leakage between the oscillator pins.
  - (g) 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.
- (2) Includes parasitic bond and package capacitance (approximately 2 pF per pin). Because the PCB adds additional capacitance, it is recommended to verify the correct load by measuring the ACLK frequency. For a correct setup, the effective load capacitance should always match the specification of the used crystal.
- (3) Requires external capacitors at both terminals. Values are specified by crystal manufacturers.
- (4) Frequencies below the MIN specification set the fault flag, frequencies above the MAX specification do not set the fault flag, and frequencies in between might set the flag.
- (5) Measured with logic-level input frequency, but also applies to operation with crystals.

# **Typical Characteristics - LFXT1 Oscillator in HF Mode (XTS = 1)**



**Figure 14.**



**Figure 15.**

## Timer\_A

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

| PARAMETER                                  | TEST CONDITIONS                                                           | V <sub>CC</sub> | MIN | TYP | MAX | UNIT |
|--------------------------------------------|---------------------------------------------------------------------------|-----------------|-----|-----|-----|------|
| f <sub>TA</sub> Timer_A clock frequency    | Internal: SMCLK, ACLK<br>External: TACLK, INCLK<br>Duty cycle = 50% ± 10% | 2.2 V           |     |     | 10  | MHz  |
|                                            |                                                                           | 3 V             |     |     | 16  |      |
| t <sub>TA,cap</sub> Timer_A capture timing | TA0, TA1, TA2                                                             | 2.2 V/3 V       | 20  |     |     | ns   |

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

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

| PARAMETER                                                                        | TEST CONDITIONS                                                                                                                                     | V <sub>CC</sub> | MIN  | TYP  | MAX                 | UNIT |
|----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|------|------|---------------------|------|
| I <sub>(DD)</sub>                                                                | CAON = 1, CARSEL = 0, CAREF = 0                                                                                                                     | 2.2 V           |      | 25   | 40                  | μA   |
|                                                                                  |                                                                                                                                                     | 3 V             |      | 45   | 60                  |      |
| I <sub>(Refladder/RefDiode)</sub>                                                | CAON = 1, CARSEL = 0, CAREF = 1/2/3,<br>No load at P2.3/CA0/TA1 and P2.4/CA1/TA2                                                                    | 2.2 V           |      | 30   | 50                  | μA   |
|                                                                                  |                                                                                                                                                     | 3 V             |      | 45   | 71                  |      |
| V <sub>(IC)</sub> Common-mode input voltage range                                | CAON = 1                                                                                                                                            | 2.2 V/3 V       | 0    |      | V <sub>CC</sub> - 1 | V    |
| V <sub>(Ref025)</sub> (Voltage at 0.25 V <sub>CC</sub> node) / V <sub>CC</sub>   | PCA0 = 1, CARSEL = 1, CAREF = 1,<br>No load at P2.3/CA0/TA1 and P2.4/CA1/TA2                                                                        | 2.2 V/3 V       | 0.23 | 0.24 | 0.25                |      |
| V <sub>(Ref050)</sub> (Voltage at 0.5 V <sub>CC</sub> node) / V <sub>CC</sub>    | PCA0 = 1, CARSEL = 1, CAREF = 2,<br>No load at P2.3/CA0/TA1 and P2.4/CA1/TA2                                                                        | 2.2 V/3 V       | 0.47 | 0.48 | 0.5                 |      |
| V <sub>(RefVT)</sub> See <a href="#">Figure 19</a> and <a href="#">Figure 20</a> | PCA0 = 1, CARSEL = 1, CAREF = 3,<br>No load at P2.3/CA0/TA1 and P2.4/CA1/TA2,<br>T <sub>A</sub> = 85°C                                              | 2.2 V           | 390  | 480  | 540                 | mV   |
|                                                                                  |                                                                                                                                                     | 3 V             | 400  | 490  | 550                 |      |
| V <sub>(offset)</sub> Offset voltage <sup>(2)</sup>                              |                                                                                                                                                     | 2.2 V/3 V       | -30  |      | 30                  | mV   |
| V <sub>hys</sub> Input hysteresis                                                | CAON = 1                                                                                                                                            | 2.2 V/3 V       | 0    | 0.7  | 1.4                 | mV   |
| t <sub>(response)</sub> Response time (low-high and high-low)                    | T <sub>A</sub> = 25°C, Overdrive 10 mV,<br>Without filter: CAF = 0 <sup>(3)</sup><br>(see <a href="#">Figure 16</a> and <a href="#">Figure 17</a> ) | 2.2 V           | 80   | 165  | 300                 | ns   |
|                                                                                  |                                                                                                                                                     | 3 V             | 70   | 120  | 240                 |      |
|                                                                                  | T <sub>A</sub> = 25°C, Overdrive 10 mV,<br>With filter: CAF = 1 <sup>(3)</sup><br>(see <a href="#">Figure 16</a> and <a href="#">Figure 17</a> )    | 2.2 V           | 1.4  | 1.9  | 2.8                 | μs   |
|                                                                                  |                                                                                                                                                     | 3 V             | 0.9  | 1.5  | 2.2                 |      |

(1) The leakage current for the Comparator\_A+ terminals is identical to I<sub>lkg(Px.y)</sub> specification.

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

(3) Response time measured at P2.2/CAOUT.

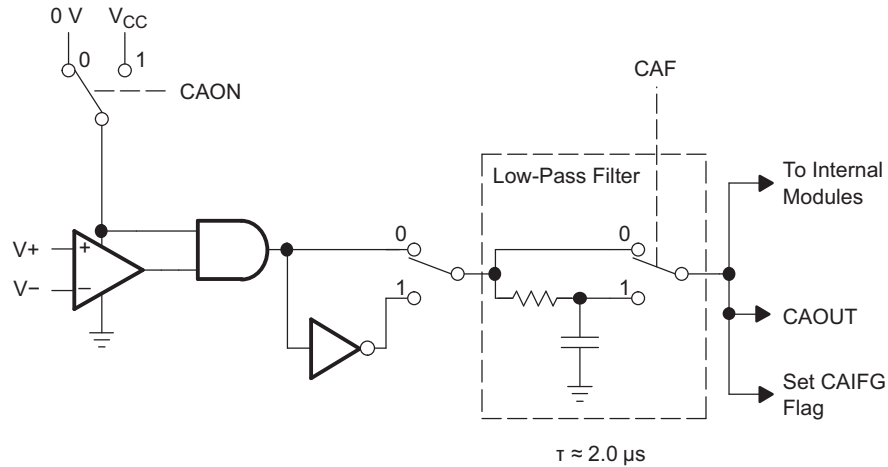


Figure 16. Comparator\_A+ Module Block Diagram

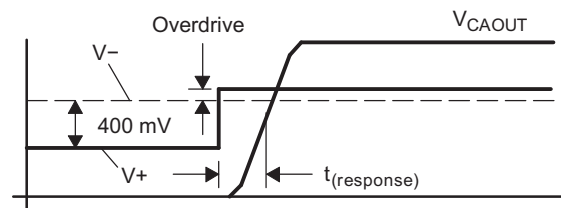


Figure 17. Overdrive Definition

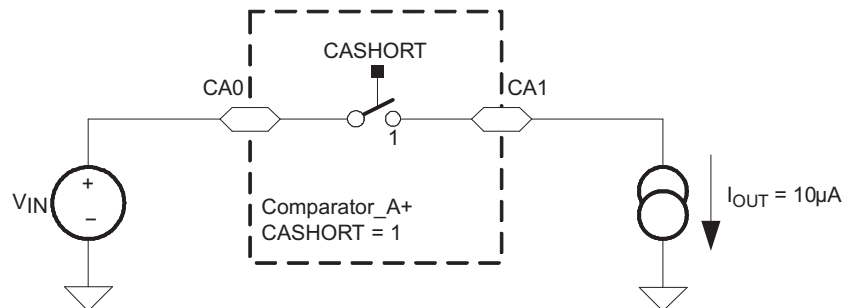


Figure 18. Comparator\_A+ Short Resistance Test Condition

**Typical Characteristics - Comparator\_A+**

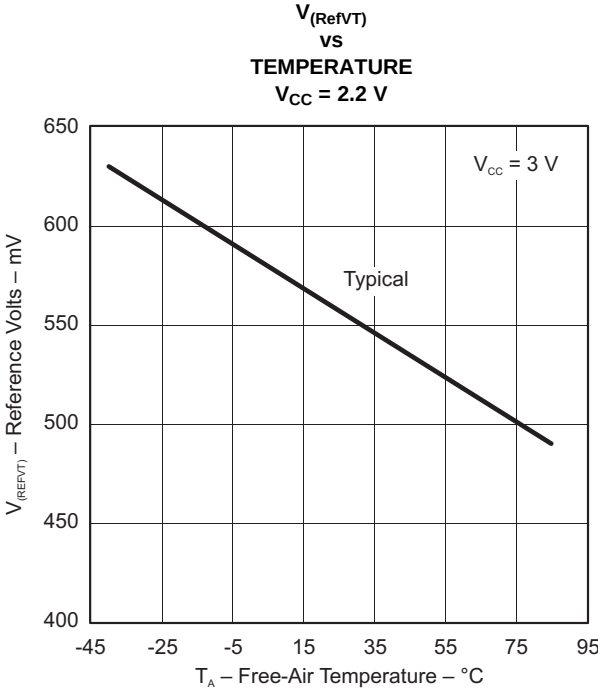


Figure 19.

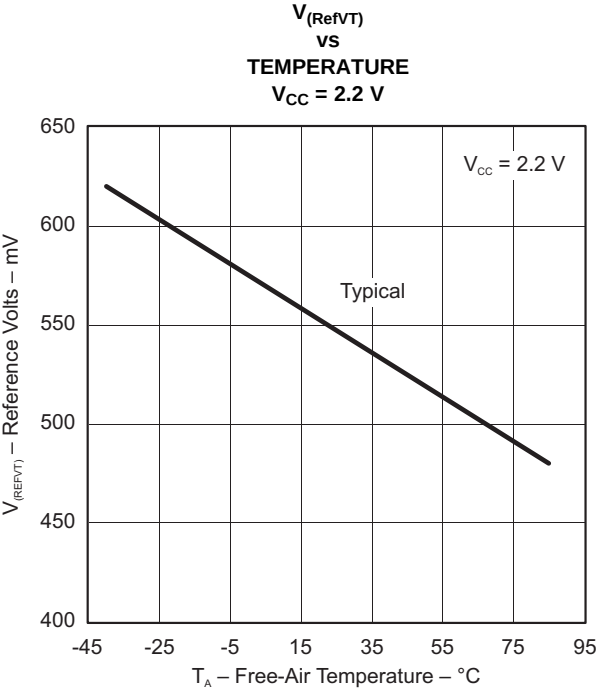


Figure 20.

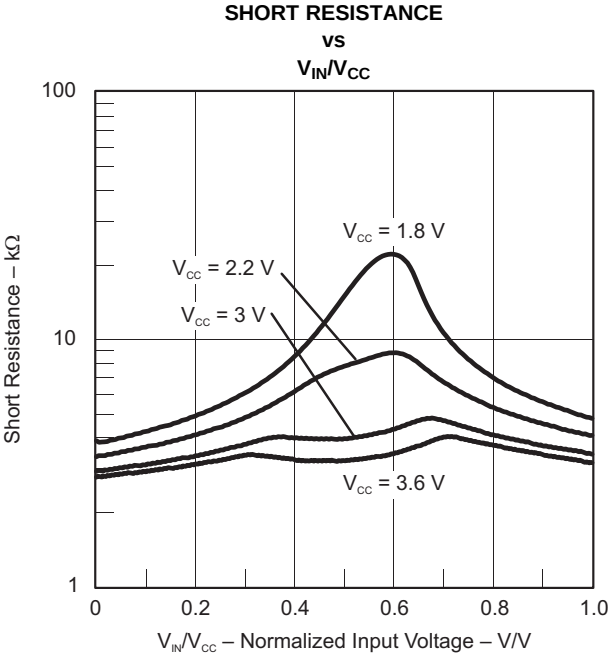


Figure 21.

## Flash Memory

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

| PARAMETER                   | TEST CONDITIONS                                     | V <sub>CC</sub>       | MIN             | TYP             | MAX | UNIT             |
|-----------------------------|-----------------------------------------------------|-----------------------|-----------------|-----------------|-----|------------------|
| V <sub>CC</sub> (PGM/ERASE) | Program and erase supply voltage                    |                       | 2.2             |                 | 3.6 | V                |
| f <sub>FTG</sub>            | Flash timing generator frequency                    |                       | 257             |                 | 476 | kHz              |
| I <sub>PGM</sub>            | Supply current from V <sub>CC</sub> during program  | 2.2 V/3.6 V           |                 | 3               | 5   | mA               |
| I <sub>ERASE</sub>          | Supply current from V <sub>CC</sub> during erase    | 2.2 V/3.6 V           |                 | 3               | 7   | mA               |
| t <sub>CPT</sub>            | Cumulative program time <sup>(1)</sup>              | 2.2 V/3.6 V           |                 |                 | 10  | ms               |
| t <sub>CMErase</sub>        | Cumulative mass erase time                          | 2.2 V/3.6 V           | 20              |                 |     | ms               |
|                             | Program/erase endurance                             |                       | 10 <sup>4</sup> | 10 <sup>5</sup> |     | cycles           |
| t <sub>Retention</sub>      | Data retention duration                             | T <sub>J</sub> = 25°C | 100             |                 |     | years            |
| t <sub>Word</sub>           | Word or byte program time                           | See <sup>(2)</sup>    |                 | 30              |     | t <sub>FTG</sub> |
| t <sub>Block, 0</sub>       | Block program time for first byte or word           | See <sup>(2)</sup>    |                 | 25              |     | t <sub>FTG</sub> |
| t <sub>Block, 1-63</sub>    | Block program time for each additional byte or word | See <sup>(2)</sup>    |                 | 18              |     | t <sub>FTG</sub> |
| t <sub>Block, End</sub>     | Block program end-sequence wait time                | See <sup>(2)</sup>    |                 | 6               |     | t <sub>FTG</sub> |
| t <sub>Mass Erase</sub>     | Mass erase time                                     | See <sup>(2)</sup>    |                 | 10593           |     | t <sub>FTG</sub> |
| t <sub>Seg Erase</sub>      | Segment erase time                                  | See <sup>(2)</sup>    |                 | 4819            |     | t <sub>FTG</sub> |

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

(2) These values are hardwired into the flash controller's state machine (t<sub>FTG</sub> = 1/f<sub>FTG</sub>).

## RAM

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

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

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

## JTAG Interface

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

| PARAMETER             | V <sub>CC</sub> | MIN | TYP | MAX | UNIT |
|-----------------------|-----------------|-----|-----|-----|------|
| f <sub>TCK</sub>      | 2.2 V           | 0   |     | 5   | MHz  |
|                       | 3 V             | 0   |     | 10  | MHz  |
| R <sub>Internal</sub> | 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.

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

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

| PARAMETER           | T <sub>A</sub> | MIN | MAX | UNIT |
|---------------------|----------------|-----|-----|------|
| V <sub>CC(FB)</sub> | 25°C           | 2.5 |     | V    |
| V <sub>FB</sub>     | 25°C           | 6   | 7   | V    |
| I <sub>FB</sub>     | 25°C           |     | 100 | mA   |
| t <sub>FB</sub>     | 25°C           |     | 1   | ms   |

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

## APPLICATION INFORMATION

## Port P1 Pin Schematic: P1.0 to P1.3, Input/Output With Schmitt Trigger

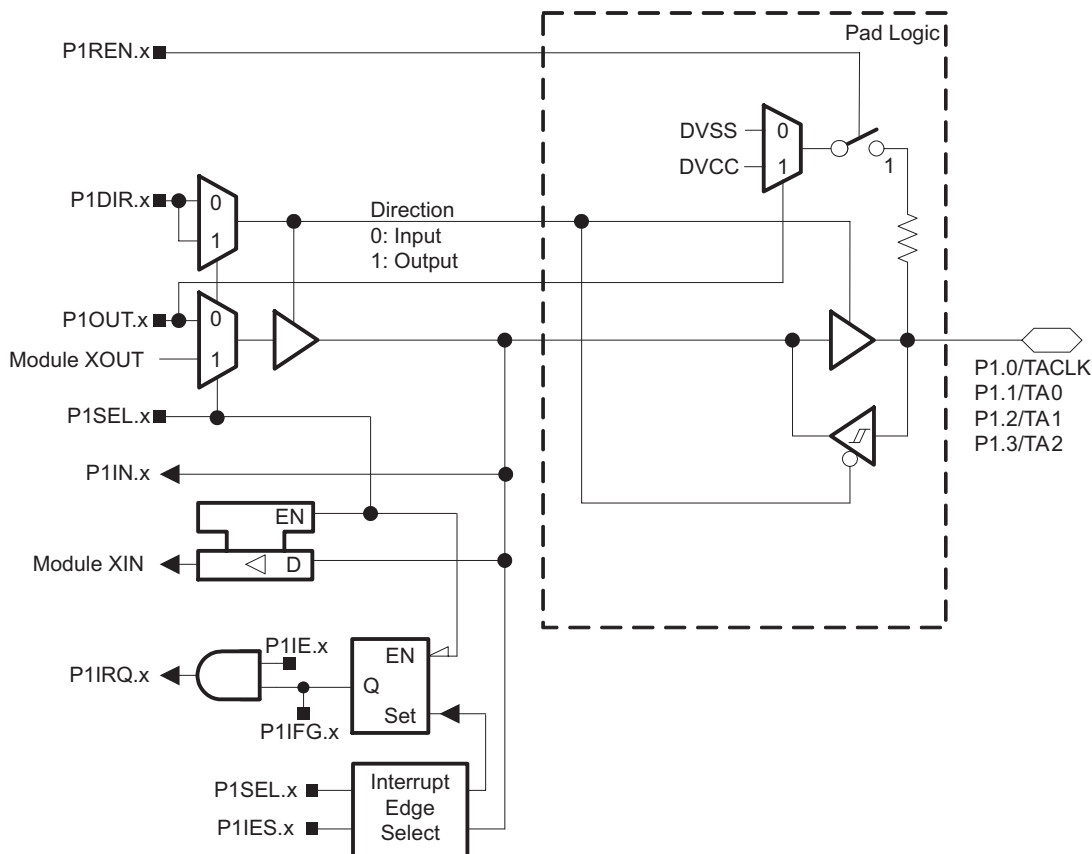
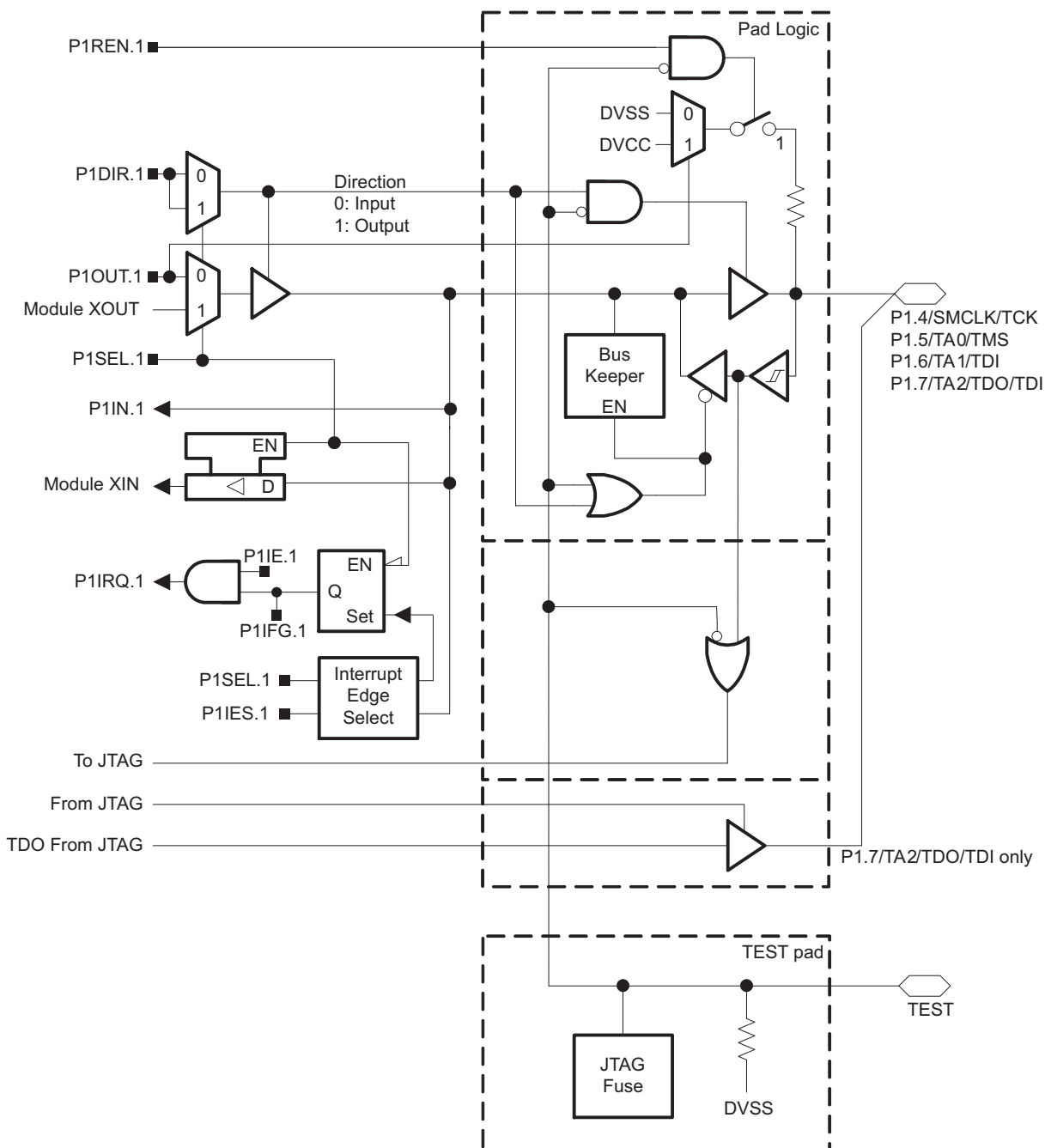


Table 17. Port P1 (P1.0 to P1.3) Pin Functions

| PIN NAME (P1.x) | x | FUNCTION                  | CONTROL BITS / SIGNALS |         |
|-----------------|---|---------------------------|------------------------|---------|
|                 |   |                           | P1DIR.x                | P1SEL.x |
| P1.0/TACLK      | 0 | P1.0 <sup>(1)</sup> (I/O) | I: 0; O: 1             | 0       |
|                 |   | TACLK                     | 0                      | 1       |
|                 |   | DVSS                      | 1                      | 1       |
| P1.1/TA0        | 1 | P1.1 <sup>(1)</sup> (I/O) | I: 0; O: 1             | 0       |
|                 |   | Timer_A3.CCI0A            | 0                      | 1       |
|                 |   | Timer_A3.TA0              | 1                      | 1       |
| P1.2/TA1        | 2 | P1.2 <sup>(1)</sup> (I/O) | I: 0; O: 1             | 0       |
|                 |   | Timer_A3.CCI0A            | 0                      | 1       |
|                 |   | Timer_A3.TA0              | 1                      | 1       |
| P1.3/TA2        | 3 | P1.3 <sup>(1)</sup> (I/O) | I: 0; O: 1             | 0       |
|                 |   | Timer_A3.CCI0A            | 0                      | 1       |
|                 |   | Timer_A3.TA0              | 1                      | 1       |

(1) Default after reset (PUC/POR)

## Port P1 Pin Schematic: P1.4 to P1.7, Input/Output With Schmitt Trigger



**Table 18. Port P1 (P1.4 to P1.7) Pin Functions**

| PIN NAME (P1.x)   | x | FUNCTION                  | CONTROL BITS / SIGNALS <sup>(1)</sup> |         |      |
|-------------------|---|---------------------------|---------------------------------------|---------|------|
|                   |   |                           | P1DIR.x                               | P1SEL.x | TEST |
| P1.4/SMCLK/TCK    | 4 | P1.4 <sup>(2)</sup> (I/O) | I: 0; O: 1                            | 0       | 0    |
|                   |   | SMCLK                     | 1                                     | 1       | 0    |
|                   |   | TCK                       | X                                     | X       | 1    |
| P1.5/TA0/TMS      | 5 | P1.5 <sup>(2)</sup> (I/O) | I: 0; O: 1                            | 0       | 0    |
|                   |   | Timer_A3.TA0              | 1                                     | 1       | 0    |
|                   |   | TMS                       | X                                     | X       | 1    |
| P1.6/TA1/TDI/TCLK | 6 | P1.6 <sup>(2)</sup> (I/O) | I: 0; O: 1                            | 0       | 0    |
|                   |   | Timer_A3.TA1              | 1                                     | 1       | 0    |
|                   |   | TDI/TCLK <sup>(3)</sup>   | X                                     | X       | 1    |
| P1.7/TA2/TDO/TDI  | 7 | P1.7 <sup>(2)</sup> (I/O) | I: 0; O: 1                            | 0       | 0    |
|                   |   | Timer_A3.TA2              | 1                                     | 1       | 0    |
|                   |   | TDO/TDI <sup>(3)</sup>    | X                                     | X       | 1    |

(1) X = don't care

(2) Default after reset (PUC/POR)

(3) Function controlled by JTAG

## Port P2 Pin Schematic: P2.0 to P2.5, Input/Output With Schmitt Trigger

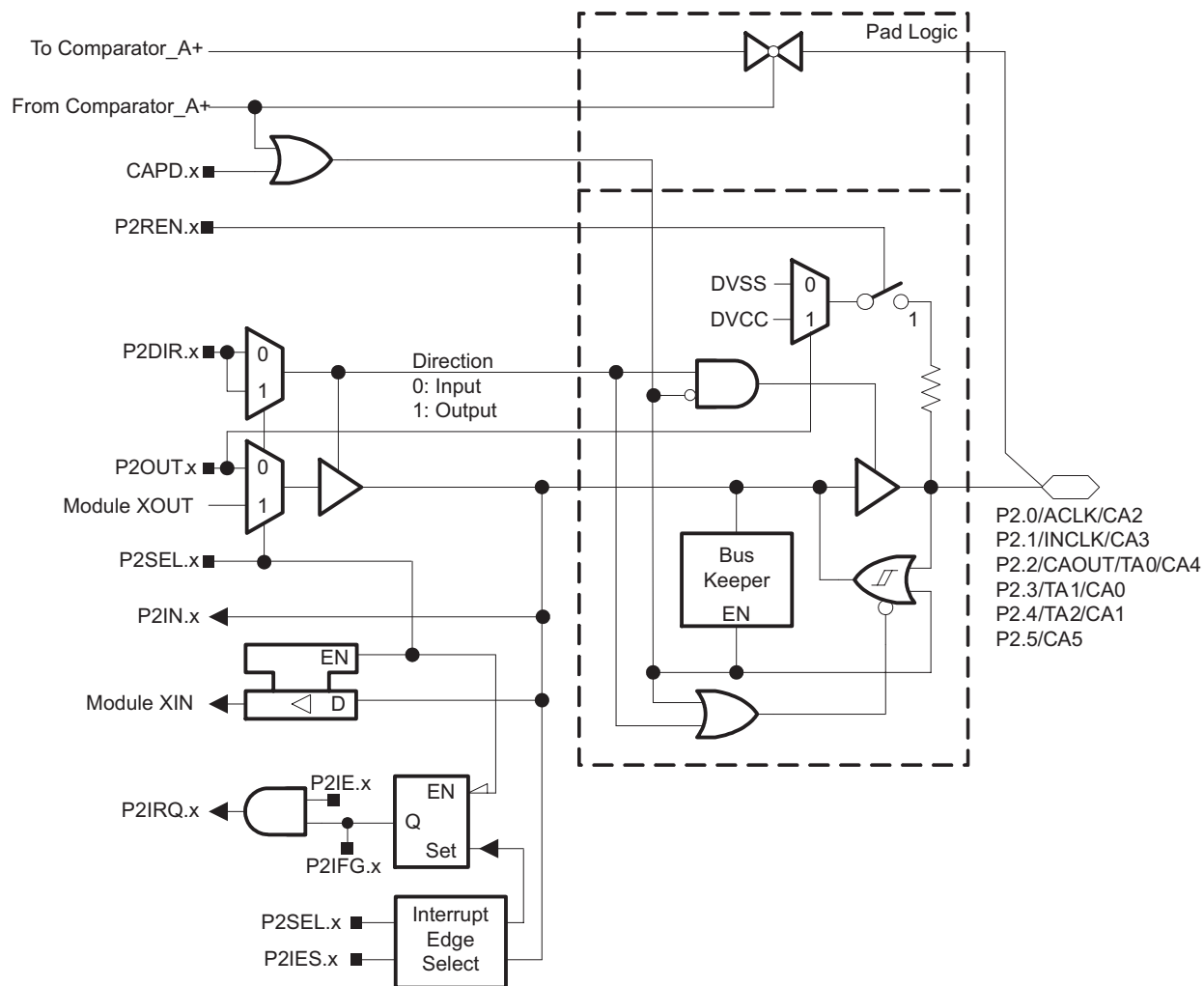


Table 19. Control Signal "From Comparator\_A+"

| PIN NAME           | FUNCTION | SIGNAL "From Comparator_A+" = 1 <sup>(1)</sup> |       |    |       |       |       |
|--------------------|----------|------------------------------------------------|-------|----|-------|-------|-------|
|                    |          | P2CA4                                          | P2CA0 | OR | P2CA3 | P2CA2 | P2CA1 |
| P2.0/ACLK/CA2      | CA2      | 1                                              | 1     |    | 0     | 1     | 0     |
| P2.1/INCLK/CA3     | CA3      | N/A                                            | N/A   |    | 0     | 1     | 1     |
| P2.2/CAOUT/TA0/CA4 | CA4      | N/A                                            | N/A   |    | 1     | 0     | 0     |
| P2.3/TA1/CA0       | CA0      | 0                                              | 1     |    | N/A   | N/A   | N/A   |
| P2.4/TA2/CA1       | CA1      | 1                                              | 0     |    | 0     | 0     | 1     |
| P2.5/CA5           | CA5      | N/A                                            | N/A   |    | 1     | 0     | 1     |

(1) N/A = Not available or not applicable

**Table 20. Port P2 (P2.0 to P2.5) Pin Functions**

| PIN NAME (P2.x)    | x | FUNCTION                  | CONTROL BITS / SIGNALS <sup>(1)</sup> |         |        |
|--------------------|---|---------------------------|---------------------------------------|---------|--------|
|                    |   |                           | P2DIR.x                               | P2SEL.x | CAPD.x |
| P2.0/ACLK/CA2      | 0 | P2.0 <sup>(2)</sup> (I/O) | I: 0; O: 1                            | 0       | 0      |
|                    |   | ACLK                      | 1                                     | 1       | 0      |
|                    |   | CA2 <sup>(3)</sup>        | X                                     | X       | 1      |
| P2.1/INCLK/CA3     | 1 | P2.1 <sup>(2)</sup> (I/O) | I: 0; O: 1                            | 0       | 0      |
|                    |   | Timer_A3.INCLK            | 0                                     | 1       | 0      |
|                    |   | DVSS                      | 1                                     | 1       | 0      |
|                    |   | CA3 <sup>(3)</sup>        | X                                     | X       | 1      |
| P2.2/CAOUT/TA0/CA4 | 2 | P2.2 <sup>(2)</sup> (I/O) | I: 0; O: 1                            | 0       | 0      |
|                    |   | Timer_A3.CCI0B            | 0                                     | 1       | 0      |
|                    |   | CAOUT                     | 1                                     | 1       | 0      |
|                    |   | CA4 <sup>(3)</sup>        | X                                     | X       | 1      |
| P2.3/TA1/CA0       | 3 | P2.3 <sup>(2)</sup> (I/O) | I: 0; O: 1                            | 0       | 0      |
|                    |   | Timer_A3.TA1              | 1                                     | 1       | 0      |
|                    |   | CA0 <sup>(3)</sup>        | X                                     | X       | 1      |
| P2.4/TA2/CA1       | 4 | P2.4 <sup>(2)</sup> (I/O) | I: 0; O: 1                            | 0       | 0      |
|                    |   | Timer_A3.TA2              | 1                                     | 1       | 0      |
|                    |   | CA1 <sup>(3)</sup>        | X                                     | X       | 1      |
| P2.5/CA5           | 5 | P2.5 <sup>(2)</sup> (I/O) | I: 0; O: 1                            | 0       | 0      |
|                    |   | CA5 <sup>(3)</sup>        | X                                     | X       | 1      |

(1) X = don't care

(2) Default after reset (PUC/POR)

(3) Setting the CAPD.x bit disables the output driver as well as the input Schmitt trigger to prevent parasitic cross currents when applying analog signals. Selecting the CAx input pin to the comparator multiplexer with the P2CAx bits automatically disables the input buffer for that pin, regardless of the state of the associated CAPD.x bit.

# Port P2 Pin Schematic: P2.6, Input/Output With Schmitt Trigger and Crystal Oscillator Input

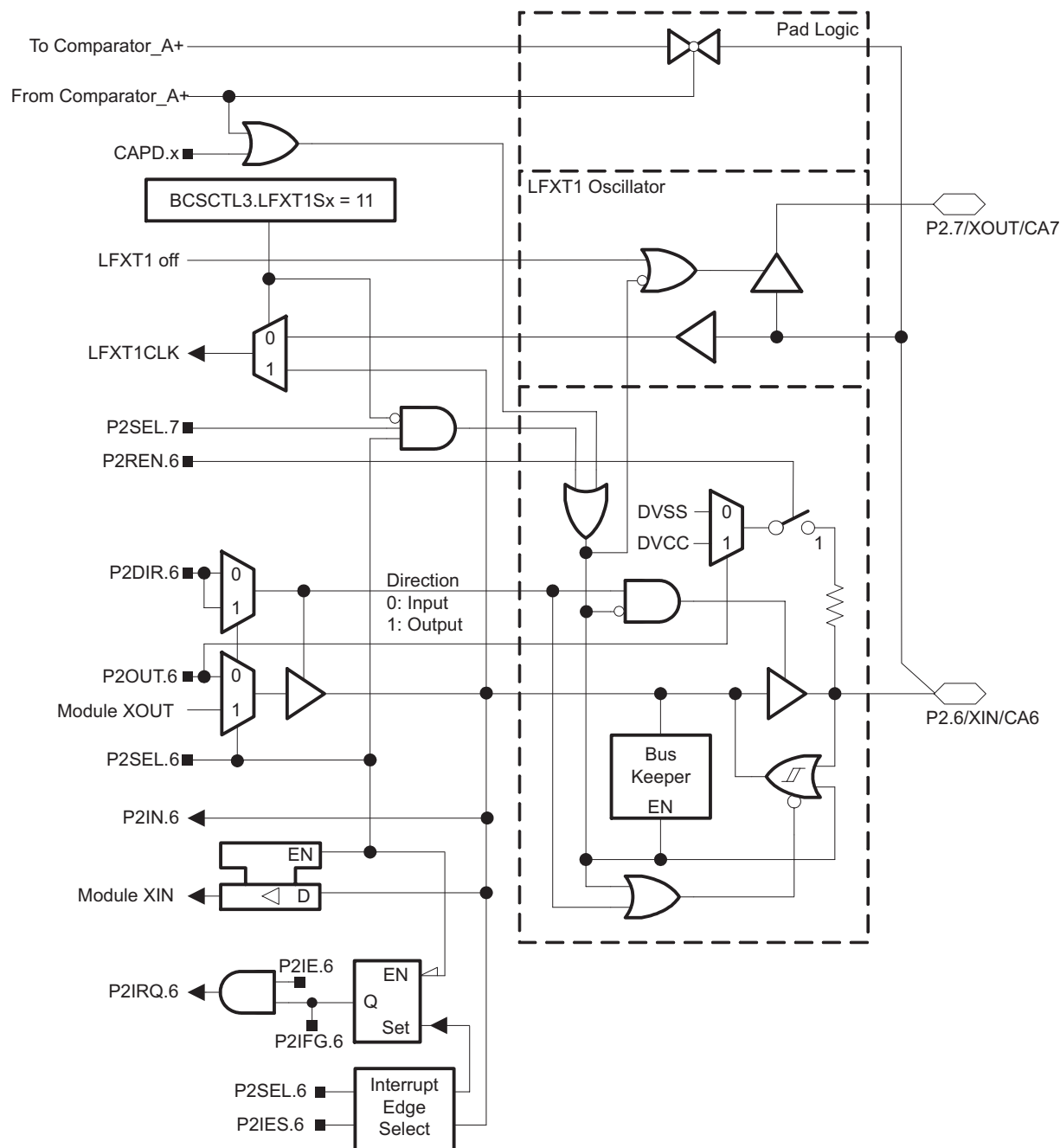


Table 21. Control Signal "From Comparator\_A+"

| PIN NAME     | FUNCTION | SIGNAL "From Comparator_A+" = 1 |       |       |
|--------------|----------|---------------------------------|-------|-------|
|              |          | P2CA3                           | P2CA2 | P2CA1 |
| P2.6/XIN/CA6 | CA6      | 1                               | 1     | 0     |

**Table 22. Port P2 (P2.6) Pin Functions**

| PIN NAME (P2.x) | x | FUNCTION           | CONTROL BITS / SIGNALS <sup>(1)</sup> |         |        |
|-----------------|---|--------------------|---------------------------------------|---------|--------|
|                 |   |                    | P2DIR.x                               | P2SEL.x | CAPD.x |
| P2.6/XIN/CA6    | 6 | P2.6 (I/O)         | I: 0; O: 1                            | 0       | 0      |
|                 |   | XIN <sup>(2)</sup> | X                                     | 1       | 0      |
|                 |   | CA6 <sup>(3)</sup> | X                                     | X       | 1      |

(1) X = don't care

(2) Default after reset (PUC/POR)

(3) Setting the CAPD.x bit disables the output driver as well as the input Schmitt trigger to prevent parasitic cross currents when applying analog signals. Selecting the CAx input pin to the comparator multiplexer with the P2CAx bits automatically disables the input buffer for that pin, regardless of the state of the associated CAPD.x bit.

# Port P2 Pin Schematic: P2.7, Input/Output With Schmitt Trigger and Crystal Oscillator Output

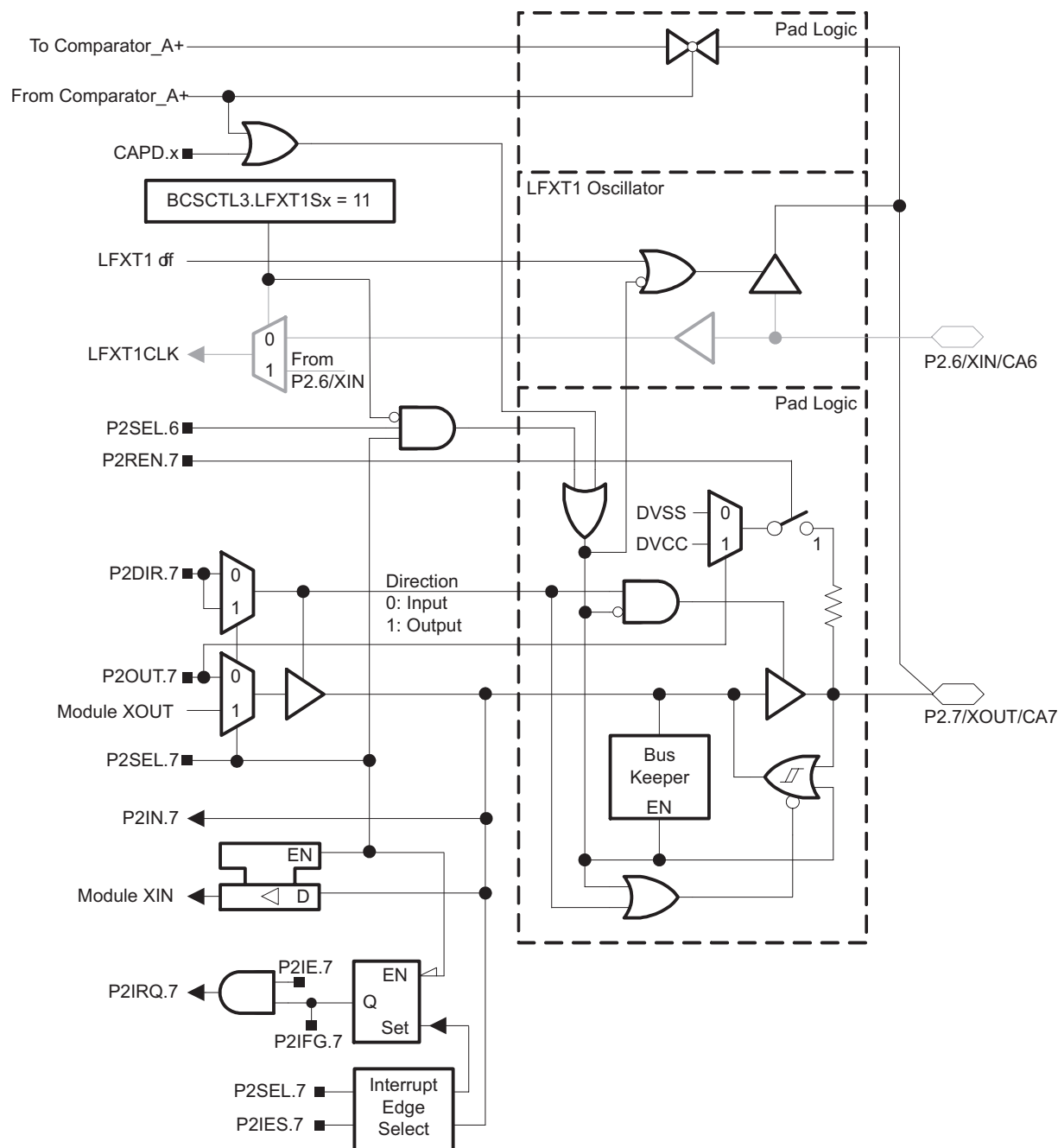


Table 23. Control Signal "From Comparator\_A+"

| PIN NAME      | FUNCTION | SIGNAL "From Comparator_A+" = 1 |       |       |
|---------------|----------|---------------------------------|-------|-------|
|               |          | P2CA3                           | P2CA2 | P2CA1 |
| P2.7/XOUT/CA7 | CA7      | 1                               | 1     | 1     |

**Table 24. Port P2 (P2.7) Pin Functions**

| PIN NAME (P2.x) | x | FUNCTION               | CONTROL BITS / SIGNALS <sup>(1)</sup> |         |        |
|-----------------|---|------------------------|---------------------------------------|---------|--------|
|                 |   |                        | P2DIR.x                               | P2SEL.x | CAPD.x |
| P2.7/XOUT/CA7   | 6 | P2.7 (I/O)             | I: 0; O: 1                            | 0       | 0      |
|                 |   | XOUT <sup>(2)(3)</sup> | X                                     | 1       | 0      |
|                 |   | CA7 <sup>(4)</sup>     | X                                     | X       | 1      |

(1) X = don't care

(2) Default after reset (PUC/POR)

(3) If the pin XOUT/P2.7/CA7 is used as an input a current can flow until P2SEL.7 is cleared due to the oscillator output driver connection to this pin after reset.

(4) Setting theCAPD.x bit disables the output driver as well as the input Schmitt trigger to prevent parasitic cross currents when applying analog signals. Selecting the CAx input pin to the comparator multiplexer with the P2CAx bits automatically disables the input buffer for that pin, regardless of the state of the associated CAPD.x bit.

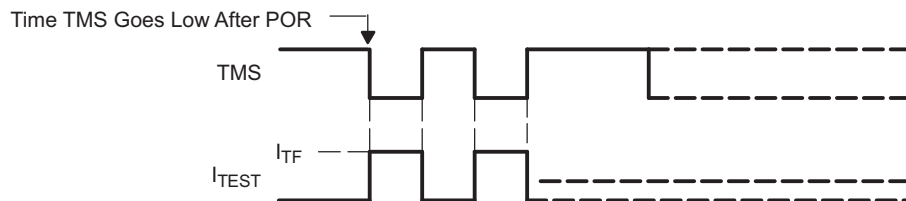
## JTAG Fuse Check Mode

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

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

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

The fuse check current flows only when the fuse check mode is active and the TMS pin is in a low state (see [Figure 22](#)). Therefore, the additional current flow can be prevented by holding the TMS pin high (default condition).



**Figure 22. Fuse Check Mode Current**

### NOTE

The CODE and RAM data protection is ensured if the JTAG fuse is blown and the 256-bit bootloader access key is used. Also, see the [Bootstrap Loader](#) section for more information.

## REVISION HISTORY

| Literature Number | Summary                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|-------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| SLAS439           | PRODUCT PREVIEW release                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| SLAS439A          | PRODUCTION DATA release                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| SLAS439B          | <p>Corrected instruction cycle time to 62.5ns, pg 1.</p> <p>Updated Figure 1, pg 12.</p> <p>Updated Figures 2 and 3, pg 13.</p> <p>R<sub>PULL</sub> unit corrected from <math>\Omega</math> to k<math>\Omega</math>, pg 15.</p> <p>MAX load current specification and Note 3 removed from "outputs" table, pg 16.</p> <p>MIN and MAX percentages for "calibrated DCO frequencies - tolerance over supply voltage VCC" corrected from 2.5% to 3% to match the specified frequency ranges., pg 22.</p> |
| SLAS439C          | <p>MSP430x21x1T production data sheet release.</p> <p>105°C characterization results added.</p>                                                                                                                                                                                                                                                                                                                                                                                                      |
| SLAS439D          | Corrected Timer_A2 to Timer_A3 and added TACCR2 to Interrupt Flag column in "interrupt vector addresses", pg 6                                                                                                                                                                                                                                                                                                                                                                                       |
| SLAS439E          | <p>Changed T<sub>stg</sub>, Programmed device, to -40°C to 150°C in <a href="#">Absolute Maximum Ratings</a>.</p> <p>Corrected Test Conditions for OA<sub>HF</sub> row and and Duty Cycle row in <a href="#">Crystal Oscillator LFX1, High-Frequency Mode</a>.</p>                                                                                                                                                                                                                                   |
| SLAS439F          | Changed T <sub>stg</sub> , Programmed device, to -55°C to 150°C in <a href="#">Absolute Maximum Ratings</a> .                                                                                                                                                                                                                                                                                                                                                                                        |

## PACKAGING INFORMATION

| Orderable Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package<br>Qty | Eco Plan<br>(2) | Lead finish/<br>Ball material<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples                 |
|------------------|---------------|--------------|--------------------|------|----------------|-----------------|--------------------------------------|----------------------|--------------|-------------------------|-------------------------|
| MSP430F2101IDGV  | ACTIVE        | TVSOP        | DGV                | 20   | 90             | RoHS & Green    | NIPDAU                               | Level-2-260C-1 YEAR  | -40 to 85    | 4F2101                  | <a href="#">Samples</a> |
| MSP430F2101IDGVR | ACTIVE        | TVSOP        | DGV                | 20   | 2000           | RoHS & Green    | NIPDAU                               | Level-2-260C-1 YEAR  | -40 to 85    | 4F2101                  | <a href="#">Samples</a> |
| MSP430F2101IDW   | ACTIVE        | SOIC         | DW                 | 20   | 25             | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | M430F2101               | <a href="#">Samples</a> |
| MSP430F2101IDWR  | ACTIVE        | SOIC         | DW                 | 20   | 2000           | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | M430F2101               | <a href="#">Samples</a> |
| MSP430F2101IPW   | ACTIVE        | TSSOP        | PW                 | 20   | 70             | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | 430F2101                | <a href="#">Samples</a> |
| MSP430F2101IPWR  | ACTIVE        | TSSOP        | PW                 | 20   | 2000           | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | 430F2101                | <a href="#">Samples</a> |
| MSP430F2101IRGER | ACTIVE        | VQFN         | RGE                | 24   | 3000           | RoHS & Green    | NIPDAU                               | Level-2-260C-1 YEAR  | -40 to 85    | M430F<br>2101           | <a href="#">Samples</a> |
| MSP430F2101IRGET | ACTIVE        | VQFN         | RGE                | 24   | 250            | RoHS & Green    | NIPDAU                               | Level-2-260C-1 YEAR  | -40 to 85    | M430F<br>2101           | <a href="#">Samples</a> |
| MSP430F2101TDGV  | ACTIVE        | TVSOP        | DGV                | 20   | 90             | RoHS & Green    | NIPDAU                               | Level-2-260C-1 YEAR  | -40 to 105   | 4F2101T                 | <a href="#">Samples</a> |
| MSP430F2101TDGVR | ACTIVE        | TVSOP        | DGV                | 20   | 2000           | RoHS & Green    | NIPDAU                               | Level-2-260C-1 YEAR  | -40 to 105   | 4F2101T                 | <a href="#">Samples</a> |
| MSP430F2101TDW   | ACTIVE        | SOIC         | DW                 | 20   | 25             | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 105   | M430F2101T              | <a href="#">Samples</a> |
| MSP430F2101TDWR  | ACTIVE        | SOIC         | DW                 | 20   | 2000           | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 105   | M430F2101T              | <a href="#">Samples</a> |
| MSP430F2101TPW   | ACTIVE        | TSSOP        | PW                 | 20   | 70             | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 105   | 4F2101T                 | <a href="#">Samples</a> |
| MSP430F2101TPWR  | ACTIVE        | TSSOP        | PW                 | 20   | 2000           | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 105   | 4F2101T                 | <a href="#">Samples</a> |
| MSP430F2101TRGER | ACTIVE        | VQFN         | RGE                | 24   | 3000           | RoHS & Green    | NIPDAU                               | Level-2-260C-1 YEAR  | -40 to 105   | M430F<br>2101T          | <a href="#">Samples</a> |
| MSP430F2111IDGV  | ACTIVE        | TVSOP        | DGV                | 20   | 90             | RoHS & Green    | NIPDAU                               | Level-2-260C-1 YEAR  | -40 to 85    | 4F2111                  | <a href="#">Samples</a> |
| MSP430F2111IDGVR | ACTIVE        | TVSOP        | DGV                | 20   | 2000           | RoHS & Green    | NIPDAU                               | Level-2-260C-1 YEAR  | -40 to 85    | 4F2111                  | <a href="#">Samples</a> |
| MSP430F2111IDW   | ACTIVE        | SOIC         | DW                 | 20   | 25             | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | M430F2111               | <a href="#">Samples</a> |
| MSP430F2111IDWR  | ACTIVE        | SOIC         | DW                 | 20   | 2000           | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | M430F2111               | <a href="#">Samples</a> |

| Orderable Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package<br>Qty | Eco Plan<br>(2) | Lead finish/<br>Ball material<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples                 |
|------------------|---------------|--------------|--------------------|------|----------------|-----------------|--------------------------------------|----------------------|--------------|-------------------------|-------------------------|
| MSP430F2111IPW   | ACTIVE        | TSSOP        | PW                 | 20   | 70             | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | 430F2111                | <a href="#">Samples</a> |
| MSP430F2111IPWR  | ACTIVE        | TSSOP        | PW                 | 20   | 2000           | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | 430F2111                | <a href="#">Samples</a> |
| MSP430F2111IRGER | ACTIVE        | VQFN         | RGE                | 24   | 3000           | RoHS & Green    | NIPDAU                               | Level-2-260C-1 YEAR  | -40 to 85    | M430F<br>2111           | <a href="#">Samples</a> |
| MSP430F2111IRGET | ACTIVE        | VQFN         | RGE                | 24   | 250            | RoHS & Green    | NIPDAU                               | Level-2-260C-1 YEAR  | -40 to 85    | M430F<br>2111           | <a href="#">Samples</a> |
| MSP430F2111TDGVR | ACTIVE        | TVSOP        | DGV                | 20   | 2000           | RoHS & Green    | NIPDAU                               | Level-2-260C-1 YEAR  | -40 to 105   | 4F2111T                 | <a href="#">Samples</a> |
| MSP430F2111TDW   | ACTIVE        | SOIC         | DW                 | 20   | 25             | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 105   | M430F2111T              | <a href="#">Samples</a> |
| MSP430F2111TDWR  | ACTIVE        | SOIC         | DW                 | 20   | 2000           | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 105   | M430F2111T              | <a href="#">Samples</a> |
| MSP430F2111TPW   | ACTIVE        | TSSOP        | PW                 | 20   | 70             | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 105   | 4F2111T                 | <a href="#">Samples</a> |
| MSP430F2111TPWR  | ACTIVE        | TSSOP        | PW                 | 20   | 2000           | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 105   | 4F2111T                 | <a href="#">Samples</a> |
| MSP430F2111TRGER | ACTIVE        | VQFN         | RGE                | 24   | 3000           | RoHS & Green    | NIPDAU                               | Level-2-260C-1 YEAR  | -40 to 105   | M430F<br>2111T          | <a href="#">Samples</a> |
| MSP430F2111TRGET | ACTIVE        | VQFN         | RGE                | 24   | 250            | RoHS & Green    | NIPDAU                               | Level-2-260C-1 YEAR  | -40 to 105   | M430F<br>2111T          | <a href="#">Samples</a> |
| MSP430F2121IDGV  | ACTIVE        | TVSOP        | DGV                | 20   | 90             | RoHS & Green    | NIPDAU                               | Level-2-260C-1 YEAR  | -40 to 85    | 4F2121                  | <a href="#">Samples</a> |
| MSP430F2121IDGVR | ACTIVE        | TVSOP        | DGV                | 20   | 2000           | RoHS & Green    | NIPDAU                               | Level-2-260C-1 YEAR  | -40 to 85    | 4F2121                  | <a href="#">Samples</a> |
| MSP430F2121IDW   | ACTIVE        | SOIC         | DW                 | 20   | 25             | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | M430F2121               | <a href="#">Samples</a> |
| MSP430F2121IDWR  | ACTIVE        | SOIC         | DW                 | 20   | 2000           | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | M430F2121               | <a href="#">Samples</a> |
| MSP430F2121IPW   | ACTIVE        | TSSOP        | PW                 | 20   | 70             | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | 430F2121                | <a href="#">Samples</a> |
| MSP430F2121IPWR  | ACTIVE        | TSSOP        | PW                 | 20   | 2000           | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | 430F2121                | <a href="#">Samples</a> |
| MSP430F2121IRGER | ACTIVE        | VQFN         | RGE                | 24   | 3000           | RoHS & Green    | NIPDAU                               | Level-2-260C-1 YEAR  | -40 to 85    | M430F<br>2121           | <a href="#">Samples</a> |
| MSP430F2121IRGET | ACTIVE        | VQFN         | RGE                | 24   | 250            | RoHS & Green    | NIPDAU                               | Level-2-260C-1 YEAR  | -40 to 85    | M430F<br>2121           | <a href="#">Samples</a> |
| MSP430F2121TDGVR | ACTIVE        | TVSOP        | DGV                | 20   | 2000           | RoHS & Green    | NIPDAU                               | Level-2-260C-1 YEAR  | -40 to 105   | 4F2121T                 | <a href="#">Samples</a> |

| Orderable Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package<br>Qty | Eco Plan<br>(2) | Lead finish/<br>Ball material<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples                 |
|------------------|---------------|--------------|--------------------|------|----------------|-----------------|--------------------------------------|----------------------|--------------|-------------------------|-------------------------|
| MSP430F2121TDW   | ACTIVE        | SOIC         | DW                 | 20   | 25             | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 105   | M430F2121T              | <a href="#">Samples</a> |
| MSP430F2121TDWR  | ACTIVE        | SOIC         | DW                 | 20   | 2000           | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 105   | M430F2121T              | <a href="#">Samples</a> |
| MSP430F2121TPW   | ACTIVE        | TSSOP        | PW                 | 20   | 70             | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 105   | 4F2121T                 | <a href="#">Samples</a> |
| MSP430F2121TPWR  | ACTIVE        | TSSOP        | PW                 | 20   | 2000           | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 105   | 4F2121T                 | <a href="#">Samples</a> |
| MSP430F2121TRGET | ACTIVE        | VQFN         | RGE                | 24   | 250            | RoHS & Green    | NIPDAU                               | Level-2-260C-1 YEAR  | -40 to 105   | M430F<br>2121T          | <a href="#">Samples</a> |
| MSP430F2131IDGV  | ACTIVE        | TVSOP        | DGV                | 20   | 90             | RoHS & Green    | NIPDAU                               | Level-2-260C-1 YEAR  | -40 to 85    | 4F2131                  | <a href="#">Samples</a> |
| MSP430F2131IDGVR | ACTIVE        | TVSOP        | DGV                | 20   | 2000           | RoHS & Green    | NIPDAU                               | Level-2-260C-1 YEAR  | -40 to 85    | 4F2131                  | <a href="#">Samples</a> |
| MSP430F2131IDW   | ACTIVE        | SOIC         | DW                 | 20   | 25             | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | M430F2131               | <a href="#">Samples</a> |
| MSP430F2131IDWR  | ACTIVE        | SOIC         | DW                 | 20   | 2000           | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | M430F2131               | <a href="#">Samples</a> |
| MSP430F2131IPW   | ACTIVE        | TSSOP        | PW                 | 20   | 70             | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | 430F2131                | <a href="#">Samples</a> |
| MSP430F2131IPWR  | ACTIVE        | TSSOP        | PW                 | 20   | 2000           | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 85    | 430F2131                | <a href="#">Samples</a> |
| MSP430F2131IRGER | ACTIVE        | VQFN         | RGE                | 24   | 3000           | RoHS & Green    | NIPDAU                               | Level-2-260C-1 YEAR  | -40 to 85    | M430F<br>2131           | <a href="#">Samples</a> |
| MSP430F2131IRGET | ACTIVE        | VQFN         | RGE                | 24   | 250            | RoHS & Green    | NIPDAU                               | Level-2-260C-1 YEAR  | -40 to 85    | M430F<br>2131           | <a href="#">Samples</a> |
| MSP430F2131TDGV  | ACTIVE        | TVSOP        | DGV                | 20   | 90             | RoHS & Green    | NIPDAU                               | Level-2-260C-1 YEAR  | -40 to 105   | 4F2131T                 | <a href="#">Samples</a> |
| MSP430F2131TDGVR | ACTIVE        | TVSOP        | DGV                | 20   | 2000           | RoHS & Green    | NIPDAU                               | Level-2-260C-1 YEAR  | -40 to 105   | 4F2131T                 | <a href="#">Samples</a> |
| MSP430F2131TDW   | ACTIVE        | SOIC         | DW                 | 20   | 25             | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 105   | M430F2131T              | <a href="#">Samples</a> |
| MSP430F2131TDWR  | ACTIVE        | SOIC         | DW                 | 20   | 2000           | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 105   | M430F2131T              | <a href="#">Samples</a> |
| MSP430F2131TPW   | ACTIVE        | TSSOP        | PW                 | 20   | 70             | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 105   | 4F2131T                 | <a href="#">Samples</a> |
| MSP430F2131TPWR  | ACTIVE        | TSSOP        | PW                 | 20   | 2000           | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 105   | 4F2131T                 | <a href="#">Samples</a> |
| MSP430F2131TRGER | ACTIVE        | VQFN         | RGE                | 24   | 3000           | RoHS & Green    | NIPDAU                               | Level-2-260C-1 YEAR  | -40 to 105   | M430F<br>2131T          | <a href="#">Samples</a> |

| Orderable Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package<br>Qty | Eco Plan<br>(2) | Lead finish/<br>Ball material<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples                 |
|------------------|---------------|--------------|--------------------|------|----------------|-----------------|--------------------------------------|----------------------|--------------|-------------------------|-------------------------|
| MSP430F2131TRGET | ACTIVE        | VQFN         | RGE                | 24   | 250            | RoHS & Green    | NIPDAU                               | Level-2-260C-1 YEAR  | -40 to 105   | M430F<br>2131T          | <a href="#">Samples</a> |

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

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

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

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

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

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

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

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

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

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

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

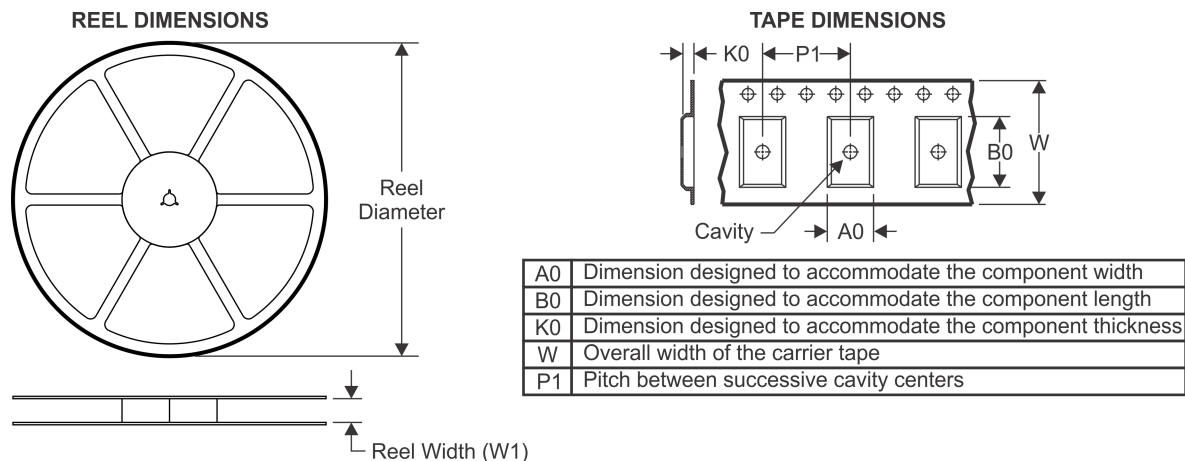
(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "-" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

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

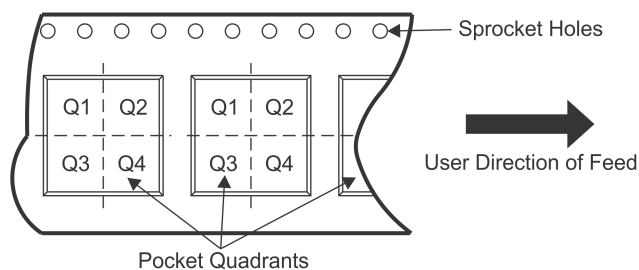
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## TAPE AND REEL INFORMATION



### QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE

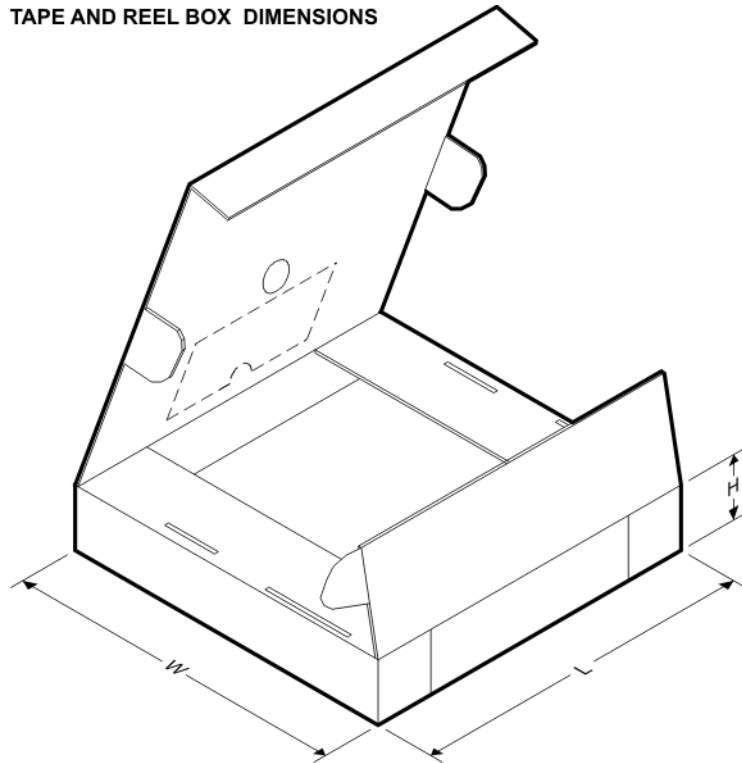


\*All dimensions are nominal

| Device           | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|------------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| MSP430F2101DGVR  | TVSOP        | DGV             | 20   | 2000 | 330.0              | 12.4               | 6.9     | 5.6     | 1.6     | 8.0     | 12.0   | Q1            |
| MSP430F2101DWR   | SOIC         | DW              | 20   | 2000 | 330.0              | 24.4               | 10.8    | 13.3    | 2.7     | 12.0    | 24.0   | Q1            |
| MSP430F2101IPWR  | TSSOP        | PW              | 20   | 2000 | 330.0              | 16.4               | 6.95    | 7.1     | 1.6     | 8.0     | 16.0   | Q1            |
| MSP430F2101IRGER | VQFN         | RGE             | 24   | 3000 | 330.0              | 12.4               | 4.25    | 4.25    | 1.15    | 8.0     | 12.0   | Q2            |
| MSP430F2101IRGET | VQFN         | RGE             | 24   | 250  | 180.0              | 12.4               | 4.25    | 4.25    | 1.15    | 8.0     | 12.0   | Q2            |
| MSP430F2101TDGVR | TVSOP        | DGV             | 20   | 2000 | 330.0              | 12.4               | 6.9     | 5.6     | 1.6     | 8.0     | 12.0   | Q1            |
| MSP430F2101TDWR  | SOIC         | DW              | 20   | 2000 | 330.0              | 24.4               | 10.8    | 13.3    | 2.7     | 12.0    | 24.0   | Q1            |
| MSP430F2101TPWR  | TSSOP        | PW              | 20   | 2000 | 330.0              | 16.4               | 6.95    | 7.1     | 1.6     | 8.0     | 16.0   | Q1            |
| MSP430F2101TRGER | VQFN         | RGE             | 24   | 3000 | 330.0              | 12.4               | 4.25    | 4.25    | 1.15    | 8.0     | 12.0   | Q2            |
| MSP430F2111DGVR  | TVSOP        | DGV             | 20   | 2000 | 330.0              | 12.4               | 6.9     | 5.6     | 1.6     | 8.0     | 12.0   | Q1            |
| MSP430F2111DWR   | SOIC         | DW              | 20   | 2000 | 330.0              | 24.4               | 10.8    | 13.3    | 2.7     | 12.0    | 24.0   | Q1            |
| MSP430F2111IPWR  | TSSOP        | PW              | 20   | 2000 | 330.0              | 16.4               | 6.95    | 7.1     | 1.6     | 8.0     | 16.0   | Q1            |
| MSP430F2111IRGER | VQFN         | RGE             | 24   | 3000 | 330.0              | 12.4               | 4.25    | 4.25    | 1.15    | 8.0     | 12.0   | Q2            |
| MSP430F2111IRGET | VQFN         | RGE             | 24   | 250  | 180.0              | 12.4               | 4.25    | 4.25    | 1.15    | 8.0     | 12.0   | Q2            |
| MSP430F2111TDGVR | TVSOP        | DGV             | 20   | 2000 | 330.0              | 12.4               | 6.9     | 5.6     | 1.6     | 8.0     | 12.0   | Q1            |
| MSP430F2111TDWR  | SOIC         | DW              | 20   | 2000 | 330.0              | 24.4               | 10.8    | 13.3    | 2.7     | 12.0    | 24.0   | Q1            |
| MSP430F2111TPWR  | TSSOP        | PW              | 20   | 2000 | 330.0              | 16.4               | 6.95    | 7.1     | 1.6     | 8.0     | 16.0   | Q1            |
| MSP430F2111TRGER | VQFN         | RGE             | 24   | 3000 | 330.0              | 12.4               | 4.25    | 4.25    | 1.15    | 8.0     | 12.0   | Q2            |

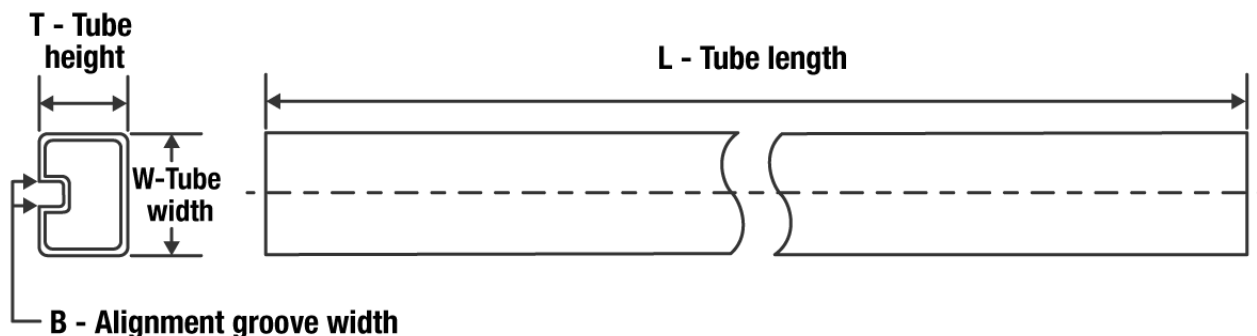
| Device           | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|------------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| MSP430F2111TRGET | VQFN         | RGE             | 24   | 250  | 180.0              | 12.4               | 4.25    | 4.25    | 1.15    | 8.0     | 12.0   | Q2            |
| MSP430F2121IDGVR | TVSOP        | DGV             | 20   | 2000 | 330.0              | 12.4               | 6.9     | 5.6     | 1.6     | 8.0     | 12.0   | Q1            |
| MSP430F2121IDWR  | SOIC         | DW              | 20   | 2000 | 330.0              | 24.4               | 10.8    | 13.3    | 2.7     | 12.0    | 24.0   | Q1            |
| MSP430F2121IPWR  | TSSOP        | PW              | 20   | 2000 | 330.0              | 16.4               | 6.95    | 7.1     | 1.6     | 8.0     | 16.0   | Q1            |
| MSP430F2121IRGER | VQFN         | RGE             | 24   | 3000 | 330.0              | 12.4               | 4.25    | 4.25    | 1.15    | 8.0     | 12.0   | Q2            |
| MSP430F2121IRGET | VQFN         | RGE             | 24   | 250  | 180.0              | 12.4               | 4.25    | 4.25    | 1.15    | 8.0     | 12.0   | Q2            |
| MSP430F2121TDGVR | TVSOP        | DGV             | 20   | 2000 | 330.0              | 12.4               | 6.9     | 5.6     | 1.6     | 8.0     | 12.0   | Q1            |
| MSP430F2121TDWR  | SOIC         | DW              | 20   | 2000 | 330.0              | 24.4               | 10.8    | 13.3    | 2.7     | 12.0    | 24.0   | Q1            |
| MSP430F2121TPWR  | TSSOP        | PW              | 20   | 2000 | 330.0              | 16.4               | 6.95    | 7.1     | 1.6     | 8.0     | 16.0   | Q1            |
| MSP430F2121TRGET | VQFN         | RGE             | 24   | 250  | 180.0              | 12.4               | 4.25    | 4.25    | 1.15    | 8.0     | 12.0   | Q2            |
| MSP430F2131IDGVR | TVSOP        | DGV             | 20   | 2000 | 330.0              | 12.4               | 6.9     | 5.6     | 1.6     | 8.0     | 12.0   | Q1            |
| MSP430F2131IDWR  | SOIC         | DW              | 20   | 2000 | 330.0              | 24.4               | 10.8    | 13.3    | 2.7     | 12.0    | 24.0   | Q1            |
| MSP430F2131IPWR  | TSSOP        | PW              | 20   | 2000 | 330.0              | 16.4               | 6.95    | 7.0     | 1.4     | 8.0     | 16.0   | Q1            |
| MSP430F2131IRGER | VQFN         | RGE             | 24   | 3000 | 330.0              | 12.4               | 4.25    | 4.25    | 1.15    | 8.0     | 12.0   | Q2            |
| MSP430F2131IRGET | VQFN         | RGE             | 24   | 250  | 180.0              | 12.4               | 4.25    | 4.25    | 1.15    | 8.0     | 12.0   | Q2            |
| MSP430F2131TDGVR | TVSOP        | DGV             | 20   | 2000 | 330.0              | 12.4               | 6.9     | 5.6     | 1.6     | 8.0     | 12.0   | Q1            |
| MSP430F2131TDWR  | SOIC         | DW              | 20   | 2000 | 330.0              | 24.4               | 10.8    | 13.3    | 2.7     | 12.0    | 24.0   | Q1            |
| MSP430F2131TPWR  | TSSOP        | PW              | 20   | 2000 | 330.0              | 16.4               | 6.95    | 7.1     | 1.6     | 8.0     | 16.0   | Q1            |
| MSP430F2131TRGER | VQFN         | RGE             | 24   | 3000 | 330.0              | 12.4               | 4.25    | 4.25    | 1.15    | 8.0     | 12.0   | Q2            |
| MSP430F2131TRGET | VQFN         | RGE             | 24   | 250  | 180.0              | 12.4               | 4.25    | 4.25    | 1.15    | 8.0     | 12.0   | Q2            |

## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

| Device           | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|------------------|--------------|-----------------|------|------|-------------|------------|-------------|
| MSP430F2101IDGVR | TVSOP        | DGV             | 20   | 2000 | 853.0       | 449.0      | 35.0        |
| MSP430F2101IDWR  | SOIC         | DW              | 20   | 2000 | 367.0       | 367.0      | 45.0        |
| MSP430F2101IPWR  | TSSOP        | PW              | 20   | 2000 | 853.0       | 449.0      | 35.0        |
| MSP430F2101IRGER | VQFN         | RGE             | 24   | 3000 | 367.0       | 367.0      | 35.0        |
| MSP430F2101IRGET | VQFN         | RGE             | 24   | 250  | 210.0       | 185.0      | 35.0        |
| MSP430F2101TDGVR | TVSOP        | DGV             | 20   | 2000 | 853.0       | 449.0      | 35.0        |
| MSP430F2101TDWR  | SOIC         | DW              | 20   | 2000 | 367.0       | 367.0      | 45.0        |
| MSP430F2101TPWR  | TSSOP        | PW              | 20   | 2000 | 853.0       | 449.0      | 35.0        |
| MSP430F2101TRGER | VQFN         | RGE             | 24   | 3000 | 367.0       | 367.0      | 35.0        |
| MSP430F2111IDGVR | TVSOP        | DGV             | 20   | 2000 | 853.0       | 449.0      | 35.0        |
| MSP430F2111IDWR  | SOIC         | DW              | 20   | 2000 | 367.0       | 367.0      | 45.0        |
| MSP430F2111IPWR  | TSSOP        | PW              | 20   | 2000 | 853.0       | 449.0      | 35.0        |
| MSP430F2111IRGER | VQFN         | RGE             | 24   | 3000 | 367.0       | 367.0      | 35.0        |
| MSP430F2111IRGET | VQFN         | RGE             | 24   | 250  | 210.0       | 185.0      | 35.0        |
| MSP430F2111TDGVR | TVSOP        | DGV             | 20   | 2000 | 853.0       | 449.0      | 35.0        |
| MSP430F2111TDWR  | SOIC         | DW              | 20   | 2000 | 367.0       | 367.0      | 45.0        |
| MSP430F2111TPWR  | TSSOP        | PW              | 20   | 2000 | 853.0       | 449.0      | 35.0        |
| MSP430F2111TRGER | VQFN         | RGE             | 24   | 3000 | 367.0       | 367.0      | 35.0        |
| MSP430F2111TRGET | VQFN         | RGE             | 24   | 250  | 210.0       | 185.0      | 35.0        |
| MSP430F2121IDGVR | TVSOP        | DGV             | 20   | 2000 | 853.0       | 449.0      | 35.0        |
| MSP430F2121IDWR  | SOIC         | DW              | 20   | 2000 | 367.0       | 367.0      | 45.0        |
| MSP430F2121IPWR  | TSSOP        | PW              | 20   | 2000 | 853.0       | 449.0      | 35.0        |
| MSP430F2121IRGER | VQFN         | RGE             | 24   | 3000 | 367.0       | 367.0      | 35.0        |
| MSP430F2121IRGET | VQFN         | RGE             | 24   | 250  | 210.0       | 185.0      | 35.0        |
| MSP430F2121TDGVR | TVSOP        | DGV             | 20   | 2000 | 853.0       | 449.0      | 35.0        |
| MSP430F2121TDWR  | SOIC         | DW              | 20   | 2000 | 367.0       | 367.0      | 45.0        |
| MSP430F2121TPWR  | TSSOP        | PW              | 20   | 2000 | 853.0       | 449.0      | 35.0        |
| MSP430F2121TRGET | VQFN         | RGE             | 24   | 250  | 210.0       | 185.0      | 35.0        |
| MSP430F2131IDGVR | TVSOP        | DGV             | 20   | 2000 | 853.0       | 449.0      | 35.0        |
| MSP430F2131IDWR  | SOIC         | DW              | 20   | 2000 | 367.0       | 367.0      | 45.0        |
| MSP430F2131IPWR  | TSSOP        | PW              | 20   | 2000 | 853.0       | 449.0      | 35.0        |
| MSP430F2131IRGER | VQFN         | RGE             | 24   | 3000 | 367.0       | 367.0      | 35.0        |
| MSP430F2131IRGET | VQFN         | RGE             | 24   | 250  | 210.0       | 185.0      | 35.0        |
| MSP430F2131TDGVR | TVSOP        | DGV             | 20   | 2000 | 853.0       | 449.0      | 35.0        |
| MSP430F2131TDWR  | SOIC         | DW              | 20   | 2000 | 367.0       | 367.0      | 45.0        |
| MSP430F2131TPWR  | TSSOP        | PW              | 20   | 2000 | 853.0       | 449.0      | 35.0        |
| MSP430F2131TRGER | VQFN         | RGE             | 24   | 3000 | 367.0       | 367.0      | 35.0        |
| MSP430F2131TRGET | VQFN         | RGE             | 24   | 250  | 210.0       | 185.0      | 35.0        |

**TUBE**


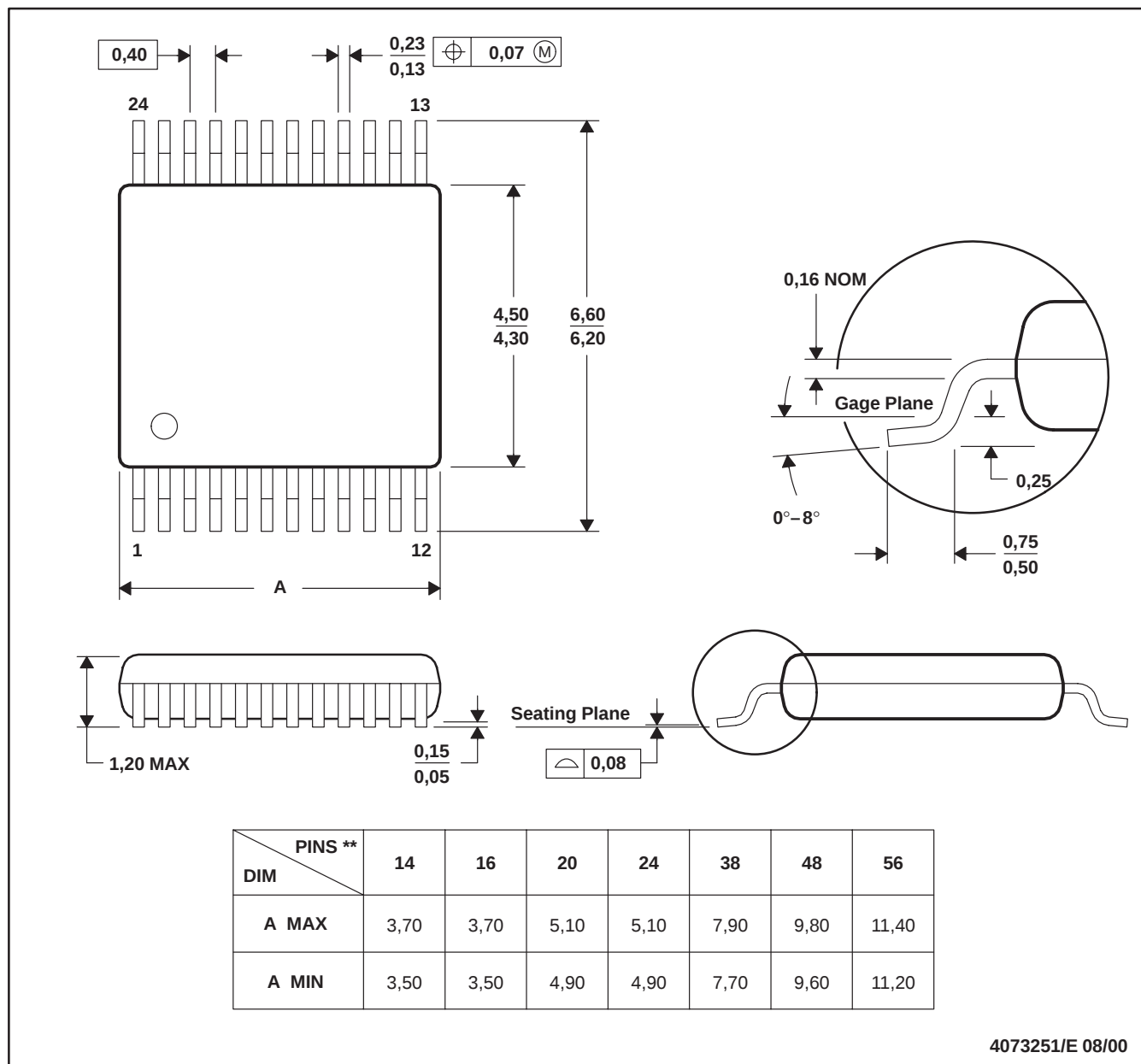
\*All dimensions are nominal

| Device          | Package Name | Package Type | Pins | SPQ | L (mm) | W (mm) | T (μm) | B (mm) |
|-----------------|--------------|--------------|------|-----|--------|--------|--------|--------|
| MSP430F2101IDGV | DGV          | TVSOP        | 20   | 90  | 530    | 10.2   | 3600   | 3.5    |
| MSP430F2101IDW  | DW           | SOIC         | 20   | 25  | 507    | 12.83  | 5080   | 6.6    |
| MSP430F2101IPW  | PW           | TSSOP        | 20   | 70  | 530    | 10.2   | 3600   | 3.5    |
| MSP430F2101TDGV | DGV          | TVSOP        | 20   | 90  | 530    | 10.2   | 3600   | 3.5    |
| MSP430F2101TDW  | DW           | SOIC         | 20   | 25  | 507    | 12.83  | 5080   | 6.6    |
| MSP430F2101TPW  | PW           | TSSOP        | 20   | 70  | 530    | 10.2   | 3600   | 3.5    |
| MSP430F2111IDGV | DGV          | TVSOP        | 20   | 90  | 530    | 10.2   | 3600   | 3.5    |
| MSP430F2111IDW  | DW           | SOIC         | 20   | 25  | 507    | 12.83  | 5080   | 6.6    |
| MSP430F2111IPW  | PW           | TSSOP        | 20   | 70  | 530    | 10.2   | 3600   | 3.5    |
| MSP430F2111TDW  | DW           | SOIC         | 20   | 25  | 507    | 12.83  | 5080   | 6.6    |
| MSP430F2111TPW  | PW           | TSSOP        | 20   | 70  | 530    | 10.2   | 3600   | 3.5    |
| MSP430F2121IDGV | DGV          | TVSOP        | 20   | 90  | 530    | 10.2   | 3600   | 3.5    |
| MSP430F2121IDW  | DW           | SOIC         | 20   | 25  | 507    | 12.83  | 5080   | 6.6    |
| MSP430F2121IPW  | PW           | TSSOP        | 20   | 70  | 530    | 10.2   | 3600   | 3.5    |
| MSP430F2121TDW  | DW           | SOIC         | 20   | 25  | 507    | 12.83  | 5080   | 6.6    |
| MSP430F2121TPW  | PW           | TSSOP        | 20   | 70  | 530    | 10.2   | 3600   | 3.5    |
| MSP430F2131IDGV | DGV          | TVSOP        | 20   | 90  | 530    | 10.2   | 3600   | 3.5    |
| MSP430F2131IDW  | DW           | SOIC         | 20   | 25  | 507    | 12.83  | 5080   | 6.6    |
| MSP430F2131IPW  | PW           | TSSOP        | 20   | 70  | 530    | 10.2   | 3600   | 3.5    |
| MSP430F2131TDGV | DGV          | TVSOP        | 20   | 90  | 530    | 10.2   | 3600   | 3.5    |
| MSP430F2131TDW  | DW           | SOIC         | 20   | 25  | 507    | 12.83  | 5080   | 6.6    |
| MSP430F2131TPW  | PW           | TSSOP        | 20   | 70  | 530    | 10.2   | 3600   | 3.5    |

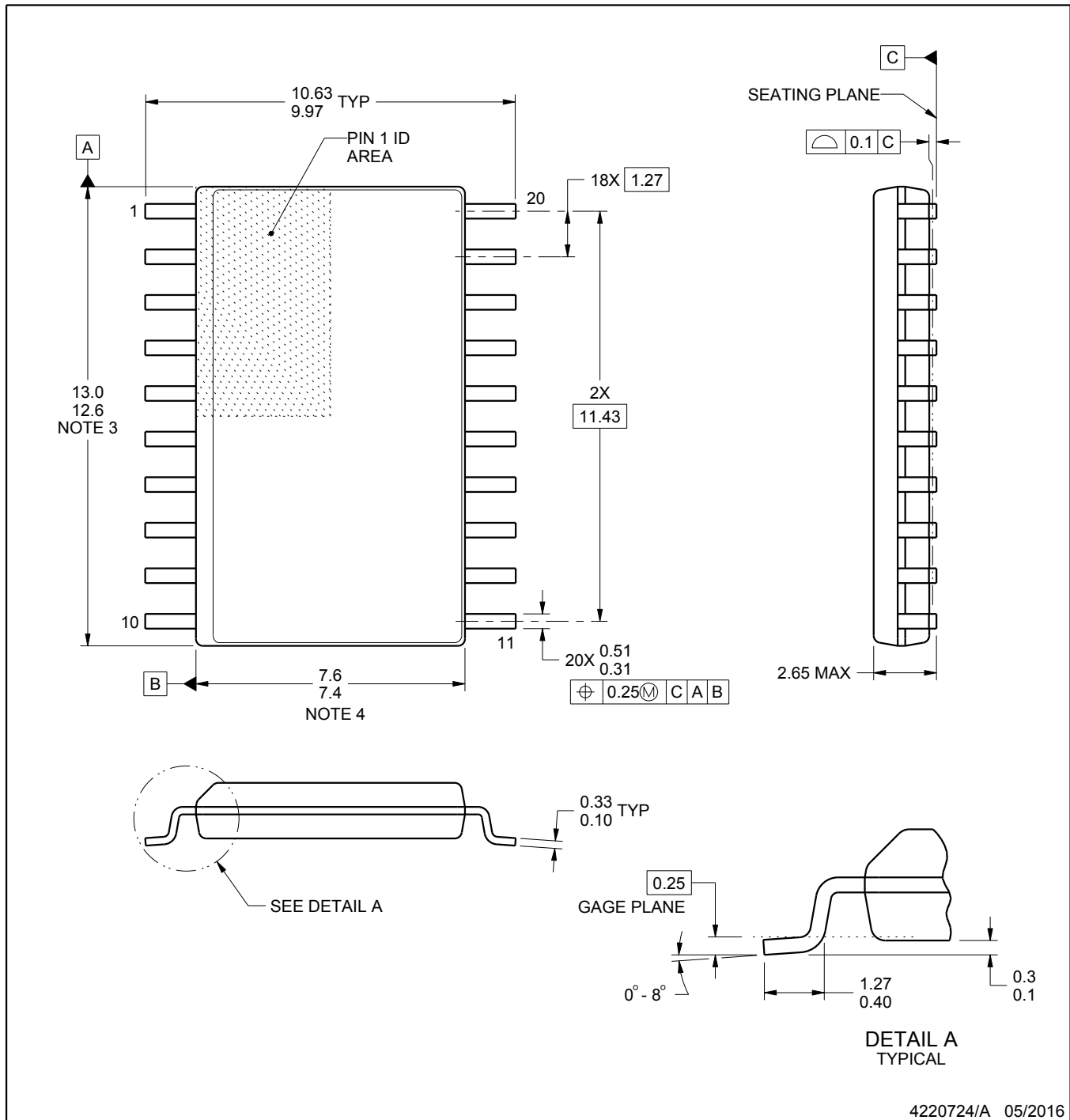
## DGV (R-PDSO-G\*\*)

## PLASTIC SMALL-OUTLINE

24 PINS SHOWN



- NOTES: A. All linear dimensions are in millimeters.  
 B. This drawing is subject to change without notice.  
 C. Body dimensions do not include mold flash or protrusion, not to exceed 0,15 per side.  
 D. Falls within JEDEC: 24/48 Pins – MO-153  
 14/16/20/56 Pins – MO-194



4220724/A 05/2016

## NOTES:

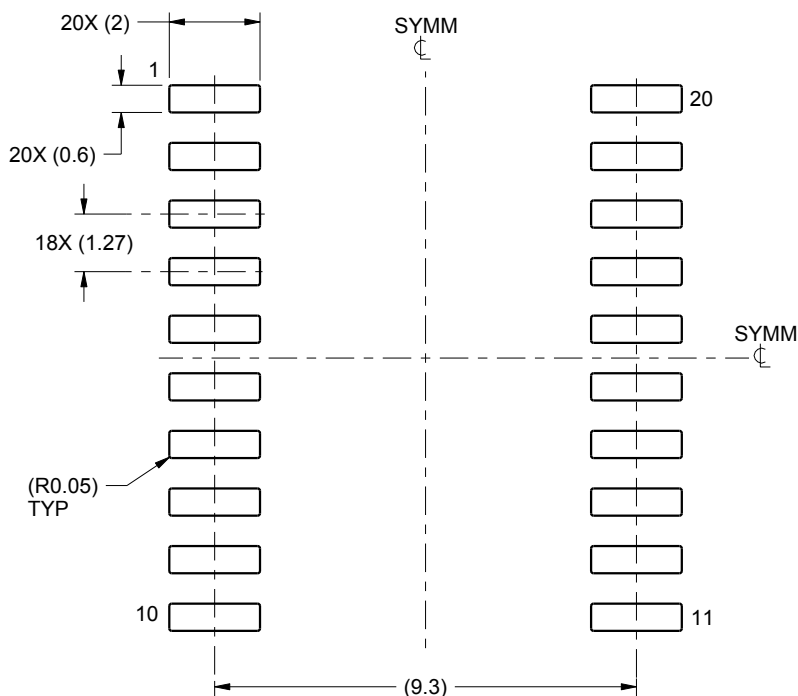
1. All linear dimensions are in millimeters. Dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.43 mm per side.
5. Reference JEDEC registration MS-013.

# EXAMPLE BOARD LAYOUT

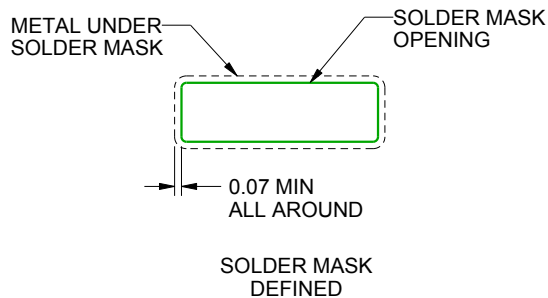
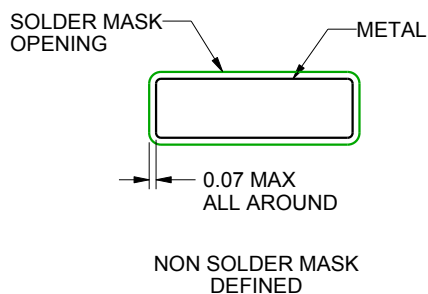
DW0020A

SOIC - 2.65 mm max height

SOIC



LAND PATTERN EXAMPLE  
SCALE:6X



SOLDER MASK DETAILS

4220724/A 05/2016

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

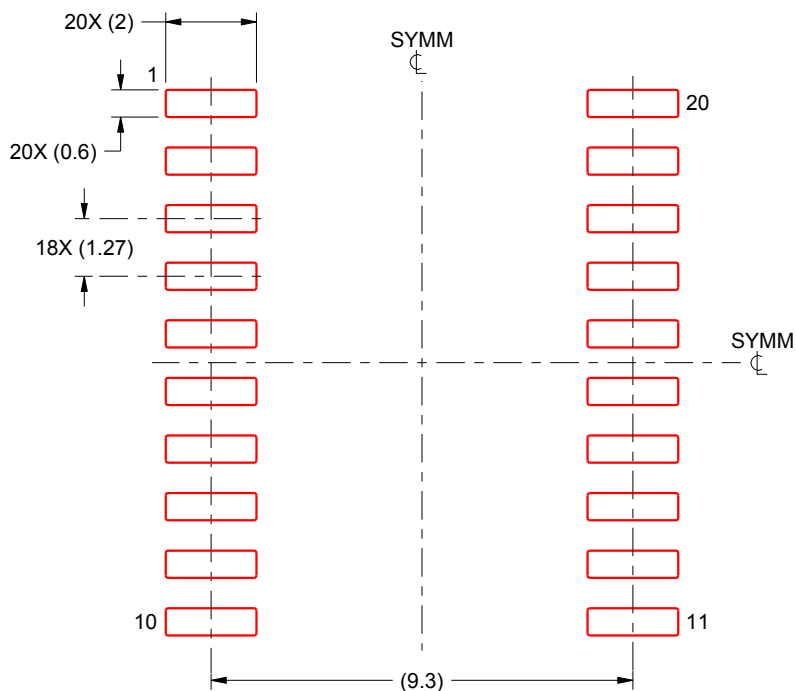
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

## EXAMPLE STENCIL DESIGN

DW0020A

SOIC - 2.65 mm max height

SOIC



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

4220724/A 05/2016

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.

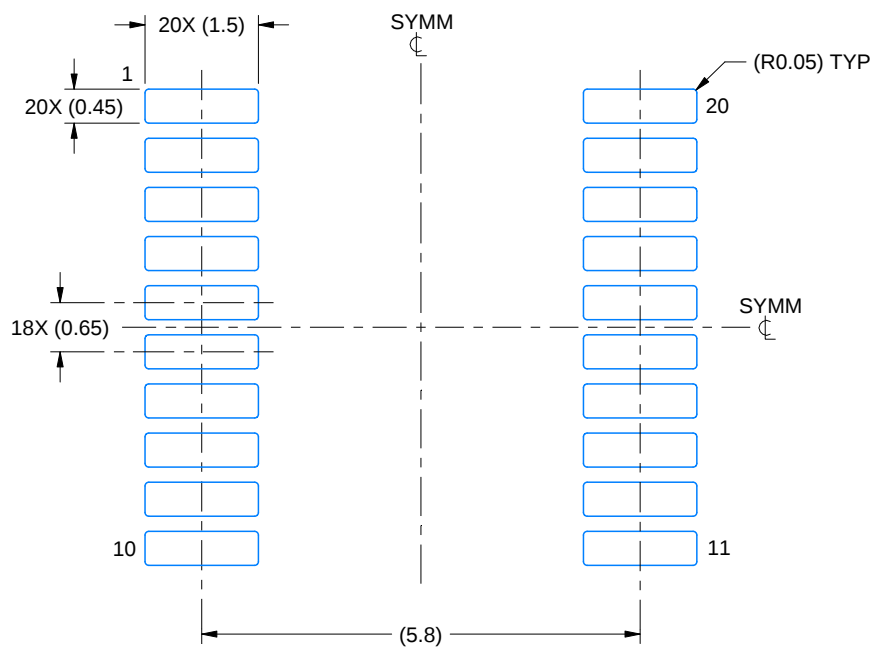


# EXAMPLE BOARD LAYOUT

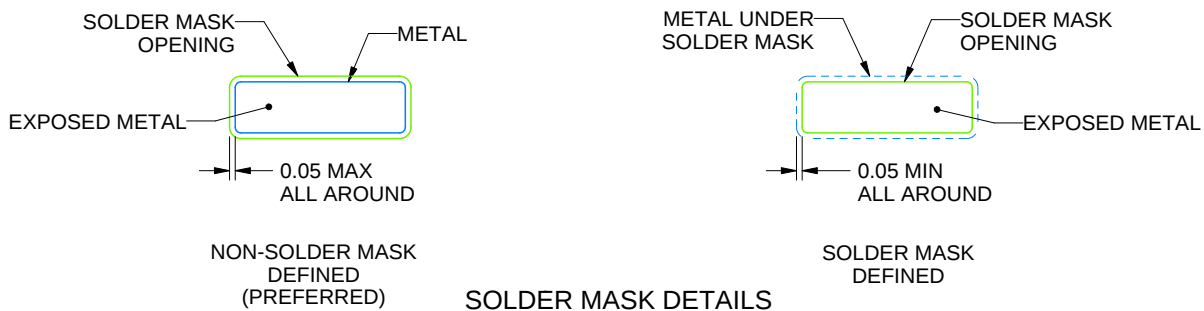
PW0020A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE: 10X



4220206/A 02/2017

NOTES: (continued)

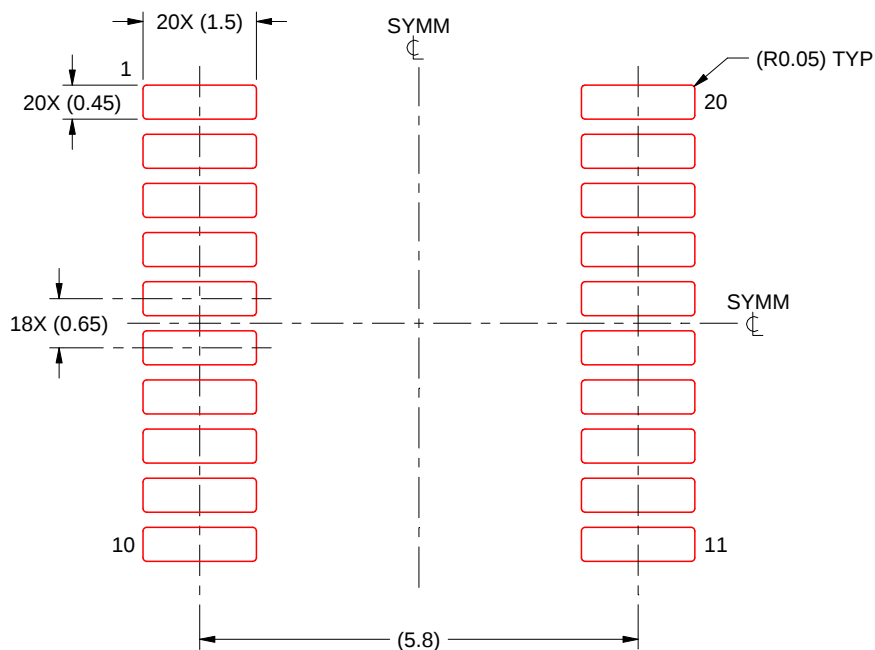
6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

## EXAMPLE STENCIL DESIGN

PW0020A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



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

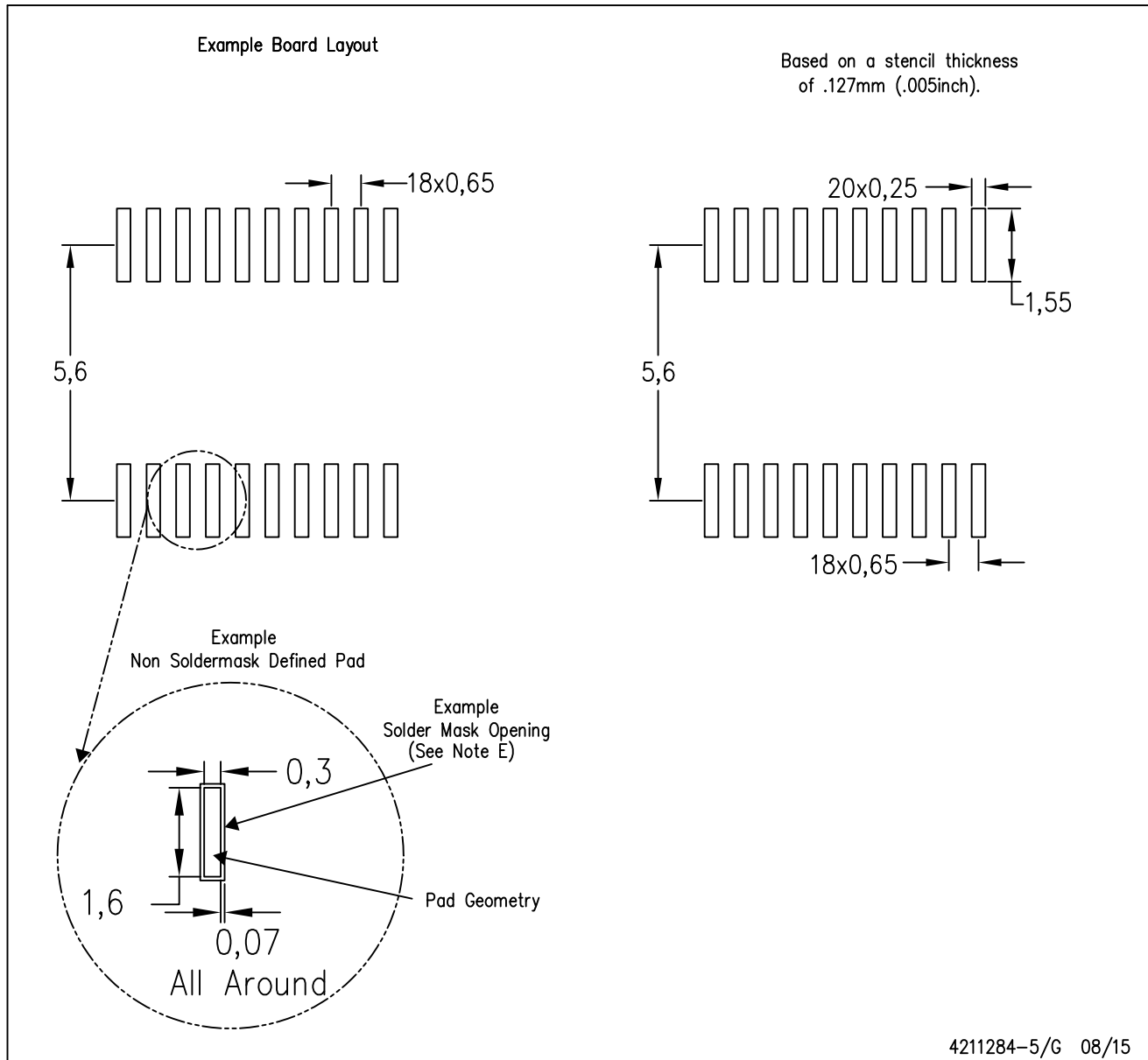
4220206/A 02/2017

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.

PW (R-PDSO-G20)

PLASTIC SMALL OUTLINE



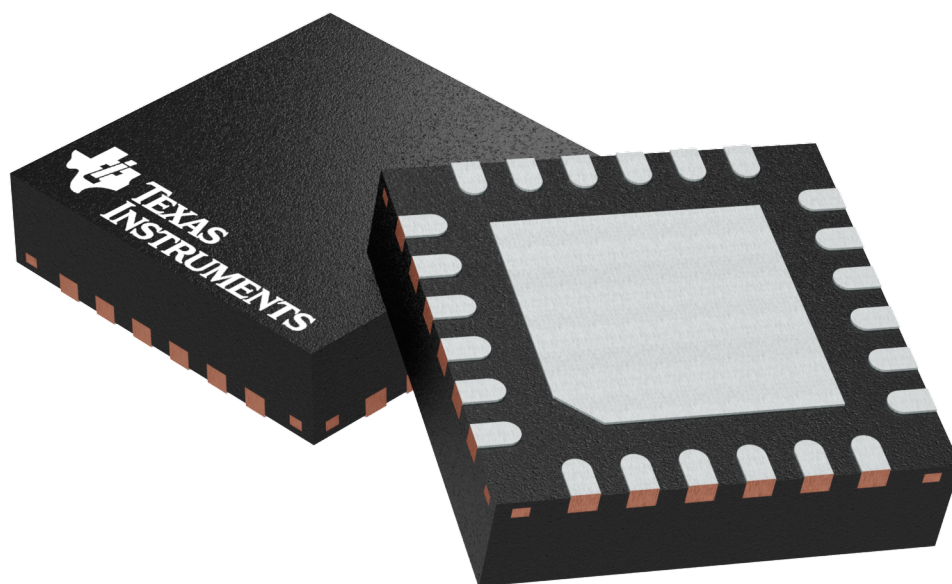
- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Publication IPC-7351 is recommended for alternate design.
  - D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
  - E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

**RGE 24**

**GENERIC PACKAGE VIEW**

**VQFN - 1 mm max height**

PLASTIC QUAD FLATPACK - NO LEAD



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

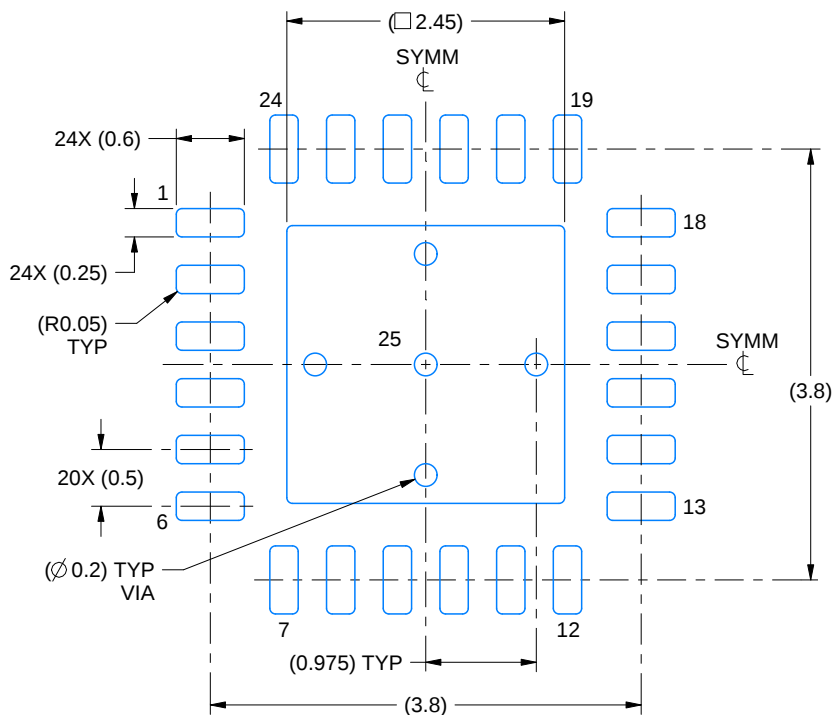
4204104/H



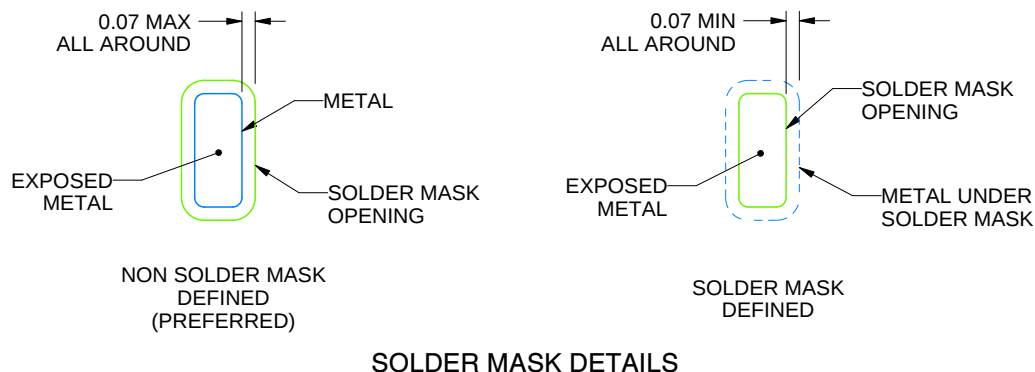
**RGE0024B**

### VQFN - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:15X



4219013/A 05/2017

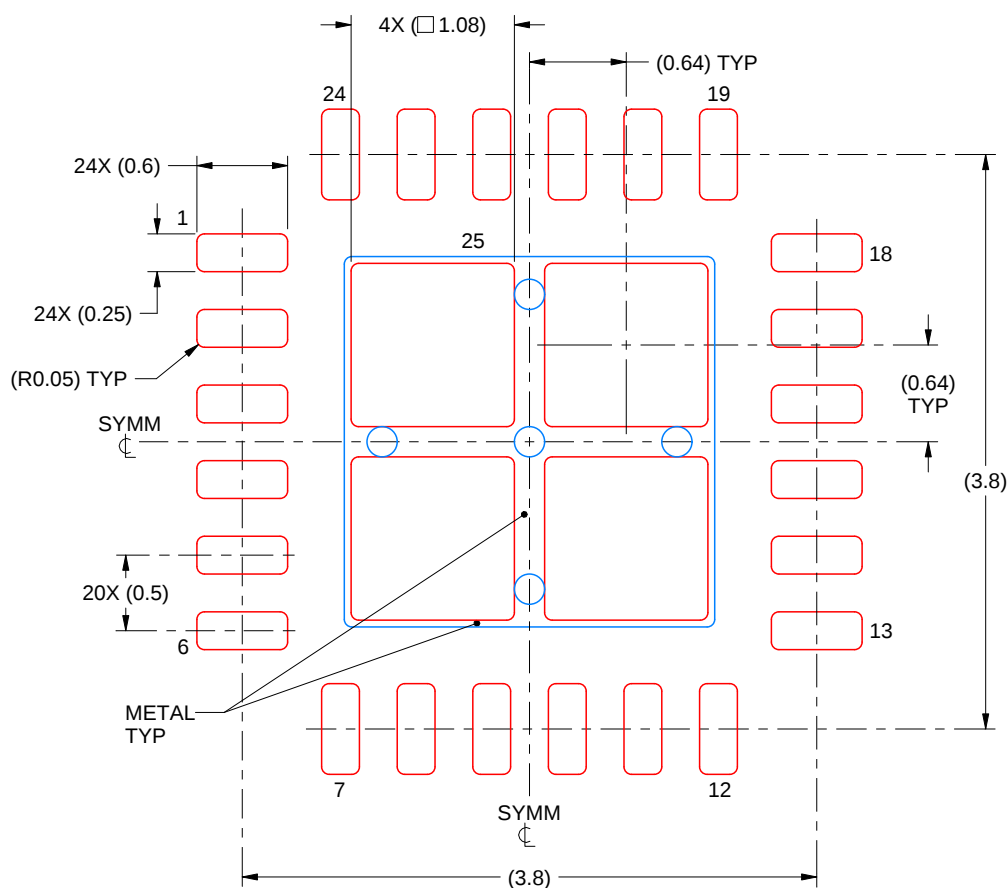
NOTES: (continued)

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

**RGE0024B**

**VQFN - 1 mm max height**

PLASTIC QUAD FLATPACK - NO LEAD



## SOLDER PASTE EXAMPLE BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD 25  
78% PRINTED SOLDER COVERAGE BY AREA UNDER PACKAGE  
SCALE:20X

4219013/A 05/2017

NOTES: (continued)

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

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