

MSP430FG43x 混合信号微控制器

1 特性

- 低电源电压范围：1.8V 至 3.6V
- 超低功耗
 - 工作模式：频率为 1 MHz 且电压为 2.2V 时为 300 μ A
 - 待机模式：1.1 μ A
 - 关断模式 (RAM 保持)：0.1 μ A
- 五种节能模式
- 在 6 μ s 内从待机模式唤醒
- 16 位 RISC 架构，125 ns 指令周期
- 单通道内部 DMA
- 具有内部基准、采样保持和自动扫描功能的 12 位模数转换器 (ADC)
- 三个可配置运算放大器
- 具有同步功能的双 12 位数模转换器 (DAC)
- 具有三个捕捉/比较寄存器的 16 位定时器 Timer_A
- 具有三个捕捉/比较 (含影子) 寄存器的 16 位定时器 Timer_B
- 片上比较器

- 串行通信接口 (USART)，按软件来选择异步 UART 或同步 SPI
- 欠压检测器
- 具有可编程电平检测功能的电源电压监控器和监测器
- 引导加载程序 (BSL)
- 串行板载编程、无需外部编程电压、通过安全保险丝实现的可编程代码保护
- 高达 128 段的集成分段液晶显示器 (LCD) 驱动器
- 采用 113 焊球 BGA (ZCA) 和 80 引脚 QFP (PN) 封装
- [器件比较](#) 汇总了可用的产品系列成员

2 应用

- 模拟和数字传感器系统
- 数字电机控制
- 遥控
- 恒温器
- 数字计时器
- 手持式仪表

3 说明

德州仪器 MSP430™ 系列超低功耗微控制器包含多种器件，它们具有面向各种应用的不同外设集。这种采用五种低功耗模式的架构经过优化，可延长便携式测量应用中的电池使用寿命。该器件具有一个强大的 16 位 RISC CPU，16 位寄存器和有助于实现最高编码效率的常数发生器。数控振荡器 (DCO) 可使器件在不到 6 μ s 的时间内从低功耗模式唤醒至活动模式。

MSP430FG43x 微控制器器件具有两个 16 位计时器、一个高性能 12 位 ADC、两个 12 位 DAC、三个可配置运算放大器、一个通用同步/异步通信接口、DMA、48 个 I/O 引脚和一个 LCD 驱动器。

有关完整的模块说明，请参阅 [MSP430x4xx 系列用户指南](#)。

器件信息

| 器件型号 ⁽¹⁾ | 封装 | 封装尺寸 ⁽²⁾ |
|---------------------|-----------|---------------------|
| MSP430FG439PN | LQFP (80) | 12mm x 12mm |
| MSP430FG439ZCA | BGA (113) | 7mm x 7mm |

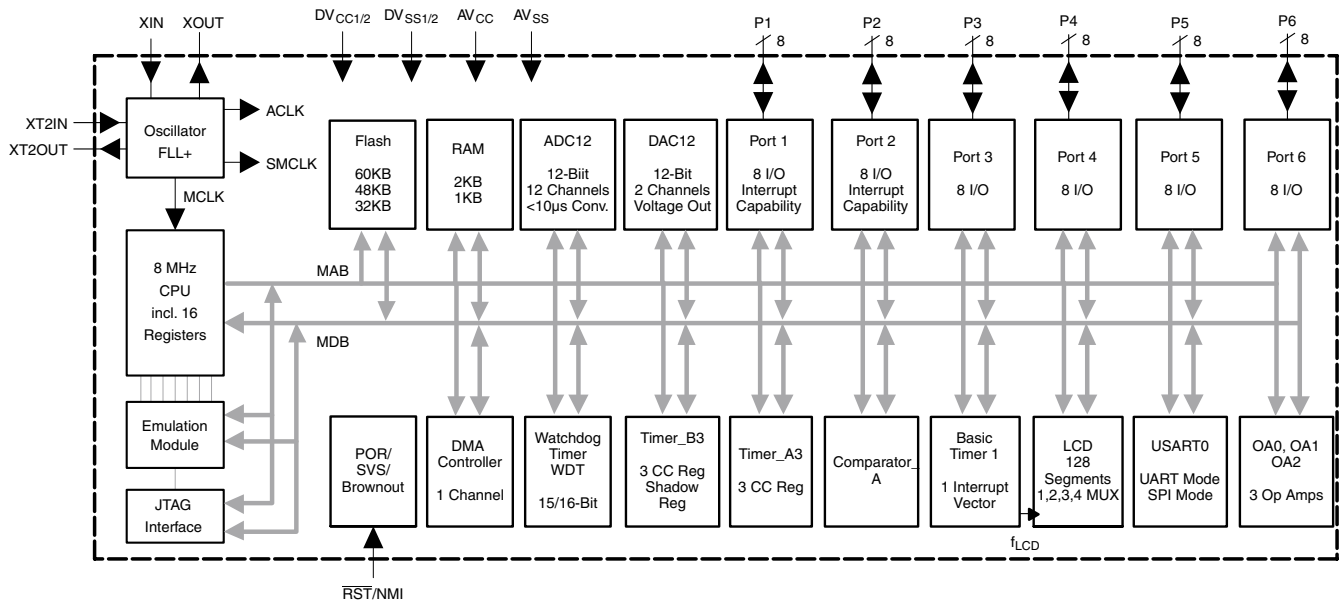
(1) 若要获得最新的器件、封装和订购信息，请参阅节 11 中的“封装选项附录”，或者浏览 TI 网站 www.ti.com。

(2) 这里显示的尺寸为近似值。若要获得包含容差值的封装尺寸，请参见节 11 中的机械数据。



4 功能方框图

图 4-1 给出了功能方框图。



功能方框图

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5 Revision History

注：以前版本的页码可能与当前版本的页码不同

Changes from revision E to revision F

Changes from June 18, 2021 to March 31, 2022

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| | |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| • Changed the t_{CONVERT} MIN value to 1.86 μs and removed ADC12DIV from the formula for the TYP value (because ADC12CLK is after this division) in 节 8.25 12-Bit ADC, Timing Parameters | 30 |
| • Changed the $R_{i(\text{VREF+})}$, $R_{i(\text{VeREF+})}$ reference input resistance MAX value to 150k Ω for DAC12_0 IR=1, DAC12_1 IR=0 in 节 8.31 12-Bit DAC, Reference Input Specifications | 35 |
| • Changed the $R_{i(\text{VREF+})}$, $R_{i(\text{VeREF+})}$ reference input resistance MAX value to 150k Ω for DAC12_0 IR=0, DAC12_1 IR=1 in 节 8.31 12-Bit DAC, Reference Input Specifications | 35 |
| • Changed the $R_{i(\text{VREF+})}$, $R_{i(\text{VeREF+})}$ reference input resistance MAX value to 75k Ω for DAC12_0 IR=DAC12_1 IR=1 in 节 8.31 12-Bit DAC, Reference Input Specifications | 35 |
| • Updated 节 10.3, Support Resources | 80 |

6 Device Comparison

The following table summarizes the available family members.

表 6-1. Device Comparison

| Device ⁽¹⁾ | FLASH (KB) ⁽²⁾ | SRAM (KB) | ADC12 | DAC12 | Comp_A | Timer_A ⁽³⁾ | Timer_B ⁽⁴⁾ | USART | LCD | I/Os | Package Type |
|-----------------------|---------------------------|-----------|-------------|------------|-------------|------------------------|------------------------|-------|-----|------|------------------|
| MSP430FG439 | 60 | 2 | 12 channels | 2 channels | 16 channels | 3 | 3 | Yes | Yes | 48 | 80 PN 113 ZCA |
| MSP430FG438 | 48 | 2 | 12 channels | 2 channels | 16 channels | 3 | 3 | Yes | Yes | 48 | 80 PN 113 ZCA |
| MSP430FG437 | 32 | 1 | 12 channels | 2 channels | 16 channels | 3 | 3 | Yes | Yes | 48 | 80 PN 113 ZCA |

- (1) For the most current package and ordering information, see the Package Option Addendum in 节 11, or see the TI web site at www.ti.com.
- (2) Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/packaging.
- (3) Each number in the sequence represents an instantiation of Timer_A with its associated number of capture/compare registers and PWM output generators available. For example, a number sequence of 3, 5 would represent two instantiations of Timer_A, the first instantiation having 3 capture/compare registers and PWM output generators and the second instantiation having 5 capture/compare registers and PWM output generators, respectively.
- (4) Each number in the sequence represents an instantiation of Timer_B with its associated number of capture/compare registers and PWM output generators available. For example, a number sequence of 3, 5 would represent two instantiations of Timer_B, the first instantiation having 3 capture/compare registers and PWM output generators and the second instantiation having 5 capture/compare registers and PWM output generators, respectively.

7 Terminal Configuration and Functions

7.1 Pin Diagrams

图 7-1 shows the pin assignments for the 80-pin PN package.

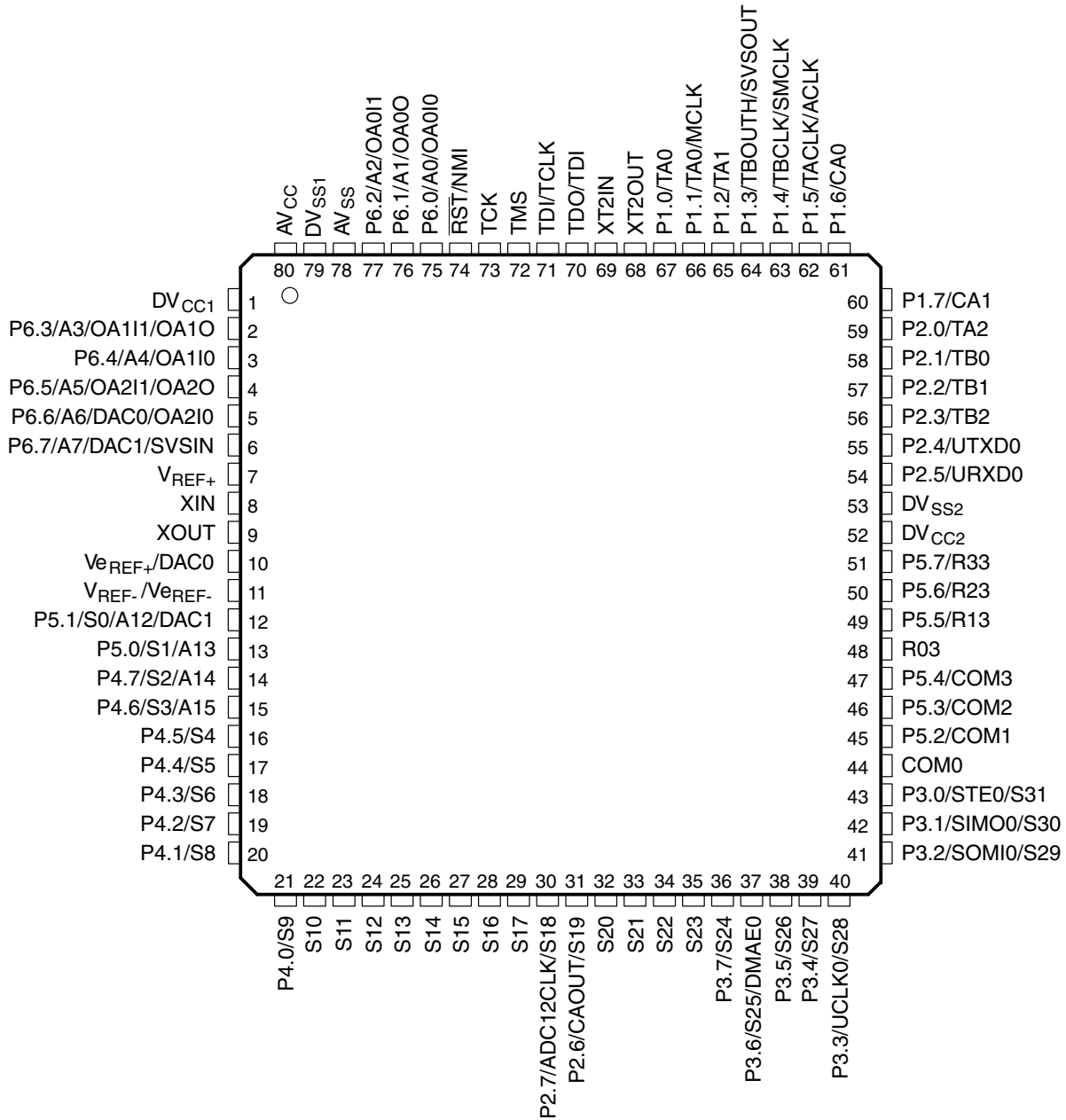


图 7-1. 80-Pin PN Package (Top View)

图 7-2 shows the pin assignments for the 113-pin ZCA package.

**ZCA PACKAGE
(TOP VIEW)**

| | | | | | | | | | | | |
|----------------|--------------|--------------|--------------|--------------|------------------|------------------|------------------|------------------|-------------------|-------------------|-------------------|
| DVSS (A1) | AVSS (A2) | AVCC (A3) | P6.1 (A4) | P6.0 (A5) | RST (A6) | XT2IN (A7) | XT2OUT (A8) | DVSS (A9) | P1.3 (A10) | P1.6 (A11) | (A12) |
| DVCC (B1) | DVSS (B2) | AVCC (B3) | P6.2 (B4) | P6.3 (B5) | DVSS (B6) | DVSS (B7) | DVSS (B8) | P1.2 (B9) | P1.5 (B10) | (B11) | P1.7 (B12) |
| VREF+ (C1) | DVCC (C2) | DVSS (C3) | | | | | | | | P2.0 (C11) | P2.4/TX (C12) |
| AVSS (D1) | P6.7 (D2) | | P6.5 (D4) | P6.4 (D5) | TMS (D6) | TDO (D7) | P1.0 (D8) | P1.1 (D9) | | P2.1 (D11) | P2.5/RX (D12) |
| XIN (E1) | AVSS (E2) | | P6.6 (E4) | (E5) | TCK (E6) | TDI (E7) | (E8) | P1.4 (E9) | | P2.2 (E11) | DVSS2 (E12) |
| XOUT (F1) | AVSS (F2) | | P5.1 (F4) | (F5) | | | (F8) | (F9) | | P2.3 (F11) | DVCC2 (F12) |
| AVSS (G1) | AVSS (G2) | | P5.0 (G4) | (G5) | | | (G8) | (G9) | | COM3 (G11) | R33 (G12) |
| VeREF+ (H1) | AVSS (H2) | | P4.7 (H4) | (H5) | (H6) | (H7) | (H8) | (H9) | | COM2 (H11) | R23 (H12) |
| VREF- (J1) | AVSS (J2) | | P4.6 (J4) | S13 (J5) | S16 (J6) | S21 (J7) | S22 (J8) | S23 (J9) | | COM1 (J11) | R13 (J12) |
| P4.5 (K1) | P4.4 (K2) | | | | | | | | | COM0 (K11) | R03 (K12) |
| P4.1 (L1) | P4.2 (L2) | P4.3 (L3) | S11 (L4) | S14 (L5) | S17 (L6) | S20 (L7) | P3.6/S25 (L8) | P3.5/S26 (L9) | P3.4/S27 (L10) | (L11) | P3.0/S31 (L12) |
| (M1) | P4.0 (M2) | S10 (M3) | S12 (M4) | S15 (M5) | P2.7/S18 (M6) | P2.6/S19 (M7) | P3.7/S24 (M8) | P3.3/S28 (M9) | P3.2/S29 (M10) | P3.1/S30 (M11) | (M12) |

图 7-2. 113-Pin ZCA Package (Top View)

7.2 Signal Descriptions

节 7.2.1 describes the signals for all device variants and package options.

7.2.1 Signal Descriptions

| TERMINAL | | | I/O | DESCRIPTION |
|--------------------|-----|--------|-----|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| NAME | NO. | | | |
| | PN | ZCA | | |
| DVCC1 | 1 | B1, C2 | | Digital supply voltage, positive terminal. |
| P6.3/A3/OA111/OA10 | 2 | B5 | I/O | General-purpose digital I/O Analog input a3—12-bit ADC OA1 output and/or input multiplexer on +terminal and -terminal |
| P6.4/A4/OA110 | 3 | D5 | I/O | General-purpose digital I/O Analog input a4—12-bit ADC OA1 input multiplexer on +terminal and -terminal |
| P6.5/A5/OA211/OA20 | 4 | D4 | I/O | General-purpose digital I/O Analog input a5—12-bit ADC OA2 output and/or input multiplexer on +terminal and -terminal |
| P6.6/A6/DAC0/OA210 | 5 | E4 | I/O | General-purpose digital I/O Analog input a6—12-bit ADC DAC12.0 output OA2 input multiplexer on +terminal and -terminal |
| P6.7/A7/DAC1/SVSIN | 6 | D2 | I/O | General-purpose digital I/O Analog input a7—12-bit ADC DAC12.1 output/analog input to supply voltage supervisor |
| VREF+ | 7 | C1 | O | Positive output terminal of the reference voltage in the ADC |
| XIN | 8 | E1 | I | Input terminal of crystal oscillator XT1 |
| XOUT | 9 | F1 | O | Output terminal of crystal oscillator XT1 |
| VeREF+/DAC0 | 10 | H1 | I/O | Positive input terminal for an external reference voltage to the 12-bit ADC/DAC12.0 output |
| VREF-/VeREF- | 11 | J1 | I | Negative terminal for the 12-bit ADC's reference voltage for both sources, the internal reference voltage or an external applied reference voltage to the 12-bit ADC. |
| P5.1/S0/A12/DAC1 | 12 | F4 | I/O | General-purpose digital I/O LCD segment output 0 Analog input a12—12-bit ADC DAC12.1 output |
| P5.0/S1/A13 | 13 | G4 | I/O | General-purpose digital I/O LCD segment output 1 Analog input a13—12-bit ADC |
| P4.7/S2/A14 | 14 | H4 | I/O | General-purpose digital I/O LCD segment output 2 Analog input a14—12-bit ADC |
| P4.6/S3/A15 | 15 | J4 | I/O | General-purpose digital I/O LCD segment output 3 Analog input a15—12-bit ADC |
| P4.5/S4 | 16 | K1 | I/O | General-purpose digital I/O LCD segment output 4 |
| P4.4/S5 | 17 | K2 | I/O | General-purpose digital I/O LCD segment output 5 |
| P4.3/S6 | 18 | L3 | I/O | General-purpose digital I/O LCD segment output 6 |
| P4.2/S7 | 19 | L2 | I/O | General-purpose digital I/O LCD segment output 7 |
| P4.1/S8 | 20 | L1 | I/O | General-purpose digital I/O LCD segment output 8 |

| TERMINAL | | | I/O | DESCRIPTION |
|-------------------|-----|-----|-----|------------------------------------------------------------------------------------------------------------------------------------|
| NAME | NO. | | | |
| | PN | ZCA | | |
| P4.0/S9 | 21 | M2 | I/O | General-purpose digital I/O LCD segment output 9 |
| S10 | 22 | M3 | O | LCD segment output 10 |
| S11 | 23 | L4 | O | LCD segment output 11 |
| S12 | 24 | M4 | O | LCD segment output 12 |
| S13 | 25 | J5 | O | LCD segment output 13 |
| S14 | 26 | L5 | O | LCD segment output 14 |
| S15 | 27 | M5 | O | LCD segment output 15 |
| S16 | 28 | J6 | O | LCD segment output 16 |
| S17 | 29 | L6 | O | LCD segment output 17 |
| P2.7/ADC12CLK/S18 | 30 | M6 | I/O | General-purpose digital I/O Conversion clock—12-bit ADC LCD segment output 18 |
| P2.6/CAOUT/S19 | 31 | M7 | I/O | General-purpose digital I/O Comparator_A output / LCD segment output 19 |
| S20 | 32 | L7 | O | LCD segment output 20 |
| S21 | 33 | J7 | O | LCD segment output 21 |
| S22 | 34 | J8 | O | LCD segment output 22 |
| S23 | 35 | J9 | O | LCD segment output 23 |
| P3.7/S24 | 36 | M8 | I/O | General-purpose digital I/O LCD segment output 24 |
| P3.6/S25/DMAE0 | 37 | L8 | I/O | General-purpose digital I/O LCD segment output 25/DMA Channel 0 external trigger |
| P3.5/S26 | 38 | L9 | I/O | General-purpose digital I/O LCD segment output 26 |
| P3.4/S27 | 39 | L10 | I/O | General-purpose digital I/O LCD segment output 27 |
| P3.3/UCLK0/S28 | 40 | M9 | I/O | General-purpose digital I/O External clock input—USART0/UART or SPI mode, clock output—USART0/SPI mode LCD segment output 28 |
| P3.2/SOMI0/S29 | 41 | M10 | I/O | General-purpose digital I/O Slave out/master in of USART0/SPI mode LCD segment output 29 |
| P3.1/SIMO0/S30 | 42 | M11 | I/O | General-purpose digital I/O Slave in/master out of USART0/SPI mode LCD segment output 30 |
| P3.0/STE0/S31 | 43 | L12 | I/O | General-purpose digital I/O Slave transmit enable-USART0/SPI mode LCD segment output 31 |
| COM0 | 44 | K11 | O | Common output, COM0–3 are used for LCD backplanes. |
| P5.2/COM1 | 45 | J11 | I/O | General-purpose digital I/O Common output, COM0–3 are used for LCD backplanes. |
| P5.3/COM2 | 46 | H11 | I/O | General-purpose digital I/O Common output, COM0–3 are used for LCD backplanes. |
| P5.4/COM3 | 47 | G11 | I/O | General-purpose digital I/O Common output, COM0–3 are used for LCD backplanes. |
| R03 | 48 | K12 | I | Input port of fourth positive (lowest) analog LCD level (V5) |
| P5.5/R13 | 49 | J12 | I/O | General-purpose digital I/O input port of third most positive analog LCD level (V4 or V3) |

| TERMINAL | | | I/O | DESCRIPTION |
|--------------------|-----|-----|-----|-------------------------------------------------------------------------------------------------------------------------------------------|
| NAME | NO. | | | |
| | PN | ZCA | | |
| P5.6/R23 | 50 | H12 | I/O | General-purpose digital I/O Input port of second most positive analog LCD level (V2) |
| P5.7/R33 | 51 | G12 | I/O | General-purpose digital I/O Output port of most positive analog LCD level (V1) |
| DVCC2 | 52 | F12 | | Digital supply voltage, positive terminal |
| DVSS2 | 53 | E12 | | Digital supply voltage, negative terminal |
| P2.5/URXD0 | 54 | D12 | I/O | General-purpose digital I/O Receive data in—USART0/UART mode |
| P2.4/UTXD0 | 55 | C12 | I/O | General-purpose digital I/O Transmit data out—USART0/UART mode |
| P2.3/TB2 | 56 | F11 | I/O | General-purpose digital I/O Timer_B3 CCR2. Capture: CCI2A/CCI2B input, compare: Out2 output |
| P2.2/TB1 | 57 | E11 | I/O | General-purpose digital I/O Timer_B3 CCR1. Capture: CCI1A/CCI1B input, compare: Out1 output |
| P2.1/TB0 | 58 | D11 | I/O | General-purpose digital I/O Timer_B3 CCR0. Capture: CCI0A/CCI0B input, compare: Out0 output |
| P2.0/TA2 | 59 | C11 | I/O | General-purpose digital I/O Timer_A Capture: CCI2A input, compare: Out2 output |
| P1.7/CA1 | 60 | B12 | I/O | General-purpose digital I/O Comparator_A input |
| P1.6/CA0 | 61 | A11 | I/O | General-purpose digital I/O Comparator_A input |
| P1.5/TACLK/ACLK | 62 | B10 | I/O | General-purpose digital I/O Timer_A, clock signal TACLK input ACLK output (divided by 1, 2, 4, or 8) |
| P1.4/TBCLK/SMCLK | 63 | E9 | I/O | General-purpose digital I/O Input clock TBCLK—Timer_B3 Submain system clock SMCLK output |
| P1.3/TBOUTH/SVSOUT | 64 | A10 | I/O | General-purpose digital I/O Switch all PWM digital output ports to high impedance—Timer_B3 TB0 to TB2 SVS: output of SVS comparator |
| P1.2/TA1 | 65 | B9 | I/O | General-purpose digital I/O Timer_A, Capture: CCI1A, compare: Out1 output |
| P1.1/TA0/MCLK | 66 | D9 | I/O | General-purpose digital I/O Timer_A. Capture: CCI0B / MCLK output. Note: TA0 is only an input on this pin BSL receive |
| P1.0/TA0 | 67 | D8 | I/O | General-purpose digital I/O Timer_A. Capture: CCI0A input, compare: Out0 output BSL transmit |
| XT2OUT | 68 | A8 | O | Output terminal of crystal oscillator XT2 |
| XT2IN | 69 | A7 | I | Input port for crystal oscillator XT2. Only standard crystals can be connected. |
| TDO/TDI | 70 | D7 | I/O | Test data output port. TDO/TDI data output or programming data input terminal |
| TDI/TCLK | 71 | E7 | I | Test data input or test clock input. The device protection fuse is connected to TDI/ TCLK. |
| TMS | 72 | D6 | I | Test mode select. TMS is used as an input port for device programming and test. |
| TCK | 73 | E6 | I | Test clock. TCK is the clock input port for device programming and test. |
| RST/NMI | 74 | A6 | I | Reset or nonmaskable interrupt input |
| P6.0/A0/OA0I0 | 75 | A5 | I/O | General-purpose digital I/O Analog input a0 – 12-bit ADC OA0 input multiplexer on +terminal and –terminal |

| TERMINAL | | | I/O | DESCRIPTION |
|---------------|-----|-----------------------------------------|-----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| NAME | NO. | | | |
| | PN | ZCA | | |
| P6.1/A1/OA00 | 76 | A4 | I/O | General-purpose digital I/O Analog input a1 – 12-bit ADC OA0 output |
| P6.2/A2/OA011 | 77 | B4 | I/O | General-purpose digital I/O Analog input a2 – 12-bit ADC OA0 input multiplexer on + terminal and – terminal |
| AVSS | 78 | A2, D1, E2, F2, G2, G1, H2, J2 | | Analog supply voltage, negative terminal. Supplies SVS, brownout, oscillator, comparator_A, port 1, and LCD resistive divider circuitry. |
| DVSS1 | 79 | A1, B2, C3, B6, B7, B8, A9 | | Digital supply voltage, negative terminal |
| AVCC | 80 | A3, B3 | | Analog supply voltage, positive terminal. Supplies SVS, brownout, oscillator, comparator_A, port 1, and LCD resistive divider circuitry; must not power up prior to DVCC1/DVCC2. |
| Reserved | | (1) | | Reserved |

(1) A12, B11, E5, E8, F5, F8, F9, G5, G8, G9, H5, H6, H7, H8, H9, L11, M1, M12 are reserved and should be connected to ground.

8 Specifications

8.1 Absolute Maximum Ratings

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

| (1) | MIN | MAX | UNIT |
|-------------------------------------------|-------|----------------|------|
| Voltage applied at V_{CC} to V_{SS} | - 0.3 | 4.1 | V |
| Voltage applied to any pin ⁽²⁾ | - 0.3 | $V_{CC} + 0.3$ | V |
| Diode current at any device terminal | | ± 2 | mA |

- 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.
- All voltages referenced to V_{SS} . The JTAG fuse-blow voltage, V_{FB} , is allowed to exceed the absolute maximum rating. The voltage is applied to the TDI/TCLK pin when blowing the JTAG fuse.

8.2 Handling Ratings

| | | MIN | MAX | UNIT | |
|-----------|---------------------------|---------------------|-----|------|----|
| T_{stg} | Storage temperature range | Unprogrammed device | -55 | 150 | °C |
| | | Programmed device | -40 | 85 | |

8.3 Recommended Operating Conditions

| | | | MIN | NOM | MAX | UNIT | |
|----------------|-------------------------------------------------------------------------------|-----------------------------------------------------------------------|-------------------|------|--------|------|------|
| V_{CC} | Supply voltage ⁽¹⁾ ($AV_{CC} = DV_{CC1} = DV_{CC2} = V_{CC}$) | During program execution | 1.8 | | 3.6 | V | |
| | | During program execution, SVS enabled and PORON = 1 ⁽²⁾ | 2 | | 3.6 | | |
| | | During flash memory programming | 2.7 | | 3.6 | | |
| V_{SS} | Supply voltage ⁽¹⁾ ($AV_{SS} = DV_{SS1} = DV_{SS2} = V_{SS}$) | | 0 | | 0 | V | |
| T_A | Operating free-air temperature range | | - 40 | | 85 | °C | |
| $f_{(LFXT1)}$ | XT1 crystal frequency ⁽³⁾ | LF selected, XTS_FLL = 0 | Watch crystal | | 32.768 | kHz | |
| | | XT1 selected, XTS_FLL = 1 | Ceramic resonator | | 450 | | 8000 |
| | | XT1 selected, XTS_FLL = 1 | Crystal | | 1000 | | 8000 |
| $f_{(XT2)}$ | XT2 crystal frequency | Ceramic resonator | | 450 | 8000 | kHz | |
| | | Crystal | | 1000 | 8000 | | |
| $f_{(System)}$ | Processor frequency (signal MCLK) | $V_{CC} = 1.8$ V | dc | | 4.15 | MHz | |
| | | $V_{CC} = 3.6$ V | dc | | 8 | | |

- 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 and operation.
- The minimum operating supply voltage is defined according to the trip point where POR is going active by decreasing the supply voltage. POR is going inactive when the supply voltage is raised above the minimum supply voltage plus the hysteresis of the SVS circuitry.
- In LF mode, the LFXT1 oscillator requires a watch crystal. In XT1 mode, LFXT1 accepts a ceramic resonator or a crystal.

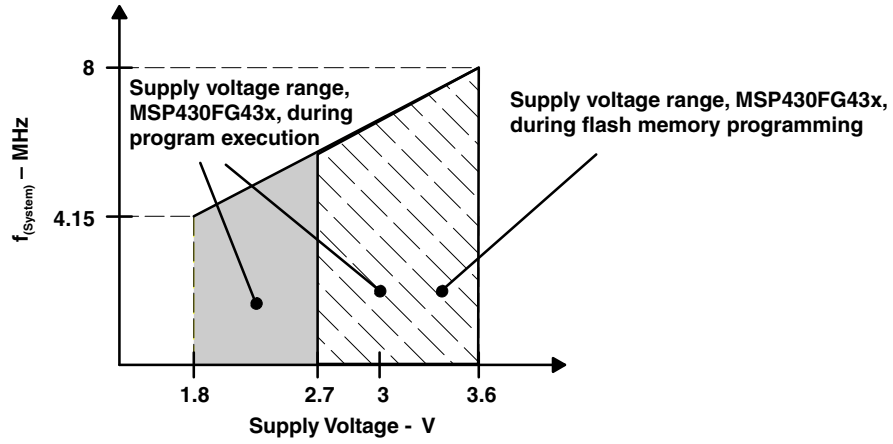


图 8-1. Frequency vs Supply Voltage, Typical Characteristic

8.4 Supply Current Into AV_{CC} + DV_{CC} Excluding External Current

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

| PARAMETER | | T _A | V _{CC} | MIN | TYP | MAX | UNIT | |
|---------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|----------------|-----------------|------|-----|-----|------|-----|
| I _(AM) | Active mode ⁽¹⁾ f _(MCLK) = f _(SMCLK) = 1 MHz, f _(ACLK) = 32768 Hz, XTS_FLL = 0, SELM = (0,1) | - 40°C to 85°C | 2.2 V | | 300 | 370 | μA | |
| | | | 3 V | | 470 | 570 | | |
| I _(LPM0) | Low-power mode (LPM0) ^{(1) (2)} | - 40°C to 85°C | 2.2 V | | 55 | 70 | μA | |
| | | | 3 V | | 95 | 150 | | |
| I _(LPM2) | Low-power mode (LPM2), f _(MCLK) = f _(SMCLK) = 0 MHz, f _(ACLK) = 32768 Hz, SCG0 = 0 ^{(3) (2)} | - 40°C to 85°C | 2.2 V | | 11 | 14 | μA | |
| | | | 3 V | | 17 | 22 | | |
| I _(LPM3) | Low-power mode (LPM3) f _(MCLK) = f _(SMCLK) = 0 MHz, f _(ACLK) = 32768 Hz, SCG0 = 1 ^{(3) (4) (2)} | - 40°C | 2.2 V | | 1 | 2 | μA | |
| | | | | 25°C | | 1.1 | | 2 |
| | | | | 60°C | | 2 | | 3 |
| | | | | 85°C | | 3.5 | | 6 |
| | | - 40°C | 3 V | | | 1.8 | | 2.8 |
| | | | | 25°C | | 1.6 | | 2.7 |
| | | | | 60°C | | 2.5 | | 3.5 |
| | | | | 85°C | | 4.2 | | 7.5 |
| I _(LPM4) | Low-power mode (LPM4) f _(MCLK) = f _(SMCLK) = 0 MHz, f _(ACLK) = 0 Hz, SCG0 = 1 ^{(3) (2)} | - 40°C | 2.2 V | | 0.1 | 0.5 | μA | |
| | | | | 25°C | | 0.1 | | 0.5 |
| | | | | 60°C | | 0.7 | | 1.1 |
| | | | | 85°C | | 1.7 | | 3 |
| | | - 40°C | 3 V | | | 0.1 | | 0.8 |
| | | | | 25°C | | 0.1 | | 0.8 |
| | | | | 60°C | | 0.8 | | 1.2 |
| | | | | 85°C | | 1.9 | | 3.5 |

(1) Timer_B is clocked by f_(DCOCLK) = f_(DCO) = 1 MHz. All inputs are tied to 0 V or to V_{CC}. Outputs do not source or sink any current.

(2) Current for brownout included.

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

(4) The current consumption in LPM3 is measured with active Basic Timer1 and LCD (ACLK selected). The current consumption of the Comparator_A and the SVS module are specified in the respective sections. The LPM3 currents are characterized with a KDS Daishinku DT-38 (6 pF) crystal and OSCCAPx = 01h.

Current consumption of active mode versus system frequency:

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

Current consumption of active mode versus supply voltage:

$$I_{(AM)} = I_{(AM)} [3 \text{ V}] + 175 \mu\text{A/V} \times (V_{\text{CC}} - 3 \text{ V})$$

8.5 Schmitt-Trigger Inputs – Ports P1 to P6, $\overline{\text{RST}}/\text{NMI}$, JTAG (TCK, TMS, TDI/TCLK, TDO/TDI)

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

| PARAMETER | | V _{CC} | MIN | MAX | UNIT |
|------------------|-----------------------------------------------------------------|-----------------|-----|------|------|
| V _{IT+} | Positive-going input threshold voltage | 2.2 V | 1.1 | 1.55 | V |
| | | 3 V | 1.5 | 1.98 | |
| V _{IT-} | Negative-going input threshold voltage | 2.2 V | 0.4 | 0.9 | V |
| | | 3 V | 0.9 | 1.3 | |
| V _{hys} | Input voltage hysteresis (V _{IT+} - V _{IT-}) | 2.2 V | 0.3 | 1.1 | V |
| | | 3 V | 0.5 | 1 | |

8.6 Inputs P_{x,y}, TAx, TBx

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

| PARAMETER | | TEST CONDITIONS | V _{CC} | MIN | MAX | UNIT |
|----------------------|--------------------------------------------------------------|------------------------------------------------------------------------------------------|-----------------|-----|-----|------|
| t _(int) | External interrupt timing | Port P1, P2: P1.x to P2.x, external trigger signal for the interrupt flag ⁽¹⁾ | 2.2 V | 62 | | ns |
| | | | 3 V | 50 | | |
| t _(cap) | Timer_A or Timer_B capture timing | TA0, TA1, TA2 TB0, TB1, TB2 | 2.2 V | 62 | | ns |
| | | | 3 V | 50 | | |
| f _(TAext) | Timer_A or Timer_B clock frequency externally applied to pin | TACLK, TBCLK, INCLK: t _(H) = t _(L) | 2.2 V | | 8 | MHz |
| f _(TBext) | | | 3 V | | 10 | |
| f _(TAint) | Timer_A or Timer_B clock frequency | SMCLK or ACLK signal selected | 2.2 V | | 8 | MHz |
| f _(TBint) | | | 3 V | | 10 | |

(1) The external signal sets the interrupt flag every time the minimum t_(int) parameters are met. It might be set with trigger signals shorter than t_(int).

8.7 Leakage Current – Ports P1 to P6

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

| PARAMETER ⁽¹⁾ | | TEST CONDITIONS | | MIN | MAX | UNIT |
|--------------------------|--------------------------|------------------------|------------------------------|-----|-----|------|
| I _{Ikg(Px.y)} | Leakage current, Port Px | V(Px.y) ⁽²⁾ | V _{CC} = 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 port pin must be selected as input.

8.8 Outputs – Ports P1 to P6

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

| PARAMETER | | TEST CONDITIONS | MIN | MAX | UNIT |
|-----------------|---------------------------|-------------------------------------------------------------------------|------------------------|------------------------|------|
| V _{OH} | High-level output voltage | I _{OH(max)} = - 1.5 mA, V _{CC} = 2.2 V ⁽¹⁾ | V _{CC} - 0.25 | V _{CC} | V |
| | | I _{OH(max)} = - 6 mA, V _{CC} = 2.2 V ⁽²⁾ | V _{CC} - 0.6 | V _{CC} | |
| | | I _{OH(max)} = - 1.5 mA, V _{CC} = 3 V ⁽¹⁾ | V _{CC} - 0.25 | V _{CC} | |
| | | I _{OH(max)} = - 6 mA, V _{CC} = 3 V ⁽²⁾ | V _{CC} - 0.6 | V _{CC} | |
| V _{OL} | Low-level output voltage | I _{OL(max)} = 1.5 mA, V _{CC} = 2.2 V ⁽¹⁾ | V _{SS} | V _{SS} + 0.25 | V |
| | | I _{OL(max)} = 6 mA, V _{CC} = 2.2 V ⁽²⁾ | V _{SS} | V _{SS} + 0.6 | |
| | | I _{OL(max)} = 1.5 mA, V _{CC} = 3 V ⁽¹⁾ | V _{SS} | V _{SS} + 0.25 | |
| | | I _{OL(max)} = 6 mA, V _{CC} = 3 V ⁽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 satisfy the maximum specified voltage drop.
- (2) The maximum total current, I_{OH(max)} and I_{OL(max)}, for all outputs combined, should not exceed ±48 mA to satisfy the maximum specified voltage drop.

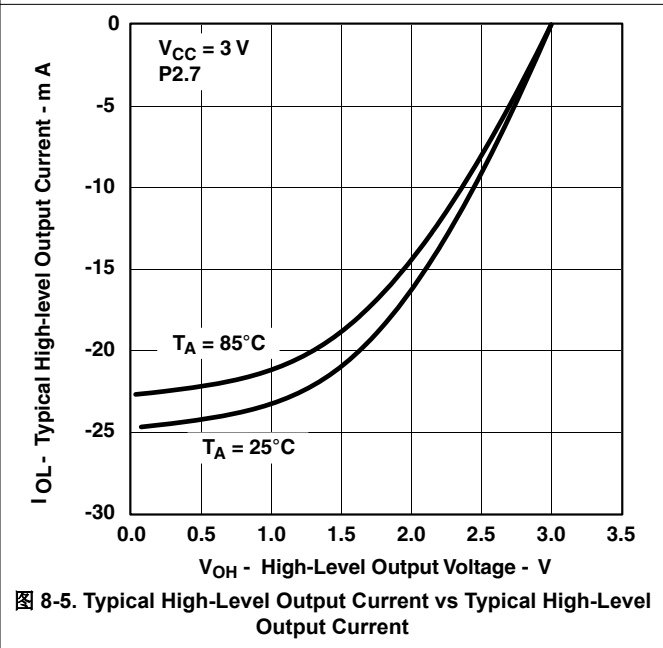
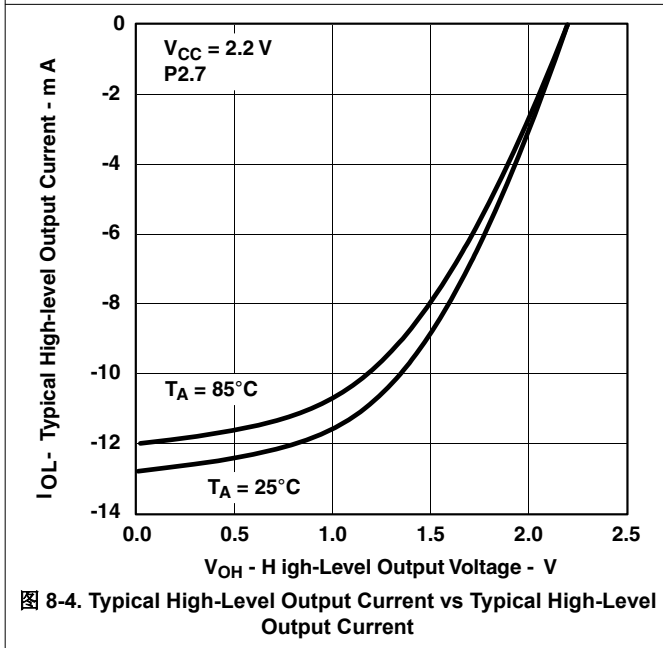
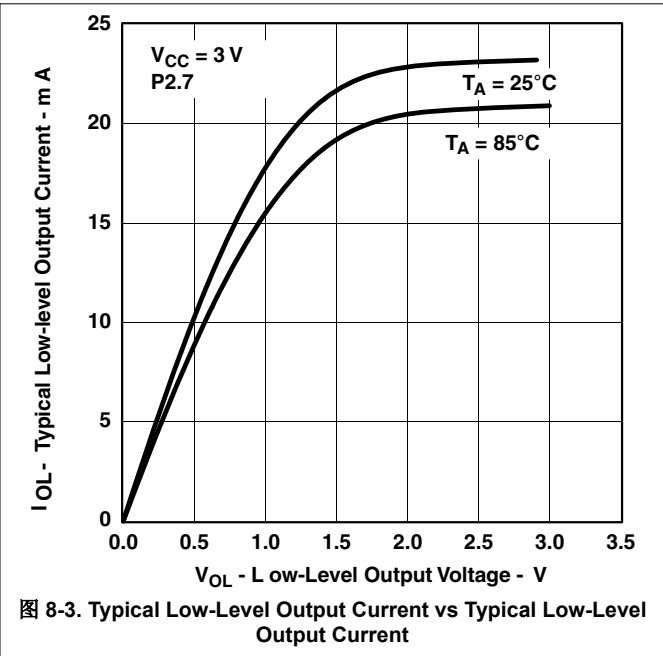
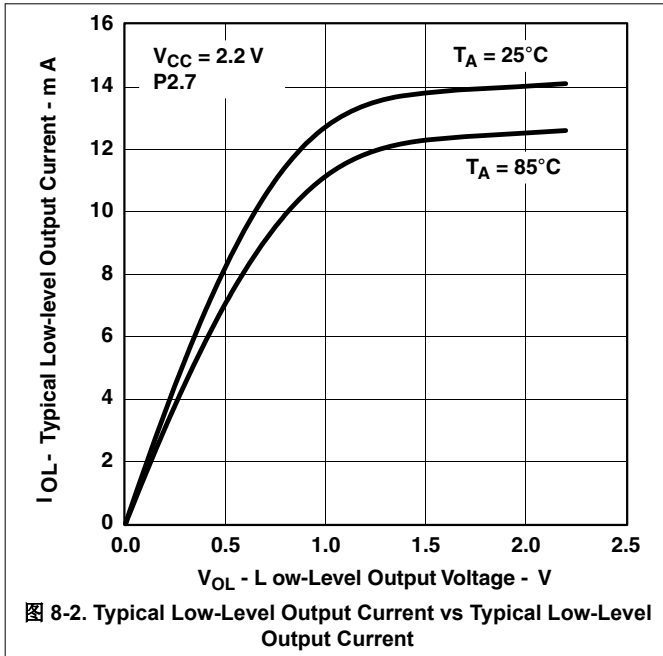
8.9 Output Frequency

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

| PARAMETER | | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|----------------------------------------------|--------------------------------|------------------------------------------------------------------------------|-----------------------------------------------------------------|----------------|-----|-----------------------|------|
| f _(Px,y) | (1 ≤ x ≤ 6, 0 ≤ y ≤ 7) | C _L = 20 F, I _L = ±1.5 mA | V _{CC} = 2.2 V, 3 V | dc | | f _(System) | MHz |
| f _(MCLK) | P1.1/TA0/MCLK | C _L = 20 pF | | | | f _(System) | MHz |
| f _(SMCLK) | P1.4/TBCLK/SMCLK | | | | | | |
| f _(ACLK) | P1.5/TACLK/ACLK | | | | | | |
| t _(Xdc) | Duty cycle of output frequency | P1.5/TACLK/ACLK, C _L = 20 pF, V _{CC} = 2.2 V, 3 V | f _(ACLK) = f _(LFXT1) = f _(XT1) | 40% | | 60% | |
| | | | f _(ACLK) = f _(LFXT1) = f _(LF) | 30% | | 70% | |
| | | | f _(ACLK) = f _(LFXT1) | | 50% | | |
| | | P1.1/TA0/MCLK, C _L = 20 pF, V _{CC} = 2.2 V, 3 V | f _(MCLK) = f _(XT1) | 40% | | 60% | |
| | | | f _(MCLK) = f _(DCOCLK) | 50% - 15 ns | 50% | 50%+ 15 ns | |
| | | P1.4/TBCLK/SMCLK, C _L = 20 pF, V _{CC} = 2.2 V, 3 V | f _(SMCLK) = f _(XT2) | 40% | | 60% | |
| f _(SMCLK) = f _(DCOCLK) | 50% - 15 ns | | 50% | 50%+ 15 ns | | | |

8.10 Typical Characteristics - Outputs

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



8.11 Wake-Up From LPM3

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

| PARAMETER | | TEST CONDITIONS | | MIN | MAX | UNIT |
|---------------|------------|-----------------|-------------------------------------|-----|-----|---------------|
| $t_{d(LPM3)}$ | Delay time | f = 1 MHz | $V_{CC} = 2.2\text{ V}, 3\text{ V}$ | | 6 | μs |
| | | f = 2 MHz | | 6 | | |
| | | f = 3 MHz | | 6 | | |

8.12 RAM

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

| PARAMETER | TEST CONDITIONS | MIN | MAX | UNIT |
|------------|---------------------------|-----|-----|------|
| V_{RAMh} | CPU halted ⁽¹⁾ | 1.6 | | V |

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

8.13 LCD

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

| PARAMETER | | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|-----------------------|----------------------|----------------------------------------------------|-------------------------------------------------------------------|-----------------------------------------------|----------------|----------------|------|
| $V_{(33)}$ | Analog voltage | Voltage at P5.7/R33 | $V_{CC} = 3\text{ V}$ | 2.5 | | $V_{CC} + 0.2$ | V |
| $V_{(23)}$ | | Voltage at P5.6/R23 | | $[V_{(33)} - V_{(03)}] \times 2/3 + V_{(03)}$ | | | |
| $V_{(13)}$ | | Voltage at P5.5/R13 | | $[V_{(33)} - V_{(03)}] \times 1/3 + V_{(03)}$ | | | |
| $V_{(33)} - V_{(03)}$ | | Voltage at R33 to R03 | | 2.5 | $V_{CC} + 0.2$ | | |
| $I_{(R03)}$ | Input leakage | R03 = V_{SS} | No load at all segment and common lines, $V_{CC} = 3\text{ V}$ | | | ± 20 | nA |
| $I_{(R13)}$ | | P5.5/R13 = $V_{CC}/3$ | | | | ± 20 | |
| $I_{(R23)}$ | | P5.6/R23 = $2 \times V_{CC}/3$ | | | | ± 20 | |
| $V_{(Sxx0)}$ | Segment line voltage | $I_{(Sxx)} = -3\ \mu\text{A}, V_{CC} = 3\text{ V}$ | | $V_{(03)}$ | | $V_{(03)} - 1$ | V |
| $V_{(Sxx1)}$ | | | | $V_{(13)}$ | | $V_{(13)} - 1$ | |
| $V_{(Sxx2)}$ | | | | $V_{(23)}$ | | $V_{(23)} - 1$ | |
| $V_{(Sxx3)}$ | | | | $V_{(33)}$ | | $V_{(33)} - 1$ | |

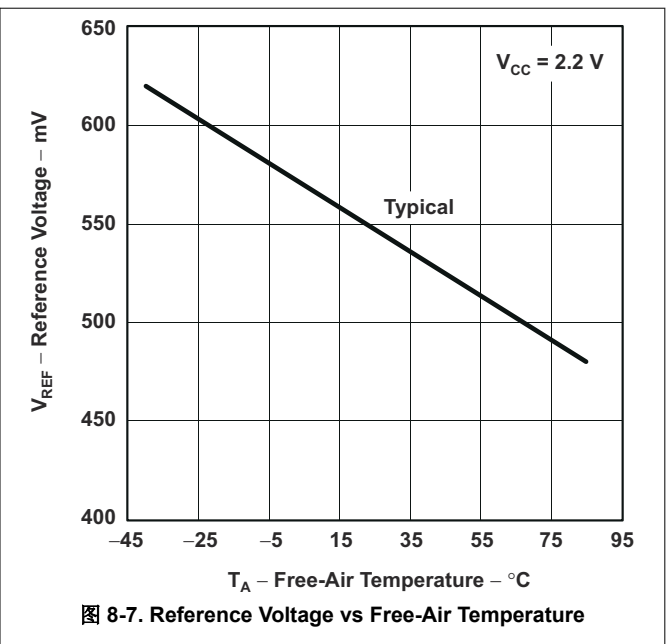
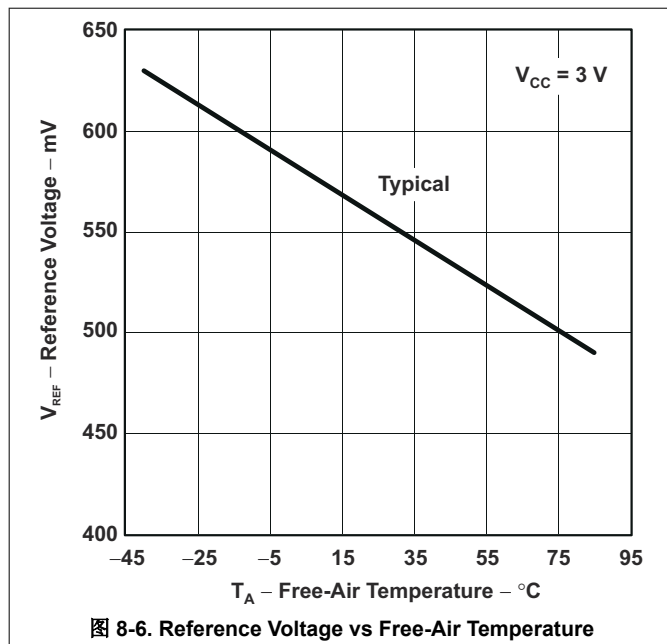
8.14 Comparator_A

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

| PARAMETER ⁽¹⁾ | TEST CONDITIONS | V _{CC} | MIN | TYP | MAX | UNIT |
|--------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|-----------------|------|---------------------|------|------|
| I _(CC) | CAON = 1, CARSEL = 0, CAREF = 0 | 2.2 V | | 25 | 50 | μA |
| | | 3 V | | 45 | 60 | |
| I _(Refladder/RefDiode) | CAON = 1, CARSEL = 0, CAREF = (1,2,3), No load at P1.6/CA0 and P1.7/CA1 | 2.2 V | | 30 | 50 | μA |
| | | 3 V | | 45 | 71 | |
| V _(Ref025) (Voltage at 0.25 V _{CC} node) / V _{CC} | PCA0 = 1, CARSEL = 1, CAREF = 1, No load at P1.6/CA0 and P1.7/CA1 | 2.2 V, 3 V | 0.23 | 0.24 | 0.25 | |
| V _(Ref050) (Voltage at 0.55 V _{CC} node) / V _{CC} | PCA0 = 1, CARSEL = 1, CAREF = 2, No load at P1.6/CA0 and P1.7/CA1 | 2.2 V, 3 V | 0.47 | 0.48 | 0.5 | |
| V _(RefVT) See 图 8-6 and 图 8-7 | PCA0 = 1, CARSEL = 1, CAREF = 3, No load at P1.6/CA0 and P1.7/CA1, T _A = 85°C | 2.2 V | 390 | 480 | 540 | mV |
| | | 3 V | 400 | 490 | 550 | |
| V _{IC} Common-mode input voltage range | CAON = 1 | 2.2 V, 3 V | 0 | V _{CC} - 1 | | V |
| V _p - V _s Offset voltage | See ⁽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 LH) | T _A = 25°C, Overdrive 10 mV, without filter: CAF = 0 | 2.2 V | 160 | 210 | 300 | ns |
| | | 3 V | 80 | 150 | 240 | |
| | T _A = 25°C, Overdrive 10 mV, with filter: CAF = 1 | 2.2 V | 1.4 | 1.9 | 3.4 | μs |
| | | 3 V | 0.9 | 1.5 | 2.6 | |
| t _(response HL) | T _A = 25°C, Overdrive 10 mV, without filter: CAF = 0 | 2.2 V | 130 | 210 | 300 | ns |
| | | 3 V | 80 | 150 | 240 | |
| | T _A = 25°C, Overdrive 10 mV, with filter: CAF = 1 | 2.2 V | 1.4 | 1.9 | 3.4 | μs |
| | | 3 V | 0.9 | 1.5 | 2.6 | |

- (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.

8.15 Comparator_A Typical Characteristics



8.15 Comparator_A Typical Characteristics (continued)

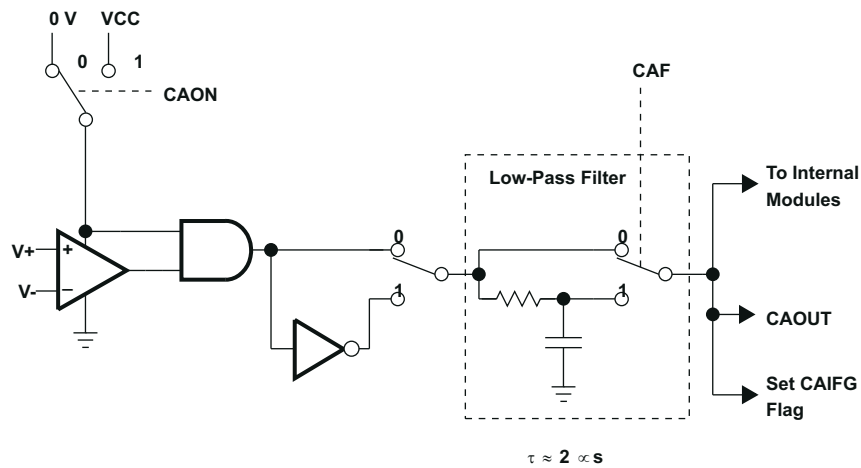


图 8-8. Block Diagram of Comparator_A Module

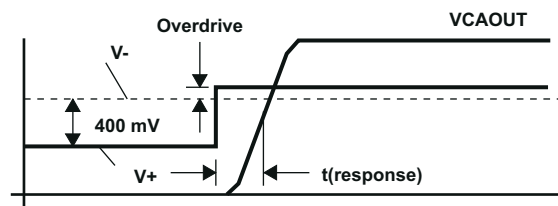


图 8-9. Overdrive Definition

8.16 Power-On Reset (POR) and Brownout Reset (BOR)

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

| PARAMETER ⁽¹⁾ | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--------------------------|-------------------------|--------------------------------------------------------------------------------------------------------|---------------------------|-----|------|---------------|
| $t_{d(BOR)}$ | Brownout ⁽²⁾ | | | | 2000 | μs |
| $V_{CC(start)}$ | | $dV_{CC}/dt \leq 3 \text{ V/s}$ (see 图 8-10) | $0.7 \times V_{(B_IT-)}$ | | | V |
| $V_{(B_IT-)}$ | | $dV_{CC}/dt \leq 3 \text{ V/s}$ (see 图 8-10 through 图 8-12) | | | 1.71 | V |
| $V_{hys(B_IT-)}$ | | $dV_{CC}/dt \leq 3 \text{ V/s}$ (see 图 8-10) | 70 | 130 | 210 | mV |
| $t_{(reset)}$ | | Pulse length needed at RST/NMI pin to accepted reset internally, $V_{CC} = 2.2 \text{ V}, 3 \text{ V}$ | 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 $\leq 1.8 \text{ V}$.
- (2) During power up, the CPU begins code execution following a period of $t_{d(BOR)}$ after $V_{CC} = V_{(B_IT-)} + V_{hys(B_IT-)}$. The default FLL+ settings must not be changed until $V_{CC} \geq V_{CC(min)}$, where $V_{CC(min)}$ is the minimum supply voltage for the desired operating frequency. See the *MSP430x4xx Family User's Guide (SLAU056)* for more information on the brownout/SVS circuit.

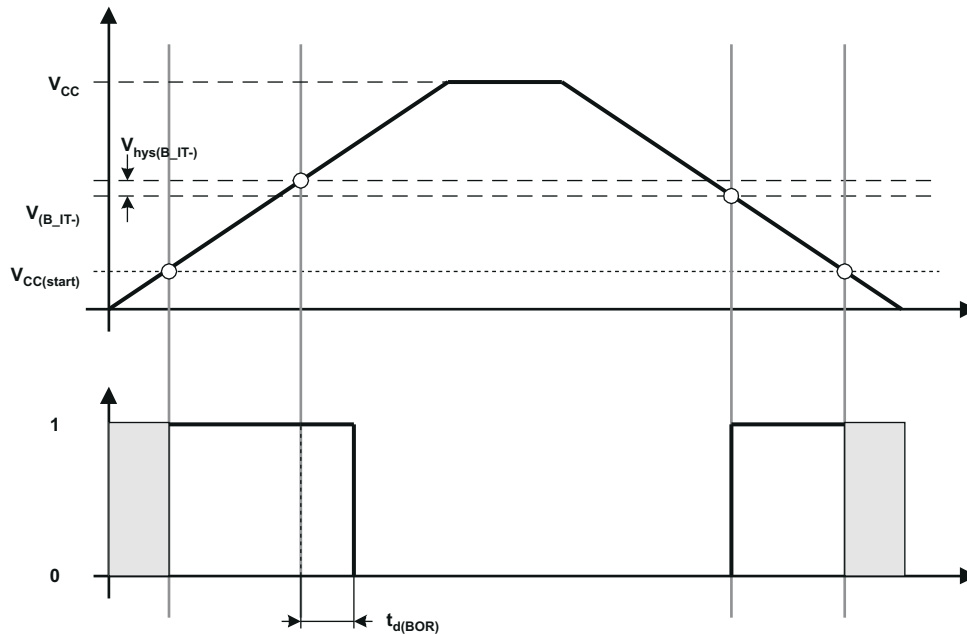


图 8-10. POR and BOR vs Supply Voltage

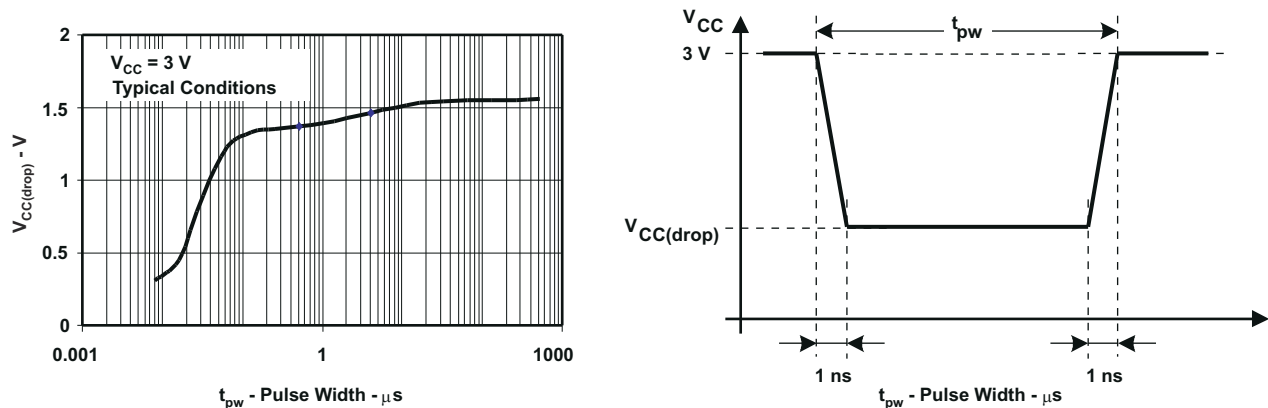


图 8-11. $V_{CC(drop)}$ Level with a Square Voltage Drop to Generate a POR or BOR Signal

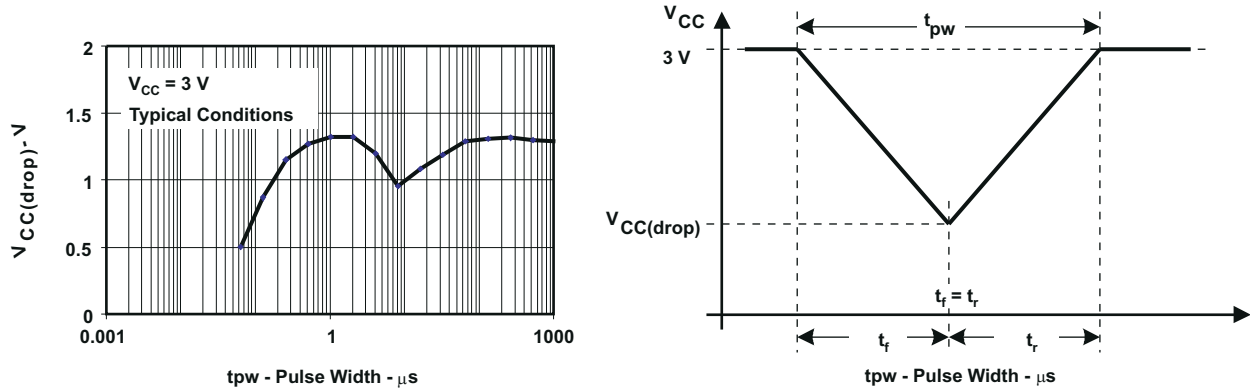


图 8-12. $V_{CC(drop)}$ Level With a Triangle Voltage Drop to Generate a POR or BOR Signal

8.17 Supply Voltage Supervisor (SVS) and Supply Voltage Monitor (SVM)

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

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT | |
|------------------------------|-----------------------------------------------------------------------------|---------------|-------------------------------|--------------------|-------------------------------|----|
| $t_{(SVSR)}$ | $dV_{CC}/dt > 30 \text{ V/ms}$ (see 图 8-13) | 5 | | 150 | μs | |
| | $dV_{CC}/dt \leq 30 \text{ V/ms}$ | | | 2000 | | |
| $t_{d(SVson)}$ | SVS on, switch from VLD = 0 to VLD \neq 0, $V_{CC} = 3 \text{ V}$ | | 150 | 300 | μs | |
| t_{settle} | VLD \neq 0 ⁽¹⁾ | | | 12 | μs | |
| $V_{(SVSstart)}$ | VLD \neq 0, $V_{CC}/dt \leq 3 \text{ V/s}$ (see 图 8-13) | | 1.55 | 1.7 | V | |
| $V_{hys(SVS_IT-)}$ | $V_{CC}/dt \leq 3 \text{ V/s}$ (see 图 8-13) | VLD = 1 | 70 | 120 | 155 | mV |
| | | VLD = 2 to 14 | $V_{(SVS_IT-)} \times 0.001$ | | $V_{(SVS_IT-)} \times 0.016$ | |
| | $V_{CC}/dt \leq 3 \text{ V/s}$ (see 图 8-13), external voltage applied on A7 | VLD = 15 | 4.4 | | 20 | mV |
| $V_{(SVS_IT-)}$ | $V_{CC}/dt \leq 3 \text{ V/s}$ (see 图 8-13) | VLD = 1 | 1.8 | 1.9 | 2.05 | V |
| | | VLD = 2 | 1.94 | 2.1 | 2.23 | |
| | | VLD = 3 | 2.05 | 2.2 | 2.35 | |
| | | VLD = 4 | 2.14 | 2.3 | 2.46 | |
| | | VLD = 5 | 2.24 | 2.4 | 2.58 | |
| | | VLD = 6 | 2.33 | 2.5 | 2.69 | |
| | | VLD = 7 | 2.46 | 2.65 | 2.84 | |
| | | VLD = 8 | 2.58 | 2.8 | 2.97 | |
| | | VLD = 9 | 2.69 | 2.9 | 3.10 | |
| | | VLD = 10 | 2.83 | 3.05 | 3.26 | |
| | | VLD = 11 | 2.94 | 3.2 | 3.39 | |
| | | VLD = 12 | 3.11 | 3.35 | 3.58 ⁽²⁾ | |
| | | VLD = 13 | 3.24 | 3.5 | 3.73 ⁽²⁾ | |
| | | VLD = 14 | 3.43 | 3.7 ⁽²⁾ | 3.96 ⁽²⁾ | |
| | $V_{CC}/dt \leq 3 \text{ V/s}$ (see 图 8-13), external voltage applied on A7 | VLD = 15 | 1.1 | 1.2 | 1.3 | |
| $I_{CC(SVS)}$ ⁽³⁾ | VLD \neq 0, $V_{CC} = 2.2 \text{ V}, 3 \text{ V}$ | | 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 \neq 0 to a different VLD value somewhere between 2 and 15. The overdrive is assumed to be $> 50 \text{ mV}$.
- (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.

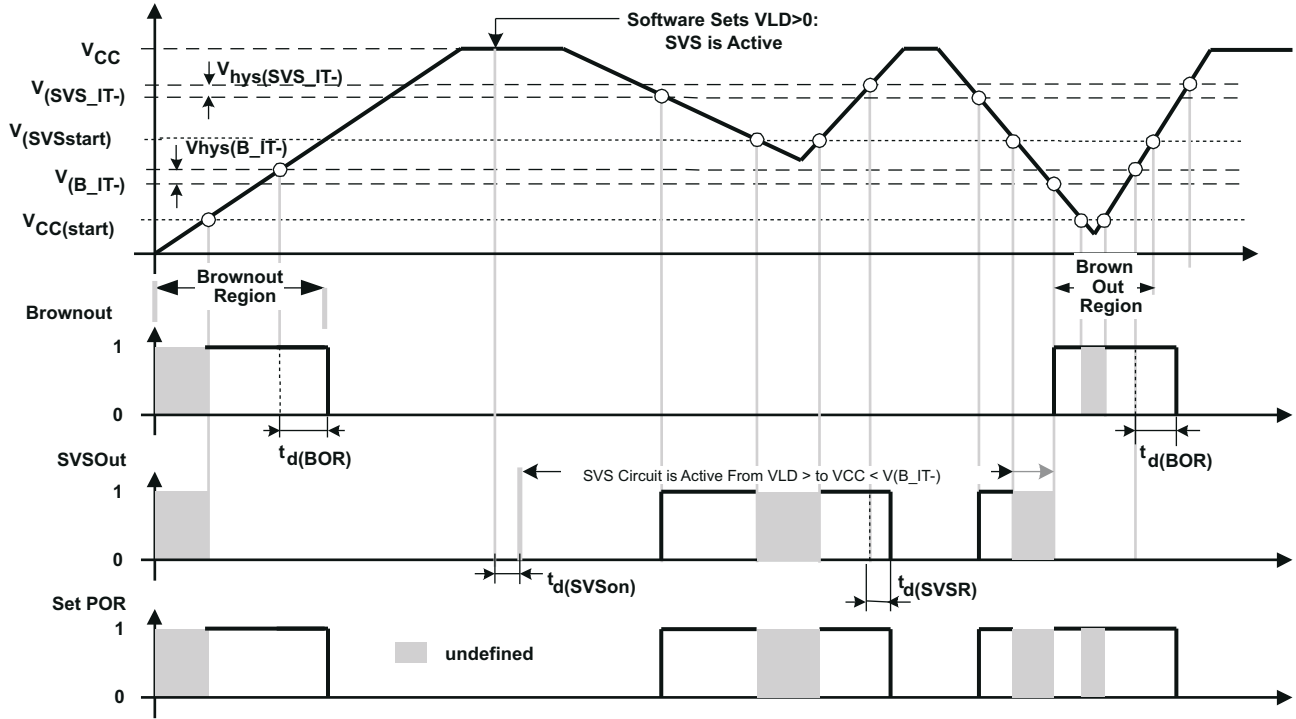


图 8-13. SVS Reset (SVSR) vs Supply Voltage

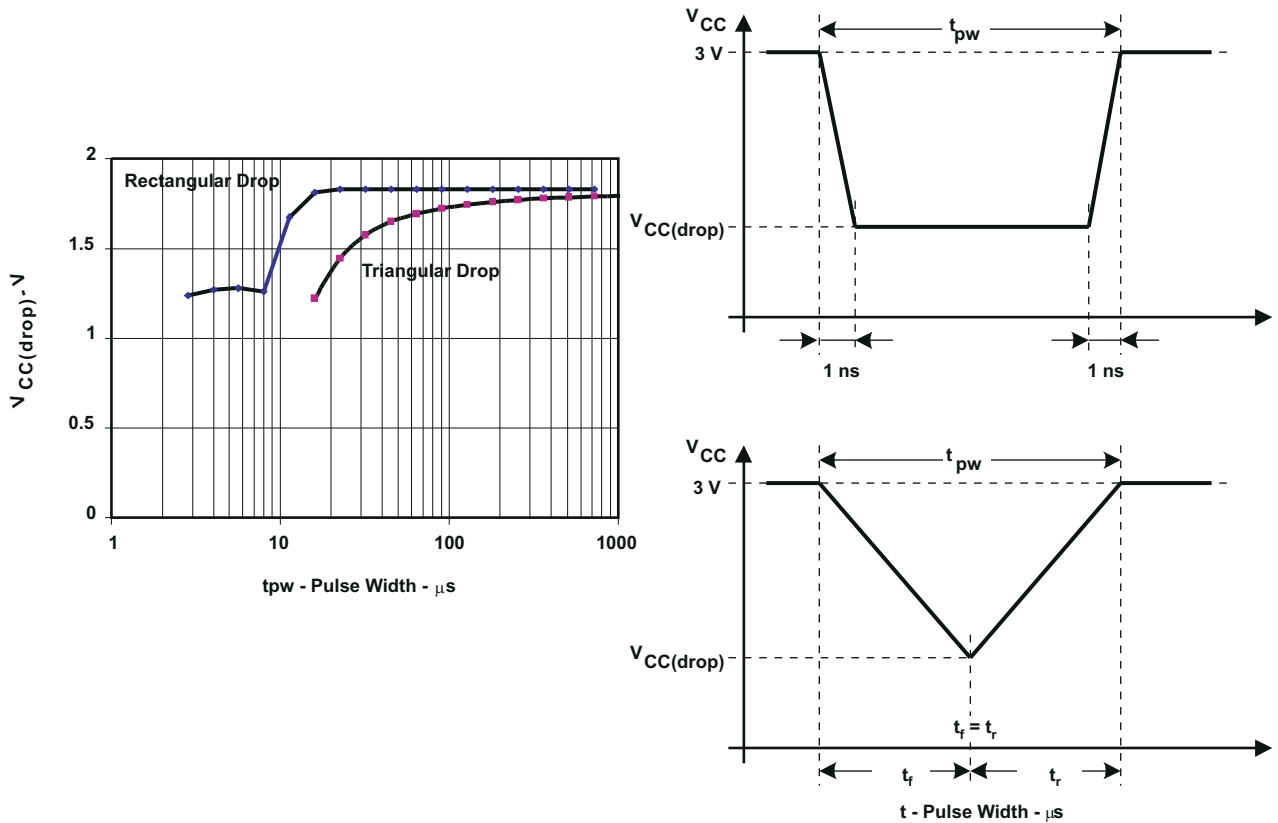


图 8-14. $V_{CC(drop)}$ With a Square Voltage Drop and a Triangle Voltage Drop to Generate an SVS Signal

8.18 DCO

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

| PARAMETER | TEST CONDITIONS | V _{CC} | MIN | TYP | MAX | UNIT |
|-----------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|------|------|------|-------------------|
| f _(DCOCLK) | N _(DCO) = 01Eh, FN ₈ = FN ₄ = FN ₃ = FN ₂ = 0, D = 2, DCOPLUS = 0, f _{Crystal} = 32.738 kHz | 2.2 V, 3 V | | 1 | | MHz |
| f _(DCO=2) | FN ₈ =FN ₄ = FN ₃ = FN ₂ = 0, DCOPLUS = 1 | 2.2 V | 0.3 | 0.65 | 1.25 | MHz |
| | | 3 V | 0.3 | 0.7 | 1.3 | |
| f _(DCO=27) | FN ₈ = FN ₄ = FN ₃ = FN ₂ = 0, DCOPLUS = 1 | 2.2 V | 2.5 | 5.6 | 10.5 | MHz |
| | | 3 V | 2.7 | 6.1 | 11.3 | |
| f _(DCO=2) | FN ₈ = FN ₄ = FN ₃ = FN ₂ = 1, DCOPLUS = 1 | 2.2 V | 0.7 | 1.3 | 2.3 | MHz |
| | | 3 V | 0.8 | 1.5 | 2.5 | |
| f _(DCO=27) | FN ₈ = FN ₄ = FN ₃ = FN ₂ = 1, DCOPLUS = 1 | 2.2 V | 5.7 | 10.8 | 18 | MHz |
| | | 3 V | 6.5 | 12.1 | 20 | |
| f _(DCO=2) | FN ₈ = FN ₄ = 0, FN ₃ = 1, FN ₂ = x, DCOPLUS = 1 | 2.2 V | 1.2 | 2 | 3 | MHz |
| | | 3 V | 1.3 | 2.2 | 3.5 | |
| f _(DCO=27) | FN ₈ = FN ₄ = 0, FN ₃ = 1, FN ₂ = x, DCOPLUS = 1 | 2.2 V | 9 | 15.5 | 25 | MHz |
| | | 3 V | 10.3 | 17.9 | 28.5 | |
| f _(DCO=2) | FN ₈ = 0, FN ₄ = 1, FN ₃ = FN ₂ = x, DCOPLUS = 1 | 2.2 V | 1.8 | 2.8 | 4.2 | MHz |
| | | 3 V | 2.1 | 3.4 | 5.2 | |
| f _(DCO=27) | FN ₈ = 0, FN ₄ = 1, FN ₃ = FN ₂ = x, DCOPLUS = 1 | 2.2 V | 13.5 | 21.5 | 33 | MHz |
| | | 3 V | 16 | 26.6 | 41 | |
| f _(DCO=2) | FN ₈ = 1, FN ₄ = FN ₃ = FN ₂ = x, DCOPLUS = 1 | 2.2 V | 2.8 | 4.2 | 6.2 | MHz |
| | | 3 V | 4.2 | 6.3 | 9.2 | |
| f _(DCO=27) | FN ₈ = 1, FN ₄ = FN ₃ = FN ₂ = x, DCOPLUS = 1 | 2.2 V | 21 | 32 | 46 | MHz |
| | | 3 V | 30 | 46 | 70 | |
| S _n | Step size between adjacent DCO taps: S _n = f _{DCO(Tap n+1)} / f _{DCO(Tap n)} (see 图 8-16 for taps 21 to 27) | 1 < TAP ≤ 20 | 1.06 | | 1.11 | |
| | | TAP = 27 | 1.07 | | 1.17 | |
| D _t | Temperature drift, N _(DCO) = 01Eh, FN ₈ = FN ₄ = FN ₃ = FN ₂ = 0, D = 2, DCOPLUS = 0 | 2.2 V | -0.2 | -0.3 | -0.4 | %/ ^o C |
| | | 3 V | -0.2 | -0.3 | -0.4 | |
| D _V | Drift with V _{CC} variation, N _(DCO) = 01Eh, FN ₈ = FN ₄ = FN ₃ = FN ₂ = 0, D = 2, DCOPLUS = 0 | 2.2 V, 3 V | 0 | 5 | 15 | %/V |

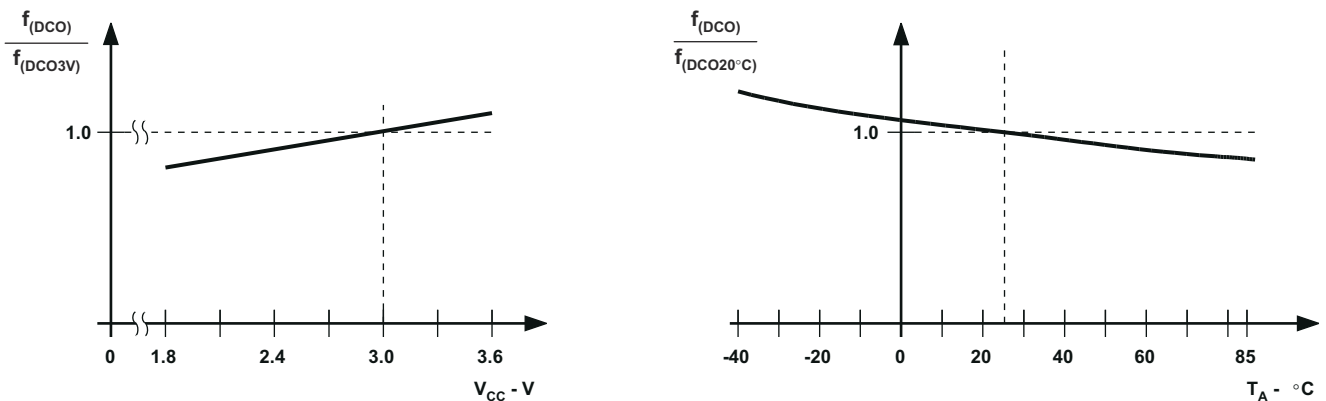


图 8-15. DCO Frequency vs Supply Voltage V_{CC} and vs Ambient Temperature

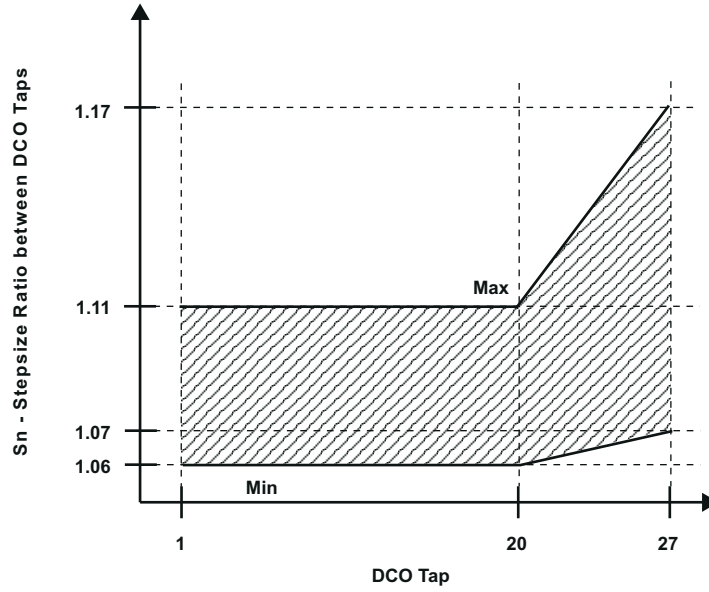


图 8-16. DCO Tap Step Size

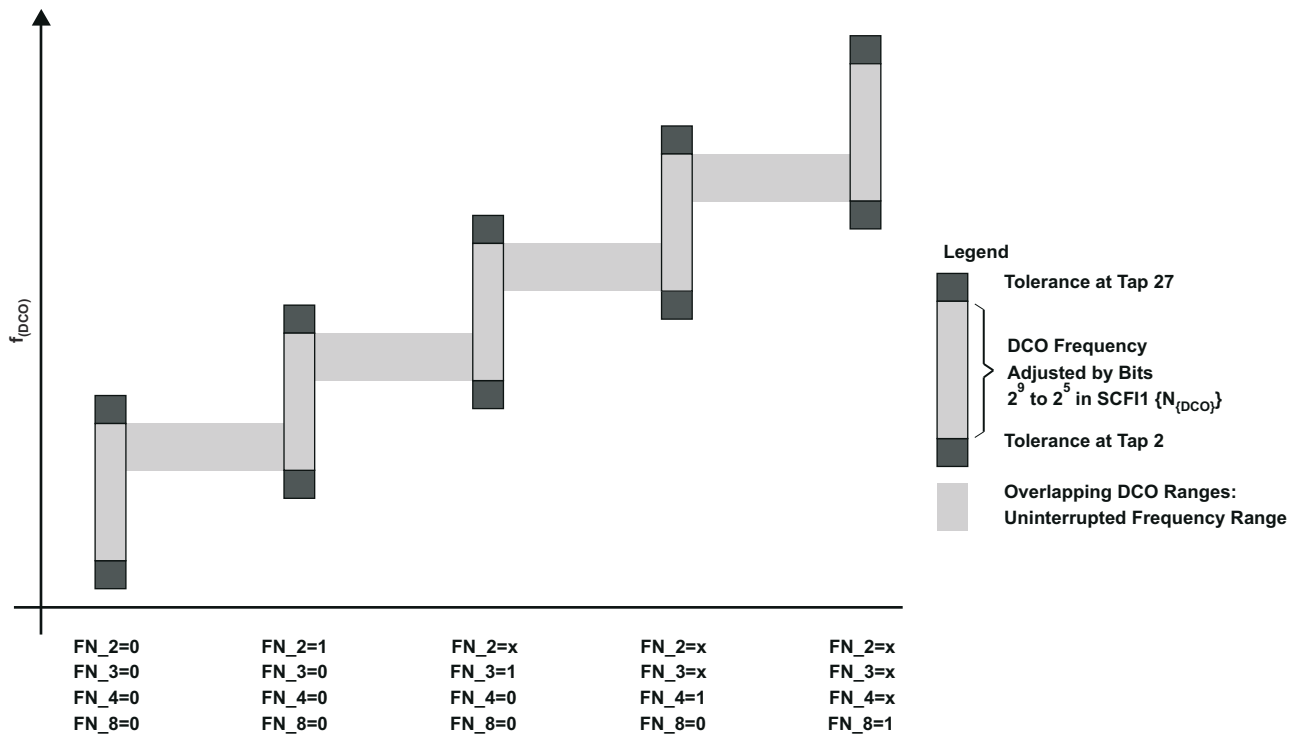


图 8-17. Five Overlapping DCO Ranges Controlled by FN_x Bits

8.19 Crystal Oscillator, XT1 Oscillator

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

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

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

8.20 Crystal Oscillator, XT2 Oscillator

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

| PARAMETER ⁽¹⁾ | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--------------------------|-------------------------------|---------------------------------------------|-----------------------|-----------------------|-----|------|
| C _{XT2IN} | Integrated input capacitance | V _{CC} = 2.2 V, 3 V | | 2 | | pF |
| C _{XT2OUT} | Integrated output capacitance | V _{CC} = 2.2 V, 3 V | | 2 | | pF |
| V _{IL} | Input levels at XT2IN | V _{CC} = 2.2 V, 3 V ⁽²⁾ | V _{SS} | 0.2 × V _{CC} | | V |
| V _{IH} | | | 0.8 × V _{CC} | V _{CC} | | V |

- (1) The oscillator needs capacitors at both terminals, with values specified by the crystal manufacturer.
- (2) Applies only when using an external logic-level clock source. Not applicable when using a crystal or resonator.

8.21 USART0

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

| PARAMETER ⁽¹⁾ | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--------------------------|----------------------|----------------------------------------------|-----|-----|-----|------|
| t _(τ) | USART0 deglitch time | V _{CC} = 2.2 V, SYNC = 0, UART mode | 200 | 430 | 800 | ns |
| | | V _{CC} = 3 V, SYNC = 0, UART mode | 150 | 280 | 500 | |

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

8.22 12-Bit ADC, Power Supply and Input Range Conditions

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

| PARAMETER ⁽¹⁾ | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--------------------------|-------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|------------------|------|------------|----------|
| V_{CC} | Analog supply voltage | V_{CC} and DV_{CC} are connected together, V_{SS} and DV_{SS} are connected together, $V_{(AVSS)} = V_{(DVSS)} = 0$ V | 2.2 | | 3.6 | V |
| $V_{(P6.x/Ax)}$ | Analog input voltage range ⁽²⁾ | All external Ax terminals, Analog inputs selected in ADC12MCTLx register and P6Sel.x = 1, $V_{(AVSS)} \leq V_{Ax} \leq V_{(AVCC)}$ | 0 | | V_{AVCC} | V |
| I_{ADC12} | Operating supply current into the AVCC terminal ⁽³⁾ | $f_{ADC12CLK} = 5.0$ MHz, ADC12ON = 1, REFON = 0, SHT0 = 0, SHT1 = 0, ADC12DIV = 0 | $V_{CC} = 2.2$ V | 0.65 | 1.3 | mA |
| | | | $V_{CC} = 3$ V | 0.8 | 1.6 | |
| I_{REF+} | Operating supply current into the AVCC terminal ⁽⁴⁾ | $f_{ADC12CLK} = 5.0$ MHz, ADC12ON = 0, REFON = 1, REF2_5V = 1 | $V_{CC} = 3$ V | 0.5 | 0.8 | mA |
| | | $f_{ADC12CLK} = 5.0$ MHz, ADC12ON = 0, REFON = 1, REF2_5V = 0 | $V_{CC} = 2.2$ V | 0.5 | 0.8 | |
| C_I | Input capacitance | Only one terminal can be selected at one time, Ax | $V_{CC} = 2.2$ V | | 40 | pF |
| R_I | Input MUX ON resistance | 0 V $\leq V_{Ax} \leq V_{AVCC}$ | $V_{CC} = 3$ V | | 2000 | Ω |

- (1) The leakage current is defined in the leakage current table with 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 AVCC. Consumption is independent of the ADC12ON control bit, unless a conversion is active. The REFON bit enables to settle the built-in reference before starting an A/D conversion.

8.23 12-Bit ADC, External Reference

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

| PARAMETER ⁽¹⁾ | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--------------------------------------|--------------------------------------------------|---------------------------------------------------|-----------------------|-----|------------|---------|
| V_{eREF+} | Positive external reference voltage input | $V_{eREF+} > V_{REF-} - I_{eREF-}$ ⁽²⁾ | 1.4 | | V_{AVCC} | V |
| $V_{REF-} - I_{eREF-}$ | Negative external reference voltage input | $V_{eREF+} > V_{REF-} - I_{eREF-}$ ⁽³⁾ | 0 | | 1.2 | V |
| $(V_{eREF+} - V_{REF-} - I_{eREF-})$ | Differential external reference voltage input | $V_{eREF+} > V_{REF-} - I_{eREF-}$ ⁽⁴⁾ | 1.4 | | V_{AVCC} | V |
| I_{VeREF+} | Static input current | 0 V $\leq V_{eREF+} \leq V_{AVCC}$ | $V_{CC} = 2.2$ V, 3 V | | ± 1 | μ A |
| $I_{VREF-} - I_{VeREF-}$ | Static input current | 0 V $\leq V_{eREF-} \leq V_{AVCC}$ | $V_{CC} = 2.2$ V, 3 V | | ± 1 | μ A |

- (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.

8.24 12-Bit ADC, Built-In Reference

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

| PARAMETER | TEST CONDITIONS | V _{CC} | MIN | TYP | 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} | 3 V | 2.4 | 2.5 | 2.6 | V |
| | REF2_5V = 0 for 1.5 V, I _{VREF+max} ≤ I _{VREF+} ≤ I _{VREF+min} | 2.2 V, 3 V | 1.44 | 1.5 | 1.56 | |
| 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, I _{VREF+min} ≥ I _{VREF+} ≥ - 0.5 mA | | 2.8 | | | |
| | REF2_5V = 1, I _{VREF+min} ≥ I _{VREF+} ≥ - 1 mA | | 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 | 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 | 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+} ⁽¹⁾ | 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 | 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 图 8-18) ⁽²⁾ | I _{VREF+} = 0.5 mA, C _{VREF+} = 10 μF, V _{REF+} = 1.5 V, V _{AVCC} = 2.2 V | | | | 17 | ms |

- (1) 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-} - I_{VREF-} and AV_{SS}: 10 μF tantalum and 100 nF ceramic.
- (2) 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.

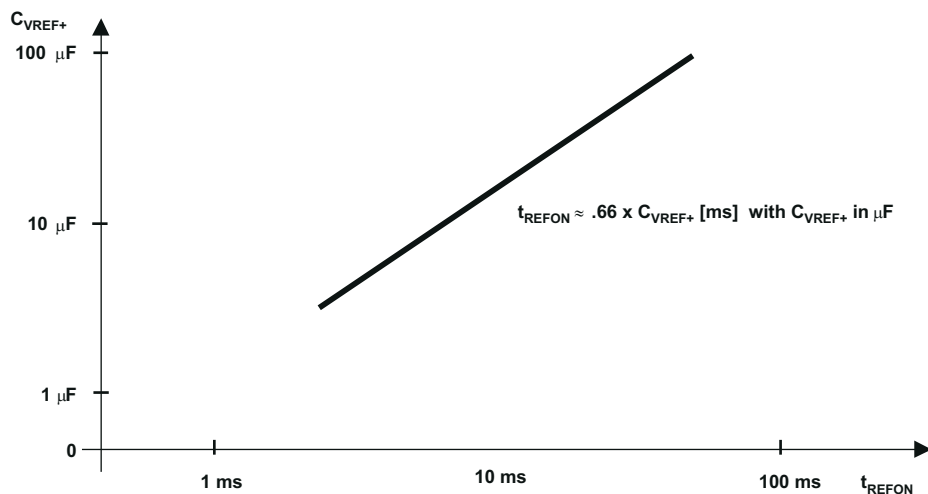


图 8-18. Typical Settling Time of Internal Reference t_{REFON} vs External Capacitor on V_{REF+}

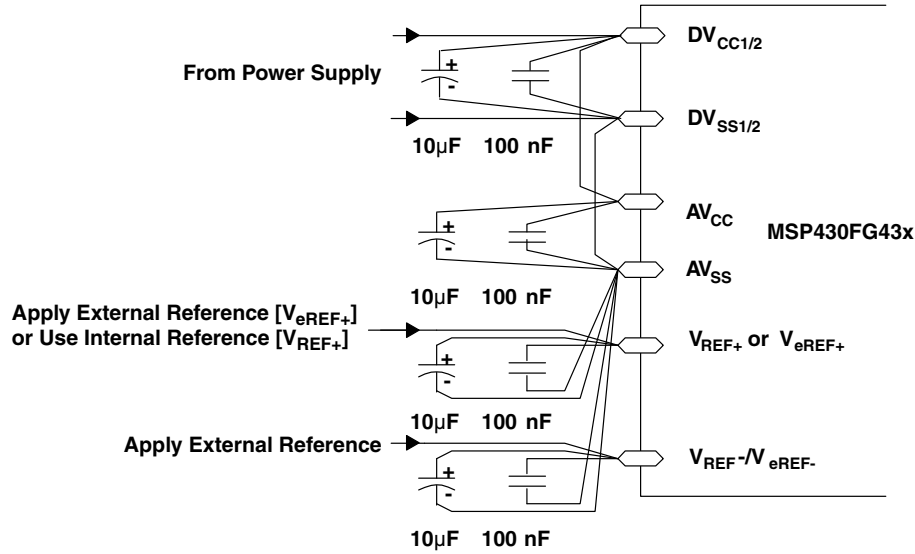


图 8-19. Supply Voltage and Reference Voltage Design V_{REF-}/V_{eREF-} - External Supply

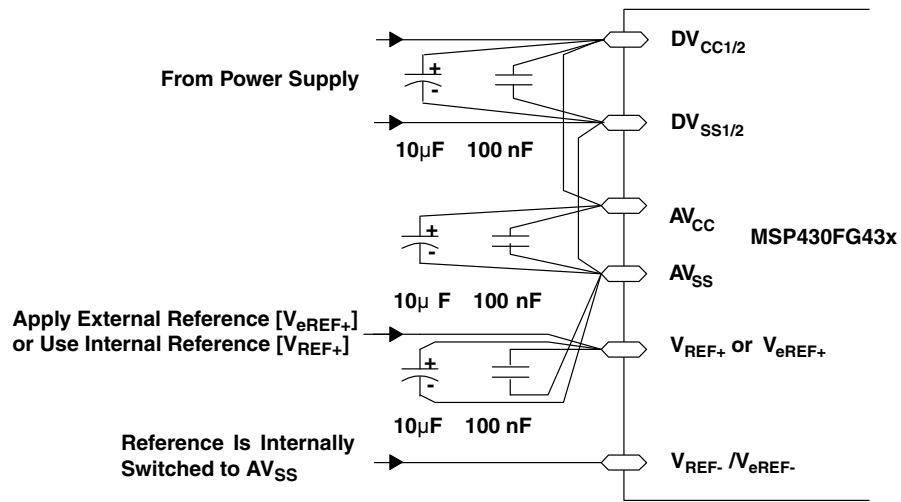


图 8-20. Supply Voltage and Reference Voltage Design $V_{REF-}/V_{eREF-} = AV_{SS}$, Internally Connected

8.25 12-Bit ADC, Timing Parameters

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

| PARAMETER | | TEST CONDITIONS | V _{CC} | MIN | TYP | MAX | UNIT |
|-----------------------|----------------------------------|--------------------------------------------------------------------------------------------------------------------------------------|-----------------|------|---------------------------------|------|------|
| f _{ADC12CLK} | ADC12 clock frequency | For specified performance of ADC12 linearity parameters | 2.2 V, 3 V | 0.45 | 5 | 7 | MHz |
| f _{ADC12OSC} | Internal ADC12 oscillator | ADC12DIV = 0, f _{ADC12CLK} = f _{ADC12OSC} | 2.2 V, 3 V | 3.7 | 5 | 7 | MHz |
| t _{CONVERT} | Conversion time | C _{VREF+} ≥ 5 μF, Internal oscillator, f _{ADC12OSC} = 3.7 MHz to 7 MHz | 2.2 V, 3 V | 1.86 | | 3.51 | μs |
| | | External f _{ADC12CLK} from ACLK, MCLK, or SMCLK, ADC12SSEL ≠ 0 | | | 13 × 1/f _{ADC12CLK} | | μs |
| t _{ADC12ON} | Turn on settling time of the ADC | See (1) | | | | 100 | ns |
| t _{Sample} | Sampling time | R _S = 400 Ω, R _I = 1000 Ω, C _I = 30 pF, τ = [R _S + R _I] × C _I (2) | 3 V | 1220 | | | ns |
| | | | 2.2 V | 1400 | | | |

(1) 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.

(2) Approximately ten Tau (τ) are needed to get an error of less than ±0.5 LSB:

$$t_{\text{Sample}} = \ln(2^{n+1}) \times (R_S + R_I) \times C_I + 800 \text{ ns, where } n = \text{ADC resolution} = 12, R_S = \text{external source resistance.}$$

8.26 12-Bit ADC, Linearity Parameters

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

| PARAMETER | | TEST CONDITIONS | V _{CC} | MIN | TYP | 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 R _S < 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 |

8.27 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 = NA, T _A = 25°C | 2.2 V | | 40 | 120 | μA |
| | | | 3 V | | 60 | 160 | |
| V _{SENSOR} | See (2) | ADC12ON = 1, INCH = 0Ah, T _A = 0°C | 2.2 V, 3 V | | 986 | | mV |
| TC _{SENSOR} | | ADC12ON = 1, INCH = 0Ah | 2.2 V, 3 V | | 3.55 ± 3% | | mV/°C |
| t _{SENSOR(sample)} | Sample time required if channel 10 is selected ⁽³⁾ | ADC12ON = 1, INCH = 0Ah, Error of conversion result ≤ 1 LSB | 2.2 V | 30 | | | μs |
| | | | 3 V | 30 | | | |
| I _{V_{MID}} | Current into divider at channel 11 ⁽⁴⁾ | ADC12ON = 1, INCH = 0Bh | 2.2 V | | | NA | μA |
| | | | 3 V | | | NA | |
| V _{MID} | AV _{CC} divider at channel 11 | ADC12ON = 1, INCH = 0Bh, V _{MID} ≈ 0.5 × V _{AVCC} | 2.2 V | | 1.1 | 1.10 ± 0.04 | V |
| | | | 3 V | | 1.5 | 1.50 ± 0.04 | |
| t _{V_{MID}(sample)} | Sample time required if channel 11 is selected ⁽⁵⁾ | 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). When REFON = 1, I_{SENSOR} is already included in I_{REF+}.
- (2) The temperature sensor offset can be as much as ±20°C. A single-point calibration is recommended in order to minimize the offset error of the built-in temperature sensor.
- (3) The typical equivalent impedance of the sensor is 51 kΩ. The sample time required includes the sensor-on time t_{SENSOR(on)}.
- (4) No additional current is needed. The V_{MID} is used during sampling.
- (5) The on-time t_{V_{MID}(on)} is included in the sampling time t_{V_{MID}(sample)}; no additional on time is needed.

8.28 12-Bit DAC, Supply Specifications

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} = DV _{CC} , AV _{SS} = DV _{SS} = 0 V | | 2.2 | | 3.6 | V |
| I _{DD} | Supply current, single DAC channel ^{(1) (2)} | DAC12AMP _x = 2, DAC12IR = 0, DAC12_xDAT = 0800h | 2.2 V, 3 V | | 50 | 110 | μA |
| | | DAC12AMP _x = 2, DAC12IR = 1, DAC12_xDAT = 0800h, V _{eREF+} = V _{REF+} = AV _{CC} | | | 50 | 110 | |
| | | DAC12AMP _x = 5, DAC12IR = 1, DAC12_xDAT = 0800h, V _{eREF+} = V _{REF+} = AV _{CC} | | | 200 | 440 | |
| | | DAC12AMP _x = 7, DAC12IR = 1, DAC12_xDAT = 0800h, V _{eREF+} = V _{REF+} = AV _{CC} | | | 700 | 1500 | |
| PSRR | Power-supply rejection ratio ^{(3) (4)} | DAC12_xDAT = 0800h, V _{REF} = 1.5 V, ΔAV _{CC} = 100 mV | 2.2 V | | 70 | | dB |
| | | DAC12_xDAT = 0800h, V _{REF} = 1.5 V or 2.5 V, ΔAV _{CC} = 100 mV | 3 V | | | | |

- (1) No load at the output pin, DAC0 or DAC1, assuming that the control bits for the shared pins are set properly.
- (2) Current into reference terminals not included. If DAC12IR = 1, current flows through the input divider (see Reference Input specifications).
- (3) PSRR = 20 × log(ΔAV_{CC} / ΔV_{DAC12_xOUT}).
- (4) V_{REF} is applied externally. The internal reference is not used.

8.29 12-Bit DAC, Linearity Specifications

over recommended operating free-air temperature range (unless otherwise noted) (see 图 8-21)

| PARAMETER | | TEST CONDITIONS | V _{CC} | MIN | TYP | MAX | UNIT |
|-----------------------------------|-------------------------------------------------------|---------------------------------------------------------------------|-----------------|------|------|-----|---------------|
| Resolution | | 12-bit monotonic | | 12 | | | bits |
| INL | Integral nonlinearity ⁽¹⁾ | V _{ref} = 1.5 V, DAC12AMP _x = 7, DAC12IR = 1 | 2.2 V | ±2.0 | ±8.0 | | LSB |
| | | V _{ref} = 2.5 V, DAC12AMP _x = 7, DAC12IR = 1 | 3 V | | | | |
| DNL | Differential nonlinearity ⁽¹⁾ | V _{ref} = 1.5 V, DAC12AMP _x = 7, DAC12IR = 1 | 2.2 V | ±0.4 | ±1.0 | | LSB |
| | | V _{ref} = 2.5 V, DAC12AMP _x = 7, DAC12IR = 1 | 3 V | | | | |
| E _O | Offset voltage without calibration ^{(1) (2)} | V _{ref} = 1.5 V, DAC12AMP _x = 7, DAC12IR = 1 | 2.2 V | | | | mV |
| | | V _{ref} = 2.5 V, DAC12AMP _x = 7, DAC12IR = 1 | 3 V | | | | |
| | Offset voltage with calibration ^{(1) (2)} | V _{ref} = 1.5 V, DAC12AMP _x = 7, DAC12IR = 1 | 2.2 V | | | | |
| | | V _{ref} = 2.5 V, DAC12AMP _x = 7, DAC12IR = 1 | 3 V | | | | |
| d _{E(O)} /d _T | Offset error temperature coefficient ⁽¹⁾ | | 2.2 V, 3 V | ±30 | | | μV/°C |
| E _G | Gain error ⁽¹⁾ | V _{REF} = 1.5 V | 2.2 V | ±3.5 | | | %FSR |
| | | V _{REF} = 2.5 V | 3 V | | | | |
| d _{E(G)} /d _T | Gain temperature coefficient ⁽¹⁾ | | 2.2 V, 3 V | 10 | | | ppm of FSR/°C |
| t _{Offset Cal} | Time for offset calibration ⁽³⁾ | DAC12AMP _x = 2 | 2.2 V, 3 V | 100 | | | ms |
| | | DAC12AMP _x = 3, 5 | | 32 | | | |
| | | DAC12AMP _x = 4, 6, 7 | | 6 | | | |

- (1) Parameters calculated from the best-fit curve from 0x0A to 0xFFF. The best-fit curve method is used to deliver coefficients "a" and "b" of the first-order equation: $y = a + b \times x$. $V_{DAC12_xOUT} = E_O + (1 + E_G) \times (V_{eREF+} / 4095) \times DAC12_xDAT$, DAC12IR = 1.
- (2) The offset calibration works on the output operational amplifier. Offset Calibration is triggered setting bit DAC12CALON.
- (3) The offset calibration can be done if DAC12AMP_x = {2, 3, 4, 5, 6, 7}. The output operational amplifier is switched off with DAC12AMP_x = {0, 1}. It is recommended that the DAC12 module be configured prior to initiating calibration. Port activity during calibration may affect accuracy and is not recommended.

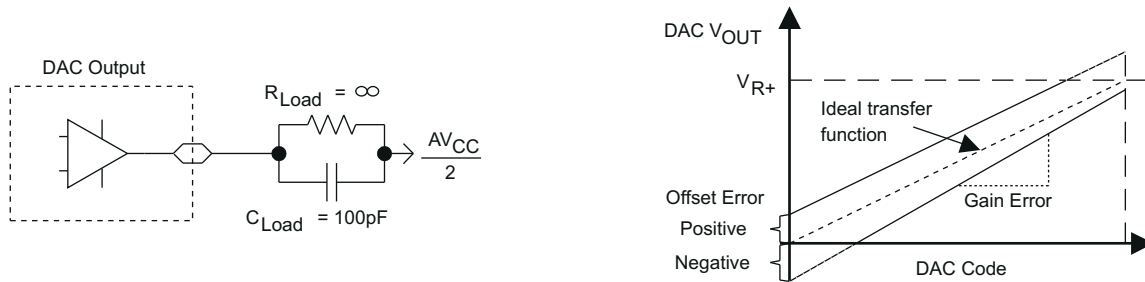


图 8-21. Linearity Test Load Conditions and Gain/Offset Definition

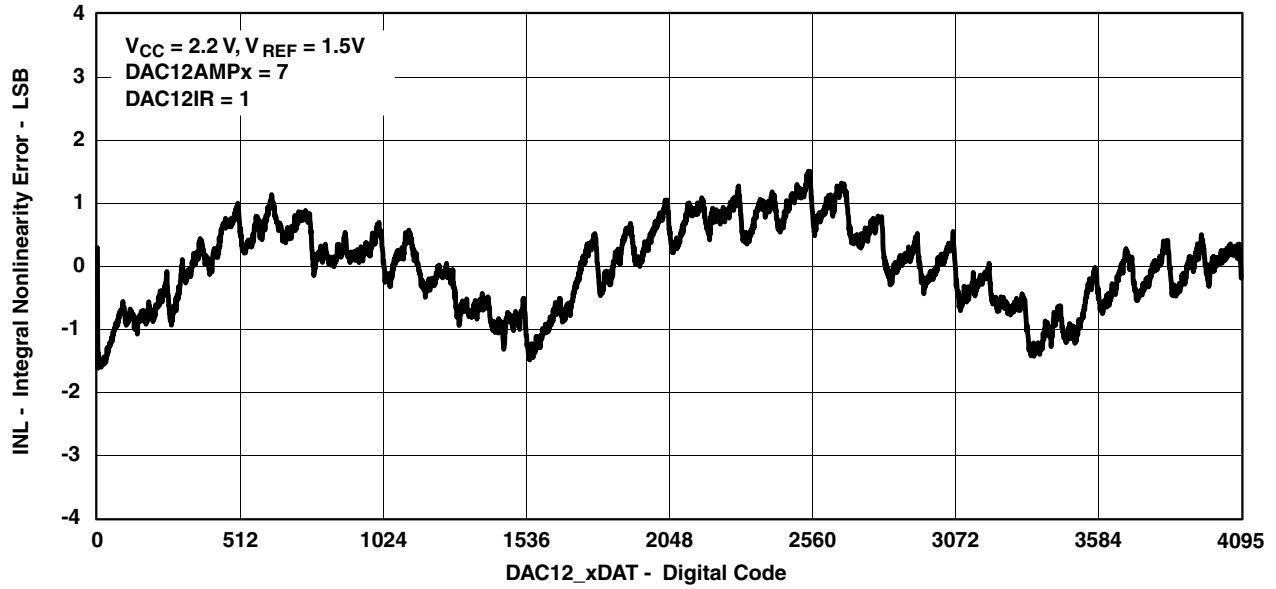


图 8-22. Typical INL Error vs Digital Input Data

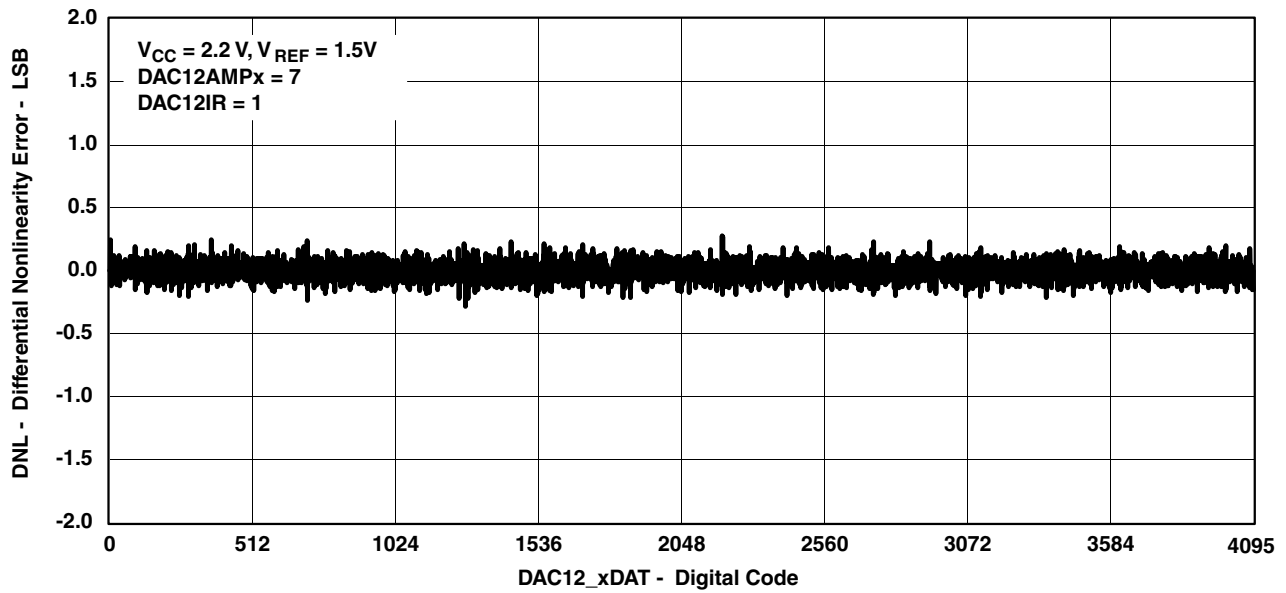


图 8-23. Typical DNL Error vs Digital Input Data

8.30 12-Bit DAC, Output Specifications

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

| PARAMETER | TEST CONDITIONS | V _{CC} | MIN | TYP | MAX | UNIT | |
|-------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------|-----------------|-----------------------------------------------------------------------------------------------------------------------|-----|------------------|------|---|
| V _O Output voltage range ⁽¹⁾ (see 图 8-24) | No Load, V _{eREF+} = AV _{CC} , DAC12_xDAT = 0h, DAC12IR = 1, DAC12AMPx = 7 | 2.2 V, 3 V | 0 | | 0.005 | V | |
| | No Load, V _{eREF+} = AV _{CC} , DAC12_xDAT = 0FFFh, DAC12IR = 1, DAC12AMPx = 7 | | AV _{CC} - 0.05 | | AV _{CC} | | |
| | R _{Load} = 3 kΩ, V _{eREF+} = AV _{CC} , DAC12_xDAT = 0h, DAC12IR = 1, DAC12AMPx = 7 | | 0 | | 0.1 | | |
| | R _{Load} = 3 kΩ, V _{eREF+} = AV _{CC} , DAC12_xDAT = 0FFFh, DAC12IR = 1, DAC12AMPx = 7 | | AV _{CC} - 0.13 | | AV _{CC} | | |
| C _{L(DAC12)} | Maximum DAC12 load capacitance | 2.2 V, 3 V | | | 100 | pF | |
| I _{L(DAC12)} | Maximum DAC12 load current | 2.2 V | - 0.5 | | +0.5 | mA | |
| | | 3 V | - 1.0 | | +1.0 | | |
| R _{O/P(DAC12)} | Output resistance (see 图 8-24) | 2.2 V, 3 V | R _{Load} = 3 kΩ, V _{O/P(DAC12)} < 0.3 V, DAC12AMPx = 7, DAC12_xDAT = 0h | | 150 | 250 | Ω |
| | | | R _{Load} = 3 kΩ, V _{O/P(DAC12)} > AV _{CC} - 0.3 V, DAC12AMPx = 7, DAC12_xDAT = 0FFFh | | 150 | 250 | |
| | | | R _{Load} = 3 kΩ, 0.3 V ≤ V _{O/P(DAC12)} ≤ AV _{CC} - 0.3 V DAC12AMPx = 7 | | 1 | 4 | |

(1) Data is valid after the offset calibration of the output amplifier.

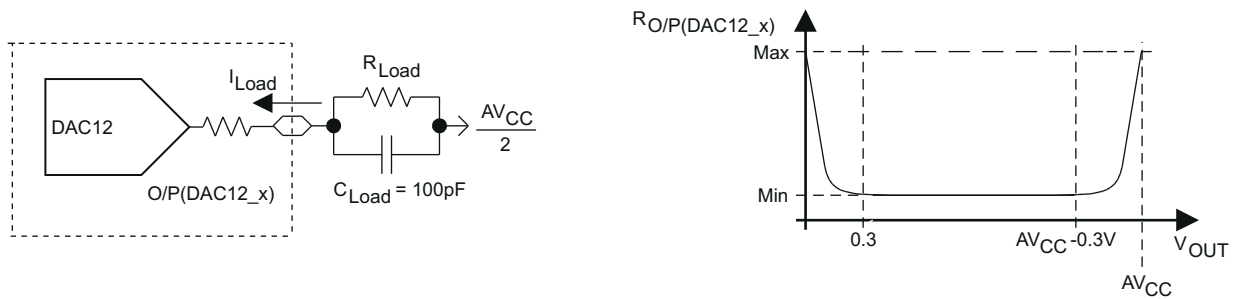


图 8-24. DAC12_x Output Resistance Tests

8.31 12-Bit DAC, Reference Input Specifications

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

| PARAMETER | | TEST CONDITIONS | V _{CC} | MIN | TYP | MAX | UNIT |
|---------------------------------------------------|-------------------------------|------------------------------------------------------------------------------|-----------------|----------------------|-----|------------------------|------|
| V _{REF+} | Reference input voltage range | DAC12IR = 0 ⁽¹⁾ (2) | 2.2 V, 3 V | AV _{CC} / 3 | | AV _{CC} + 0.2 | V |
| | | DAC12IR = 1 ⁽³⁾ (4) | | AV _{CC} | | AV _{CC} + 0.2 | |
| R _{i(VREF+)} , R _{i(VeREF+)} | Reference input resistance | DAC12_0 IR = DAC12_1 IR = 0 | 2.2 V, 3 V | 20 | | | MΩ |
| | | DAC12_0 IR = 1, DAC12_1 IR = 0 | | 40 | 48 | 150 | kΩ |
| | | DAC12_0 IR = 0, DAC12_1 IR = 1 | | 40 | 48 | 150 | |
| | | DAC12_0 IR = DAC12_1 IR = 1, DAC12_0 SREFx = DAC12_1 SREFx ⁽⁵⁾ | | 20 | 24 | 75 | |

- (1) For a full-scale output, the reference input voltage can be as high as 1/3 of the maximum output voltage swing (AV_{CC}).
- (2) The maximum voltage applied at reference input voltage terminal V_{REF+} = [AV_{CC} - V_{E(O)}] / [3 × (1 + E_G)].
- (3) For a full-scale output, the reference input voltage can be as high as the maximum output voltage swing (AV_{CC}).
- (4) The maximum voltage applied at reference input voltage terminal V_{REF+} = [AV_{CC} - V_{E(O)}] / (1 + E_G).
- (5) When DAC12IR = 1 and DAC12SREFx = 0 or 1 for both channels, the reference input resistive dividers for each DAC are in parallel, reducing the reference input resistance.

8.32 12-Bit DAC, Dynamic Specifications

V_{ref} = V_{CC}, DAC12IR = 1, over recommended operating free-air temperature range (unless otherwise noted) (see 图 8-25 and 图 8-26)

| PARAMETER | | TEST CONDITIONS | V _{CC} | MIN | TYP | MAX | UNIT |
|---------------------|--------------------------------|---------------------------------------------------------------------------------------|-----------------|---------------|------|------|------|
| t _{ON} | DAC12 on time | DAC12_xDAT = 800h, Error _{V(O)} < ±0.5 LSB ⁽¹⁾ (see 图 8-25) | 2.2 V, 3 V | | 60 | 120 | μs |
| | | DAC12AMPx = 0 → {2, 3, 4} | | | 15 | 30 | |
| | | DAC12AMPx = 0 → 7 | | | 6 | 12 | |
| t _{S(FS)} | Settling time, full scale | DAC12_xDAT = 80h → F7Fh → 80h | 2.2 V, 3 V | DAC12AMPx = 2 | 100 | 200 | μs |
| | | DAC12AMPx = 3, 5 | | 40 | 80 | | |
| | | DAC12AMPx = 4, 6, 7 | | 15 | 30 | | |
| t _{S(C-C)} | Settling time, code to code | DAC12_xDAT = 3F8h → 408h → 3F8h BF8h → C08h → BF8h | 2.2 V, 3 V | DAC12AMPx = 2 | 5 | | μs |
| | | DAC12AMPx = 3, 5 | | 2 | | | |
| | | DAC12AMPx = 4, 6, 7 | | 1 | | | |
| SR | Slew rate | DAC12_xDAT = 80h → F7Fh → 80h ⁽²⁾ | 2.2 V, 3 V | DAC12AMPx = 2 | 0.05 | 0.12 | V/μs |
| | | DAC12AMPx = 3, 5 | | 0.35 | 0.7 | | |
| | | DAC12AMPx = 4, 6, 7 | | 1.5 | 2.7 | | |
| | Glitch energy, full scale | DAC12_xDAT = 80h → F7Fh → 80h | 2.2 V, 3 V | DAC12AMPx = 2 | 10 | | nV-s |
| | | DAC12AMPx = 3, 5 | | 10 | | | |
| | | DAC12AMPx = 4, 6, 7 | | 10 | | | |

- (1) R_{Load} and C_{Load} connected to AV_{SS} (not AV_{CC}/2) in 图 8-25.
- (2) Slew rate applies to output voltage steps ≥ 200 mV.

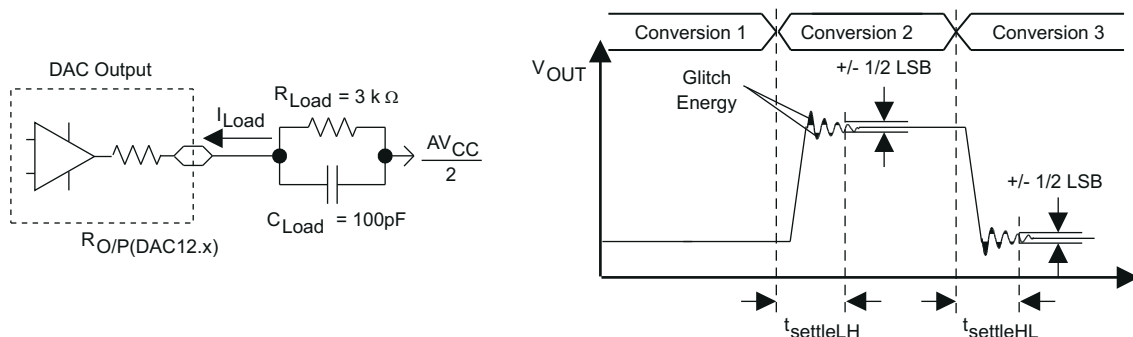


图 8-25. Settling Time and Glitch Energy Testing

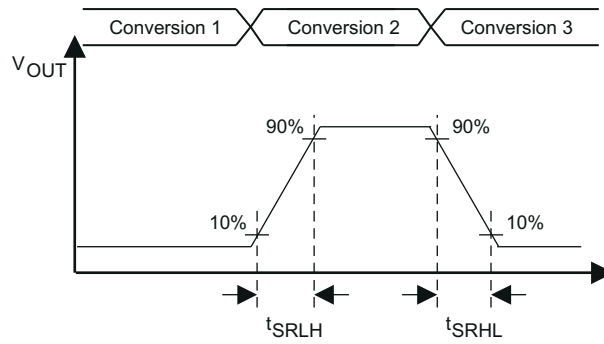


图 8-26. Slew Rate Testing

8.33 12-Bit DAC, Dynamic Specifications (Continued)

T_A = 25°C unless otherwise noted

| PARAMETER | TEST CONDITIONS | V _{CC} | MIN | TYP | MAX | UNIT |
|-------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|-----------------|-----|------|-----|------|
| BW _{-3dB} 3-dB bandwidth, V _{DC} = 1.5 V, V _{AC} = 0.1 V _{PP} (see 图 8-27) | DAC12AMPx = {2, 3, 4}, DAC12SREFx = 2, DAC12IR = 1, DAC12_xDAT = 800h | 2.2 V, 3 V | 40 | | | kHz |
| | DAC12AMPx = {5, 6}, DAC12SREFx = 2, DAC12IR = 1, DAC12_xDAT = 800h | | 180 | | | |
| | DAC12AMPx = 7, DAC12SREFx = 2, DAC12IR = 1, DAC12_xDAT = 800h | | 550 | | | |
| Channel-to-channel crosstalk ⁽¹⁾ (see 图 8-28) | DAC12_0DAT = 800h, No Load, DAC12_1DAT = 80h→F7Fh, R _{Load} = 3 kΩ f _{DAC12_1OUT} = 10 kHz with 50/50 duty cycle | 2.2 V, 3 V | | - 80 | | dB |
| | DAC12_0DAT = 80h→F7Fh, R _{Load} = 3 kΩ, DAC12_1DAT = 800h, No Load, f _{DAC12_0OUT} = 10 kHz with 50/50 duty cycle | | | - 80 | | |

(1) R_{LOAD} = 3 kΩ, C_{LOAD} = 100 pF

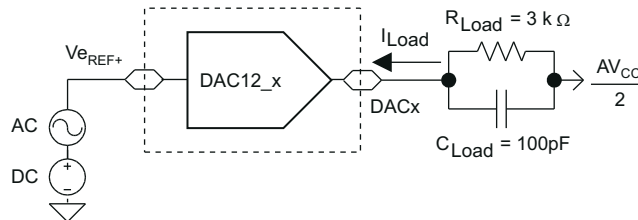


图 8-27. Test Conditions for 3-dB Bandwidth Specification

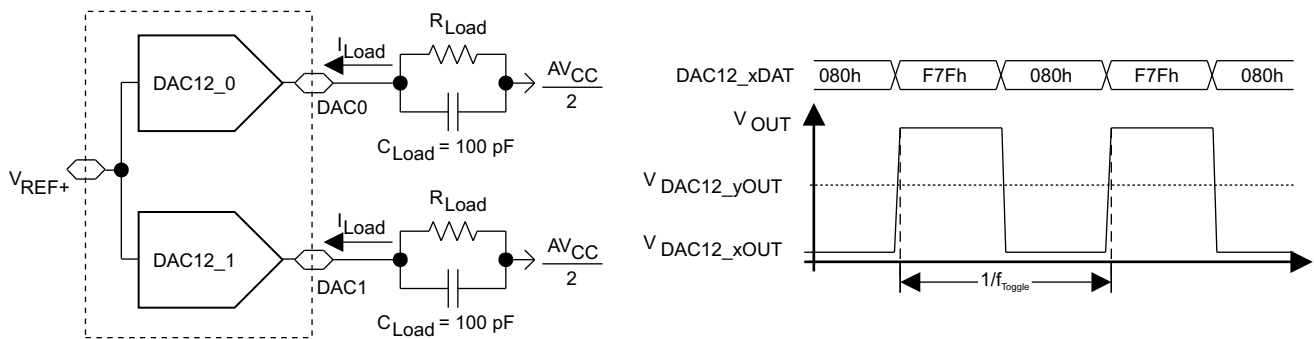


图 8-28. Crosstalk Test Conditions

8.34 Operational Amplifier (OA), Supply Specifications

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

| PARAMETER | | TEST CONDITIONS | V _{CC} | MIN | TYP | MAX | UNIT |
|-----------------|-------------------------------|-----------------------|-----------------|-----|-----|-----|------|
| V _{CC} | Supply voltage | | | 2.2 | | 3.6 | V |
| I _{CC} | Supply current ⁽¹⁾ | Fast Mode, RRIP OFF | 2.2 V, 3 V | | 180 | 290 | μA |
| | | Medium Mode, RRIP OFF | | | 110 | 190 | |
| | | Slow Mode, RRIP OFF | | | 50 | 80 | |
| | | Fast Mode, RRIP ON | | | 300 | 490 | |
| | | Medium Mode, RRIP ON | | | 190 | 350 | |
| | | Slow Mode, RRIP ON | | | 90 | 190 | |
| PSRR | Power supply rejection ratio | Non-inverting | 2.2 V, 3 V | | 70 | | dB |

(1) P6SEL.x = 1 for each corresponding pin when used in OA input or OA output mode.

8.35 Operational Amplifier (OA), Input/Output Specifications

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

| PARAMETER | | TEST CONDITIONS | V _{CC} | MIN | TYP | MAX | UNIT | |
|------------------------|----------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------|-----------------------------|------------------------------|-----------------------|-----------------|--------|--|
| V _{I/P} | Voltage supply, I/P | RRIP OFF | | - 0.1 | V _{CC} - 1.2 | | V | |
| | | RRIP ON | | - 0.1 | V _{CC} + 0.1 | | | |
| I _{Ikg} | Input leakage current, I/P ^{(1) (2)} | T _A = - 40°C to +55°C | | - 5 | ±0.5 | 5 | nA | |
| | | T _A = +55°C to +85°C | | - 20 | ±5 | 20 | | |
| V _n | Voltage noise density, I/P | Fast Mode | f _{V(I/P)} = 1 kHz | | 50 | | nV/√Hz | |
| | | Medium Mode | | | 80 | | | |
| | | Slow Mode | | | 140 | | | |
| | | Fast Mode | | f _{V(I/P)} = 10 kHz | | 30 | | |
| | | Medium Mode | | | | 50 | | |
| | | Slow Mode | | | | 65 | | |
| V _{IO} | Offset voltage, I/P | | 2.2 V, 3 V | | | ±10 | mV | |
| | Offset temperature drift, I/P | See (3) | 2.2 V, 3 V | | ±10 | | μV/°C | |
| | Offset voltage drift with supply, I/P | 0.3 V ≤ V _{IN} ≤ V _{CC} - 0.3 V ΔV _{CC} ≤ ±10%, T _A = 25°C | 2.2 V, 3 V | | | ±1.5 | mV/V | |
| V _{OH} | High-level output voltage, O/P | Fast Mode, I _{SOURCE} ≤ - 500 μA | 2.2 V | V _{CC} - 0.2 | | V _{CC} | V | |
| | | Slow Mode, I _{SOURCE} ≤ - 150 μA | 3 V | V _{CC} - 0.1 | | V _{CC} | | |
| V _{OL} | Low-level output voltage, O/P | Fast Mode, I _{SOURCE} ≤ +500 μA | 2.2 V | V _{SS} | | 0.2 | V | |
| | | Slow Mode, I _{SOURCE} ≤ +150 μA | 3 V | V _{SS} | | 0.1 | | |
| R _{O/P (OAx)} | Output resistance ⁽⁴⁾ (see 图 8-29) | R _{Load} = 3 kΩ, C _{Load} = 50 pF, RRIP ON, V _{O/P(OAx)} < 0.2 V | 2.2 V, 3 V | | 150 | 250 | Ω | |
| | | R _{Load} = 3 kΩ, C _{Load} = 50 pF, RRIP ON, V _{O/P(OAx)} > AV _{CC} - 0.2 V | | | 150 | 250 | | |
| | | R _{Load} = 3 kΩ, C _{Load} = 50 pF, RRIP ON, 0.2 V ≤ V _{O/P(OAx)} ≤ AV _{CC} - 0.2 V | | | 0.1 | 4 | | |
| CMRR | Common-mode rejection ratio | Non-inverting | 2.2 V, 3 V | | 70 | | dB | |

- (1) ESD damage can degrade input current leakage.
- (2) The input bias current is overridden by the input leakage current.
- (3) Calculated using the box method.
- (4) Specification valid for voltage-follower OAx configuration.

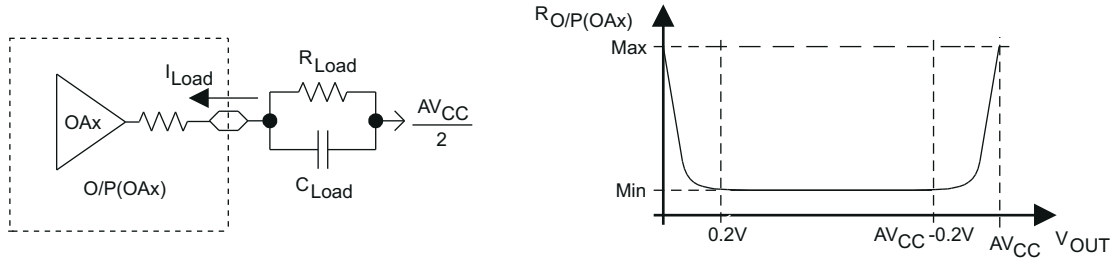


图 8-29. OAx Output Resistance Tests

8.36 Operational Amplifier (OA), Dynamic Specifications

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

| PARAMETER | | TEST CONDITIONS | V _{CC} | MIN | TYP | MAX | UNIT |
|----------------------|---------------------------------------------------|-----------------------------------------------------------------------------------------|-----------------|-----|-----|-----|------------|
| SR | Slew rate | Fast Mode | | | 1.2 | | V/ μ s |
| | | Medium Mode | | | 0.8 | | |
| | | Slow Mode | | | 0.3 | | |
| | Open-loop voltage gain | | | 100 | | | dB |
| ϕ_m | Phase margin | C _L = 50 pF | | | 60 | | deg |
| | Gain margin | C _L = 50 pF | | | 20 | | dB |
| GBW | Gain-bandwidth product (see 图 8-30 and 图 8-31) | Non-inverting, Fast Mode, R _L = 47 k Ω , C _L = 50 pF | 2.2 V, 3 V | | 2.2 | | MHz |
| | | Non-inverting, Medium Mode, R _L = 300 k Ω , C _L = 50 pF | | | 1.4 | | |
| | | Non-inverting, Slow Mode, R _L = 300 k Ω , C _L = 50 pF | | | 0.5 | | |
| t _{en(on)} | Enable time on | t _{on} , non-inverting, Gain = 1 | 2.2 V, 3 V | | 10 | 20 | μ s |
| t _{en(off)} | Enable time off | | 2.2 V, 3 V | | | 1 | μ s |

8.37 OA Dynamic Specifications Typical Characteristics

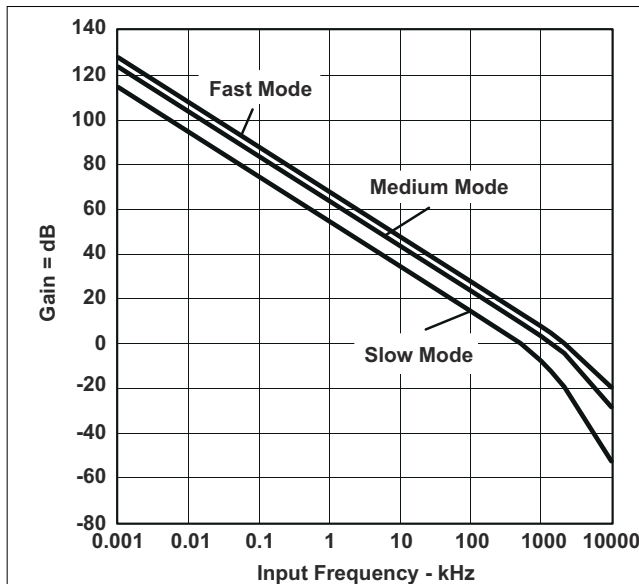


图 8-30. Typical Open-Loop Gain vs Frequency

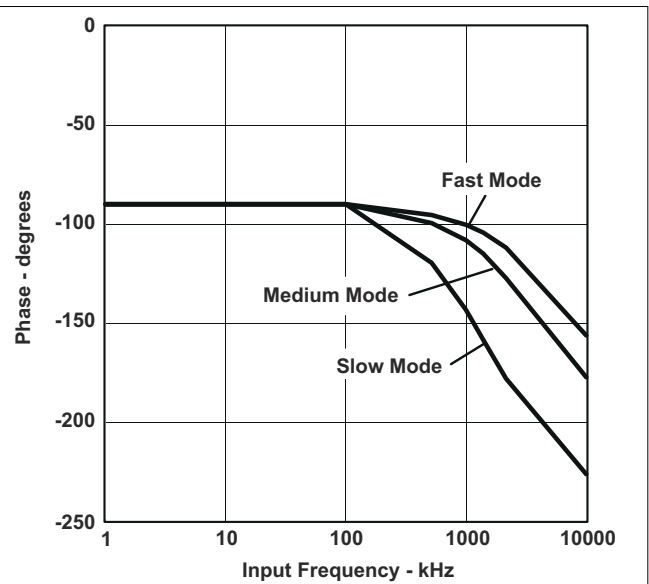


图 8-31. Typical Phase vs Frequency

8.38 Flash Memory

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

| PARAMETER | | TEST CONDITIONS | V _{CC} | MIN | TYP | MAX | UNIT |
|----------------------------|-----------------------------------------------------|-----------------------|-----------------|-----------------|-----------------|-----|------------------|
| V _{CC(PGM/ERASE)} | Program and erase supply voltage | | | 2.7 | | 3.6 | V |
| f _{FTG} | Flash timing generator frequency | | | 257 | | 476 | kHz |
| I _{PGM} | Supply current from DV _{CC} during program | | 2.7 V, 3.6 V | | 3 | 5 | mA |
| I _{ERASE} | Supply current from DV _{CC} during erase | | 2.7 V, 3.6 V | | 3 | 7 | mA |
| t _{CPT} | Cumulative program time | See (1) | 2.7 V, 3.6 V | | | 10 | ms |
| t _{CMErase} | Cumulative mass erase time | See (2) | 2.7 V, 3.6 V | 200 | | | ms |
| | Program and 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 | See (3) | | | 35 | | t _{FTG} |
| t _{Block, 0} | Block program time for first byte or word | | | | 30 | | |
| t _{Block, 1-63} | Block program time for each additional byte or word | | | | 21 | | |
| t _{Block, End} | Block program end-sequence wait time | | | | 6 | | |
| t _{Mass Erase} | Mass erase time | | | | 5297 | | |
| t _{Seg Erase} | Segment erase time | | | | 4819 | | |

- (1) The cumulative program time must not be exceeded when writing to a 64-byte flash block. This parameter applies to all programming methods: individual word or byte write and block write modes.
- (2) The mass erase duration generated by the flash timing generator is at least 11.1 ms ($= 5297 \times 1/f_{FTG,max} = 5297 \times 1 / 476$ kHz). To achieve the required cumulative mass erase time the Flash Controller's mass erase operation can be repeated until this time is met. (A worst case minimum of 19 cycles are required).
- (3) These values are hard-wired into the flash controller's state machine ($t_{FTG} = 1 / f_{FTG}$).

8.39 JTAG Interface

over recommended operating free-air temperature range (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 | MHz |
| R _{Internal} | Internal pullup resistance on TMS, TCK, TDI/TCLK | 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.

8.40 JTAG Fuse

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

| PARAMETER ⁽¹⁾ | | 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 TDI/TCLK for fuse-blow | | 6 | 7 | V |
| I _{FB} | Supply current into TDI/TCLK during fuse blow | | | 100 | mA |
| t _{FB} | Time to blow fuse | | | 1 | ms |

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

9 Detailed Description

9.1 CPU

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

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

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

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

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

9.2 Instruction Set

The instruction set consists of the original 51 instructions with three formats and seven address modes and additional instructions for the expanded address range. Each instruction can operate on word and byte data. 表 9-1 shows examples of the three types of instruction formats; 表 9-2 lists the address modes.

表 9-1. 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, un/conditional | JNE | Jump-on-equal bit = 0 |

表 9-2. Address Mode Descriptions

| ADDRESS MODE | S ⁽¹⁾ | D ⁽¹⁾ | 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 R10 + 2 → R10 |
| Immediate | ✓ | | MOV #X,TONI | MOV #45,TONI | #45 → M(TONI) |

(1) S = source D = destination

9.3 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
 - FLL+ loop control remains active
- Low-power mode 1 (LPM1)
 - CPU is disabled
 - FLL+ loop control is disabled
 - ACLK and SMCLK remain active. MCLK is disabled
- Low-power mode 2 (LPM2)
 - CPU is disabled
 - MCLK, FLL+ loop control and DCOCLK are disabled
 - DCO's dc-generator remains enabled
 - ACLK remains active
- Low-power mode 3 (LPM3)
 - CPU is disabled
 - MCLK, FLL+ loop control, and DCOCLK are disabled
 - DCO's dc-generator is disabled
 - ACLK remains active
- Low-power mode 4 (LPM4)
 - CPU is disabled
 - ACLK is disabled
 - MCLK, FLL+ loop control, and DCOCLK are disabled
 - DCO's dc-generator is disabled
 - Crystal oscillator is stopped

9.4 Interrupt Vector Addresses

The interrupt vectors and the power-up start address are located in the address range 0FFFFh to 0FFC0h. The vector contains the 16-bit address of the appropriate interrupt-handler instruction sequence.

表 9-3. Interrupt Sources, Flags, and Vectors of MSP430FG43x Configurations

| INTERRUPT SOURCE | INTERRUPT FLAG | SYSTEM INTERRUPT | WORD ADDRESS | PRIORITY |
|----------------------------------------------------------|-------------------------------------------------------------------------|----------------------------------------------------------------|--------------|-------------|
| Power-Up External Reset Watchdog Flash Memory | WDTIFG KEYV ⁽¹⁾ | Reset | 0FFFEh | 15, highest |
| NMI Oscillator Fault Flash Memory Access Violation | NMIIFG ⁽¹⁾ OFIFG ⁽¹⁾ ACCVIFG ⁽¹⁾ | (Non)maskable ⁽²⁾ (Non)maskable (Non)maskable | 0FFFCCh | 14 |
| Timer_B3 | TBCCR0 CCIFG0 ⁽³⁾ | Maskable | 0FFFAh | 13 |
| Timer_B3 | TBCCR1 CCIFG1 and TBCCR2 CCIFG2, TBIFG ^{(1) (3)} | Maskable | 0FFF8h | 12 |
| Comparator_A | CAIFG | Maskable | 0FFF6h | 11 |
| Watchdog Timer | WDTIFG | Maskable | 0FFF4h | 10 |
| USART0 Receive | URXIFG0 | Maskable | 0FFF2h | 9 |
| USART0 Transmit | UTXIFG0 | Maskable | 0FFF0h | 8 |
| ADC12 | ADC12IFG ^{(1) (3)} | Maskable | 0FFEEh | 7 |
| Timer_A3 | TACCR0 CCIFG0 ⁽³⁾ | Maskable | 0FFECCh | 6 |
| Timer_A3 | TACCR1 CCIFG1 and TACCR2 CCIFG2, TAIFG ⁽¹⁾ ⁽³⁾ | Maskable | 0FFEAh | 5 |
| I/O Port P1 (Eight Flags) | P1IFG.0 to P1IFG.7 ^{(1) (3)} | Maskable | 0FFE8h | 4 |
| DAC12 DMA | DAC12.0IFG, DAC12.1IFG, DMA0IFG ^{(1) (3)} | Maskable | 0FFE6h | 3 |
| | | | 0FFE4h | 2 |
| I/O Port P2 (Eight Flags) | P2IFG.0 to P2IFG.7 ^{(1) (3)} | Maskable | 0FFE2h | 1 |
| Basic Timer1 | BTIFG | Maskable | 0FFE0h | 0, lowest |

(1) Multiple source flags

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

(3) Interrupt flags are located in the module.

9.5 Special Function Registers (SFRs)

The MSP430 SFRs are located in the lowest address space and are organized as byte-mode registers. SFRs should be accessed with byte instructions.

Legend

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

9.5.1 Interrupt Enable Registers 1 and 2

图 9-1. Interrupt Enable Register 1 (Address = 0h)

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

表 9-4. Interrupt Enable Register 1 Field Descriptions

| BIT | FIELD | TYPE | RESET | DESCRIPTION |
|-----|--------|------|-------|--------------------------------------------------------------------------------------------------------------------------------------------|
| 7 | UTXIE0 | RW | 0h | USART0: UART and SPI transmit-interrupt enable |
| 6 | URXIE0 | RW | 0h | USART0: UART and SPI receive-interrupt enable |
| 5 | ACCVIE | RW | 0h | Flash access violation interrupt enable |
| 4 | NMIIE | RW | 0h | Nonmaskable-interrupt enable |
| 1 | OFIE | RW | 0h | Oscillator-fault-interrupt enable |
| 0 | WDTIE | RW | 0h | Watchdog-timer interrupt enable. Inactive if watchdog mode is selected. Active if watchdog timer is configured as a general-purpose timer. |

图 9-2. Interrupt Enable Register 2 (Address = 1h)

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

表 9-5. Interrupt Enable Register 2 Field Descriptions

| BIT | FIELD | TYPE | RESET | DESCRIPTION |
|-----|-------|------|-------|------------------------------|
| 7 | BTIE | RW | 0h | Basic timer interrupt enable |

9.5.2 Interrupt Flag Registers 1 and 2

图 9-3. Interrupt Flag Register 1 (Address = 2h)

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

表 9-6. Interrupt Flag Register 1 Field Descriptions

| BIT | FIELD | TYPE | RESET | DESCRIPTION |
|-----|---------|------|-------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7 | UTXIFG0 | RW | 1h | USART0: UART and SPI transmit flag |
| 6 | URXIFG0 | RW | 0h | USART0: UART and SPI receive flag |
| 4 | NMIIFG | RW | 0h | Set by RST/NMI pin |
| 1 | OFIFG | RW | 1h | Flag set on oscillator fault |
| 0 | WDTIFG | RW | 0h | Set on watchdog timer overflow (in watchdog mode) or security key violation Reset on V _{CC} power-on or a reset condition at the RST/NMI pin in reset mode |

图 9-4. Interrupt Flag Register 2 (Address = 3h)

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

表 9-7. Interrupt Flag Register 2 Field Descriptions

| BIT | FIELD | TYPE | RESET | DESCRIPTION |
|-----|-------|------|-------|------------------|
| 7 | BTIFG | RW | 0h | Basic timer flag |

9.5.3 Module Enable Registers 1 and 2

图 9-5. Module Enable Register 1 (Address = 4h)

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

表 9-8. Module Enable Register 1 Field Descriptions

| BIT | FIELD | TYPE | RESET | DESCRIPTION |
|-----|--------|------|-------|----------------------------------------------|
| 7 | UTXE0 | RW | 0h | USART0: UART mode transmit enable |
| 6 | URXE0 | RW | 0h | USART0: UART mode receive enable |
| | USPIE0 | RW | 0h | USART0: SPI mode transmit and receive enable |

图 9-6. Module Enable Register 2 (Address = 5h)

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

9.6 Memory Organization

表 9-9 shows the memory organization for all device variants.

表 9-9. Memory Organization

| | | MSP430FG437 | MSP430FG438 | MSP430FG439 |
|------------------------|-----------|--------------------|--------------------|--------------------|
| Memory | Size | 32KB | 48KB | 60KB |
| Main: interrupt vector | Flash | 0FFFFh-0FFE0h | 0FFFFh-0FFE0h | 0FFFFh-0FFE0h |
| Main: code memory | Flash | 0FFFFh-08000h | 0FFFFh-04000h | 0FFFFh-01100h |
| Information memory | Size | 256 Byte | 256 Byte | 256 Byte |
| | Flash | 010FFh-01000h | 010FFh-01000h | 010FFh-01000h |
| Boot memory | Size | 1KB | 1KB | 1KB |
| | ROM | 0FFFh-0C00h | 0FFFh-0C00h | 0FFFh-0C00h |
| RAM | Size | 1KB | 2KB | 2KB |
| | | 05FFh-0200h | 09FFh-0200h | 09FFh-0200h |
| Peripherals | 16-bit | 01FFh-0100h | 01FFh-0100h | 01FFh-0100h |
| | 8-bit | 0FFh-010h | 0FFh-010h | 0FFh-010h |
| | 8-bit SFR | 0Fh-00h | 0Fh-00h | 0Fh-00h |

9.7 Bootstrap Loader (BSL)

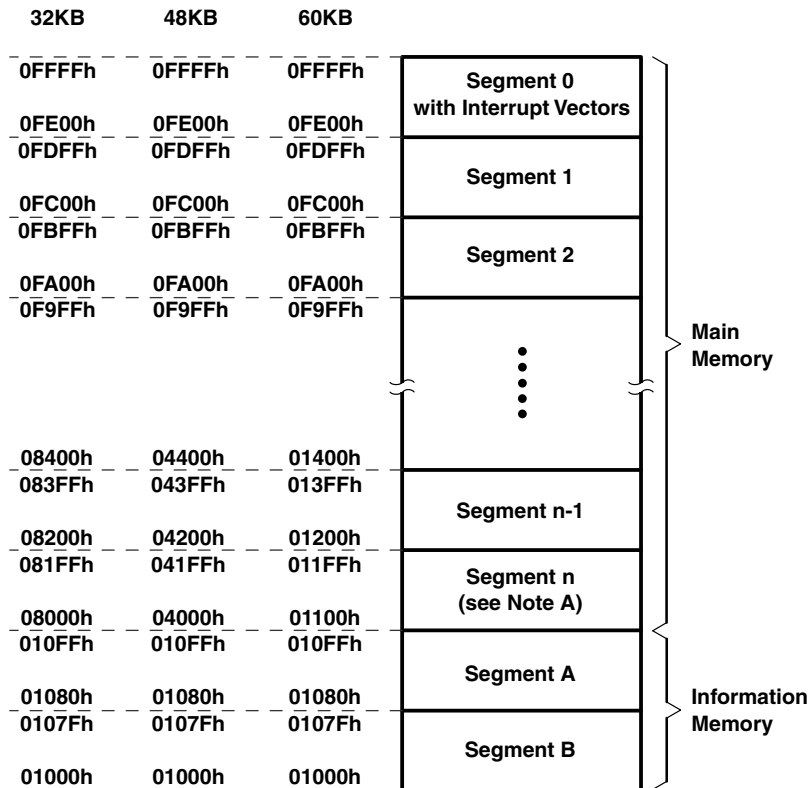
The MSP430 bootstrap loader (BSL) enables users to program the flash memory or RAM using a UART serial interface. Access to the MSP430 memory via the BSL is protected by user-defined password. For complete description of the features of the BSL and its implementation, see *MSP430 Programming Via the Bootstrap Loader (BSL)* (SLAU319).

| BSL FUNCTION | PN PACKAGE PINS | ZCA PACKAGE PINS |
|---------------|-----------------|------------------|
| Data Transmit | 67 - P1.0 | D8 - P1.0 |
| Data Receiver | 66 - P1.1 | D9 - P1.1 |

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



A. MSP430FG43x flash segment n = 256 bytes.

图 9-7. Flash Memory Segments

9.9 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 *MSP430x4xx Family User's Guide* (SLAU056).

9.9.1 DMA Controller

The DMA controller allows movement of data from one memory address to another without CPU intervention. For example, the DMA controller can be used to move data from the ADC12 conversion memory to RAM. Using the DMA controller can increase the throughput of peripheral modules. The DMA controller reduces system power consumption by allowing the CPU to remain in sleep mode without having to awaken to move data to or from a peripheral.

9.9.2 Oscillator and System Clock

The clock system in the MSP430FG43x family of devices is supported by the FLL+ module, which includes support for a 32768-Hz watch crystal oscillator, an internal digitally-controlled oscillator (DCO), and a high frequency crystal oscillator. The FLL+ clock module is designed to meet the requirements of both low system cost and low power consumption. The FLL+ features digital frequency locked loop (FLL) hardware that, in conjunction with a digital modulator, stabilizes the DCO frequency to a programmable multiple of the watch crystal frequency. The internal DCO provides a fast turn-on clock source and stabilizes in less than 6 μ s. The FLL+ module provides the following clock signals:

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

9.9.3 Brownout, Supply Voltage Supervisor

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

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

9.9.4 Digital I/O

There are 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 conditions is possible.
- Edge-selectable interrupt input capability for all the eight bits of ports P1 and P2.
- Read and write access to port-control registers is supported by all instructions

9.9.5 Basic Timer1

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

9.9.6 LCD Drive

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

9.9.7 OA

The MSP430FG43x has three configurable low-current general-purpose operational amplifiers. Each OA input and output terminal is software-selectable and offers a flexible choice of connections for various applications. The OA op amps primarily support front-end analog signal conditioning prior to analog-to-digital conversion.

9.9.8 Watchdog Timer (WDT)

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

9.9.9 USART0

The MSP430FG43x has one hardware universal synchronous/asynchronous receive transmit (USART) peripheral module that is used for serial data communication. The USART supports synchronous SPI (3 or 4 pin) and asynchronous UART communication protocols, using double-buffered transmit and receive channels.

9.9.10 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.

表 9-10. Timer_A3 Signal Connections

| INPUT PIN NUMBER | | DEVICE INPUT SIGNAL | MODULE INPUT NAME | MODULE BLOCK | MODULE OUTPUT SIGNAL | OUTPUT PIN NUMBER | |
|------------------|-----------|---------------------|-------------------|--------------|----------------------|-------------------|------------|
| ZCA | PN | | | | | PN | ZCA |
| B10 - P1.5 | 62 - P1.5 | TACLK | TACLK | | | | |
| | | ACLK | ACLK | | | | |
| | | SMCLK | SMCLK | Timer | NA | | |
| B10 - P1.5 | 62 - P1.5 | TACLK | INCLK | | | | |
| D8 - P1.0 | 67 - P1.0 | TA0 | CCI0A | | | 67 - P1.0 | D8 - P1.0 |
| D9 - P1.1 | 66 - P1.1 | TA0 | CCI0B | | | | |
| | | DVSS | GND | CCR0 | TA0 | | |
| | | DVCC | VCC | | | | |
| B9 - P1.2 | 65 - P1.2 | TA1 | CCI1A | | | 65 - P1.2 | B9 - P1.2 |
| | | CAOUT (internal) | CCI1B | | | ADC12 (internal) | |
| | | DVSS | GND | CCR1 | TA1 | | |
| | | DVCC | VCC | | | | |
| C11 - P2.0 | 59 - P2.0 | TA2 | CCI2A | | | 59 - P2.0 | C11 - P2.0 |
| | | ACLK (internal) | CCI2B | | | | |
| | | DVSS | GND | CCR2 | TA2 | | |
| | | DVCC | VCC | | | | |

9.9.11 Timer_B3

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.

表 9-11. Timer_B3 Signal Connections

| INPUT PIN NUMBER | | DEVICE INPUT SIGNAL | MODULE INPUT NAME | MODULE BLOCK | MODULE OUTPUT SIGNAL | OUTPUT PIN NUMBER | |
|------------------|-----------|---------------------|-------------------|--------------|----------------------|-------------------|------------|
| ZCA | PN | | | | | PN | ZCA |
| E9 - P1.4 | 63 - P1.4 | TBCLK | TBCLK | | | | |
| | | ACLK | ACLK | | | | |
| | | SMCLK | SMCLK | Timer | NA | | |
| E9 - P1.4 | 63 - P1.4 | TBCLK | INCLK | | | | |
| D11 - P2.1 | 58 - P2.1 | TB0 | CCI0A | | | 58 - P2.1 | D11 - P2.1 |
| D11 - P2.1 | 58 - P2.1 | TB0 | CCI0B | | | ADC12 (internal) | |
| | | DVSS | GND | CCR0 | TB0 | | |
| | | DVCC | VCC | | | | |
| E11 - P2.2 | 57 - P2.2 | TB1 | CCI1A | | | 57 - P2.2 | E11 - P2.2 |
| E11 - P2.2 | 57 - P2.2 | TB1 | CCI1B | | | ADC12 (internal) | |
| | | DVSS | GND | CCR1 | TB1 | | |
| | | DVCC | VCC | | | | |
| F11 - P2.3 | 56 - P2.3 | TB2 | CCI2A | | | 56 - P2.3 | F11 - P2.3 |
| F11 - P2.3 | 56 - P2.3 | TB2 | CCI2B | | | | |
| | | DVSS | GND | CCR2 | TB2 | | |
| | | DVCC | VCC | | | | |

9.9.12 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.

9.9.13 ADC12

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.

9.9.14 DAC12

The DAC12 module is a 12-bit, R-ladder, voltage output DAC. The DAC12 may be used in 8- or 12-bit mode, and may be used in conjunction with the DMA controller. When multiple DAC12 modules are present, they may be grouped together for synchronous operation.

9.9.15 Peripheral File Map

表 9-12 shows peripherals with word-access registers, and 表 9-13 shows peripherals with byte-access registers.

表 9-12. Peripherals With Word Access

| PERIPHERAL | REGISTER NAME | ACRONYM | OFFSET |
|------------|-----------------------------------|---------|--------|
| Watchdog | Watchdog timer control | WDTCTL | 0120h |
| Timer_B3 | Capture/compare register 2 | TBCCR2 | 0196h |
| | Capture/compare register 1 | TBCCR1 | 0194h |
| | Capture/compare register 0 | TBCCR0 | 0192h |
| | Timer_B register | TBR | 0190h |
| | Capture/compare control 2 | TBCCTL2 | 0186h |
| | Capture/compare control 1 | TBCCTL1 | 0184h |
| | Capture/compare control 0 | TBCCTL0 | 0182h |
| | Timer_B control | TBCTL | 0180h |
| | Timer_B interrupt vector | TBIV | 011Eh |
| | Capture/compare register 2 | TACCR2 | 0176h |
| | Capture/compare register 1 | TACCR1 | 0174h |
| | Capture/compare register 0 | TACCR0 | 0172h |
| Timer_A3 | Timer_A register | TAR | 0170h |
| | Capture/compare control 2 | TACCTL2 | 0166h |
| | Capture/compare control 1 | TACCTL1 | 0164h |
| | Capture/compare control 0 | TACCTL0 | 0162h |
| | Timer_A control | TACTL | 0160h |
| | Timer_A interrupt vector | TAIV | 012Eh |
| Flash | Flash control 3 | FCTL3 | 012Ch |
| | Flash control 2 | FCTL2 | 012Ah |
| | Flash control 1 | FCTL1 | 0128h |
| DMA | DMA module control 0 | DMACTL0 | 0122h |
| | DMA module control 1 | DMACTL1 | 0124h |
| | DMA channel 0 control | DMA0CTL | 01E0h |
| | DMA channel 0 source address | DMA0SA | 01E2h |
| | DMA channel 0 destination address | DMA0DA | 01E4h |
| | DMA channel 0 transfer size | DMA0SZ | 01E6h |

表 9-12. Peripherals With Word Access (continued)

| PERIPHERAL | REGISTER NAME | ACRONYM | OFFSET |
|----------------------------|--------------------------------|------------|--------|
| ADC12 (See also 表 9-13) | Conversion memory 15 | ADC12MEM15 | 015Eh |
| | Conversion memory 14 | ADC12MEM14 | 015Ch |
| | Conversion memory 13 | ADC12MEM13 | 015Ah |
| | Conversion memory 12 | ADC12MEM12 | 0158h |
| | Conversion memory 11 | ADC12MEM11 | 0156h |
| | Conversion memory 10 | ADC12MEM10 | 0154h |
| | Conversion memory 9 | ADC12MEM9 | 0152h |
| | Conversion memory 8 | ADC12MEM8 | 0150h |
| | Conversion memory 7 | ADC12MEM7 | 014Eh |
| | Conversion memory 6 | ADC12MEM6 | 014Ch |
| | Conversion memory 5 | ADC12MEM5 | 014Ah |
| | Conversion memory 4 | ADC12MEM4 | 0148h |
| | Conversion memory 3 | ADC12MEM3 | 0146h |
| | Conversion memory 2 | ADC12MEM2 | 0144h |
| | Conversion memory 1 | ADC12MEM1 | 0142h |
| | Conversion memory 0 | ADC12MEM0 | 0140h |
| | Interrupt-vector-word register | ADC12IV | 01A8h |
| | Interrupt-enable register | ADC12IE | 01A6h |
| | Interrupt-flag register | ADC12IFG | 01A4h |
| | Control register 1 | ADC12CTL1 | 01A2h |
| Control register 0 | ADC12CTL0 | 01A0h | |
| DAC12 | DAC12_1 data | DAC12_1DAT | 01CAh |
| | DAC12_1 control | DAC12_1CTL | 01C2h |
| | DAC12_0 data | DAC12_0DAT | 01C8h |
| | DAC12_0 control | DAC12_0CTL | 01C0h |

表 9-13. Peripherals With Byte Access

| PERIPHERAL | REGISTER NAME | ACRONYM | OFFSET |
|------------|--------------------------------------------|---------|--------|
| OA2 | Operational Amplifier 2 control register 1 | OA2CTL1 | 0C5h |
| | Operational Amplifier 2 control register 0 | OA2CTL0 | 0C4h |
| OA1 | Operational Amplifier 1 control register 1 | OA1CTL1 | 0C3h |
| | Operational Amplifier 1 control register 0 | OA1CTL0 | 0C2h |
| OA0 | Operational Amplifier 0 control register 1 | OA0CTL1 | 0C1h |
| | Operational Amplifier 0 control register 0 | OA0CTL0 | 0C0h |
| LCD | LCD memory 20 | LCDM20 | 0A4h |
| | ⋮ | ⋮ | ⋮ |
| | LCD memory 16 | LCDM16 | 0A0h |
| | LCD memory 15 | LCDM15 | 09Fh |
| | ⋮ | ⋮ | ⋮ |
| | LCD memory 1 | LCDM1 | 091h |
| | LCD control and mode | LCDCTL | 090h |

表 9-13. Peripherals With Byte Access (continued)

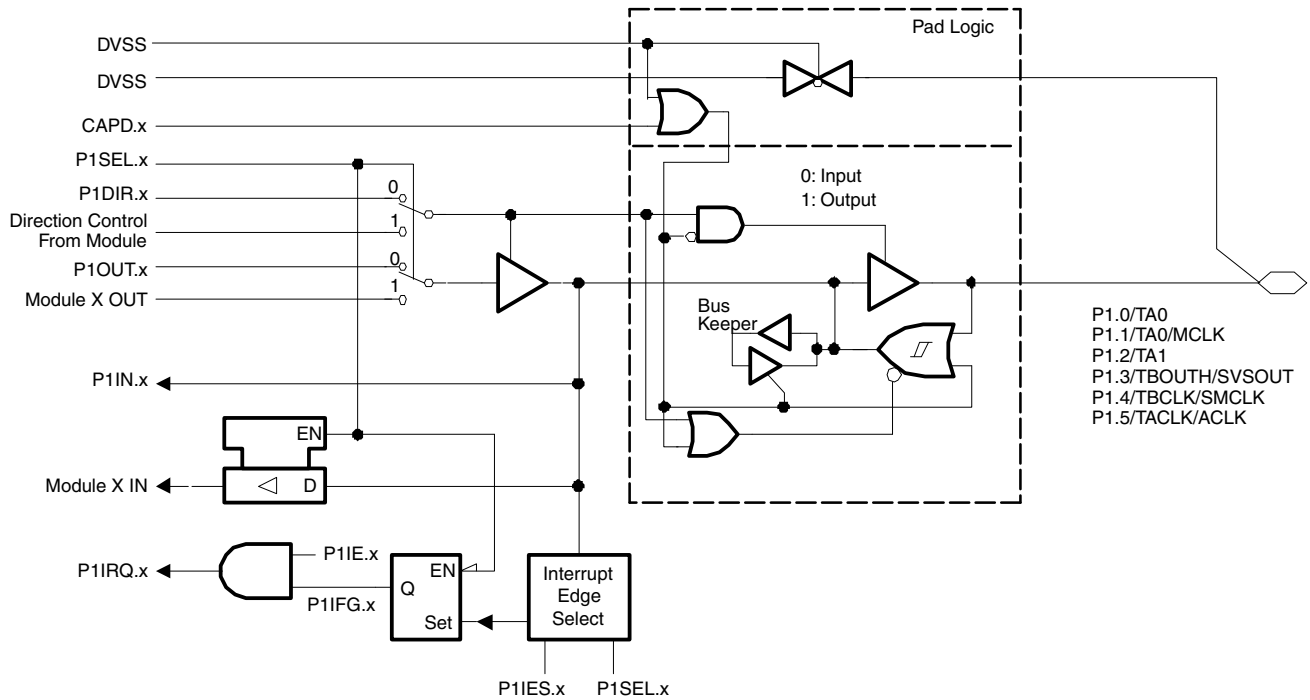
| PERIPHERAL | REGISTER NAME | ACRONYM | OFFSET |
|---------------------------------------------------------|-------------------------------------------------|-------------|--------|
| ADC12 (Memory control registers require byte access) | ADC memory-control register 15 | ADC12MCTL15 | 08Fh |
| | ADC memory-control register 14 | ADC12MCTL14 | 08Eh |
| | ADC memory-control register 13 | ADC12MCTL13 | 08Dh |
| | ADC memory-control register 12 | ADC12MCTL12 | 08Ch |
| | ADC memory-control register 11 | ADC12MCTL11 | 08Bh |
| | ADC memory-control register 10 | ADC12MCTL10 | 08Ah |
| | ADC memory-control register 9 | ADC12MCTL9 | 089h |
| | ADC memory-control register 8 | ADC12MCTL8 | 088h |
| | ADC memory-control register 7 | ADC12MCTL7 | 087h |
| | ADC memory-control register 6 | ADC12MCTL6 | 086h |
| | ADC memory-control register 5 | ADC12MCTL5 | 085h |
| | ADC memory-control register 4 | ADC12MCTL4 | 084h |
| | ADC memory-control register 3 | ADC12MCTL3 | 083h |
| | ADC memory-control register 2 | ADC12MCTL2 | 082h |
| | ADC memory-control register 1 | ADC12MCTL1 | 081h |
| | ADC memory-control register 0 | ADC12MCTL0 | 080h |
| USART0 (UART or SPI mode) | Transmit buffer | U0TXBUF | 077h |
| | Receive buffer | U0RXBUF | 076h |
| | Baud rate | U0BR1 | 075h |
| | Baud rate | U0BR0 | 074h |
| | Modulation control | U0MCTL | 073h |
| | Receive control | U0RCTL | 072h |
| | Transmit control | U0TCTL | 071h |
| | USART control | U0CTL | 070h |
| Comparator_A | Comparator_A port disable | CAPD | 05Bh |
| | Comparator_A control 2 | CACTL2 | 05Ah |
| | Comparator_A control 1 | CACTL1 | 059h |
| BrownOUT, SVS | SVS control register (Reset by brownout signal) | SVSCTL | 056h |
| FLL+ Clock | FLL+ Control 1 | FLL_CTL1 | 054h |
| | FLL+ Control 0 | FLL_CTL0 | 053h |
| | System clock frequency control | SCFQCTL | 052h |
| | System clock frequency integrator | SCF11 | 051h |
| | System clock frequency integrator | SCF10 | 050h |
| Basic Timer1 | BT counter 2 | BTCNT2 | 047h |
| | BT counter 1 | BTCNT1 | 046h |
| | BT control | BTCTL | 040h |
| Port P6 | Port P6 selection | P6SEL | 037h |
| | Port P6 direction | P6DIR | 036h |
| | Port P6 output | P6OUT | 035h |
| | Port P6 input | P6IN | 034h |
| Port P5 | Port P5 selection | P5SEL | 033h |
| | Port P5 direction | P5DIR | 032h |
| | Port P5 output | P5OUT | 031h |
| | Port P5 input | P5IN | 030h |

表 9-13. Peripherals With Byte Access (continued)

| PERIPHERAL | REGISTER NAME | ACRONYM | OFFSET |
|-------------------|-------------------------------|---------|--------|
| Port P4 | Port P4 selection | P4SEL | 01Fh |
| | Port P4 direction | P4DIR | 01Eh |
| | Port P4 output | P4OUT | 01Dh |
| | Port P4 input | P4IN | 01Ch |
| Port P3 | Port P3 selection | P3SEL | 01Bh |
| | Port P3 direction | P3DIR | 01Ah |
| | Port P3 output | P3OUT | 019h |
| | Port P3 input | P3IN | 018h |
| Port P2 | Port P2 selection | P2SEL | 02Eh |
| | Port P2 interrupt enable | P2IE | 02Dh |
| | Port P2 interrupt-edge select | P2IES | 02Ch |
| | Port P2 interrupt flag | P2IFG | 02Bh |
| | Port P2 direction | P2DIR | 02Ah |
| | Port P2 output | P2OUT | 029h |
| | Port P2 input | P2IN | 028h |
| Port P1 | Port P1 selection | P1SEL | 026h |
| | Port P1 interrupt enable | P1IE | 025h |
| | Port P1 interrupt-edge select | P1IES | 024h |
| | Port P1 interrupt flag | P1IFG | 023h |
| | Port P1 direction | P1DIR | 022h |
| | Port P1 output | P1OUT | 021h |
| | Port P1 input | P1IN | 020h |
| Special functions | SFR module enable 2 | ME2 | 005h |
| | SFR module enable 1 | ME1 | 004h |
| | SFR interrupt flag 2 | IFG2 | 003h |
| | SFR interrupt flag 1 | IFG1 | 002h |
| | SFR interrupt enable 2 | IE2 | 001h |
| | SFR interrupt enable 1 | IE1 | 000h |

9.10 Input/Output Schematics

9.10.1 Port P1, P1.0 to P1.5, Input/Output With Schmitt Trigger

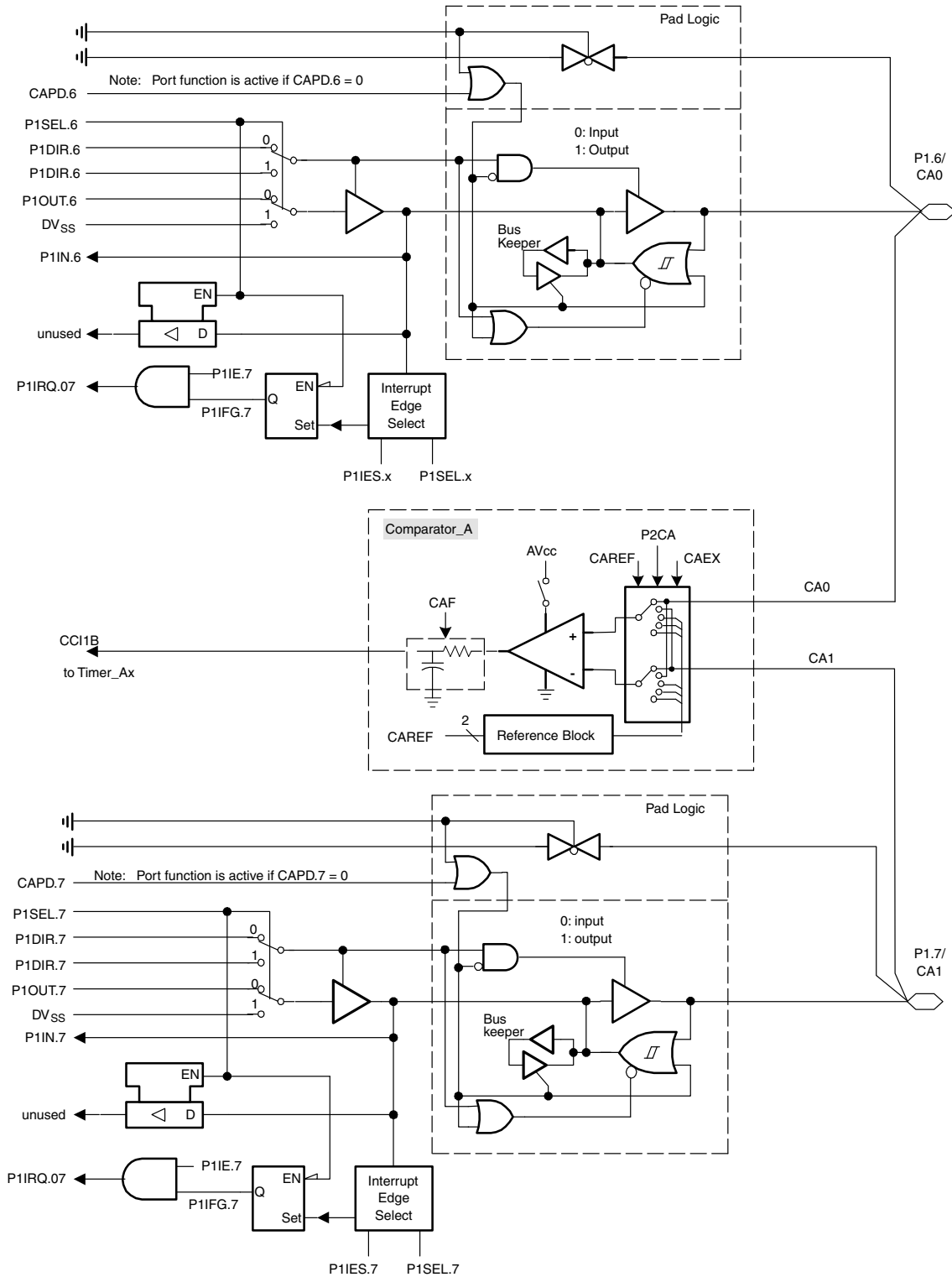


Note: $0 \leq x \leq 5$
Note: Port function is active if CAPD.x = 0

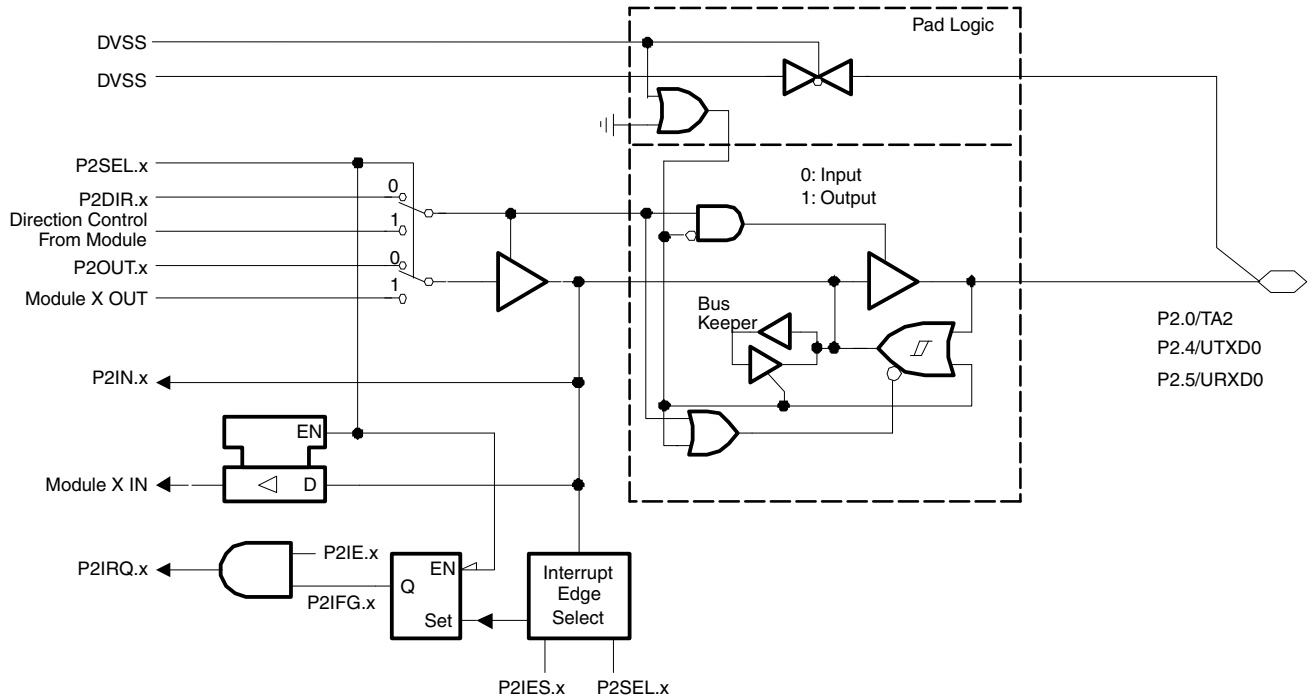
| PnSEL.x | PnDIR.x | Direction Control From Module | PnOUT.x | Module X OUT | PnIN.x | Module X IN | PnIE.x | PnIFG.x | PnIES.x |
|---------|---------|-------------------------------|---------|--------------------------|--------|-----------------------|--------|---------|---------|
| P1SEL.0 | P1DIR.0 | P1DIR.0 | P1OUT0 | Out0 sig. ⁽¹⁾ | P1IN.0 | CCI0A ⁽¹⁾ | P1IE.0 | P1IFG.0 | P1IES.0 |
| P1SEL.1 | P1DIR.1 | P1DIR.1 | P1OUT.1 | MCLK | P1IN.1 | CCI0B ⁽¹⁾ | P1IE.1 | P1IFG.1 | P1IES.1 |
| P1SEL.2 | P1DIR.2 | P1DIR.2 | P1OUT.2 | Out1 sig. ⁽¹⁾ | P1IN.2 | CCI1A ⁽¹⁾ | P1IE.2 | P1IFG.2 | P1IES.2 |
| P1SEL.3 | P1DIR.3 | P1DIR.3 | P1OUT.3 | SVSOUT | P1IN.3 | TBOUTH ⁽²⁾ | P1IE.3 | P1IFG.3 | P1IES.3 |
| P1SEL.4 | P1DIR.4 | P1DIR.4 | P1OUT.4 | SMCLK | P1IN.4 | TBCLK ⁽²⁾ | P1IE.4 | P1IFG.4 | P1IES.4 |
| P1SEL.5 | P1DIR.5 | P1DIR.5 | P1OUT.5 | ACLK | P1IN.5 | TACLK ⁽¹⁾ | P1IE.5 | P1IFG.5 | P1IES.5 |

- (1) Timer_A
(2) Timer_B

9.10.2 Port P1, P1.6 and P1.7, Input/Output With Schmitt Trigger



9.10.3 Port P2, P2.0 and P2.4 to P2.5, Input/Output With Schmitt Trigger

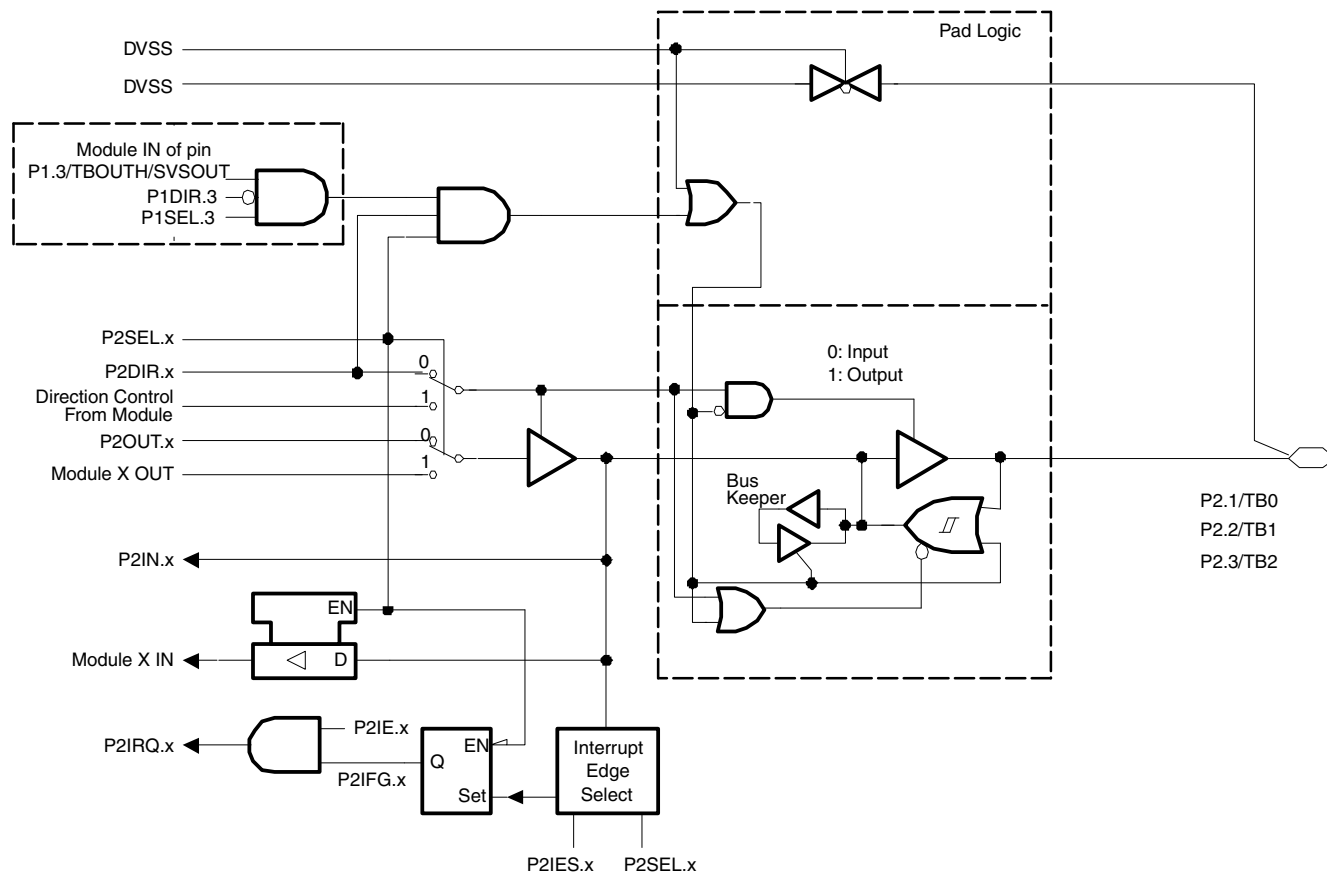


Note: x {0,4,5}

| PnSel.x | PnDIR.x | Direction Control From Module | PnOUT.x | Module X OUT | PnIN.x | Module X IN | PnIE.x | PnIFG.x | PnIES.x |
|---------|---------|-------------------------------|---------|--------------------------|--------|----------------------|--------|---------|---------|
| P2Sel.0 | P2DIR.0 | P2DIR.0 | P2OUT.0 | Out2 sig. ⁽¹⁾ | P2IN.0 | CCI2A ⁽¹⁾ | P2IE.0 | P2IFG.0 | P2IES.0 |
| P2Sel.4 | P2DIR.4 | DVCC | P2OUT.4 | UTXD0 ⁽²⁾ | P2IN.4 | unused | P2IE.4 | P2IFG.4 | P2IES.4 |
| P2Sel.5 | P2DIR.5 | DVSS | P2OUT.5 | DVSS | P2IN.5 | URXD0 ⁽²⁾ | P2IE.5 | P2IFG.5 | P2IES.5 |

- (1) Timer_A
- (2) USART0

9.10.4 Port P2, P2.1 to P2.3, Input/Output With Schmitt Trigger

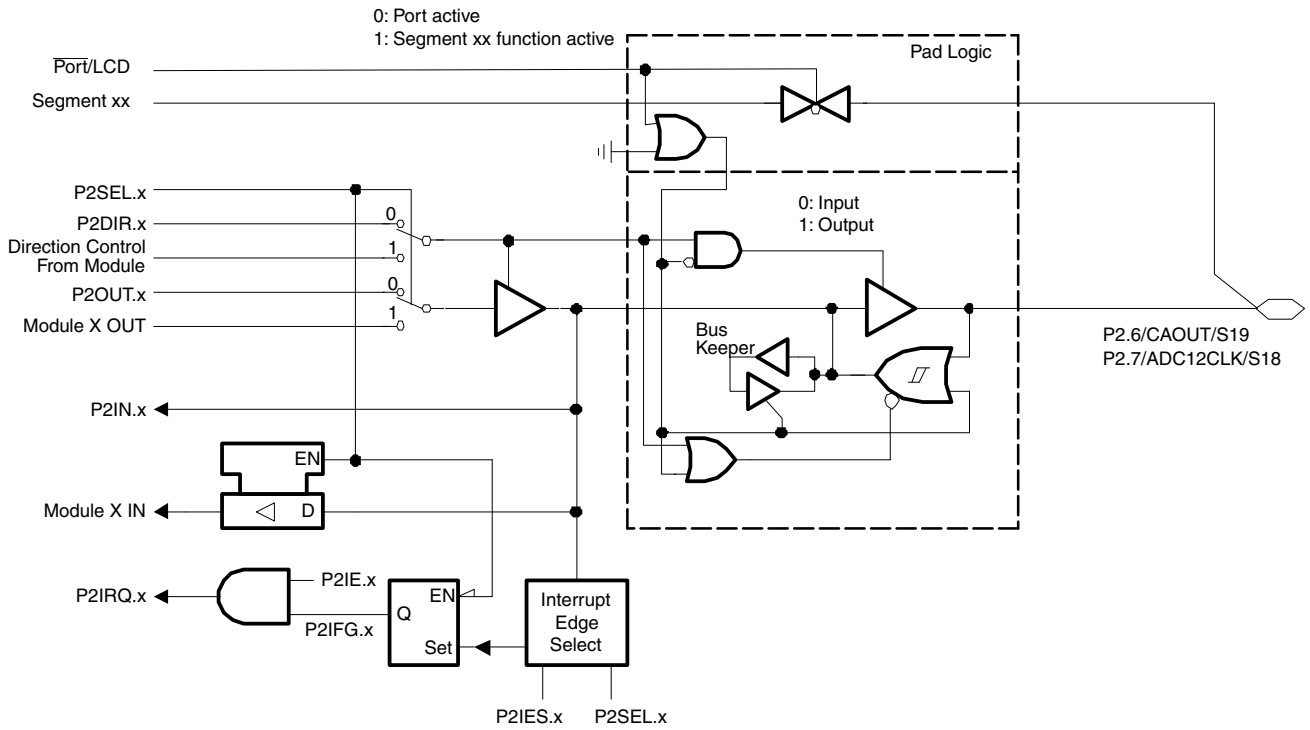


Note: $1 \leq x \leq 3$

| PnSel.x | PnDIR.x | Direction Control From Module | PnOUT.x | Module X OUT | PnIN.x | Module X IN | PnIE.x | PnIFG.x | PnIES.x |
|---------|---------|-------------------------------|---------|--------------------------|--------|-------------------------------|--------|---------|---------|
| P2Sel.1 | P2DIR.1 | P2DIR.1 | P2OUT.1 | Out0 sig. ⁽¹⁾ | P2IN.1 | CCI0A ⁽¹⁾ CCI0B | P2IE.1 | P2IFG.1 | P2IES.1 |
| P2Sel.2 | P2DIR.2 | P2DIR.2 | P2OUT.2 | Out1 sig. ⁽¹⁾ | P2IN.2 | CCI1A ⁽¹⁾ CCI1B | P2IE.2 | P2IFG.2 | P2IES.2 |
| P2Sel.3 | P2DIR.3 | P2DIR.3 | P2OUT.3 | Out2 sig. ⁽¹⁾ | P2IN.3 | CCI2A ⁽¹⁾ CCI2B | P2IE.3 | P2IFG.3 | P2IES.3 |

(1) Timer_B

9.10.5 Port P2, P2.6 and P2.7, Input/Output With Schmitt Trigger

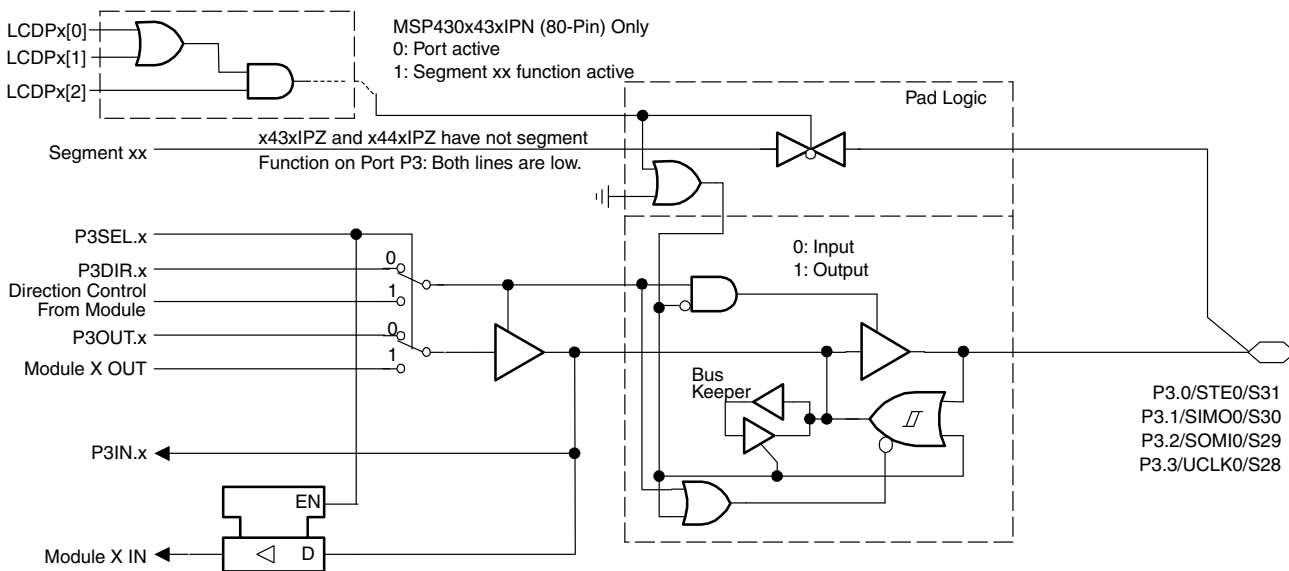


Note: $6 \leq x \leq 7$

| PnSel.x | PnDIR.x | Direction Control From Module | PnOUT.x | Module X OUT | PnIN.x | Module X IN | PnIE.x | PnIFG.x | PnIES.x | Port/LCD |
|---------|---------|-------------------------------|---------|-------------------------|--------|-------------|--------|---------|---------|----------------------------|
| P2Sel.6 | P2DIR.6 | P2DIR.6 | P2OUT.6 | CAOUT ⁽¹⁾ | P2IN.6 | unused | P2IE.6 | P2IFG.6 | P2IES.6 | 0: LCDP _x < 02h |
| P2Sel.7 | P2DIR.7 | P2DIR.7 | P2OUT.7 | ADC12CLK ⁽²⁾ | P2IN.7 | unused | P2IE.7 | P2IFG.7 | P2IES.7 | 0: LCDP _x < 02h |

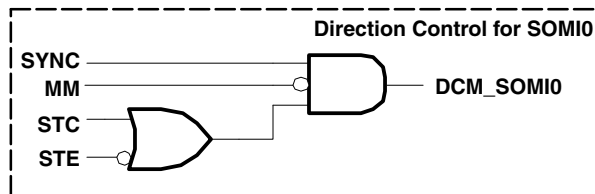
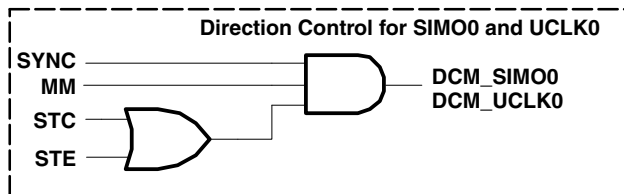
- (1) Comparator_A
- (2) ADC12

9.10.6 Port P3, P3.0 to P3.3, Input/Output With Schmitt Trigger

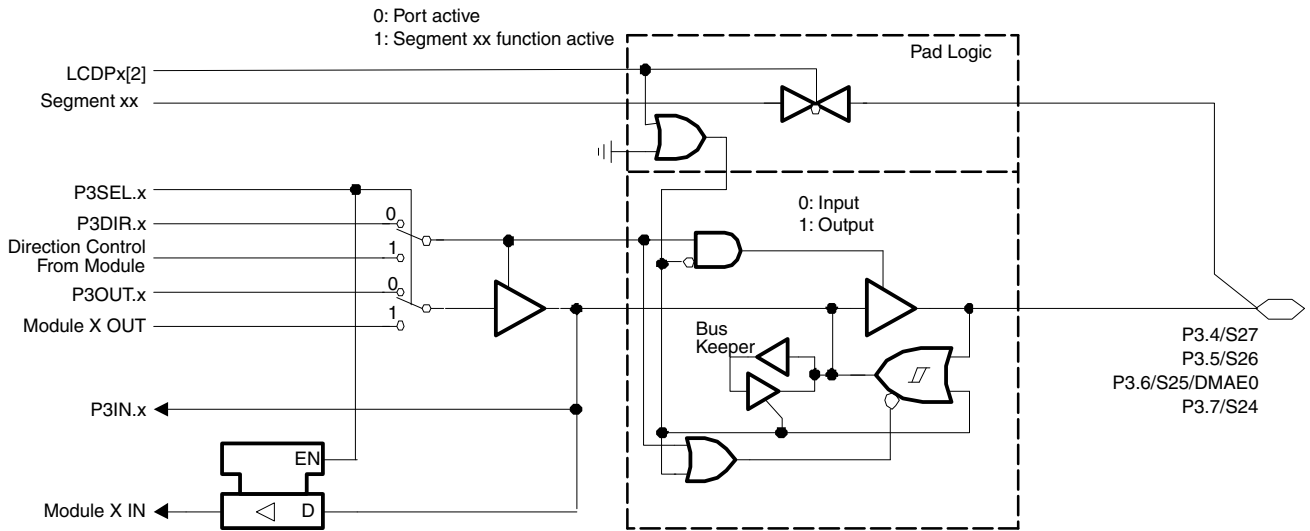


Note: $0 \leq x \leq 3$

| PnSel.x | PnDIR.x | Direction Control From Module | PnOUT.x | Module X OUT | PnIN.x | Module X IN |
|---------|---------|-------------------------------|---------|--------------|--------|-------------|
| P3Sel.0 | P3DIR.0 | DVSS | P3OUT.0 | DVSS | P3IN.0 | STE0(in) |
| P3Sel.1 | P3DIR.1 | DCM_SIMO0 | P3OUT.1 | SIMO0(out) | P3IN.1 | SIMO0(in) |
| P3Sel.2 | P3DIR.2 | DCM_SOMI0 | P3OUT.2 | SOMI0(out) | P3IN.2 | SOMI0(in) |
| P3Sel.3 | P3DIR.3 | DCM_UCLK0 | P3OUT.3 | UCLK0(out) | P3IN.3 | UCLK0(in) |



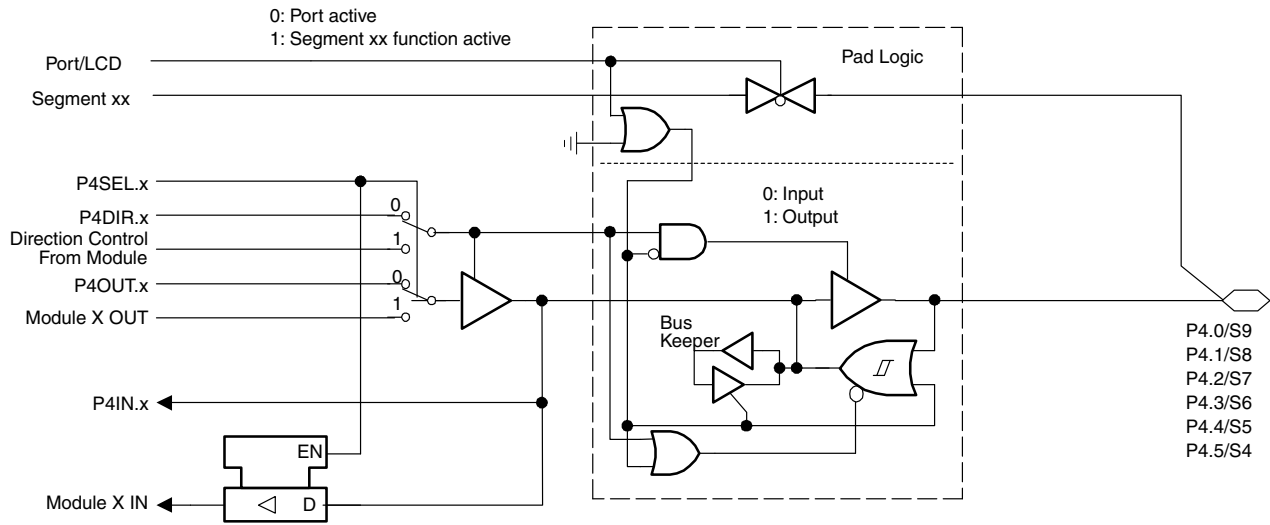
9.10.7 Port P3, P3.4 to P3.7, Input/Output With Schmitt Trigger



Note: $4 \leq x \leq 7$

| PnSel.x | PnDIR.x | Direction Control From Module | PnOUT.x | Module X OUT | PnIN.x | Module X IN |
|---------|---------|-------------------------------|---------|--------------|--------|-------------|
| P3SEL.4 | P3DIR.4 | P3DIR.4 | P3OUT.4 | DVSS | P3IN.4 | unused |
| P3SEL.5 | P3DIR.5 | P3DIR.5 | P3OUT.5 | DVSS | P3IN.5 | unused |
| P3SEL.6 | P3DIR.6 | P3DIR.6 | P3OUT.6 | DVSS | P3IN.6 | DMAE0 |
| P3SEL.7 | P3DIR.7 | P3DIR.7 | P3OUT.7 | DVSS | P3IN.7 | unused |

9.10.8 Port P4, P4.0 to P4.5, Input/Output With Schmitt Trigger

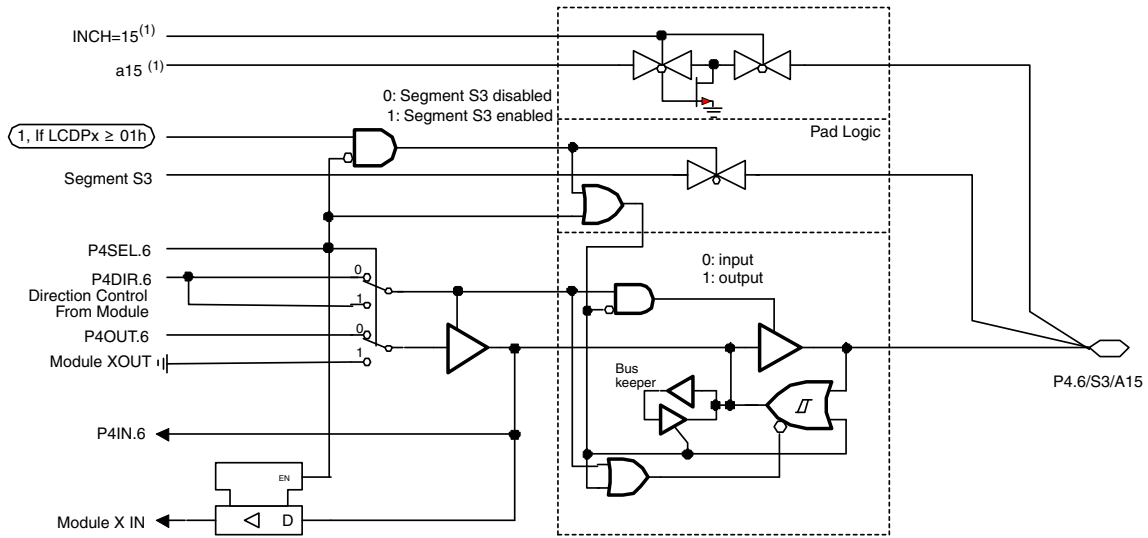


Note: $0 \leq x \leq 5$

| PnSEL.x | PnDIR.x | Direction Control From Module | PnOUT.x | Module X OUT | PnIN.x | Module X IN |
|---------|---------|-------------------------------|---------|--------------|--------|-------------|
| P4SEL.0 | P4DIR.0 | P4DIR.0 | P4OUT.0 | DVSS | P4IN.0 | unused |
| P4SEL.1 | P4DIR.1 | P4DIR.1 | P4OUT.1 | DVSS | P4IN.1 | unused |
| P4SEL.2 | P4DIR.2 | P4DIR.2 | P4OUT.2 | DVSS | P4IN.2 | unused |
| P4SEL.3 | P4DIR.3 | P4DIR.3 | P4OUT.3 | DVSS | P4IN.3 | unused |
| P4SEL.4 | P4DIR.4 | P4DIR.4 | P4OUT.4 | DVSS | P4IN.4 | unused |
| P4SEL.5 | P4DIR.5 | P4DIR.5 | P4OUT.5 | DVSS | P4IN.5 | unused |

| DEVICE | PORT BITS | PORT FUNCTION | LCD SEGMENT FUNCTION |
|-------------|--------------|---------------|----------------------|
| MSP430FG43x | P4.0 to P4.5 | LCDPx < 01h | LCDPx ≥ 01h |

9.10.9 Port P4, P4.6, Input/Output With Schmitt Trigger

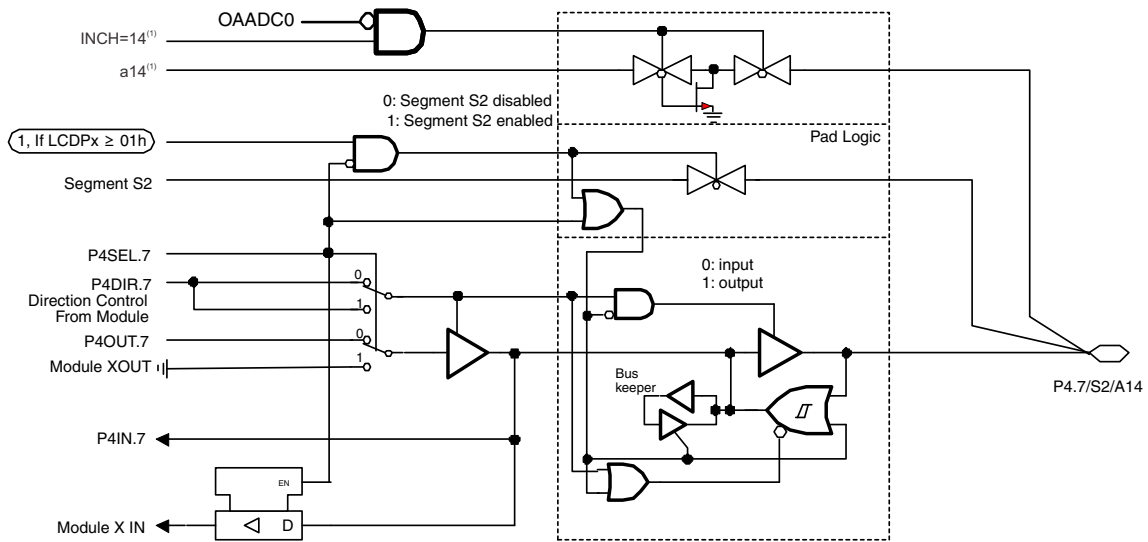


⁽¹⁾Signal from or to ADC12

| PnSEL.x | PnDIR.x | Direction Control From Module | PnOUT.x | Module X OUT | PnIN.x | Module X IN |
|---------|---------|-------------------------------|---------|--------------|--------|-------------|
| P4SEL.6 | P4DIR.6 | P4DIR.6 | P4OUT.6 | DVSS | P4IN.6 | unused |

| DEVICE | PORT BITS | PORT FUNCTION | LCD SEGMENT FUNCTION |
|-------------|-----------|---------------|----------------------|
| MSP430FG43x | P4.6 | LCDPx < 01h | LCDPx ≥ 01h |

9.10.10 Port P4, P4.7, Input/Output With Schmitt Trigger

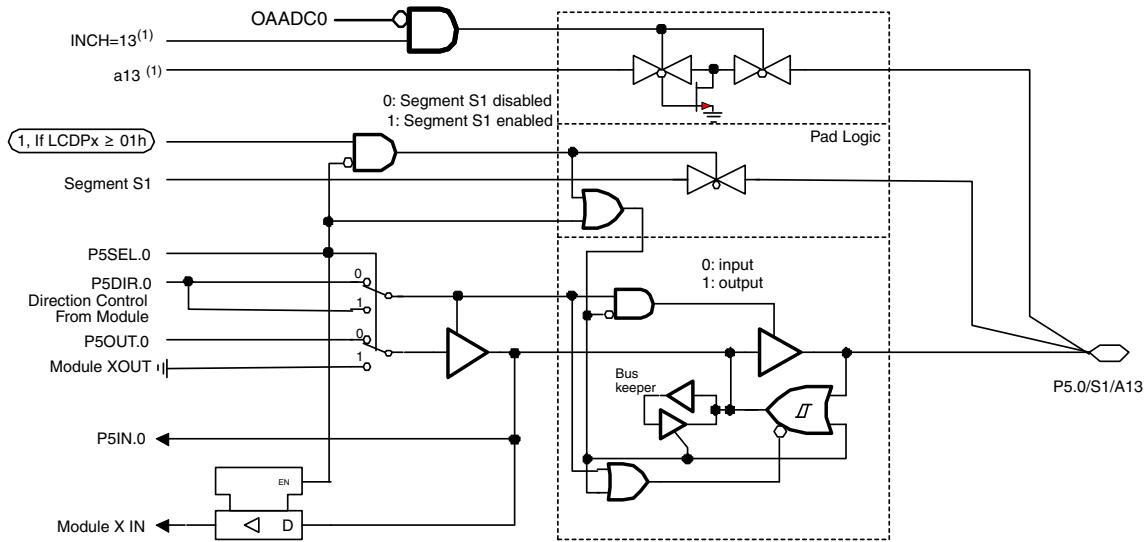


(1) Signal from or to ADC12

| PnSel.x | PnDIR.x | Direction Control From Module | PnOUT.x | Module X OUT | PnIN.x | Module X IN |
|---------|---------|-------------------------------|---------|--------------|--------|-------------|
| P4Sel.7 | P4DIR.7 | P4DIR.7 | P4OUT.7 | DVSS | P4IN.7 | Unused |

| DEVICE | PORT BITS | PORT FUNCTION | LCD SEGMENT FUNCTION |
|-------------|-----------|---------------|----------------------|
| MSP430FG43x | P4.7 | LCDPx < 01h | LCDPx ≥ 01h |

9.10.11 Port P5, P5.0, Input/Output With Schmitt Trigger

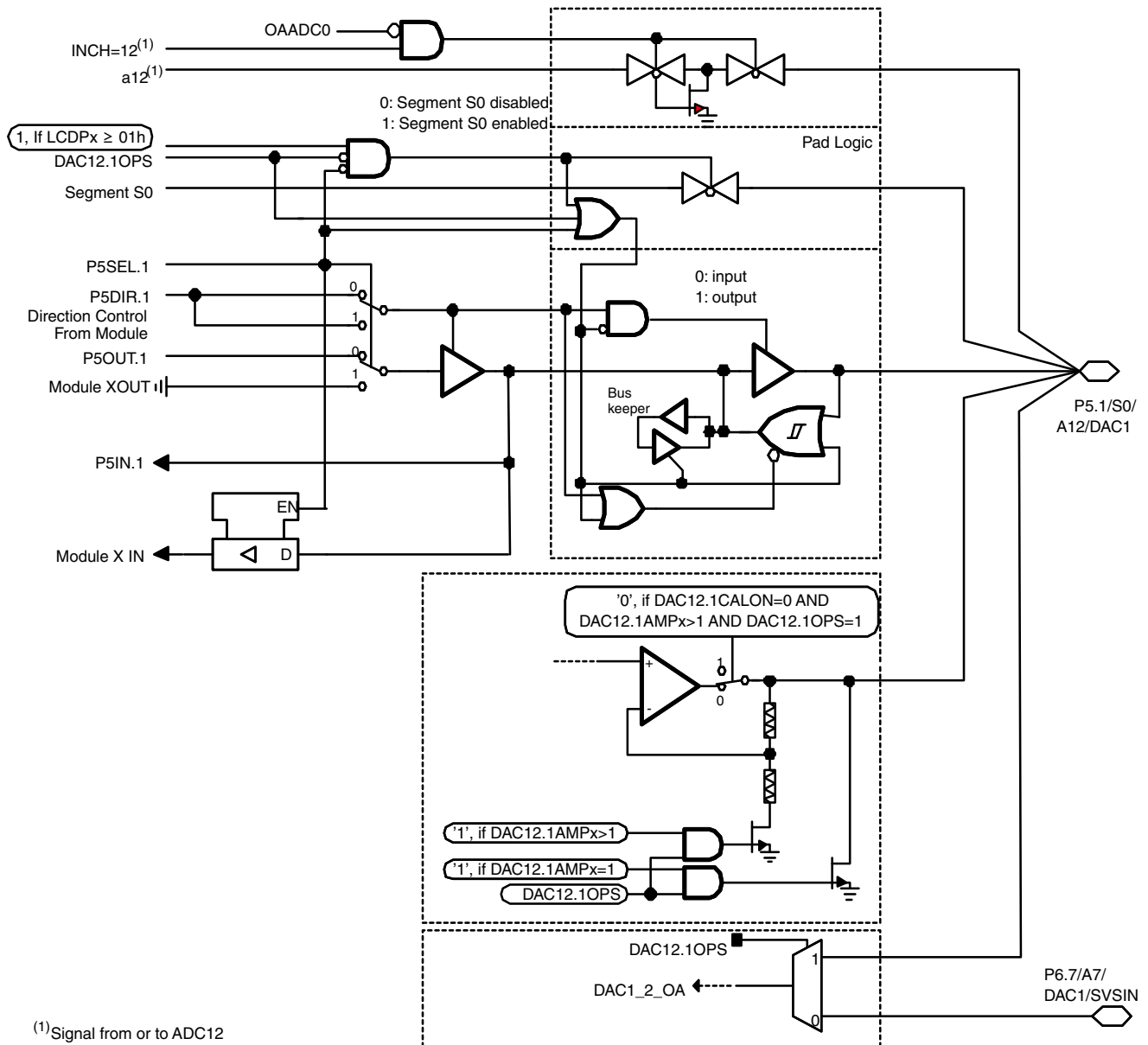


⁽¹⁾ Signal from or to ADC12

| PnSEL.x | PnDIR.x | Direction Control From Module | PnOUT.x | Module X OUT | PnIN.x | Module X IN |
|---------|---------|-------------------------------|---------|--------------|--------|-------------|
| P5SEL.0 | P5DIR.0 | P5DIR.0 | P5OUT.0 | DVSS | P5IN.0 | unused |

| DEVICE | PORT BITS | PORT FUNCTION | LCD SEGMENT FUNCTION |
|-------------|-----------|---------------|----------------------|
| MSP430FG43x | P5.0 | LCDPx < 01h | LCDPx ≥ 01h |

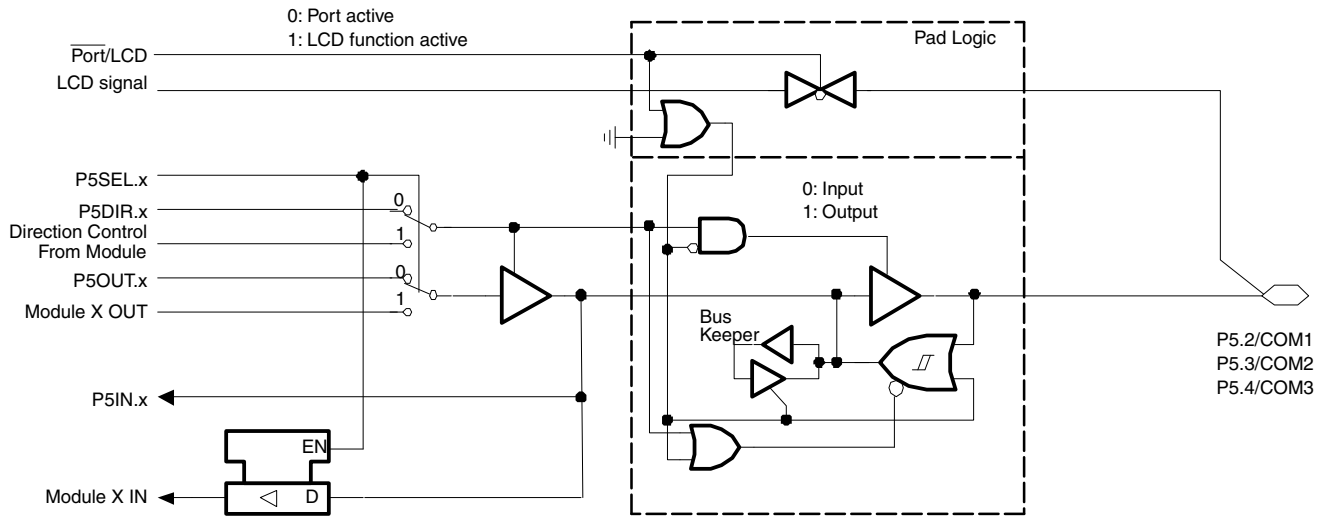
9.10.12 Port P5, P5.1, Input/Output With Schmitt Trigger



| Function | Description | P5SEL.1 | LCDPx | DAC12.1OPS | DAC12.1AMPx |
|----------|------------------------------------------------------------------------------|---------|------------|------------|-------------|
| DAC12 | 3-State | X | X | 1 | 0 |
| | 0 V | X | X | 1 | 1 |
| | DAC1 output (the output voltage can be converted with ADC12, channel A12) | X | X | 1 | > 1 |
| ADC12 | Channel 12, A12 | 1 | X | 0 | X |
| LCD | Segment S0, initial state | 0 | $\geq 01h$ | 0 | X |
| Port | P5.1 | 0 | < 01h | 0 | X |

| PnSEL.x | PnDIR.x | Direction Control From Module | PnOUT.x | Module X OUT | PnIN.x | Module X IN | Segment | Port/LCD |
|---------|---------|-------------------------------|---------|--------------|--------|-------------|---------|----------------|
| P5SEL.1 | P5DIR.1 | P5DIR.1 | P5OUT.1 | DVSS | P5IN.1 | Unused | S0 | 0: LCDPx < 01h |

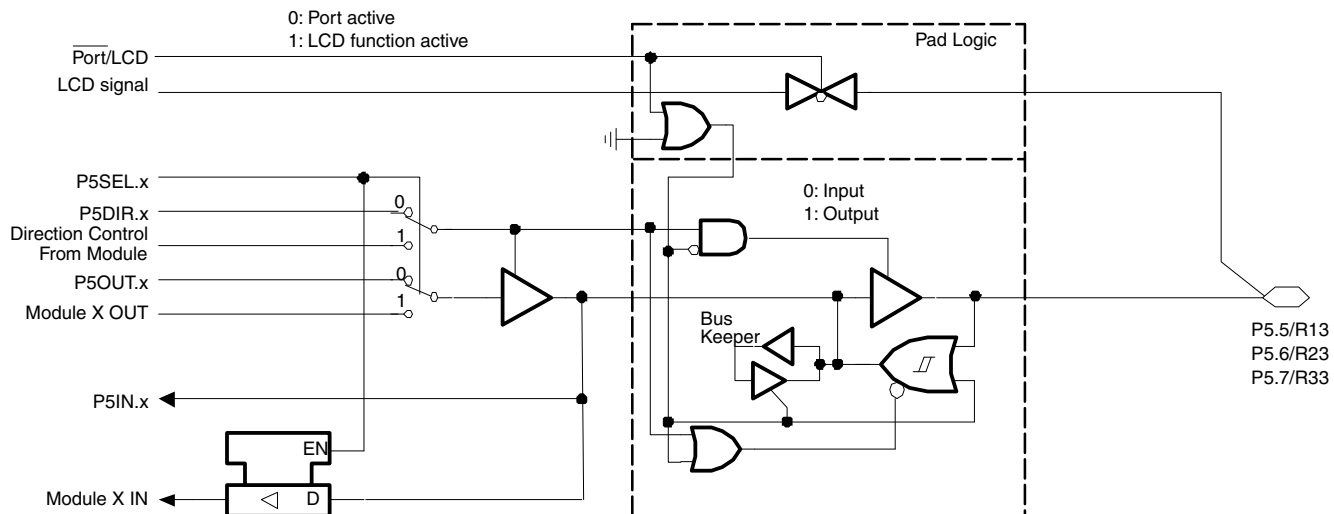
9.10.13 Port P5, P5.2 to P5.4, Input/Output With Schmitt Trigger



Note: $2 \leq x \leq 4$

| PnSel.x | PnDIR.x | Direction Control From Module | PnOUT.x | Module X OUT | PnIN.x | Module X IN | LCD signal | Port/LCD |
|---------|---------|-------------------------------|---------|--------------|--------|-------------|------------|----------|
| P5Sel.2 | P5DIR.2 | P5DIR.2 | P5OUT.2 | DVSS | P5IN.2 | Unused | COM1 | P5SEL.2 |
| P5Sel.3 | P5DIR.3 | P5DIR.3 | P5OUT.3 | DVSS | P5IN.3 | Unused | COM2 | P5SEL.3 |
| P5Sel.4 | P5DIR.4 | P5DIR.4 | P5OUT.4 | DVSS | P5IN.4 | Unused | COM3 | P5SEL.4 |

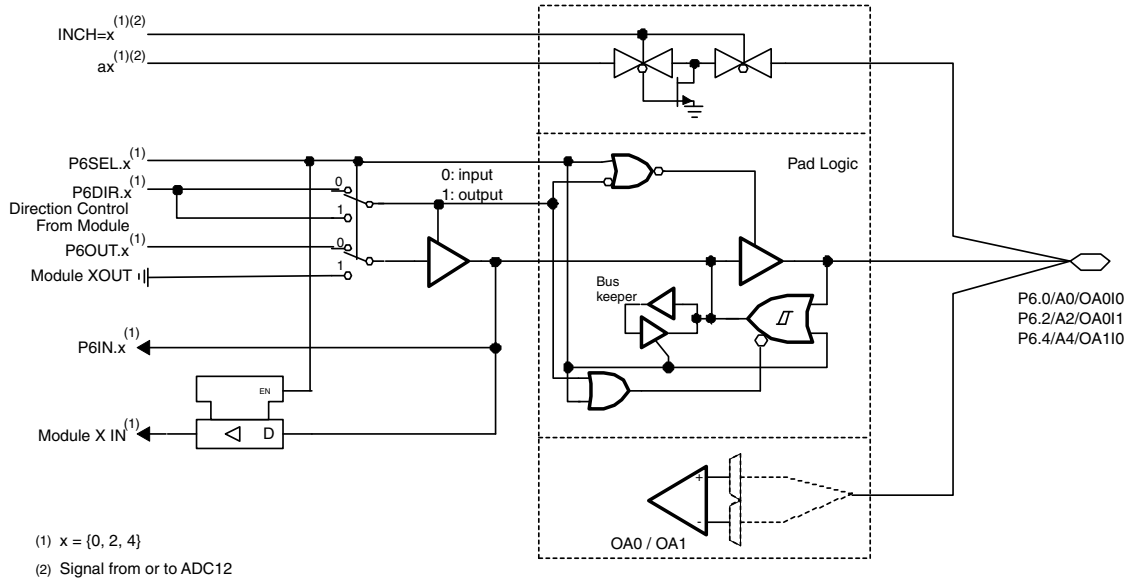
9.10.14 Port P5, P5.5 to P5.7, Input/Output With Schmitt Trigger



Note: $5 \leq x \leq 7$

| PnSel.x | PnDIR.x | Direction Control From Module | PnOUT.x | Module X OUT | PnIN.x | Module X IN | LCD signal | Port/LCD |
|---------|---------|-------------------------------|---------|--------------|--------|-------------|------------|----------|
| P5Sel.5 | P5DIR.5 | P5DIR.5 | P5OUT.5 | DVSS | P5IN.5 | Unused | R13 | P5SEL.5 |
| P5Sel.6 | P5DIR.6 | P5DIR.6 | P5OUT.6 | DVSS | P5IN.6 | Unused | R23 | P5SEL.6 |
| P5Sel.7 | P5DIR.7 | P5DIR.7 | P5OUT.7 | DVSS | P5IN.7 | Unused | R33 | P5SEL.7 |

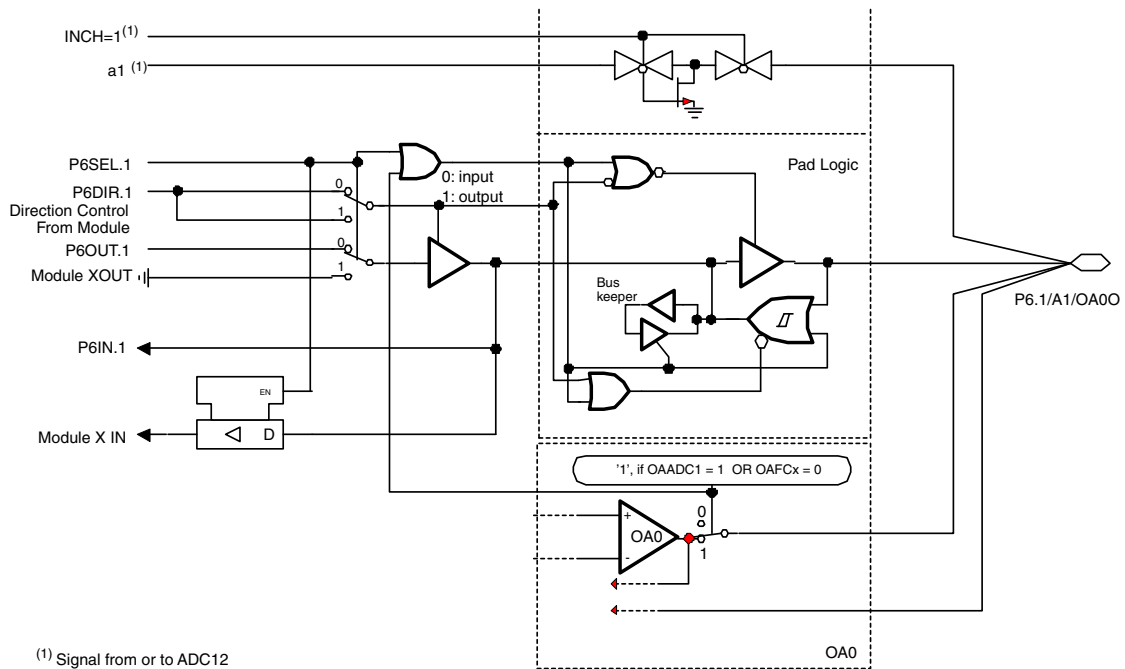
9.10.15 Port P6, P6.0, P6.2, and P6.4, Input/Output With Schmitt Trigger



| PnSel.x ⁽¹⁾ | PnDIR.x | Direction Control From Module | PnOUT.x | Module X OUT | PnIN.x | Module X IN |
|------------------------|---------|-------------------------------|---------|--------------|--------|-------------|
| P6Sel.0 | P6DIR.0 | P6DIR.0 | P6OUT.0 | DVSS | P6IN.0 | unused |
| P6Sel.2 | P6DIR.2 | P6DIR.2 | P6OUT.2 | DVSS | P6IN.2 | unused |
| P6Sel.4 | P6DIR.4 | P6DIR.4 | P6OUT.4 | DVSS | P6IN.4 | unused |

(1) The signal at pin P6.x/Ax is used by the 12-bit ADC module.

9.10.16 Port P6, P6.1, Input/Output With Schmitt Trigger

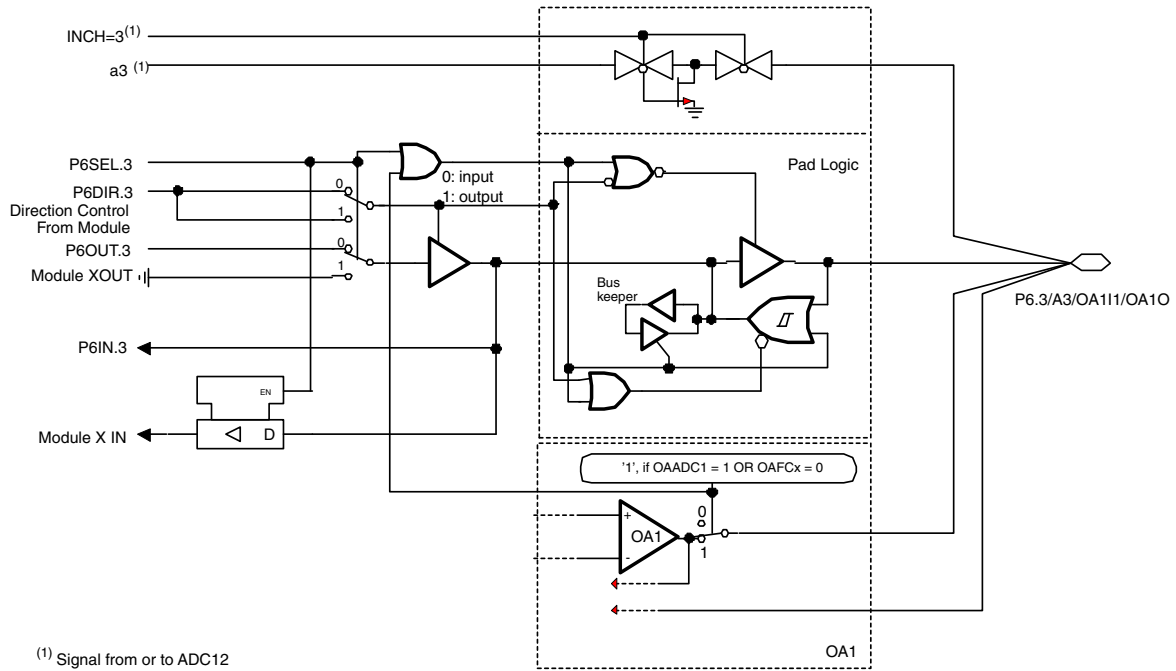


(1) Signal from or to ADC12

| PnSel.x ⁽¹⁾ | PnDIR.x | Direction Control From Module | PnOUT.x | Module X OUT | PnIN.x | Module X IN |
|------------------------|---------|-------------------------------|---------|--------------|--------|-------------|
| P6Sel.1 | P6DIR.1 | P6DIR.1 | P6OUT.1 | DVSS | P6IN.1 | unused |

(1) The signal at pin P6.x/Ax is used by the 12-bit ADC module.

9.10.17 Port P6, P6.3, Input/Output With Schmitt Trigger

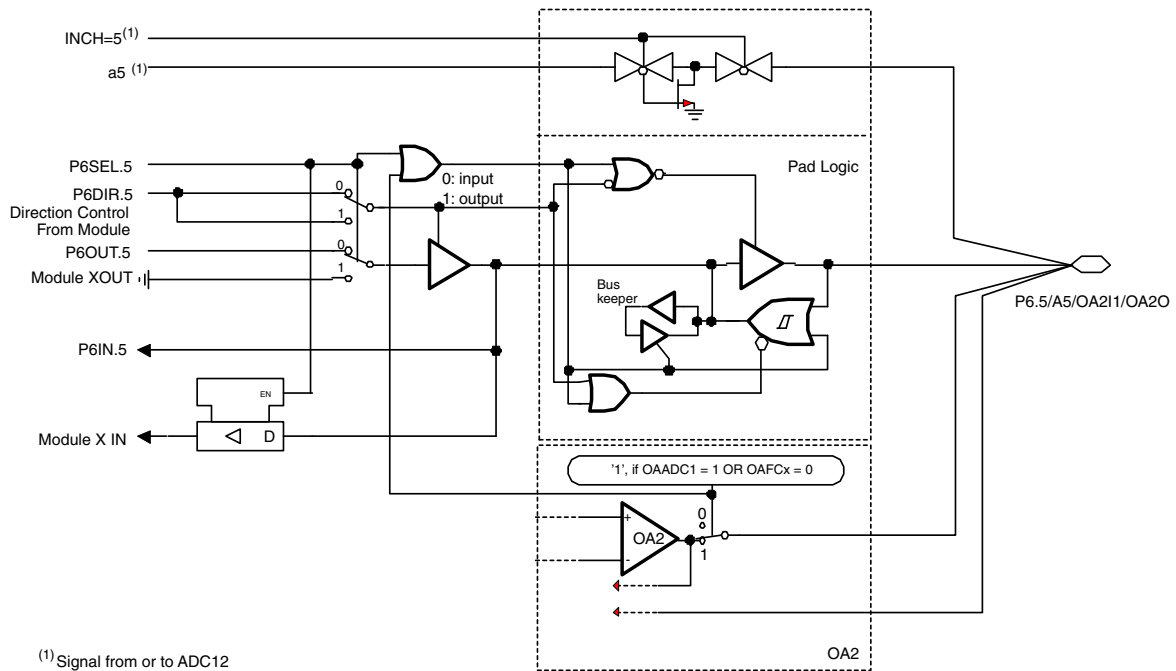


(1) Signal from or to ADC12

| PnSel.x ⁽¹⁾ | PnDIR.x | Direction Control From Module | PnOUT.x | Module X OUT | PnIN.x | Module X IN |
|------------------------|---------|-------------------------------|---------|--------------|--------|-------------|
| P6Sel.3 | P6DIR.3 | P6DIR.3 | P6OUT.3 | DVSS | P6IN.3 | unused |

(1) The signal at pin P6.x/Ax is used by the 12-bit ADC module.

9.10.18 Port P6, P6.5, Input/Output With Schmitt Trigger

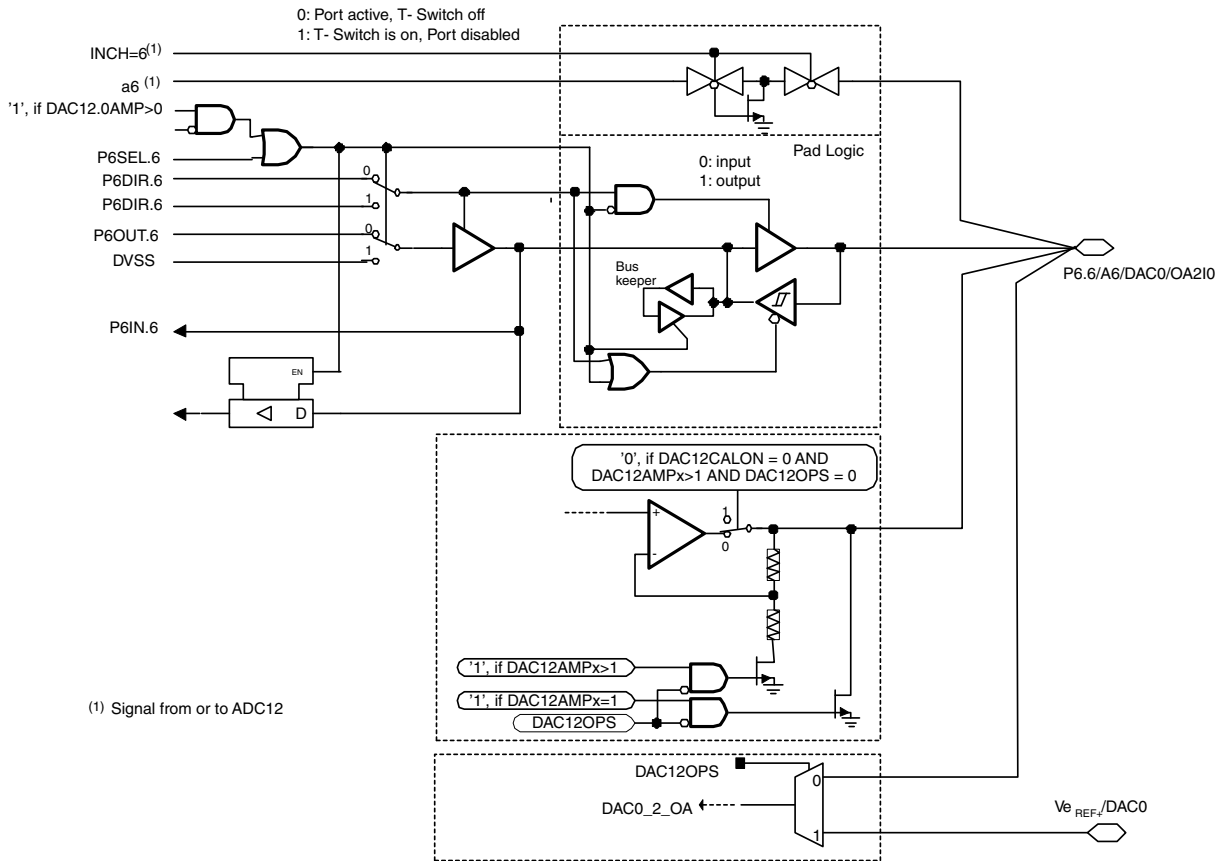


(1) Signal from or to ADC12

| PnSel.x ⁽¹⁾ | PnDIR.x | Direction Control From Module | PnOUT.x | Module X OUT | PnIN.x | Module X IN |
|------------------------|---------|-------------------------------|---------|--------------|--------|-------------|
| P6Sel.5 | P6DIR.5 | P6DIR.5 | P6OUT.5 | DVSS | P6IN.5 | unused |

(1) The signal at pins P6.x/Ax is used by the 12-bit ADC module.

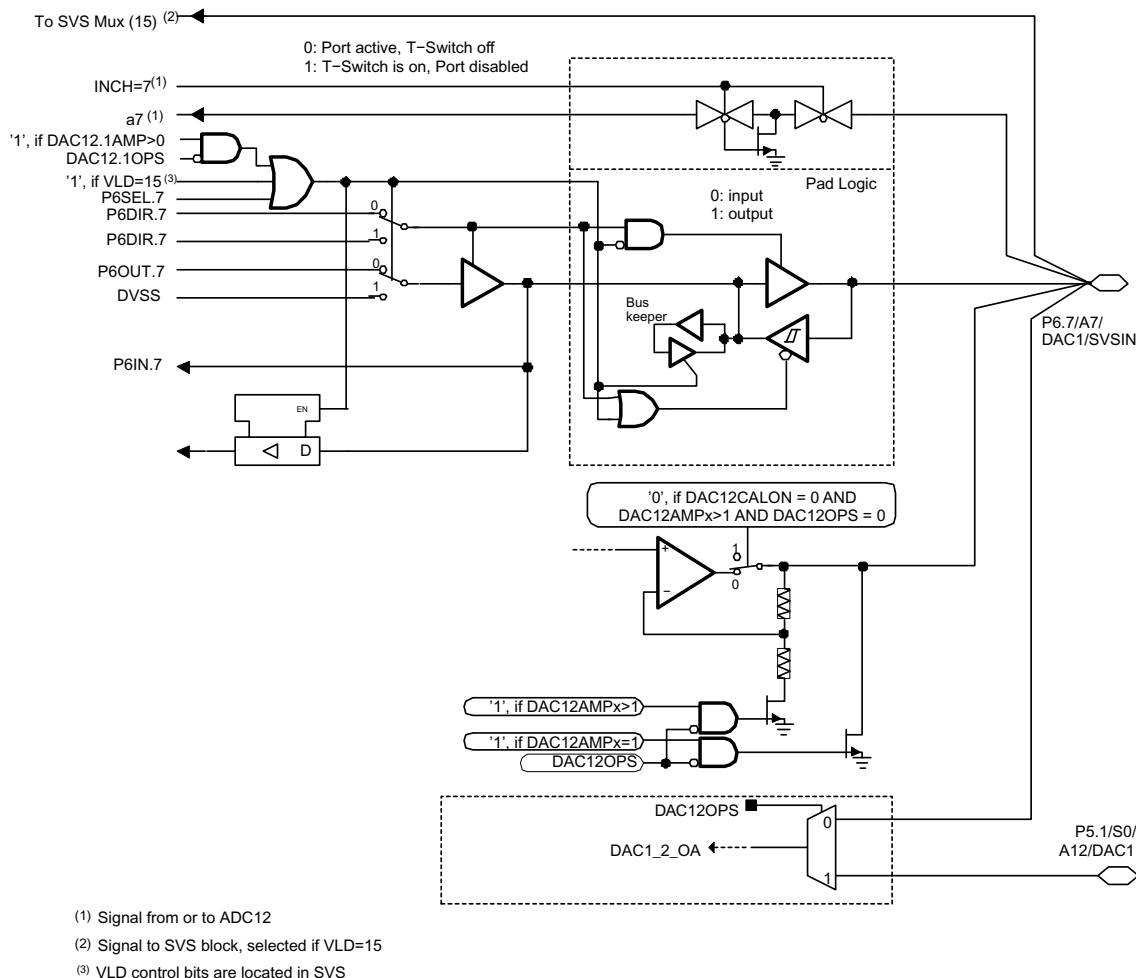
9.10.19 Port P6, P6.6, Input/Output With Schmitt Trigger



| PnSel.x ⁽¹⁾ | PnDIR.x | Direction Control From Module | PnOUT.x | Module X OUT | PnIN.x | Module X IN |
|------------------------|---------|-------------------------------|---------|--------------|--------|-------------|
| P6Sel.6 | P6DIR.6 | P6DIR.6 | P6OUT.6 | DVSS | P6IN.6 | unused |

(1) The signal at pins P6.x/Ax is used by the 12-bit ADC module.

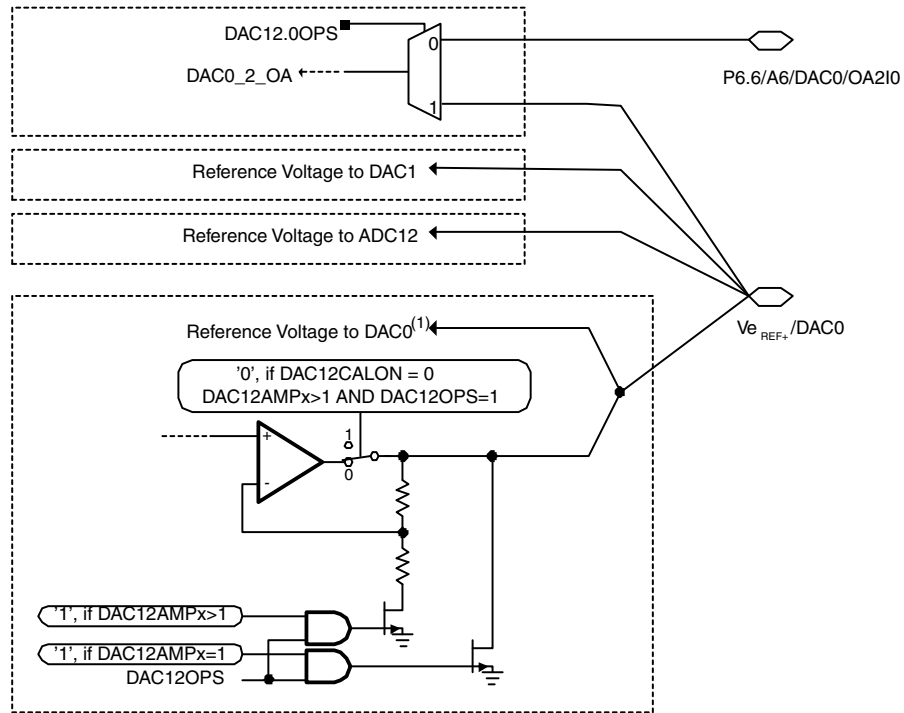
9.10.20 Port P6, P6.7, Input/Output With Schmitt Trigger



| PnSel.x ⁽¹⁾ | PnDIR.x | Direction Control From Module | PnOUT.x | Module X OUT | PnIN.x | Module X IN |
|------------------------|---------|-------------------------------|---------|--------------|--------|-------------|
| P6Sel.7 | P6DIR.7 | P6DIR.7 | P6OUT.7 | DVSS | P6IN.7 | unused |

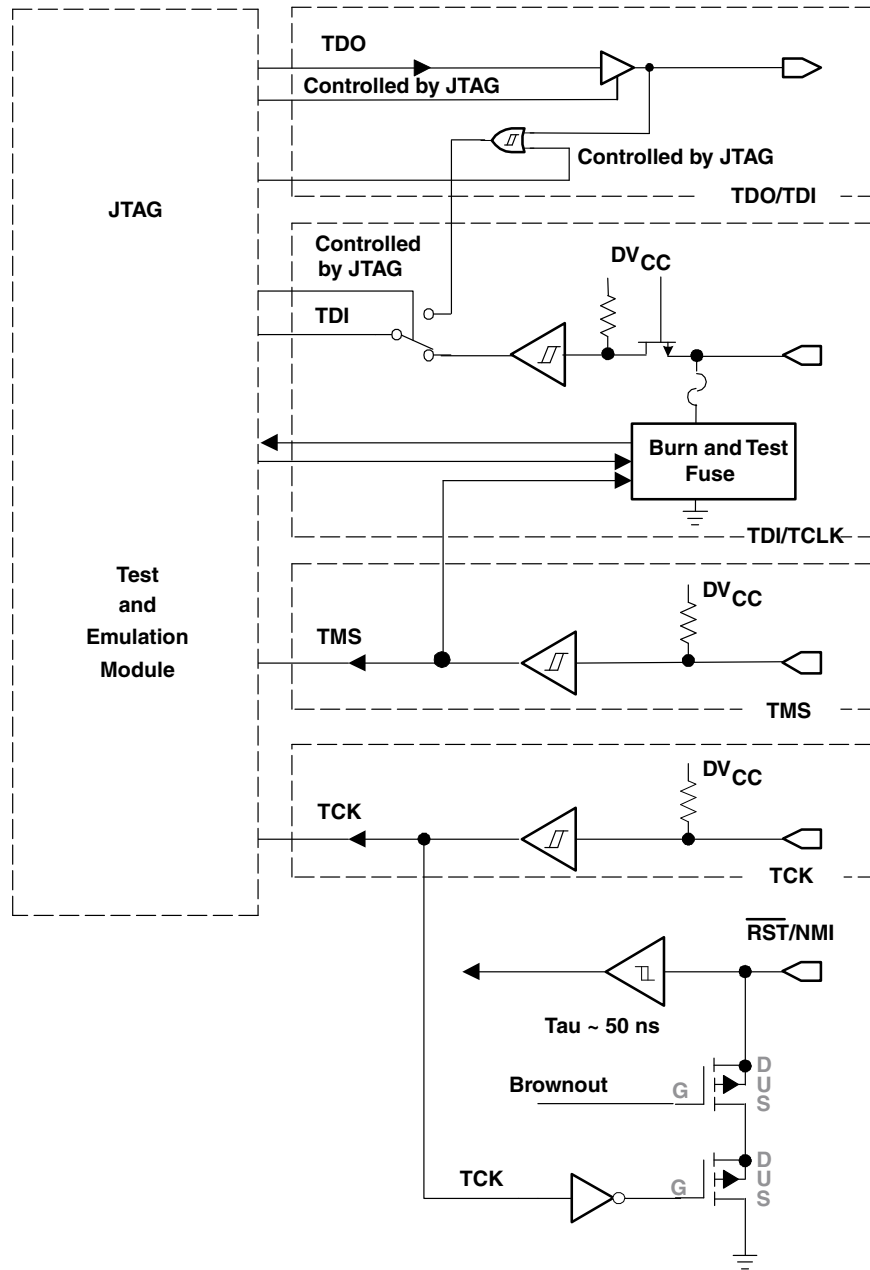
(1) The signal at pins P6.x/Ax is used by the 12-bit ADC module. The signal at pin P6.7/A7/SVSIN is also connected to the input multiplexer in the module brownout/supply voltage supervisor.

9.10.21 VeREF+/DAC0



(1) If the reference of DAC0 is taken from pin Ve_{REF+}/DAC0, unpredictable voltage levels will be on pin. In this situation, the DAC0 output is fed back to its own reference input.

9.10.22 JTAG Pins TMS, TCK, TDI/TCLK, TDO/TDI, Input/Output With Schmitt Trigger or Output



9.10.23 JTAG Fuse Check Mode

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

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

The fuse check current only flows when the fuse check mode is active and the TMS pin is in a low state (see [图 9-8](#)). Therefore, the additional current flow can be prevented by holding the TMS pin high (default condition). The JTAG pins are terminated internally and therefore do not require external termination.

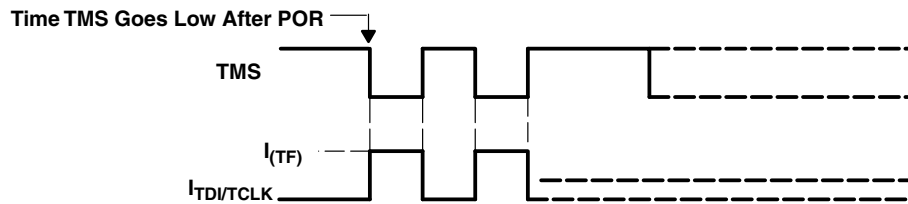


图 9-8. Fuse Check Mode Current

10 Device and Documentation Support

10.1 Device Support

10.1.1 Development Support

TI offers an extensive line of development tools, including tools to evaluate the performance of the processors, generate code, develop algorithm implementations, and fully integrate and debug software and hardware modules. The tool's support documentation is electronically available within the Code Composer Studio™ Integrated Development Environment (IDE).

The following products support development of the MSP430FG43x device applications:

Software Development Tools: Code Composer Studio™ Integrated Development Environment (IDE): including Editor C/C++/Assembly Code Generation, and Debug plus additional development tools.

For a complete listing of development-support tools for the MSP430FG43x platform, visit the Texas Instruments website at www.ti.com. For information on pricing and availability, contact the nearest TI field sales office or authorized distributor.

10.1.1.1 Development Kit

The [MSP-FET430U80](#) is a powerful flash emulation tool that includes the hardware and software required to quickly begin application development on the MSP430 MCU. It includes a ZIF socket target board and a USB debugging interface (MSP-FET) used to program and debug the MSP430 in-system through the JTAG interface or the pin saving Spy Bi-Wire (2-wire JTAG) protocol. The flash memory can be erased and programmed in seconds with only a few keystrokes, and because the MSP430 flash is ultra-low power, no external power supply is required.

The debugging tool interfaces the MSP430 to the included integrated software environment and includes code to start your design immediately.

10.1.2 Device Nomenclature

To designate the stages in the product development cycle, TI assigns prefixes to the part numbers of all MSP MCU devices. Each MSP MCU commercial family member has one of two prefixes: MSP or XMS. These prefixes represent evolutionary stages of product development from engineering prototypes (XMS) through fully qualified production devices (MSP).

XMS - Experimental device that is not necessarily representative of the final device's electrical specifications

MSP - Fully qualified production device

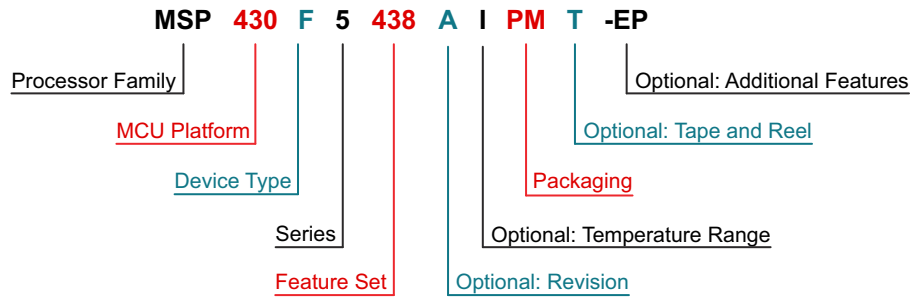
XMS devices are shipped against the following disclaimer:

"Developmental product is intended for internal evaluation purposes."

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

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

TI device nomenclature also includes a suffix with the device family name. This suffix indicates the temperature range, package type, and distribution format. [Figure 10-1](#) provides a legend for reading the complete device name.



| | | | |
|---------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Processor Family | CC = Embedded RF Radio MSP = Mixed-Signal Processor XMS = Experimental Silicon PMS = Prototype Device | | |
| MCU Platform | 430 = MSP430 low-power microcontroller platform | | |
| Device Type | <table border="0" style="width: 100%;"> <tr> <td style="width: 50%;">Memory Type C = ROM F = Flash FR = FRAM G = Flash L = No nonvolatile memory</td> <td style="width: 50%;">Specialized Application AFE = Analog front end BQ = Contactless power CG = ROM medical FE = Flash energy meter FG = Flash medical FW = Flash electronic flow meter</td> </tr> </table> | Memory Type C = ROM F = Flash FR = FRAM G = Flash L = No nonvolatile memory | Specialized Application AFE = Analog front end BQ = Contactless power CG = ROM medical FE = Flash energy meter FG = Flash medical FW = Flash electronic flow meter |
| Memory Type C = ROM F = Flash FR = FRAM G = Flash L = No nonvolatile memory | Specialized Application AFE = Analog front end BQ = Contactless power CG = ROM medical FE = Flash energy meter FG = Flash medical FW = Flash electronic flow meter | | |
| Series | <table border="0" style="width: 100%;"> <tr> <td style="width: 50%;">1 = Up to 8 MHz 2 = Up to 16 MHz 3 = Legacy 4 = Up to 16 MHz with LCD driver</td> <td style="width: 50%;">5 = Up to 25 MHz 6 = Up to 25 MHz with LCD driver 0 = Low-voltage series</td> </tr> </table> | 1 = Up to 8 MHz 2 = Up to 16 MHz 3 = Legacy 4 = Up to 16 MHz with LCD driver | 5 = Up to 25 MHz 6 = Up to 25 MHz with LCD driver 0 = Low-voltage series |
| 1 = Up to 8 MHz 2 = Up to 16 MHz 3 = Legacy 4 = Up to 16 MHz with LCD driver | 5 = Up to 25 MHz 6 = Up to 25 MHz with LCD driver 0 = Low-voltage series | | |
| Feature Set | Various levels of integration within a series | | |
| Optional: Revision | Updated version of the base part number | | |
| Optional: Temperature Range | S = 0°C to 50°C C = 0°C to 70°C I = -40°C to 85°C T = -40°C to 105°C | | |
| Packaging | http://www.ti.com/packaging | | |
| Optional: Tape and Reel | T = Small reel R = Large reel No markings = Tube or tray | | |
| Optional: Additional Features | -EP = Enhanced product (-40°C to 105°C) -HT = Extreme temperature parts (-55°C to 150°C) -Q1 = Automotive Q100 qualified | | |

图 10-1. Device Nomenclature

10.2 Documentation Support

The following documents describe the MSP430FG43x microcontrollers. Copies of these documents are available on the Internet at www.ti.com.

[MSP430x4xx Family User's Guide](#)

Detailed description of all modules and peripherals available in this device family.

[MSP430FG439 Microcontroller Errata](#)

Describes the known exceptions to the functional specifications for all silicon revisions of this device.

[MSP430FG438 Microcontroller Errata](#)

Describes the known exceptions to the functional specifications for all silicon revisions of this device.

[MSP430FG437 Microcontroller Errata](#)

Describes the known exceptions to the functional specifications for all silicon revisions of this device.

10.3 Support Resources

[TI E2E™ support forums](#) are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

[MSP Academy](#) is a starting point for all developers to learn about the MSP430 MCU Platform, which provides affordable solutions for many applications. MSP Academy delivers easy-to-use training modules that span a wide range of topics and LaunchPad development kits in the MSP430 MCU portfolio.

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10.4 Trademarks

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10.5 Electrostatic Discharge Caution



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.

10.6 术语表

[TI 术语表](#)

本术语表列出并解释了术语、首字母缩略词和定义。

11 Mechanical Packaging and Orderable Information

11.1 Packaging Information

The following pages include mechanical packaging and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

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 |
|------------------|---------------|--------------|-----------------|------|-------------|-----------------|--------------------------------------|----------------------|--------------|-------------------------|-------------------------|
| MSP430FG437IPN | ACTIVE | LQFP | PN | 80 | 119 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 85 | M430FG437 | Samples |
| MSP430FG437IPNR | ACTIVE | LQFP | PN | 80 | 1000 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 85 | M430FG437 | Samples |
| MSP430FG437IZCAR | ACTIVE | NFBGA | ZCA | 113 | 2500 | RoHS & Green | SNAGCU | Level-3-260C-168 HR | -40 to 85 | FG437 | Samples |
| MSP430FG437IZCAT | ACTIVE | NFBGA | ZCA | 113 | 250 | RoHS & Green | SNAGCU | Level-3-260C-168 HR | -40 to 85 | FG437 | Samples |
| MSP430FG438IPN | ACTIVE | LQFP | PN | 80 | 119 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 85 | M430FG438 | Samples |
| MSP430FG438IPNR | ACTIVE | LQFP | PN | 80 | 1000 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 85 | M430FG438 | Samples |
| MSP430FG438IZCAR | ACTIVE | NFBGA | ZCA | 113 | 2500 | RoHS & Green | SNAGCU | Level-3-260C-168 HR | -40 to 85 | FG438 | Samples |
| MSP430FG438IZCAT | ACTIVE | NFBGA | ZCA | 113 | 250 | RoHS & Green | SNAGCU | Level-3-260C-168 HR | -40 to 85 | FG438 | Samples |
| MSP430FG439IPN | ACTIVE | LQFP | PN | 80 | 119 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 85 | M430FG439 | Samples |
| MSP430FG439IPNR | ACTIVE | LQFP | PN | 80 | 1000 | RoHS & Green | NIPDAU | Level-3-260C-168 HR | -40 to 85 | M430FG439 | Samples |
| MSP430FG439IZCAR | ACTIVE | NFBGA | ZCA | 113 | 2500 | RoHS & Green | SNAGCU | Level-3-260C-168 HR | -40 to 85 | FG439 | Samples |
| MSP430FG439IZCAT | ACTIVE | NFBGA | ZCA | 113 | 250 | RoHS & Green | SNAGCU | Level-3-260C-168 HR | -40 to 85 | FG439 | 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".

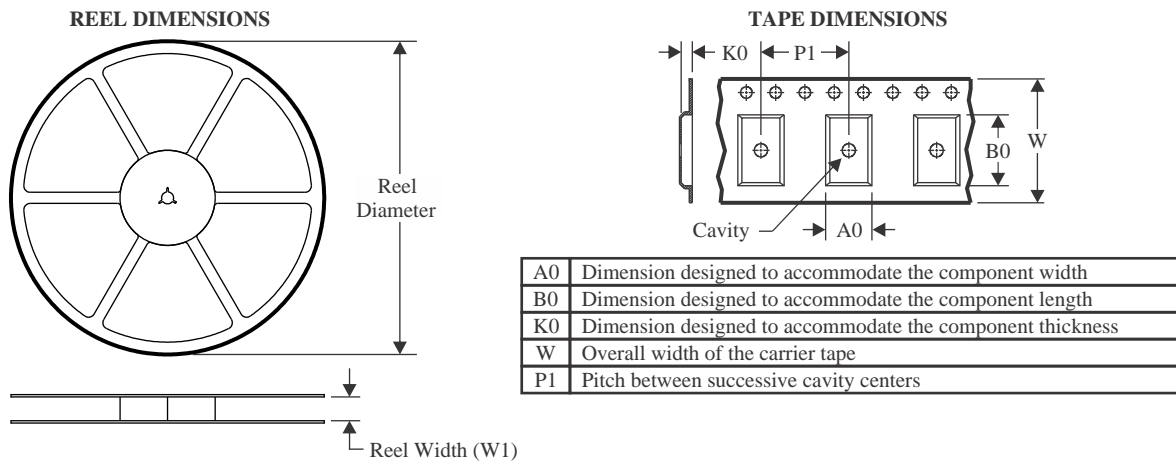
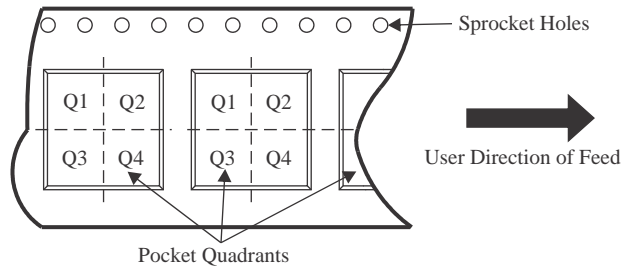
RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

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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TAPE AND REEL INFORMATION

QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE


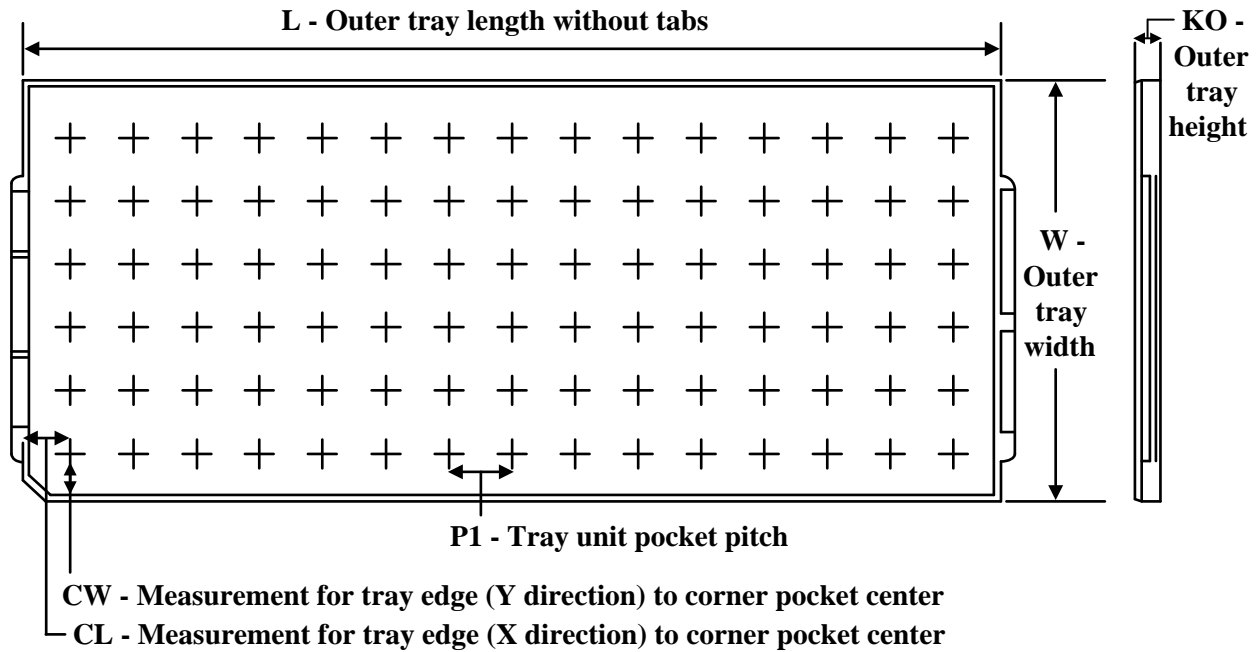
*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|------------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| MSP430FG437IPNR | LQFP | PN | 80 | 1000 | 330.0 | 24.4 | 15.0 | 15.0 | 2.1 | 20.0 | 24.0 | Q2 |
| MSP430FG437IZCAR | NFBGA | ZCA | 113 | 2500 | 330.0 | 16.4 | 7.3 | 7.3 | 1.5 | 12.0 | 16.0 | Q1 |
| MSP430FG438IPNR | LQFP | PN | 80 | 1000 | 330.0 | 24.4 | 15.0 | 15.0 | 2.1 | 20.0 | 24.0 | Q2 |
| MSP430FG439IPNR | LQFP | PN | 80 | 1000 | 330.0 | 24.4 | 15.0 | 15.0 | 2.1 | 20.0 | 24.0 | Q2 |
| MSP430FG439IZCAR | NFBGA | ZCA | 113 | 2500 | 330.0 | 16.4 | 7.3 | 7.3 | 1.5 | 12.0 | 16.0 | Q1 |
| MSP430FG439IZCAT | NFBGA | ZCA | 113 | 250 | 330.0 | 16.4 | 7.3 | 7.3 | 1.5 | 12.0 | 16.0 | Q1 |

TAPE AND REEL BOX DIMENSIONS


*All dimensions are nominal

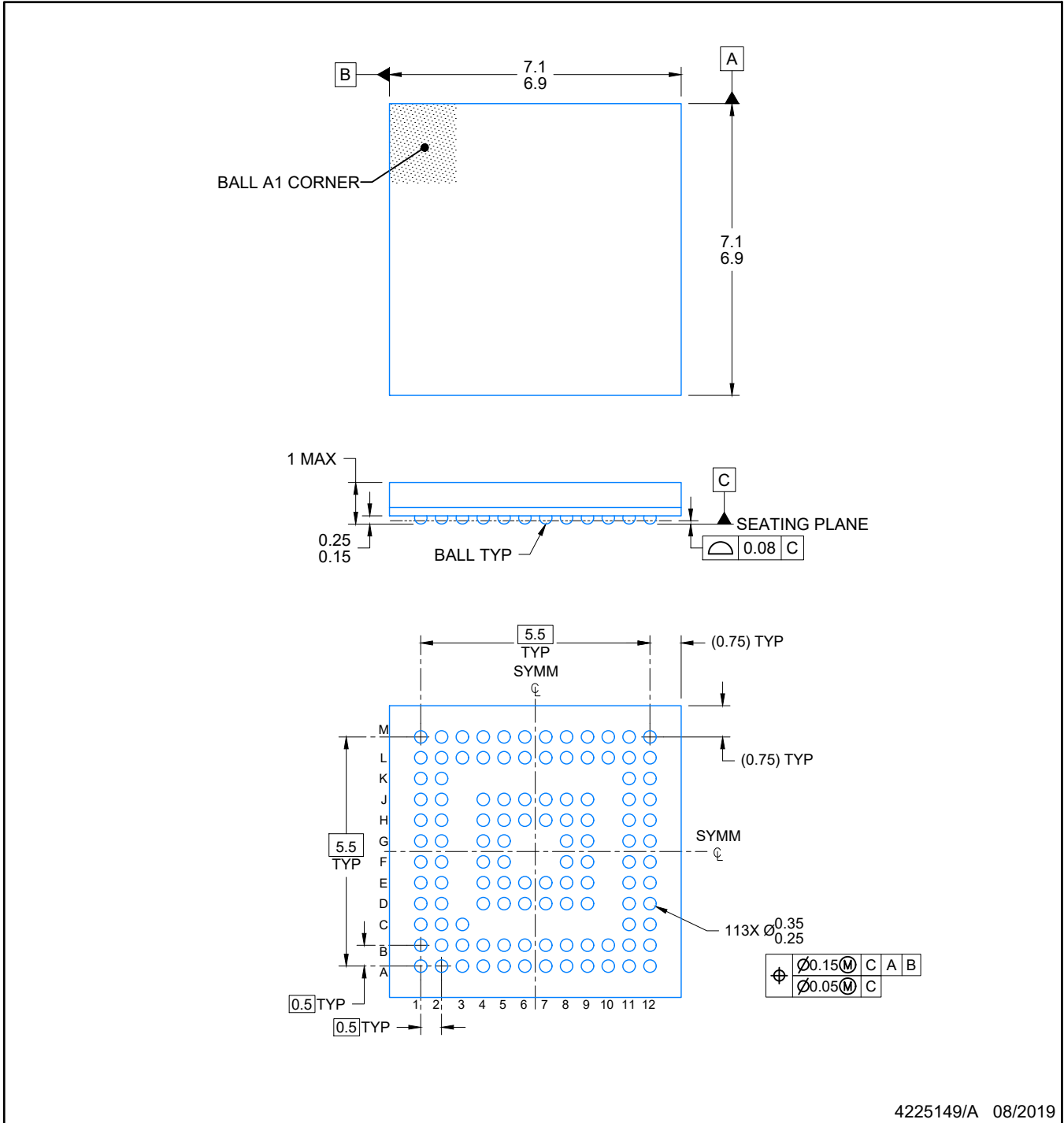
| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|------------------|--------------|-----------------|------|------|-------------|------------|-------------|
| MSP430FG437IPNR | LQFP | PN | 80 | 1000 | 367.0 | 367.0 | 45.0 |
| MSP430FG437IZCAR | NFBGA | ZCA | 113 | 2500 | 341.0 | 336.6 | 31.8 |
| MSP430FG438IPNR | LQFP | PN | 80 | 1000 | 367.0 | 367.0 | 45.0 |
| MSP430FG439IPNR | LQFP | PN | 80 | 1000 | 367.0 | 367.0 | 45.0 |
| MSP430FG439IZCAR | NFBGA | ZCA | 113 | 2500 | 341.0 | 336.6 | 31.8 |
| MSP430FG439IZCAT | NFBGA | ZCA | 113 | 250 | 341.0 | 336.6 | 31.8 |

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) |
|------------------|--------------|--------------|------|------|-------------------|----------------------|--------|--------|---------|---------|---------|---------|
| MSP430FG437IPN | PN | LQFP | 80 | 119 | 7x17 | 180 | 315 | 135.9 | 7620 | 17.9 | 14.3 | 13.95 |
| MSP430FG437IZCAR | ZCA | NFBGA | 113 | 2500 | 10 x 26 | 150 | 315 | 135.9 | 7620 | 11.8 | 10 | 10.35 |
| MSP430FG437IZCAT | ZCA | NFBGA | 113 | 250 | 10 x 26 | 150 | 315 | 135.9 | 7620 | 11.8 | 10 | 10.35 |
| MSP430FG438IPN | PN | LQFP | 80 | 119 | 7x17 | 180 | 315 | 135.9 | 7620 | 17.9 | 14.3 | 13.95 |
| MSP430FG438IZCAR | ZCA | NFBGA | 113 | 2500 | 10 x 26 | 150 | 315 | 135.9 | 7620 | 11.8 | 10 | 10.35 |
| MSP430FG438IZCAT | ZCA | NFBGA | 113 | 250 | 10 x 26 | 150 | 315 | 135.9 | 7620 | 11.8 | 10 | 10.35 |
| MSP430FG439IPN | PN | LQFP | 80 | 119 | 7x17 | 180 | 315 | 135.9 | 7620 | 17.9 | 14.3 | 13.95 |
| MSP430FG439IZCAR | ZCA | NFBGA | 113 | 2500 | 10 x 26 | 150 | 315 | 135.9 | 7620 | 11.8 | 10 | 10.35 |
| MSP430FG439IZCAT | ZCA | NFBGA | 113 | 250 | 10 x 26 | 150 | 315 | 135.9 | 7620 | 11.8 | 10 | 10.35 |

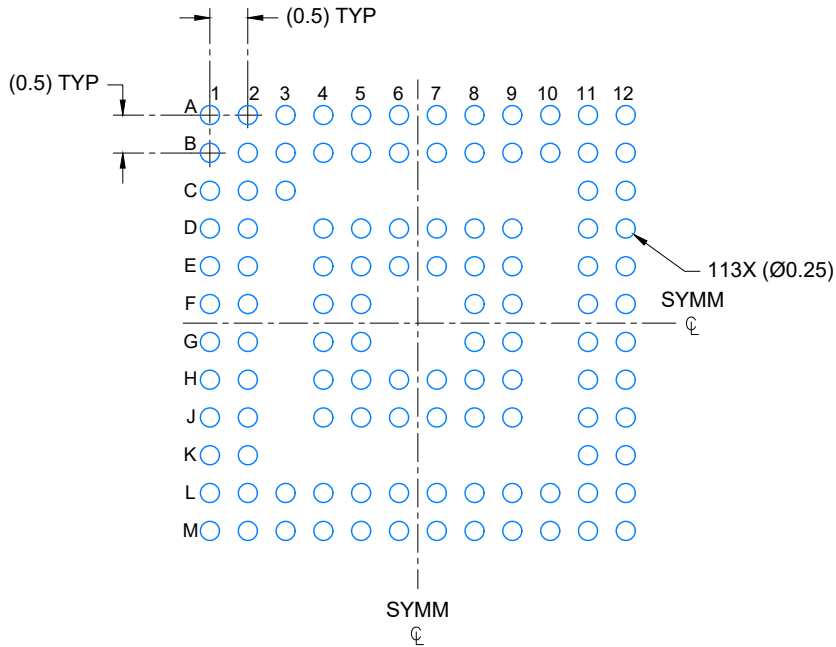


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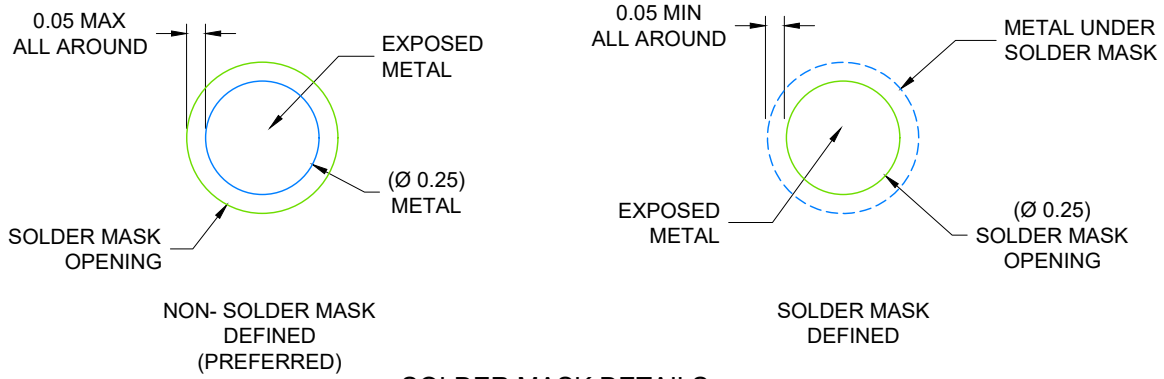
NOTES:

NanoFree is a trademark of Texas Instruments.

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.



LAND PATTERN EXAMPLE
SCALE: 10X



SOLDER MASK DETAILS
NOT TO SCALE

4225149/A 08/2019

NOTES: (continued)

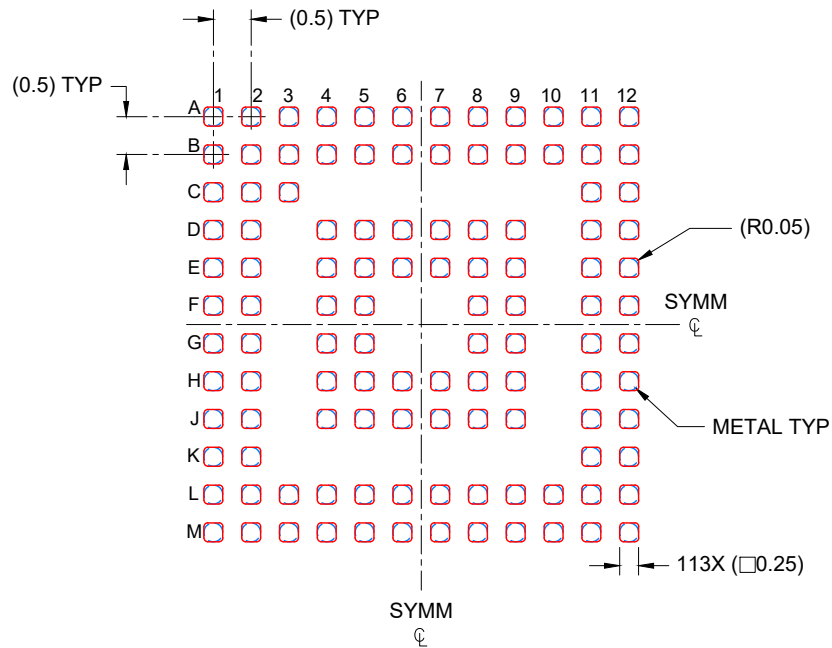
- Final dimensions may vary due to manufacturing tolerance considerations and also routing constraints. Refer to Texas Instruments Literature number SNVA009 (www.ti.com/lit/snva009).

EXAMPLE STENCIL DESIGN

ZCA0113A

NFBGA - 1 mm max height

PLASTIC BALL GRID ARRAY



SOLDER PASTE EXAMPLE
BASED ON 0.100 mm THICK STENCIL
SCALE: 10X

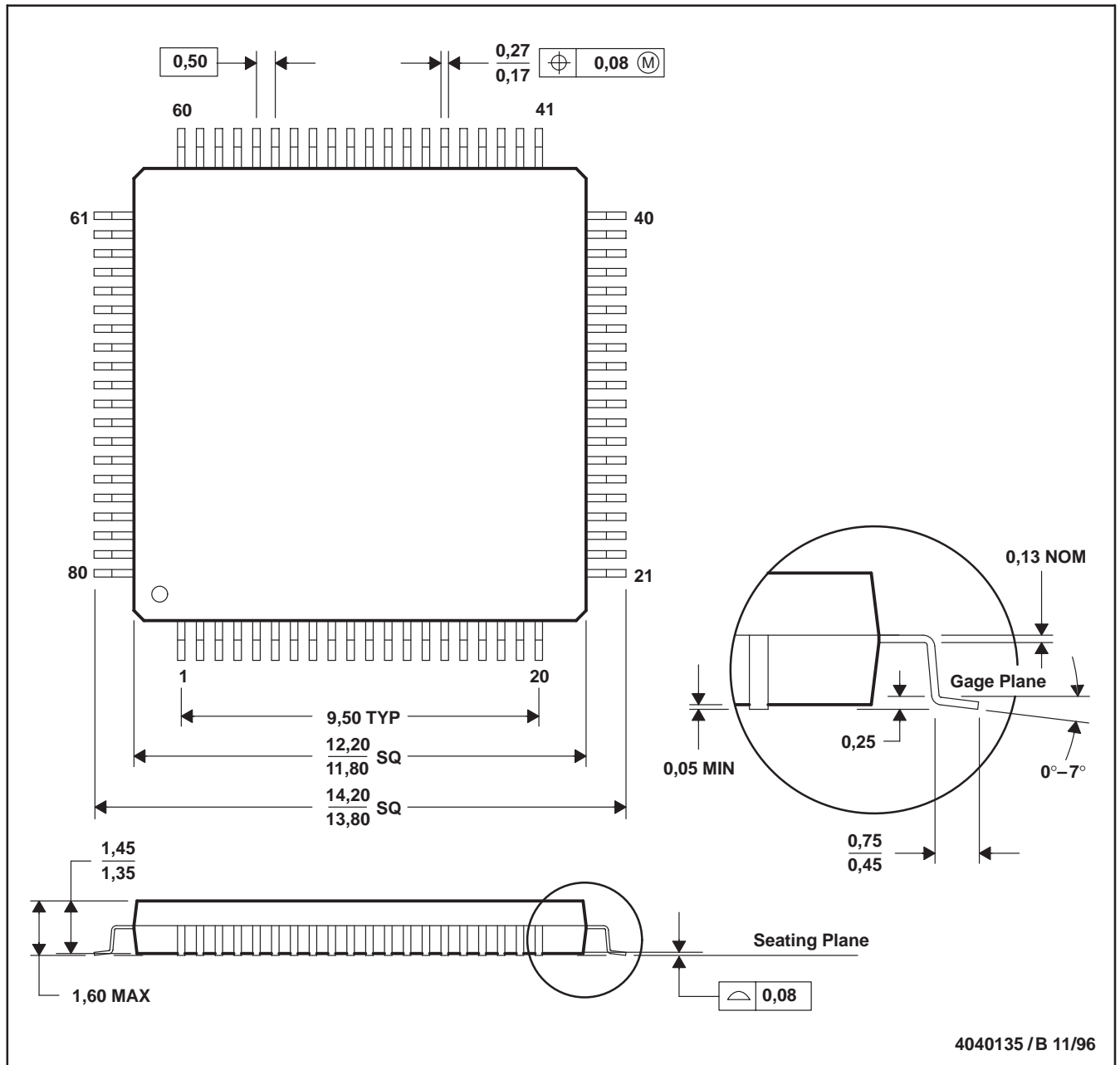
4225149/A 08/2019

NOTES: (continued)

4. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release.

PN (S-PQFP-G80)

PLASTIC QUAD FLATPACK



- NOTES: A. All linear dimensions are in millimeters.
 B. This drawing is subject to change without notice.
 C. Falls within JEDEC MS-026

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