# MIXED SIGNAL MICROCONTROLLER

## FEATURES

- Low Supply-Voltage Range, 1.8 V to 3.6 V
- Ultra-Low Power Consumption
  - Active Mode: 270 µA at 1 MHz, 2.2 V
  - Standby Mode (VLO): 0.3 µA
  - Off Mode (RAM Retention): 0.1 µA
- Ultra-Fast Wake-Up From Standby Mode in Less Than 1 µs
- 16-Bit RISC Architecture, 62.5-ns Instruction Cycle Time
- Basic Clock Module Configurations:
  - Internal Frequencies up to 16 MHz
  - Internal Very Low-Power LF Oscillator
  - 32-kHz Crystal
  - Internal Frequencies up to 16 MHz With Four Calibrated Frequencies to ±1%
  - Resonator
  - External Digital Clock Source
  - External Resistor
- 12-Bit Analog-to-Digital (A/D) Converter With Internal Reference, Sample-and-Hold, and Autoscan Feature
- 16-Bit Timer_A With Three Capture/Compare Registers
- 16-Bit Timer_B With Seven Capture/Compare With Shadow Registers
- Four Universal Serial Communication Interfaces (USCI)
  - USCI_A0 and USCI_A1
  - Enhanced UART Supporting Auto-Baudrate Detection
  - IrDA Encoder and Decoder
  - Synchronous SPI
  - USCI_B0 and USCI_B1
  - $I^2C$™
  - Synchronous SPI
- On-Chip Comparator
- Supply Voltage Supervisor/Monitor With Programmable Level Detection
- Brownout Detector
- Bootstrap Loader
- Serial Onboard Programming, No External Programming Voltage Needed, Programmable Code Protection by Security Fuse
- Family Members Include:
  - MSP430F233
    - 8KB+256B Flash Memory,
    - 1KB RAM
  - MSP430F235
    - 16KB+256B Flash Memory
    - 2KB RAM
  - MSP430F247, MSP430F2471 (1)
    - 32KB+256B Flash Memory
    - 4KB RAM
  - MSP430F248, MSP430F2481
    - 48KB+256B Flash Memory
    - 4KB RAM
  - MSP430F249, MSP430F2491
    - 60KB+256B Flash Memory
    - 2KB RAM
  - MSP430F2410
    - 56KB+256B Flash Memory
    - 4KB RAM
- Available in 64-Pin QFP and 64-Pin QFN Packages (See Available Options)
- For Complete Module Descriptions, See *MSP430x2xx Family User's Guide* (SLAU144)

(1) The MSP430F24x1 devices are identical to the MSP430F24x devices, with the exception that the ADC12 module is not implemented on the MSP430F24x1.

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This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

## DESCRIPTION

The Texas Instruments MSP430™ family of ultra-low power microcontrollers consists 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 calibrated digitally controlled oscillator (DCO) allows wake-up from low-power modes to active mode in less than 1 µs.

The MSP430F23x, MSP430F24x(1), and MSP430F2410 series are microcontroller configurations with two built-in 16-bit timers, a fast 12-bit A/D converter (not MSP430F24x1), a comparator, four (two in MSP430F23x) universal serial communication interface (USCI) modules, and up to 48 I/O pins. The MSP430F24x1 devices are identical to the MSP430F24x devices, with the exception that the ADC12 module is not implemented. The MSP430F23x devices are identical to the MSP430F24x devices, with the exception that a reduced Timer_B, one USCI module, and less RAM are integrated.

Typical applications include sensor systems, industrial control applications, and hand-held meters.

**Table 1. Available Options**

| $T_A$ | PACKAGED DEVICES(1)(2) | |
|---|---|---|
| | PLASTIC 64-PIN QFP (PM) | PLASTIC 64-PIN QFN (RGC) |
| -40°C to 105°C | MSP430F233TPM | MSP430F233TRGC |
| | MSP430F235TPM | MSP430F235TRGC |
| | MSP430F247TPM | MSP430F247TRGC |
| | MSP430F2471TPM | MSP430F2471TRGC |
| | MSP430F248TPM | MSP430F248TRGC |
| | MSP430F2481TPM | MSP430F2481TRGC |
| | MSP430F249TPM | MSP430F249TRGC |
| | MSP430F2491TPM | MSP430F2491TRGC |
| | MSP430F2410TPM | MSP430F2410TRGC |

(1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI web site at www.ti.com.
(2) Package drawings, thermal data, and symbolization are available at www.ti.com/packaging.

### Development Tool Support

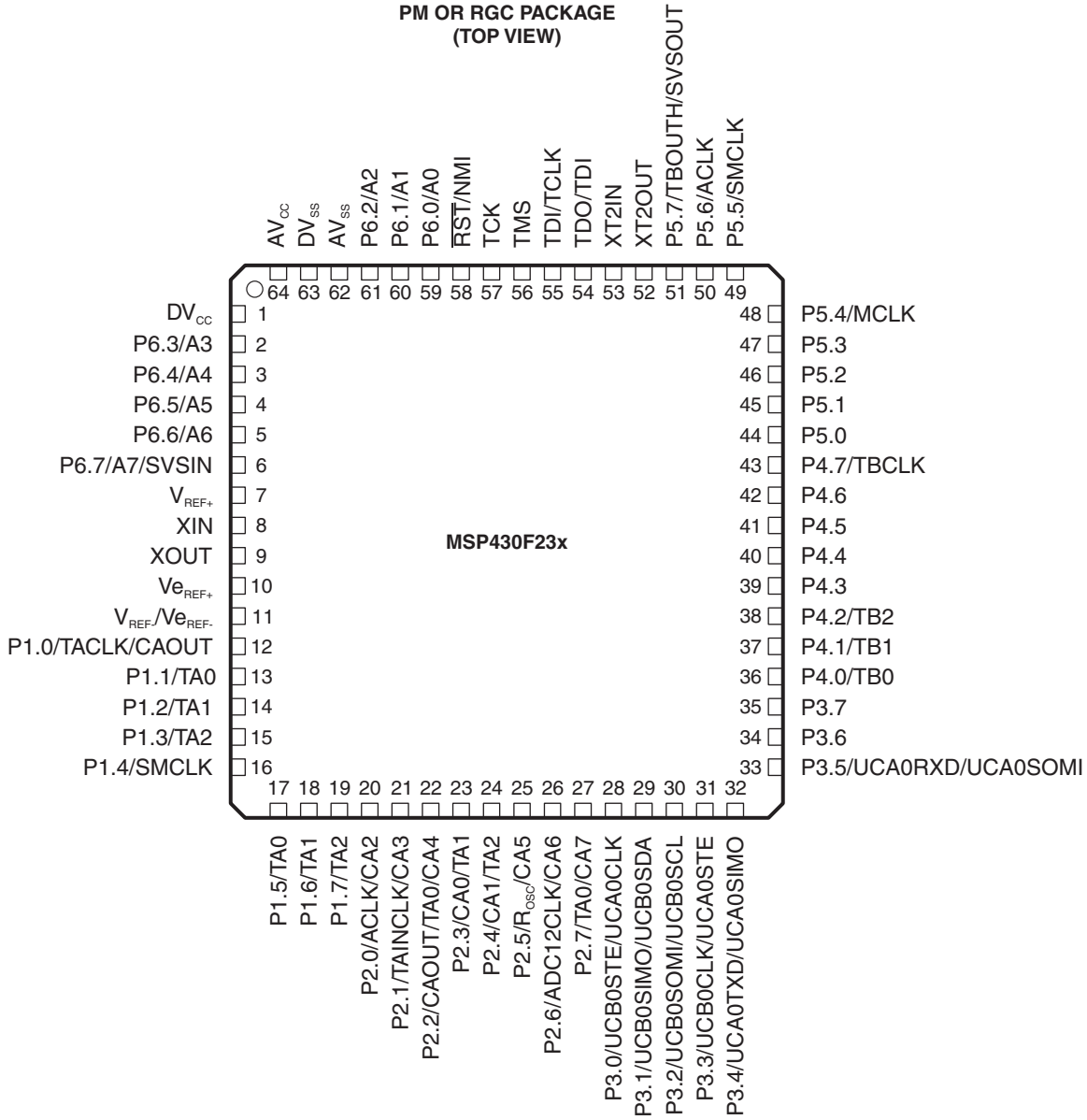
All MSP430 microcontrollers include an Embedded Emulation Module (EEM) allowing advanced debugging and programming through easy to use development tools. Recommended hardware options include the following:

- Debugging and Programming Interface
  - MSP-FET430UIF (USB)
  - MSP-FET430PIF (Parallel Port)
- Debugging and Programming Interface with Target Board
  - MSP-FET430U64 (PM package)
- Standalone Target Board
  - MSP-TS430PM64 (PM package)
- Production Programmer
  - MSP-GANG430


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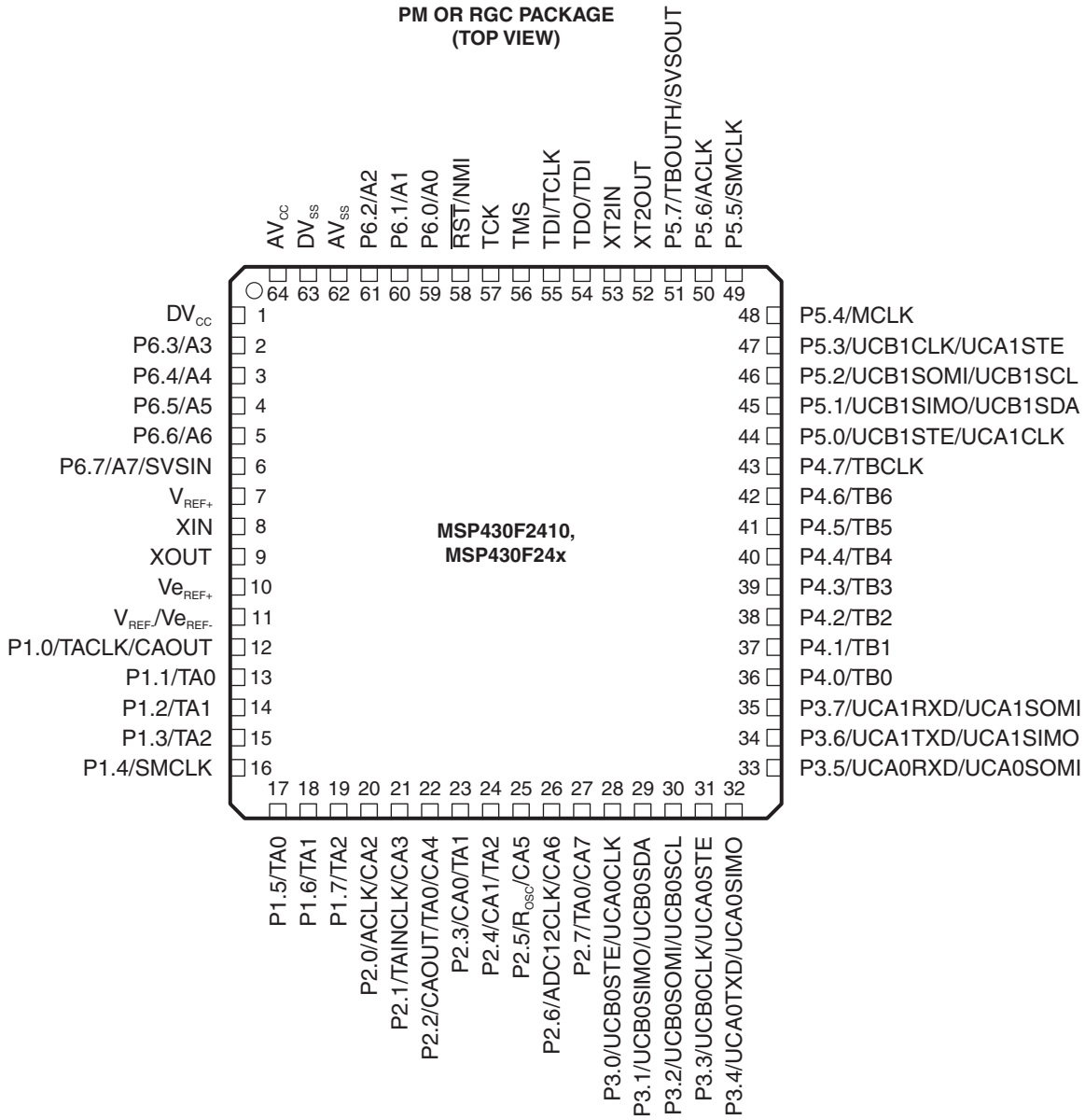
## Device Pinout, MSP430F23x

**PM OR RGC PACKAGE**
**(TOP VIEW)**



## Device Pinout, MSP430F24x, MSP430F2410

**PM OR RGC PACKAGE**
**(TOP VIEW)**

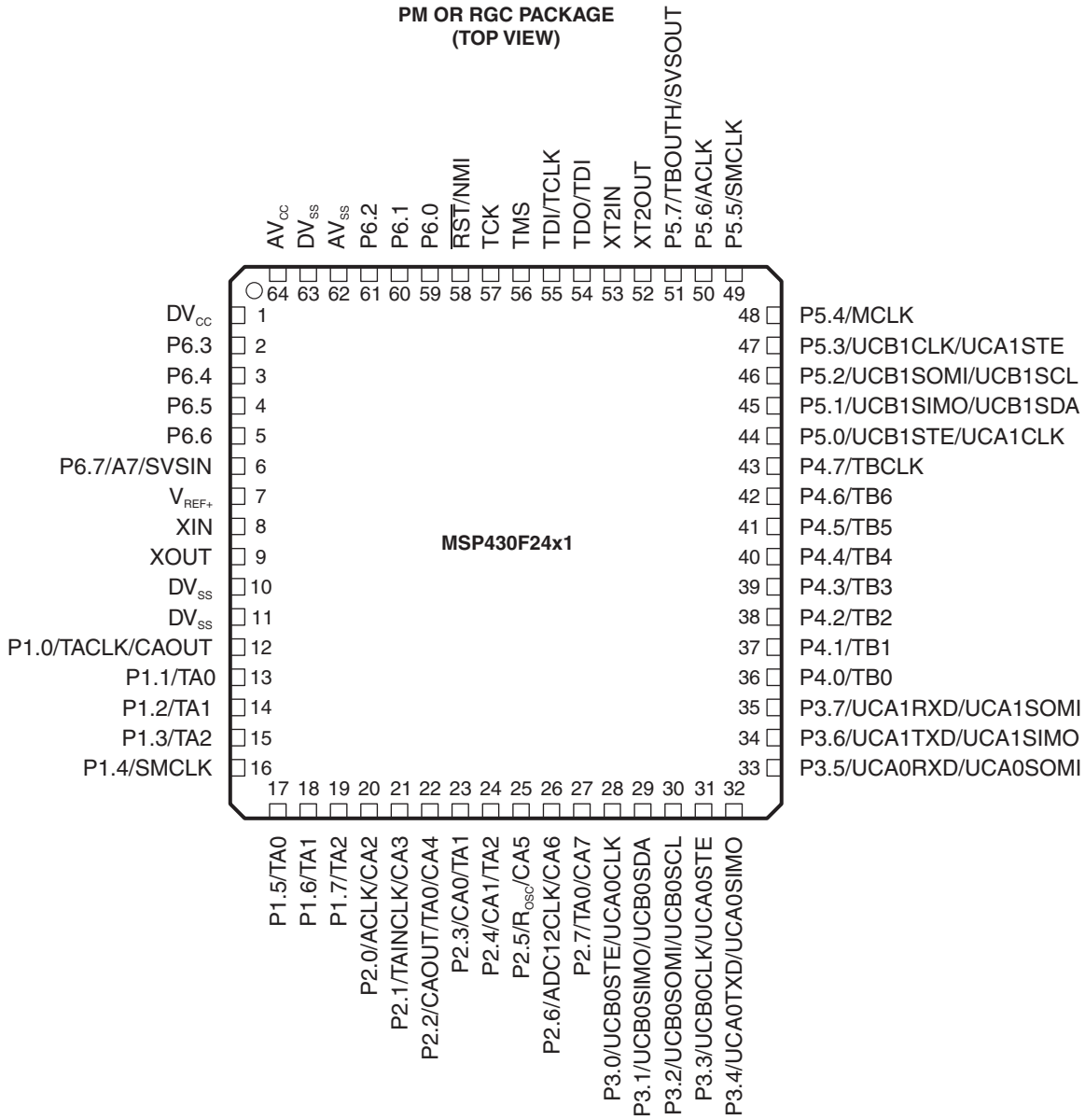




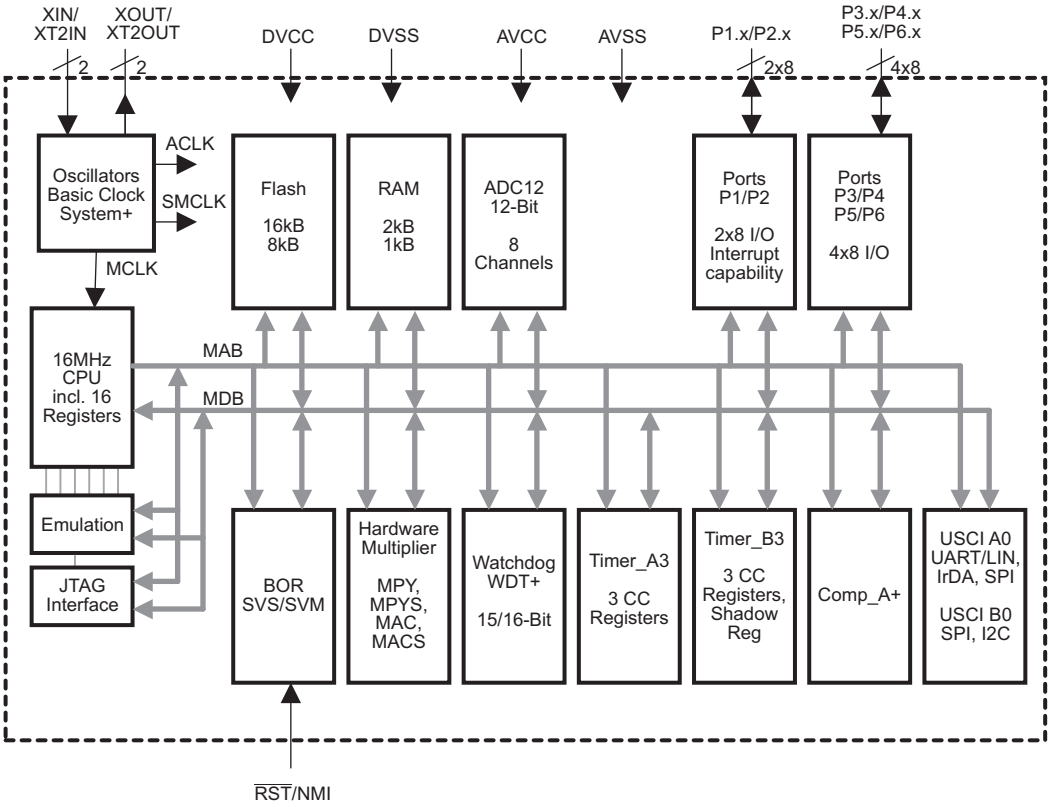
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## Device Pinout, MSP430F24x1

PM OR RGC PACKAGE
(TOP VIEW)



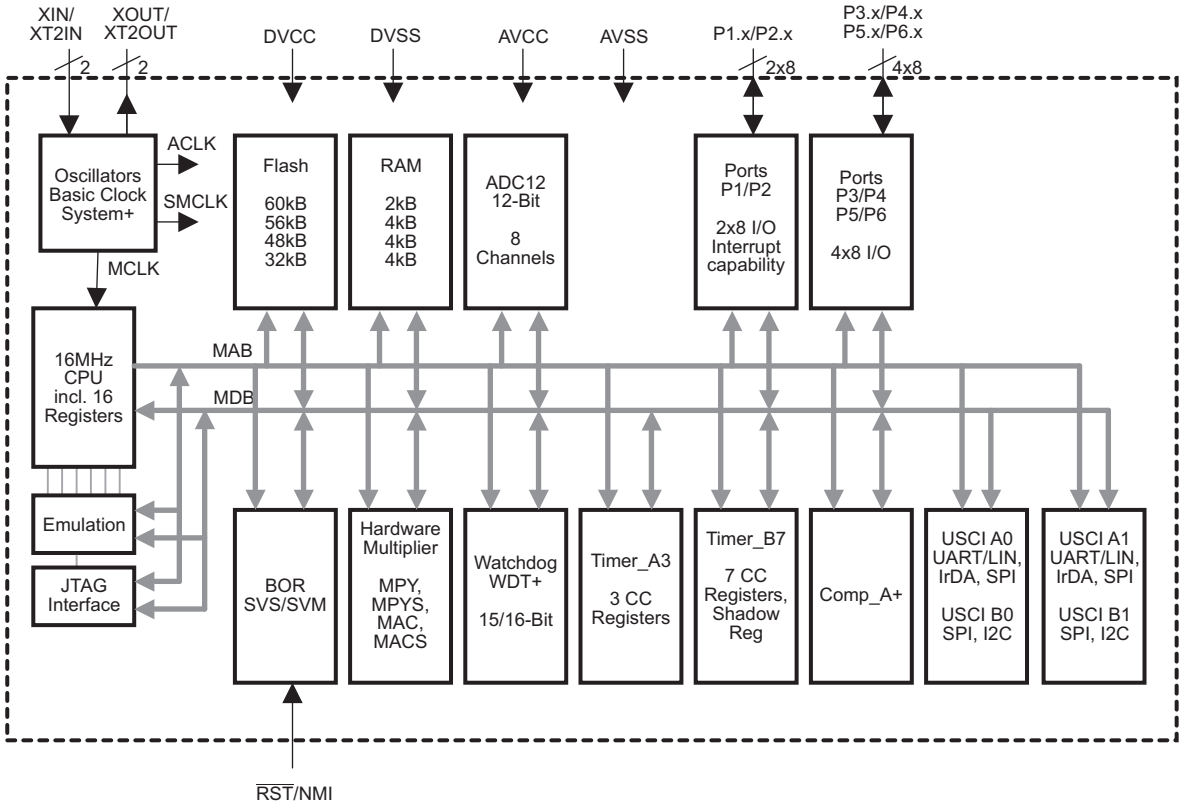
## Functional Block Diagram, MSP430F23x



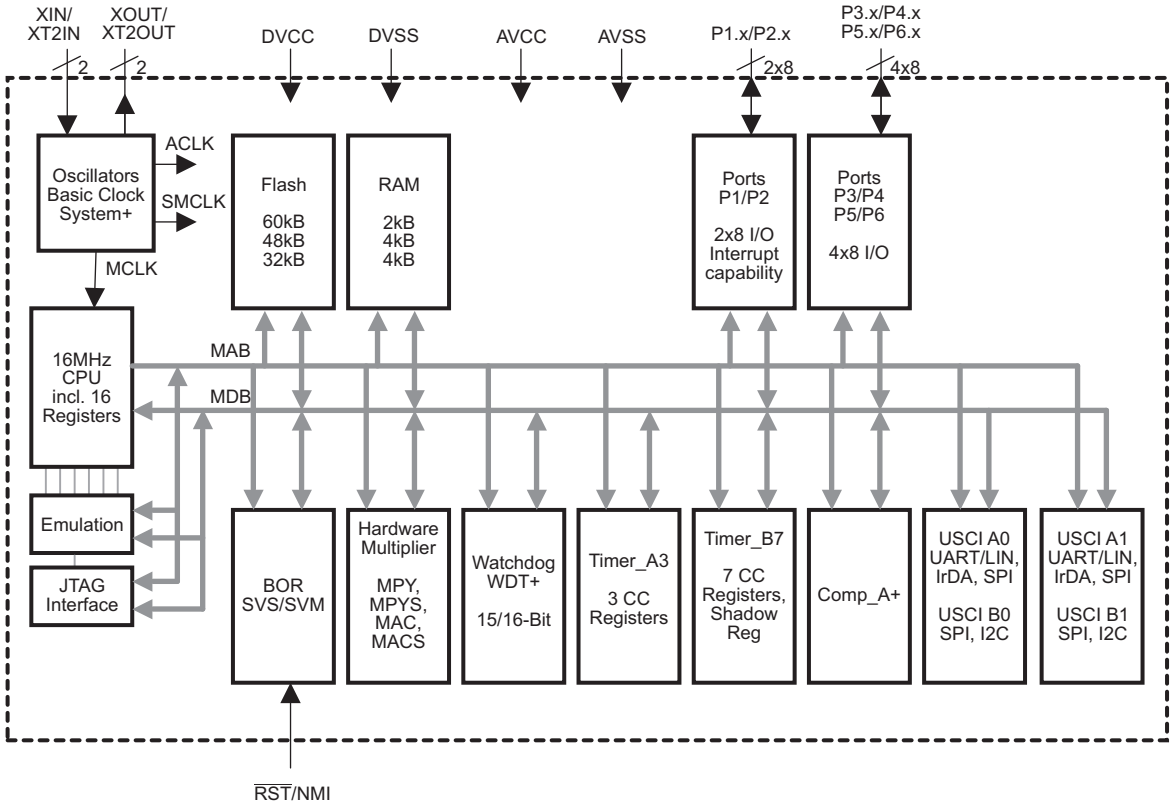


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## Functional Block Diagram, MSP430F24x, MSP430F2410



## Functional Block Diagram, MSP430F24x1





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## Table 2. Terminal Functions, MSP430F23x

| TERMINAL | | I/O | DESCRIPTION |
|---|---|---|---|
| NAME | NO. | | |
| $AV_{CC}$ | 64 | | Analog supply voltage, positive. Supplies only the analog portion of ADC12. |
| $AV_{SS}$ | 62 | | Analog supply voltage, negative. Supplies only the analog portion of ADC12. |
| $DV_{CC}$ | 1 | | Digital supply voltage, positive. Supplies all digital parts. |
| $DV_{SS}$ | 63 | | Digital supply voltage, negative. Supplies all digital parts. |
| P1.0/TACLK/CAOUT | 12 | I/O | General-purpose digital I/O / Timer_A, clock signal TACLK input/Comparator_A output |
| P1.1/TA0 | 13 | I/O | General-purpose digital I/O / Timer_A, capture: CCI0A input, compare: Out0 output/BSL transmit |
| P1.2/TA1 | 14 | I/O | General-purpose digital I/O / Timer_A, capture: CCI1A input, compare: Out1 output |
| P1.3/TA2 | 15 | I/O | General-purpose digital I/O / Timer_A, capture: CCI2A input, compare: Out2 output |
| P1.4/SMCLK | 16 | I/O | General-purpose digital I/O / SMCLK signal output |
| P1.5/TA0 | 17 | I/O | General-purpose digital I/O / Timer_A, compare: Out0 output |
| P1.6/TA1 | 18 | I/O | General-purpose digital I/O / Timer_A, compare: Out1 output |
| P1.7/TA2 | 19 | I/O | General-purpose digital I/O / Timer_A, compare: Out2 output |
| P2.0/ACLK/CA2 | 20 | I/O | General-purpose digital I/O / ACLK output/Comparator_A input |
| P2.1/TAINCLK/CA3 | 21 | I/O | General-purpose digital I/O / Timer_A, clock signal at INCLK |
| P2.2/CAOUT/TA0/CA4 | 22 | I/O | General-purpose digital I/O / Timer_A, capture: CCI0B input/Comparator_A output/BSL receive/Comparator_A input |
| P2.3/CA0/TA1 | 23 | I/O | General-purpose digital I/O / Timer_A, compare: Out1 output/Comparator_A input |
| P2.4/CA1/TA2 | 24 | I/O | General-purpose digital I/O / Timer_A, compare: Out2 output/Comparator_A input |
| P2.5/$R_{OSC}$/CA5 | 25 | I/O | General-purpose digital I/O / input for external resistor defining the DCO nominal frequency/Comparator_A input |
| P2.6/ADC12CLK/CA6 | 26 | I/O | General-purpose digital I/O / conversion clock - 12-bit ADC/Comparator_A input |
| P2.7/TA0/CA7 | 27 | I/O | General-purpose digital I/O / Timer_A, compare: Out0 output/Comparator_A input |
| P3.0/UCB0STE/ UCA0CLK | 28 | I/O | General-purpose digital I/O / USCI_B0 slave transmit enable/USCI A0 clock input/output |
| P3.1/UCB0SIMO/UCB0SDA | 29 | I/O | General-purpose digital I/O / USCI_B0 slave in/master out in SPI mode, SDA $I^2C$ data in $I^2C$ mode |
| P3.2/UCB0SOMI/ UCB0SCL | 30 | I/O | General-purpose digital I/O / USCI_B0 slave out/master in in SPI mode, SCL $I^2C$ clock in $I^2C$ mode |
| P3.3/UCB0CLK/UCA0STE | 31 | I/O | General-purpose digital I/O / USCI_B0 clock input/output, USCI A0 slave transmit enable |
| P3.4/UCA0TXD/ UCA0SIMO | 32 | I/O | General-purpose digital I/O / USCI_A0 transmit data output in UART mode, slave data in/master out in SPI mode |
| P3.5/UCA0RXD/ UCA0SOMI | 33 | I/O | General-purpose digital I/O / USCI_A0 receive data input in UART mode, slave data out/master in in SPI mode |
| P3.6 | 34 | I/O | General-purpose digital I/O |
| P3.7 | 35 | I/O | General-purpose digital I/O |
| P4.0/TB0 | 36 | I/O | General-purpose digital I/O / Timer_B, capture: CCI0A/B input, compare: Out0 output |
| P4.1/TB1 | 37 | I/O | General-purpose digital I/O / Timer_B, capture: CCI1A/B input, compare: Out1 output |
| P4.2/TB2 | 38 | I/O | General-purpose digital I/O / Timer_B, capture: CCI2A/B input, compare: Out2 output |
| P4.3 | 39 | I/O | General-purpose digital I/O |
| P4.4 | 40 | I/O | General-purpose digital I/O |
| P4.5 | 41 | I/O | General-purpose digital I/O |
| P4.6 | 42 | I/O | General-purpose digital I/O |
| P4.7/TBCLK | 43 | I/O | General-purpose digital I/O / Timer_B, clock signal TBCLK input |
| P5.0 | 44 | I/O | General-purpose digital I/O |
| P5.1 | 45 | I/O | General-purpose digital I/O |
| P5.2 | 46 | I/O | General-purpose digital I/O |
| P5.3 | 47 | I/O | General-purpose digital I/O |
| P5.4/MCLK | 48 | I/O | General-purpose digital I/O / main system clock MCLK output |
| P5.5/SMCLK | 49 | I/O | General-purpose digital I/O / submain system clock SMCLK output |
| P5.6/ACLK | 50 | I/O | General-purpose digital I/O / auxiliary clock ACLK output |
| P5.7/TBOUTH/SVSOUT | 51 | I/O | General-purpose digital I/O / switch all PWM digital output ports to high impedance - Timer_B TB0 to TB6/SVS comparator output |
| P6.0/A0 | 59 | I/O | General-purpose digital I/O / analog input A0 - 12-bit ADC |
| P6.1/A1 | 60 | I/O | General-purpose digital I/O / analog input A1 - 12-bit ADC |
| P6.2/A2 | 61 | I/O | General-purpose digital I/O / analog input A2 - 12-bit ADC |

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**Table 2. Terminal Functions, MSP430F23x (continued)**

| TERMINAL | | I/O | DESCRIPTION |
|---|---|---|---|
| NAME | NO. | | |
| P6.3/A3 | 2 | I/O | General-purpose digital I/O / analog input A3 - 12-bit ADC |
| P6.4/A4 | 3 | I/O | General-purpose digital I/O / analog input A4 - 12-bit ADC |
| P6.5/A5 | 4 | I/O | General-purpose digital I/O / analog input A5 - 12-bit ADC |
| P6.6/A6 | 5 | I/O | General-purpose digital I/O / analog input A6 - 12-bit ADC |
| P6.7/A7/SVSIN | 6 | I/O | General-purpose digital I/O / analog input A7 - 12-bit ADC/SVS input |
| XT2OUT | 52 | O | Output terminal of crystal oscillator XT2 |
| XT2IN | 53 | I | Input port for crystal oscillator XT2 |
| RST/NMI | 58 | I | Reset input, nonmaskable interrupt input, or bootstrap loader start (in flash devices) |
| TCK | 57 | I | Test clock (JTAG). TCK is the clock input port for device programming test and bootstrap loader start. |
| TDI/TCLK | 55 | I | Test data input or test clock input. The device protection fuse is connected to TDI/TCLK. |
| TDO/TDI | 54 | I/O | Test data output. TDO/TDI data output or programming data input terminal. |
| TMS | 56 | I | Test mode select. TMS is used as an input port for device programming and test. |
| $V_{eREF+}$ | 10 | I | Input for an external reference voltage |
| $V_{REF+}$ | 7 | O | Output of positive terminal of the reference voltage in the ADC12 |
| $V_{REF-}/V_{eREF-}$ | 11 | I | Negative terminal for the reference voltage for both sources, the internal reference voltage, or an external applied reference voltage |
| XIN | 8 | I | Input for crystal oscillator XT1. Standard or watch crystals can be connected. |
| XOUT | 9 | O | Output for crystal oscillator XT1. Standard or watch crystals can be connected. |
| QFN Pad | NA | NA | QFN package pad connection to $DV_{SS}$ recommended |


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## Table 3. Terminal Functions, MSP430F24x, MSP430F2410

| TERMINAL | | I/O | DESCRIPTION |
|---|---|---|---|
| NAME | NO. | | |
| $AV_{CC}$ | 64 | | Analog supply voltage, positive terminal. Supplies only the analog portion of ADC12. |
| $AV_{SS}$ | 62 | | Analog supply voltage, negative terminal. Supplies only the analog portion of ADC12. |
| $DV_{CC}$ | 1 | | Digital supply voltage, positive terminal. Supplies all digital parts. |
| $DV_{SS}$ | 63 | | Digital supply voltage, negative terminal. Supplies all digital parts. |
| P1.0/TACLK/CAOUT | 12 | I/O | General-purpose digital I/O / Timer_A, clock signal TACLK input/Comparator_A output |
| P1.1/TA0 | 13 | I/O | General-purpose digital I/O / Timer_A, capture: CCI0A input, compare: Out0 output/BSL transmit |
| P1.2/TA1 | 14 | I/O | General-purpose digital I/O / Timer_A, capture: CCI1A input, compare: Out1 output |
| P1.3/TA2 | 15 | I/O | General-purpose digital I/O / Timer_A, capture: CCI2A input, compare: Out2 output |
| P1.4/SMCLK | 16 | I/O | General-purpose digital I/O / SMCLK signal output |
| P1.5/TA0 | 17 | I/O | General-purpose digital I/O / Timer_A, compare: Out0 output |
| P1.6/TA1 | 18 | I/O | General-purpose digital I/O / Timer_A, compare: Out1 output |
| P1.7/TA2 | 19 | I/O | General-purpose digital I/O / Timer_A, compare: Out2 output |
| P2.0/ACLK/CA2 | 20 | I/O | General-purpose digital I/O / ACLK output/Comparator_A input |
| P2.1/TAINCLK/CA3 | 21 | I/O | General-purpose digital I/O / Timer_A, clock signal at INCLK |
| P2.2/CAOUT/TA0/CA4 | 22 | I/O | General-purpose digital I/O / Timer_A, capture: CCI0B input / Comparator_A output/BSL receive/Comparator_A input |
| P2.3/CA0/TA1 | 23 | I/O | General-purpose digital I/O / Timer_A, compare: Out1 output / Comparator_A input |
| P2.4/CA1/TA2 | 24 | I/O | General-purpose digital I/O / Timer_A, compare: Out2 output / Comparator_A input |
| P2.5/$R_{OSC}$/CA5 | 25 | I/O | General-purpose digital I/O / Input for external resistor defining the DCO nominal frequency / Comparator_A input |
| P2.6/ADC12CLK/CA6 | 26 | I/O | General-purpose digital I/O / Conversion clock - 12-bit ADC / Comparator_A input |
| P2.7/TA0/CA7 | 27 | I/O | General-purpose digital I/O / Timer_A, compare: Out0 output / Comparator_A input |
| P3.0/UCB0STE/ UCA0CLK | 28 | I/O | General-purpose digital I/O / USCI_B0 slave transmit enable / USCI A0 clock input/output |
| P3.1/UCB0SIMO/UCB0SDA | 29 | I/O | General-purpose digital I/O / USCI_B0 slave in/master out in SPI mode, SDA $I^2C$ data in $I^2C$ mode |
| P3.2/UCB0SOMI/ UCB0SCL | 30 | I/O | General-purpose digital I/O / USCI_B0 slave out/master in in SPI mode, SCL $I^2C$ clock in $I^2C$ mode |
| P3.3/UCB0CLK/UCA0STE | 31 | I/O | General-purpose digital I/O / USCI_B0 clock input/output, USCI A0 slave transmit enable |
| P3.4/UCA0TXD/UCA0SIMO | 32 | I/O | General-purpose digital I/O / USCI_A- transmit data output in UART mode, slave data in/master out in SPI mode |
| P3.5/UCA0RXD/ UCA0SOMI | 33 | I/O | General-purpose digital I/O / USCI_A0 receive data input in UART mode, slave data out/master in in SPI mode |
| P3.6/UCA1TXD/UCA1SIMO | 34 | I/O | General-purpose digital I/O / USCI_A1 transmit data output in UART mode, slave data in/master out in SPI mode |
| P3.7/UCA1RXD/ UCA1SOMI | 35 | I/O | General-purpose digital I/O / USCI_A1 receive data input in UART mode, slave data out/master in in SPI mode |
| P4.0/TB0 | 36 | I/O | General-purpose digital I/O / Timer_B, capture: CCI0A/B input, compare: Out0 output |
| P4.1/TB1 | 37 | I/O | General-purpose digital I/O / Timer_B, capture: CCI1A/B input, compare: Out1 output |
| P4.2/TB2 | 38 | I/O | General-purpose digital I/O / Timer_B, capture: CCI2A/B input, compare: Out2 output |
| P4.3/TB3 | 39 | I/O | General-purpose digital I/O / Timer_B, capture: CCI3A/B input, compare: Out3 output |
| P4.4/TB4 | 40 | I/O | General-purpose digital I/O / Timer_B, capture: CCI4A/B input, compare: Out4 output |
| P4.5/TB5 | 41 | I/O | General-purpose digital I/O / Timer_B, capture: CCI5A/B input, compare: Out5 output |
| P4.6/TB6 | 42 | I/O | General-purpose digital I/O / Timer_B, capture: CCI6A input, compare: Out6 output |
| P4.7/TBCLK | 43 | I/O | General-purpose digital I/O / Timer_B, clock signal TBCLK input |
| P5.0/UCB1STE/UCA1CLK | 44 | I/O | General-purpose digital I/O / USCI_B1 slave transmit enable / USCI_A1 clock input/output |
| P5.1/UCB1SIMO/UCB1SDA | 45 | I/O | General-purpose digital I/O / USCI_B1 slave in/master out in SPI mode, SDA $I^2C$ data in $I^2C$ mode |
| P5.2/UCB1SOMI/UCB1SCL | 46 | I/O | General-purpose digital I/O / USCI_B1 slave out/master in in SPI mode, SCL $I^2C$ clock in $I^2C$ mode |
| P5.3/UCB1CLK/UCA1STE | 47 | I/O | General-purpose digital I/O / USCI_B1 clock input/output, USCI_A1 slave transmit enable |
| P5.4/MCLK | 48 | I/O | General-purpose digital I/O / main system clock MCLK output |
| P5.5/SMCLK | 49 | I/O | General-purpose digital I/O / submain system clock SMCLK output |
| P5.6/ACLK | 50 | I/O | General-purpose digital I/O / auxiliary clock ACLK output |
| P5.7/TBOUTH/SVSOUT | 51 | I/O | General-purpose digital I/O / switch all PWM digital output ports to high impedance - Timer_B TB0 to TB6/SVS comparator output |
| P6.0/A0 | 59 | I/O | General-purpose digital I/O / analog input A0 - 12-bit ADC |

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**Table 3. Terminal Functions, MSP430F24x, MSP430F2410 (continued)**

| TERMINAL | | I/O | DESCRIPTION |
|---|---|---|---|
| NAME | NO. | | |
| P6.1/A1 | 60 | I/O | General-purpose digital I/O / analog input A1 - 12-bit ADC |
| P6.2/A2 | 61 | I/O | General-purpose digital I/O / analog input A2 - 12-bit ADC |
| P6.3/A3 | 2 | I/O | General-purpose digital I/O / analog input A3 - 12-bit ADC |
| P6.4/A4 | 3 | I/O | General-purpose digital I/O / analog input A4 - 12-bit ADC |
| P6.5/A5 | 4 | I/O | General-purpose digital I/O / analog input A5 - 12-bit ADC |
| P6.6/A6 | 5 | I/O | General-purpose digital I/O / analog input A6 - 12-bit ADC |
| P6.7/A7/SVSIN | 6 | I/O | General-purpose digital I/O / analog input A7 - 12-bit ADC/SVS input |
| XT2OUT | 52 | O | Output of crystal oscillator XT2 |
| XT2IN | 53 | I | Input for crystal oscillator XT2 |
| RST/NMI | 58 | I | Reset input, nonmaskable interrupt input, or bootstrap loader start (in flash devices) |
| TCK | 57 | I | Test clock (JTAG). TCK is the clock input port for device programming test and bootstrap loader start. |
| TDI/TCLK | 55 | I | Test data input or test clock input. The device protection fuse is connected to TDI/TCLK. |
| TDO/TDI | 54 | I/O | Test data output. TDO/TDI data output or programming data input terminal. |
| TMS | 56 | I | Test mode select. TMS is used as an input port for device programming and test. |
| $V_{eREF+}$ | 10 | I | Input for an external reference voltage |
| $V_{REF+}$ | 7 | O | Positive output of the reference voltage in the ADC12 |
| $V_{REF-}/V_{eREF-}$ | 11 | I | Negative input for the reference voltage for both sources, the internal reference voltage, or an external applied reference voltage |
| XIN | 8 | I | Input for crystal oscillator XT1. Standard or watch crystals can be connected. |
| XOUT | 9 | O | Output for crystal oscillator XT1. Standard or watch crystals can be connected. |
| QFN Pad | NA | NA | QFN package pad connection to $DV_{SS}$ recommended (RGC package only) |


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## Table 4. Terminal Functions, MSP430F24x1

| TERMINAL | | I/O | DESCRIPTION |
|---|---|---|---|
| NAME | NO. | | |
| $AV_{CC}$ | 64 | | Analog supply voltage, positive. Supplies only the analog portion of ADC12. |
| $AV_{SS}$ | 62 | | Analog supply voltage, negative. Supplies only the analog portion of ADC12. |
| $DV_{CC}$ | 1 | | Digital supply voltage, positive. Supplies all digital parts. |
| $DV_{SS}$ | 63 | | Digital supply voltage, negative. Supplies all digital parts. |
| P1.0/TACLK/CAOUT | 12 | I/O | General-purpose digital I/O / Timer_A, clock signal TACLK input / Comparator_A output |
| P1.1/TA0 | 13 | I/O | General-purpose digital I/O / Timer_A, capture: CCI0A input, compare: Out0 output / BSL transmit |
| P1.2/TA1 | 14 | I/O | General-purpose digital I/O / Timer_A, capture: CCI1A input, compare: Out1 output |
| P1.3/TA2 | 15 | I/O | General-purpose digital I/O / Timer_A, capture: CCI2A input, compare: Out2 output |
| P1.4/SMCLK | 16 | I/O | General-purpose digital I/O / SMCLK signal output |
| P1.5/TA0 | 17 | I/O | General-purpose digital I/O / Timer_A, compare: Out0 output |
| P1.6/TA1 | 18 | I/O | General-purpose digital I/O / Timer_A, compare: Out1 output |
| P1.7/TA2 | 19 | I/O | General-purpose digital I/O / Timer_A, compare: Out2 output |
| P2.0/ACLK/CA2 | 20 | I/O | General-purpose digital I/O / ACLK output/Comparator_A input |
| P2.1/TAINCLK/CA3 | 21 | I/O | General-purpose digital I/O / Timer_A, clock signal at INCLK |
| P2.2/CAOUT/TA0/CA4 | 22 | I/O | General-purpose digital I/O / Timer_A, capture: CCI0B input / Comparator_A output/BSL receive/Comparator_A input |
| P2.3/CA0/TA1 | 23 | I/O | General-purpose digital I/O / Timer_A, compare: Out1 output / Comparator_A input |
| P2.4/CA1/TA2 | 24 | I/O | General-purpose digital I/O / Timer_A, compare: Out2 output / Comparator_A input |
| P2.5/$R_{OSC}$/CA5 | 25 | I/O | General-purpose digital I/O / input for external resistor defining the DCO nominal frequency / Comparator_A input |
| P2.6/ADC12CLK/CA6 | 26 | I/O | General-purpose digital I/O / conversion clock - 12-bit ADC / Comparator_A input |
| P2.7/TA0/CA7 | 27 | I/O | General-purpose digital I/O / Timer_A, compare: Out0 output/Comparator_A input |
| P3.0/UCB0STE/ UCA0CLK | 28 | I/O | General-purpose digital I/O / USCI_B0 slave transmit enable/USCI A0 clock input/output |
| P3.1/UCB0SIMO/UCB0SDA | 29 | I/O | General-purpose digital I/O / USCI_B0 slave in/master out in SPI mode, SDA $I^2C$ data in $I^2C$ mode |
| P3.2/UCB0SOMI/ UCB0SCL | 30 | I/O | General-purpose digital I/O / USCI_B0 slave out/master in in SPI mode, SCL $I^2C$ clock in $I^2C$ mode |
| P3.3/UCB0CLK/UCA0STE | 31 | I/O | General-purpose digital I/O / USCI_B0 clock input/output, USCI A0 slave transmit enable |
| P3.4/UCA0TXD/UCA0SIMO | 32 | I/O | General-purpose digital I/O / USCI_A0 transmit data output in UART mode, slave data in/master out in SPI mode |
| P3.5/UCA0RXD/ UCA0SOMI | 33 | I/O | General-purpose digital I/O / USCI_A0 receive data input in UART mode, slave data out/master in in SPI mode |
| P3.6/UCA1TXD/UCA1SIMO | 34 | I/O | General-purpose digital I/O / USCI_A1 transmit data output in UART mode, slave data in/master out in SPI mode |
| P3.7/UCA1RXD/ UCA1SOMI | 35 | I/O | General-purpose digital I/O / USCI_A1 receive data input in UART mode, slave data out/master in in SPI mode |
| P4.0/TB0 | 36 | I/O | General-purpose digital I/O / Timer_B, capture: CCI0A/B input, compare: Out0 output |
| P4.1/TB1 | 37 | I/O | General-purpose digital I/O / Timer_B, capture: CCI1A/B input, compare: Out1 output |
| P4.2/TB2 | 38 | I/O | General-purpose digital I/O / Timer_B, capture: CCI2A/B input, compare: Out2 output |
| P4.3/TB3 | 39 | I/O | General-purpose digital I/O / Timer_B, capture: CCI3A/B input, compare: Out3 output |
| P4.4/TB4 | 40 | I/O | General-purpose digital I/O / Timer_B, capture: CCI4A/B input, compare: Out4 output |
| P4.5/TB5 | 41 | I/O | General-purpose digital I/O / Timer_B, capture: CCI5A/B input, compare: Out5 output |
| P4.6/TB6 | 42 | I/O | General-purpose digital I/O / Timer_B, capture: CCI6A input, compare: Out6 output |
| P4.7/TBCLK | 43 | I/O | General-purpose digital I/O / Timer_B, clock signal TBCLK input |
| P5.0/UCB1STE/UCA1CLK | 44 | I/O | General-purpose digital I/O / USCI_B1 slave transmit enable/USCI_A1 clock input/output |
| P5.1/UCB1SIMO/UCB1SDA | 45 | I/O | General-purpose digital I/O / USCI_B1 slave in/master out in SPI mode, SDA $I^2C$ data in $I^2C$ mode |
| P5.2/UCB1SOMI/UCB1SCL | 46 | I/O | General-purpose digital I/O / USCI_B1 slave out/master in in SPI mode, SCL $I^2C$ clock in $I^2C$ mode |
| P5.3/UCB1CLK/UCA1STE | 47 | I/O | General-purpose digital I/O / USCI_B1 clock input/output, USCI_A1 slave transmit enable |
| P5.4/MCLK | 48 | I/O | General-purpose digital I/O / main system clock MCLK output |
| P5.5/SMCLK | 49 | I/O | General-purpose digital I/O / submain system clock SMCLK output |
| P5.6/ACLK | 50 | I/O | General-purpose digital I/O / auxiliary clock ACLK output |
| P5.7/TBOUTH/SVSOUT | 51 | I/O | General-purpose digital I/O / switch all PWM digital output ports to high impedance - Timer_B TB0 to TB6/SVS comparator output |
| P6.0 | 59 | I/O | General-purpose digital I/O |

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**Table 4. Terminal Functions, MSP430F24x1 (continued)**

| TERMINAL | | I/O | DESCRIPTION |
|---|---|---|---|
| NAME | NO. | | |
| P6.1 | 60 | I/O | General-purpose digital I/O |
| P6.2 | 61 | I/O | General-purpose digital I/O |
| P6.3 | 2 | I/O | General-purpose digital I/O |
| P6.4 | 3 | I/O | General-purpose digital I/O |
| P6.5 | 4 | I/O | General-purpose digital I/O |
| P6.6 | 5 | I/O | General-purpose digital I/O |
| P6.7/SVSIN | 6 | I/O | General-purpose digital I/O / SVS input |
| XT2OUT | 52 | O | Output terminal of crystal oscillator XT2 |
| XT2IN | 53 | I | Input port for crystal oscillator XT2 |
| RST/NMI | 58 | I | Reset input, nonmaskable interrupt input, or bootstrap loader start (in flash devices). |
| TCK | 57 | I | Test clock (JTAG). TCK is the clock input for device programming test and bootstrap loader start. |
| TDI/TCLK | 55 | I | Test data input or test clock input. The device protection fuse is connected to TDI/TCLK. |
| TDO/TDI | 54 | I/O | Test data output. TDO/TDI data output or programming data input terminal. |
| TMS | 56 | I | Test mode select. TMS is used as an input port for device programming and test. |
| $DV_{SS}$ | 10 | I | Connected to $DV_{SS}$ |
| Reserved | 7 | O | Reserved, do not connect externally |
| $DV_{SS}$ | 11 | I | Connected to $DV_{SS}$ |
| XIN | 8 | I | Input for crystal oscillator XT1. Standard or watch crystals can be connected. |
| XOUT | 9 | O | Output for crystal oscillator XT1. Standard or watch crystals can be connected. |
| QFN Pad | NA | NA | QFN package pad connection to $DV_{SS}$ recommended (RGC package only) |


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# SHORT-FORM DESCRIPTION

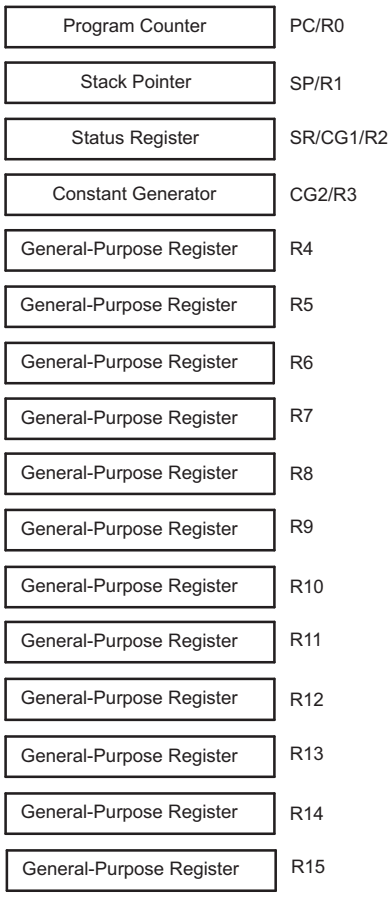
## CPU

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 5 shows examples of the three types of instruction formats; Table 6 shows the address modes.

**Table 5. 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 6. Address Mode Descriptions**

| ADDRESS MODE | S (1) | D (2) | 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

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## Operating Modes

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

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.


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## Interrupt Vector Addresses

The interrupt vectors and the power-up starting address are located in the address range 0xFFFF to 0xFFC0. The vector contains the 16-bit address of the appropriate interrupt-handler instruction sequence. If the reset vector (0xFFFE) contains 0xFFFF (for example, if flash is not programmed) the CPU enters LPM4 after power-up.

**Table 7. 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(1) | PORIFG<br>WDTIFG<br>RSTIFG<br>KEYV<br>(see (2)) | Reset | 0xFFFE | 31, highest |
| NMI<br>Oscillator fault<br>Flash memory access violation | NMIIFG<br>OFIFG<br>ACCVIFG(2)(3) | (Non)maskable<br>(Non)maskable<br>(Non)maskable | 0xFFFC | 30 |
| Timer_B7(4) | TBCCR0 CCIFG(5) | Maskable | 0xFFFA | 29 |
| Timer_B7(4) | TBCCR1 to TBCCR6 CCIFGs,<br>TBIFG(2)(5) | Maskable | 0xFFF8 | 28 |
| Comparator_A+ | CAIFG | Maskable | 0xFFF6 | 27 |
| Watchdog timer+ | WDTIFG | Maskable | 0xFFF4 | 26 |
| Timer_A3 | TACCR0 CCIFG(5) | Maskable | 0xFFF2 | 25 |
| Timer_A3 | TACCR1 CCIFG<br>TACCR2 CCIFG TAIFG(2)(5) | Maskable | 0xFFF0 | 24 |
| USCI_A0/USCI_B0 receive<br>USCI_B0 I2C status | UCA0RXIFG, UCB0RXIFG(2)(6) | Maskable | 0xFFEE | 23 |
| USCI_A0/USCI_B0 transmit<br>USCI_B0 I2C receive / transmit | UCA0TXIFG, UCB0TXIFG(2)(7) | Maskable | 0xFFEC | 22 |
| ADC12(8) | ADC12IFG(2)(5) | Maskable | 0xFFEA | 21 |
| | | | 0xFFE8 | 20 |
| I/O port P2 (eight flags) | P2IFG.0 to P2IFG.7(2)(5) | Maskable | 0xFFE6 | 19 |
| I/O port P1 (eight flags) | P1IFG.0 to P1IFG.7(2)(5) | Maskable | 0xFFE4 | 18 |
| USCI_A1/USCI_B1 receive<br>USCI_B1 I2C status | UCA1RXIFG, UCB1RXIFG(2)(6) | Maskable | 0xFFE2 | 17 |
| USCI_A1/USCI_B1 transmit<br>USCI_B1 I2C receive / transmit | UCA1TXIFG, UCB1TXIFG(2)(7) | Maskable | 0xFFE0 | 16 |
| Reserved(9)(10) | Reserved | | 0xFFDE to 0xFFC0 | 15 to 0, lowest |

(1) 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.
(2) Multiple source flags
(3) (Non)maskable: The individual interrupt-enable bit can disable an interrupt event, but the general-interrupt enable cannot.
(4) Timer_B7 in MSP430F24x(1)/MSP430F2410 family has seven CCRs, Timer_B3 in MSP430F23x family has three CCRs. In Timer_B3, there are only interrupt flags TBCCR0 CCIFG, TBCCR1 CCIFG, and TBCCR2 CCIFG, and the interrupt enable bits TBCCTL0 CCIE, TBCCTL1 CCIE, and TBCCTL2 CCIE.
(5) Interrupt flags are located in the module.
(6) In SPI mode: UCB0RXIFG. In I2C mode: UCALIFG, UCNACKIFG, ICSTTIFG, UCSTPIFG.
(7) In UART/SPI mode: UCB0TXIFG. In I2C mode: UCB0RXIFG, UCB0TXIFG.
(8) ADC12 is not implemented in the MSP430F24x1 family.
(9) The address 0xFFDE is used as bootstrap loader security key (BSLSKEY). A 0xAA55 at this location disables the BSL completely. A zero disables the erasure of the flash if an invalid password is supplied.
(10) The interrupt vectors at addresses 0xFFDE to 0xFFC0 are not used in this device and can be used for regular program code if necessary.

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## Special Function Registers

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

**Legend**

| | |
|---|---|
| rw | Bit can be read and written. |
| rw-0, 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 8. 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 9. Interrupt Enable 2**

| Address | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|
| 01h | | | | | UCB0TXIE | UCB0RXIE | UCA0TXIE | UCA0RXIE |
| | | | | | rw-0 | rw-0 | rw-0 | rw-0 |

| | |
|---|---|
| UCA0RXIE | USCI_A0 receive-interrupt enable |
| UCA0TXIE | USCI_A0 transmit-interrupt enable |
| UCB0RXIE | USCI_B0 receive-interrupt enable |
| UCB0TXIE | USCI_B0 transmit-interrupt enable |

**Table 10. 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 $V_{CC}$ power-up or a reset condition at $\overline{RST}$/NMI pin in reset mode. |
| OFIFG | Flag set on oscillator fault |
| RSTIFG | External reset interrupt flag. Set on a reset condition at $\overline{RST}$/NMI pin in reset mode. Reset on $V_{CC}$ power up. |
| PORIFG | Power-on reset interrupt flag. Set on $V_{CC}$ power up. |
| NMIIFG | Set via $\overline{RST}$/NMI pin |

**Table 11. Interrupt Flag Register 2**

| Address | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|
| 03h | | | | | UCB0TXIFG | UCB0RXIFG | UCA0TXIFG | UCA0RXIFG |
| | | | | | rw-1 | rw-0 | rw-1 | rw-0 |

| | |
|---|---|
| UCA0RXIFG | USCI_A0 receive-interrupt flag |
| UCA0TXIFG | USCI_A0 transmit-interrupt flag |
| UCB0RXIFG | USCI_B0 receive-interrupt flag |
| UCB0TXIFG | USCI_B0 transmit-interrupt flag |


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## Memory Organization

**Table 12. Memory Organization**

| | | MSP430F233 | MSP430F235 | MSP430F249<br>MSP430F2491 |
|---|---|---|---|---|
| Memory<br>Main: interrupt vector<br>Main: code memory | Size<br>Flash<br>Flash | 8KB<br>0xFFFF to 0xFFC0<br>0xFFFF to 0xE000 | 16KB<br>0xFFFF to 0xFFC0<br>0xFFFF to 0xC000 | 60KB<br>0xFFFF to 0xFFC0<br>0xFFFF to 0x1100 |
| RAM (Total) | Size | 1KB<br>0x05FF to 0x0200 | 2KB<br>0x09FF to 0x0200 | 2KB<br>0x09FF to 0x0200 |
| Information memory | Size<br>Flash | 256 Byte<br>0x10FF to 0x1000 | 256 Byte<br>0x10FF to 0x1000 | 256 Byte<br>0x10FF to 0x1000 |
| Boot memory | Size<br>ROM | 1KB<br>0x0FFF to 0x0C00 | 1KB<br>0x0FFF to 0x0C00 | 1KB<br>0x0FFF to 0x0C00 |
| RAM | Size | 1KB<br>0x05FF to 0x0200 | 2KB<br>0x09FF to 0x0200 | 2KB<br>0x09FF to 0x0200 |
| Peripherals | 16 bit<br>8 bit<br>SFR | 0x01FF to 0x0100<br>0x00FF to 0x0010<br>0x000F to 0x0000 | 0x01FF to 0x0100<br>0x00FF to 0x0010<br>0x000F to 0x0000 | 0x01FF to 0x0100<br>0x00FF to 0x0010<br>0x000F to 0x0000 |

| | | MSP430F247<br>MSP430F2471 | MSP430F248<br>MSP430F2481 | MSP430F2410 |
|---|---|---|---|---|
| Memory<br>Main: interrupt vector<br>Main: code memory | Size<br>Flash<br>Flash | 32KB<br>0xFFFF to 0xFFC0<br>0xFFFF to 0x8000 | 48KB<br>0xFFFF to 0xFFC0<br>0xFFFF to 0x4000 | 56KB<br>0xFFFF to 0xFFC0<br>0xFFFF to 0x2100 |
| RAM (total) | Size | 4KB<br>0x20FF to 0x1100 | 4KB<br>0x20FF to 0x1100 | 4KB<br>0x20FF to 0x1100 |
| Extended | Size | 2KB<br>0x20FF to 0x1900 | 2KB<br>0x20FF to 0x1900 | 2KB<br>0x20FF to 0x1900 |
| Mirrored | Size | 2KB<br>0x18FF to 0x1100 | 2KB<br>0x18FF to 0x1100 | 2KB<br>0x18FF to 0x1100 |
| Information memory | Size<br>Flash | 256 Byte<br>0x10FF to 0x1000 | 256 Byte<br>0x10FF to 0x1000 | 256 Byte<br>0x10FF to 0x1000 |
| Boot memory | Size<br>ROM | 1KB<br>0x0FFF to 0x0C00 | 1KB<br>0x0FFF to 0x0C00 | 1KB<br>0x0FFF to 0x0C00 |
| RAM (mirrored at<br>0x18FF to 0x1100) | Size | 2KB<br>0x09FF to 0x0200 | 2KB<br>0x09FF to 0x0200 | 2KB<br>0x09FF to 0x0200 |
| Peripherals | 16 bit<br>8 bit<br>SFR | 0x01FF to 0x0100<br>0x00FF to 0x0010<br>0x000F to 0x0000 | 0x01FF to 0x0100<br>0x00FF to 0x0010<br>0x000F to 0x0000 | 0x01FF to 0x0100<br>0x00FF to 0x0010<br>0x000F to 0x0000 |

## 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. For complete description of the features of the BSL and its implementation, see the *MSP430 Programming Via the Bootstrap Loader User's Guide* (SLAU319).

**Table 13. BSL Function Pins**

| BSL FUNCTION | PM, RGC PACKAGE PINS |
|---|---|
| Data transmit | 13 - P1.1 |
| Data receive | 22 - 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

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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.


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## 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 very-low-power low-frequency 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 µs. The basic clock module provides the following clock signals:

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

## Calibration Data Stored in Information Memory Segment A

Calibration data is stored for the DCO and for the ADC12. It is organized in a tag-length-value (TLV) structure.

**Table 14. Tags Used by the ADC Calibration Tags**

| NAME | ADDRESS | VALUE | DESCRIPTION |
|---|---|---|---|
| TAG_DCO_30 | 0x10F6 | 0x01 | DCO frequency calibration at $V_{CC}$ = 3 V and$T_A$ = 25°C at calibration |
| TAG_ADC12_1 | 0x10DA | 0x10 | ADC12_1 calibration tag |
| TAG_EMPTY | - | 0xFE | Identifier for empty memory areas |

**Table 15. Labels Used by the ADC Calibration Tags**

| LABEL | CONDITION AT CALIBRATION / DESCRIPTION | SIZE | ADDRESS OFFSET |
|---|---|---|---|
| CAL_ADC_25T85 | INCHx = 0x1010, REF2_5 = 1, $T_A$ = 85°C | word | 0x000E |
| CAL_ADC_25T30 | INCHx = 0x1010, REF2_5 = 1, $T_A$ = 30°C | word | 0x000C |
| CAL_ADC_25VREF_FACTOR | REF2_5 = 1, $T_A$ = 30°C, $I_{VREF+}$ = 1.0 mA | word | 0x000A |
| CAL_ADC_15T85 | INCHx = 0x1010, REF2_5 = 0, $T_A$ = 85°C | word | 0x0008 |
| CAL_ADC_15T30 | INCHx = 0x1010, REF2_5 = 0, $T_A$ = 30°C | word | 0x0006 |
| CAL_ADC_15VREF_FACTOR | REF2_5 = 0, $T_A$ = 30°C, $I_{VREF+}$ = 0.5 mA | word | 0x0004 |
| CAL_ADC_OFFSET | External Vref = 1.5 V, $f_{ADC12CLK}$ = 5 MHz | word | 0x0002 |
| CAL_ADC_GAIN_FACTOR | External Vref = 1.5 V, $f_{ADC12CLK}$ = 5 MHz | word | 0x0000 |
| CAL_BC1_1MHZ | - | byte | 0x0007 |
| CAL_DCO_1MHZ | - | byte | 0x0006 |
| CAL_BC1_8MHZ | - | byte | 0x0005 |
| CAL_DCO_8MHZ | - | byte | 0x0004 |
| CAL_BC1_12MHZ | - | byte | 0x0003 |
| CAL_DCO_12MHZ | - | byte | 0x0002 |
| CAL_BC1_16MHZ | - | byte | 0x0001 |
| CAL_DCO_16MHZ | - | byte | 0x0000 |

## Brownout, Supply Voltage Supervisor (SVS)

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

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

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## Digital I/O

There are up to six 8-bit I/O ports implemented—ports P1 through P6:

- 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.

## Hardware Multiplier

The multiplication operation is supported by a dedicated peripheral module. The module performs 16x16, 16x8, 8x16, and 8x8 bit operations. The module is capable of supporting signed and unsigned multiplication as well as signed and unsigned multiply and accumulate operations. The result of an operation can be accessed immediately after the operands have been loaded into the peripheral registers. No additional clock cycles are required.

## 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 16. Timer_A3 Signal Connections**

| INPUT PIN NUMBER | DEVICE INPUT SIGNAL | MODULE INPUT NAME | MODULE BLOCK | MODULE OUTPUT SIGNAL | OUTPUT PIN NUMBER |
|---|---|---|---|---|---|
| 12 - P1.0 | TACLK | TACLK | Timer | NA | |
| | ACLK | ACLK | | | |
| | SMCLK | SMCLK | | | |
| 21 - P2.1 | TAINCLK | INCLK | | | |
| 13 - P1.1 | TA0 | CCI0A | CCR0 | TA0 | 13 - P1.1 |
| 22 - P2.2 | TA0 | CCI0B | | | 17 - P1.5 |
| | $DV_{SS}$ | GND | | | 27 - P2.7 |
| | $DV_{CC}$ | $V_{CC}$ | | | |
| 14 - P1.2 | TA1 | CCI1A | CCR1 | TA1 | 14 - P1.2 |
| | CAOUT (internal) | CCI1B | | | 18 - P1.6 |
| | $DV_{SS}$ | GND | | | 23 - P2.3 |
| | $DV_{CC}$ | $V_{CC}$ | | | ADC12(1) (internal) |
| 15 - P1.3 | TA2 | CCI2A | CCR2 | TA2 | 15 - P1.3 |
| | ACLK (internal) | CCI2B | | | 19 - P1.7 |
| | $DV_{SS}$ | GND | | | 24 - P2.4 |
| | $DV_{CC}$ | $V_{CC}$ | | | |

(1) Not available in the MSP430F24x1 devices.


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## Timer_B7 (MSP430F24x(1) and MSP430F2410 Devices)

Timer_B7 is a 16-bit timer/counter with seven capture/compare registers. Timer_B7 can support multiple capture/compares, PWM outputs, and interval timing. Timer_B7 also has extensive interrupt capabilities. Interrupts may be generated from the counter on overflow conditions and from each of the capture/compare registers.

**Table 17. Timer_B7 Signal Connections**

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

(1) Not available in the MSP430F24x1 devices.
(2) Not available in the MSP430F24x1 devices.

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### Timer_B3 (MSP430F23x Devices)

Timer_B3 is a 16-bit timer/counter with three capture/compare registers. Timer_B3 can support multiple capture/compares, PWM outputs, and interval timing. Timer_B3 also has extensive interrupt capabilities. Interrupts may be generated from the counter on overflow conditions and from each of the capture/compare registers.

**Table 18. Timer_B3 Signal Connections**

| INPUT PIN NUMBER | DEVICE INPUT SIGNAL | MODULE INPUT NAME | MODULE BLOCK | MODULE OUTPUT SIGNAL | OUTPUT PIN NUMBER |
|---|---|---|---|---|---|
| 43 - P4.7 | TBCLK | TBCLK | Timer | NA | |
| | ACLK | ACLK | | | |
| | SMCLK | SMCLK | | | |
| 43 - P4.7 | TBCLK | INCLK | | | |
| 36 - P4.0 | TB0 | CCI0A | CCR0 | TB0 | 36 - P4.0 |
| 36 - P4.0 | TB0 | CCI0B | | | ADC12 (internal) |
| | $DV_{SS}$ | GND | | | |
| | $DV_{CC}$ | $V_{CC}$ | | | |
| 37 - P4.1 | TB1 | CCI1A | CCR1 | TB1 | 37 - P4.1 |
| 37 - P4.1 | TB1 | CCI1B | | | ADC12 (internal) |
| | $DV_{SS}$ | GND | | | |
| | $DV_{CC}$ | $V_{CC}$ | | | |
| 38 - P4.2 | TB2 | CCI2A | CCR2 | TB2 | 38 - P4.2 |
| 38 - P4.2 | TB2 | CCI2B | | | |
| | $DV_{SS}$ | GND | | | |
| | $DV_{CC}$ | $V_{CC}$ | | | |

### Universal Serial Communications Interface (USCI)

The USCI modules are used for serial data communication. The USCI module supports synchronous communication protocols, such as SPI (3 or 4 pin) or $I^2C$, and asynchronous combination protocols, such as UART, enhanced UART with automatic baudrate detection (LIN), and IrDA.

The USCI A module provides support for SPI (3 or 4 pin), UART, enhanced UART, and IrDA.

The USCI B module provides support for SPI (3 or 4 pin) and $I^2C$.

### 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.

### ADC12 (MSP430F23x, MSP430F24x, and MSP430F2410 Devices)

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


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## Peripheral File Map

**Table 19. Peripheral File Map**

| MODULE | REGISTER NAME | SHORT FORM | ADDRESS |
|---|---|---|---|
| **ADC12** (MSP430F24x, MSP430F2410, and MSP430F23x) | Interrupt-vector-word register | ADC12IV | 0x01A8 |
| | Interrupt-enable register | ADC12IE | 0x01A6 |
| | Interrupt-flag register | ADC12IFG | 0x01A4 |
| | Control register 1 | ADC12CTL1 | 0x01A2 |
| | Control register 0 | ADC12CTL0 | 0x01A0 |
| | Conversion memory 15 | ADC12MEM15 | 0x015E |
| | Conversion memory 14 | ADC12MEM14 | 0x015C |
| | Conversion memory 13 | ADC12MEM13 | 0x015A |
| | Conversion memory 12 | ADC12MEM12 | 0x0158 |
| | Conversion memory 11 | ADC12MEM11 | 0x0156 |
| | Conversion memory 10 | ADC12MEM10 | 0x0154 |
| | Conversion memory 9 | ADC12MEM9 | 0x0152 |
| | Conversion memory 8 | ADC12MEM8 | 0x0150 |
| | Conversion memory 7 | ADC12MEM7 | 0x014E |
| | Conversion memory 6 | ADC12MEM6 | 0x014C |
| | Conversion memory 5 | ADC12MEM5 | 0x014A |
| | Conversion memory 4 | ADC12MEM4 | 0x0148 |
| | Conversion memory 3 | ADC12MEM3 | 0x0146 |
| | Conversion memory 2 | ADC12MEM2 | 0x0144 |
| | Conversion memory 1 | ADC12MEM1 | 0x0142 |
| | Conversion memory 0 | ADC12MEM0 | 0x0140 |
| | ADC memory-control register15 | ADC12MCTL15 | 0x008F |
| | ADC memory-control register14 | ADC12MCTL14 | 0x008E |
| | ADC memory-control register13 | ADC12MCTL13 | 0x008D |
| | ADC memory-control register12 | ADC12MCTL12 | 0x008C |
| | ADC memory-control register11 | ADC12MCTL11 | 0x008B |
| | ADC memory-control register10 | ADC12MCTL10 | 0x008A |
| | ADC memory-control register9 | ADC12MCTL9 | 0x0089 |
| | ADC memory-control register8 | ADC12MCTL8 | 0x0088 |
| | ADC memory-control register7 | ADC12MCTL7 | 0x0087 |
| | ADC memory-control register6 | ADC12MCTL6 | 0x0086 |
| | ADC memory-control register5 | ADC12MCTL5 | 0x0085 |
| | ADC memory-control register4 | ADC12MCTL4 | 0x0084 |
| | ADC memory-control register3 | ADC12MCTL3 | 0x0083 |
| | ADC memory-control register2 | ADC12MCTL2 | 0x0082 |
| | ADC memory-control register1 | ADC12MCTL1 | 0x0081 |
| | ADC memory-control register0 | ADC12MCTL0 | 0x0080 |

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**Table 19. Peripheral File Map (continued)**

| MODULE | REGISTER NAME | SHORT FORM | ADDRESS |
|---|---|---|---|
| **Timer_B7** (MSP430F24x(1) and MSP430F2410) | Capture/compare register 6 | TBCCR6 | 0x019E |
| | Capture/compare register 5 | TBCCR5 | 0x019C |
| | Capture/compare register 4 | TBCCR4 | 0x019A |
| | Capture/compare register 3 | TBCCR3 | 0x0198 |
| | Capture/compare register 2 | TBCCR2 | 0x0196 |
| | Capture/compare register 1 | TBCCR1 | 0x0194 |
| | Capture/compare register 0 | TBCCR0 | 0x0192 |
| | Timer_B register | TBR | 0x0190 |
| | Capture/compare control 6 | TBCCTL6 | 0x018E |
| | Capture/compare control 5 | TBCCTL5 | 0x018C |
| | Capture/compare control 4 | TBCCTL4 | 0x018A |
| | Capture/compare control 3 | TBCCTL3 | 0x0188 |
| | Capture/compare control 2 | TBCCTL2 | 0x0186 |
| | Capture/compare control 1 | TBCCTL1 | 0x0184 |
| | Capture/compare control 0 | TBCCTL0 | 0x0182 |
| | Timer_B control | TBCTL | 0x0180 |
| | Timer_B interrupt vector | TBIV | 0x011E |
| **Timer_B3** (MSP430F23x) | Capture/compare register 2 | TBCCR2 | 0x0196 |
| | Capture/compare register 1 | TBCCR1 | 0x0194 |
| | Capture/compare register 0 | TBCCR0 | 0x0192 |
| | Timer_B register | TBR | 0x0190 |
| | Capture/compare control 2 | TBCCTL2 | 0x0186 |
| | Capture/compare control 1 | TBCCTL1 | 0x0184 |
| | Capture/compare control 0 | TBCCTL0 | 0x0182 |
| | Timer_B control | TBCTL | 0x0180 |
| | Timer_B interrupt vector | TBIV | 0x011E |
| **Timer_A3** | Capture/compare register 2 | TACCR2 | 0x0176 |
| | Capture/compare register 1 | TACCR1 | 0x0174 |
| | Capture/compare register 0 | TACCR0 | 0x0172 |
| | Timer_A register | TAR | 0x0170 |
| | Reserved | | 0x016E |
| | Reserved | | 0x016C |
| | Reserved | | 0x016A |
| | Reserved | | 0x0168 |
| | Capture/compare control 2 | TACCTL2 | 0x0166 |
| | Capture/compare control 1 | TACCTL1 | 0x0164 |
| | Capture/compare control 0 | TACCTL0 | 0x0162 |
| | Timer_A control | TACTL | 0x0160 |
| | Timer_A interrupt vector | TAIV | 0x012E |
| **Hardware Multiplier** | Sum extend | SUMEXT | 0x013E |
| | Result high word | RESHI | 0x013C |
| | Result low word | RESLO | 0x013A |
| | Second operand | OP2 | 0x0138 |
| | Multiply signed + accumulate/operand1 | MACS | 0x0136 |
| | Multiply + accumulate/operand1 | MAC | 0x0134 |
| | Multiply signed/operand1 | MPYS | 0x0132 |
| | Multiply unsigned/operand1 | MPY | 0x0130 |


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**Table 19. Peripheral File Map (continued)**

| MODULE | REGISTER NAME | SHORT FORM | ADDRESS |
|---|---|---|---|
| **Flash** | Flash control 4 | FCTL4 | 0x01BE |
| | Flash control 3 | FCTL3 | 0x012C |
| | Flash control 2 | FCTL2 | 0x012A |
| | Flash control 1 | FCTL1 | 0x0128 |
| **Watchdog** | Watchdog Timer control | WDTCTL | 0x0120 |
| **USCI A0/B0** | USCI A0 auto baud rate control | UCA0ABCTL | 0x005D |
| | USCI A0 transmit buffer | UCA0TXBUF | 0x0067 |
| | USCI A0 receive buffer | UCA0RXBUF | 0x0066 |
| | USCI A0 status | UCA0STAT | 0x0065 |
| | USCI A0 modulation control | UCA0MCTL | 0x0064 |
| | USCI A0 baud rate control 1 | UCA0BR1 | 0x0063 |
| | USCI A0 baud rate control 0 | UCA0BR0 | 0x0062 |
| | USCI A0 control 1 | UCA0CTL1 | 0x0061 |
| | USCI A0 control 0 | UCA0CTL0 | 0x0060 |
| | USCI A0 IrDA receive control | UCA0IRRCTL | 0x005F |
| | USCI A0 IrDA transmit control | UCA0IRTCLT | 0x005E |
| | USCI B0 transmit buffer | UCB0TXBUF | 0x006F |
| | USCI B0 receive buffer | UCB0RXBUF | 0x006E |
| | USCI B0 status | UCB0STAT | 0x006D |
| | USCI B0 I2C Interrupt enable | UCB0CIE | 0x006C |
| | USCI B0 baud rate control 1 | UCB0BR1 | 0x006B |
| | USCI B0 baud rate control 0 | UCB0BR0 | 0x006A |
| | USCI B0 control 1 | UCB0CTL1 | 0x0069 |
| | USCI B0 control 0 | UCB0CTL0 | 0x0068 |
| | USCI B0 I2C slave address | UCB0SA | 0x011A |
| | USCI B0 I2C own address | UCB0OA | 0x0118 |

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**Table 19. Peripheral File Map (continued)**

| MODULE | REGISTER NAME | SHORT FORM | ADDRESS |
|---|---|---|---|
| **USCI A1/B1** (MSP430F24x(1) and MSP430F2410) | USCI A1 auto baud rate control | UCA1ABCTL | 0x00CD |
| | USCI A1 transmit buffer | UCA1TXBUF | 0x00D7 |
| | USCI A1 receive buffer | UCA1RXBUF | 0x00D6 |
| | USCI A1 status | UCA1STAT | 0x00D5 |
| | USCI A1 modulation control | UCA1MCTL | 0x00D4 |
| | USCI A1 baud rate control 1 | UCA1BR1 | 0x00D3 |
| | USCI A1 baud rate control 0 | UCA1BR0 | 0x00D2 |
| | USCI A1 control 1 | UCA1CTL1 | 0x00D1 |
| | USCI A1 control 0 | UCA1CTL0 | 0x00D0 |
| | USCI A1 IrDA receive control | UCA1IRRCTL | 0x00CF |
| | USCI A1 IrDA transmit control | UCA1IRTCLT | 0x00CE |
| | USCI B1 transmit buffer | UCB1TXBUF | 0x00DF |
| | USCI B1 receive buffer | UCB1RXBUF | 0x00DE |
| | USCI B1 status | UCB1STAT | 0x00DD |
| | USCI B1 I2C Interrupt enable | UCB1CIE | 0x00DC |
| | USCI B1 baud rate control 1 | UCB1BR1 | 0x00DB |
| | USCI B1 baud rate control 0 | UCB1BR0 | 0x00DA |
| | USCI B1 control 1 | UCB1CTL1 | 0x00D9 |
| | USCI B1 control 0 | UCB1CTL0 | 0x00D8 |
| | USCI B1 I2C slave address | UCB1SA | 0x017E |
| | USCI B1 I2C own address | UCB1OA | 0x017C |
| | USCI A1/B1 interrupt enable | UC1IE | 0x0006 |
| | USCI A1/B1 interrupt flag | UC1IFG | 0x0007 |
| **Comparator_A+** | Comparator_A port disable | CAPD | 0x005B |
| | Comparator_A control2 | CACTL2 | 0x005A |
| | Comparator_A control1 | CACTL1 | 0x0059 |
| **Basic Clock** | Basic clock system control3 | BCSCTL3 | 0x0053 |
| | Basic clock system control2 | BCSCTL2 | 0x0058 |
| | Basic clock system control1 | BCSCTL1 | 0x0057 |
| | DCO clock frequency control | DCOCTL | 0x0056 |
| **Brownout, SVS** | SVS control register (reset by brownout signal) | SVSCTL | 0x0055 |
| **Port P6** | Port P6 resistor enable | P6REN | 0x0013 |
| | Port P6 selection | P6SEL | 0x0037 |
| | Port P6 direction | P6DIR | 0x0036 |
| | Port P6 output | P6OUT | 0x0035 |
| | Port P6 input | P6IN | 0x0034 |
| **Port P5** | Port P5 resistor enable | P5REN | 0x0012 |
| | Port P5 selection | P5SEL | 0x0033 |
| | Port P5 direction | P5DIR | 0x0032 |
| | Port P5 output | P5OUT | 0x0031 |
| | Port P5 input | P5IN | 0x0030 |
| **Port P4** | Port P4 resistor enable | P4REN | 0x0011 |
| | Port P4 selection | P4SEL | 0x001F |
| | Port P4 direction | P4DIR | 0x001E |
| | Port P4 output | P4OUT | 0x001D |
| | Port P4 input | P4IN | 0x001C |


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**Table 19. Peripheral File Map (continued)**

| MODULE | REGISTER NAME | SHORT FORM | ADDRESS |
|---|---|---|---|
| **Port P3** | Port P3 resistor enable | P3REN | 0x0010 |
| | Port P3 selection | P3SEL | 0x001B |
| | Port P3 direction | P3DIR | 0x001A |
| | Port P3 output | P3OUT | 0x0019 |
| | Port P3 input | P3IN | 0x0018 |
| **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 Functions** | SFR interrupt flag2 | IFG2 | 0x0003 |
| | SFR interrupt flag1 | IFG1 | 0x0002 |
| | SFR interrupt enable2 | IE2 | 0x0001 |
| | SFR interrupt enable1 | IE1 | 0x0000 |

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## Absolute Maximum Ratings(1)

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

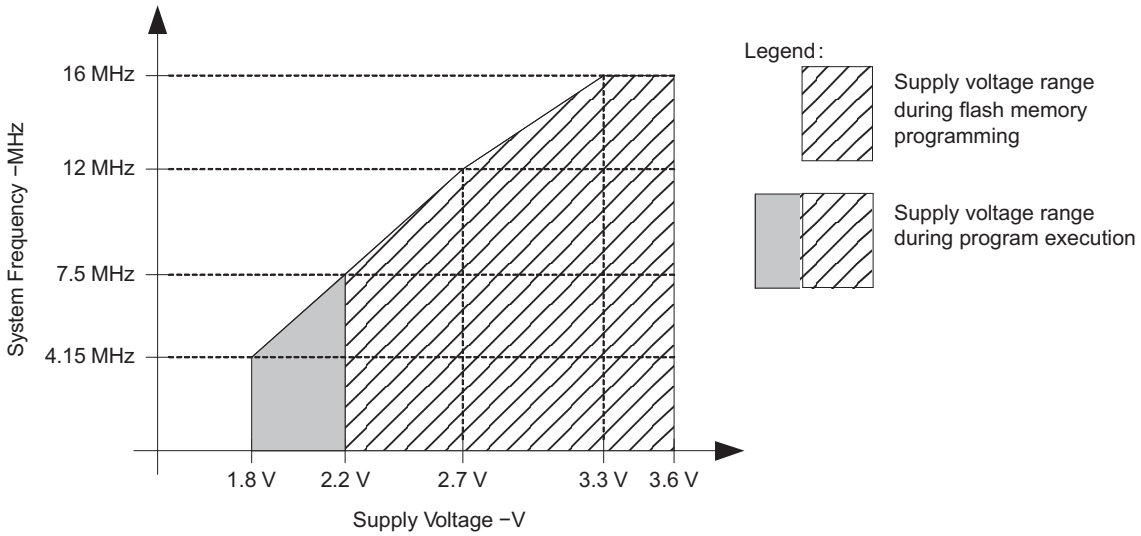
(1) Stresses beyond those listed under *absolute maximum ratings*may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *recommended operating conditions*is not implied. Exposure to 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(1)(2)

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

| | | | | MIN | NOM | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $V_{CC}$ | Supply voltage(3) | $AV_{CC} = DV_{CC} = V_{CC}$ | During program execution | 1.8 | | 3.6 | V |
| | | | During program or erase flash memory | 2.2 | | 3.6 | V |
| $V_{SS}$ | 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)(1)(2) (see Figure 1) | $V_{CC}$ = 1.8 V, Duty cycle = 50% ± 10% | | dc | | 4.15 | MHz |
| | | $V_{CC}$ = 2.7 V, Duty cycle = 50% ± 10% | | dc | | 12 | |
| | | $V_{CC}$ ≥ 3.3 V, Duty cycle = 50% ± 10% | | dc | | 16 | |

(1) The MSP430 CPU is clocked directly with MCLK. Both the high and low phase of MCLK must not exceed the pulse duration of the specified maximum frequency.
(2) Modules might have a different maximum input clock specification. See the specification of the respective module in this data sheet.
(3) It is recommended to power $AV_{CC}$ and $DV_{CC}$ from the same source. A maximum difference of 0.3 V between $AV_{CC}$ and $DV_{CC}$ can be tolerated during power-up.




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**


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## Active Mode Supply Current (Into $DV_{CC}$ and $AV_{CC}$) Excluding External Current[1][2]

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 |
|---|---|---|---|---|---|---|---|---|
| $I_{AM,1MHz}$ | Active mode (AM) current (1 MHz) | $f_{DCO} = f_{MCLK} = f_{SMCLK}$ = 1 MHz, $f_{ACLK}$ = 32768 Hz, Program executes in flash, BCSCTL1 = CALBC1_1MHZ, DCOCTL = CALDCO_1MHZ, CPUOFF = 0, SCG0 = 0, SCG1 = 0, OSCOFF = 0 | -40°C to 85°C | 2.2 V | | 275 | 312 | µA |
| | | | 105°C | | | 295 | 318 | |
| | | | -40°C to 85°C | 3 V | | 386 | 445 | |
| | | | 105°C | | | 417 | 449 | |
| $I_{AM,1MHz}$ | Active mode (AM) current (1 MHz) | $f_{DCO} = f_{MCLK} = f_{SMCLK}$ = 1 MHz, $f_{ACLK}$ = 32768 Hz, Program executes in RAM, BCSCTL1 = CALBC1_1MHZ, DCOCTL = CALDCO_1MHZ, CPUOFF = 0, SCG0 = 0, SCG1 = 0, OSCOFF = 0 | -40°C to 85°C | 2.2 V | | 230 | 261 | µA |
| | | | 105°C | | | 248 | 267 | |
| | | | -40°C to 85°C | 3.3 V | | 321 | 366 | |
| | | | 105°C | | | 344 | 370 | |
| $I_{AM,4kHz}$ | Active mode (AM) current (4 kHz) | $f_{MCLK} = f_{SMCLK} = f_{ACLK}$ = 32768 Hz/8 = 4096 Hz, $f_{DCO}$ = 0 Hz, Program executes in flash, SELMx = 11, SELS = 1, DIVMx = DIVSx = DIVAx = 11, CPUOFF = 0, SCG0 = 1, SCG1 = 0, OSCOFF = 0 | -40°C to 85°C | 2.2 V | | 1.5 | 3.8 | µA |
| | | | 105°C | | | 6 | 10.5 | |
| | | | -40°C to 85°C | 3 V | | 2 | 4.7 | |
| | | | 105°C | | | 7 | 12.2 | |
| $I_{AM,100kHz}$ | Active mode (AM) current (100 kHz) | $f_{MCLK} = f_{SMCLK} = f_{DCO(0, 0)} \approx$ 100 kHz, $f_{ACLK}$ = 0 Hz, Program executes in flash, RSELx = 0, DCOx = 0, CPUOFF = 0, SCG0 = 0, SCG1 = 0, OSCOFF = 1 | -40°C to 85°C | 2.2 V | | 55 | 72 | µA |
| | | | 105°C | | | 70 | 81 | |
| | | | -40°C to 85°C | 3 V | | 67 | 89 | |
| | | | 105°C | | | 84 | 100 | |

(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.

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## Typical Characteristics - Active-Mode Supply Current (Into $DV_{CC}$ and $AV_{CC}$ )

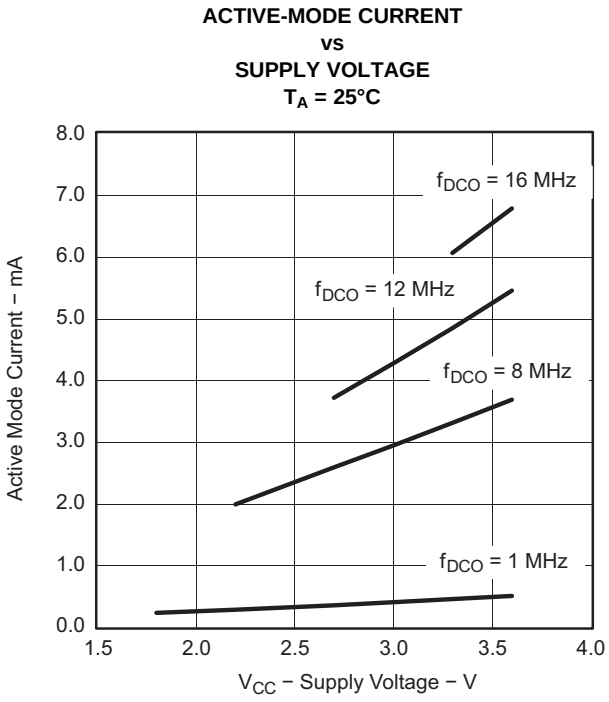



**Figure 2.**

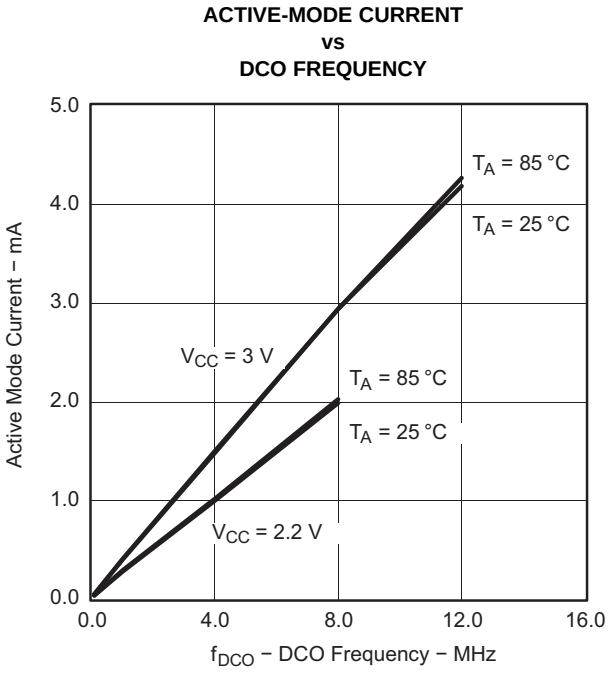



**Figure 3.**


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## Low-Power-Mode Supply Currents (Into $V_{CC}$) Excluding External Current[1][2]

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[3] | $f_{MCLK}$ = 0 MHz, $f_{SMCLK} = f_{DCO}$ = 1 MHz, $f_{ACLK}$ = 32768 Hz, BCSCTL1 = CALBC1_1MHZ, DCOCTL = CALDCO_1MHZ, CPUOFF = 1, SCG0 = 0, SCG1 = 0, OSCOFF = 0 | -40°C to 85°C | 2.2 V | | 60 | 65 | µA |
| | | | 105°C | | | 63 | 72 | |
| | | | -40°C to 85°C | 3 V | | 75 | 90 | |
| | | | 105°C | | | 80 | 95 | |
| $I_{LPM0,100kHz}$ | Low-power mode 0 (LPM0) current[3] | $f_{MCLK}$ = 0 MHz, $f_{SMCLK} = f_{DCO(0,\ 0)} \approx$ 100 kHz, $f_{ACLK}$ = 0 Hz, RSELx = 0, DCOx = 0, CPUOFF = 1, SCG0 = 0, SCG1 = 0, OSCOFF = 1 | -40°C to 85°C | 2.2 V | | 33 | 38 | µA |
| | | | 105°C | | | 36 | 43 | |
| | | | -40°C to 85°C | 3 V | | 36 | 42 | |
| | | | 105°C | | | 40 | 47 | |
| $I_{LPM2}$ | Low-power mode 2 (LPM2) current[4] | $f_{MCLK} = f_{SMCLK}$ = 0 MHz, $f_{DCO}$ = 1 MHz, $f_{ACLK}$ = 32768 Hz, BCSCTL1 = CALBC1_1MHZ, DCOCTL = CALDCO_1MHZ, CPUOFF = 1, SCG0 = 0, SCG1 = 1, OSCOFF = 0 | -40°C to 85°C | 2.2 V | | 20 | 25 | µA |
| | | | 105°C | | | 25 | 30 | |
| | | | -40°C to 85°C | 3 V | | 23 | 30 | |
| | | | 105°C | | | 28 | 35 | |
| $I_{LPM3,LFXT1}$ | Low-power mode 3 (LPM3) current[4] | $f_{DCO} = f_{MCLK} = f_{SMCLK}$ = 0 MHz, $f_{ACLK}$ = 32768 Hz, CPUOFF = 1, SCG0 = 1, SCG1 = 1, OSCOFF = 0 | -40°C | 2.2 V | | 0.8 | 1.2 | µA |
| | | | 25°C | | | 0.9 | 1.3 | |
| | | | 85°C | | | 2.4 | 3 | |
| | | | 105°C | | | 6 | 13 | |
| | | | -40°C | 3 V | | 0.9 | 1.3 | |
| | | | 25°C | | | 1 | 1.4 | |
| | | | 85°C | | | 3.9 | 4.3 | |
| | | | 105°C | | | 10 | 15 | |
| $I_{LPM3,VLO}$ | Low-power mode 3 current, (LPM3)[4] | $f_{DCO} = f_{MCLK} = f_{SMCLK}$ = 0 MHz, $f_{ACLK}$ from internal LF oscillator (VLO), CPUOFF = 1, SCG0 = 1, SCG1 = 1, OSCOFF = 0 | -40°C | 2.2 V | | 0.3 | 0.9 | µA |
| | | | 25°C | | | 0.3 | 0.9 | |
| | | | 85°C | | | 1.8 | 2.4 | |
| | | | 105°C | | | 5.5 | 13 | |
| | | | -40°C | 3 V | | 0.4 | 1 | |
| | | | 25°C | | | 0.4 | 1 | |
| | | | 85°C | | | 2 | 3 | |
| | | | 105°C | | | 9 | 15 | |
| $I_{LPM4}$ | Low-power mode 4 (LPM4) current[5] | $f_{DCO} = f_{MCLK} = f_{SMCLK}$ = 0 MHz, $f_{ACLK}$ = 0 Hz, CPUOFF = 1, SCG0 = 1, SCG1 = 1, OSCOFF = 1 | -40°C | 2.2 V, 3 V | | 0.1 | 0.5 | µA |
| | | | 25°C | | | 0.1 | 0.5 | |
| | | | 85°C | | | 1.6 | 2.5 | |
| | | | 105°C | | | 6.5 | 13 | |

(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+ is included. The WDT+ is clocked by SMCLK.
(4) Current for Brownout and WDT+ is included. The WDT+ is clocked by ACLK.
(5) Current for Brownout is included.

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## Typical Characteristics - LPM4 Current

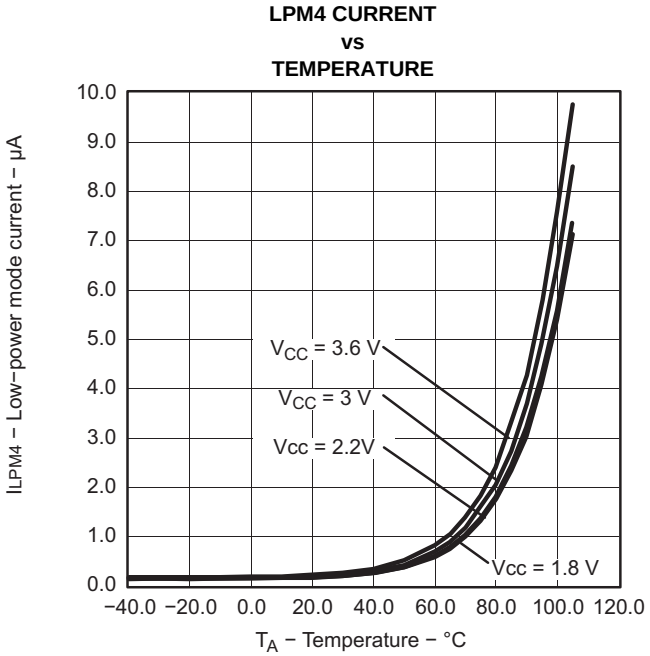



**Figure 4.**


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## Schmitt-Trigger Inputs (Ports P1, P2, P3, P4, P5, P6, $\overline{RST}$/NMI, JTAG, XIN, XT2IN)

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

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

## Inputs (Ports P1, P2)

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

| PARAMETER | | TEST CONDITIONS | $V_{CC}$ | MIN | MAX | UNIT |
|---|---|---|---|---|---|---|
| $t_{(int)}$ | External interrupt timing | Port P1, P2: P1.x to P2.x, External trigger pulse width to set interrupt flag(1) | 2.2 V, 3 V | 20 | | ns |
| $t_{cap}$ | Timer_A Timer_B capture timing | TA0, TA1, TA2 | 2.2 V | 62 | | ns |
| | | TB0, TB1, TB2, TB3, TB4, TB5, TB6 | 3 V | 50 | | |
| $f_{TAext}$, $f_{TBext}$ | Timer_A, Timer_B clock frequency externally applied to pin | TACLK, TBCLK, INCLK: $t_{(H)} = t_{(L)}$ | 2.2 V | | 8 | MHz |
| | | | 3 V | | 10 | |
| $f_{TAint}$, $f_{TBint}$ | Timer_A, Timer_B clock frequency | SMCLK or ACLK signal selected | 2.2 V | | 8 | MHz |
| | | | 3 V | | 10 | |

(1) An external signal sets the interrupt flag every time the minimum interrupt pulse width $t_{(int)}$ is met. It may be set even with trigger signals shorter than $t_{(int)}$ .

## Leakage Current (Ports P1, P2, P3, P4, P5, P6)

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

| PARAMETER | | TEST CONDITIONS | $V_{CC}$ | MIN | MAX | UNIT |
|---|---|---|---|---|---|---|
| $I_{lkg(Px.y)}$ | High-impedance leakage current | See (1) (2) | 2.2 V, 3 V | | ±50 | nA |

(1) The leakage current is measured with $V_{SS}$ or $V_{CC}$ applied to the corresponding pins, unless otherwise noted.
(2) The leakage of the digital port pins is measured individually. The port pin is selected for input and the pullup/pulldown resistor is disabled.

## Standard Inputs ($\overline{RST}$/NMI)

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

| PARAMETER | | TEST CONDITIONS | $V_{CC}$ | MIN | MAX | UNIT |
|---|---|---|---|---|---|---|
| $V_{IL}$ | Low-level input voltage | | 2.2 V, 3 V | $V_{SS}$ | $V_{SS}$ + 0.6 | V |
| $V_{IH}$ | High-level input voltage | | 2.2 V, 3 V | 0.8 $V_{CC}$ | $V_{CC}$ | V |

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## Outputs (Ports P1, P2, P3, P4, P5, P6)

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

| PARAMETER | | TEST CONDITIONS | $V_{CC}$ | MIN | MAX | UNIT |
|---|---|---|---|---|---|---|
| $V_{OH}$ | High-level output voltage | $I_{OH(max)}$ = -1.5 mA (1) | 2.2 V | $V_{CC}$ - 0.25 | $V_{CC}$ | V |
| | | $I_{OH(max)}$ = -6 mA (2) | | $V_{CC}$ - 0.6 | $V_{CC}$ | |
| | | $I_{OH(max)}$ = -1.5 mA(1) | 3 V | $V_{CC}$ - 0.25 | $V_{CC}$ | |
| | | $I_{OH(max)}$ = -6 mA(2) | | $V_{CC}$ - 0.6 | $V_{CC}$ | |
| $V_{OL}$ | Low-level output voltage | $I_{OL(max)}$ = 1.5 mA(1) | 2.2 V | $V_{SS}$ | $V_{SS}$ + 0.25 | V |
| | | $I_{OL(max)}$ = 6 mA(2) | | $V_{SS}$ | $V_{SS}$ + 0.6 | |
| | | $I_{OL(max)}$ = 1.5 mA(1) | 3 V | $V_{SS}$ | $V_{SS}$ + 0.25 | |
| | | $I_{OL(max)}$ = 6 mA(2) | | $V_{SS}$ | $V_{SS}$ + 0.6 | |

(1) The maximum total current, $I_{OH(max)}$ and $I_{OL(max)}$, for all outputs combined, should not exceed ±12 mA to hold the maximum voltage drop specified.
(2) The maximum total current, $I_{OH(max)}$ and $I_{OL(max)}$, for all outputs combined, should not exceed ±48 mA to hold the maximum voltage drop specified.

## Output Frequency (Ports P1, P2, P3, P4, P5, P6)

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

| PARAMETER | | TEST CONDITIONS | $V_{CC}$ | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $f_{Px.y}$ | Port output frequency with load | P1.4/SMCLK, $C_L$ = 20 pF, $R_L$ = 1 kΩ(1)(2) | 2.2 V | DC | | 10 | MHz |
| | | | 3 V | DC | | 12 | |
| $f_{Port°CLK}$ | Clock output frequency | P2.0/ACLK/CA2, P1.4/SMCLK, $C_L$ = 20 pF(2) | 2.2 V | DC | | 12 | MHz |
| | | | 3 V | DC | | 16 | |
| $t_{(Xdc)}$ | Duty cycle of output frequency | P1.0/TACLK/CAOUT, $C_L$ = 20 pF, LF mode | | 30% | 50% | 70% | |
| | | P1.0/TACLK/CAOUT, $C_L$ = 20 pF, XT1 mode | | 40% | 50% | 60% | |
| | | P1.1/TA0, $C_L$ = 20 pF, XT1 mode | | 40% | | 60% | |
| | | P1.1/TA0, $C_L$ = 20 pF, DCO | | 50% – 15 ns | 50% | 50% + 15 ns | |
| | | P1.4/SMCLK, $C_L$ = 20 pF, XT2 mode | | 40% | | 60% | |
| | | P1.4/SMCLK, $C_L$ = 20 pF, DCO | | 50% – 15 ns | | 50% + 15 ns | |

(1) A resistive divider with two 0.5-kΩ resistors between $V_{CC}$ and $V_{SS}$ 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% $V_{CC}$ at the specified toggle frequency.


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## Typical Characteristics - Outputs

One output loaded at a time.

**TYPICAL LOW-LEVEL OUTPUT CURRENT vs LOW-LEVEL OUTPUT VOLTAGE**

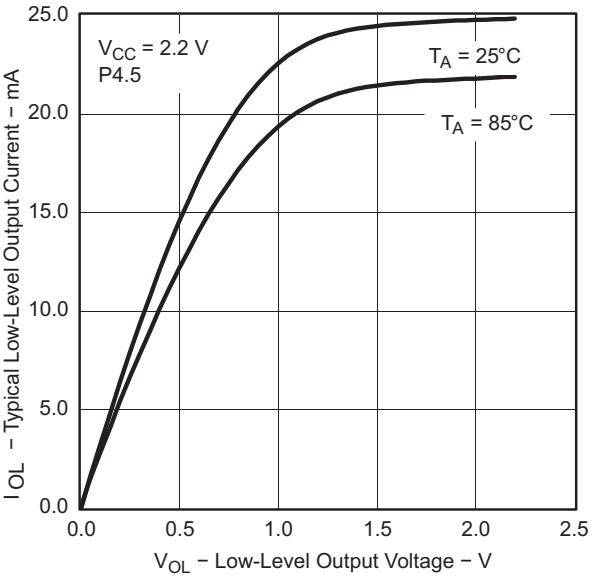



**Figure 5.**

**TYPICAL LOW-LEVEL OUTPUT CURRENT vs LOW-LEVEL OUTPUT VOLTAGE**

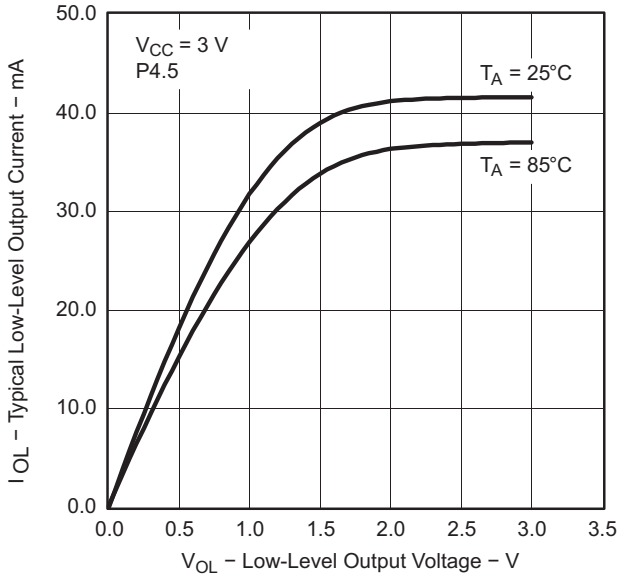



**Figure 6.**

**TYPICAL HIGH-LEVEL OUTPUT CURRENT vs HIGH-LEVEL OUTPUT VOLTAGE**

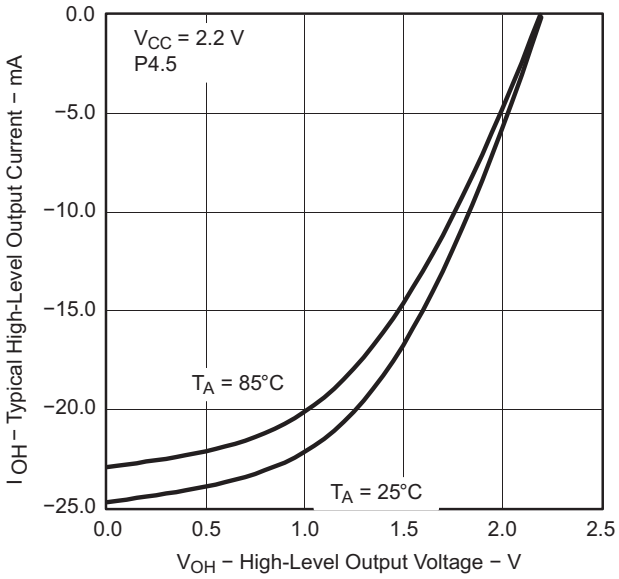



**Figure 7.**

**TYPICAL HIGH-LEVEL OUTPUT CURRENT vs HIGH-LEVEL OUTPUT VOLTAGE**

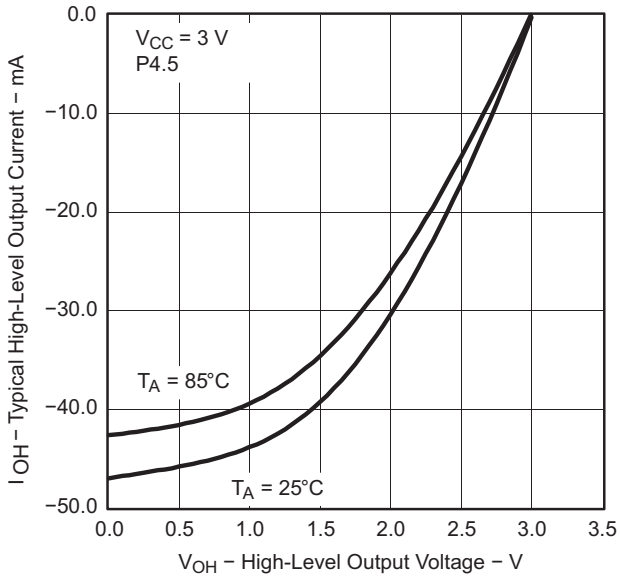



**Figure 8.**

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## POR and Brownout Reset (BOR)(1)(2)

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

| PARAMETER | | TEST CONDITIONS | $V_{CC}$ | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $V_{CC(start)}$ | Operating voltage | $dV_{CC}/dt \le 3$ V/s | | | | $0.7 \times V_{(B_IT-)}$ | V |
| $V_{(B_IT-)}$ | Negative going $V_{CC}$ reset threshold voltage | $dV_{CC}/dt \le 3$ V/s | | | | 1.71 | V |
| $V_{hys(B_IT-)}$ | $V_{CC}$ reset threshold hysteresis | $dV_{CC}/dt \le 3$ V/s | | 70 | 130 | 210 | mV |
| $t_{d(BOR)}$ | BOR reset release delay time | | | | | 2000 | µs |
| $t_{(reset)}$ | Pulse duration needed at $\overline{RST}$/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 $I_{CC}$ current consumption data. The voltage level $V_{(B_IT-)} + V_{hys(B_IT-)}$ is ≤ 1.8 V.

(2) During power up, the CPU begins code execution following a period of $t_{d(BOR)}$ after $V_{CC} = V_{(B_IT-)} + V_{hys(B_IT-)}$ . The default DCO settings must not be changed until $V_{CC} \ge V_{CC(min)}$, where $V_{CC(min)}$ is the minimum supply voltage for the desired operating frequency.

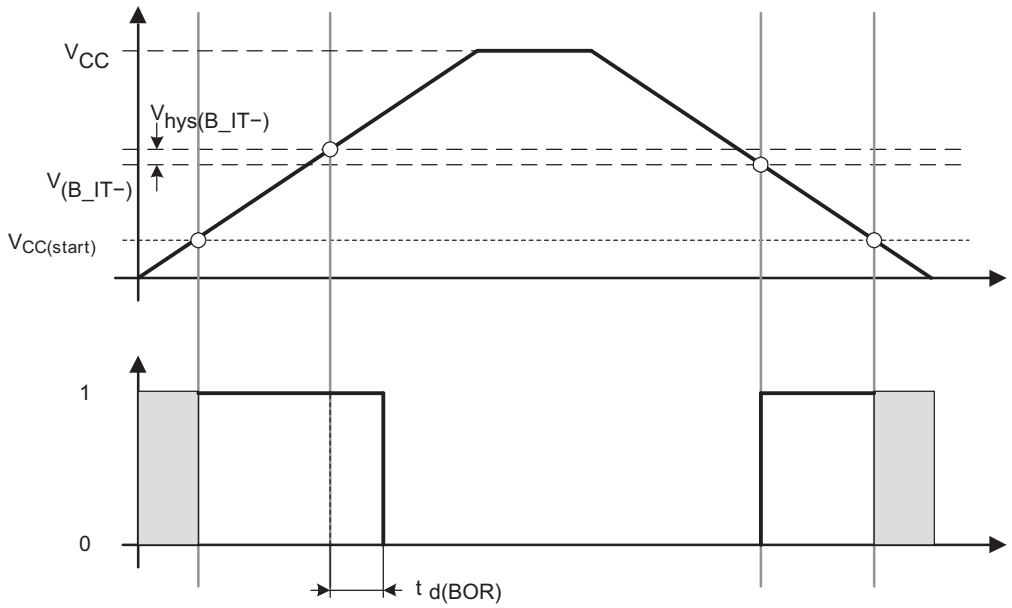



**Figure 9. POR/Brownout Reset (BOR) vs Supply Voltage**


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

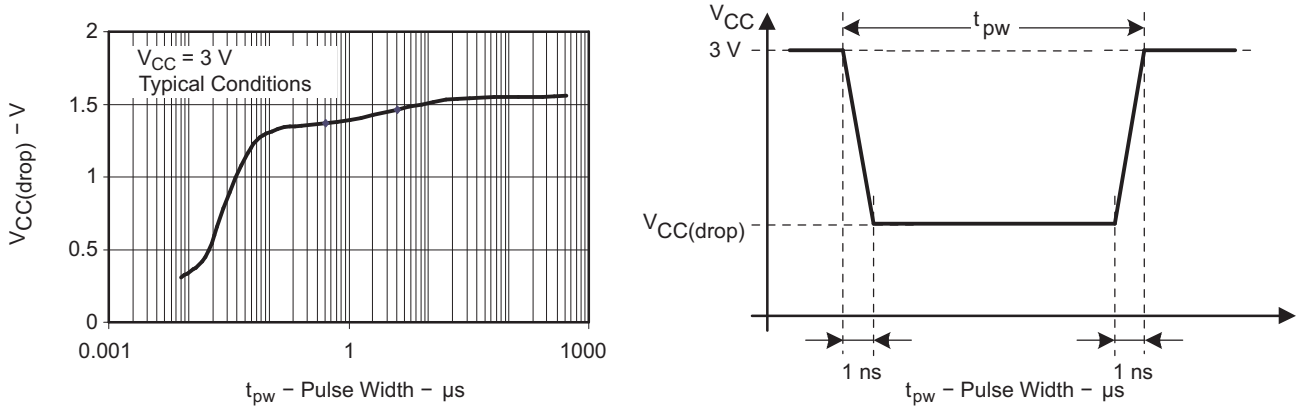



**Figure 10. $V_{CC(drop)}$ Level With a Square Voltage Drop to Generate a POR/Brownout Signal**

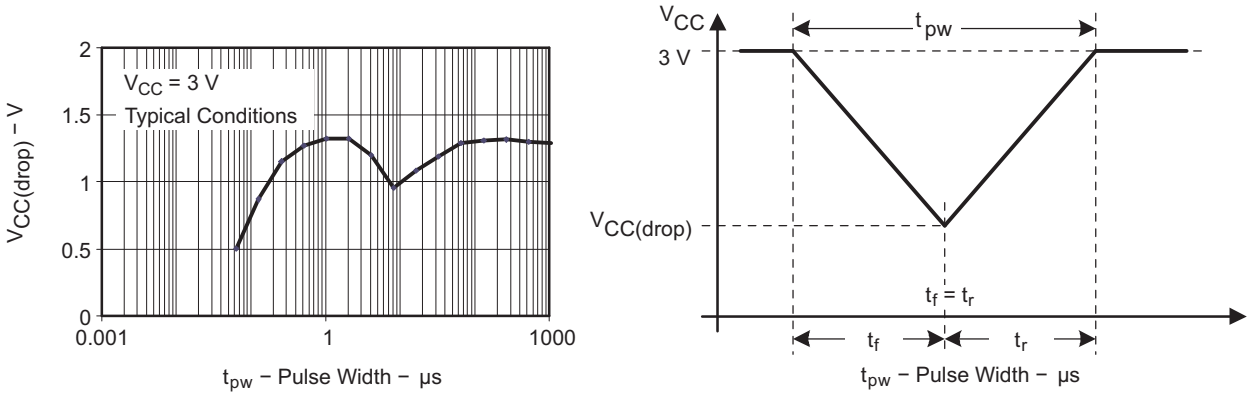



**Figure 11. $V_{CC(drop)}$ Level With a Triangle Voltage Drop to Generate a POR/Brownout Signal**

## SVS (Supply Voltage Supervisor and Supply Voltage Monitor)

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

| PARAMETER | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| $t_{(SVSR)}$ | $dV_{CC}/dt$ > 30 V/ms (see Figure 12) | | 1 | | 150 | µs |
| | $dV_{CC}/dt$ ≤ 30 V/ms | | | | 2000 | |
| $t_{d(SVSon)}$ | SVSon, switch from VLD = 0 to VLD ≠ 0, $V_{CC}$ = 3 V | | 150 | | 300 | µs |
| $t_{settle}$ | VLD ≠ 0 (1) | | | | 12 | µs |
| $V_{(SVSstart)}$ | VLD ≠ 0, $V_{CC}/dt$ ≤ 3 V/s (see Figure 12) | | | 1.55 | 1.7 | V |
| $V_{hys(SVS_IT-)}$ | $V_{CC}/dt$ ≤ 3 V/s (see Figure 12) | VLD = 1 | 70 | 120 | 155 | mV |
| | | VLD = 2 to 14 | 0.001 × $V_{(SVS_IT-)}$ | | 0.016 × $V_{(SVS_IT-)}$ | |
| | $V_{CC}/dt$ ≤ 3 V/s (see Figure 12), external voltage applied on A7 | VLD = 15 | 4.4 | | 20 | mV |
| $V_{(SVS_IT-)}$ | $V_{CC}/dt$ ≤ 3V/s (see Figure 12 and Figure 13) | VLD = 1 | 1.8 | 1.9 | 2.05 | V |
| | | VLD = 2 | 1.94 | 2.1 | 2.25 | |
| | | VLD = 3 | 2.05 | 2.2 | 2.37 | |
| | | VLD = 4 | 2.14 | 2.3 | 2.48 | |
| | | VLD = 5 | 2.24 | 2.4 | 2.6 | |
| | | VLD = 6 | 2.33 | 2.5 | 2.71 | |
| | | VLD = 7 | 2.46 | 2.65 | 2.86 | |
| | | VLD = 8 | 2.58 | 2.8 | 3 | |
| | | VLD = 9 | 2.69 | 2.9 | 3.13 | |
| | | VLD = 10 | 2.83 | 3.05 | 3.29 | |
| | | VLD = 11 | 2.94 | 3.2 | 3.42 | |
| | | VLD = 12 | 3.11 | 3.35 | 3.61 (2) | |
| | | VLD = 13 | 3.24 | 3.5 | 3.76 (2) | |
| | | VLD = 14 | 3.43 | 3.7 (2) | 3.99 (2) | |
| | $V_{CC}/dt$ ≤ 3 V/s (see Figure 12 and Figure 13), external voltage applied on A7 | VLD = 15 | 1.1 | 1.2 | 1.3 | |
| $I_{CC(SVS)}$ (3) | VLD ≠ 0, $V_{CC}$ = 2.2 V, 3 V | | | 10 | 15 | µA |

(1) $t_{settle}$ is the settling time that the comparator output needs to have a stable level after VLD is switched from VLD ≠ 0 to a different VLD value somewhere between 2 and 15. The overdrive is assumed to be > 50 mV.
(2) The recommended operating voltage range is limited to 3.6 V.
(3) The current consumption of the SVS module is not included in the $I_{CC}$ current consumption data.


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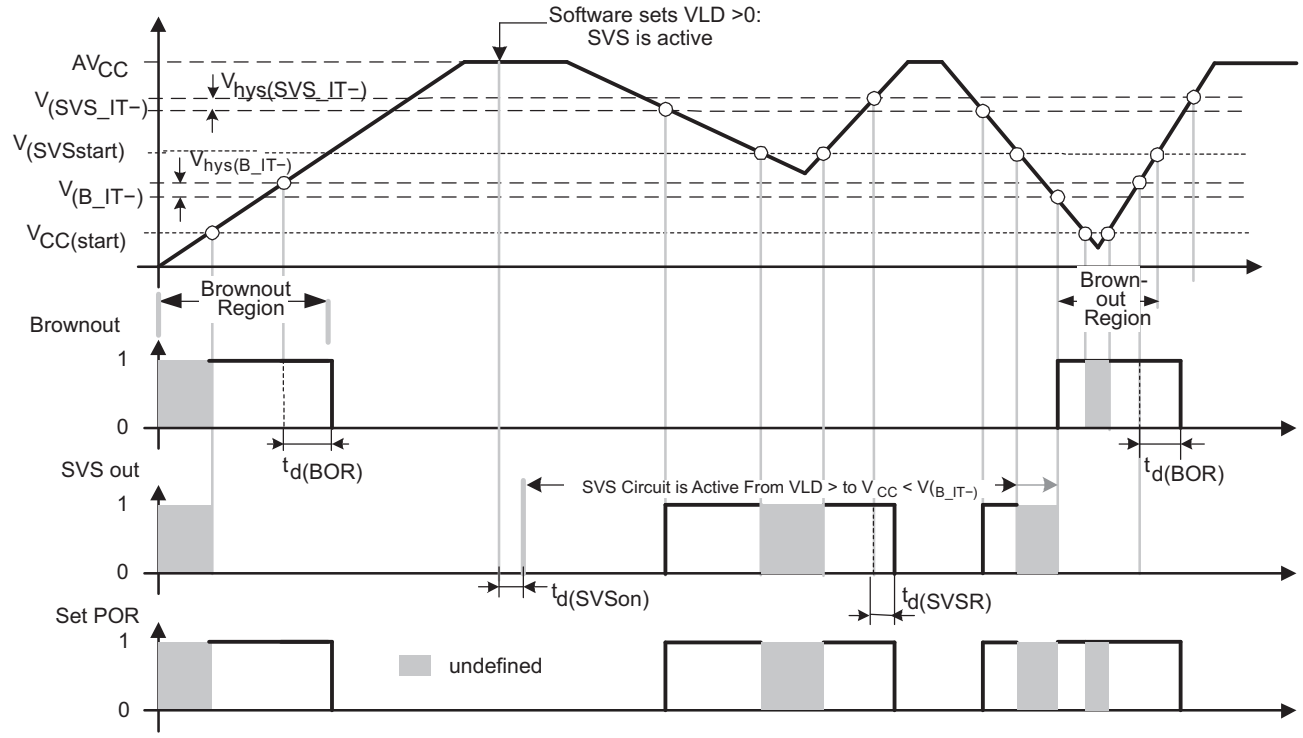



**Figure 12. SVS Reset (SVSR) vs Supply Voltage**

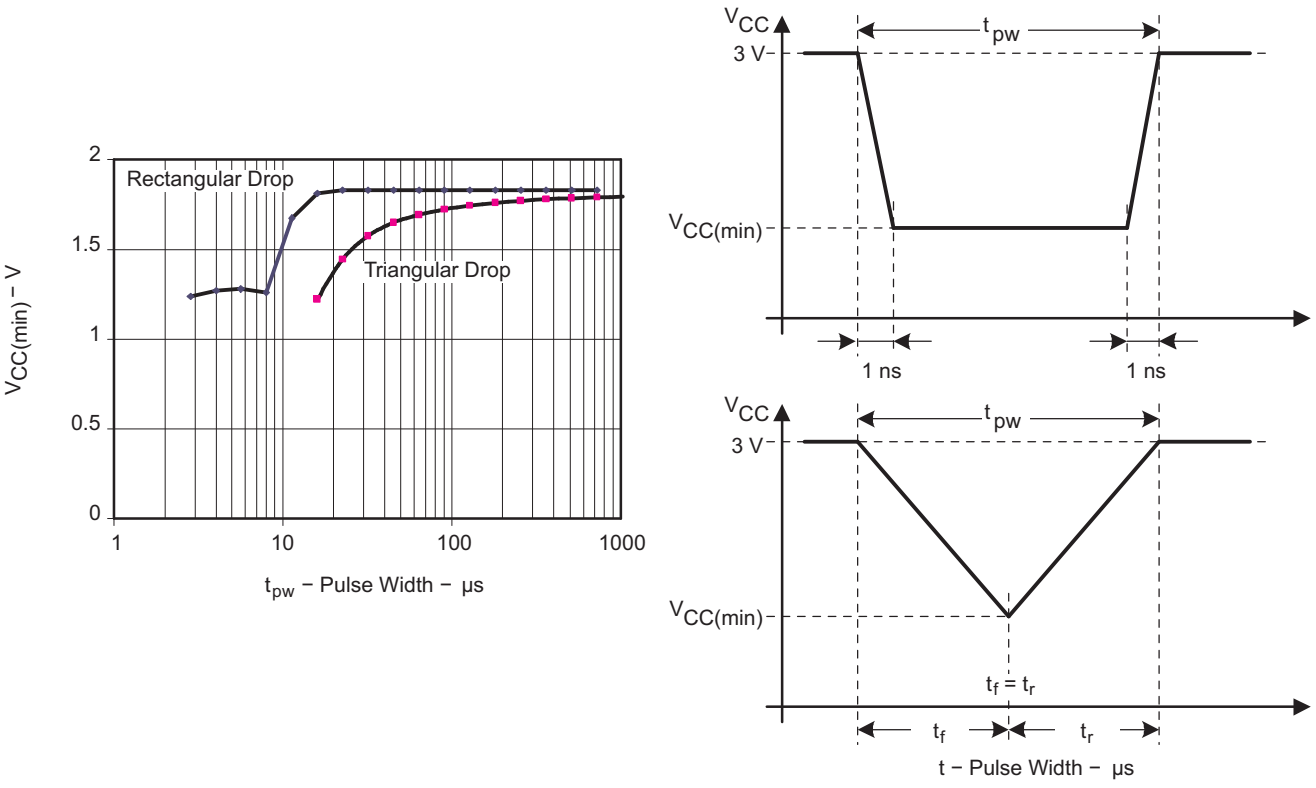



**Figure 13. $V_{CC(min)}$: Square Voltage Drop and Triangle Voltage Drop to Generate an SVS Signal (VLD = 1)**

## 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 $S_{DCO}$ .
- Modulation control bits MODx select how often $f_{DCO(RSEL,DCO+1)}$ is used within the period of 32 DCOCLK cycles. The frequency $f_{DCO(RSEL,DCO)}$ is used for the remaining cycles. The frequency is an average equal to:

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

## DCO Frequency

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

| PARAMETER | | TEST CONDITIONS | $V_{CC}$ | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $V_{CC}$ | Supply voltage range | RSELx < 14 | | 1.8 | | 3.6 | V |
| | | RSELx = 14 | | 2.2 | | 3.6 | |
| | | RSELx = 15 | | 3.0 | | 3.6 | |
| $f_{DCO(0,0)}$ | DCO frequency (0, 0) | RSELx = 0, DCOx = 0, MODx = 0 | 2.2 V, 3 V | 0.06 | | 0.14 | MHz |
| $f_{DCO(0,3)}$ | DCO frequency (0, 3) | RSELx = 0, DCOx = 3, MODx = 0 | 2.2 V, 3 V | 0.07 | | 0.17 | MHz |
| $f_{DCO(1,3)}$ | DCO frequency (1, 3) | RSELx = 1, DCOx = 3, MODx = 0 | 2.2 V, 3 V | 0.10 | | 0.20 | MHz |
| $f_{DCO(2,3)}$ | DCO frequency (2, 3) | RSELx = 2, DCOx = 3, MODx = 0 | 2.2 V, 3 V | 0.14 | | 0.28 | MHz |
| $f_{DCO(3,3)}$ | DCO frequency (3, 3) | RSELx = 3, DCOx = 3, MODx = 0 | 2.2 V, 3 V | 0.20 | | 0.40 | MHz |
| $f_{DCO(4,3)}$ | DCO frequency (4, 3) | RSELx = 4, DCOx = 3, MODx = 0 | 2.2 V, 3 V | 0.28 | | 0.54 | MHz |
| $f_{DCO(5,3)}$ | DCO frequency (5, 3) | RSELx = 5, DCOx = 3, MODx = 0 | 2.2 V, 3 V | 0.39 | | 0.77 | MHz |
| $f_{DCO(6,3)}$ | DCO frequency (6, 3) | RSELx = 6, DCOx = 3, MODx = 0 | 2.2 V, 3 V | 0.54 | | 1.06 | MHz |
| $f_{DCO(7,3)}$ | DCO frequency (7, 3) | RSELx = 7, DCOx = 3, MODx = 0 | 2.2 V, 3 V | 0.80 | | 1.50 | MHz |
| $f_{DCO(8,3)}$ | DCO frequency (8, 3) | RSELx = 8, DCOx = 3, MODx = 0 | 2.2 V, 3 V | 1.10 | | 2.10 | MHz |
| $f_{DCO(9,3)}$ | DCO frequency (9, 3) | RSELx = 9, DCOx = 3, MODx = 0 | 2.2 V, 3 V | 1.60 | | 3.00 | MHz |
| $f_{DCO(10,3)}$ | DCO frequency (10, 3) | RSELx = 10, DCOx = 3, MODx = 0 | 2.2 V, 3 V | 2.50 | | 4.30 | MHz |
| $f_{DCO(11,3)}$ | DCO frequency (11, 3) | RSELx = 11, DCOx = 3, MODx = 0 | 2.2 V, 3 V | 3.00 | | 5.50 | MHz |
| $f_{DCO(12,3)}$ | DCO frequency (12, 3) | RSELx = 12, DCOx = 3, MODx = 0 | 2.2 V, 3 V | 4.30 | | 7.30 | MHz |
| $f_{DCO(13,3)}$ | DCO frequency (13, 3) | RSELx = 13, DCOx = 3, MODx = 0 | 2.2 V, 3 V | 6.00 | | 9.60 | MHz |
| $f_{DCO(14,3)}$ | DCO frequency (14, 3) | RSELx = 14, DCOx = 3, MODx = 0 | 2.2 V, 3 V | 8.60 | | 13.9 | MHz |
| $f_{DCO(15,3)}$ | DCO frequency (15, 3) | RSELx = 15, DCOx = 3, MODx = 0 | 3 V | 12.0 | | 18.5 | MHz |
| $f_{DCO(15,7)}$ | DCO frequency (15, 7) | RSELx = 15, DCOx = 7, MODx = 0 | 3 V | 16.0 | | 26.0 | MHz |
| $S_{RSEL}$ | Frequency step between range RSEL and RSEL+1 | $S_{RSEL} = f_{DCO(RSEL+1,DCO)} / f_{DCO(RSEL,DCO)}$ | 2.2 V, 3 V | | | 1.55 | ratio |
| $S_{DCO}$ | Frequency step between tap DCO and DCO+1 | $S_{DCO} = f_{DCO(RSEL,DCO+1)} / f_{DCO(RSEL,DCO)}$ | 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 | % |


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## Calibrated DCO Frequencies - Tolerance at Calibration

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 |
|---|---|---|---|---|---|---|---|---|
| | Frequency tolerance at calibration | | 25°C | 3 V | -1 | ±0.2 | +1 | % |
| $f_{CAL(1MHz)}$ | 1-MHz calibration value | BCSCTL1 = CALBC1_1MHZ, DCOCTL = CALDCO_1MHZ, Gating time: 5 ms | 25°C | 3 V | 0.990 | 1 | 1.010 | MHz |
| $f_{CAL(8MHz)}$ | 8-MHz calibration value | BCSCTL1 = CALBC1_8MHZ, DCOCTL = CALDCO_8MHZ, Gating time: 5 ms | 25°C | 3 V | 7.920 | 8 | 8.080 | MHz |
| $f_{CAL(12MHz)}$ | 12-MHz calibration value | BCSCTL1 = CALBC1_12MHZ, DCOCTL = CALDCO_12MHZ, Gating time: 5 ms | 25°C | 3 V | 11.88 | 12 | 12.12 | MHz |
| $f_{CAL(16MHz)}$ | 16-MHz calibration value | BCSCTL1 = CALBC1_16MHZ, DCOCTL = CALDCO_16MHZ, 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 | $T_A$ | $V_{CC}$ | 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 | ±1.0 | 2.5 | % |
| | 12-MHz tolerance over temperature | | 0°C to 85°C | 3 V | -2.5 | ±1.0 | 2.5 | % |
| | 16-MHz tolerance over temperature | | 0°C to 85°C | 3 V | -3 | ±2.0 | 3 | % |
| $f_{CAL(1MHz)}$ | 1-MHz calibration value | BCSCTL1 = CALBC1_1MHZ, DCOCTL = CALDCO_1MHZ, 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 | |
| $f_{CAL(8MHz)}$ | 8-MHz calibration value | BCSCTL1 = CALBC1_8MHZ, DCOCTL = CALDCO_8MHZ, 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 | |
| $f_{CAL(12MHz)}$ | 12-MHz calibration value | BCSCTL1 = CALBC1_12MHZ, DCOCTL = CALDCO_12MHZ, Gating time: 5 ms | 0°C to 85°C | 2.2 V | 11.64 | 12 | 12.36 | MHz |
| | | | | 3 V | 11.64 | 12 | 12.36 | |
| | | | | 3.6 V | 11.64 | 12 | 12.36 | |
| $f_{CAL(16MHz)}$ | 16-MHz calibration value | BCSCTL1 = CALBC1_16MHZ, DCOCTL = CALDCO_16MHZ, Gating time: 2 ms | 0°C to 85°C | 3 V | 15.52 | 16 | 16.48 | MHz |
| | | | | 3.6 V | 15 | 16 | 16.48 | |

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## 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 | -6 | ±2 | +3 | % |
| $f_{CAL(1MHz)}$ | 1-MHz calibration value | BCSCTL1 = CALBC1_1MHZ, DCOCTL = CALDCO_1MHZ, 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, DCOCTL = CALDCO_8MHZ, 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, DCOCTL = CALDCO_12MHZ, 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, DCOCTL = CALDCO_16MHZ, 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 | | -40°C to 105°C | 1.8 V to 3.6 V | -5 | ±2 | +5 | % |
| | 8-MHz tolerance overall | | -40°C to 105°C | 1.8 V to 3.6 V | -5 | ±2 | +5 | % |
| | 12-MHz tolerance overall | | -40°C to 105°C | 2.2 V to 3.6 V | -5 | ±2 | +5 | % |
| | 16-MHz tolerance overall | | -40°C to 105°C | 3 V to 3.6 V | -6 | ±3 | +6 | % |
| $f_{CAL(1MHz)}$ | 1-MHz calibration value | BCSCTL1 = CALBC1_1MHZ, DCOCTL = CALDCO_1MHZ, Gating time: 5 ms | -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, DCOCTL = CALDCO_8MHZ, Gating time: 5 ms | -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, DCOCTL = CALDCO_12MHZ, Gating time: 5 ms | -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, DCOCTL = CALDCO_16MHZ, Gating time: 2 ms | -40°C to 105°C | 3 V to 3.6 V | 15 | 16 | 17 | MHz |


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## Typical Characteristics - Calibrated DCO Frequency

**CALIBRATED 1-MHz FREQUENCY vs SUPPLY VOLTAGE**

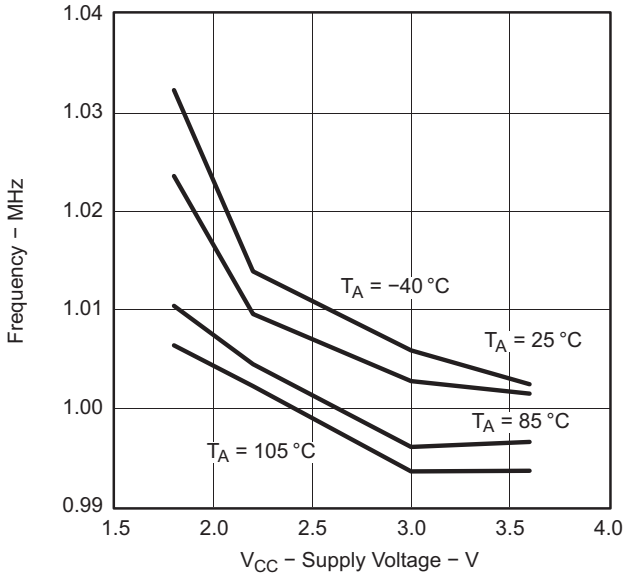



**Figure 14.**

**CALIBRATED 8-MHz FREQUENCY vs SUPPLY VOLTAGE**

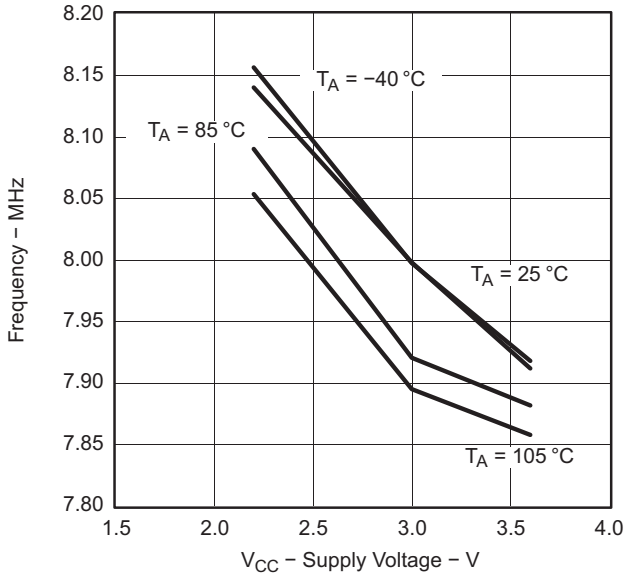



**Figure 15.**

**CALIBRATED 12-MHz FREQUENCY vs SUPPLY VOLTAGE**

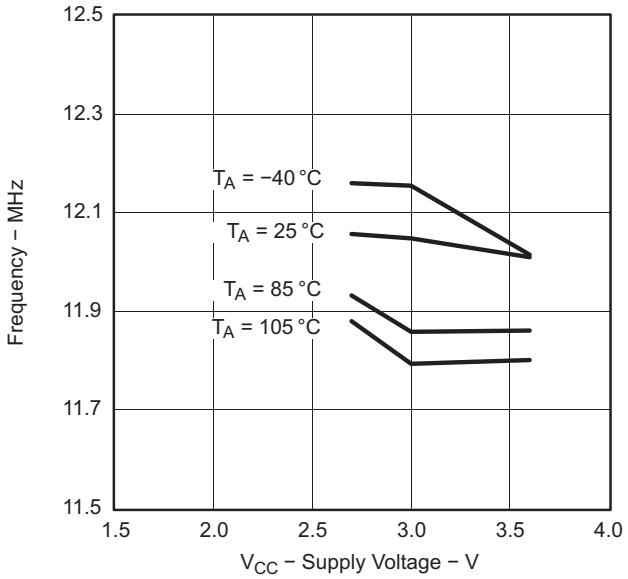



**Figure 16.**

**CALIBRATED 16-MHz FREQUENCY vs SUPPLY VOLTAGE**

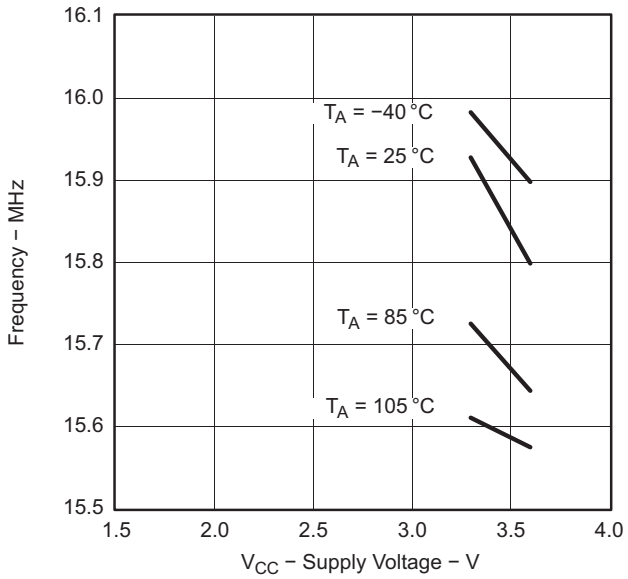



**Figure 17.**

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## 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 | $V_{CC}$ | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $t_{DCO,LPM3/4}$ | DCO clock wake-up time from LPM3/4 (1) | BCSCTL1 = CALBC1_1MHZ, DCOCTL = CALDCO_1MHZ | 2.2 V, 3 V | | | 2 | µs |
| | | BCSCTL1 = CALBC1_8MHZ, DCOCTL = CALDCO_8MHZ | | | | 1.5 | |
| | | BCSCTL1 = CALBC1_12MHZ, DCOCTL = CALDCO_12MHZ | | | | 1 | |
| | | BCSCTL1 = CALBC1_16MHZ, DCOCTL = CALDCO_16MHZ | 3 V | | | 1 | |
| $t_{CPU,LPM3/4}$ | CPU wake-up time from LPM3/4 (2) | | | | $1 / f_{MCLK} + t_{Clock,LPM3/4}$ | | |

(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

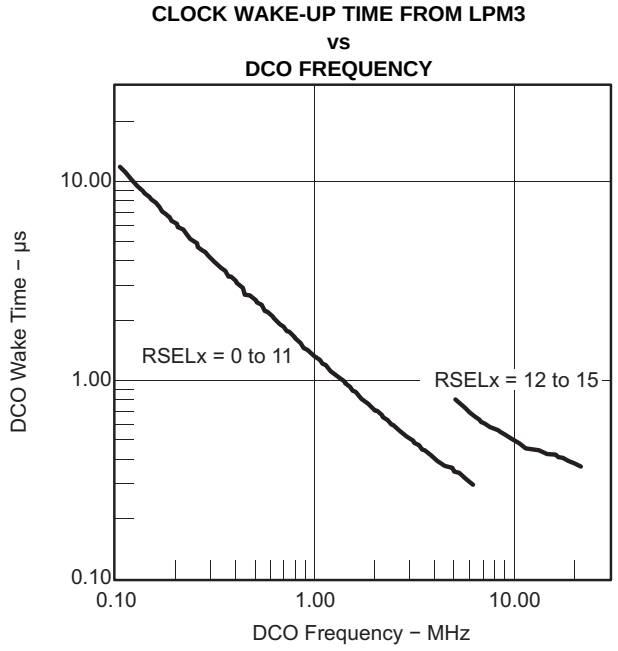



**Figure 18.**


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## DCO With External Resistor $R_{OSC}$ (1)

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

| PARAMETER | | TEST CONDITIONS | $V_{CC}$ | TYP | UNIT |
|---|---|---|---|---|---|
| $f_{DCO,ROSC}$ | DCO output frequency with $R_{OSC}$ | DCOR = 1, RSELx = 4, DCOx = 3, MODx = 0, $T_A$ = 25°C | 2.2 V | 1.8 | MHz |
| | | | 3 V | 1.95 | |
| $D_T$ | Temperature drift | DCOR = 1, RSELx = 4, DCOx = 3, MODx = 0 | 2.2 V, 3 V | ±0.1 | %/°C |
| $D_V$ | Drift with $V_{CC}$ | DCOR = 1, RSELx = 4, DCOx = 3, MODx = 0 | 2.2 V, 3 V | 10 | %/V |

(1) $R_{OSC}$ = 100 kΩ. Metal film resistor, type 0257, 0.6 W with 1% tolerance and $T_K$ = ±50 ppm/°C.

## Typical Characteristics - DCO With External Resistor $R_{OSC}$

**DCO FREQUENCY vs $R_{OSC}$ $V_{CC}$ = 2.2 V, $T_A$ = 25°C**

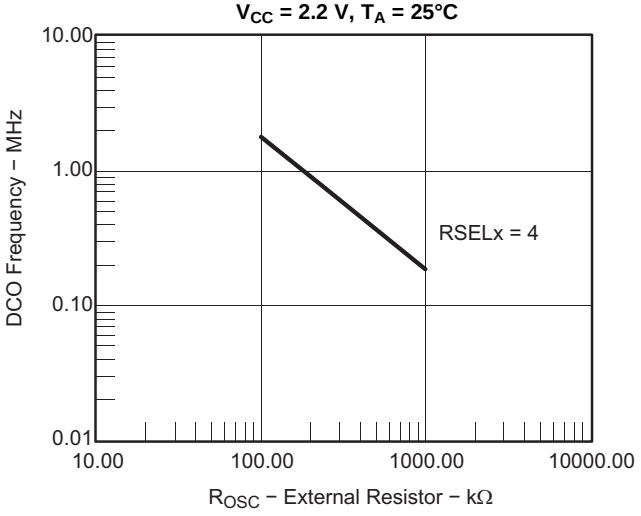



**Figure 19.**

**DCO FREQUENCY vs $R_{OSC}$ $V_{CC}$ = 3 V, $T_A$ = 25°C**

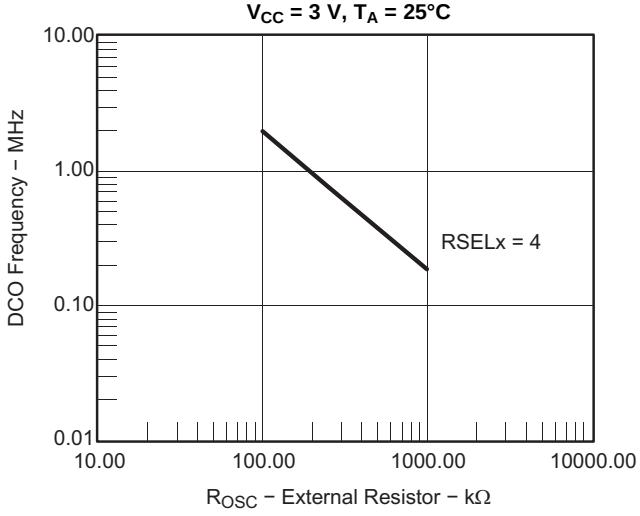



**Figure 20.**

**DCO FREQUENCY vs TEMPERATURE $V_{CC}$ = 3 V**

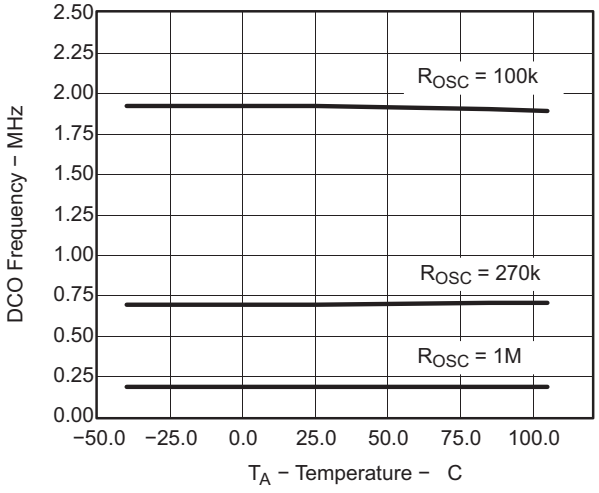



**Figure 21.**

**DCO FREQUENCY vs SUPPLY VOLTAGE $T_A$ = 25°C**

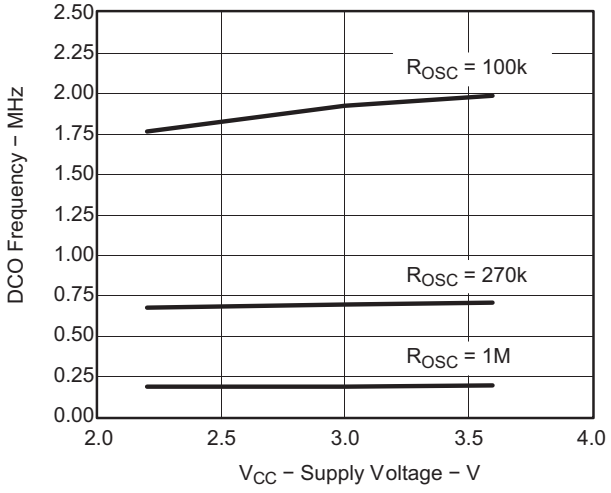



**Figure 22.**

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## Crystal Oscillator LFXT1, Low-Frequency Mode(1)

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

| PARAMETER | | TEST CONDITIONS | $V_{CC}$ | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $f_{LFXT1,LF}$ | LFXT1 oscillator crystal frequency, LF mode 0, 1 | XTS = 0, LFXT1Sx = 0 or 1 | 1.8 V to 3.6 V | | 32768 | | Hz |
| $f_{LFXT1,LF,logic}$ | LFXT1 oscillator logic level square wave input frequency, LF mode | XTS = 0, LFXT1Sx = 3, XCAPx = 0 | 1.8 V to 3.6 V | 10000 | 32768 | 50000 | Hz |
| $OA_{LF}$ | Oscillation allowance for LF crystals | XTS = 0, LFXT1Sx = 0, $f_{LFXT1,LF}$ = 32768 Hz, $C_{L,eff}$ = 6 pF | | | 500 | | kΩ |
| | | XTS = 0, LFXT1Sx = 0, $f_{LFXT1,LF}$ = 32768 Hz, $C_{L,eff}$ = 12 pF | | | 200 | | |
| $C_{L,eff}$ | Integrated effective load capacitance, LF mode(2) | 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, $f_{LFXT1,LF}$ = 32768 Hz | 2.2 V, 3 V | 30 | 50 | 70 | % |
| $f_{Fault,LF}$ | Oscillator fault frequency, LF mode(3) | XTS = 0, LFXT1Sx = 3, XCAPx = 0(4) | 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 or 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.

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

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

| PARAMETER | | $V_{CC}$ | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| $f_{VLO}$ | VLO frequency | 2.2 V, 3 V | 4 | 12 | 20 | kHz |
| $df_{VLO}/dT$ | VLO frequency temperature drift (1) | 2.2 V, 3 V | | 0.5 | | %/°C |
| $df_{VLO}/dV_{CC}$ | VLO frequency supply voltage drift (2) | 1.8 V to 3.6 V | | 4 | | %/V |

(1) Calculated using the box method:
I version: (MAX(-40 to 85°C) - MIN(-40 to 85°C))/MIN(-40 to 85°C)/(85°C - (-40°C))
T version: (MAX(-40 to 105°C) - MIN(-40 to 105°C))/MIN(-40 to 105°C)/(105°C - (-40°C))

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


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## Crystal Oscillator LFXT1, High-Frequency Mode(1)

| PARAMETER | | TEST CONDITIONS | $V_{CC}$ | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $f_{LFXT1,HF0}$ | LFXT1 oscillator crystal frequency, HF mode 0 | XTS = 1, LFXT1Sx = 0, XCAPx = 0 | 1.8 V to 3.6 V | 0.4 | | 1 | MHz |
| $f_{LFXT1,HF1}$ | LFXT1 oscillator crystal frequency, HF mode 1 | XTS = 1, LFXT1Sx = 1, XCAPx = 0 | 1.8 V to 3.6 V | 1 | | 4 | MHz |
| $f_{LFXT1,HF2}$ | LFXT1 oscillator crystal frequency, HF mode 2 | XTS = 1, LFXT1Sx = 2, XCAPx = 0 | 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 | |
| $f_{LFXT1,HF,logic}$ | LFXT1 oscillator logic-level square-wave input frequency, HF mode | XTS = 1, LFXT1Sx = 3, XCAPx = 0 | 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 | |
| $OA_{HF}$ | Oscillation allowance for HF crystals (see Figure 23 and Figure 24) | XTS = 1, XCAPx = 0, LFXT1Sx = 0, $f_{LFXT1,HF}$ = 1 MHz, $C_{L,eff}$ = 15 pF | | | 2700 | | Ω |
| | | XTS = 1, XCAPx = 0, LFXT1Sx = 1, $f_{LFXT1,HF}$ = 4 MHz, $C_{L,eff}$ = 15 pF | | | 800 | | |
| | | XTS = 1, XCAPx = 0, LFXT1Sx = 2, $f_{LFXT1,HF}$ = 16 MHz, $C_{L,eff}$ = 15 pF | | | 300 | | |
| $C_{L,eff}$ | Integrated effective load capacitance, HF mode(2) | XTS = 1, XCAPx = 0(3) | | | 1 | | pF |
| | Duty cycle, HF mode | XTS = 1, XCAPx = 0, Measured at P1.4/SMCLK, $f_{LFXT1,HF}$ = 10 MHz | 2.2 V, 3 V | 40 | 50 | 60 | % |
| | | XTS = 1, XCAPx = 0, Measured at P1.4/SMCLK, $f_{LFXT1,HF}$ = 16 MHz | | 40 | 50 | 60 | |
| $f_{Fault,HF}$ | Oscillator fault frequency (4) | XTS = 1, LFXT1Sx = 3, XCAPx = 0(5) | 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 or 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.

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

**OSCILLATION ALLOWANCE vs CRYSTAL FREQUENCY $C_{L,eff}$ = 15 pF, $T_A$ = 25°C**

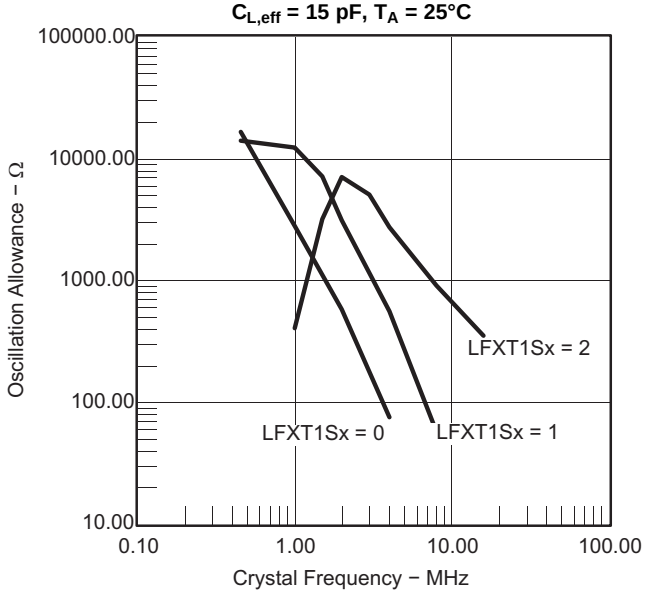



**Figure 23.**

**OSCILLATOR SUPPLY CURRENT vs CRYSTAL FREQUENCY $C_{L,eff}$ = 15 pF, $T_A$ = 25°C**

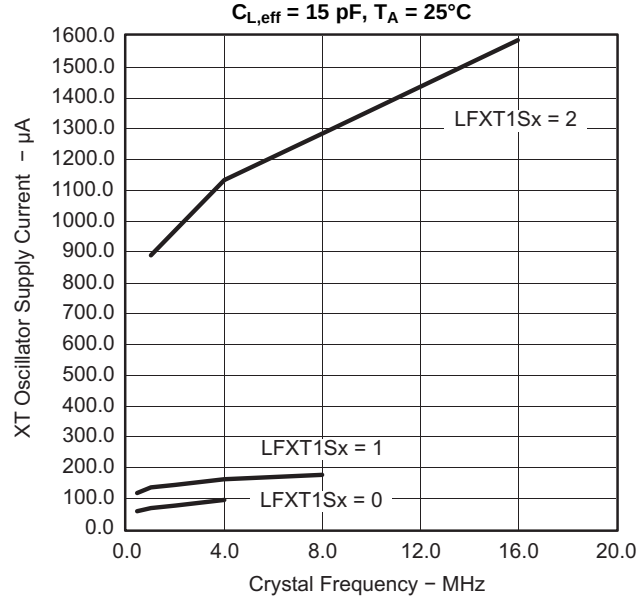



**Figure 24.**


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## Crystal Oscillator XT2[1]

| PARAMETER | | TEST CONDITIONS | $V_{CC}$ | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $f_{XT2}$ | XT2 oscillator crystal frequency, mode 0 | XT2Sx = 0 | 1.8 V to 3.6 V | 0.4 | | 1 | MHz |
| $f_{XT2}$ | XT2 oscillator crystal frequency, mode 1 | XT2Sx = 1 | 1.8 V to 3.6 V | 1 | | 4 | MHz |
| $f_{XT2}$ | XT2 oscillator crystal frequency, mode 2 | XT2Sx = 2 | 1.8 V to 2.2 V | 2 | | 10 | MHz |
| | | | 2.2 V to 3.0 V | 2 | | 12 | |
| | | | 3.0 V to 3.6 V | 2 | | 16 | |
| $f_{XT2}$ | XT2 oscillator logic-level square-wave input frequency | XT2Sx = 3 | 1.8 V to 2.2 V | 0.4 | | 10 | MHz |
| | | | 2.2 V to 3.0 V | 0.4 | | 12 | |
| | | | 3.0 V to 3.6 V | 0.4 | | 16 | |
| OA | Oscillation allowance (see Figure 25 and Figure 26) | XT2Sx = 0, $f_{XT2}$ = 1 MHz, $C_{L,eff}$ = 15 pF | | | 2700 | | Ω |
| | | XT2Sx = 1, $f_{XT2}$ = 4 MHz, $C_{L,eff}$ = 15 pF | | | 800 | | |
| | | XT2Sx = 2, $f_{XT2}$ = 16 MHz, $C_{L,eff}$ = 15 pF | | | 300 | | |
| $C_{L,eff}$ | Integrated effective load capacitance, HF mode[2] | See [3] | | | 1 | | pF |
| | Duty cycle | Measured at P1.4/SMCLK, $f_{XT2}$ = 10 MHz | 2.2 V, 3 V | 40 | 50 | 60 | % |
| | | Measured at P1.4/SMCLK, $f_{XT2}$ = 16 MHz | | 40 | 50 | 60 | |
| $f_{Fault}$ | Oscillator fault frequency, HF mode[4] | XT2Sx = 3[5] | 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 XT2IN and XT2OUT.
(d) Avoid running PCB traces underneath or adjacent to the XT2IN and XT2OUT pins.
(e) Use assembly materials and praxis to avoid any parasitic load on the oscillator XT2IN and XT2OUT pins.
(f) If conformal coating is used, ensure that it does not induce capacitive or resistive leakage between the oscillator pins.

(2) Includes parasitic bond and package capacitance (approximately 2 pF per pin). Because the PCB adds additional capacitance, 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.

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## Typical Characteristics - XT2 Oscillator

**OSCILLATION ALLOWANCE vs CRYSTAL FREQUENCY $C_{L,eff}$ = 15 pF, $T_A$ = 25°C**

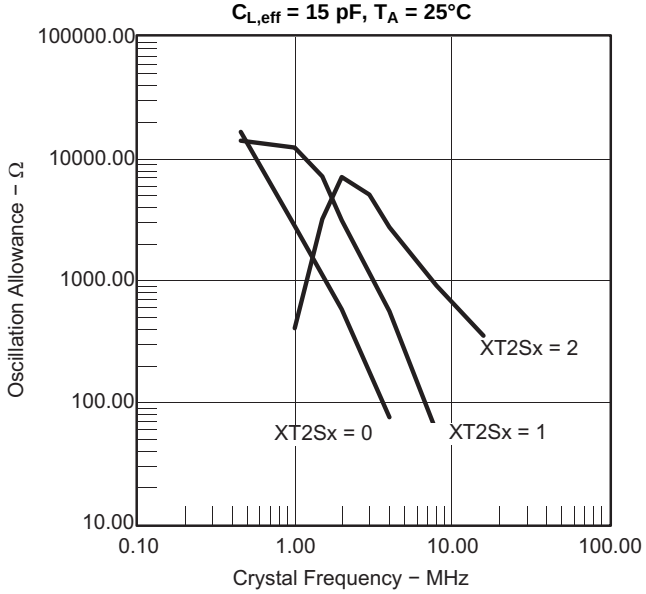



**Figure 25.**

**OSCILLATOR SUPPLY CURRENT vs CRYSTAL FREQUENCY $C_{L,eff}$ = 15 pF, $T_A$ = 25°C**

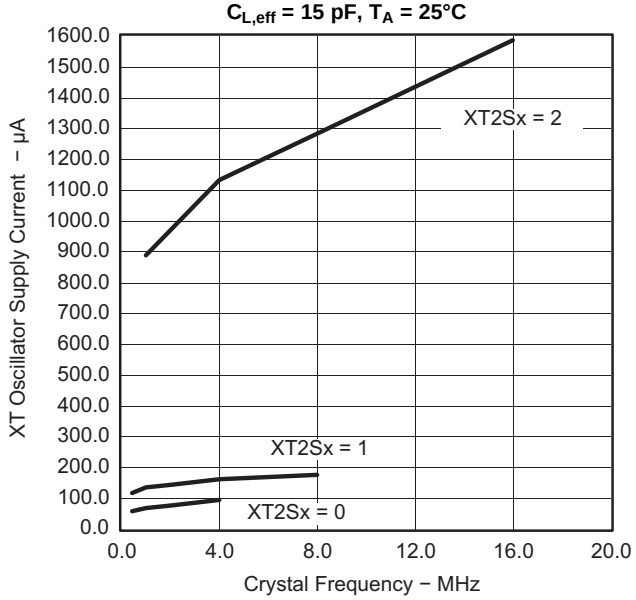



**Figure 26.**


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## Timer_A

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

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

## Timer_B

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

| PARAMETER | | TEST CONDITIONS | $V_{CC}$ | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $f_{TB}$ | Timer_B clock frequency | Internal: SMCLK, ACLK<br>External: TACLK, INCLK<br>Duty cycle = 50% ± 10% | 2.2 V | | | 10 | MHz |
| | | | 3 V | | | 16 | |
| $t_{TB,cap}$ | Timer_B capture timing | TB0, TB1, TB2 | 2.2 V, 3 V | 20 | | | ns |

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## USCI (UART Mode)

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

| PARAMETER | | CONDITIONS | $V_{CC}$ | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $f_{USCI}$ | USCI input clock frequency | Internal: SMCLK, ACLK<br>External: UCLK<br>Duty cycle = 50% ± 10% | | | | $f_{SYSTEM}$ | MHz |
| $f_{BITCLK}$ | BITCLK clock frequency (equals baud rate in MBaud)(1) | | 2.2 V, 3 V | | | 1 | MHz |
| $t_\tau$ | UART receive deglitch time(2) | | 2.2 V | 50 | 150 | | ns |
| | | | 3 V | 50 | 100 | | |

(1) The DCO wake-up time must be considered in LPM3/4 for baudrates above 1 MHz.
(2) Pulses on the UART receive input (UCxRX) shorter than the UART receive deglitch time are suppressed.

## USCI (SPI Master Mode)(1)

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)
(see Figure 27 and Figure 28)

| PARAMETER | | TEST CONDITIONS | $V_{CC}$ | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $f_{USCI}$ | USCI input clock frequency | SMCLK, ACLK<br>Duty cycle = 50% ± 10% | | | | $f_{SYSTEM}$ | MHz |
| $t_{SU,MI}$ | SOMI input data setup time | | 2.2 V | 110 | | | ns |
| | | | 3 V | 75 | | | |
| $t_{HD,MI}$ | SOMI input data hold time | | 2.2 V | 0 | | | ns |
| | | | 3 V | 0 | | | |
| $t_{VALID,MO}$ | SIMO output data valid time | UCLK edge to SIMO valid,<br>$C_L$ = 20 pF | 2.2 V | | | 30 | ns |
| | | | 3 V | | | 20 | |

(1) $f_{UCxCLK} = 1/2t_{LO/HI}$ with $t_{LO/HI} \geq \max(t_{VALID,MO(USCI)} + t_{SU,SI(Slave)}, t_{SU,MI(USCI)} + t_{VALID,SO(Slave)})$.
For the slave's parameters $t_{SU,SI(Slave)}$ and $t_{VALID,SO(Slave)}$, see the SPI parameters of the attached slave.

## USCI (SPI Slave Mode)(1)

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)
(see Figure 29 and Figure 30)

| PARAMETER | | TEST CONDITIONS | $V_{CC}$ | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $t_{STE,LEAD}$ | STE lead time, STE low to clock | | 2.2 V, 3 V | | 50 | | ns |
| $t_{STE,LAG}$ | STE lag time, Last clock to STE high | | 2.2 V, 3 V | 10 | | | ns |
| $t_{STE,ACC}$ | STE access time, STE low to SOMI data out | | 2.2 V, 3 V | | 50 | | ns |
| $t_{STE,DIS}$ | STE disable time, STE high to SOMI high impedance | | 2.2 V, 3 V | | 50 | | ns |
| $t_{SU,SI}$ | SIMO input data setup time | | 2.2 V | 20 | | | ns |
| | | | 3 V | 15 | | | |
| $t_{HD,SI}$ | SIMO input data hold time | | 2.2 V | 10 | | | ns |
| | | | 3 V | 10 | | | |
| $t_{VALID,SO}$ | SOMI output data valid time | UCLK edge to SOMI valid,<br>$C_L$ = 20 pF | 2.2 V | | 75 | 110 | ns |
| | | | 3 V | | 50 | 75 | |

(1) $f_{UCxCLK} = 1/2t_{LO/HI}$ with $t_{LO/HI} \geq \max(t_{VALID,MO(Master)} + t_{SU,SI(USCI)}, t_{SU,MI(Master)} + t_{VALID,SO(USCI)})$.
For the master's parameters $t_{SU,MI(Master)}$ and $t_{VALID,MO(Master)}$ see the SPI parameters of the attached slave.


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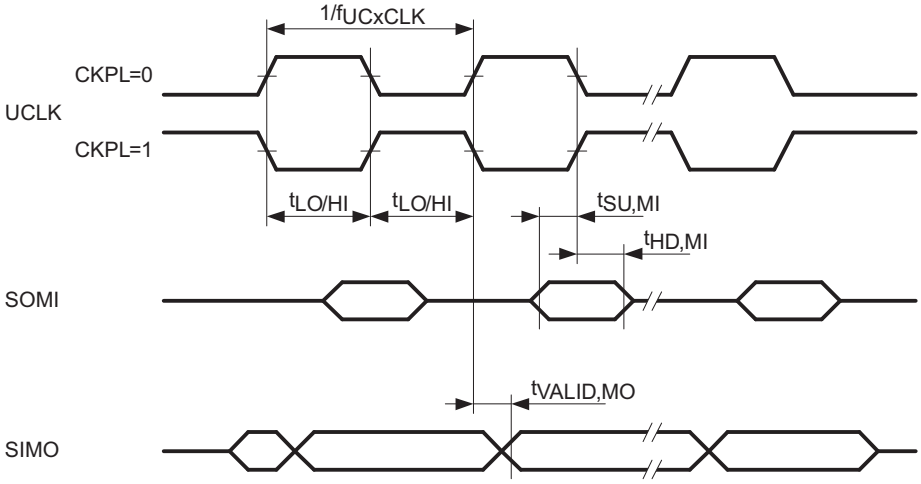



**Figure 27. SPI Master Mode, CKPH = 0**

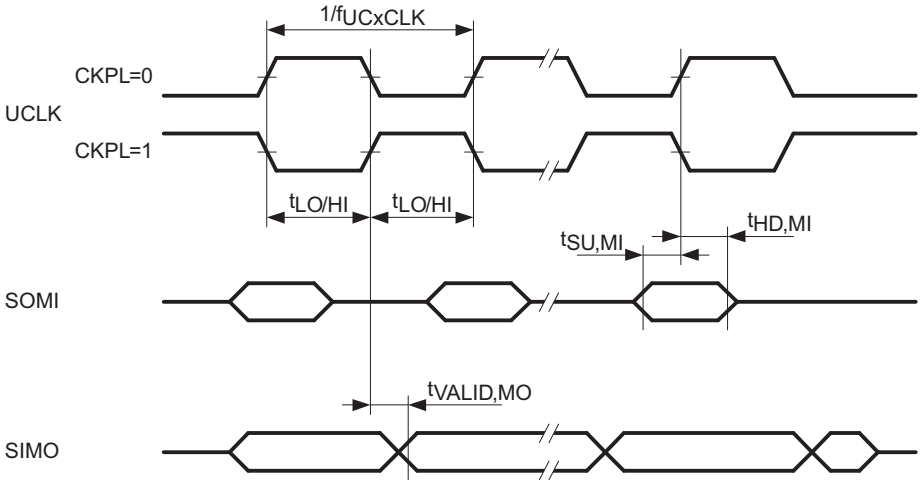



**Figure 28. SPI Master Mode, CKPH = 1**

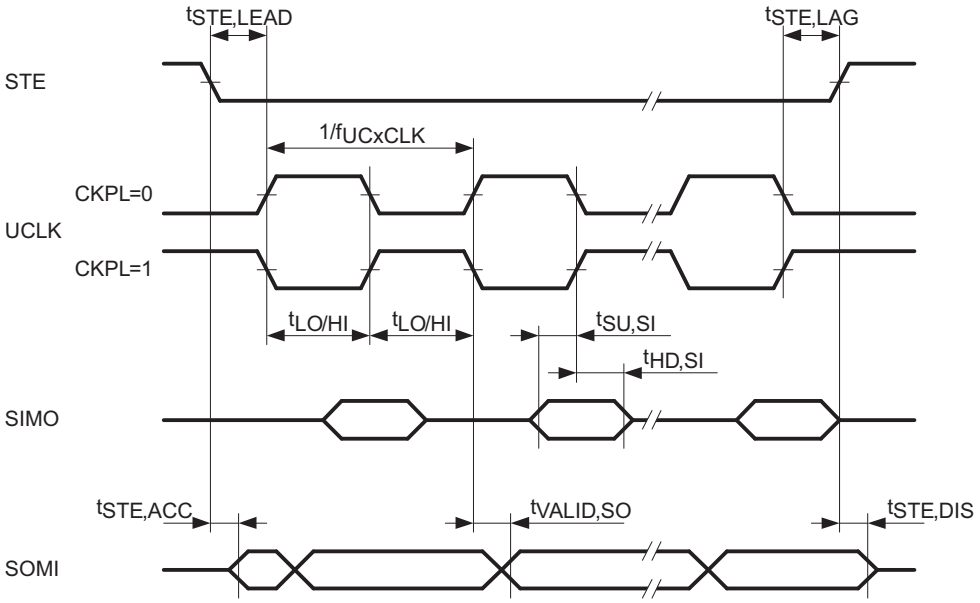



**Figure 29. SPI Slave Mode, CKPH = 0**

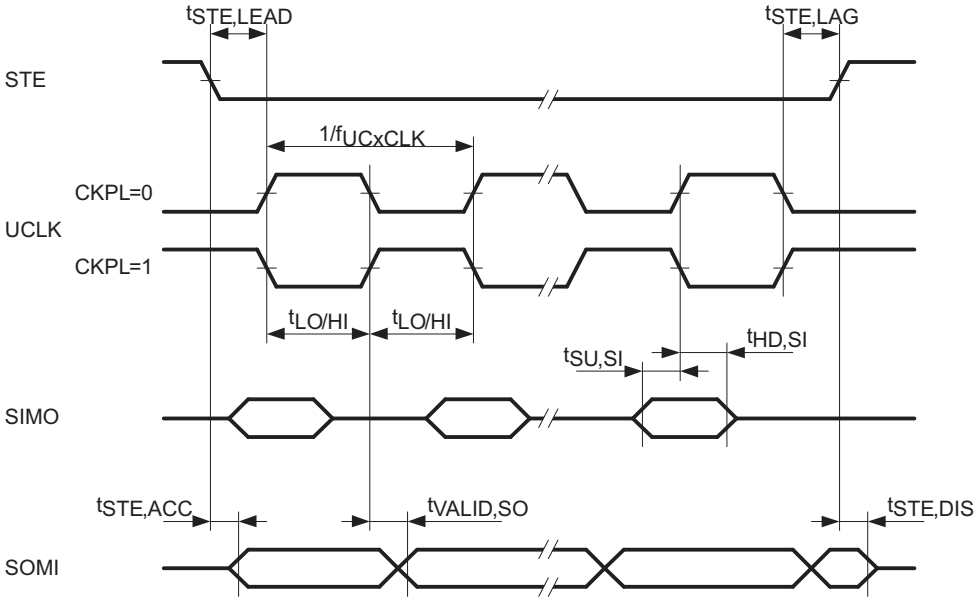



**Figure 30. SPI Slave Mode, CKPH = 1**


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## USCI ($I^2C$ Mode)

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted) (see Figure 31)

| PARAMETER | | TEST CONDITIONS | $V_{CC}$ | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $f_{USCI}$ | USCI input clock frequency | Internal: SMCLK, ACLK<br>External: UCLK<br>Duty cycle = 50% ± 10% | | | | $f_{SYSTEM}$ | MHz |
| $f_{SCL}$ | SCL clock frequency | | 2.2 V, 3 V | 0 | | 400 | kHz |
| $t_{HD,STA}$ | Hold time (repeated) START | $f_{SCL}$ ≤ 100 kHz | 2.2 V, 3 V | 4 | | | µs |
| | | $f_{SCL}$ > 100 kHz | | 0.6 | | | |
| $t_{SU,STA}$ | Setup time for a repeated START | $f_{SCL}$ ≤ 100 kHz | 2.2 V, 3 V | 4.7 | | | µs |
| | | $f_{SCL}$ > 100 kHz | | 0.6 | | | |
| $t_{HD,DAT}$ | Data hold time | | 2.2 V, 3 V | 0 | | | ns |
| $t_{SU,DAT}$ | Data setup time | | 2.2 V, 3 V | 250 | | | ns |
| $t_{SU,STO}$ | Setup time for STOP | | 2.2 V, 3 V | 4 | | | µs |
| $t_{SP}$ | Pulse width of spikes suppressed by input filter | | 2.2 V | 50 | 150 | 600 | ns |
| | | | 3 V | 50 | 100 | 600 | |

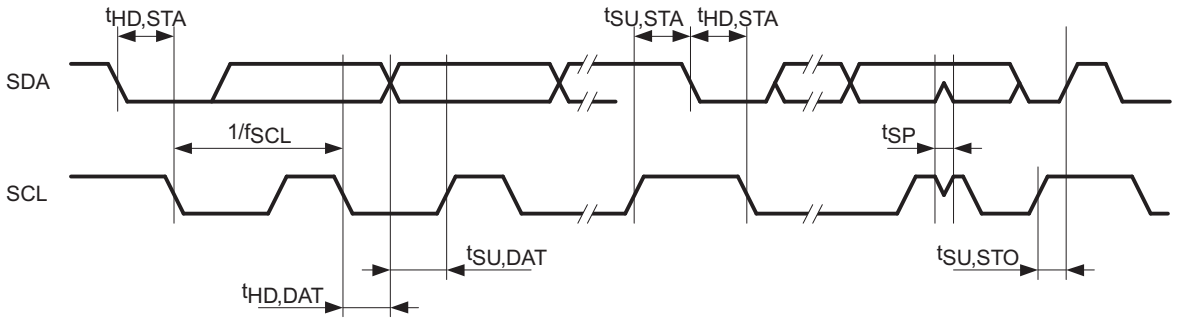



**Figure 31. $I^2C$ Mode Timing**

## Comparator_A+ (1)

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

| PARAMETER | | TEST CONDITIONS | $V_{CC}$ | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $I_{(DD)}$ | | CAON = 1, CARSEL = 0, CAREF = 0 | 2.2 V | | 25 | 40 | µA |
| | | | 3 V | | 45 | 60 | |
| $I_{(Refladder/RefDiode)}$ | | CAON = 1, CARSEL = 0, CAREF = 1/2/3, No load at P2.3/CA0/TA1 and P2.4/CA1/TA2 | 2.2 V | | 30 | 50 | µA |
| | | | 3 V | | 45 | 71 | |
| $V_{IC}$ | Common-mode input voltage range | CAON = 1 | 2.2 V, 3 V | 0 | | $V_{CC}$ - 1 | V |
| $V_{(Ref025)}$ | Voltage at 0.25 $V_{CC}$ node / $V_{CC}$ | PCA0 = 1, CARSEL = 1, CAREF = 1, No load at P2.3/CA0/TA1 and P2.4/CA1/TA2 | 2.2 V, 3 V | 0.23 | 0.24 | 0.25 | |
| $V_{(Ref050)}$ | Voltage at 0.5 $V_{CC}$ node / $V_{CC}$ | PCA0 = 1, CARSEL = 1, CAREF = 2, No load at P2.3/CA0/TA1 and P2.4/CA1/TA2 | 2.2 V, 3 V | 0.47 | 0.48 | 0.5 | |
| $V_{(RefVT)}$ | See Figure 36 and Figure 37 | PCA0 = 1, CARSEL = 1, CAREF = 3, No load at P2.3/CA0/TA1 and P2.4/CA1/TA2, $T_A$ = 85°C | 2.2 V | 390 | 480 | 540 | mV |
| | | | 3 V | 400 | 490 | 550 | |
| $V_{(offset)}$ | Offset voltage (2) | | 2.2 V, 3 V | -30 | | 30 | mV |
| $V_{hys}$ | Input hysteresis | CAON = 1 | 2.2 V, 3 V | 0 | 0.7 | 1.4 | mV |
| $t_{(response)}$ | Response time (low-to-high and high-to-low) | $T_A$ = 25°C, Overdrive 10 mV, Without filter: CAF = 0 (3) (see Figure 32 and Figure 33) | 2.2 V | 80 | 165 | 300 | ns |
| | | | 3 V | 70 | 120 | 240 | |
| | | $T_A$ = 25°C, Overdrive 10 mV, Without filter: CAF = 1 (3) (see Figure 32 and Figure 33) | 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 $I_{lkg(Px.y)}$ 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) The response time is measured at P2.2/CAOUT/TA0/CA4 with an input voltage step, with Comparator_A+ already enabled (CAON = 1). If CAON is set at the same time, a settling time of up to 300 ns is added to the response time.


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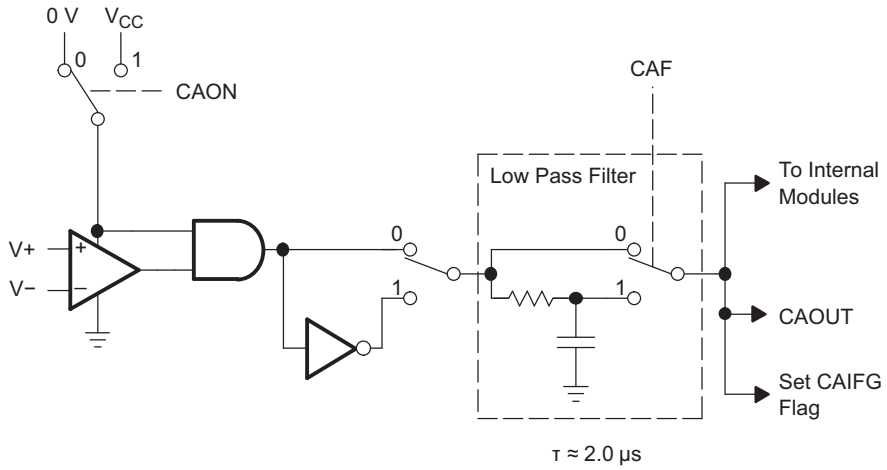



**Figure 32. Comparator_A+ Block Diagram**

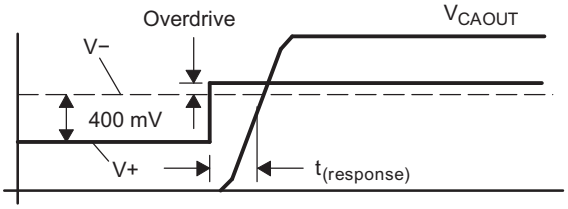



**Figure 33. Comparator_A+ Overdrive Definition**

**Figure 34. Comparator_A+ Short Resistance Test Condition**

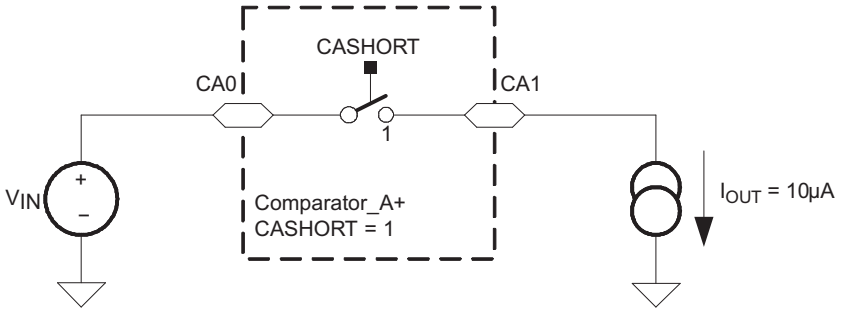



**Figure 35. Comparator_A+ Short Resistance Test Condition**

## Typical Characteristics, Comparator_A+

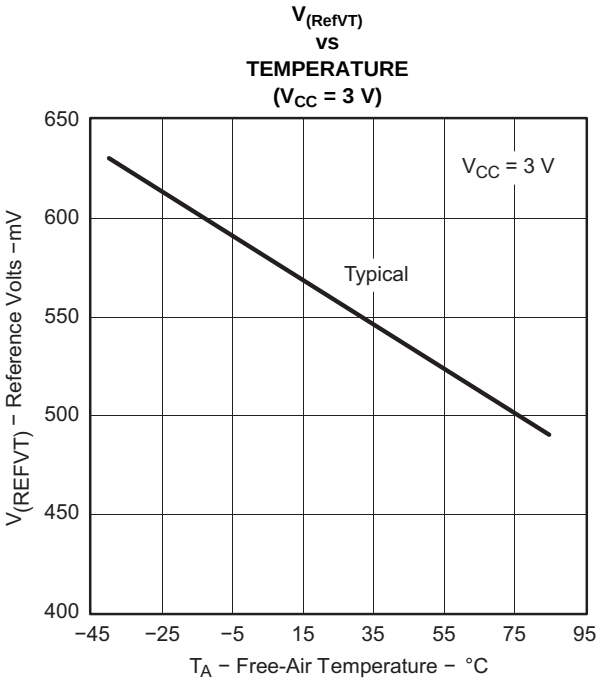



Figure 1. $V_{(RefVT)}$ vs Temperature, $V_{CC}$ = 3 V

**Figure 36.**

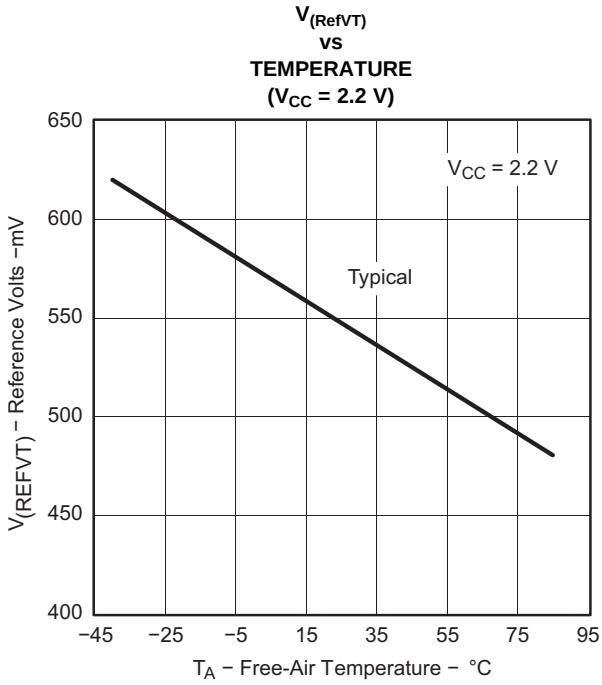



**Figure 37.**

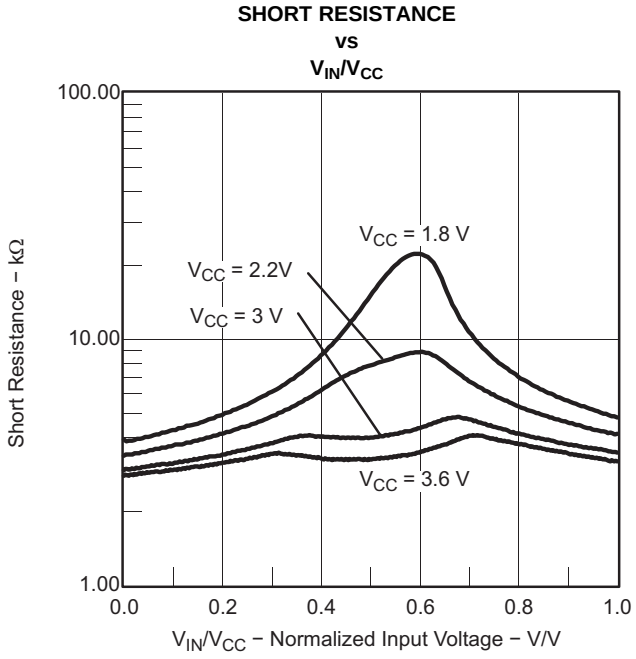



**Figure 38.**


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## 12-bit ADC, Power Supply and Input Range Conditions(1)

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

| PARAMETER | | TEST CONDITIONS | $V_{CC}$ | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $AV_{CC}$ | Analog supply voltage | $AV_{CC}$ and $DV_{CC}$ are connected together<br>$AV_{SS}$ and $DV_{SS}$ are connected together<br>$V_{(AVSS)} = V_{(DVSS)} = 0$ V | | 2.2 | | 3.6 | V |
| $V_{(P6.x/Ax)}$ | Analog input voltage range(2) | All P6.0/A0 to P6.7/A7 terminals, Analog inputs selected in ADC12MCTLx register,<br>P6Sel.x = 1, 0 ≤ × ≤ 7,<br>$V_{(AVSS)} \le V_{P6.x/Ax} \le V_{(AVCC)}$ | | 0 | | $V_{AVCC}$ | V |
| $I_{ADC12}$ | Operating supply current into $AV_{CC}$ terminal(3) | $f_{ADC12CLK}$ = 5 MHz,<br>ADC12ON = 1, REFON = 0,<br>SHT0 = 0, SHT1 = 0, ADC12DIV = 0 | 2.2 V | | 0.65 | 0.8 | mA |
| | | | 3 V | | 0.8 | 1 | |
| $I_{REF+}$ | Operating supply current into $AV_{CC}$ terminal(4) | $f_{ADC12CLK}$ = 5 MHz,<br>ADC12ON = 0, REFON = 1, REF2_5V = 1 | 3 V | | 0.5 | 0.7 | mA |
| | | $f_{ADC12CLK}$ = 5 MHz,<br>ADC12ON = 0, REFON = 1, REF2_5V = 0 | 2.2 V | | 0.5 | 0.7 | mA |
| | | | 3 V | | 0.5 | 0.7 | |
| $C_I$ | Input capacitance(5) | Only one terminal can be selected at one time, P6.x/Ax | 2.2 V | | | 40 | pF |
| $R_I$ | Input MUX ON resistance(5) | 0 V ≤ $V_{Ax}$ ≤ $V_{AVCC}$ | 3 V | | | 2000 | Ω |

(1) The leakage current is defined in the leakage current table with P6.x/Ax parameter.
(2) The analog input voltage range must be within the selected reference voltage range $V_{R+}$ to $V_{R-}$ for valid conversion results.
(3) The internal reference supply current is not included in current consumption parameter $I_{ADC12}$.
(4) The internal reference current is supplied via terminal $AV_{CC}$. Consumption is independent of the ADC12ON control bit, unless a conversion is active. The REFON bit enables settling of the built-in reference before starting an A/D conversion.
(5) Not production tested, limits verified by design.

## 12-Bit ADC, External Reference(1)

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

| PARAMETER | | TEST CONDITIONS | $V_{CC}$ | MIN | MAX | UNIT |
|---|---|---|---|---|---|---|
| $V_{eREF+}$ | Positive external reference voltage input | $V_{eREF+} > V_{REF-}/V_{eREF-}$ (2) | | 1.4 | $V_{AVCC}$ | V |
| $V_{REF-}/V_{eREF-}$ | Negative external reference voltage input | $V_{eREF+} > V_{REF-}/V_{eREF-}$ (3) | | 0 | 1.2 | V |
| ($V_{eREF+}$ – $V_{REF-}/V_{eREF-}$) | Differential external reference voltage input | $V_{eREF+} > V_{REF-}/V_{eREF-}$ (4) | | 1.4 | $V_{AVCC}$ | V |
| $I_{VeREF+}$ | Static leakage current | 0 V ≤ $V_{eREF+}$ ≤ $V_{AVCC}$ | 2.2 V, 3 V | | ±1 | µA |
| $I_{VREF-/VeREF-}$ | Static leakage current | 0 V ≤ $V_{eREF-}$ ≤ $V_{AVCC}$ | 2.2 V, 3 V | | ±1 | µA |

(1) The external reference is used during conversion to charge and discharge the capacitance array. The input capacitance, $C_I$, is also the dynamic load for an external reference during conversion. The dynamic impedance of the reference supply should follow the recommendations on analog-source impedance to allow the charge to settle for 12-bit accuracy.
(2) The accuracy limits the minimum positive external reference voltage. Lower reference voltage levels may be applied with reduced accuracy requirements.
(3) The accuracy limits the maximum negative external reference voltage. Higher reference voltage levels may be applied with reduced accuracy requirements.
(4) The accuracy limits minimum external differential reference voltage. Lower differential reference voltage levels may be applied with reduced accuracy requirements.

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## 12-Bit ADC, Built-In Reference

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

| PARAMETER | | TEST CONDITIONS | $T_A$ | $V_{CC}$ | MIN | NOM | MAX | UNIT |
|---|---|---|---|---|---|---|---|---|
| $V_{REF+}$ | Positive built-in reference voltage output | REF2_5V = 1 for 2.5 V, $I_{VREF+}$max ≤ $I_{VREF+}$ ≤ $I_{VREF+}$min | -40°C to 85°C | 3 V | 2.4 | 2.5 | 2.6 | V |
| | | | 105°C | | 2.37 | 2.5 | 2.64 | |
| | | REF2_5V = 0 for 1.5 V, $I_{VREF+}$max ≤ $I_{VREF+}$ ≤ $I_{VREF+}$min | -40°C to 85°C | 2.2 V, 3 V | 1.44 | 1.5 | 1.56 | |
| | | | 105°C | | 1.42 | 1.5 | 1.57 | |
| $AV_{CC(min)}$ | $AV_{CC}$ minimum voltage, positive built-in reference active | REF2_5V = 0, $I_{VREF+}$max ≤ $I_{VREF+}$ ≤ $I_{VREF+}$min | | | 2.2 | | | V |
| | | REF2_5V = 1, -0.5 mA ≤ $I_{VREF+}$ ≤ $I_{VREF+}$min | | | 2.8 | | | |
| | | REF2_5V = 1, -1 mA ≤ $I_{VREF+}$ ≤ $I_{VREF+}$min | | | 2.9 | | | |
| $I_{VREF+}$ | Load current out of $V_{REF+}$ terminal | | | 2.2 V | 0.01 | | -0.5 | mA |
| | | | | 3 V | 0.01 | | -1 | |
| $I_{L(VREF)+}$ | Load-current regulation, $V_{REF+}$ terminal (1) | $I_{VREF+}$ = 500 µA ± 100 µA, Analog input voltage ≈ 0.75 V, REF2_5V = 0 | | 2.2 V | | | ±2 | LSB |
| | | | | 3 V | | | ±2 | |
| | | $I_{VREF+}$ = 500 µA ± 100 µA, Analog input voltage ≈ 1.25 V, REF2_5V = 1 | | 3 V | | | ±2 | LSB |
| $I_{DL(VREF)+}$ | Load current regulation, $V_{REF+}$ terminal (2) | $I_{VREF+}$ = 100 µA → 900 µA, $C_{VREF+}$ = 5 µF, ax ≈ 0.5 × $V_{REF+}$, Error of conversion result ≤ 1 LSB | | 3 V | | | 20 | ns |
| $C_{VREF+}$ | Capacitance at pin $V_{REF+}$ (3) | REFON = 1, 0 mA ≤ $I_{VREF+}$ ≤ $I_{VREF+}$max | | 2.2 V, 3 V | 5 | 10 | | µF |
| $T_{REF+}$ | Temperature coefficient of built-in reference (2) | $I_{VREF+}$ is a constant in the range of 0 mA ≤ $I_{VREF+}$ ≤ 1 mA | | 2.2 V, 3 V | | | ±100 | ppm/°C |
| $t_{REFON}$ | Settle time of internal reference voltage (see Figure 39 ) (4) (2) | $I_{VREF+}$ = 0.5 mA, $C_{VREF+}$ = 10 µF, $V_{REF+}$ = 1.5 V, $V_{AVCC}$ = 2.2 V | | 2.2 V | | | 17 | ms |

(1) Not production tested, limits characterized.
(2) Not production tested, limits verified by design.
(3) The internal buffer operational amplifier and the accuracy specifications require an external capacitor. All INL and DNL tests uses two capacitors between pins $V_{REF+}$ and $AV_{SS}$ and $V_{REF-}/V_{eREF-}$ and $AV_{SS}$: 10 µF tantalum and 100 nF ceramic.
(4) The condition is that the error in a conversion started after $t_{REFON}$ is less than ±0.5 LSB. The settling time depends on the external capacitive load.

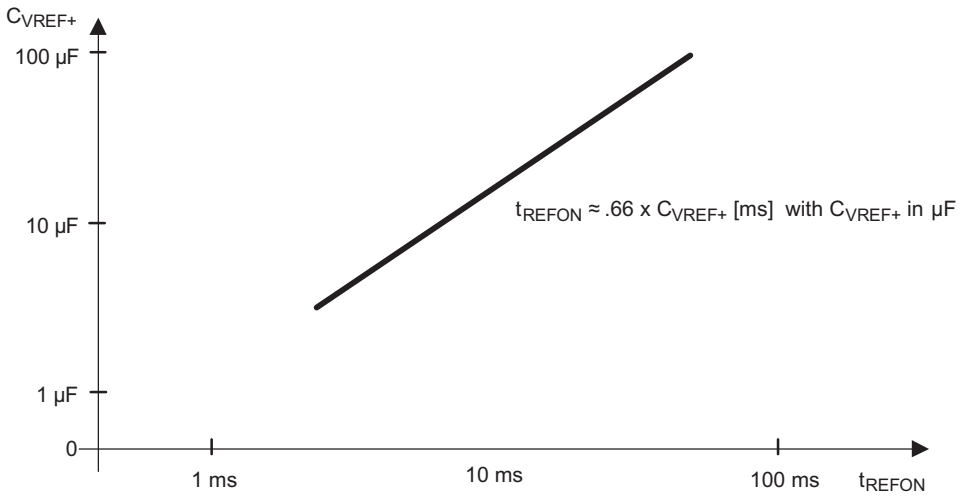



**Figure 39. Typical Settling Time of Internal Reference $t_{REFON}$ vs External Capacitor on $V_{REF+}$**


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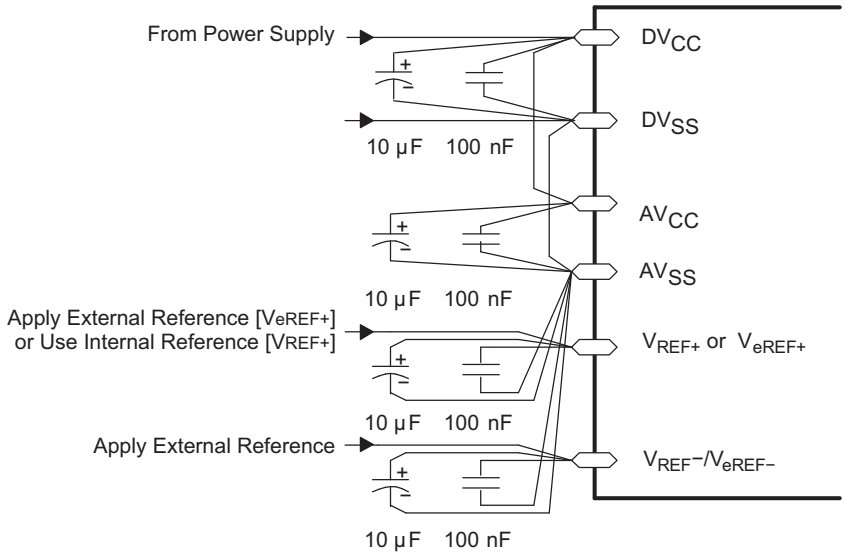



**Figure 40. Supply Voltage and Reference Voltage Design $V_{REF-}/V_{eREF-}$ External Supply**

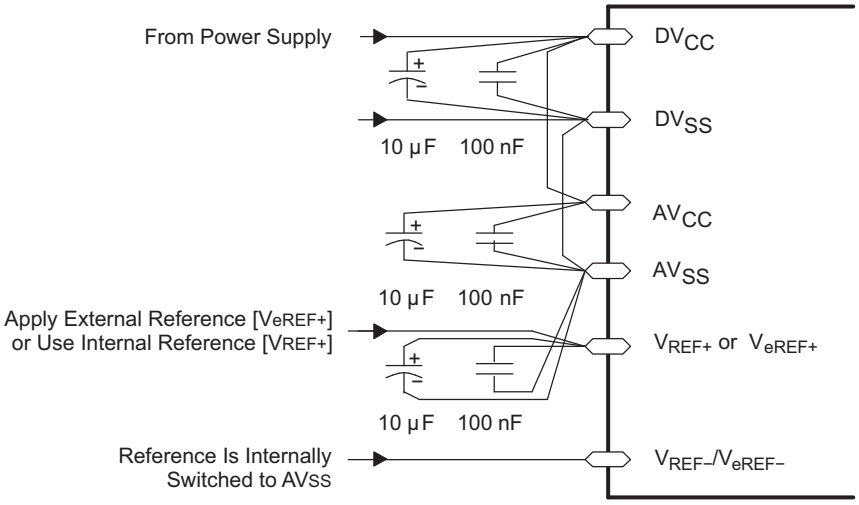



**Figure 41. Supply Voltage and Reference Voltage Design $V_{REF-}/V_{eREF-}$ = $AV_{SS}$, Internally Connected**

## 12-Bit ADC, Timing Parameters

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

| PARAMETER | | TEST CONDITIONS | $V_{CC}$ | MIN | NOM | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $f_{ADC12CLK}$ | | For specified performance of ADC12 linearity parameters | 2.2 V, 3 V | 0.45 | 5 | 6.3 | MHz |
| $f_{ADC12OSC}$ | Internal ADC12 oscillator | ADC12DIV = 0, $f_{ADC12CLK} = f_{ADC12OSC}$ | 2.2 V, 3 V | 3.7 | 5 | 6.3 | MHz |
| $t_{CONVERT}$ | Conversion time | $C_{VREF+} \geq 5$ µF, Internal oscillator, $f_{ADC12OSC}$ = 3.7 MHz to 6.3 MHz | 2.2 V, 3 V | 2.06 | | 3.51 | µs |
| | | External $f_{ADC12CLK}$ from ACLK, MCLK, or SMCLK, ADC12SSEL ≠ 0 | | | 13 × ADC12DIV × $1/f_{ADC12CLK}$ | | µs |
| $t_{ADC12ON}$ | Turn-on settling time of the ADC (1) | See (2) | | | | 100 | ns |
| $t_{Sample}$ | Sampling time (1) | $R_S$ = 400 Ω, $R_I$ = 1000 Ω, $C_I$ = 30 pF, $\tau = [R_S + R_I] \times C_I$ (3) | 3 V | 1220 | | | ns |
| | | | 2.2 V | 1400 | | | |

(1) Limits verified by design
(2) The condition is that the error in a conversion started after $t_{ADC12ON}$ is less than ±0.5 LSB. The reference and input signal are already settled.
(3) Approximately ten Tau (τ) are needed to get an error of less than ±0.5 LSB:
$t_{Sample} = \ln(2^{n+1}) \times (R_S + R_I) \times C_I + 800$ ns, where n = ADC resolution = 12, $R_S$ = external source resistance

## 12-Bit ADC, Linearity Parameters

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

| PARAMETER | | TEST CONDITIONS | $V_{CC}$ | MIN | NOM | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $E_I$ | Integral linearity error | 1.4 V ≤ ($V_{eREF+} - V_{REF-}/V_{eREF-}$) min ≤ 1.6 V | 2.2 V, 3 V | | | ±2 | LSB |
| | | 1.6 V < ($V_{eREF+} - V_{REF-}/V_{eREF-}$) min ≤ $V_{AVCC}$ | | | | ±1.7 | |
| $E_D$ | Differential linearity error | ($V_{eREF+} - V_{REF-}/V_{eREF-}$) min ≤ ($V_{eREF+} - V_{REF-}/V_{eREF-}$), $C_{VREF+}$ = 10 µF (tantalum) and 100 nF (ceramic) | 2.2 V, 3 V | | | ±1 | LSB |
| $E_O$ | Offset error | ($V_{eREF+} - V_{REF-}/V_{eREF-}$) min ≤ ($V_{eREF+} - V_{REF-}/V_{eREF-}$), Internal impedance of source RS < 100 Ω, $C_{VREF+}$ = 10 µF (tantalum) and 100 nF (ceramic) | 2.2 V, 3 V | | ±2 | ±4 | LSB |
| $E_G$ | Gain error | ($V_{eREF+} - V_{REF-}/V_{eREF-}$)min ≤ ($V_{eREF+} - V_{REF-}/V_{eREF-}$), $C_{VREF+}$ = 10 µF (tantalum) and 100 nF (ceramic) | 2.2 V, 3 V | | ±1.1 | ±2 | LSB |
| $E_T$ | Total unadjusted error | ($V_{eREF+} - V_{REF-}/V_{eREF-}$ )min ≤ ($V_{eREF+} - V_{REF-}/V_{eREF-}$), $C_{VREF+}$ = 10 µF (tantalum) and 100 nF (ceramic) | 2.2 V, 3 V | | ±2 | ±5 | LSB |


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

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

| PARAMETER | | TEST CONDITIONS | $V_{CC}$ | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $I_{SENSOR}$ | Operating supply current into $AV_{CC}$ terminal (1) | REFON = 0, INCH = 0Ah, ADC12ON = 1, $T_A$ = 25°C | 2.2 V | | 40 | 120 | µA |
| | | | 3V | | 60 | 160 | |
| $V_{SENSOR}$ (2) (3) | | ADC12ON = 1, INCH = 0Ah, $T_A$ = 0°C | 2.2 V | | 986 | | mV |
| | | | 3V | | 986 | | |
| $TC_{SENSOR}$ (3) | | ADC12ON = 1, INCH = 0Ah | 2.2 V | | 3.55 | 3.55 ± 3% | mV/°C |
| | | | 3V | | 3.55 | 3.55 ± 3% | |
| $t_{SENSOR(sample)}$ (3) | Sample time required if channel 10 is selected (4) | ADC12ON = 1, INCH = 0Ah, Error of conversion result ≤ 1 LSB | 2.2 V | 30 | | | µs |
| | | | 3V | 30 | | | |
| $I_{VMID}$ | Current into divider at channel 11 (5) | ADC12ON = 1, INCH = 0Bh | 2.2 V | | | NA | µA |
| | | | 3V | | | NA | |
| $V_{MID}$ | $AV_{CC}$ divider at channel 11 | ADC12ON = 1, INCH = 0Bh, $V_{MID}$ is ~0.5 × $V_{AVCC}$ | 2.2 V | | 1.1 | 1.1 ± 0.04 | V |
| | | | 3V | | 1.5 | 1.5 ± 0.04 | |
| $t_{VMID(sample)}$ | Sample time required if channel 11 is selected (6) | ADC12ON = 1, INCH = 0Bh, Error of conversion result ≤ 1 LSB | 2.2 V | 1400 | | | ns |
| | | | 3 V | 1220 | | | |

(1) The sensor current $I_{SENSOR}$ is consumed if (ADC12ON = 1 and REFON = 1), or (ADC12ON = 1 AND INCH = 0Ah and sample signal is high). Therefore it includes the constant current through the sensor and the reference.
(2) The temperature sensor offset can be as much as ±20°C. A single-point calibration is recommended to minimize the offset error of the built-in temperature sensor.
(3) Limits characterized
(4) The typical equivalent impedance of the sensor is 51 kΩ. The sample time required includes the sensor-on time $t_{SENSOR(on)}$
(5) No additional current is needed. The $V_{MID}$ is used during sampling.
(6) The on-time $t_{VMID(on)}$ is included in the sampling time $t_{VMID(sample)}$, no additional on time is needed.

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## Flash Memory

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

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

(1) The cumulative program time must not be exceeded when writing to a 64-byte flash block. This parameter applies to all programming methods: individual word/byte write and block write modes.
(2) These values are hardwired into the flash controller's state machine ($t_{FTG} = 1/f_{FTG}$).

## RAM

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

| PARAMETER | | TEST CONDITIONS | MIN | MAX | UNIT |
|---|---|---|---|---|---|
| $V_{(RAMh)}$ | RAM retention supply voltage (1) | CPU halted | 1.6 | | V |

(1) This parameter defines the minimum supply voltage $V_{CC}$ 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 | | TEST CONDITIONS | $V_{CC}$ | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $f_{TCK}$ | TCK input frequency | See (1) | 2.2 V | 0 | | 5 | MHz |
| | | | 3 V | 0 | | 10 | |
| $R_{Internal}$ | Internal pulldown resistance on TEST | See (2) | 2.2 V, 3 V | 25 | 60 | 90 | kΩ |

(1) $f_{TCK}$ may be restricted to meet the timing requirements of the module selected.
(2) TMS, TDI/TCLK, and TCK pullup resistors are implemented in all versions.

## JTAG Fuse(1)

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

| PARAMETER | | TEST CONDITIONS | MIN | MAX | UNIT |
|---|---|---|---|---|---|
| $V_{CC(FB)}$ | Supply voltage during fuse-blow condition | $T_A$ = 25°C | 2.5 | | V |
| $V_{FB}$ | Voltage level on TEST for fuse blow | | 6 | 7 | V |
| $I_{FB}$ | Supply current into TEST during fuse blow | | | 100 | mA |
| $t_{FB}$ | Time to blow fuse | | | 1 | ms |

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


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## APPLICATION INFORMATION

### Port P1 Pin Schematic: P1.0 to P1.7, Input/Output With Schmitt Trigger

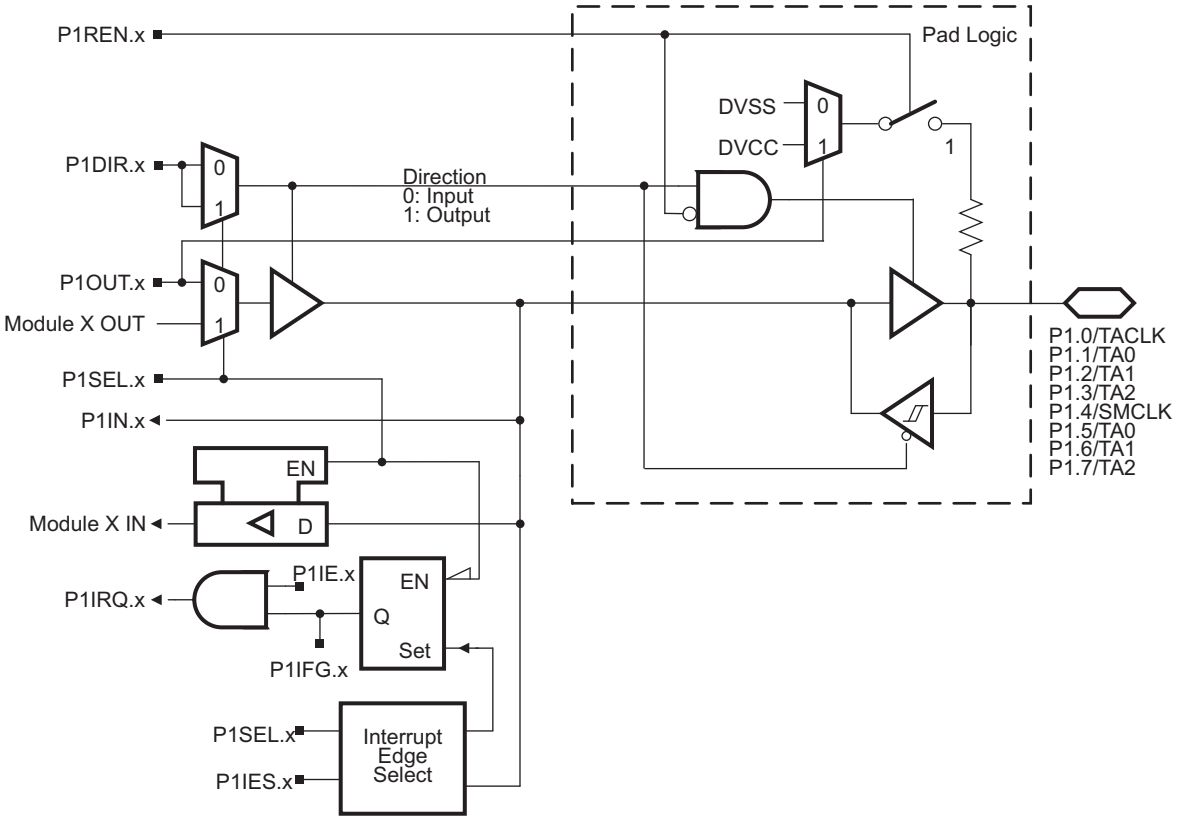


**Table 20. Port P1.0 to P1.7 Pin Functions**

| PIN NAME (P1.x) | x | FUNCTION | CONTROL BITS / SIGNALS | |
|---|---|---|---|---|
| | | | P1DIR.x | P1SEL.x |
| P1.0/TACLK | 0 | P1.0 (I/O) | I: 0; O: 1 | 0 |
| | | Timer_A3.TACLK | 0 | 1 |
| | | CAOUT | 1 | 1 |
| P1.1/TA0 | 1 | P1.1 (I/O) | I: 0; O: 1 | 0 |
| | | Timer_A3.CCI0A | 0 | 1 |
| | | Timer_A3.TA0 | 1 | 1 |
| P1.2/TA1 | 2 | P1.2 (I/O) | I: 0; O: 1 | 0 |
| | | Timer_A3.CCI1A | 0 | 1 |
| | | Timer_A3.TA1 | 1 | 1 |
| P1.3/TA2 | 3 | P1.3 (I/O) | I: 0; O: 1 | 0 |
| | | Timer_A3.CCI2A | 0 | 1 |
| | | Timer_A3.TA2 | 1 | 1 |
| P1.4/SMCLK | 4 | P1.4 (I/O) | I: 0; O: 1 | 0 |
| | | SMCLK | 1 | 1 |
| P1.5/TA0 | 5 | P1.5 (I/O) | I: 0; O: 1 | 0 |
| | | Timer_A3.TA0 | 1 | 1 |
| P1.6/TA1 | 6 | P1.6 (I/O) | I: 0; O: 1 | 0 |
| | | Timer_A3.TA1 | 1 | 1 |
| P1.7/TA2 | 7 | P1.7 (I/O) | I: 0; O: 1 | 0 |
| | | Timer_A3.TA2 | 1 | 1 |


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## Port P2 Pin Schematic: P2.0 to P2.4, P2.6, and P2.7, Input/Output With Schmitt Trigger

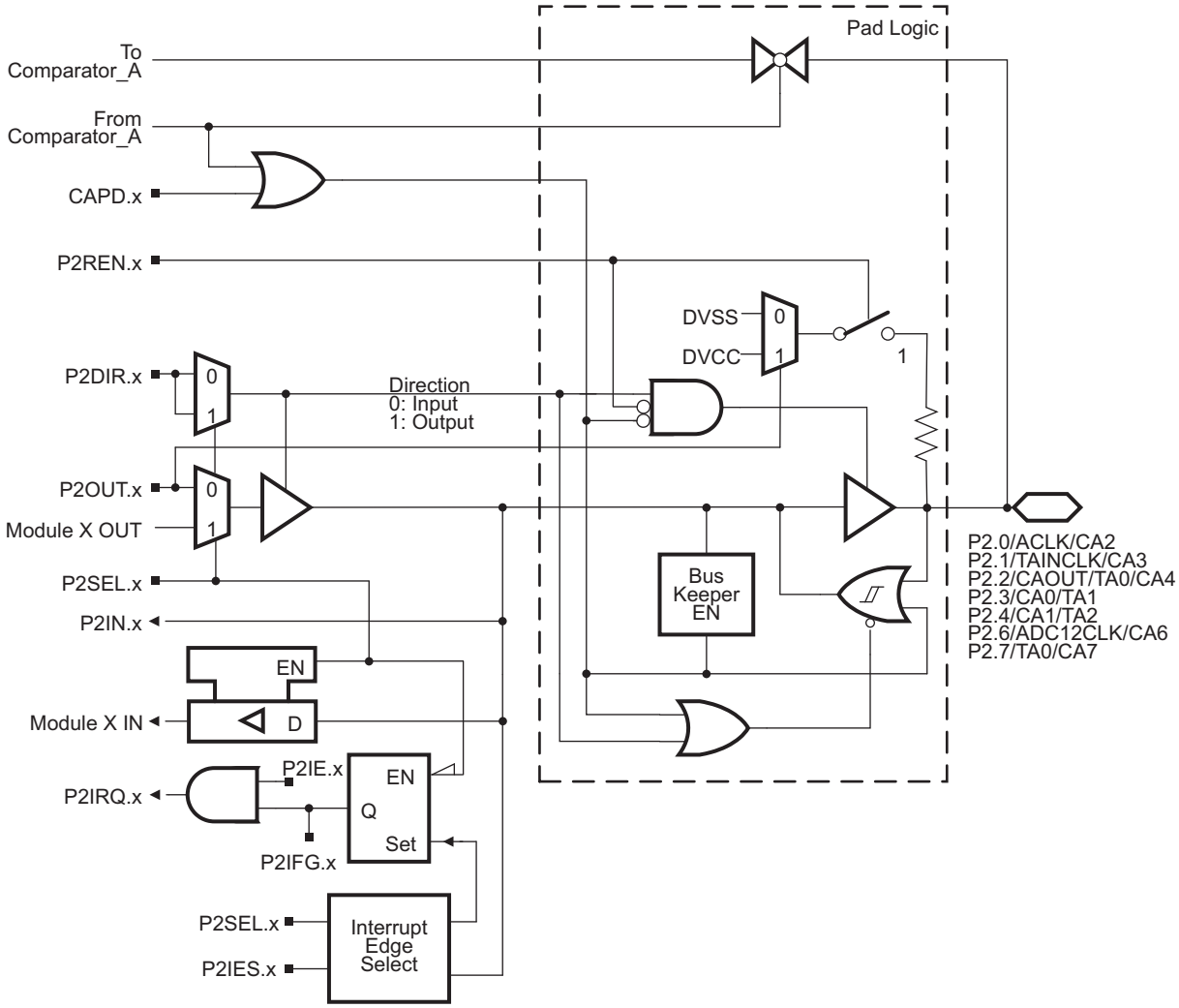


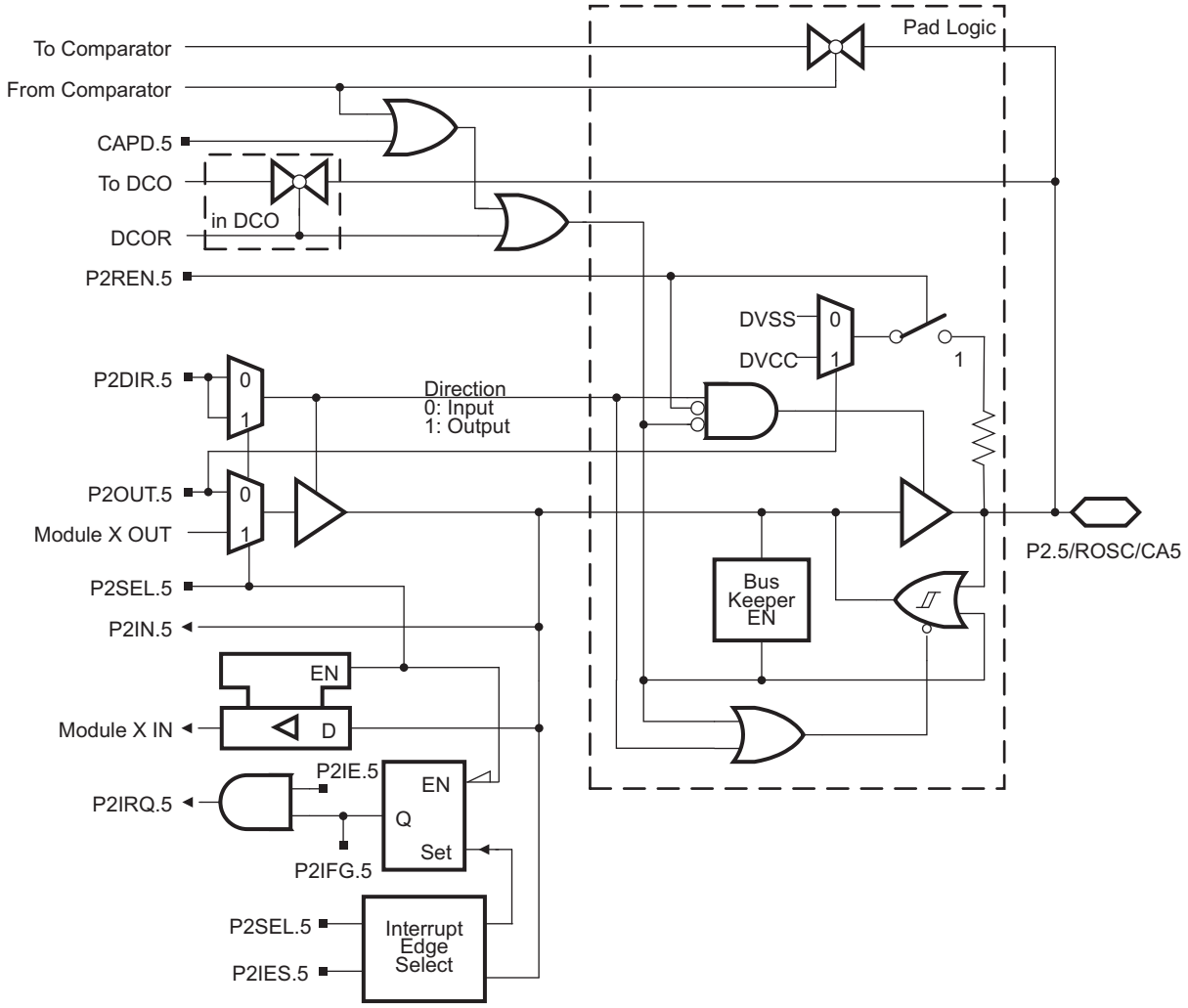
**Table 21. Port P2.0 to P2.4, P2.6, and P2.7 Pin Functions**

| PIN NAME (P2.x) | x | FUNCTION | CONTROL BITS / SIGNALS(1) | | |
|---|---|---|---|---|---|
| | | | CAPD.x | P2DIR.x | P2SEL.x |
| P2.0/ACLK/CA2 | 0 | P2.0 (I/O) | 0 | I: 0; O: 1 | 0 |
| | | ACLK | 0 | 1 | 1 |
| | | CA2 | 1 | X | X |
| P2.1/TAINCLK/CA3 | 1 | P2.1 (I/O) | 0 | I: 0; O: 1 | 0 |
| | | Timer_A3.INCLK | 0 | 0 | 1 |
| | | $DV_{SS}$ | 0 | 1 | 1 |
| | | CA3 | 1 | X | X |
| P2.2/CAOUT/TA0/CA4 | 2 | P2.2 (I/O) | 0 | I: 0; O: 1 | 0 |
| | | CAOUT | 0 | 1 | 1 |
| | | TA0 | 0 | 0 | 1 |
| | | CA4 | 1 | X | X |
| P2.3/CA0/TA1 | 3 | P2.3 (I/O) | 0 | I: 0; O: 1 | 0 |
| | | Timer_A3.TA1 | 0 | 1 | 1 |
| | | CA0 | 1 | X | X |
| P2.4/CA1/TA2 | 4 | P2.4 (I/O) | 0 | I: 0; O: 1 | 0 |
| | | Timer_A3.TA2 | 0 | 1 | X |
| | | CA1 | 1 | X | 1 |
| P2.6/ADC12CLK(2)/CA6 | 6 | P2.6 (I/O) | 0 | I: 0; O: 1 | 0 |
| | | ADC12CLK(2) | 0 | 1 | 1 |
| | | CA6 | 1 | X | X |
| P2.7/TA0/CA7 | 7 | P2.7 (I/O) | 0 | I: 0; O: 1 | 0 |
| | | Timer_A3.TA0 | 0 | 1 | 1 |
| | | CA7 | 1 | X | X |

(1) X = Don't care
(2) MSP430F24x and MSP430F23x devices only


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

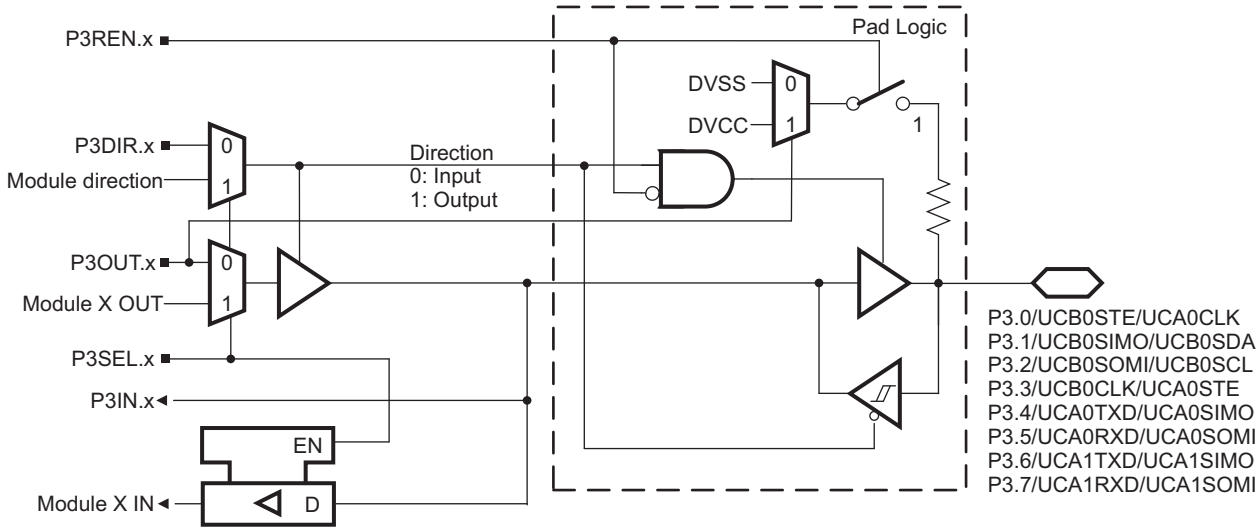



### Table 22. Port P2.5 Pin Functions

| PIN NAME (P2.x) | x | FUNCTION | CONTROL BITS / SIGNALS[1] | | | |
|---|---|---|---|---|---|---|
| | | | CAPD | DCOR | P2DIR.5 | P2SEL.5 |
| P2.5/$R_{OSC}$/CA5 | 5 | P2.5 (I/O) | 0 | 0 | I: 0; O: 1 | 0 |
| | | $R_{OSC}$ | 0 | 1 | X | X |
| | | $DV_{SS}$ | 0 | 0 | 1 | 1 |
| | | CA5 | 1 or selected | 0 | X | X |

(1) X = Don't care

## Port P3 Pin Schematic: P3.0 to P3.7, Input/Output With Schmitt Trigger




### Table 23. Port P3.0 to P3.7 Pin Functions

| PIN NAME (P3.x) | x | FUNCTION | CONTROL BITS / SIGNALS[1] | |
|---|---|---|---|---|
| | | | P3DIR.x | P3SEL.x |
| P3.0/UCB0STE/UCA0CLK | 0 | P3.0 (I/O) | I: 0; O: 1 | 0 |
| | | UCB0STE/UCA0CLK[2][3] | X | 1 |
| P3.1/UCB0SIMO/UCB0SDA | 1 | P3.1 (I/O) | I: 0; O: 1 | 0 |
| | | UCB0SIMO/UCB0SDA[2][4] | X | 1 |
| P3.2/UCB0SOMI/UCB0SCL | 2 | P3.2 (I/O) | I: 0; O: 1 | 0 |
| | | UCB0SOMI/UCB0SCL[2][4] | X | 1 |
| P3.3/UCB0CLK/UCA0STE | 3 | P3.3 (I/O) | I: 0; O: 1 | 0 |
| | | UCB0CLK/UCA0STE[2] | X | 1 |
| P3.4/UCA0TXD/UCA0SIMO | 4 | P3.4 (I/O) | I: 0; O: 1 | 0 |
| | | UCA0TXD/UCA0SIMO[2] | X | 1 |
| P3.5/UCA0RXD/UCA0SOMI | 5 | P3.5 (I/O) | I: 0; O: 1 | 0 |
| | | UCA0RXD/UCA0SOMI[2] | X | 1 |
| P3.6/UCA1TXD[5]/UCA1SIMO[5] | 6 | P3.6 (I/O) | I: 0; O: 1 | 0 |
| | | UCA1TXD[5]/UCA1SIMO[5][2] | X | 1 |
| P3.7/UCA1RXD[5]/UCA1SOMI[5] | 7 | P3.7 (I/O) | I: 0; O: 1 | 0 |
| | | UCA1RXD[5]/UCA1SOMI[5][2] | X | 1 |

(1) X = Don't care
(2) The pin direction is controlled by the USCI module.
(3) UCA0CLK function takes precedence over UCB0STE function. If the pin is required as UCA0CLK input or output, USCI A/B0 is forced to 3-wire SPI mode if 4-wire SPI mode is selected.
(4) If $I^2C$ functionality is selected, the output drives only the logical 0 to $V_{SS}$ level.
(5) MSP430F24x and MSP430F24x1 devices only


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## Port P4 Pin Schematic: P4.0 to P4.7, Input/Output With Schmitt Trigger

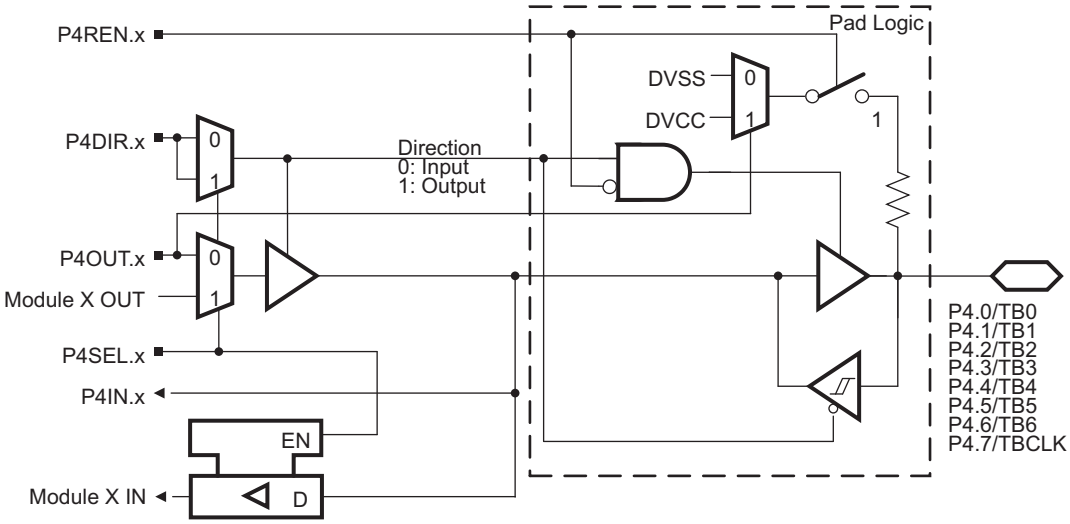



**Table 24. Port P4.0 to P4.7 Pin Functions**

| PIN NAME (P4.x) | x | FUNCTION | CONTROL BITS / SIGNALS | |
|---|---|---|---|---|
| | | | P4DIR.x | P4SEL.x |
| P4.0/TB0 | 0 | P4.0 (I/O) | I: 0; O: 1 | 0 |
| | | Timer_B7.CCI0A and Timer_B7.CCI0B | 0 | 1 |
| | | Timer_B7.TB0 | 1 | 1 |
| P4.1/TB1 | 1 | P4.1 (I/O) | I: 0; O: 1 | 0 |
| | | Timer_B7.CCI1A and Timer_B7.CCI1B | 0 | 1 |
| | | Timer_B7.TB1 | 1 | 1 |
| P4.2/TB2 | 2 | P4.2 (I/O) | I: 0; O: 1 | 0 |
| | | Timer_B7.CCI2A and Timer_B7.CCI2B | 0 | 1 |
| | | Timer_B7.TB2 | 1 | 1 |
| P4.3/TB3(1) | 3 | P4.3 (I/O) | I: 0; O: 1 | 0 |
| | | Timer_B7.CCI3A and Timer_B7.CCI3B(1) | 0 | 1 |
| | | Timer_B7.TB3(1) | 1 | 1 |
| P4.4/TB4(1) | 4 | P4.4 (I/O) | I: 0; O: 1 | 0 |
| | | Timer_B7.CCI4A and Timer_B7.CCI4B(1) | 0 | 1 |
| | | Timer_B7.TB4(1) | 1 | 1 |
| P4.5/TB5(1) | 5 | P4.5 (I/O) | I: 0; O: 1 | 0 |
| | | Timer_B7.CCI5A and Timer_B7.CCI5B(1) | 0 | 1 |
| | | Timer_B7.TB5(1) | 1 | 1 |
| P4.6/TB6(1) | 6 | P4.6 (I/O) | I: 0; O: 1 | 0 |
| | | Timer_B7.CCI6A and Timer_B7.CCI6B(1) | 0 | 1 |
| | | Timer_B7.TB6(1) | 1 | 1 |
| P4.7/TBCLK | 7 | P4.7 (I/O) | I: 0; O: 1 | 0 |
| | | Timer_B7.TBCLK | 0 | 1 |

(1) MSP430F24x and MSP430F24x1 devices only

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## Port P5 Pin Schematic: P5.0 to P5.3, Input/Output With Schmitt Trigger

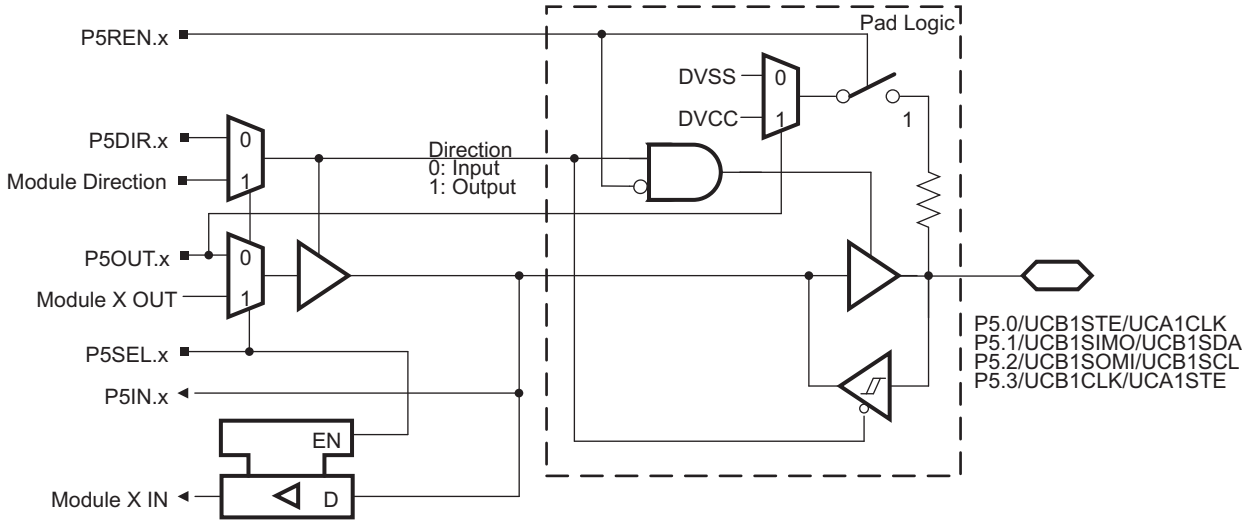



**Table 25. Port P5.0 to P5.3 Pin Functions**

| PIN NAME (P5.x) | x | FUNCTION | CONTROL BITS / SIGNALS(1) | |
|---|---|---|---|---|
| | | | P5DIR.x | P5SEL.x |
| P5.0/UCB1STE(2)/UCA1CLK(2) | 0 | P5.0 (I/O) | I: 0; O: 1 | 0 |
| | | UCB1STE(2)/UCA1CLK(2)(3)(4) | X | 1 |
| P5.1/UCB1SIMO(2)/UCB1SDA(2) | 1 | P5.1 (I/O) | I: 0; O: 1 | 0 |
| | | UCB1SIMO(2)/UCB1SDA(2)(3)(5) | X | 1 |
| P5.2/UCB1SOMI(2)/UCB1SCL(2) | 2 | P5.2 (I/O) | I: 0; O: 1 | 0 |
| | | UCB1SOMI(2)/UCB1SCL(2)(3)(5) | X | 1 |
| P5.3/UCB1CLK(2)/UCA1STE(2) | 3 | P5.3 (I/O) | I: 0; O: 1 | 0 |
| | | UCB1CLK(2)/UCA1STE(2)(3) | X | 1 |

(1) X = Don't care
(2) MSP430F24x and MSP430F24x1 devices only
(3) The pin direction is controlled by the USCI module.
(4) UCA0CLK function takes precedence over UCB0STE function. If the pin is required as UCA0CLK input or output, USCI A/B0 is forced to 3-wire SPI mode if 4-wire SPI mode is selected.
(5) If $I^2C$ functionality is selected, the output drives only the logical 0 to $V_{SS}$ level.


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## Port P5 Pin Schematic: P5.4 to P5.7, Input/Output With Schmitt Trigger

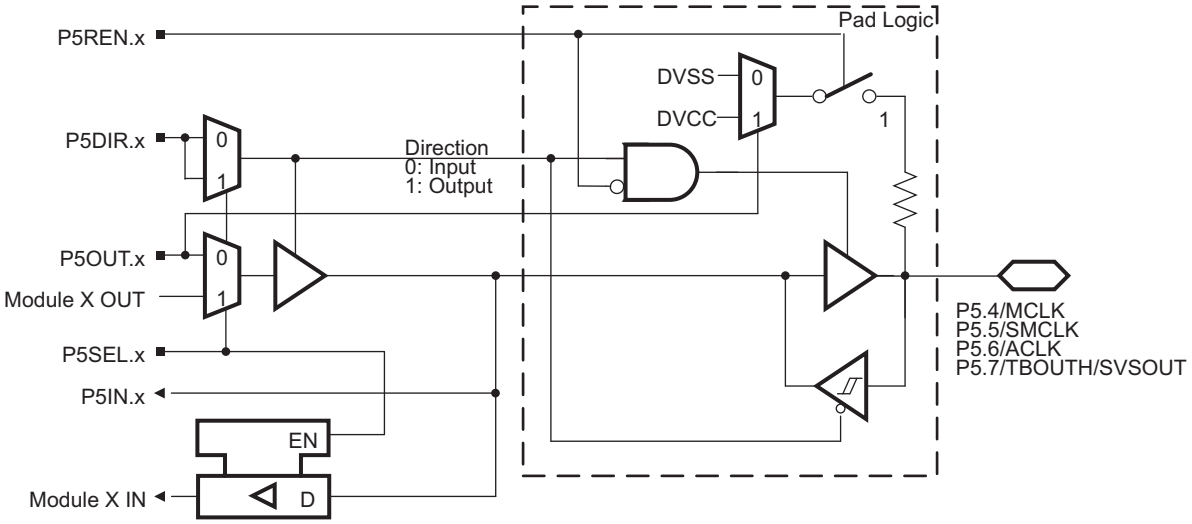



**Table 26. Port P5.4 to P5.7 Pin Functions**

| PIN NAME (P5.x) | x | FUNCTION | CONTROL BITS / SIGNALS | |
|---|---|---|---|---|
| | | | P5DIR.x | P5SEL.x |
| P5.4/MCLK | 4 | P5.4 (I/O) | I: 0; O: 1 | 0 |
| | | MCLK | 1 | 1 |
| P5.5/SMCLK | 5 | P5.5 (I/O) | I: 0; O: 1 | 0 |
| | | SMCLK | 1 | 1 |
| P5.6/ACLK | 6 | P5.6 (I/O) | I: 0; O: 1 | 0 |
| | | ACLK | 1 | 1 |
| P5.7/TBOUTH/SVSOUT | 7 | P5.7 (I/O) | I: 0; O: 1 | 0 |
| | | Timer_B7.TBOUTH | 0 | 1 |
| | | SVSOUT | 1 | 1 |

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## Port P6 Pin Schematic: P6.0 to P6.6, Input/Output With Schmitt Trigger

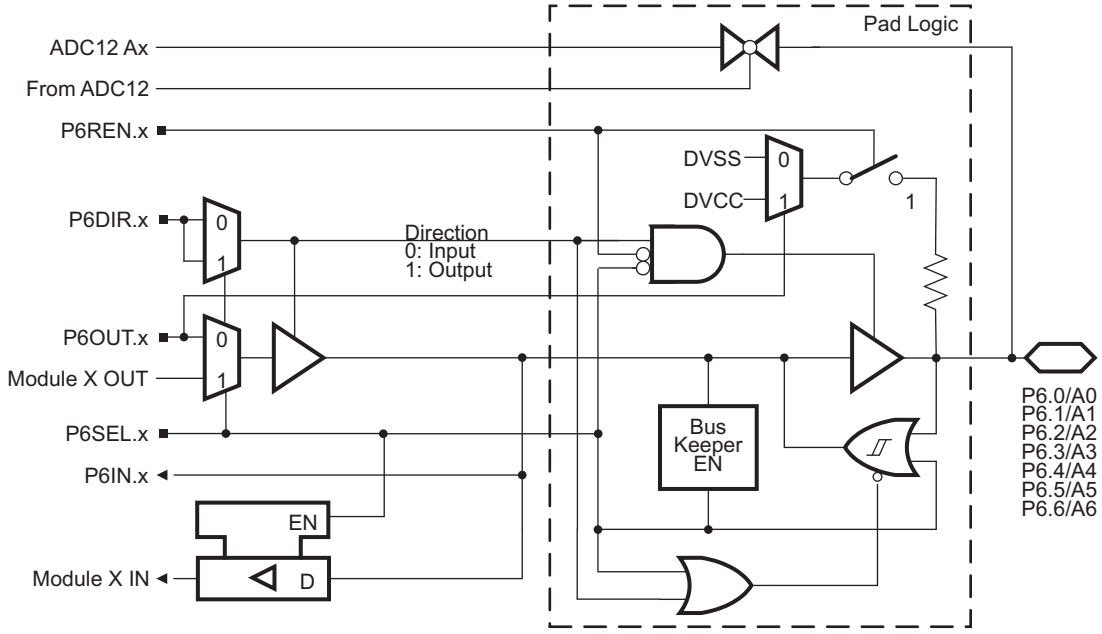



**Table 27. Port P6.0 to P6.6 Pin Functions**

| PIN NAME (P6.x) | x | FUNCTION | CONTROL BITS / SIGNALS(1) | |
|---|---|---|---|---|
| | | | P6DIR.x | P6SEL.x |
| P6.0/A0(2) | 0 | P5.0 (I/O) | I: 0; O: 1 | 0 |
| | | A0(2) | X | 1 |
| P6.1/A1(2) | 1 | P5.1 (I/O) | I: 0; O: 1 | 0 |
| | | A1(2) | X | 1 |
| P6.2/A2(2) | 2 | P5.2 (I/O) | I: 0; O: 1 | 0 |
| | | A2(2) | X | 1 |
| P6.3/A3(2) | 3 | P5.3 (I/O) | I: 0; O: 1 | 0 |
| | | A3(2) | X | 1 |
| P6.4/A4(2) | 4 | P5.4 (I/O) | I: 0; O: 1 | 0 |
| | | A4(2) | X | 1 |
| P6.5/A5(2) | 5 | P5.5 (I/O) | I: 0; O: 1 | 0 |
| | | A5(2) | X | 1 |
| P6.6/A6(2) | 6 | P6.6 (I/O) | I: 0; O: 1 | 0 |
| | | A6(2) | X | 1 |

(1) X = Don't care
(2) MSP430F24x and MSP430F23x devices only


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## Port P6 Pin Schematic: P6.7, Input/Output With Schmitt Trigger

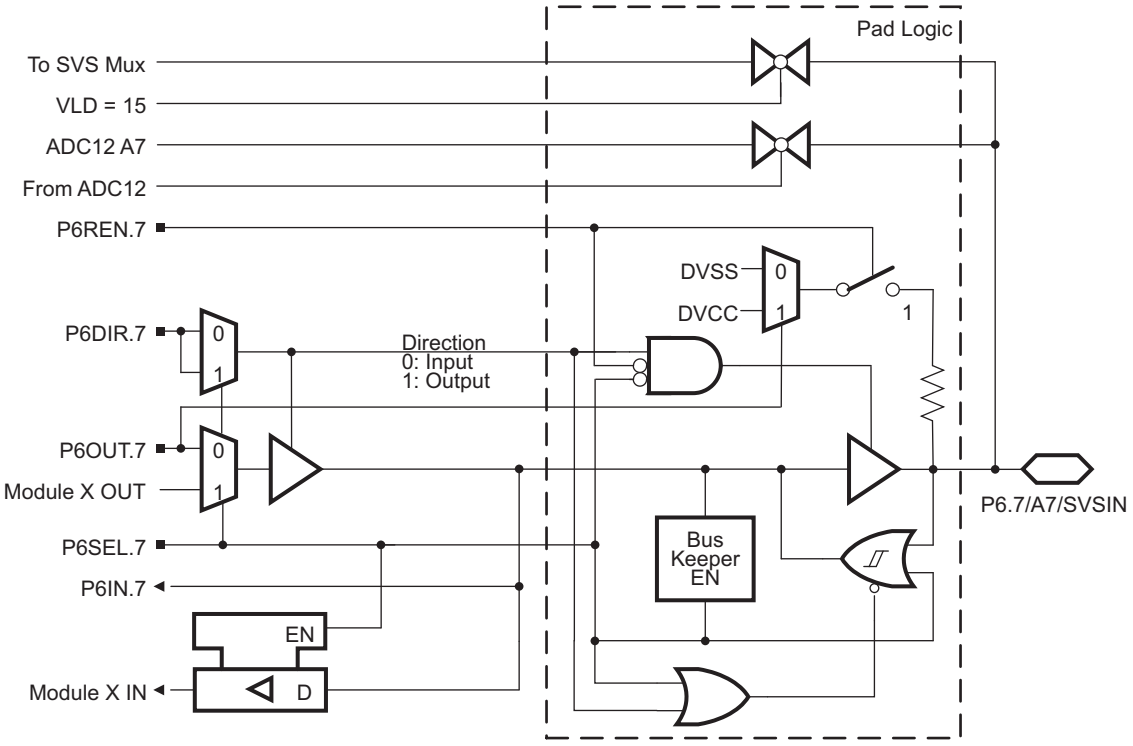
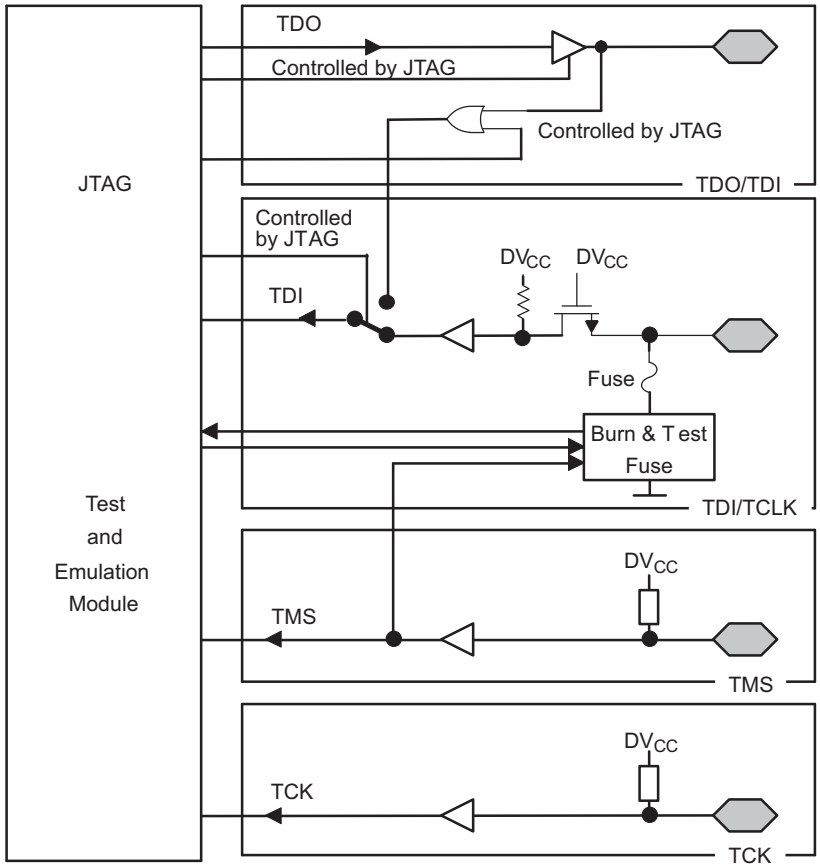



**Table 28. Port P6.7 Pin Functions**

| PIN NAME (P6.x) | x | FUNCTION | CONTROL BITS / SIGNALS(1) | | |
|---|---|---|---|---|---|
| | | | P6DIR.x | P6SEL.x | INCHy |
| P6.7/A7/SVSIN | 7 | P6.7 (I/O) | I: 0; O: 1 | 0 | 0 |
| | | $DV_{SS}$ | 1 | 1 | 0 |
| | | A7(2) | X | X | 1 (y = 7) |
| | | SVSIN (VLD = 15) | X | X | 1 |

(1) X = Don't care
(2) MSP430F24x and MSP430F23x devices only

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




During Programming Activity and During Blowing of the Fuse, Pin TDO/TDI Is Used to Apply the Test Input Data for JTAG Circuitry


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## 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 42). Therefore, the additional current flow can be prevented by holding the TMS pin high (default condition).

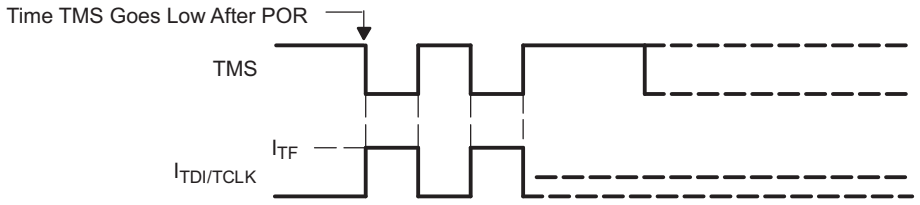



**Figure 42. Fuse Check Mode Current**

**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.

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## REVISION HISTORY

| LITERATURE NUMBER | SUMMARY |
|---|---|
| SLAS547 | Product Preview release |
| SLAS547A | Production Data release |
| SLAS547B | Corrected terminal names and descriptions for pins 34 and 35 in "Terminal Functions - MSP430F23x" (page 9)<br>Corrected terminal names for pins 13, 14, and 15 in "Terminal Functions - MSP430F24x1" (page 13)<br>Corrected interrupt source and flag entries for USCI_A1/USCI_B1 in "interrupt vector addresses" table (page 17)<br>Changed index values from 1-3 to 0-2 in Figures 23 to 26 (pages 52 and 54)<br>Changed $f_{max,BITCLK}$ and $t_\tau$ parameters in "USCI (UART mode)" table (page 56)<br>Corrected "Port P1.0 to P1.7 pin functions" table (page 72)<br>Removed incorrect CAPD.x column in "Port P6.0 to P6.6 pin functions" table (page 80) |
| SLAS547C | Added Development Tool Support section (page 2)<br>Updated parametric values in "low-power mode supply current into $V_{CC}$ excluding external current" table (page 34) |
| SLAS547D | Updated notes and $t_{CMErase}$ MIN value "flash memory" table (page 34) |
| SLAS547E | Changed limits on $t_{d(SVSon)}$ parameter (page 41) |
| SLAS547F | Changed "Port 6.0 to 6.6 Pin Functions" table (page 77)<br>Changed "Port 6.7 Pin Functions" table (page 78) |
| SLAS547G | Changed $T_{stg}$, Programmed device, to -55°C to 150°C in Absolute Maximum Ratings |
| SLAS547H | Corrected formatting error of $T_A$ column in Active Mode Supply Current (both $I_{AM,1MHz}$ parameters) and in Low-Power-Mode Supply Currents ($I_{LPM0,1MHz}$ and $I_{LPM0,100kHz}$ parameters) |
| SLAS547I | Corrected number of capture/compare registers in description in Timer_B3 (MSP430F23x Devices).<br>Added typical test conditions in Recommended Operating Conditions.<br>Removed "Timer_A3.CCIxA" entries from P1.5 through P1.7 in Table 20. |


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## PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead finish/ Ball material (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MSP430F233TPM | ACTIVE | LQFP | PM | 64 | 160 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 105 | M430F233T REV # | Samples |
| MSP430F233TPMR | ACTIVE | LQFP | PM | 64 | 1000 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 105 | M430F233T REV # | Samples |
| MSP430F233TRGCR | ACTIVE | VQFN | RGC | 64 | 2500 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 105 | M430F233T | Samples |
| MSP430F233TRGCT | ACTIVE | VQFN | RGC | 64 | 250 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 105 | M430F233T | Samples |
| MSP430F235TPM | ACTIVE | LQFP | PM | 64 | 160 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 105 | M430F235T REV # | Samples |
| MSP430F235TPMR | ACTIVE | LQFP | PM | 64 | 1000 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 105 | M430F235T REV # | Samples |
| MSP430F235TRGCR | ACTIVE | VQFN | RGC | 64 | 2500 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 105 | M430F235T | Samples |
| MSP430F235TRGCT | ACTIVE | VQFN | RGC | 64 | 250 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 105 | M430F235T | Samples |
| MSP430F2410TPM | ACTIVE | LQFP | PM | 64 | 160 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 105 | M430F2410T REV # | Samples |
| MSP430F2410TPMR | ACTIVE | LQFP | PM | 64 | 1000 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 105 | M430F2410T REV # | Samples |
| MSP430F2410TRGCR | ACTIVE | VQFN | RGC | 64 | 2500 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 105 | M430F2410T | Samples |
| MSP430F2410TRGCT | ACTIVE | VQFN | RGC | 64 | 250 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 105 | M430F2410T | Samples |
| MSP430F2471TPM | ACTIVE | LQFP | PM | 64 | 160 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 105 | M430F2471T REV # | Samples |
| MSP430F2471TPMR | ACTIVE | LQFP | PM | 64 | 1000 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 105 | M430F2471T REV # | Samples |
| MSP430F2471TRGCR | ACTIVE | VQFN | RGC | 64 | 2500 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 105 | M430F2471T | Samples |
| MSP430F2471TRGCT | ACTIVE | VQFN | RGC | 64 | 250 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 105 | M430F2471T | Samples |
| MSP430F247TPM | ACTIVE | LQFP | PM | 64 | 160 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 105 | M430F247T REV # | Samples |
| MSP430F247TPMR | ACTIVE | LQFP | PM | 64 | 1000 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 105 | M430F247T REV # | Samples |

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead finish/ Ball material (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|---|---|---|---|---|---|---|---|---|---|---|---|
| MSP430F247TRGCR | ACTIVE | VQFN | RGC | 64 | 2500 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 105 | M430F247T | Samples |
| MSP430F247TRGCT | ACTIVE | VQFN | RGC | 64 | 250 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 105 | M430F247T | Samples |
| MSP430F2481TPM | ACTIVE | LQFP | PM | 64 | 160 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 105 | M430F2481T REV # | Samples |
| MSP430F2481TPMR | ACTIVE | LQFP | PM | 64 | 1000 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 105 | M430F2481T REV # | Samples |
| MSP430F2481TRGCR | ACTIVE | VQFN | RGC | 64 | 2500 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 105 | M430F2481T | Samples |
| MSP430F2481TRGCT | ACTIVE | VQFN | RGC | 64 | 250 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 105 | M430F2481T | Samples |
| MSP430F248TPM | ACTIVE | LQFP | PM | 64 | 160 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 105 | M430F248T REV # | Samples |
| MSP430F248TPMR | ACTIVE | LQFP | PM | 64 | 1000 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 105 | M430F248T REV # | Samples |
| MSP430F248TRGCR | ACTIVE | VQFN | RGC | 64 | 2500 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 105 | M430F248T | Samples |
| MSP430F248TRGCT | ACTIVE | VQFN | RGC | 64 | 250 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 105 | M430F248T | Samples |
| MSP430F2491TPM | ACTIVE | LQFP | PM | 64 | 160 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 105 | M430F2491T REV # | Samples |
| MSP430F2491TPMR | ACTIVE | LQFP | PM | 64 | 1000 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 105 | M430F2491T REV # | Samples |
| MSP430F2491TRGCR | ACTIVE | VQFN | RGC | 64 | 2500 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 105 | M430F2491T | Samples |
| MSP430F2491TRGCT | ACTIVE | VQFN | RGC | 64 | 250 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 105 | M430F2491T | Samples |
| MSP430F249TPM | ACTIVE | LQFP | PM | 64 | 160 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 105 | M430F249T REV # | Samples |
| MSP430F249TPMR | ACTIVE | LQFP | PM | 64 | 1000 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 105 | M430F249T REV # | Samples |
| MSP430F249TRGCR | ACTIVE | VQFN | RGC | 64 | 2500 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 105 | M430F249T | Samples |
| MSP430F249TRGCT | ACTIVE | VQFN | RGC | 64 | 250 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 105 | M430F249T | Samples |

**(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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**OTHER QUALIFIED VERSIONS OF MSP430F249 :**

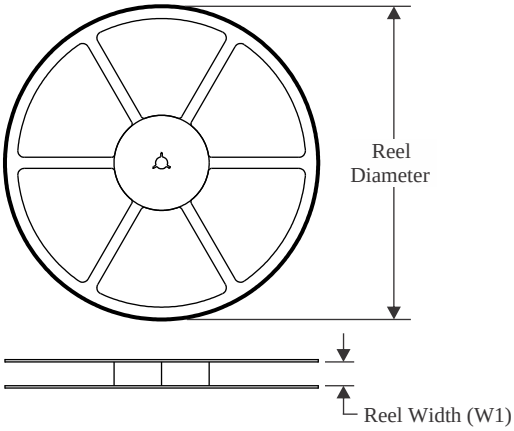
- Enhanced Product: MSP430F249-EP

NOTE: Qualified Version Definitions:

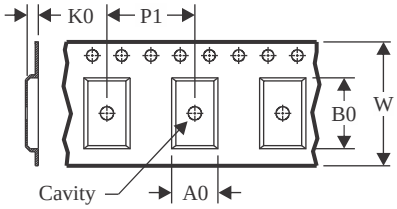
- Enhanced Product - Supports Defense, Aerospace and Medical Applications

## TAPE AND REEL INFORMATION

**REEL DIMENSIONS**

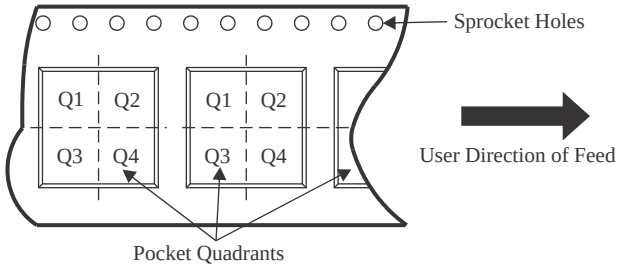



**TAPE DIMENSIONS**




| | |
|---|---|
| A0 | Dimension designed to accommodate the component width |
| B0 | Dimension designed to accommodate the component length |
| K0 | Dimension designed to accommodate the component thickness |
| W | Overall width of the carrier tape |
| P1 | Pitch between successive cavity centers |

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

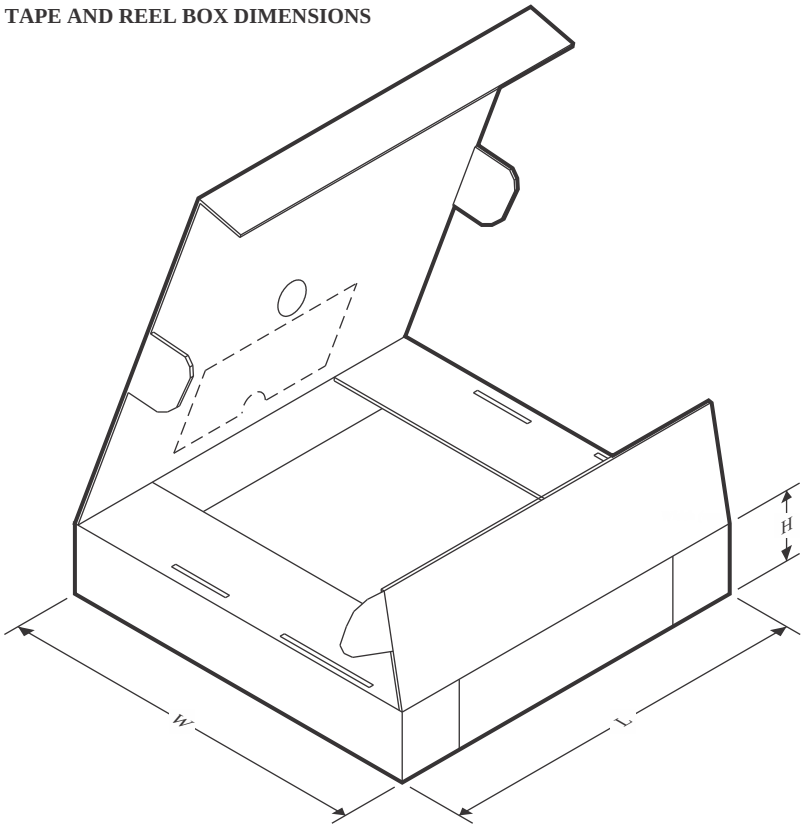



*All dimensions are nominal

| 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MSP430F233TPMR | LQFP | PM | 64 | 1000 | 330.0 | 24.4 | 13.0 | 13.0 | 2.1 | 16.0 | 24.0 | Q2 |
| MSP430F233TRGCR | VQFN | RGC | 64 | 2500 | 330.0 | 16.4 | 9.3 | 9.3 | 1.5 | 12.0 | 16.0 | Q2 |
| MSP430F233TRGCT | VQFN | RGC | 64 | 250 | 180.0 | 16.4 | 9.3 | 9.3 | 1.5 | 12.0 | 16.0 | Q2 |
| MSP430F235TPMR | LQFP | PM | 64 | 1000 | 330.0 | 24.4 | 13.0 | 13.0 | 2.1 | 16.0 | 24.0 | Q2 |
| MSP430F235TRGCR | VQFN | RGC | 64 | 2500 | 330.0 | 16.4 | 9.3 | 9.3 | 1.5 | 12.0 | 16.0 | Q2 |
| MSP430F235TRGCT | VQFN | RGC | 64 | 250 | 180.0 | 16.4 | 9.3 | 9.3 | 1.5 | 12.0 | 16.0 | Q2 |
| MSP430F2410TPMR | LQFP | PM | 64 | 1000 | 330.0 | 24.4 | 13.0 | 13.0 | 2.1 | 16.0 | 24.0 | Q2 |
| MSP430F2410TRGCR | VQFN | RGC | 64 | 2500 | 330.0 | 16.4 | 9.3 | 9.3 | 1.5 | 12.0 | 16.0 | Q2 |
| MSP430F2410TRGCT | VQFN | RGC | 64 | 250 | 180.0 | 16.4 | 9.3 | 9.3 | 1.5 | 12.0 | 16.0 | Q2 |
| MSP430F2471TPMR | LQFP | PM | 64 | 1000 | 330.0 | 24.4 | 13.0 | 13.0 | 2.1 | 16.0 | 24.0 | Q2 |
| MSP430F2471TRGCR | VQFN | RGC | 64 | 2500 | 330.0 | 16.4 | 9.3 | 9.3 | 1.5 | 12.0 | 16.0 | Q2 |
| MSP430F2471TRGCT | VQFN | RGC | 64 | 250 | 180.0 | 16.4 | 9.3 | 9.3 | 1.5 | 12.0 | 16.0 | Q2 |
| MSP430F247TPMR | LQFP | PM | 64 | 1000 | 330.0 | 24.4 | 13.0 | 13.0 | 2.1 | 16.0 | 24.0 | Q2 |
| MSP430F247TRGCR | VQFN | RGC | 64 | 2500 | 330.0 | 16.4 | 9.3 | 9.3 | 1.5 | 12.0 | 16.0 | Q2 |
| MSP430F247TRGCT | VQFN | RGC | 64 | 250 | 180.0 | 16.4 | 9.3 | 9.3 | 1.5 | 12.0 | 16.0 | Q2 |
| MSP430F2481TPMR | LQFP | PM | 64 | 1000 | 330.0 | 24.4 | 13.0 | 13.0 | 2.1 | 16.0 | 24.0 | Q2 |

| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MSP430F2481TRGCR | VQFN | RGC | 64 | 2500 | 330.0 | 16.4 | 9.3 | 9.3 | 1.5 | 12.0 | 16.0 | Q2 |
| MSP430F2481TRGCT | VQFN | RGC | 64 | 250 | 180.0 | 16.4 | 9.3 | 9.3 | 1.5 | 12.0 | 16.0 | Q2 |
| MSP430F248TPMR | LQFP | PM | 64 | 1000 | 330.0 | 24.4 | 13.0 | 13.0 | 2.1 | 16.0 | 24.0 | Q2 |
| MSP430F248TRGCR | VQFN | RGC | 64 | 2500 | 330.0 | 16.4 | 9.3 | 9.3 | 1.5 | 12.0 | 16.0 | Q2 |
| MSP430F248TRGCT | VQFN | RGC | 64 | 250 | 180.0 | 16.4 | 9.3 | 9.3 | 1.5 | 12.0 | 16.0 | Q2 |
| MSP430F2491TPMR | LQFP | PM | 64 | 1000 | 330.0 | 24.4 | 13.0 | 13.0 | 2.1 | 16.0 | 24.0 | Q2 |
| MSP430F2491TRGCR | VQFN | RGC | 64 | 2500 | 330.0 | 16.4 | 9.3 | 9.3 | 1.5 | 12.0 | 16.0 | Q2 |
| MSP430F2491TRGCT | VQFN | RGC | 64 | 250 | 180.0 | 16.4 | 9.3 | 9.3 | 1.5 | 12.0 | 16.0 | Q2 |
| MSP430F249TPMR | LQFP | PM | 64 | 1000 | 330.0 | 24.4 | 13.0 | 13.0 | 2.1 | 16.0 | 24.0 | Q2 |
| MSP430F249TRGCR | VQFN | RGC | 64 | 2500 | 330.0 | 16.4 | 9.3 | 9.3 | 1.5 | 12.0 | 16.0 | Q2 |
| MSP430F249TRGCT | VQFN | RGC | 64 | 250 | 180.0 | 16.4 | 9.3 | 9.3 | 1.5 | 12.0 | 16.0 | Q2 |

TAPE AND REEL BOX DIMENSIONS

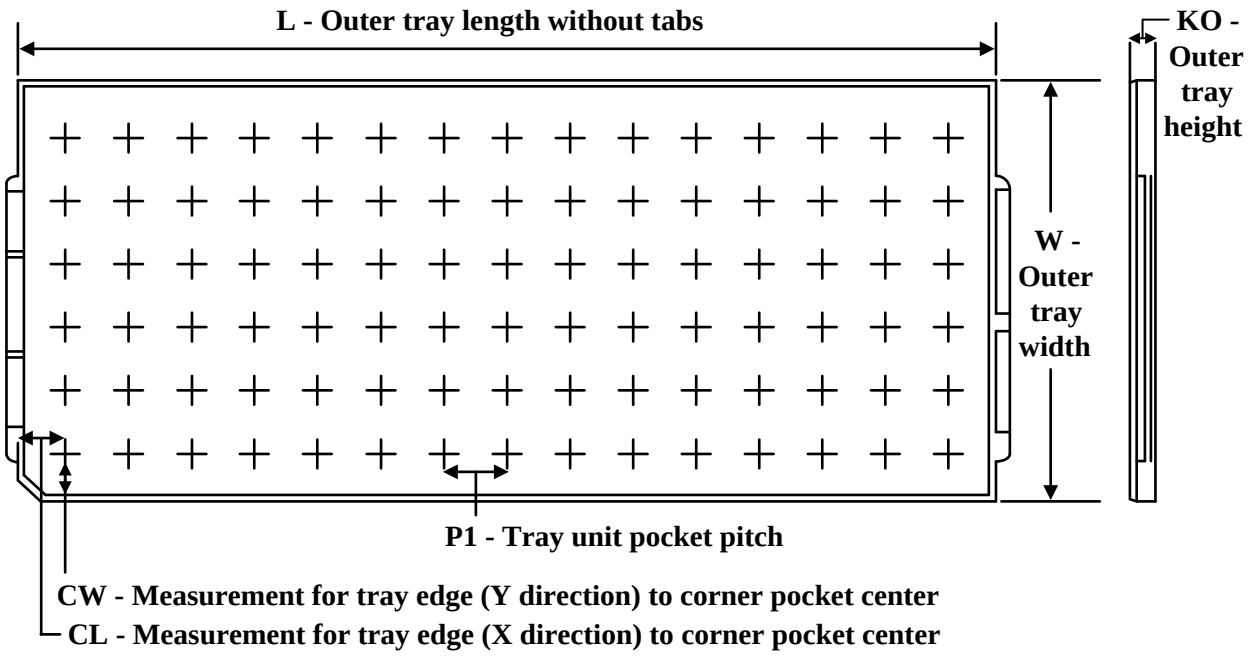



*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---|---|---|---|---|---|---|---|
| MSP430F233TPMR | LQFP | PM | 64 | 1000 | 336.6 | 336.6 | 41.3 |
| MSP430F233TRGCR | VQFN | RGC | 64 | 2500 | 356.0 | 356.0 | 35.0 |
| MSP430F233TRGCT | VQFN | RGC | 64 | 250 | 210.0 | 185.0 | 35.0 |
| MSP430F235TPMR | LQFP | PM | 64 | 1000 | 336.6 | 336.6 | 41.3 |
| MSP430F235TRGCR | VQFN | RGC | 64 | 2500 | 356.0 | 356.0 | 35.0 |
| MSP430F235TRGCT | VQFN | RGC | 64 | 250 | 210.0 | 185.0 | 35.0 |
| MSP430F2410TPMR | LQFP | PM | 64 | 1000 | 336.6 | 336.6 | 41.3 |
| MSP430F2410TRGCR | VQFN | RGC | 64 | 2500 | 356.0 | 356.0 | 35.0 |
| MSP430F2410TRGCT | VQFN | RGC | 64 | 250 | 210.0 | 185.0 | 35.0 |
| MSP430F2471TPMR | LQFP | PM | 64 | 1000 | 336.6 | 336.6 | 41.3 |
| MSP430F2471TRGCR | VQFN | RGC | 64 | 2500 | 367.0 | 367.0 | 38.0 |
| MSP430F2471TRGCT | VQFN | RGC | 64 | 250 | 210.0 | 185.0 | 35.0 |
| MSP430F247TPMR | LQFP | PM | 64 | 1000 | 336.6 | 336.6 | 41.3 |
| MSP430F247TRGCR | VQFN | RGC | 64 | 2500 | 367.0 | 367.0 | 38.0 |
| MSP430F247TRGCT | VQFN | RGC | 64 | 250 | 210.0 | 185.0 | 35.0 |
| MSP430F2481TPMR | LQFP | PM | 64 | 1000 | 336.6 | 336.6 | 41.3 |
| MSP430F2481TRGCR | VQFN | RGC | 64 | 2500 | 367.0 | 367.0 | 38.0 |
| MSP430F2481TRGCT | VQFN | RGC | 64 | 250 | 210.0 | 185.0 | 35.0 |

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---|---|---|---|---|---|---|---|
| MSP430F248TPMR | LQFP | PM | 64 | 1000 | 336.6 | 336.6 | 41.3 |
| MSP430F248TRGCR | VQFN | RGC | 64 | 2500 | 367.0 | 367.0 | 38.0 |
| MSP430F248TRGCT | VQFN | RGC | 64 | 250 | 210.0 | 185.0 | 35.0 |
| MSP430F2491TPMR | LQFP | PM | 64 | 1000 | 336.6 | 336.6 | 41.3 |
| MSP430F2491TRGCR | VQFN | RGC | 64 | 2500 | 356.0 | 356.0 | 35.0 |
| MSP430F2491TRGCT | VQFN | RGC | 64 | 250 | 210.0 | 185.0 | 35.0 |
| MSP430F249TPMR | LQFP | PM | 64 | 1000 | 336.6 | 336.6 | 41.3 |
| MSP430F249TRGCR | VQFN | RGC | 64 | 2500 | 356.0 | 356.0 | 35.0 |
| MSP430F249TRGCT | VQFN | RGC | 64 | 250 | 210.0 | 185.0 | 35.0 |

## TRAY




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

*All dimensions are nominal

| Device | Package Name | Package Type | Pins | SPQ | Unit array matrix | Max temperature (°C) | L (mm) | W (mm) | K0 (µm) | P1 (mm) | CL (mm) | CW (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MSP430F233TPM | PM | LQFP | 64 | 160 | 8 X 20 | 150 | 315 | 135.9 | 7620 | 15.2 | 13.1 | 13 |
| MSP430F233TPM | PM | LQFP | 64 | 160 | 8 x 20 | 150 | 315 | 135.9 | 7620 | 15.2 | 13.1 | 13 |
| MSP430F235TPM | PM | LQFP | 64 | 160 | 8 X 20 | 150 | 315 | 135.9 | 7620 | 15.2 | 13.1 | 13 |
| MSP430F235TPM | PM | LQFP | 64 | 160 | 8 x 20 | 150 | 315 | 135.9 | 7620 | 15.2 | 13.1 | 13 |
| MSP430F2410TPM | PM | LQFP | 64 | 160 | 8 X 20 | 150 | 315 | 135.9 | 7620 | 15.2 | 13.1 | 13 |
| MSP430F2410TPM | PM | LQFP | 64 | 160 | 8 x 20 | 150 | 315 | 135.9 | 7620 | 15.2 | 13.1 | 13 |
| MSP430F2471TPM | PM | LQFP | 64 | 160 | 8 x 20 | 150 | 315 | 135.9 | 7620 | 15.2 | 13.1 | 13 |
| MSP430F2471TPM | PM | LQFP | 64 | 160 | 8 X 20 | 150 | 315 | 135.9 | 7620 | 15.2 | 13.1 | 13 |
| MSP430F247TPM | PM | LQFP | 64 | 160 | 8 X 20 | 150 | 315 | 135.9 | 7620 | 15.2 | 13.1 | 13 |
| MSP430F247TPM | PM | LQFP | 64 | 160 | 8 x 20 | 150 | 315 | 135.9 | 7620 | 15.2 | 13.1 | 13 |
| MSP430F2481TPM | PM | LQFP | 64 | 160 | 8 X 20 | 150 | 315 | 135.9 | 7620 | 15.2 | 13.1 | 13 |
| MSP430F2481TPM | PM | LQFP | 64 | 160 | 8 x 20 | 150 | 315 | 135.9 | 7620 | 15.2 | 13.1 | 13 |
| MSP430F248TPM | PM | LQFP | 64 | 160 | 8 X 20 | 150 | 315 | 135.9 | 7620 | 15.2 | 13.1 | 13 |
| MSP430F248TPM | PM | LQFP | 64 | 160 | 8 x 20 | 150 | 315 | 135.9 | 7620 | 15.2 | 13.1 | 13 |
| MSP430F2491TPM | PM | LQFP | 64 | 160 | 8 x 20 | 150 | 315 | 135.9 | 7620 | 15.2 | 13.1 | 13 |
| MSP430F2491TPM | PM | LQFP | 64 | 160 | 8 X 20 | 150 | 315 | 135.9 | 7620 | 15.2 | 13.1 | 13 |
| MSP430F249TPM | PM | LQFP | 64 | 160 | 8 X 20 | 150 | 315 | 135.9 | 7620 | 15.2 | 13.1 | 13 |

| Device | Package Name | Package Type | Pins | SPQ | Unit array matrix | Max temperature (°C) | L (mm) | W (mm) | K0 (µm) | P1 (mm) | CL (mm) | CW (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MSP430F249TPM | PM | LQFP | 64 | 160 | 8 x 20 | 150 | 315 | 135.9 | 7620 | 15.2 | 13.1 | 13 |

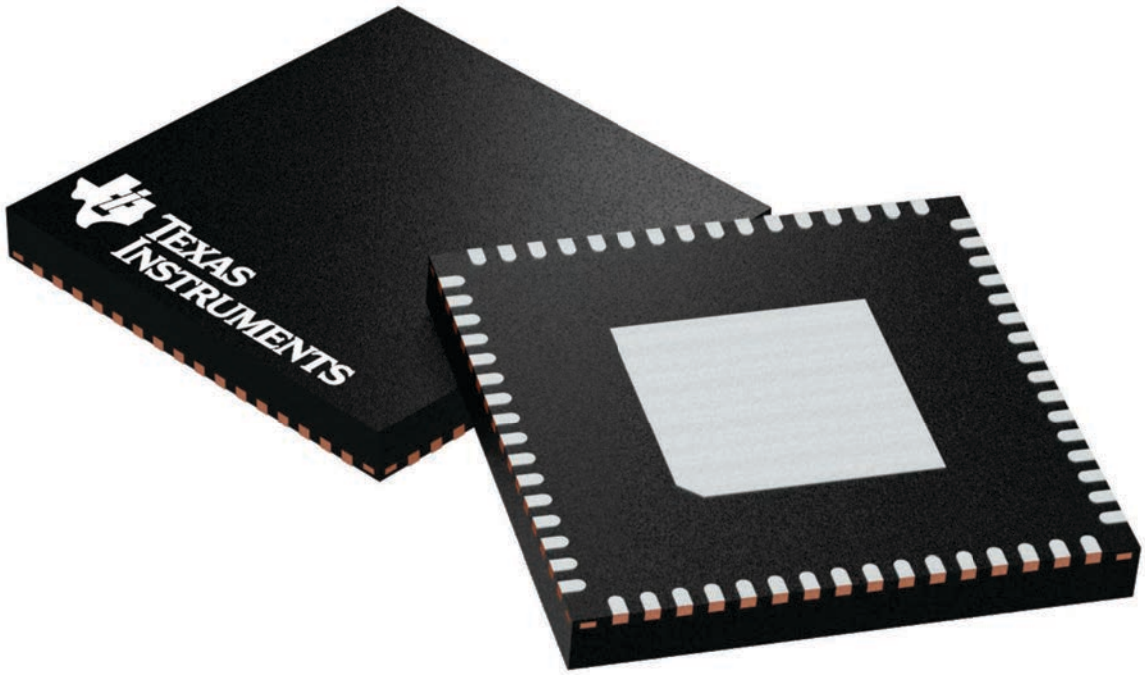
# GENERIC PACKAGE VIEW

## RGC 64

## VQFN - 1 mm max height

**9 x 9, 0.5 mm pitch**

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.

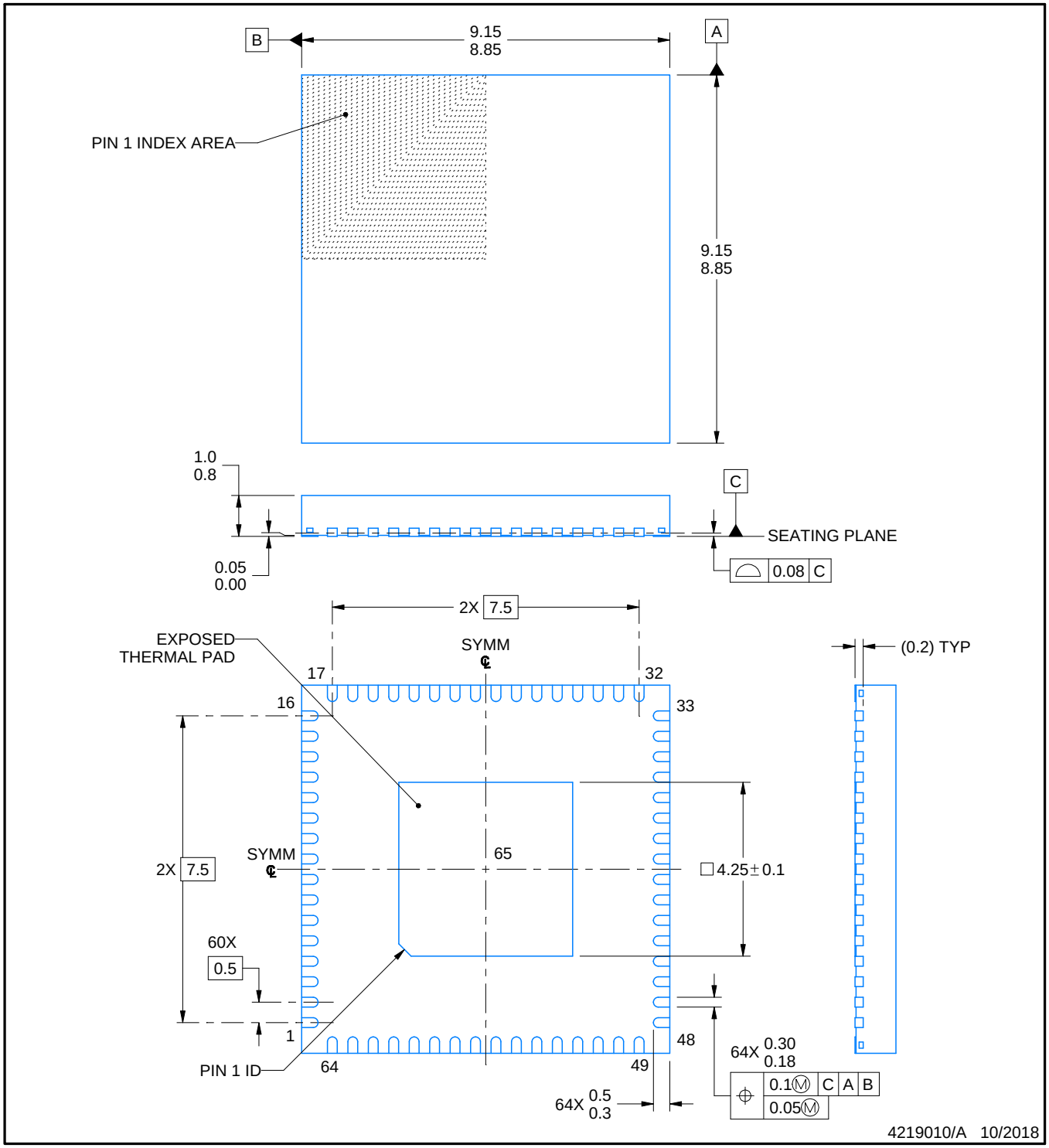
4224597/A

# PACKAGE OUTLINE

## RGC0064B

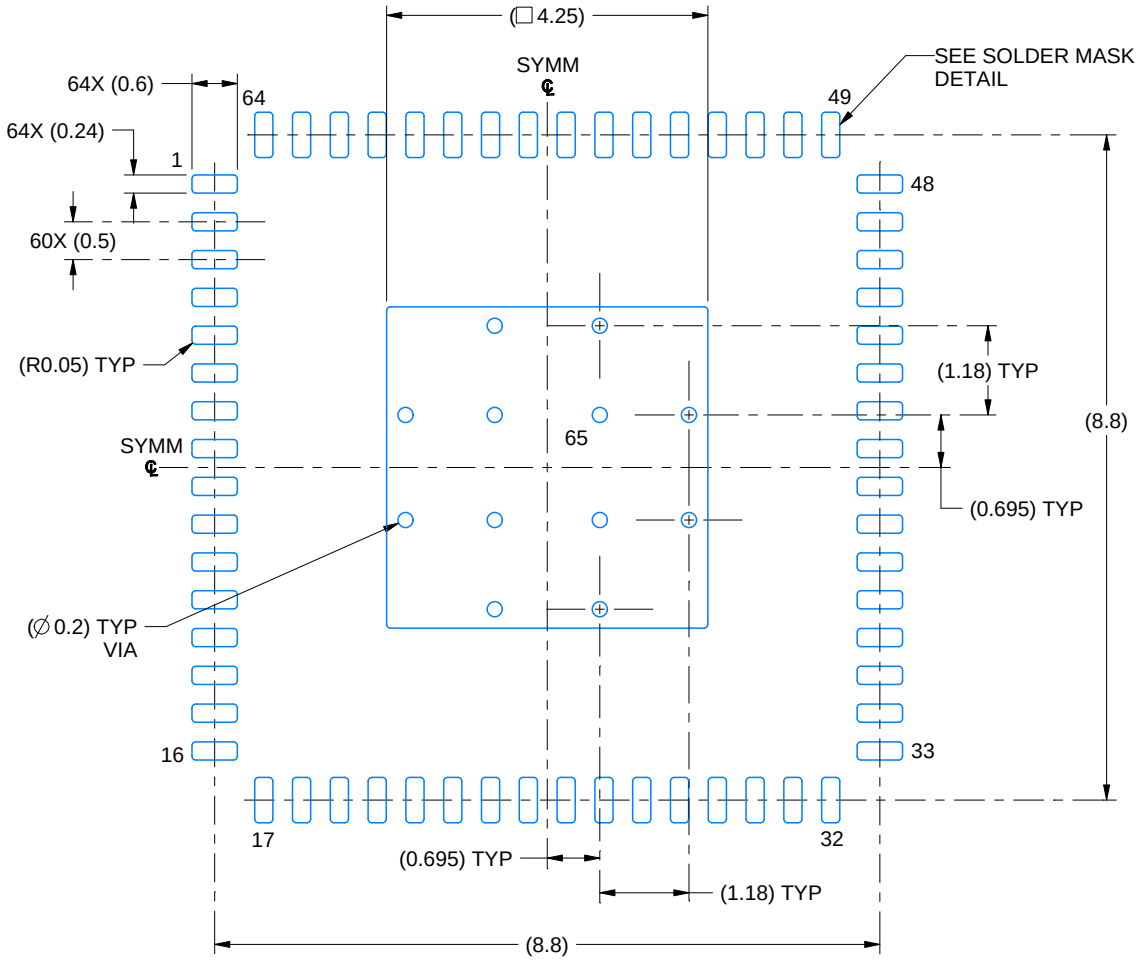
## VQFN - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD

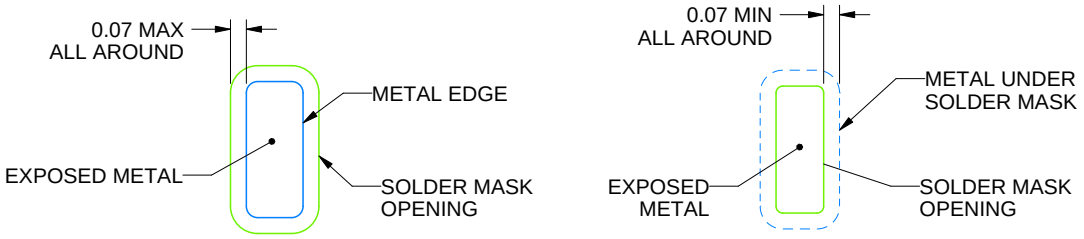



NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.




LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 10X

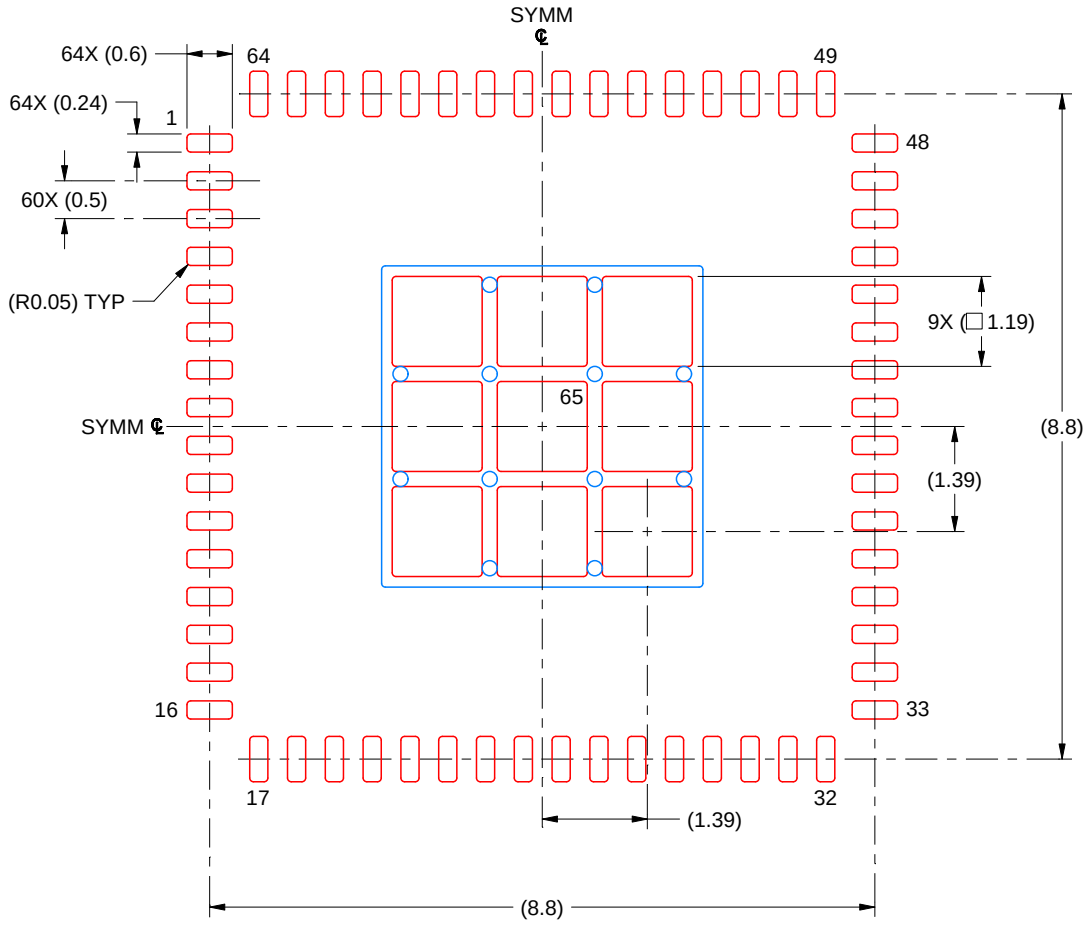



SOLDER MASK DETAILS

4219010/A 10/2018

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/slua271).
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.




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

EXPOSED PAD 65
71% PRINTED SOLDER COVERAGE BY AREA UNDER PACKAGE

4219010/A 10/2018

NOTES: (continued)

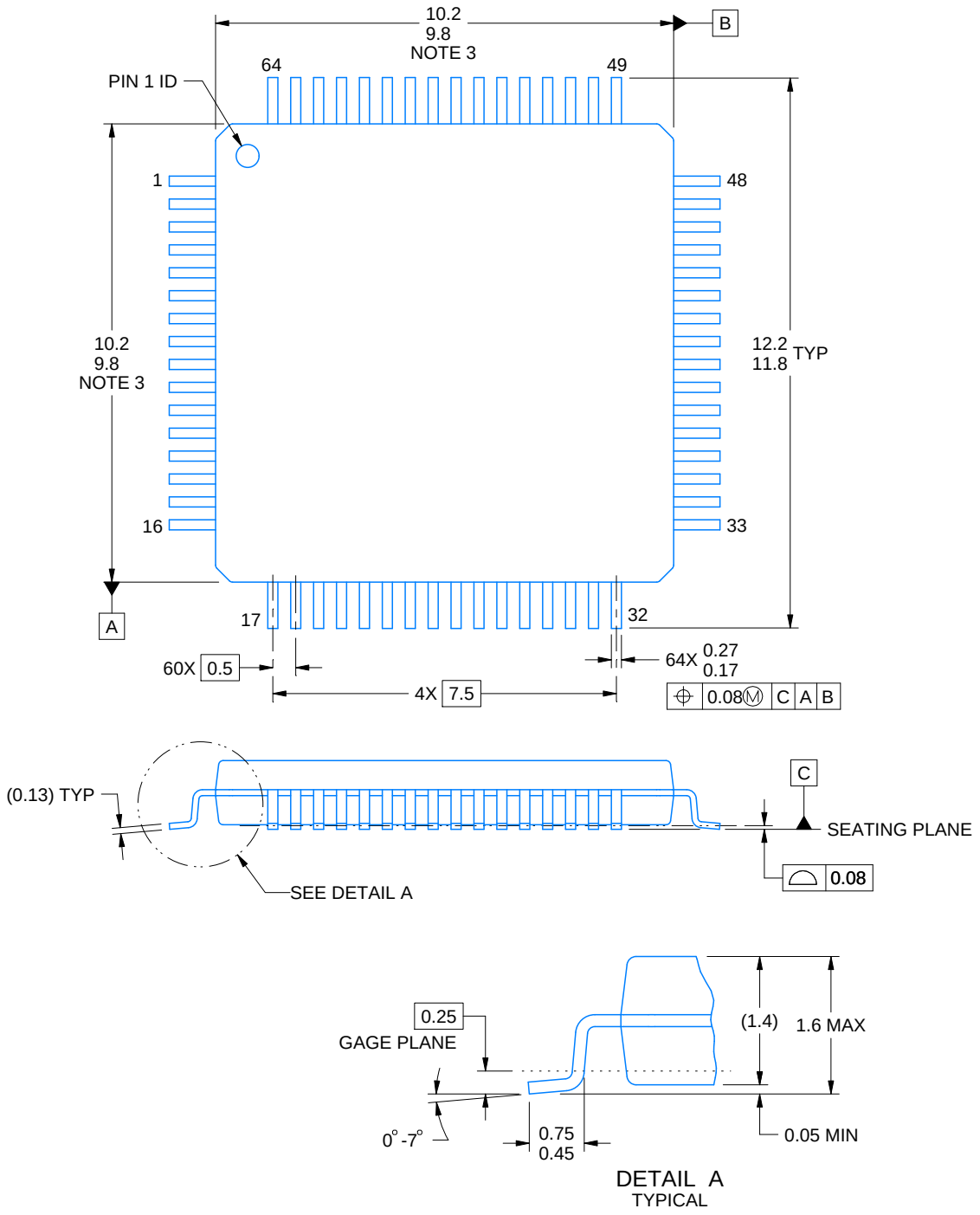
6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

# PACKAGE OUTLINE

## PM0064A

## LQFP - 1.6 mm max height

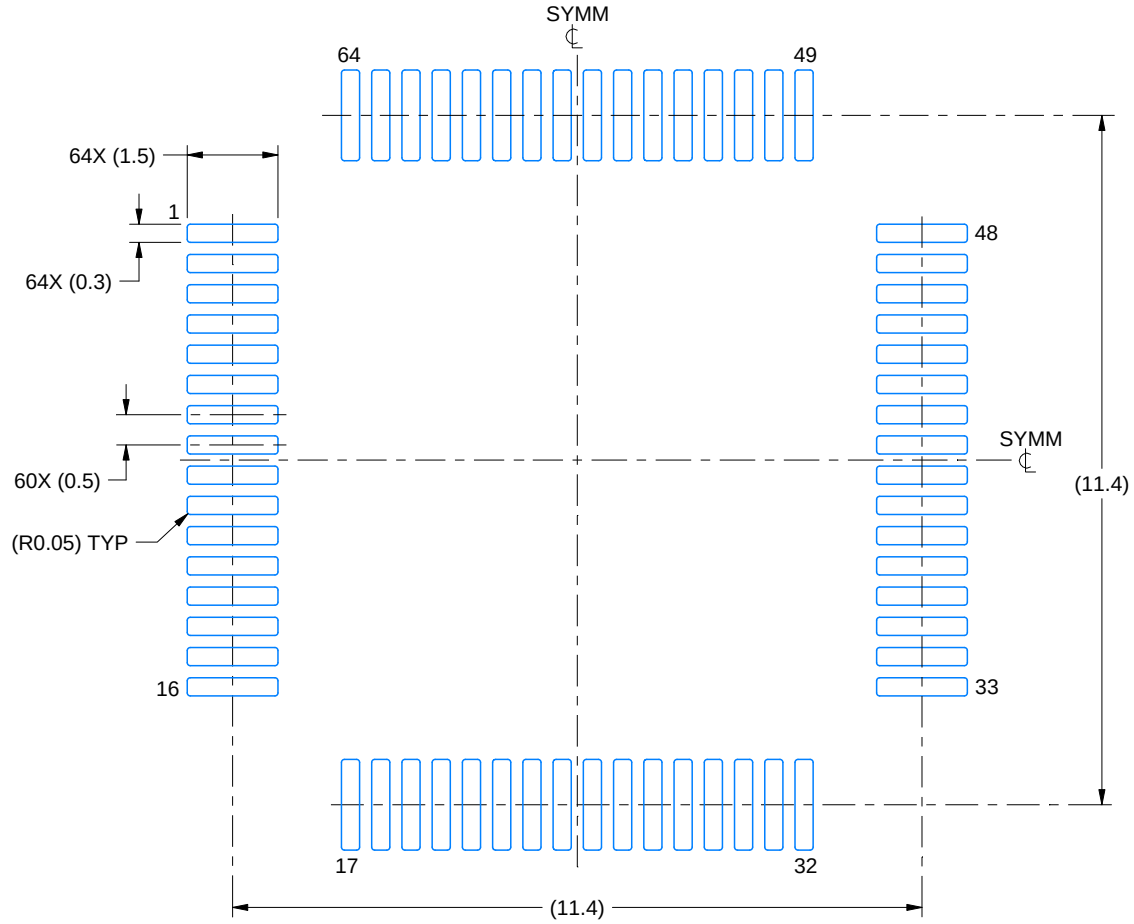
PLASTIC QUAD FLATPACK



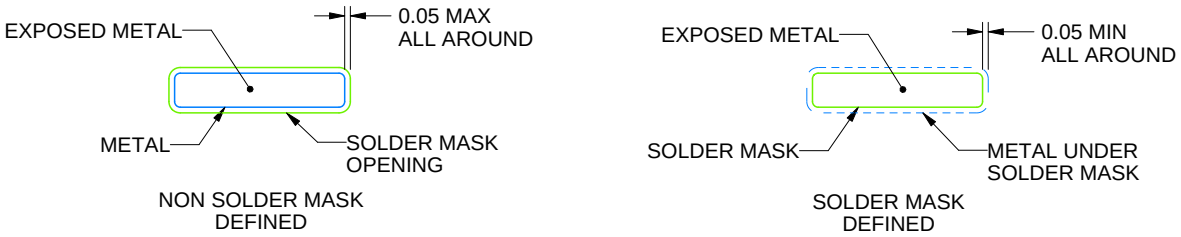

4215162/A 03/2017

NOTES:

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




LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:8X

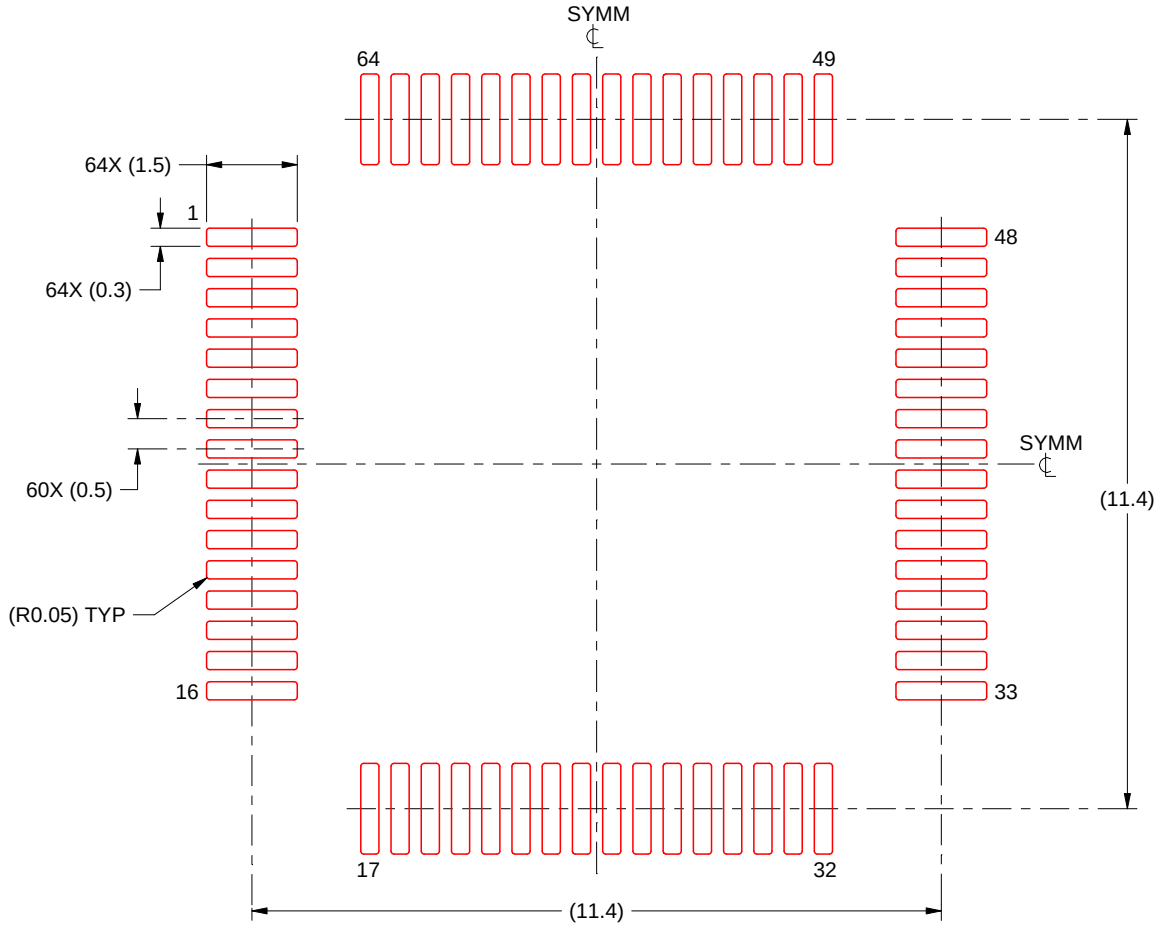



SOLDER MASK DETAILS

4215162/A 03/2017

NOTES: (continued)

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




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

4215162/A 03/2017

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.

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