MSP430FR600x Ultrasonic Sensing MSP430™ Microcontrollers for Water-Metering Applications

1 Features

- Best-in-class ultrasonic water-flow measurement with ultra-low power consumption
  - <100-ps differential time-of-flight (dTOF) accuracy
  - High-precision time measurement resolution of 20 ps
  - Ability to detect low flow rates (4-6 liters per hour)
  - Approximately 4-µA current consumption with one measurement per second
- Compliant to and exceeds ISO 4064, OIML R49, and EN 1434 accuracy standards
- Ability to directly interface standard ultrasonic sensors (up to 2.5 MHz)
- Integrated analog front end – ultrasonic sensing solution (USS)
  - Programmable pulse generation (PPG) to generate pulses at different frequencies
  - Integrated physical interface (PHY) with low-impedance (4-Ω) output driver to control input and output channels
  - High-performance high-speed 12-bit sigma-delta ADC (SDHS) with output data rates up to 8 Msps
  - Programmable gain amplifier (PGA) with –6.5 dB to 30.8 dB
  - High-performance phase-locked loop (PLL) with output range of 68 MHz to 80 MHz
- Low-energy accelerator (LEA)
  - Operation independent of CPU
  - 4KB of RAM shared with CPU
  - Efficient 256-point complex FFT: Up to 40× faster than Arm® Cortex®-M0+ core
- Embedded microcontroller
  - 16-bit RISC architecture up to 16-MHz clock
  - Wide supply voltage range from 3.6 V down to 1.8 V (minimum supply voltage is restricted by SVS levels, see the SVS specifications)
- Optimized ultra-low-power modes
  - Active mode: approximately 120 µA/MHz
  - Standby mode with real-time clock (RTC) (LPM3.5): 450 nA [1]
  - Shutdown (LPM4.5): 30 nA
- Ferroelectric random access memory (FRAM)
  - Up to 256KB of nonvolatile memory
  - Ultra-low-power writes
  - Fast write at 125 ns per word (64KB in 4 ms)
  - Unified memory = program + data + storage in one space
  - 10^{15} write cycle endurance
  - Radiation resistant and nonmagnetic
- Intelligent digital peripherals
  - 32-bit hardware multiplier (MPY)
  - 6-channel internal DMA
  - RTC with calendar and alarm functions
  - Six 16-bit timers with up to seven capture/compare registers each
  - 32-bit and 16-bit cyclic redundancy check (CRC)
- High-performance analog
  - 16-channel analog comparator
  - 12-bit SAR ADC featuring window comparator, internal reference, and sample-and-hold, up to 16 external input channels
  - Integrated LCD driver with contrast control for up to 264 segments
- Multifunction input/output ports
  - Accessible bit-, byte-, and word-wise (in pairs)
  - Edge-selectable wake from LPM on all ports
  - Programmable pullup and pulldown on all ports
- Code security and encryption
  - 128- or 256-bit AES security encryption and decryption coprocessor
  - Random number seed for random number generation algorithms
  - IP encapsulation protects memory from external access
  - FRAM provides inherent security advantages
- Enhanced serial communication
  - Up to four eUSCI_A serial communication ports
    - UART with automatic baud-rate detection
    - IrDA encode and decode
  - Up to two eUSCI_B serial communication ports
    - I^2C with multiple-slave addressing
  - Hardware UART or I^2C bootloader (BSL)

[1] The RTC is clocked by a 3.7-pF crystal.

- Flexible clock system
  - Fixed-frequency DCO with 10 selectable factory-trimmed frequencies
  - Low-power low-frequency internal clock source (VLO)
  - 32-kHz crystals (LFXT)
  - High-frequency crystals (HFXT)
- Development tools and software (also see Tools and Software)
  - Ultrasonic Sensing Design Center graphical user interface
  - Ultrasonic sensing software library
  - EVM430-FR6047 water meter evaluation module
  - MSP-TS430PZ100E target socket board for 100-pin package
  - Free professional development environments with EnergyTrace++ technology
  - MSP430Ware™ for MSP430™ microcontrollers
- Device Comparison summarizes the available device variants and package options

2 Applications

- Ultrasonic smart water meter
- Ultrasonic smart heat meter
- Liquid level sensing
- Water leak detector

3 Description

The Texas Instruments MSP430FR600x family of ultrasonic sensing and measurement SoCs are powerful, highly integrated microcontrollers (MCUs) that are optimized for water and heat meters. The MSP430FR600x MCUs offer an integrated ultrasonic sensing solution (USS) module, which provides high accuracy for a wide range of flow rates. The USS module helps achieve ultra-low-power metering combined with lower system cost due to maximum integration requiring very few external components. MSP430FR600x MCUs implement a high-speed ADC-based signal acquisition followed by optimized digital signal processing using the integrated low-energy accelerator (LEA) module to deliver a high-accuracy metering solution with ultra-low power optimum for battery-powered metering applications.

The USS module includes a programmable pulse generator (PPG) and a physical interface (PHY) with a low-impedance output driver for optimum sensor excitation to deliver best results for zero-flow drift (ZFD). The module also includes a programmable gain amplifier (PGA) and a high-speed 12-bit 8-Msps sigma-delta ADC (SDHS) for accurate signal acquisition from industry-standard ultrasonic transducers.

Additionally, MSP430FR600x MCUs integrate other peripherals to improve system integration for metering. The MSP430FR600x MCUs also have an on-chip 8-mux LCD driver, an RTC, a 12-bit SAR ADC, an analog comparator, an advanced encryption accelerator (AES256), and a cyclic redundancy check (CRC) module.

MSP430FR600x MCUs are supported by an extensive hardware and software ecosystem with reference designs and code examples to get your design started quickly. Development kits include the MSP-TS430PZ100E 100-pin target development board and EVM430-FR6047 ultrasonic water flow meter EVM. TI also provides free software including the ultrasonic sensing design center, ultrasonic sensing software library, and MSP430Ware™ software.

TI's MSP430 ultra-low-power (ULP) FRAM microcontroller platform combines uniquely embedded FRAM and a holistic ultra-low-power system architecture, letting system designers increase performance while lowering energy consumption. FRAM technology combines the low-energy fast writes, flexibility, and endurance of RAM with the nonvolatility of flash.

For complete module descriptions, see the *MSP430FR58xx, MSP430FR59xx, and MSP430FR6xx Family User's Guide*.

Device Information

PART NUMBER(1) (2)	PACKAGE	BODY SIZE(3)
MSP430FR6007IPZ MSP430FR6005IPZ	LQFP (100)	14 mm × 14 mm

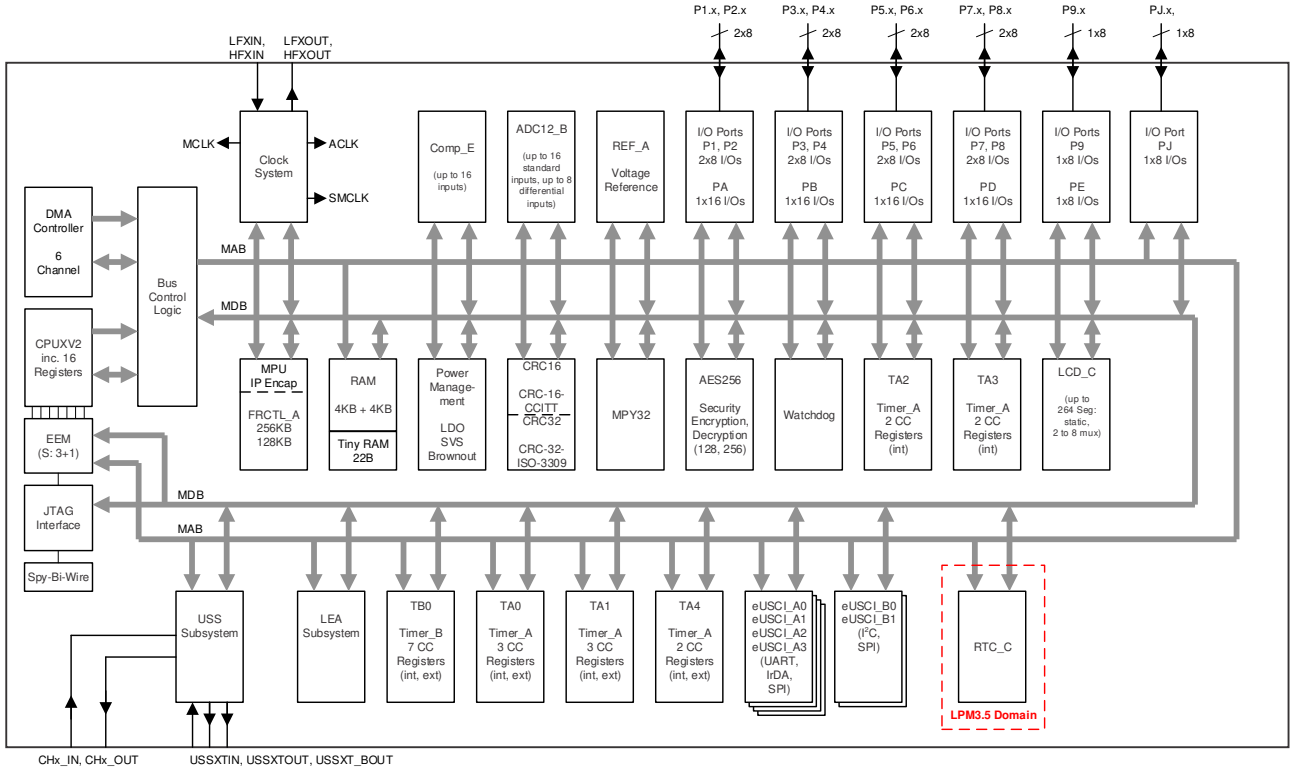
(1) For the most current part, package, and ordering information for all available devices, see the *Package Option Addendum* in Section 12, or see the TI website at www.ti.com.

(2) For a comparison of all available device variants, see Section 6.

(3) The sizes shown here are approximations. For the package dimensions with tolerances, see the *Mechanical Data* in Section 12.

4 Functional Block Diagram

Figure 4-1 show the functional block diagrams of the devices.



NOTE: The device has 8KB of RAM, and 4KB of the RAM is shared with the LEA subsystem.

Figure 4-1. MSP430FR600x Functional Block Diagram

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5 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from initial release to revision A

Changes from March 31, 2020 to December 1, 2020	Page
• Added the note that begins "XT1CLK and VLOCLK can be active during LPM4..." in Section 9.5, *Operating Modes*	69
• Added the INTERRUPT VECTOR REGISTER column, moved register names from the INTERRUPT FLAG column, and corrected interrupt flag names as necessary in Table 9-4, *Interrupt Sources, Flags, and Vectors*	72
• Corrected the table notes for Table 9-31, *Port P5 (P5.0 to P5.7) Pin Functions*	105
• Corrected the address range for "Main: interrupt vectors" in Table 9-45, *Memory Organization*	134

6 Device Comparison

Table 6-1 summarizes the available family members.

Table 6-1. Device Comparison

DEVICE(1) (2)	FRAM (KB)	SRAM (KB)	CLOCK SYSTEM	LEA	USS USSXT	ADC12_B (Channels)	Comp_E (Channels)	Timer_A(3)	Timer_B(4)	eUSCI_A(5)	eUSCI_B(6)	AES	BSL	I/Os	PACKAGE
MSP430FR6007	256	8	DCO **HFXT** **LFXT**	Yes	Yes	16 external, 2 internal	16	3, 3(7) 2, 2,2(8)	7	4	2	Yes	UART	76	100 PZ (LQFP)
MSP430FR6005	128	8	DCO **HFXT** **LFXT**	Yes	Yes	16 external, 2 internal	16	3, 3(7) 2, 2,2(8)	7	4	2	Yes	UART	76	100 PZ (LQFP)

(1) For the most current package and ordering information, see the *Package Option Addendum* in Section 12, or see the TI website 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 three capture/compare registers and PWM output generators and the second instantiation having five 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 three capture/compare registers and PWM output generators and the second instantiation having five capture/compare registers and PWM output generators, respectively.

(5) eUSCI_A supports UART with automatic baud-rate detection, IrDA encode and decode, and SPI.

(6) eUSCI_B supports I^2C with multiple slave addresses and SPI.

(7) Timers TA0 and TA1 provide internal and external capture/compare inputs and internal and external PWM outputs.

(8) Timers TA2 and TA3 provide only internal capture/compare inputs and only internal PWM outputs (if any) whereas Timer TA4 provides internal, external capture/compare inputs and internal, external PWM outputs.

6.1 Related Products

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

TI 16-bit and 32-bit microcontrollers

High-performance, low-power solutions to enable the autonomous future

Products for MSP430 ultra-low-power sensing & measurement microcontrollers

One platform. One ecosystem. Endless possibilities.

Companion products for MSP430FR6007

Review products that are frequently purchased or used with this product.

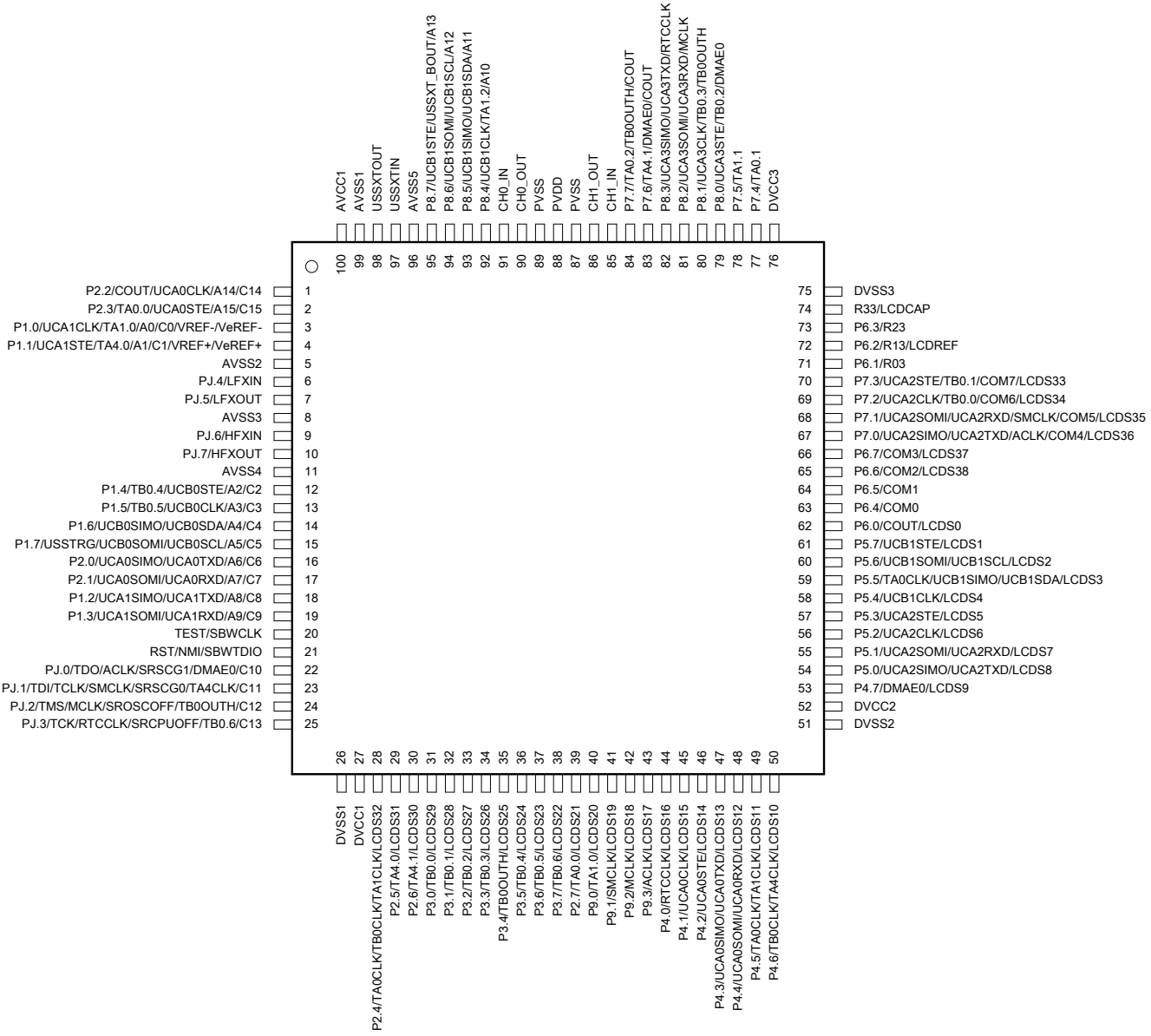
Reference designs for MSP430FR6007

Find reference designs leveraging the best in TI technology – from analog and power management to embedded processors.

7 Terminal Configuration and Functions

7.1 Pin Diagram

Figure 7-1 and Figure 7-1 show the pinouts of the 100-pin PZ packages.



On devices with UART BSL: P2.0 is BSLTX, P2.1 is BSLRX
On devices with I²C BSL: P1.6 is BSLSDA, P1.7 is BSLSCL

Figure 7-1. MSP430FR600x 100-Pin PZ Package (Top View)

7.2 Pin Attributes

Table 7-1 lists the attributes of each pin.

Table 7-1. Pin Attributes

PIN NUMBER	SIGNAL NAME[1] [4]	SIGNAL TYPE[2]	BUFFER TYPE[3]	POWER SOURCE[5]	RESET STATE AFTER BOR[7]
1	P2.2	I/O	LVCMOS	DVCC	OFF
	COUT	O	LVCMOS	DVCC	–
	UCA0CLK	I/O	LVCMOS	DVCC	–
	A14	I	Analog	DVCC	–
	C14	I	Analog	DVCC	–
2	P2.3	I/O	LVCMOS	DVCC	OFF
	TA0.0	I/O	LVCMOS	DVCC	–
	UCA0STE	I/O	LVCMOS	DVCC	–
	A15	I	Analog	DVCC	–
	C15	I	Analog	DVCC	–
3	P1.0	I/O	LVCMOS	DVCC	OFF
	UCA1CLK	I/O	LVCMOS	DVCC	–
	TA1.0	I/O	LVCMOS	DVCC	–
	A0	I	Analog	DVCC	–
	C0	I	Analog	DVCC	–
	VREF-	O	Analog	DVCC	–
	VeREF-	I	Analog	DVCC	–
4	P1.1	I/O	LVCMOS	DVCC	OFF
	UCA1STE	I/O	LVCMOS	DVCC	–
	TA4.0	I/O	LVCMOS	DVCC	–
	A1	I	Analog	DVCC	–
	C1	I	Analog	DVCC	–
	VREF+	O	Analog	DVCC	–
	VeREF+	I	Analog	DVCC	–
5	AVSS2	P	Power	–	N/A
6	PJ.4	I/O	LVCMOS	DVCC	OFF
	LFXIN	I	Analog	DVCC	–
7	PJ.5	I/O	LVCMOS	DVCC	OFF
	LFXOUT	O	Analog	DVCC	–
8	AVSS3	P	Power	–	N/A
9	PJ.6	I/O	LVCMOS	DVCC	–
	HFXIN	I	Analog	DVCC	–
10	PJ.7	I/O	LVCMOS	DVCC	OFF
	HFXOUT	O	Analog	DVCC	–
11	AVSS4	P	Power	–	N/A
12	P1.4	I/O	LVCMOS	DVCC	OFF
	TB0.4	I/O	LVCMOS	DVCC	–
	UCB0STE	I/O	LVCMOS	DVCC	–
	A2	I	Analog	DVCC	–
	C2	I	Analog	DVCC	–

Table 7-1. Pin Attributes (continued)

PIN NUMBER	SIGNAL NAME[1] [4]	SIGNAL TYPE[2]	BUFFER TYPE[3]	POWER SOURCE[5]	RESET STATE AFTER BOR[7]
13	P1.5	I/O	LVCMOS	DVCC	OFF
	TB0.5	I/O	LVCMOS	DVCC	–
	UCB0CLK	I/O	LVCMOS	DVCC	–
	A3	I	Analog	DVCC	–
	C3	I	Analog	DVCC	–
14	P1.6	I/O	LVCMOS	DVCC	OFF
	UCB0SIMO	I/O	LVCMOS	DVCC	–
	UCB0SDA	I/O	LVCMOS	DVCC	–
	A4	I	Analog	DVCC	–
	C4	I	Analog	DVCC	–
15	P1.7	I/O	LVCMOS	DVCC	OFF
	USSTRG	I	LVCMOS	DVCC	–
	UCB0SOMI	I/O	LVCMOS	DVCC	–
	UCB0SCL	I/O	LVCMOS	DVCC	–
	A5	I	Analog	DVCC	–
	C5	I	Analog	DVCC	–
16	P2.0	I/O	LVCMOS	DVCC	OFF
	UCA0TXD	O	LVCMOS	DVCC	–
	UCA0SIMO	I/O	LVCMOS	DVCC	–
	A6	I	Analog	DVCC	–
	C6	I	Analog	DVCC	–
17	P2.1	I/O	LVCMOS	DVCC	OFF
	UCA0RXD	I	LVCMOS	DVCC	–
	UCA0SOMI	I/O	LVCMOS	DVCC	–
	A7	I	Analog	DVCC	–
	C7	I	Analog	DVCC	–
18	P1.2	I/O	LVCMOS	DVCC	OFF
	UCA1TXD	O	LVCMOS	DVCC	–
	UCA1SIMO	I/O	LVCMOS	DVCC	–
	A8	I	Analog	DVCC	–
	C8	I	Analog	DVCC	–
19	P1.3	I/O	LVCMOS	DVCC	OFF
	UCA1RXD	I	LVCMOS	DVCC	–
	UCA1SOMI	I/O	LVCMOS	DVCC	–
	A9	I	Analog	DVCC	–
	C9	I	Analog	DVCC	–
20	TEST	I	LVCMOS	DVCC	PD
	SBWTCK	I	LVCMOS	DVCC	–
21	$\overline{\text{RST}}$	I/O	LVCMOS	DVCC	PU
	NMI	I	LVCMOS	DVCC	–
	SBWTDIO	I/O	LVCMOS	DVCC	–

Table 7-1. Pin Attributes (continued)

PIN NUMBER	SIGNAL NAME[1] [4]	SIGNAL TYPE[2]	BUFFER TYPE[3]	POWER SOURCE[5]	RESET STATE AFTER BOR[7]
22	PJ.0	I/O	LVCMOS	DVCC	OFF
	TDO	O	LVCMOS	DVCC	–
	ACLK	O	LVCMOS	DVCC	–
	SRSCG1	O	LVCMOS	DVCC	–
	DMAE0	I	LVCMOS	DVCC	–
	C10	I	Analog	DVCC	–
23	PJ.1	I/O	LVCMOS	DVCC	OFF
	TDI	I	LVCMOS	DVCC	–
	TCLK	I	LVCMOS	DVCC	–
	SMCLK	O	LVCMOS	DVCC	–
	SRSCG0	O	LVCMOS	DVCC	–
	TA4CLK	I	LVCMOS	DVCC	–
	C11	I	Analog	DVCC	–
24	PJ.2	I/O	LVCMOS	DVCC	OFF
	TMS	I	LVCMOS	DVCC	–
	MCLK	O	LVCMOS	DVCC	–
	SROSCOFF	O	LVCMOS	DVCC	–
	TB0OUTH	I	LVCMOS	DVCC	–
	C12	I	Analog	DVCC	–
25	PJ.3	I/O	LVCMOS	DVCC	OFF
	TCK	I	LVCMOS	DVCC	–
	RTCCLK	O	LVCMOS	DVCC	–
	SRCPUOFF	O	LVCMOS	DVCC	–
	TB0.6	I/O	LVCMOS	DVCC	–
	C13	I	Analog	DVCC	–
26	DVSS1	P	Power	–	N/A
27	DVCC1	P	Power	–	N/A
28	P2.4	I/O	LVCMOS	DVCC	OFF
	TA0CLK	I	LVCMOS	DVCC	–
	TB0CLK	I	LVCMOS	DVCC	–
	TA1CLK	I	LVCMOS	DVCC	–
	S32	O	Analog	DVCC	–
29	P2.5	I/O	LVCMOS	DVCC	OFF
	TA4.0	I/O	LVCMOS	DVCC	–
	S31	O	Analog	DVCC	–
30	P2.6	I/O	LVCMOS	DVCC	OFF
	TA4.1	I/O	LVCMOS	DVCC	–
	S30	O	Analog	DVCC	–
31	P3.0	I/O	LVCMOS	DVCC	OFF
	TB0.0	I/O	LVCMOS	DVCC	–
	S29	O	Analog	DVCC	–
32	P3.1	I/O	LVCMOS	DVCC	OFF
	TB0.1	O	LVCMOS	DVCC	–
	S28	O	Analog	DVCC	–

Table 7-1. Pin Attributes (continued)

PIN NUMBER	SIGNAL NAME[1] [4]	SIGNAL TYPE[2]	BUFFER TYPE[3]	POWER SOURCE[5]	RESET STATE AFTER BOR[7]
33	P3.2	I/O	LVCMOS	DVCC	OFF
	TB0.2	O	LVCMOS	DVCC	–
	S27	O	Analog	DVCC	–
34	P3.3	I/O	LVCMOS	DVCC	OFF
	TB0.3	I/O	LVCMOS	DVCC	–
	S26	O	Analog	DVCC	–
35	P3.4	I/O	LVCMOS	DVCC	OFF
	TB0OUTH	I	LVCMOS	DVCC	–
	S25	O	Analog	DVCC	–
36	P3.5	I/O	LVCMOS	DVCC	OFF
	TB0.4	I/O	LVCMOS	DVCC	–
	S24	O	Analog	DVCC	–
37	P3.6	I/O	LVCMOS	DVCC	OFF
	TB0.5	I/O	LVCMOS	DVCC	–
	S23	O	Analog	DVCC	–
38	P3.7	I/O	LVCMOS	DVCC	OFF
	TB0.6	I/O	LVCMOS	DVCC	–
	S22	O	Analog	DVCC	–
39	P2.7	I/O	LVCMOS	DVCC	OFF
	TA0.0	I/O	LVCMOS	DVCC	–
	S21	O	Analog	DVCC	–
40	P9.0	I/O	LVCMOS	DVCC	OFF
	TA1.0	I/O	LVCMOS	DVCC	–
	S20	O	Analog	DVCC	–
41	P9.1	I/O	LVCMOS	DVCC	OFF
	SMCLK	O	LVCMOS	DVCC	–
	S19	O	Analog	DVCC	–
42	P9.2	I/O	LVCMOS	DVCC	OFF
	MCLK	O	LVCMOS	DVCC	–
	S18	O	Analog	DVCC	–
43	P9.3	I/O	LVCMOS	DVCC	OFF
	ACLK	O	LVCMOS	DVCC	–
	S17	O	Analog	DVCC	–
44	P4.0	I/O	LVCMOS	DVCC	OFF
	RTCCLK	O	LVCMOS	DVCC	–
	S16	O	Analog	DVCC	–
45	P4.1	I/O	LVCMOS	DVCC	OFF
	UCA0CLK	I/O	LVCMOS	DVCC	–
	S15	O	Analog	DVCC	–
46	P4.2	I/O	LVCMOS	DVCC	OFF
	UCA0STE	I/O	LVCMOS	DVCC	–
	S14	O	Analog	DVCC	–

Table 7-1. Pin Attributes (continued)

PIN NUMBER	SIGNAL NAME[1] [4]	SIGNAL TYPE[2]	BUFFER TYPE[3]	POWER SOURCE[5]	RESET STATE AFTER BOR[7]
47	P4.3	I/O	LVCMOS	DVCC	OFF
	UCA0TXD	O	LVCMOS	DVCC	–
	UCA0SIMO	I/O	LVCMOS	DVCC	–
	S13	O	Analog	DVCC	–
48	P4.4	I/O	LVCMOS	DVCC	OFF
	UCA0RXD	I	LVCMOS	DVCC	–
	UCA0SOMI	I/O	LVCMOS	DVCC	–
	S12	O	Analog	DVCC	–
49	P4.5	I/O	LVCMOS	DVCC	OFF
	TA0CLK	I	LVCMOS	DVCC	–
	TA1CLK	I	LVCMOS	DVCC	–
	S11	O	Analog	DVCC	–
50	P4.6	I/O	LVCMOS	DVCC	OFF
	TB0CLK	I	LVCMOS	DVCC	–
	TA4CLK	I	LVCMOS	DVCC	–
	S10	O	Analog	DVCC	–
51	DVSS2	P	Power	–	N/A
52	DVCC2	P	Power	–	N/A
53	P4.7	I/O	LVCMOS	DVCC	OFF
	DMAE0	I	LVCMOS	DVCC	–
	S9	O	Analog	DVCC	–
54	P5.0	I/O	LVCMOS	DVCC	OFF
	UCA2TXD	O	LVCMOS	DVCC	–
	UCA2SIMO	I/O	LVCMOS	DVCC	–
	S8	O	Analog	DVCC	–
55	P5.1	I/O	LVCMOS	DVCC	OFF
	UCA2RXD	I	LVCMOS	DVCC	–
	UCA2SOMI	I/O	LVCMOS	DVCC	–
	S7	O	Analog	DVCC	–
56	P5.2	I/O	LVCMOS	DVCC	OFF
	UCA2CLK	I/O	LVCMOS	DVCC	–
	S6	O	Analog	DVCC	–
57	P5.3	I/O	LVCMOS	DVCC	OFF
	UCA2STE	I/O	LVCMOS	DVCC	–
	S5	O	Analog	DVCC	–
58	P5.4	I/O	LVCMOS	DVCC	OFF
	UCB1CLK	I/O	LVCMOS	DVCC	–
	S4	O	Analog	DVCC	–
59	P5.5	I/O	LVCMOS	DVCC	OFF
	TA0CLK	I	LVCMOS	DVCC	–
	UCB1SIMO	I/O	LVCMOS	DVCC	–
	UCB1SDA	I/O	LVCMOS	DVCC	–
	S3	O	Analog	DVCC	–

Table 7-1. Pin Attributes (continued)

PIN NUMBER	SIGNAL NAME[1] [4]	SIGNAL TYPE[2]	BUFFER TYPE[3]	POWER SOURCE[5]	RESET STATE AFTER BOR[7]
60	P5.6	I/O	LVCMOS	DVCC	OFF
	UCB1SOMI	I/O	LVCMOS	DVCC	–
	UCB1SCL	I/O	LVCMOS	DVCC	–
	S2	O	Analog	DVCC	–
61	P5.7	I/O	LVCMOS	DVCC	OFF
	UCB1STE	I/O	LVCMOS	DVCC	–
	S1	O	Analog	DVCC	–
62	P6.0	I/O	LVCMOS	DVCC	OFF
	COUT	I	LVCMOS	DVCC	–
	S0	O	Analog	DVCC	–
63	P6.4	I/O	LVCMOS	DVCC	OFF
	COM0	O	Analog	DVCC	–
64	P6.5	I/O	LVCMOS	DVCC	OFF
	COM1	O	Analog	DVCC	–
65	P6.6	I/O	LVCMOS	DVCC	OFF
	COM2	O	Analog	DVCC	–
	S38	O	Analog	DVCC	–
66	P6.7	I/O	LVCMOS	DVCC	OFF
	COM3	O	Analog	DVCC	–
	S37	O	Analog	DVCC	–
67	P7.0	I/O	LVCMOS	DVCC	OFF
	UCA2TXD	O	LVCMOS	DVCC	–
	UCA2SIMO	I/O	LVCMOS	DVCC	–
	ACLK	O	LVCMOS	DVCC	–
	COM4	O	Analog	DVCC	–
	S36	O	Analog	DVCC	–
68	P7.1	I/O	LVCMOS	DVCC	OFF
	UCA2RXD	I	LVCMOS	DVCC	–
	UCA2SOMI	I/O	LVCMOS	DVCC	–
	SMCLK	O	LVCMOS	DVCC	–
	COM5	O	Analog	DVCC	–
	S35	O	Analog	DVCC	–
69	P7.2	I/O	LVCMOS	DVCC	OFF
	UCA2CLK	I/O	LVCMOS	DVCC	–
	TB0.0	I/O	LVCMOS	DVCC	–
	COM6	O	Analog	DVCC	–
	S34	O	Analog	DVCC	–
70	P7.3	I/O	LVCMOS	DVCC	OFF
	UCA2STE	I/O	LVCMOS	DVCC	–
	TB0.1	I/O	LVCMOS	DVCC	–
	COM7	O	Analog	DVCC	–
	S33	O	Analog	DVCC	–
71	P6.1	I/O	LVCMOS	DVCC	OFF
	R03	I/O	Analog	DVCC	–

Table 7-1. Pin Attributes (continued)

PIN NUMBER	SIGNAL NAME[1] [4]	SIGNAL TYPE[2]	BUFFER TYPE[3]	POWER SOURCE[5]	RESET STATE AFTER BOR[7]
72	P6.2	I/O	LVCMOS	DVCC	OFF
	R13	I/O	Analog	DVCC	–
	LCDREF	I	Analog	-	–
73	P6.3	I/O	LVCMOS	DVCC	OFF
	R23	I/O	Analog	DVCC	–
74	R33	I/O	Analog	DVCC	-
	LCDCAP	I/O	Analog	DVCC	–
75	DVSS3	P	Power	–	N/A
76	DVCC3	P	Power	–	N/A
77	P7.4	I/O	LVCMOS	DVCC	OFF
	TA0.1	I/O	LVCMOS	DVCC	–
78	P7.5	I/O	LVCMOS	DVCC	OFF
	TA1.1	I/O	LVCMOS	DVCC	–
79	P8.0	I/O	LVCMOS	DVCC	OFF
	UCA3STE	I/O	LVCMOS	DVCC	–
	TB0.2	I/O	LVCMOS	DVCC	–
	DMAE0	I	LVCMOS	DVCC	–
80	P8.1	I/O	LVCMOS	DVCC	OFF
	UCA3CLK	I/O	LVCMOS	DVCC	–
	TB0.3	I/O	LVCMOS	DVCC	–
	TB0OUTH	I	LVCMOS	DVCC	–
81	P8.2	I/O	LVCMOS	DVCC	OFF
	UCA3RXD	O	LVCMOS	DVCC	–
	UCA3SOMI	I/O	LVCMOS	DVCC	–
	MCLK	O	LVCMOS	DVCC	–
82	P8.3	I/O	LVCMOS	DVCC	OFF
	UCA3TXD	O	LVCMOS	DVCC	–
	UCA3SIMO	I/O	LVCMOS	DVCC	–
	RTCCLK	O	LVCMOS	DVCC	–
83	P7.6	I/O	LVCMOS	DVCC	OFF
	TA4.1	I/O	LVCMOS	DVCC	–
	DMAE0	I	LVCMOS	DVCC	–
	COUT	O	LVCMOS	DVCC	–
84	P7.7	I/O	LVCMOS	DVCC	OFF
	TA0.2	I/O	LVCMOS	DVCC	–
	TB0OUTH	I	LVCMOS	DVCC	–
	COUT	O	LVCMOS	DVCC	–
85	CH1_IN	I	Analog	PVCC	–
86	CH1_OUT	O	Analog	PVCC	–
87	PVSS	P	Power	–	N/A
88	PVCC	P	Power	–	N/A
89	PVSS	P	Power	–	N/A
90	CH0_OUT	O	Analog	PVCC	–
91	CH0_IN	I	Analog	PVCC	–

Table 7-1. Pin Attributes (continued)

PIN NUMBER	SIGNAL NAME[1] [4]	SIGNAL TYPE[2]	BUFFER TYPE[3]	POWER SOURCE[5]	RESET STATE AFTER BOR[7]
92	P8.4	I/O	LVCMOS	DVCC	OFF
	UCB1CLK	I/O	LVCMOS	DVCC	–
	TA1.2	I/O	LVCMOS	DVCC	–
	A10	I	Analog	DVCC	–
93	P8.5	I/O	LVCMOS	DVCC	OFF
	UCB1SIMO	I/O	LVCMOS	DVCC	–
	UCB1SDA	I/O	LVCMOS	DVCC	–
	A11	I	Analog	DVCC	–
94	P8.6	I/O	LVCMOS	DVCC	OFF
	UCB1SOMI	I/O	LVCMOS	DVCC	–
	UCB1SCL	I/O	LVCMOS	DVCC	–
	A12	I	Analog	DVCC	–
95	P8.7	I/O	LVCMOS	DVCC	OFF
	UCB1STE	I/O	LVCMOS	DVCC	–
	USSXT_BOUT	I/O	LVCMOS	DVCC	–
	A13	I	Analog	DVCC	–
96	AVSS5	P	Power	–	N/A
97	USSXTIN[6]	I	Analog	1.5 V	–
98	USSXTOUT[6]	O	Analog	1.5 V	–
99	AVSS1	P	Power	–	N/A
100	AVCC1	P	Power	–	N/A

(1) The signal that is listed first for each pin is the reset default pin name.
(2) Signal Types: I = Input, O = Output, I/O = Input or Output.
(3) Buffer Types: LVCMOS, Analog, or Power (see Table 7-3 for details)
(4) To determine the pin mux encodings for each pin, see Section 9.14.
(5) The power source shown in this table is the I/O power source, which may differ from the module power source.
(6) Do not connect USSXTIN and USSXTOUT pins to AVCC nor to DVCC. USSXTIN does not support bypass mode, so do not drive an external clock on the USSXTIN pin.
(7) Reset States:
OFF = High impedance with Schmitt-trigger input and pullup or pulldown (if available) disabled
PU = Pullup is enabled
PD = Pulldown is enabled
N/A = Not applicable

7.3 Signal Descriptions

Table 7-2 describes the signals.

Table 7-2. Signal Descriptions

FUNCTION	SIGNAL NAME	PIN NO.	PIN TYPE[1]	DESCRIPTION
		PZ		
ADC	A0	3	I	ADC analog input A0
	A1	4	I	ADC analog input A1
	A2	12	I	ADC analog input A2
	A3	13	I	ADC analog input A3
	A4	14	I	ADC analog input A4
	A5	15	I	ADC analog input A5
	A6	16	I	ADC analog input A6
	A7	17	I	ADC analog input A7
	A8	18	I	ADC analog input A8
	A9	19	I	ADC analog input A9
	A10	92	I	ADC analog input A10
	A11	93	I	ADC analog input A11
	A12	94	I	ADC analog input A12
	A13	95	I	ADC analog input A13
	A14	1	I	ADC analog input A14
	A15	2	I	ADC analog input A15
	VREF+	4	O	Output of positive reference voltage
	VREF-	3	O	Output of negative reference voltage
	VeREF+	4	I	Input for an external positive reference voltage to the ADC
	VeREF-	3	I	Input for an external negative reference voltage to the ADC
Clock	ACLK	22, 43, 67	O	ACLK output
	HFXIN	9	I	Input for high-frequency crystal oscillator HFXT
	HFXOUT	10	O	Output for high-frequency crystal oscillator HFXT
	LFXIN	6	I	Input for low-frequency crystal oscillator LFXT
	LFXOUT	7	O	Output of low-frequency crystal oscillator LFXT
	MCLK	24, 42, 81	O	MCLK output
	SMCLK	23, 41, 68	O	SMCLK output

Table 7-2. Signal Descriptions (continued)

FUNCTION	SIGNAL NAME	PIN NO.	PIN TYPE[1]	DESCRIPTION
		PZ		
Comparator	C0	3	I	Comparator input C0
	C1	4	I	Comparator input C1
	C2	12	I	Comparator input C2
	C3	13	I	Comparator input C3
	C4	14	I	Comparator input C4
	C5	15	I	Comparator input C5
	C6	16	I	Comparator input C6
	C7	17	I	Comparator input C7
	C8	18	I	Comparator input C8
	C9	19	I	Comparator input C9
	C10	22	I	Comparator input C10
	C11	23	I	Comparator input C11
	C12	24	I	Comparator input C12
	C13	25	I	Comparator input C13
	C14	1	I	Comparator input C14
	C15	2	I	Comparator input C15
	COUT	1, 83, 84	O	Comparator output
DMA	DMAE0	22, 79, 83	I	External DMA trigger
Debug	SBWTCK	20	I	Spy-Bi-Wire input clock
	SBWTDIO	21	I/O	Spy-Bi-Wire data input/output
	SRCPUOFF	25	O	Low-power debug: CPU Status register bit CPUOFF
	SROSCOFF	24	O	Low-power debug: CPU Status register bit OSCOFF
	SRSCG0	23	O	Low-power debug: CPU Status register bit SCG0
	SRSCG1	22	O	Low-power debug: CPU Status register bit SCG1
	TCK	25	I	Test clock
	TCLK	23	I	Test clock input
	TDI	23	I	Test data input
	TDO	22	O	Test data output port
	TEST	20	I	Test mode pin, selects digital I/O on JTAG pins
	TMS	24	I	Test mode select
GPIO Port 1	P1.0	3	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P1.1	4	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P1.2	18	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P1.3	19	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P1.4	12	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P1.5	13	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P1.6	14	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P1.7	15	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5

Table 7-2. Signal Descriptions (continued)

FUNCTION	SIGNAL NAME	PIN NO.	PIN TYPE[1]	DESCRIPTION
		PZ		
GPIO Port 2	P2.0	16	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P2.1	17	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P2.2	1	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P2.3	2	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P2.4	28	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P2.5	29	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P2.6	30	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P2.7	39	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
GPIO Port 3	P3.0	31	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P3.1	32	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P3.2	33	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P3.3	34	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P3.4	35	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P3.5	36	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P3.6	37	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P3.7	38	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
GPIO Port 4	P4.0	44	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P4.1	45	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P4.2	46	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P4.3	47	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P4.4	48	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P4.5	49	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P4.6	50	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P4.7	53	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
GPIO Port 5	P5.0	54	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P5.1	55	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P5.2	56	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P5.3	57	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P5.4	58	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P5.5	59	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P5.6	60	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P5.7	61	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
GPIO Port 6	P6.0	62	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P6.1	71	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P6.2	72	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P6.3	73	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P6.4	63	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P6.5	64	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P6.6	65	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P6.7	66	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5

Table 7-2. Signal Descriptions (continued)

FUNCTION	SIGNAL NAME	PIN NO.	PIN TYPE[1]	DESCRIPTION
		PZ		
GPIO Port 7	P7.0	67	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P7.1	68	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P7.2	69	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P7.3	70	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P7.4	77	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P7.5	78	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P7.6	83	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P7.7	84	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
GPIO Port 8	P8.0	79	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P8.1	80	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P8.2	81	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P8.3	82	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P8.4	92	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P8.5	93	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P8.6	94	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P8.7	95	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
GPIO Port 9	P9.0	40	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P9.1	41	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P9.2	42	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
	P9.3	43	I/O	General-purpose digital I/O with port interrupt and wakeup from LPMx.5
GPIO Port J	PJ.0	22	I/O	General-purpose digital I/O
	PJ.1	23	I/O	General-purpose digital I/O
	PJ.2	24	I/O	General-purpose digital I/O
	PJ.3	25	I/O	General-purpose digital I/O
	PJ.4	6	I/O	General-purpose digital I/O
	PJ.5	7	I/O	General-purpose digital I/O
	PJ.6	9	I/O	General-purpose digital I/O
	PJ.7	10	I/O	General-purpose digital I/O
I^2C	UCB0SCL	15	I/O	I^2C clock for eUSCI_B0 I^2C mode
	UCB0SDA	14	I/O	I^2C data for eUSCI_B0 I^2C mode
	UCB1SCL	94, 60	I/O	I^2C clock for eUSCI_B1 I^2C mode
	UCB1SDA	93, 59	I/O	I^2C data for eUSCI_B1 I^2C mode

Table 7-2. Signal Descriptions (continued)

FUNCTION	SIGNAL NAME	PIN NO.	PIN TYPE[1]	DESCRIPTION
		PZ		
LCD	COM0	63	O	LCD common output COM0 for LCD backplane
	COM1	64	O	LCD common output COM1 for LCD backplane
	COM2	65	O	LCD common output COM2 for LCD backplane
	COM3	66	O	LCD common output COM3 for LCD backplane
	COM4	67	O	LCD common output COM4 for LCD backplane
	COM5	68	O	LCD common output COM5 for LCD backplane
	COM6	69	O	LCD common output COM6 for LCD backplane
	COM7	70	O	LCD common output COM7 for LCD backplane
	LCDCAP	74	I/O	LCD capacitor connection CAUTION: LCDCAP/R33 must be connected to DVSS if not used.
	LCDREF	72	I	External reference voltage input for regulated LCD voltage
	R03	71	I/O	Input/output port of lowest analog LCD voltage (V5)
	R13	72	I/O	Input/output port of third most positive analog LCD voltage (V3 or V4)
	R23	73	I/O	Input/output port of second most positive analog LCD voltage (V2)
	R33	74	I/O	Input/output port of most positive analog LCD voltage (V1) CAUTION: LCDCAP/R33 must be connected to DVSS if not used.
	S0	62	O	LCD segment output
	S1	61	O	LCD segment output
	S2	60	O	LCD segment output
	S3	59	O	LCD segment output
	S4	58	O	LCD segment output
	S5	57	O	LCD segment output
	S6	56	O	LCD segment output
	S7	55	O	LCD segment output
	S8	54	O	LCD segment output
	S9	53	O	LCD segment output
	S10	50	O	LCD segment output
	S11	49	O	LCD segment output
	S12	48	O	LCD segment output
	S13	47	O	LCD segment output
	S14	46	O	LCD segment output
	S15	45	O	LCD segment output
	S16	44	O	LCD segment output
	S17	43	O	LCD segment output
	S18	42	O	LCD segment output
	S19	41	O	LCD segment output
	S20	40	O	LCD segment output
	S21	39	O	LCD segment output
	S22	38	O	LCD segment output
	S23	37	O	LCD segment output
	S24	36	O	LCD segment output
	S25	35	O	LCD segment output
	S26	34	O	LCD segment output
	S27	33	O	LCD segment output
	S28	32	O	LCD segment output

Table 7-2. Signal Descriptions (continued)

FUNCTION	SIGNAL NAME	PIN NO.	PIN TYPE[1]	DESCRIPTION
		PZ		
LCD (continued)	S29	31	O	LCD segment output
	S30	30	O	LCD segment output
	S31	29	O	LCD segment output
	S32	28	O	LCD segment output
	S33	70	O	LCD segment output
	S34	69	O	LCD segment output
	S35	68	O	LCD segment output
	S36	67	O	LCD segment output
	S37	66	O	LCD segment output
	S38	65	O	LCD segment output
Power	AVCC1	100	P	Analog power supply
	AVSS1	99	P	Analog ground supply
	AVSS2	5	P	Analog ground supply
	AVSS3	8	P	Analog ground supply
	AVSS4	11	P	Analog ground supply
	AVSS5	96	P	Analog ground supply
	DVCC1	27	P	Digital power supply
	DVCC2	52	P	Digital power supply
	DVCC3	76	P	Digital power supply
	DVSS1	26	P	Digital ground supply
	DVSS2	51	P	Digital ground supply
	DVSS3	75	P	Digital ground supply
	PVCC	88	P	USS power supply
	PVSS	87, 89	P	USS ground supply
RTC	RTCCLK	25, 44, 82	O	RTC clock calibration output

Table 7-2. Signal Descriptions (continued)

FUNCTION	SIGNAL NAME	PIN NO.	PIN TYPE[1]	DESCRIPTION
		PZ		
SPI	UCA0CLK	1, 45	I/O	Clock signal input for eUSCI_A0 SPI slave mode Clock signal output for eUSCI_A0 SPI master mode
	UCA0SIMO	16, 47	I/O	Slave in/master out for eUSCI_A0 SPI mode
	UCA0SOMI	17, 48	I/O	Slave out/master in for eUSCI_A0 SPI mode
	UCA0STE	2, 46	I/O	Slave transmit enable for eUSCI_A0 SPI mode
	UCA1CLK	3	I/O	Clock signal input for eUSCI_A1 SPI slave mode Clock signal output for eUSCI_A1 SPI master mode
	UCA1SIMO	18	I/O	Slave in/master out for eUSCI_A1 SPI mode
	UCA1SOMI	19	I/O	Slave out/master in for eUSCI_A1 SPI mode
	UCA1STE	4	I/O	Slave transmit enable for eUSCI_A1 SPI mode
	UCA2CLK	69, 56	I/O	Clock signal input for eUSCI_A2 SPI slave mode Clock signal output for eUSCI_A2 SPI master mode
	UCA2SIMO	67, 54	I/O	Slave in/master out for eUSCI_A2 SPI mode
	UCA2SOMI	68, 55	I/O	Slave out/master in for eUSCI_A2 SPI mode
	UCA2STE	70, 57	I/O	Slave transmit enable for eUSCI_A2 SPI mode
	UCA3CLK	80	I/O	Clock signal input for eUSCI_A3 SPI slave mode Clock signal output for eUSCI_A3 SPI master mode
	UCA3SIMO	82	I/O	Slave in/master out for eUSCI_A3 SPI mode
	UCA3SOMI	81	I/O	Slave out/master in for eUSCI_A3 SPI mode
	UCA3STE	79	I/O	Slave transmit enable for eUSCI_A3 SPI mode
	UCB0CLK	13	I/O	Clock signal input for eUSCI_B0 SPI slave mode Clock signal output for eUSCI_B0 SPI master mode
	UCB0SIMO	14	I/O	Slave in/master out for eUSCI_B0 SPI mode
	UCB0SOMI	15	I/O	Slave out/master in for eUSCI_B0 SPI mode
	UCB0STE	12	I/O	Slave transmit enable for eUSCI_B0 SPI mode
	UCB1CLK	92, 58	I/O	Clock signal input for eUSCI_B1 SPI slave mode Clock signal output for eUSCI_B1 SPI master mode
	UCB1SIMO	93, 59	I/O	Slave in/master out for eUSCI_B1 SPI mode
	UCB1SOMI	94, 60	I/O	Slave out/master in for eUSCI_B1 SPI mode
	UCB1STE	95, 61	I/O	Slave transmit enable for eUSCI_B1 SPI mode
System	NMI	21	I	Nonmaskable interrupt input
	$\overline{\text{RST}}$	21	I/O	Reset input active low

Table 7-2. Signal Descriptions (continued)

FUNCTION	SIGNAL NAME	PIN NO.	PIN TYPE[1]	DESCRIPTION
		PZ		
Timer	TA0.0	2	I/O	TA0 CCR0 capture: CCI0A input, compare: Out0
	TA0.0	39	I/O	TA0 CCR0 capture: CCI0B input, compare: Out0
	TA0.1	77	I/O	TA0 CCR1 capture: CCI1A input, compare: Out1
	TA0.2	84	I/O	TA0 CCR2 capture: CCI2A input, compare: Out2
	TA0CLK	28, 49, 59	I	TA0 input clock
	TA1.0	3	I/O	TA1 CCR0 capture: CCI0A input, compare: Out0
	TA1.0	40	I/O	TA1 CCR0 capture: CCI0B input, compare: Out0
	TA1.1	78	I/O	TA1 CCR1 capture: CCI1A input, compare: Out1
	TA1.2	92	I/O	TA1 CCR2 capture: CCI2A input, compare: Out2
	TA1CLK	28, 49	I	TA1 input clock
	TA4.0	4	I/O	TA4 CCR0 capture: CCI0A input, compare: Out0
	TA4.0	29	I/O	TA4 CCR0 capture: CCI0B input, compare: Out0
	TA4.1	30	I/O	TA4CCR1 capture: CCI1B input, compare: Out1
	TA4.1	83	I/O	TA4 CCR1 capture: CCI1A input, compare: Out1
	TA4CLK	23, 50	I	TA4 input clock
	TB0.0	31	I/O	TB0 CCR0 capture: CCI0B input, compare: Out0
	TB0.0	69	I/O	TB0 CCR0 capture: CCI0A input, compare: Out0
	TB0.1	32	I/O	TB0 CCR1 capture: CCI1A input, compare: Out1
	TB0.1	70	O	TB0 CCR1 compare: Out1
	TB0.2	33	I/O	TB0 CCR2 capture: CCI2A input, compare: Out2
	TB0.2	79	O	TB0 CCR2 compare: Out2
	TB0.3	34	I/O	TB0 CCR3 capture: CCI3A input, compare: Out3
	TB0.3	80	I/O	TB0 CCR3 capture: CCI3B input, compare: Out3
	TB0.4	12	I/O	TB0 CCR4 capture: CCI4A input, compare: Out4
	TB0.4	36	I/O	TB0 CCR4 capture: CCI4B input, compare: Out4
	TB0.5	13	I/O	TB0 CCR5 capture: CCI5A input, compare: Out5
	TB0.5	37	I/O	TB0CCR5 capture: CCI5B input, compare: Out5
	TB0.6	25	I/O	TB0 CCR6 capture: CCI6B input, compare: Out6
	TB0.6	38	I/O	TB0 CCR6 capture: CCI6A input, compare: Out6
	TB0CLK	28, 50	I	TB0 clock input
	TB0OUTH	24, 35, 80, 84	I	Switch all PWM outputs high impedance input – TB0
UART	UCA0RXD	17, 48	I	Receive data for eUSCI_A0 UART mode
	UCA0TXD	16, 47	O	Transmit data for eUSCI_A0 UART mode
	UCA1RXD	19	I	Receive data for eUSCI_A1 UART mode
	UCA1TXD	18	O	Transmit data for eUSCI_A1 UART mode
	UCA2RXD	68, 55	I	Receive data for eUSCI_A2 UART mode
	UCA2TXD	67, 54	O	Transmit data for eUSCI_A2 UART mode
	UCA3RXD	81	I	Receive data for eUSCI_A3 UART mode
	UCA3TXD	82	O	Transmit data for eUSCI_A3 UART mode

Table 7-2. Signal Descriptions (continued)

FUNCTION	SIGNAL NAME	PIN NO.	PIN TYPE[1]	DESCRIPTION
		PZ		
USS	USSTRG	15	I	USS trigger
	USSXTIN	97	I	Input for crystal or resonator of oscillator USSXT
	USSXTOUT	98	O	Output for crystal or resonator of oscillator USSXT
	USSXT_BOUT	95	O	Buffered output clock of USSXT
	CH0_IN	91	I	USS channel 0 RX
	CH0_OUT	90	I/O	USS channel 0 TX
	CH1_IN	85	I	USS channel 1 RX
	CH1_OUT	86	I/O	USS channel 1 TX

(1) I = input, O = output, P = power

7.4 Pin Multiplexing

Pin multiplexing for these devices is controlled by both register settings and operating modes (for example, if the device is in test mode). For details of the settings for each pin and diagrams of the multiplexed ports, see Section 9.14.

7.5 Buffer Type

Table 7-3 describes the buffer types that are referenced in Table 7-1.

Table 7-3. Buffer Type

BUFFER TYPE (STANDARD)	NOMINAL VOLTAGE	HYSTERESIS	PULLUP (PU) OR PULLDOWN (PD)	NOMINAL PU OR PD STRENGTH (µA)	OUTPUT DRIVE STRENGTH (mA)	OTHER CHARACTERISTICS
Analog[2]	3.0 V	N	N/A	N/A	N/A	See analog modules in Section 8 for details.
LVCMOS	3.0 V	Y[1]	Programmable	See Section 8.13.5	See Section 8.13.5	
Power (DVCC)[3]	3.0 V	N	N/A	N/A	N/A	SVS enables hysteresis on DVCC.
Power (AVCC)[3]	3.0 V	N	N/A	N/A	N/A	
Power (PVCC)[3]	3.0 V	N	N/A	N/A	N/A	
Power (DVSS and AVSS)[3]	0 V	N	N/A	N/A	N/A	

(1) Only for input pins
(2) This is a switch, not a buffer.
(3) This is supply input, not a buffer.

7.6 Connection of Unused Pins

Table 7-4 lists the correct termination of unused pins.

Table 7-4. Connection of Unused Pins

PIN(1)	POTENTIAL	COMMENT
AVCC	DV_{CC}	
PVCC	DV_{CC}	
AVSS	DV_{SS}	
PVSS	DV_{SS}	
CHx_IN, CHx_OUT	DV_{SS}	
USSXTIN	DV_{SS}	Do not connect to DVCC, AVCC, or PVCC
USSXTOUT	Open	
Px.0 to Px.7	Open	Switched to port function, output direction (PxDIR.n = 1)
$\overline{RST}$/NMI/ SBWTDIO	DV_{CC} or V_{CC}	47-kΩ pullup or internal pullup selected with 10-nF (2.2-nF(2)) pulldown
PJ.0/TDO PJ.1/TDI PJ.2/TMS PJ.3/TCK	Open	The JTAG pins are shared with general-purpose I/O function (PJ.x). If these pins are not used, set them to port function, output direction. If used as JTAG pins, leave them open.
TEST	Open	This pin always has an internal pulldown enabled.

(1) For any unused pin with a secondary function that is shared with general-purpose I/O, follow the guidelines for the Px.0 to Px.7 pins.
(2) The pulldown capacitor must not exceed 2.2 nF when using devices with Spy-Bi-Wire interface in Spy-Bi-Wire mode or in 4-wire JTAG mode with TI tools like FET interfaces or GANG programmers.

8 Specifications

8.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)(1)

			MIN	MAX	UNIT
V_{CC}	Supply voltage(3)	At DVCC and AVCC pins	–0.3	4.1	V
		At DVCC, AVCC, and PVCC pins	–0.3	4.1	
	Voltage difference between DVCC and AVCC pins(2)			±0.3	V
	Voltage difference among DVCC, AVCC, and PVCC pins(2)			±0.3	V
V_I	Input voltage(3)	Applied to CHx_IN	–0.3	1.65	V
		Applied to CHx_IN with a duty cycle of 10% over 1 ms	–0.3	1.8	
		Applied to USSXTIN (USSXTOUT)	–0.3	1.5	
		Applied to any other pin	–0.3	V_{CC} + 0.3 V (4.1 V Max)	
	Diode current at any device pin			±2	mA
T_{stg}	Storage temperature (4)		–40	125	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

(2) Voltage differences between DVCC and AVCC that exceed the specified limits can cause malfunction of the device including erroneous writes to RAM and FRAM.

(3) Voltages are referenced to V_{SS}.

(4) Higher temperature may be applied during board soldering according to the current JEDEC J-STD-020 specification with peak reflow temperatures not higher than classified on the device label on the shipping boxes or reels.

8.2 ESD Ratings

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

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

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

8.3 Recommended Operating Conditions

TYP data are based on V_{CC} = 3.0 V and T_A = 25°C (unless otherwise noted)

			MIN	NOM	MAX	UNIT
V_{CC}	Supply voltage range applied at all DVCC and AVCC pins(1) (3) (4) (2)		1.8(7)		3.6	V
V_{CC}	Supply voltage range applied at PVCC pin(1)		2.2		3.6	V
V_{SS}	Supply voltage applied at all DVSS, AVSS, and PVSS pins			0		V
T_A	Operating free-air temperature		–40		85	°C
C_{DVCC}	Capacitor value at DVCC(5)		1 – 20%			µF
f_{SYSTEM}	Processor frequency (maximum MCLK frequency)(6)	No FRAM wait states (NWAITSx = 0)	0		8(9)	MHz
		With FRAM wait states (NWAITSx = 1)(8)	0		16(10)	
f_{LEA}	LEA processor frequency		0		16(10)	
f_{ACLK}	Maximum ACLK frequency				50	kHz
f_{SMCLK}	Maximum SMCLK frequency				16(10)	MHz

(1) TI recommends powering the AVCC, DVCC, PVCC pins from the same source. At a minimum, during power up, power down, and device operation, the voltage difference among AVCC, DVCC, PVCC must not exceed the limits specified in *Absolute Maximum Ratings*. Exceeding the specified limits can cause malfunction of the device including erroneous writes to RAM and FRAM.

(2) The USS module must be disabled if AVCC and DVCC are lower than 2.2 V.

(3) Fast supply voltage changes can trigger a BOR reset even within the recommended supply voltage range. To avoid unwanted BOR resets, the supply voltage must change by less than 0.05 V per microsecond (±0.05 V/µs). Following the recommendation for capacitor C_{DVCC} should limit the slopes accordingly.

(4) Modules may have a different supply voltage range specification. See the specification of the respective module in this data sheet.

(5) As a decoupling capacitor for each supply pin pair (DVCC and DVSS or AVCC and AVSS), place a low-ESR 100-nF (minimum) ceramic capacitor as close as possible (within a few millimeters) to the respective pin pairs. For the PVCC and PVSS pair, place a low-ESR 22-µF (minimum) ceramic capacitor as close as possible (within a few millimeters) to the pin pair.

(6) Modules may have a different maximum input clock specification. See the specification of each module in this data sheet.

(7) The minimum supply voltage is defined by the supervisor SVS levels. See the PMM SVS threshold parameters for the exact values.

(8) Wait states occur only on actual FRAM accesses; that is, on FRAM cache misses. RAM and peripheral accesses are always excecuted without wait states.

(9) DCO settings and HF crystals with a typical value less than or equal to the specified MAX value are permitted.

(10) DCO settings and HF crystals with a typical value less than or equal to the specified MAX value are permitted. If a clock source with a higher typical value is used, the clock must be divided in the clock system.

8.4 Active Mode Supply Current Into V_{CC} Excluding External Current

over recommended operating free-air temperature (unless otherwise noted)(1) (2)

PARAMETER	EXECUTION MEMORY	V_{CC}	FREQUENCY ($f_{MCLK} = f_{SMCLK}$)										UNIT
			1 MHz 0 WAIT STATES (NWAITSx = 0)		4 MHz 0 WAIT STATES (NWAITSx = 0)		8 MHz 0 WAIT STATES (NWAITSx = 0)		12 MHz 1 WAIT STATE (NWAITSx = 1)		16 MHz 1 WAIT STATE (NWAITSx = 1)		
			TYP	MAX	TYP	MAX	TYP	MAX	TYP	MAX	TYP	MAX	
$I_{AM, FRAM\_UNI}$ (Unified memory)(3)	FRAM	3.0 V	225		665		1275		1550		1970		µA
$I_{AM, FRAM}$ (0%)(4) (5)	FRAM 0% cache hit ratio	3.0 V	420		1455		2850		2330		3000		µA
$I_{AM, FRAM}$ (50%)(4) (5)	FRAM 50% cache hit ratio	3.0 V	275		855	1022	1650	1888	1770	2041	2265	2606	µA
$I_{AM, FRAM}$ (66%)(4) (5)	FRAM 66% cache hit ratio	3.0 V	220		650		1240	1443	1490	1735	1880	2197	µA
$I_{AM, FRAM}$ (75%)(4) (5)	FRAM 75% cache hit ratio	3.0 V	192	261	535		1015	1170	1290	1490	1620	1870	µA
$I_{AM, FRAM}$ (100%)(4) (5)	FRAM 100% cache hit ratio	3.0 V	125		237		450		670		790		µA
$I_{AM, RAM}$ (6) (5)	RAM	3.0 V	140		323		590		880		1070		µA
$I_{AM, RAM\ only}$ (7) (5)	RAM	3.0 V	90	182	292		540		830		1020	1313	µA

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

(2) Characterized with program executing typical data processing.
f_{ACLK} = 32768 Hz, $f_{MCLK} = f_{SMCLK} = f_{DCO}$ at specified frequency, except for 12 MHz. For 12 MHz, f_{DCO} = 24 MHz and $f_{MCLK} = f_{SMCLK} = f_{DCO}/2$.
At MCLK frequencies above 8 MHz, the FRAM requires wait states. When wait states are required, the effective MCLK frequency ($f_{MCLK,eff}$) decreases. The effective MCLK frequency also depends on the cache hit ratio. SMCLK is not affected by the number of wait states or the cache hit ratio.
The following equation can be used to compute $f_{MCLK,eff}$:
$f_{MCLK,eff} = f_{MCLK}$ / [wait states × (1 – cache hit ratio) + 1]
For example, with 1 wait state and 75% cache hit ratio, $f_{MCKL,eff} = f_{MCLK}$ / [1 × (1 – 0.75) + 1] = f_{MCLK} / 1.25.

(3) Represents typical program execution. Program and data reside entirely in FRAM. All execution is from FRAM.

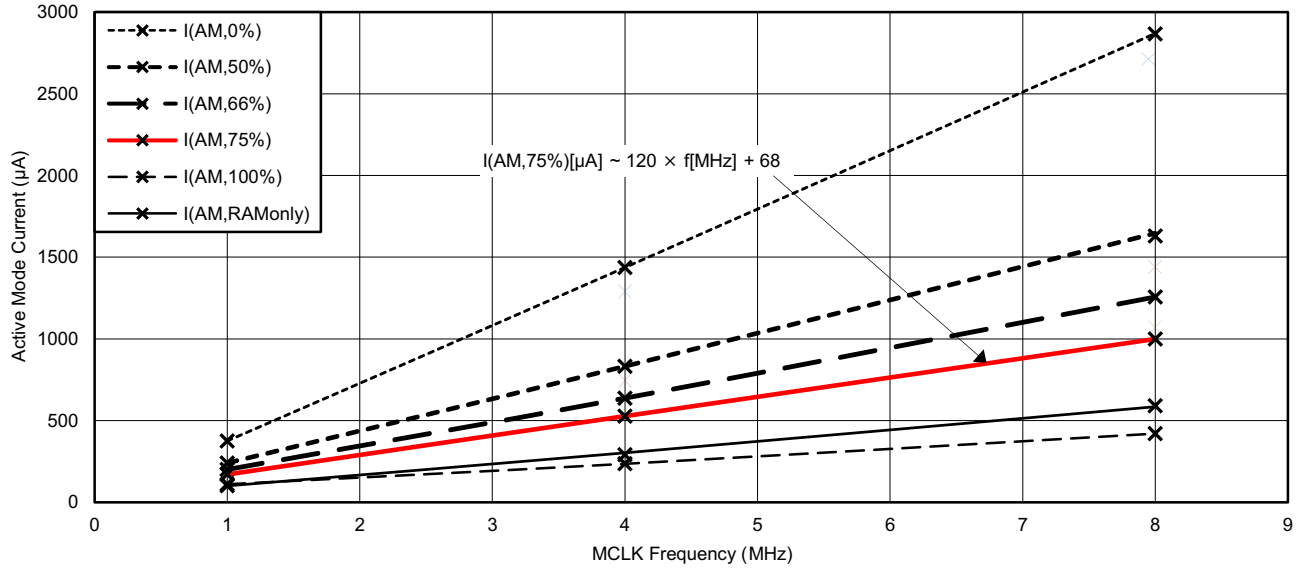
(4) Program resides in FRAM. Data resides in SRAM. Average current dissipation varies with cache hit-to-miss ratio as specified. Cache hit ratio represents number cache accesess divided by the total number of FRAM accesses. For example, a 75% ratio implies three of every four accesses is from cache, and the remaining are FRAM accesses.

(5) See Section 8.5 for typical curves. Each characteristic equation shown in the graph is computed using the least squares method for best linear fit using the typical data shown in Section 8.4.

(6) Program and data reside entirely in RAM. All execution is from RAM.

(7) Program and data reside entirely in RAM. All execution is from RAM. FRAM is off.

8.5 Typical Characteristics, Active Mode Supply Currents



A. $I_{(AM,cache\ hit\ ratio)}$: Program resides in FRAM. Data resides in SRAM. Average current dissipation varies with cache hit-to-miss ratio as specified. Cache hit ratio represents number cache accesses divided by the total number of FRAM accesses. For example, a 75% ratio implies three of every four accesses is from cache, and the remaining are FRAM accesses.

B. $I_{(AM,RAMonly)}$: Program and data reside entirely in RAM. All execution is from RAM. FRAM is off.

Figure 8-1. Typical Active Mode Supply Currents, No Wait States

8.6 Low-Power Mode (LPM0, LPM1) Supply Currents Into V_{CC} Excluding External Current

over recommended operating free-air temperature (unless otherwise noted)(1) (2)

PARAMETER	V_{CC}	FREQUENCY (f_{SMCLK})										UNIT
		1 MHz		4 MHz		8 MHz		12 MHz		16 MHz		
		TYP	MAX	TYP	MAX	TYP	MAX	TYP	MAX	TYP	MAX	
I_{LPM0}	2.2 V	80		115		180		276		250		µA
	3.0 V	95	148	125	178	190	245	286	340	265	316	
I_{LPM1}	2.2 V	40		70		136		230		205		µA
	3.0 V	40	70	70		136		235		210	250	

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

(2) Current for watchdog timer clocked by SMCLK included.
f_{ACLK} = 32768 Hz, f_{MCLK} = 0 MHz, f_{SMCLK} = f_{DCO} at specified frequency, except for 12 MHz. For 12 MHz, f_{DCO} = 24 MHz and f_{MCLK} = f_{SMCLK} = f_{DCO} / 2.

8.7 Low-Power Mode (LPM2, LPM3, LPM4) Supply Currents (Into V_{CC}) Excluding External Current

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted) (see Figure 8-2 and Figure 8-3)

PARAMETER		V_{CC}	TEMPERATURE								UNIT
			–40°C		25°C		60°C		85°C		
			TYP	MAX	TYP	MAX	TYP	MAX	TYP	MAX	
$I_{LPM2,XT12}$	Low-power mode 2, 12-pF crystal(1) (3) (4)	2.2 V	0.8		1.3		4.1		10.8		µA
		3 V	0.8		1.3		4.1		10.8		
$I_{LPM2,XT3.7}$	Low-power mode 2, 3.7-pF crystal(1) (2) (4)	2.2 V	0.6		1.2		4.0		10.7		µA
		3 V	0.6		1.2		4.0		10.7		
$I_{LPM2,VLO}$	Low-power mode 2, VLO, includes SVS(5)	2.2 V	0.5		1.0		3.8		10.5		µA
		3 V	0.5		1.0		3.8		10.5		
$I_{LPM3,XT12}$	Low-power mode 3, 12-pF crystal, includes SVS(1) (3) (6)	2.2 V	0.8	1.1	1.0		2.2		4.5	10.1	µA
		3 V	0.8		1.0		2.2		4.5		
$I_{LPM3,XT3.7}$	Low-power mode 3, 3.7-pF crystal, excludes SVS(1) (2) (7)	2.2 V	0.5		0.7		2.1		4.4	9.8	µA
		3 V	0.5		0.7		2.1		4.4	9.8	
$I_{LPM3,VLO}$	Low-power mode 3, VLO, excludes SVS(8)	2.2 V	0.4		0.5	1.2	1.9		4.2	9.6	µA
		3 V	0.4		0.5		1.9		4.2		
$I_{LPM3,VLO,RAMoff}$	Low-power mode 3, VLO, excludes SVS, RAM powered-down completely(8)	2.2 V	0.36		0.47	1.1	1.4	2.9	2.6	8.2	µA
		3 V	0.36		0.47		1.4		2.6		
$I_{LPM4,SVS}$	Low-power mode 4, includes SVS(9)	2.2 V	0.5		0.6	1.2	1.9		4.3	9.7	µA
		3 V	0.5	0.8	0.6		1.9		4.3		
I_{LPM4}	Low-power mode 4, excludes SVS(10)	2.2 V	0.3		0.4	1.1	1.7		4.0	9.4	µA
		3 V	0.3		0.4		1.7		4.0		
$I_{LPM4,RAMoff}$	Low-power mode 4, excludes SVS, RAM powered-down completely(10)	2.2 V	0.3		0.37	1.0	1.2	2.8	2.5	8	µA
		3 V	0.3		0.37		1.2		2.5		
$I_{IDLE,GroupA}$	Additional idle current if one or more modules from Group A (see Table 9-3) are activated in LPM3 or LPM4	3 V			0.02				0.3		µA
$I_{IDLE,GroupB}$	Additional idle current if one or more modules from Group B (see Table 9-3) are activated in LPM3 or LPM4	3 V			0.02				0.35		µA
$I_{IDLE,GroupC}$	Additional idle current if one or more modules from Group C (see Table 9-3) are activated in LPM3 or LPM4	3 V			0.02				0.38		µA

(1) Not applicable for devices with HF crystal oscillator only.

(2) Characterized with a Seiko SSP-T7-FL (SMD) crystal with a load capacitance of 3.7 pF. The internal and external load capacitance are chosen to closely match the required 3.7-pF load.

(3) Characterized with a Micro Crystal MS1V-T1K crystal with a load capacitance of 12.5 pF. The internal and external load capacitance are chosen to closely match the required 12.5-pF load.

(4) Low-power mode 2, crystal oscillator test conditions:
Current for watchdog timer clocked by ACLK and RTC clocked by XT1 included. Current for brownout and SVS included.
CPUOFF = 1, SCG0 = 0 SCG1 = 1, OSCOFF = 0 (LPM2), f_{XT1} = 32768 Hz, $f_{ACLK} = f_{XT1}$, $f_{MCLK} = f_{SMCLK}$ = 0 MHz

(5) Low-power mode 2, VLO test conditions:
Current for watchdog timer clocked by ACLK included. RTC disabled (RTCHOLD = 1). Current for brownout and SVS included.
CPUOFF = 1, SCG0 = 0 SCG1 = 1, OSCOFF = 0 (LPM2), f_{XT1} = 0 Hz, $f_{ACLK} = f_{VLO}$, $f_{MCLK} = f_{SMCLK}$ = 0 MHz

(6) Low-power mode 3, 12-pF crystal including SVS test conditions:
Current for watchdog timer clocked by ACLK and RTC clocked by XT1 included. Current for brownout and SVS included (SVSHE = 1).
CPUOFF = 1, SCG0 = 1 SCG1 = 1, OSCOFF = 0 (LPM3), f_{XT1} = 32768 Hz, $f_{ACLK} = f_{XT1}$, $f_{MCLK} = f_{SMCLK}$ = 0 MHz
Activating additional peripherals increases the current consumption due to active supply current contribution as well as due to additional idle current. Refer to the idle currents specified for the respective peripheral groups.

(7) Low-power mode 3, 3.7-pF crystal excluding SVS test conditions:
Current for watchdog timer clocked by ACLK and RTC clocked by XT1 included. Current for brownout included. SVS disabled (SVSHE = 0).
CPUOFF = 1, SCG0 = 1 SCG1 = 1, OSCOFF = 0 (LPM3), f_{XT1} = 32768 Hz, $f_{ACLK} = f_{XT1}$, $f_{MCLK} = f_{SMCLK}$ = 0 MHz
Activating additional peripherals increases the current consumption due to active supply current contribution as well as due to additional idle current. Refer to the idle currents specified for the respective peripheral groups.

(8) Low-power mode 3, VLO excluding SVS test conditions:
Current for watchdog timer clocked by ACLK included. RTC disabled (RTCHOLD = 1). RAM disabled (RCCTL0 = 5A55h). Current for brownout included. SVS disabled (SVSHE = 0).
CPUOFF = 1, SCG0 = 1 SCG1 = 1, OSCOFF = 0 (LPM3), f_{XT1} = 0 Hz, $f_{ACLK} = f_{VLO}$, $f_{MCLK} = f_{SMCLK}$ = 0 MHz
Activating additional peripherals increases the current consumption due to active supply current contribution as well as due to additional idle current. Refer to the idle currents specified for the respective peripheral groups.

(9) Low-power mode 4 including SVS test conditions:
Current for brownout and SVS included (SVSHE = 1).
CPUOFF = 1, SCG0 = 1 SCG1 = 1, OSCOFF = 1 (LPM4), f_{XT1} = 0 Hz, f_{ACLK} = 0 Hz, $f_{MCLK} = f_{SMCLK}$ = 0 MHz
Activating additional peripherals increases the current consumption due to active supply current contribution as well as due to additional idle current. Refer to the idle currents specified for the respective peripheral groups.

(10) Low-power mode 4 excluding SVS test conditions:
Current for brownout included. SVS disabled (SVSHE = 0). RAM disabled (RCCTL0 = 5A55h).
CPUOFF = 1, SCG0 = 1 SCG1 = 1, OSCOFF = 1 (LPM4), f_{XT1} = 0 Hz, f_{ACLK} = 0 Hz, $f_{MCLK} = f_{SMCLK}$ = 0 MHz
Activating additional peripherals increases the current consumption due to active supply current contribution as well as due to additional idle current. Refer to the idle currents specified for the respective peripheral groups.

8.8 Low-Power Mode With LCD Supply Currents (Into V_{CC}) Excluding External Current

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

PARAMETER		V_{CC}	TEMPERATURE (T_A)								UNIT
			–40°C		25°C		60°C		85°C		
			TYP	MAX	TYP	MAX	TYP	MAX	TYP	MAX	
$I_{LPM3,XT12}$ LCD, ext. bias	Low-power mode 3 (LPM3) current,12 pF crystal, LCD 4-mux mode, external biasing, excludes SVS(1) (2)	3.0 V	0.9		1.1		2.5		5.1		µA
$I_{LPM3,XT12}$ LCD, int. bias	Low-power mode 3 (LPM3) current,12 pF crystal, LCD 4-mux mode, internal biasing, charge pump disabled, excludes SVS(1) (3)	3.0 V	1.3		1.4	2.0	2.2	4.5	4.9	12.5	µA
$I_{LPM3,XT12}$ LCD,CP	Low-power mode 3 (LPM3) current,12 pF crystal, LCD 4-mux mode, internal biasing, charge pump enabled, 1/3 bias, excludes SVS(1) (4)	2.2 V	3.6		4		5.1		8.1		µA
		3.0 V	3.4		3.7		4.9		8.1		µA

(1) Current for watchdog timer clocked by ACLK and RTC clocked by XT1 included. Current for brownout included. SVS disabled (SVSHE = 0).
CPUOFF = 1, SCG0 = 1 SCG1 = 1, OSCOFF = 0 (LPM3),
f_{XT1} = 32768 Hz, $f_{ACLK} = f_{XT1}$, $f_{MCLK} = f_{SMCLK}$ = 0 MHz
Activating additional peripherals increases the current consumption due to active supply current contribution as well as due to additional idle current - idle current of Group containing LCD module already included. Refer to the idle currents specified for the respective peripheral groups.

(2) LCDMx = 11 (4-mux mode), LCDREXT = 1, LCDEXTBIAS = 1 (external biasing), LCD2B = 0 (1/3 bias), LCDCPEN = 0 (charge pump disabled), LCDSSEL = 0, LCDPREx = 101, LCDDIVx = 00011 (f_{LCD} = 32768 Hz / 32 / 4 = 256 Hz)
Current through external resistors not included (voltage levels are supplied by test equipment).
Even segments S0, S2,... = 0, odd segments S1, S3,... = 1. No LCD panel load.

(3) LCDMx = 11 (4-mux mode), LCDREXT = 0, LCDEXTBIAS = 0 (internal biasing), LCD2B = 0 (1/3 bias), LCDCPEN = 0 (charge pump disabled), LCDSSEL = 0, LCDPREx = 101, LCDDIVx = 00011 (f_{LCD} = 32768 Hz / 32 / 4 = 256 Hz)
Even segments S0, S2,... = 0, odd segments S1, S3,... = 1. No LCD panel load.

(4) LCDMx = 11 (4-mux mode), LCDREXT = 0, LCDEXTBIAS = 0 (internal biasing), LCD2B = 0 (1/3 bias), LCDCPEN = 1 (charge pump enabled), VLCDx = 1000 (V_{LCD} = 3 V typical), LCDSSEL = 0, LCDPREx = 101, LCDDIVx = 00011 (f_{LCD} = 32768 Hz / 32 / 4 = 256 Hz)
Even segments S0, S2,... = 0, odd segments S1, S3,... = 1. No LCD panel load.

8.9 Low-Power Mode (LPMx.5) Supply Currents (Into V_{CC}) Excluding External Current

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted) (see Figure 8-4 and Figure 8-5)

PARAMETER		V_{CC}	TEMPERTURE (T_A)								UNIT
			–40°C		25°C		60°C		85°C		
			TYP	MAX	TYP	MAX	TYP	MAX	TYP	MAX	
$I_{LPM3.5,XT12}$	Low-power mode 3.5, 12-pF crystal including SVS(1) (3) (4)	2.2 V	0.45		0.5		0.55		0.75		µA
		3.0 V	0.45		0.5		0.55		0.75		
$I_{LPM3.5,XT3.7}$	Low-power mode 3.5, 3.7-pF crystal excluding SVS(1) (2) (5)	2.2 V	0.3		0.35		0.4		0.65		µA
		3.0 V	0.3		0.35		0.4		0.65		
$I_{LPM4.5,SVS}$	Low-power mode 4.5, including SVS(6)	2.2 V	0.23		0.2		0.28		0.4		µA
		3.0 V	0.23		0.2		0.28		0.4		
$I_{LPM4.5}$	Low-power mode 4.5, excluding SVS(7)	2.2 V	0.035		0.045		0.075		0.15		µA
		3.0 V	0.035		0.045		0.075		0.15		

(1) Not applicable for devices with HF crystal oscillator only.

(2) Characterized with a Seiko SSP-T7-FL (SMD) crystal with a load capacitance of 3.7 pF. The internal and external load capacitance are chosen to closely match the required 3.7-pF load.

(3) Characterized with a Micro Crystal MS1V-T1K crystal with a load capacitance of 12.5 pF. The internal and external load capacitance are chosen to closely match the required 12.5-pF load.

(4) Low-power mode 3.5, 1-pF crystal including SVS test conditions:
Current for RTC clocked by XT1 included. Current for brownout and SVS included (SVSHE = 1). Core regulator disabled.
PMMREGOFF = 1, CPUOFF = 1, SCG0 = 1 SCG1 = 1, OSCOFF = 1 (LPMx.5),
f_{XT1} = 32768 Hz, $f_{ACLK} = f_{XT1}$, $f_{MCLK} = f_{SMCLK}$ = 0 MHz

(5) Low-power mode 3.5, 3.7-pF crystal excluding SVS test conditions:
Current for RTC clocked by XT1 included.Current for brownout included. SVS disabled (SVSHE = 0). Core regulator disabled.
PMMREGOFF = 1, CPUOFF = 1, SCG0 = 1 SCG1 = 1, OSCOFF = 1 (LPMx.5),
f_{XT1} = 32768 Hz, $f_{ACLK} = f_{XT1}$, $f_{MCLK} = f_{SMCLK}$ = 0 MHz

(6) Low-power mode 4.5 including SVS test conditions:
Current for brownout and SVS included (SVSHE = 1). Core regulator disabled.
PMMREGOFF = 1, CPUOFF = 1, SCG0 = 1 SCG1 = 1, OSCOFF = 1 (LPMx.5),
f_{XT1} = 0 Hz, f_{ACLK} = 0 Hz, $f_{MCLK} = f_{SMCLK}$ = 0 MHz

(7) Low-power mode 4.5 excluding SVS test conditions:
Current for brownout included. SVS disabled (SVSHE = 0). Core regulator disabled.
PMMREGOFF = 1, CPUOFF = 1, SCG0 = 1 SCG1 = 1, OSCOFF = 1 (LPMx.5),
f_{XT1} = 0 Hz, f_{ACLK} = 0 Hz, $f_{MCLK} = f_{SMCLK}$ = 0 MHz

8.10 Typical Characteristics, Low-Power Mode Supply Currents

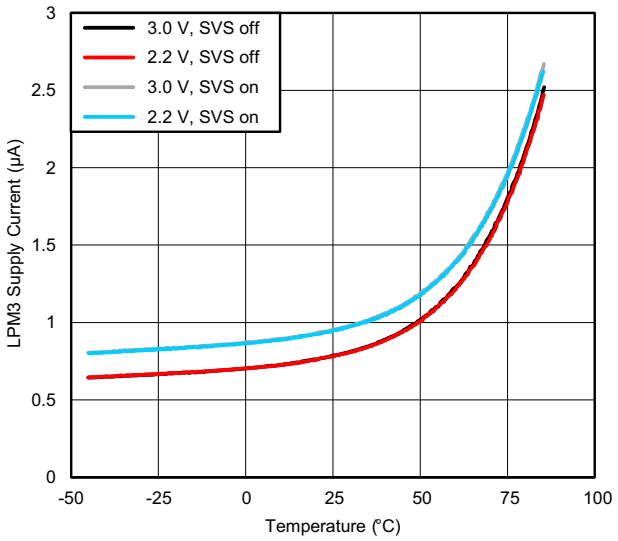


Figure 8-2. LPM3 Supply Current ($I_{LPM3,XT3.7}$) vs Temperature

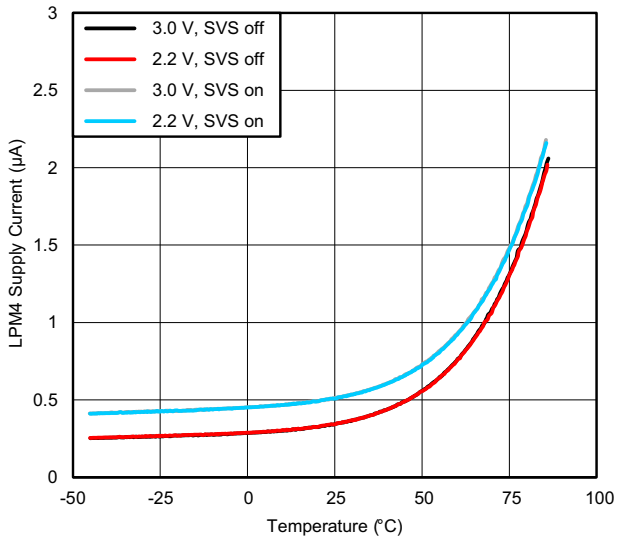


Figure 8-3. LPM4 Supply Current ($I_{LPM4,SVS}$) vs Temperature

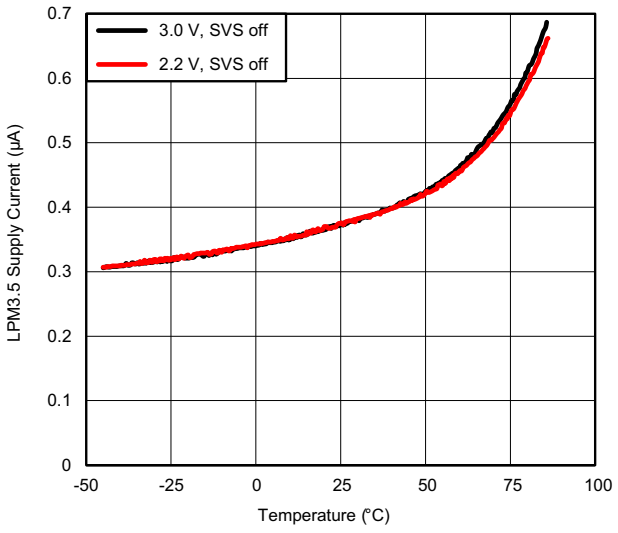


Figure 8-4. LPM3.5 Supply Current ($I_{LPM3.5,XT3.7}$) vs Temperature

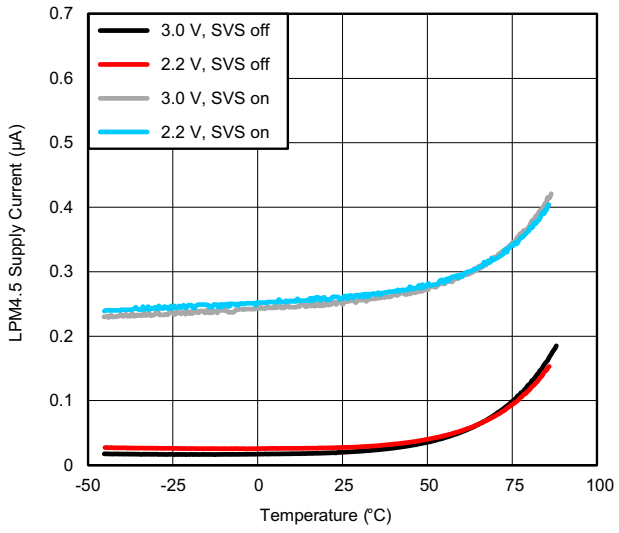


Figure 8-5. LPM4.5 Supply Current ($I_{LPM4.5}$) vs Temperature

8.11 Current Consumption per Module

MODULE(1)	TEST CONDITIONS	REFERENCE CLOCK	MIN	TYP	MAX	UNIT
Timer_A		Module input clock		2.5		µA/MHz
Timer_B		Module input clock		3.8		µA/MHz
eUSCI_A	UART mode	Module input clock		6.3	7.0	µA/MHz
	SPI mode			4.4	4.8	
eUSCI_B	SPI mode	Module input clock		4.4		µA/MHz
	I^2C mode, 100 kbaud			4.4		
RTC_C		32 kHz		100		nA
MPY	Only from start to end of operation	MCLK		28		µA/MHz
CRC16	Only from start to end of operation	MCLK		3.3		µA/MHz
CRC32	Only from start to end of operation	MCLK		3.3		µA/MHz
LEA	256-point complex FFT, data = nonzero	MCLK	68	86		µA/MHz
	256-point complex FFT, data = zero			66		

(1) For other module currents not listed here, see the module-specific parameter sections.

8.12 Thermal Resistance Characteristics for 100-Pin LQFP (PZ) Package

THERMAL METRIC(1)		VALUE(2)	UNIT
$R\theta_{JA}$	Junction-to-ambient thermal resistance, still air	57.6	°C/W
$R\theta_{JC(TOP)}$	Junction-to-case (top) thermal resistance	14.9	°C/W
$R\theta_{JB}$	Junction-to-board thermal resistance	35.6	°C/W
Ψ_{JB}	Junction-to-board thermal characterization parameter	35.0	°C/W
Ψ_{JT}	Junction-to-top thermal characterization parameter	0.6	°C/W
$R\theta_{JC(BOTTOM)}$	Junction-to-case (bottom) thermal resistance	N/A(3)	°C/W

(1) For more information about traditional and new thermal metrics, see Semiconductor and IC Package Thermal Metrics.

(2) These values are based on a JEDEC-defined 2S2P system (with the exception of the Theta JC ($R\theta_{JC}$) value, which is based on a JEDEC-defined 1S0P system) and will change based on environment and application. For more information, see these EIA/JEDEC standards:

- JESD51-2, *Integrated Circuits Thermal Test Method Environmental Conditions - Natural Convection (Still Air)*
- JESD51-3, *Low Effective Thermal Conductivity Test Board for Leaded Surface Mount Packages*
- JESD51-7, *High Effective Thermal Conductivity Test Board for Leaded Surface Mount Packages*
- JESD51-9, *Test Boards for Area Array Surface Mount Package Thermal Measurements*

(3) N/A = not applicable

8.13 Timing and Switching Characteristics

8.13.1 Power Supply Sequencing

TI recommends powering the AVCC, DVCC, and PVCC pins from the same source. At a minimum, during power up, power down, and device operation, the voltage difference among AVCC, DVCC, and PVCC must not exceed the limits specified in Section 8.1. Exceeding the specified limits can cause malfunction of the device including erroneous writes to RAM and FRAM.

8.13.1.1 Brownout and Device Reset Power Ramp Requirements

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

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
V_{VCC_BOR-}	Brownout power-down level(1)	$\lvert dDV_{CC}/d_t \rvert$ < 3 V/s	0.7	1.66	V
V_{VCC_BOR+}	Brownout power-up level(1)	$\lvert dDV_{CC}/d_t \rvert$ < 3 V/s(2)	0.79	1.68	V

(1) Fast supply voltage changes can trigger a BOR reset even within the recommended supply voltage range. To avoid unwanted BOR resets, the supply voltage must change by less than 0.05 V per microsecond (±0.05 V/µs). Following the recommendation for capacitor C_{DVCC} should limit the slopes accordingly.

(2) The brownout levels are measured with a slowly changing supply.

8.13.1.2 SVS

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$I_{SVSH,LPM}$	SVS_H current consumption, low-power modes			170	300	nA
V_{SVSH-}	SVS_H power-down level(1)		1.75	1.80	1.85	V
V_{SVSH+}	SVS_H power-up level(1)		1.77	1.88	1.99	V
V_{SVSH_hys}	SVS_H hysteresis		40		120	mV
$t_{PD,SVSH,\ AM}$	SVS_H propagation delay, active mode	dV_{Vcc}/dt = –10 mV/µs			10	µs

(1) For additional information, see the Dynamic Voltage Scaling Power Solution for MSP430 Devices With Single-Channel LDO Reference Design.

8.13.2 Reset Timing

8.13.2.1 Reset Input

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

PARAMETER		V_{CC}	MIN	TYP	MAX	UNIT
$t_{(RST)}$	External reset pulse duration on $\overline{RST}$ (1)	2.2 V, 3.0 V	2			µs

(1) Not applicable if the $\overline{RST}$/NMI pin is configured as NMI .

8.13.3 Clock Specifications

Section 8.13.3.1 lists the characteristics of the low-frequency oscillator.

8.13.3.1 Low-Frequency Crystal Oscillator, LFXT

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)(4)

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
$I_{VCC.LFXT}$	Current consumption	f_{OSC} = 32768 Hz, LFXTBYPASS = 0,LFXTDRIVE = {0}, T_A = 25°C, $C_{L,eff}$ = 3.7 pF, ESR ≈ 44 kΩ	3.0 V		180		nA
		f_{OSC} = 32768 Hz, LFXTBYPASS = 0, LFXTDRIVE = {1}, T_A = 25°C, $C_{L,eff}$ = 6 pF, ESR ≈ 40 kΩ			185		
		f_{OSC} = 32768 Hz, LFXTBYPASS = 0, LFXTDRIVE = {2}, T_A = 25°C, $C_{L,eff}$ = 9 pF, ESR ≈ 40 kΩ			225		
		f_{OSC} = 32768 Hz, LFXTBYPASS = 0, LFXTDRIVE = {3}, T_A = 25°C, $C_{L,eff}$ = 12.5 pF, ESR ≈ 40 kΩ			330		
f_{LFXT}	LFXT oscillator crystal frequency	LFXTBYPASS = 0			32768		Hz
DC_{LFXT}	LFXT oscillator duty cycle	Measured at ACLK, f_{LFXT} = 32768 Hz		30%		70%	
$f_{LFXT,SW}$	LFXT oscillator logic-level square-wave input frequency	LFXTBYPASS = 1(5) (8)		10.5	32.768	50	kHz
$DC_{LFXT, SW}$	LFXT oscillator logic-level square-wave input duty cycle	LFXTBYPASS = 1		30%		70%	
OA_{LFXT}	Oscillation allowance for LF crystals(9)	LFXTBYPASS = 0, LFXTDRIVE = {1}, f_{LFXT} = 32768 Hz, $C_{L,eff}$ = 6 pF			210		kΩ
		LFXTBYPASS = 0, LFXTDRIVE = {3}, f_{LFXT} = 32768 Hz, $C_{L,eff}$ = 12.5 pF			300		
C_{LFXIN}	Integrated load capacitance at LFXIN terminal(6) (7)				2		pF
C_{LFXOUT}	Integrated load capacitance at LFXOUT terminal(6) (7)				2		pF
$t_{START,LFXT}$	Start-up time(2)	f_{OSC} = 32768 Hz, LFXTBYPASS = 0, LFXTDRIVE = {0}, T_A = 25°C, $C_{L,eff}$ = 3.7 pF	3.0 V		800		ms
		f_{OSC} = 32768 Hz, LFXTBYPASS = 0, LFXTDRIVE = {3}, T_A = 25°C, $C_{L,eff}$ = 12.5 pF	3.0 V		1000		
$f_{Fault,LFXT}$	Oscillator fault frequency(3) (1)			0		3500	Hz

(1) Measured with logic-level input frequency but also applies to operation with crystals.
(2) Includes start-up counter of 1024 clock cycles.
(3) Frequencies above the MAX specification do not set the fault flag. Frequencies between the MIN and MAX specifications may set the flag. A static condition or stuck at fault condition will set the flag.
(4) To improve EMI on the LFXT oscillator, observe the following guidelines:
- Keep the trace between the device and the crystal as short as possible.
- Design a good ground plane around the oscillator pins.
- Prevent crosstalk from other clock or data lines into oscillator pins LFXIN and LFXOUT.
- Avoid running PCB traces underneath or adjacent to the LFXIN and LFXOUT pins.
- Use assembly materials and processes that avoid any parasitic load on the oscillator LFXIN and LFXOUT pins.

- If conformal coating is used, ensure that it does not induce capacitive or resistive leakage between the oscillator pins.

(5) When LFXTBYPASS is set, LFXT circuits are automatically powered down. Input signal is a digital square wave with parametrics defined in the Schmitt-trigger Inputs section of this data sheet. Duty cycle requirements are defined by $DC_{LFXT, SW}$.

(6) This represents all the parasitic capacitance present at the LFXIN and LFXOUT terminals, respectively, including parasitic bond and package capacitance. The effective load capacitance, $C_{L,eff}$ can be computed as $C_{IN} \times C_{OUT} / (C_{IN} + C_{OUT})$, where C_{IN} and C_{OUT} is the total capacitance at the LFXIN and LFXOUT terminals, respectively.

(7) Requires external capacitors at both terminals to meet the effective load capacitance specified by crystal manufacturers. Recommended effective load capacitance values supported are 3.7 pF, 6 pF, 9 pF, and 12.5 pF. Maximum shunt capacitance of 1.6 pF. The PCB adds additional capacitance, so it must also be considered in the overall capacitance. Verify that the recommended effective load capacitance of the selected crystal is met.

(8) Maximum frequency of operation of the entire device cannot be exceeded.

(9) Oscillation allowance is based on a safety factor of 5 for recommended crystals. The oscillation allowance is a function of the LFXTDRIVE settings and the effective load. In general, comparable oscillator allowance can be achieved based on the following guidelines, but should be evaluated based on the actual crystal selected for the application:

- For LFXTDRIVE = {0}, $C_{L,eff}$ = 3.7 pF
- For LFXTDRIVE = {1}, $C_{L,eff}$ = 6 pF
- For LFXTDRIVE = {2}, 6 pF ≤ $C_{L,eff}$ ≤ 9 pF
- For LFXTDRIVE = {3}, 9 pF ≤ $C_{L,eff}$ ≤ 12.5 pF

8.13.3.2 High-Frequency Crystal Oscillator, HFXT

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)(5)

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
$I_{DVCC.HFXT}$	HFXT oscillator crystal current HF mode at typical ESR	f_{OSC} = 4 MHz, HFXTBYPASS = 0, HFXTDRIVE = 0, HFFREQ = 1(8), T_A = 25°C, $C_{L,eff}$ = 18 pF, typical ESR, C_{shunt}	3.0 V		75		µA
		f_{OSC} = 8 MHz, HFXTBYPASS = 0, HFXTDRIVE = 1, HFFREQ = 1, T_A = 25°C, $C_{L,eff}$ = 18 pF, typical ESR, C_{shunt}			120		
		f_{OSC} = 16 MHz, HFXTBYPASS = 0, HFXTDRIVE = 2, HFFREQ = 2, T_A = 25°C, $C_{L,eff}$ = 18 pF, typical ESR, C_{shunt}			190		
		f_{OSC} = 24 MHz HFXTBYPASS = 0, HFXTDRIVE = 3, HFFREQ = 3, T_A = 25°C, $C_{L,eff}$ = 18 pF, typical ESR, C_{shunt}			250		
f_{HFXT}	HFXT oscillator crystal frequency, crystal mode	HFXTBYPASS = 0, HFFREQ = 1(8) (7)		4		8	MHz
		HFXTBYPASS = 0, HFFREQ = 2(7)		8.01		16	
		HFXTBYPASS = 0, HFFREQ = 3(7)		16.01		24	
DC_{HFXT}	HFXT oscillator duty cycle	Measured at SMCLK, f_{HFXT} = 16 MHz		40%	50%	60%	
$f_{HFXT,SW}$	HFXT oscillator logic-level square-wave input frequency, bypass mode	HFXTBYPASS = 1, HFFREQ = 0(6) (7)		0.9		4	MHz
		HFXTBYPASS = 1, HFFREQ = 1(6) (7)		4.01		8	
		HFXTBYPASS = 1, HFFREQ = 2(6) (7)		8.01		16	
		HFXTBYPASS = 1, HFFREQ = 3(6) (7)		16.01		24	
$DC_{HFXT, SW}$	HFXT oscillator logic-level square-wave input duty cycle	HFXTBYPASS = 1		40%		60%	
OA_{HFXT}	Oscillation allowance for HFXT crystals(9)	HFXTBYPASS = 0, HFXTDRIVE = 0, HFFREQ = 1(8), $f_{HFXT,HF}$ = 4 MHz, $C_{L,eff}$ = 16 pF			450		Ω
		HFXTBYPASS = 0, HFXTDRIVE = 1, HFFREQ = 1, $f_{HFXT,HF}$ = 8 MHz, $C_{L,eff}$ = 16 pF			320		
		HFXTBYPASS = 0, HFXTDRIVE = 2, HFFREQ = 2, $f_{HFXT,HF}$ = 16 MHz, $C_{L,eff}$ = 16 pF			200		
		HFXTBYPASS = 0, HFXTDRIVE = 3, HFFREQ = 3, $f_{HFXT,HF}$ = 24 MHz, $C_{L,eff}$ = 16 pF			200		

8.13.3.2 High-Frequency Crystal Oscillator, HFXT (continued)

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)(5)

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
$t_{START,HFXT}$	Start-up time(10)	f_{OSC} = 4 MHz, HFXTBYPASS = 0, HFXTDRIVE = 0, HFFREQ = 1, T_A = 25°C, $C_{L,eff}$ = 16 pF	3.0 V		1.6		ms
		f_{OSC} = 24 MHz, HFXTBYPASS = 0, HFXTDRIVE = 3, HFFREQ = 3, T_A = 25°C, $C_{L,eff}$ = 16 pF	3.0 V		0.6		
C_{HFXIN}	Integrated load capacitance at HFXIN terminal(1) (2)				2		pF
C_{HFXOUT}	Integrated load capacitance at HFXOUT terminal(1) (2)				2		pF
$f_{Fault,HFXT}$	Oscillator fault frequency(4) (3)			0		800	kHz

(1) This represents all the parasitic capacitance present at the HFXIN and HFXOUT terminals, respectively, including parasitic bond and package capacitance. The effective load capacitance, $C_{L,eff}$ can be computed as $C_{IN} \times C_{OUT} / (C_{IN} + C_{OUT})$, where C_{IN} and C_{OUT} is the total capacitance at the HFXIN and HFXOUT terminals, respectively.

(2) Requires external capacitors at both terminals to meet the effective load capacitance specified by crystal manufacturers. Recommended effective load capacitance values supported are 14 pF, 16 pF, and 18 pF. Maximum shunt capacitance of 7 pF. The PCB adds additional capacitance, so it must also be considered in the overall capacitance. Verify that the recommended effective load capacitance of the selected crystal is met.

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

(4) Frequencies above the MAX specification do not set the fault flag. Frequencies between the MIN and MAX specifications might set the flag. A static condition or stuck at fault condition will set the flag.

(5) To improve EMI on the HFXT oscillator the following guidelines should be observed.
- Keep the traces 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 HFXIN and HFXOUT.
- Avoid running PCB traces underneath or adjacent to the HFXIN and HFXOUT pins.
- Use assembly materials and processes that avoid any parasitic load on the oscillator LFXIN and LFXOUT pins.
- If conformal coating is used, ensure that it does not induce capacitive or resistive leakage between the oscillator pins.

(6) When HFXTBYPASS is set, HFXT circuits are automatically powered down. Input signal is a digital square wave with parametrics defined in the Schmitt-trigger Inputs section of this datasheet. Duty cycle requirements are defined by $DC_{HFXT, SW}$.

(7) Maximum frequency of operation of the entire device cannot be exceeded.

(8) HFFREQ = {0} is not supported for HFXT crystal mode of operation.

(9) Oscillation allowance is based on a safety factor of 5 for recommended crystals.

(10) Includes start-up counter of 1024 clock cycles.

8.13.3.3 DCO

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

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
f_{DCO1}	DCO frequency range 1 MHz, trimmed	Measured at SMCLK, divide by 1, DCORSEL = 0, DCOFSEL = 0, DCORSEL = 1, DCOFSEL = 0			1	±3.5%	MHz
$f_{DCO2.7}$	DCO frequency range 2.7 MHz, trimmed	Measured at SMCLK, divide by 1, DCORSEL = 0, DCOFSEL = 1			2.667	±3.5%	MHz
$f_{DCO3.5}$	DCO frequency range 3.5 MHz, trimmed	Measured at SMCLK, divide by 1, DCORSEL = 0, DCOFSEL = 2			3.5	±3.5%	MHz
f_{DCO4}	DCO frequency range 4 MHz, trimmed	Measured at SMCLK, divide by 1, DCORSEL = 0, DCOFSEL = 3			4	±3.5%	MHz
$f_{DCO5.3}$	DCO frequency range 5.3 MHz, trimmed	Measured at SMCLK, divide by 1, DCORSEL = 0, DCOFSEL = 4, DCORSEL = 1, DCOFSEL = 1			5.333	±3.5%	MHz
f_{DCO7}	DCO frequency range 7 MHz, trimmed	Measured at SMCLK, divide by 1, DCORSEL = 0, DCOFSEL = 5, DCORSEL = 1, DCOFSEL = 2			7	±3.5%	MHz
f_{DCO8}	DCO frequency range 8 MHz, trimmed	Measured at SMCLK, divide by 1, DCORSEL = 0, DCOFSEL = 6, DCORSEL = 1, DCOFSEL = 3			8	±3.5%	MHz
f_{DCO16}	DCO frequency range 16 MHz, trimmed	Measured at SMCLK, divide by 1, DCORSEL = 1, DCOFSEL = 4			16	±3.5%(2)	MHz
f_{DCO21}	DCO frequency range 21 MHz, trimmed	Measured at SMCLK, divide by 2, DCORSEL = 1, DCOFSEL = 5			21	±3.5%(2)	MHz
f_{DCO24}	DCO frequency range 24 MHz, trimmed	Measured at SMCLK, divide by 2, DCORSEL = 1, DCOFSEL = 6			24	±3.5%(2)	MHz
$f_{DCO,DC}$	Duty cycle	Measured at SMCLK, divide by 1, No external divide, all DCORSEL and DCOFSEL settings except DCORSEL = 1, DCOFSEL = 5 and DCORSEL = 1, DCOFSEL = 6		48%	50%	52%	
$t_{DCO, JITTER}$	DCO jitter	Based on f_{signal} = 10 kHz and DCO used for 12-bit SAR ADC sampling source. This achieves >74-dB SNR due to jitter; that is, limited by ADC performance.			2	3	ns
df_{DCO}/dT	DCO temperature drift(1)		3.0 V		0.01		%/°C

(1) Calculated using the box method: (MAX(–40°C to 85°C) – MIN(–40°C to 85°C)) / MIN(–40°C to 85°C) / (85°C – (–40°C))

(2) After a wakeup from LPM1, LPM2, LPM3, or LPM4, the DCO frequency f_{DCO} might exceed the specified frequency range for a few clock cycles by up to 5% before settling to the specified steady state frequency range.

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

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{VLO}	Current consumption			100		nA
f_{VLO}	VLO frequency	Measured at ACLK	6	9.4	14	kHz
df_{VLO}/d_T	VLO frequency temperature drift	Measured at ACLK(1)		0.2		%/°C
df_{VLO}/dV_{CC}	VLO frequency supply voltage drift	Measured at ACLK(2)		0.7		%/V
$f_{VLO,DC}$	Duty cycle	Measured at ACLK	40%	50%	60%	

(1) Calculated using the box method: (MAX(–40°C to 85°C) – MIN(–40°C to 85°C)) / MIN(–40°C to 85°C) / (85°C – (–40°C))
(2) Calculated using the box method: (MAX(1.8 V to 3.6 V) – MIN(1.8 V to 3.6 V)) / MIN(1.8 V to 3.6 V) / (3.6 V – 1.8 V)

8.13.3.5 Module Oscillator (MODOSC)

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{MODOSC}	Current consumption	Enabled		25		µA
f_{MODOSC}	MODOSC frequency		4.0	4.8	5.4	MHz
f_{MODOSC}/dT	MODOSC frequency temperature drift(1)			0.08		%/°C
f_{MODOSC}/dV_{CC}	MODOSC frequency supply voltage drift(2)			1.4		%/V
DC_{MODOSC}	Duty cycle	Measured at SMCLK, divide by 1	40%	50%	60%	

(1) Calculated using the box method: (MAX(–40°C to 85°C) – MIN(–40°C to 85°C)) / MIN(–40°C to 85°C) / (85°C – (–40°C))
(2) Calculated using the box method: (MAX(1.8 V to 3.6 V) – MIN(1.8 V to 3.6 V)) / MIN(1.8 V to 3.6 V) / (3.6 V – 1.8 V)

8.13.4 Wake-up Characteristics

8.13.4.1 Wake-up Times From Low-Power Modes and Reset

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

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
$t_{WAKE-UP\ FRAM}$	(Additional) wake-up time to activate the FRAM in AM if previously disabled by the FRAM controller or from an LPM if immediate activation is selected for wakeup				6	10	µs
$t_{WAKE-UP\ LPM0}$	Wake-up time from LPM0 to active mode(1)		2.2 V, 3.0 V			400 + 1.5/f_{DCO}	ns
$t_{WAKE-UP\ LPM1}$	Wake-up time from LPM1 to active mode(1)		2.2 V, 3.0 V		6		µs
$t_{WAKE-UP\ LPM2}$	Wake-up time from LPM2 to active mode(1)		2.2 V, 3.0 V		6		µs
$t_{WAKE-UP\ LPM3}$	Wake-up time from LPM3 to active mode(1)		2.2 V, 3.0 V		6.6 + 2.0/f_{DCO}	9.6 + 2.5/f_{DCO}	µs
$t_{WAKE-UP\ LPM4}$	Wake-up time from LPM4 to active mode(1)		2.2 V, 3.0 V		6.6 + 2.0/f_{DCO}	9.6 + 2.5/f_{DCO}	µs
$t_{WAKE-UP\ LPM3.5}$	Wake-up time from LPM3.5 to active mode(2)		2.2 V, 3.0 V		350	450	µs
$t_{WAKE-UP\ LPM4.5}$	Wake-up time from LPM4.5 to active mode(2)	SVSHE = 1	2.2 V, 3.0 V		350	450	µs
		SVSHE = 0	2.2 V, 3.0 V		0.4	0.8	ms
$t_{WAKE-UP-RST}$	Wake-up time from a $\overline{RST}$ pin triggered reset to active mode(2)		2.2 V, 3.0 V		480	596	µs
$t_{WAKE-UP-BOR}$	Wake-up time from power-up to active mode (2)		2.2 V, 3.0 V		0.5	1	ms

(1) The wake-up time is measured from the edge of an external wake-up signal (for example, port interrupt or wake-up event) to the first externally observable MCLK clock edge with MCLKREQEN = 1. This time includes the activation of the FRAM during wakeup. With MCLKREQEN = 0, the externally observable MCLK clock is gated one additional cycle.

(2) The wake-up time is measured from the edge of an external wake-up signal (for example, port interrupt or wake-up event) until the first instruction of the user program is executed.

8.13.4.2 Typical Wake-up Charges

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)(1)

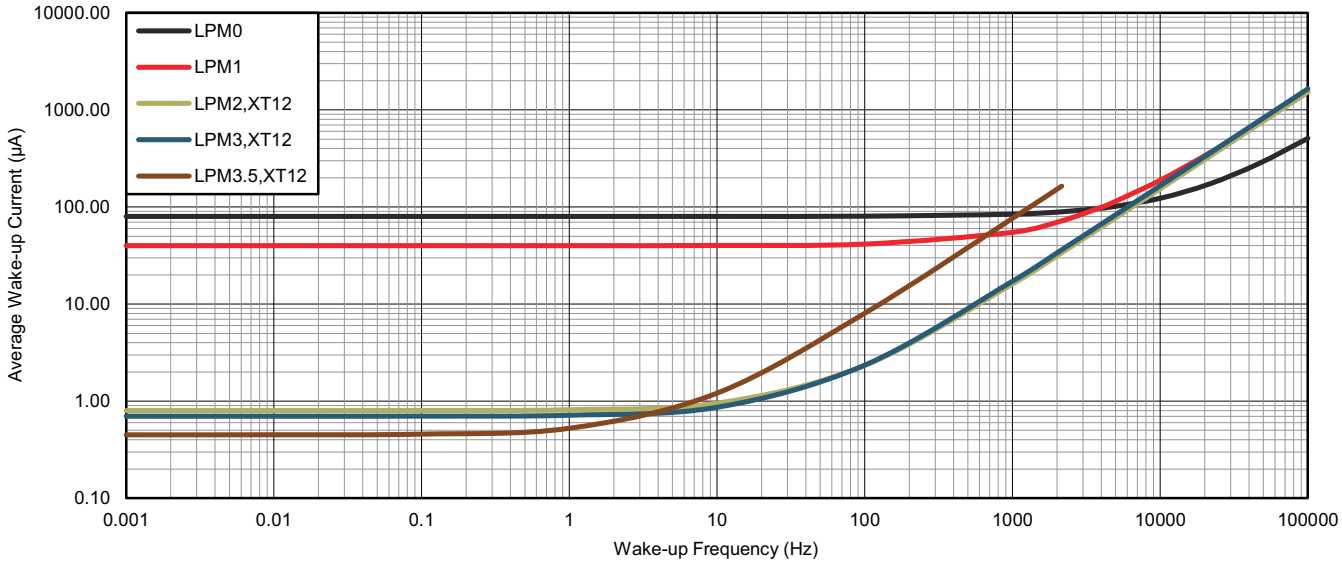
PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$Q_{WAKE-UP\ FRAM}$	Charge used for activating the FRAM in AM or during wakeup from LPM0 if previously disabled by the FRAM controller.			16.5		nAs
$Q_{WAKE-UP\ LPM0}$	Charge used to wake up from LPM0 to active mode (with FRAM active)			3.8		nAs
$Q_{WAKE-UP\ LPM1}$	Charge used to wake up from LPM1 to active mode (with FRAM active)			21		nAs
$Q_{WAKE-UP\ LPM2}$	Charge used to wake up from LPM2 to active mode (with FRAM active)			22		nAs
$Q_{WAKE-UP\ LPM3}$	Charge used to wake up from LPM3 to active mode (with FRAM active)			28		nAs
$Q_{WAKE-UP\ LPM4}$	Charge used to wake up from LPM4 to active mode (with FRAM active)			28		nAs
$Q_{WAKE-UP\ LPM3.5}$	Charge used to wake up from LPM3.5 to active mode(2)			170		nAs
$Q_{WAKE-UP\ LPM4.5}$	Charge used to wake up from LPM4.5 to active mode(2)	SVSHE = 1		173		nAs
		SVSHE = 0		171		
$Q_{WAKE-UP-RESET}$	Charge used for reset from $\overline{RST}$ or BOR event to active mode(2)			148		nAs

(1) Charge used during the wake-up time from a given low-power mode to active mode. This does not include the energy required in active mode (for example, for an interrupt service routine).

(2) Charge required until start of user code. This does not include the energy required to reconfigure the device.

8.13.4.3 Typical Characteristics, Average LPM Currents vs Wake-up Frequency

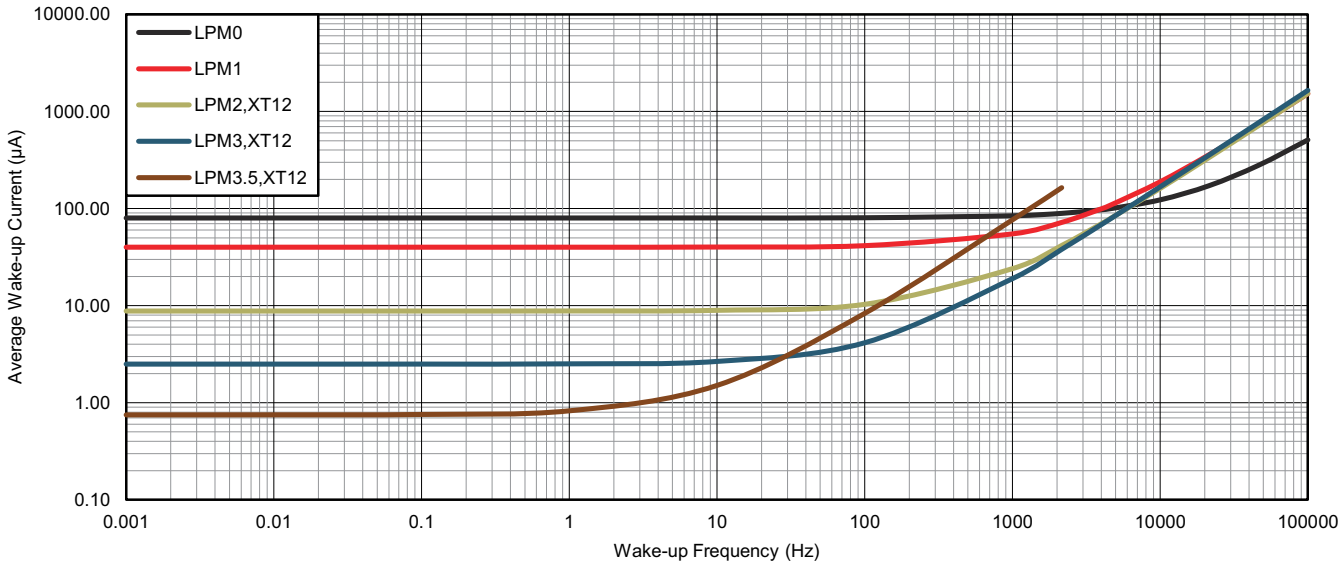
Figure 8-6 shows the average LPM currents vs wake-up frequency at 25°C.



The average wake-up current does not include the energy required in active mode; for example, for an interrupt service routine or to reconfigure the device.

Figure 8-6. Average LPM Currents vs Wake-up Frequency at 25°C

Figure 8-7 shows the average LPM currents vs wake-up frequency at 85°C.



The average wake-up current does not include the energy required in active mode; for example, for an interrupt service routine or to reconfigure the device.

Figure 8-7. Average LPM Currents vs Wake-up Frequency at 85°C

8.13.5 Digital I/Os

8.13.5.1 Digital Inputs

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

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
V_{IT+}	Positive-going input threshold voltage		2.2 V	1.2		1.65	V
			3.0 V	1.65		2.25	
V_{IT-}	Negative-going input threshold voltage		2.2 V	0.55		1.00	V
			3.0 V	0.75		1.35	
V_{hys}	Input voltage hysteresis ($V_{IT+} – V_{IT-}$)		2.2 V	0.44		0.98	V
			3.0 V	0.60		1.30	
R_{Pull}	Pullup or pulldown resistor	For pullup: $V_{IN} = V_{SS}$ For pulldown: $V_{IN} = V_{CC}$		20	35	50	kΩ
$C_{I,dig}$	Input capacitance, digital only port pins	$V_{IN} = V_{SS}$ or V_{CC}			3		pF
$C_{I,ana}$	Input capacitance, port pins with shared analog functions(1)	$V_{IN} = V_{SS}$ or V_{CC}			5		pF
$I_{lkg(Px.y)}$	High-impedance input leakage current	See (2) (3)	2.2 V, 3.0 V	–20		+20	nA
$t_{(int)}$	External interrupt timing (external trigger pulse duration to set interrupt flag)(4)	Ports with interrupt capability (see Section 7.3)	2.2 V, 3.0 V	20			ns
$t_{(RST)}$	External reset pulse duration on $\overline{RST}$ (5)		2.2 V, 3.0 V	2			µs

(1) If the port pins PJ.4/LFXIN and PJ.5/LFXOUT are used as digital I/Os, they are connected by a 4-pF capacitor and a 35-MΩ resistor in series. At frequencies of approximately 1 kHz and lower, the 4-pF capacitor can add to the pin capacitance of PJ.4/LFXIN and/or PJ.5/LFXOUT.

(2) The input leakage current is measured with V_{SS} or V_{CC} applied to the corresponding pins, unless otherwise noted.

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

(4) An external signal sets the interrupt flag every time the minimum interrupt pulse duration $t_{(int)}$ is met. It might be set by trigger signals shorter than $t_{(int)}$.

(5) Not applicable if $\overline{RST}$/NMI pin configured as NMI

8.13.5.2 Digital Outputs

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

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
V_{OH}	High-level output voltage (see Figure 8-10 and Figure 8-11)	$I_{(OHmax)}$ = –1 mA(1)	2.2 V	V_{CC} – 0.25		V_{CC}	V
		$I_{(OHmax)}$ = –3 mA(2)		V_{CC} – 0.60		V_{CC}	
		$I_{(OHmax)}$ = –2 mA(1)	3.0 V	V_{CC} – 0.25		V_{CC}	
		$I_{(OHmax)}$ = –6 mA(2)		V_{CC} – 0.60		V_{CC}	
V_{OL}	Low-level output voltage (see Figure 8-8 and Figure 8-9)	$I_{(OLmax)}$ = 1 mA(1)	2.2 V	V_{SS}		V_{SS} + 0.25	V
		$I_{(OLmax)}$ = 3 mA(2)		V_{SS}		V_{SS} + 0.60	
		$I_{(OLmax)}$ = 2 mA(1)	3.0 V	V_{SS}		V_{SS} + 0.25	
		$I_{(OLmax)}$ = 6 mA(2)		V_{SS}		V_{SS} + 0.60	
$f_{Px.y}$	Port output frequency (with load)(5)	C_L = 20 pF, R_L (3) (4)	2.2 V	16			MHz
			3.0 V	16			
f_{Port_CLK}	Clock output frequency(5)	ACLK, MCLK, or SMCLK at configured output port, C_L = 20 pF(4)	2.2 V	16			MHz
			3.0 V	16			
$t_{rise,dig}$	Port output rise time, digital only port pins	C_L = 20 pF	2.2 V		4	15	ns
			3.0 V		3	15	
$t_{fall,dig}$	Port output fall time, digital only port pins	C_L = 20 pF	2.2 V		4	15	ns
			3.0 V		3	15	
$t_{rise,ana}$	Port output rise time, port pins with shared analog functions	C_L = 20 pF	2.2 V		6	15	ns
			3.0 V		4	15	
$t_{fall,ana}$	Port output fall time, port pins with shared analog functions	C_L = 20 pF	2.2 V		6	15	ns
			3.0 V		4	15	

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

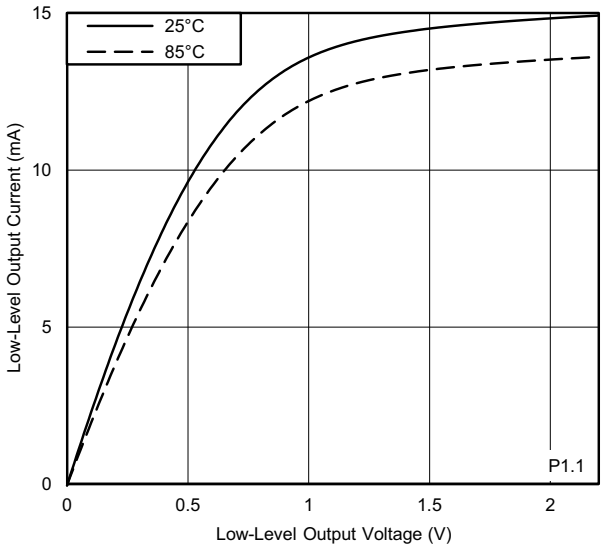
(2) The maximum total current, $I_{(OHmax)}$ and $I_{(OLmax)}$, for all outputs combined should not exceed ±100 mA to hold the maximum voltage drop specified.

(3) A resistive divider with 2 × R1 and R1 = 1.6 kΩ between V_{CC} and V_{SS} is used as load. The output is connected to the center tap of the divider. C_L = 20 pF is connected from the output to V_{SS}.

(4) The output voltage reaches at least 10% and 90% V_{CC} at the specified toggle frequency.

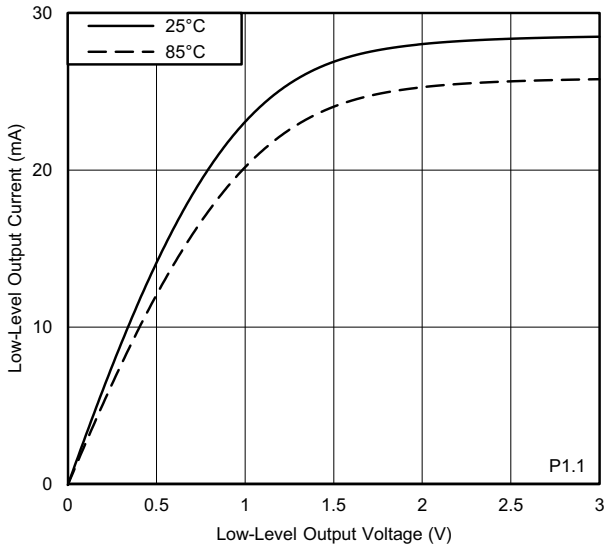
(5) The port can output frequencies at least up to the specified limit, and the port might support higher frequencies.

8.13.5.3 Typical Characteristics, Digital Outputs



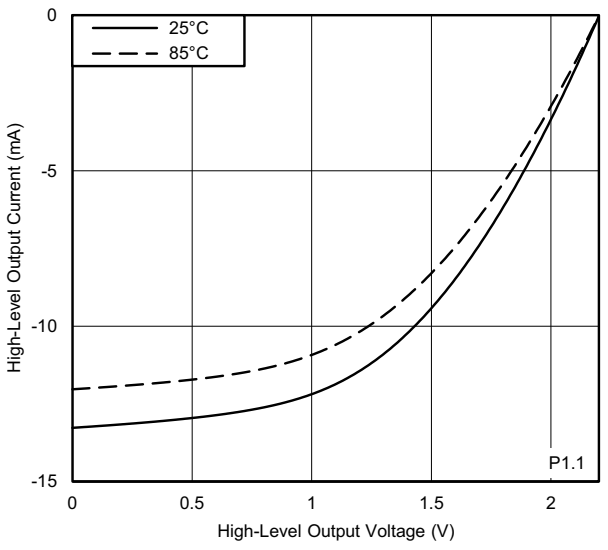
V_{CC} = 2.2 V

Figure 8-8. Typical Low-Level Output Current vs Low-Level Output Voltage



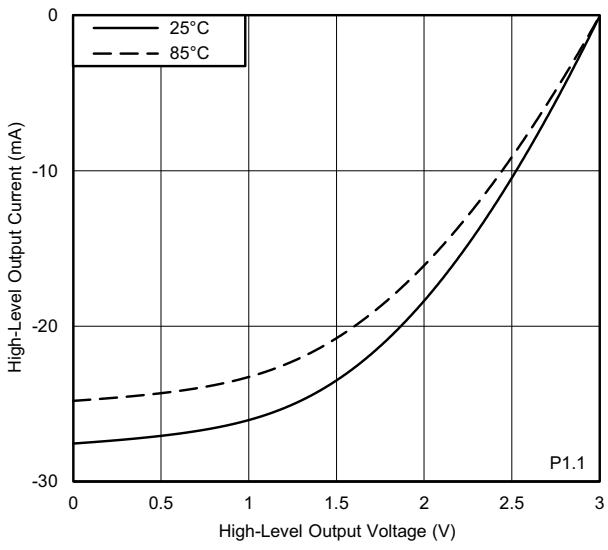
V_{CC} = 3.0 V

Figure 8-9. Typical Low-Level Output Current vs Low-Level Output Voltage



V_{CC} = 2.2 V

Figure 8-10. Typical High-Level Output Current vs High-Level Output Voltage



V_{CC} = 3.0 V

Figure 8-11. Typical High-Level Output Current vs High-Level Output Voltage

8.13.6 LEA

8.13.6.1 Low-Energy Accelerator (LEA) Performance

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

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
f_{LEA}	Frequency for specified performance	MCLK			16		MHz
W_LEA_FFT	LEA subsystem energy on fast Fourier transform	Complex FFT 128 pt. Q.15 with random data in LEA-RAM	V_{CORE} = 3 V, MCLK = 16 MHz		350		nJ
W_LEA_FIR	LEA subsystem energy on finite impulse response	Real FIR on random Q.31 data with 128 taps on 24 points	V_{CORE} = 3 V, MCLK = 16 MHz		2.6		µJ
W_LEA_ADD	LEA subsystem energy on additions	On 32 Q.31 elements with random value out of LEA-RAM with linear address increment	V_{CORE} = 3 V, MCLK = 16 MHz		6.6		nJ

8.13.7 Timer_A and Timer_B

8.13.7.1 Timer_A

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

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
f_{TA}	Timer_A input clock frequency	Internal: SMCLK or ACLK, External: TACLK, Duty cycle = 50% ±10%	2.2 V, 3.0 V			16	MHz
$t_{TA,cap}$	Timer_A capture timing	All capture inputs, minimum pulse duration required for capture	2.2 V, 3.0 V	20			ns

8.13.7.2 Timer_B

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

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
f_{TB}	Timer_B input clock frequency	Internal: SMCLK or ACLK, External: TBCLK, Duty cycle = 50% ±10%	2.2 V, 3.0 V			16	MHz
$t_{TB,cap}$	Timer_B capture timing	All capture inputs, minimum pulse duration required for capture	2.2 V, 3.0 V	20			ns

8.13.8 eUSCI

8.13.8.1 eUSCI (UART Mode) Clock Frequency

PARAMETER		CONDITIONS	MIN	MAX	UNIT
f_{eUSCI}	eUSCI input clock frequency	Internal: SMCLK or ACLK, External: UCLK, Duty cycle = 50% ±10%		16	MHz
f_{BITCLK}	BITCLK clock frequency (equals baud rate in MBaud)			4	MHz

8.13.8.2 eUSCI (UART Mode) Switching Characteristics

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

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
t_t	UART receive deglitch time(1)	UCGLITx = 0	2.2 V, 3.0 V	5		30	ns
		UCGLITx = 1		20		90	
		UCGLITx = 2		35		160	
		UCGLITx = 3		50		220	

(1) Pulses on the UART receive input (UCxRX) shorter than the UART receive deglitch time are suppressed. Thus the selected deglitch time can limit the maximum useable baud rate. To ensure that pulses are correctly recognized, their duration should exceed the maximum specification of the deglitch time.

8.13.8.3 eUSCI (SPI Master Mode) Clock Frequency

PARAMETER		TEST CONDITIONS	MIN	MAX	UNIT
f_{eUSCI}	eUSCI input clock frequency	Internal: SMCLK or ACLK, Duty cycle = 50% ±10%		16	MHz

8.13.8.4 eUSCI (SPI Master Mode) Switching Characteristics

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)(1)

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
$t_{STE,LEAD}$	STE lead time, STE active to clock	UCSTEM = 1, UCMODEx = 01 or 10		1			UCxCLK cycles
$t_{STE,LAG}$	STE lag time, Last clock to STE inactive	UCSTEM = 1, UCMODEx = 01 or 10		1			UCxCLK cycles
$t_{STE,ACC}$	STE access time, STE active to SIMO data out	UCSTEM = 0, UCMODEx = 01 or 10	2.2 V, 3.0 V			60	ns
$t_{STE,DIS}$	STE disable time, STE inactive to SOMI high impedance	UCSTEM = 0, UCMODEx = 01 or 10	2.2 V, 3.0 V			80	ns
$t_{SU,MI}$	SOMI input data setup time		2.2 V	40			ns
			3.0 V	40			
$t_{HD,MI}$	SOMI input data hold time		2.2 V	0			ns
			3.0 V	0			
$t_{VALID,MO}$	SIMO output data valid time(2)	UCLK edge to SIMO valid, C_L = 20 pF	2.2 V			11	ns
			3.0 V			10	
$t_{HD,MO}$	SIMO output data hold time(3)	C_L = 20 pF	2.2 V		0		ns
			3.0 V		0		

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

(2) Specifies the time to drive the next valid data to the SIMO output after the output changing UCLK clock edge. See the timing diagrams in Figure 8-12 and Figure 8-13.

(3) Specifies how long data on the SIMO output is valid after the output changing UCLK clock edge. Negative values indicate that the data on the SIMO output can become invalid before the output changing clock edge observed on UCLK. See the timing diagrams in Figure 8-12 and Figure 8-13.

8.13.8.5 eUSCI (SPI Master Mode) Timing Diagrams

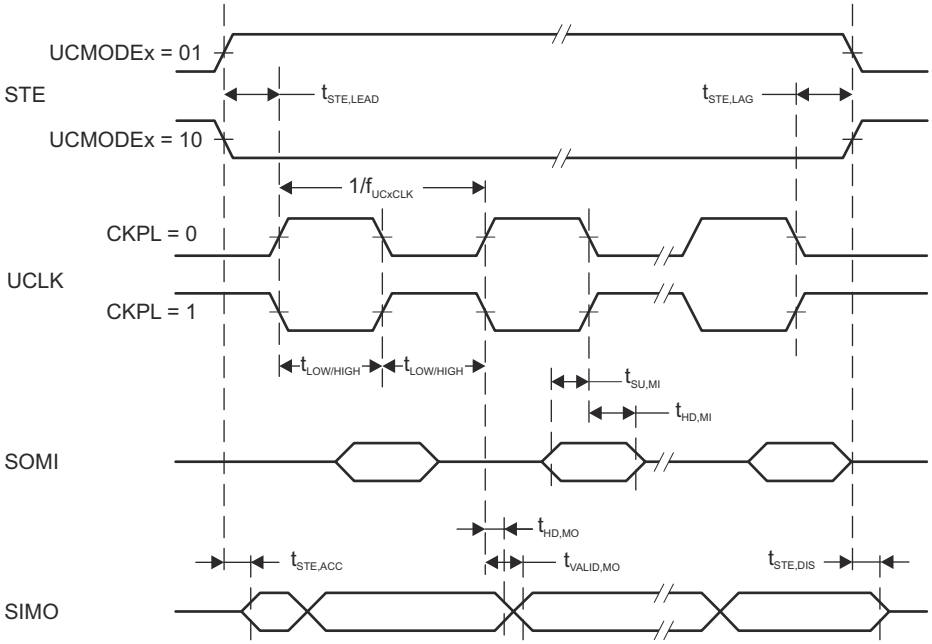


Figure 8-12. SPI Master Mode, CKPH = 0

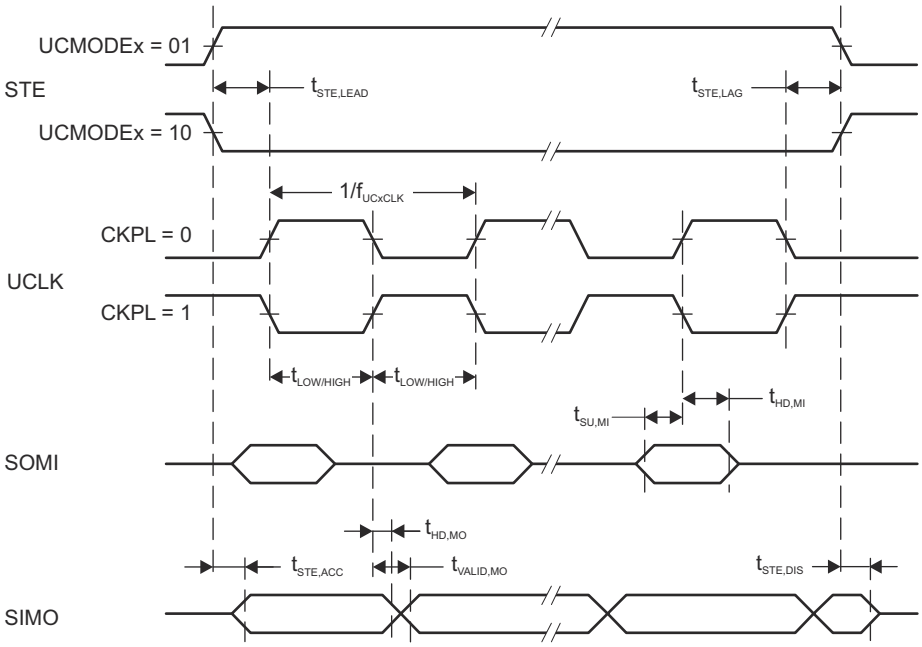


Figure 8-13. SPI Master Mode, CKPH = 1

8.13.8.6 eUSCI (SPI Slave Mode) Switching Characteristics

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)[1]

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	MAX	UNIT
$t_{STE,LEAD}$	STE lead time, STE active to clock		2.2 V	45		ns
			3.0 V	40		
$t_{STE,LAG}$	STE lag time, Last clock to STE inactive		2.2 V	2		ns
			3.0 V	3		
$t_{STE,ACC}$	STE access time, STE active to SOMI data out		2.2 V		45	ns
			3.0 V		40	
$t_{STE,DIS}$	STE disable time, STE inactive to SOMI high impedance		2.2 V		50	ns
			3.0 V		45	
$t_{SU,SI}$	SIMO input data setup time		2.2 V	4		ns
			3.0 V	4		
$t_{HD,SI}$	SIMO input data hold time		2.2 V	7		ns
			3.0 V	7		
$t_{VALID,SO}$	SOMI output data valid time[2]	UCLK edge to SOMI valid, C_L = 20 pF	2.2 V		35	ns
			3.0 V		35	
$t_{HD,SO}$	SOMI output data hold time[3]	C_L = 20 pF	2.2 V	0		ns
			3.0 V	0		

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

(2) Specifies the time to drive the next valid data to the SOMI output after the output changing UCLK clock edge. See the timing diagrams in Figure 8-14 and Figure 8-15.

(3) Specifies how long data on the SOMI output is valid after the output changing UCLK clock edge. See the timing diagrams in Figure 8-14 and Figure 8-15.

8.13.8.7 eUSCI (SPI Slave Mode) Timing Diagrams

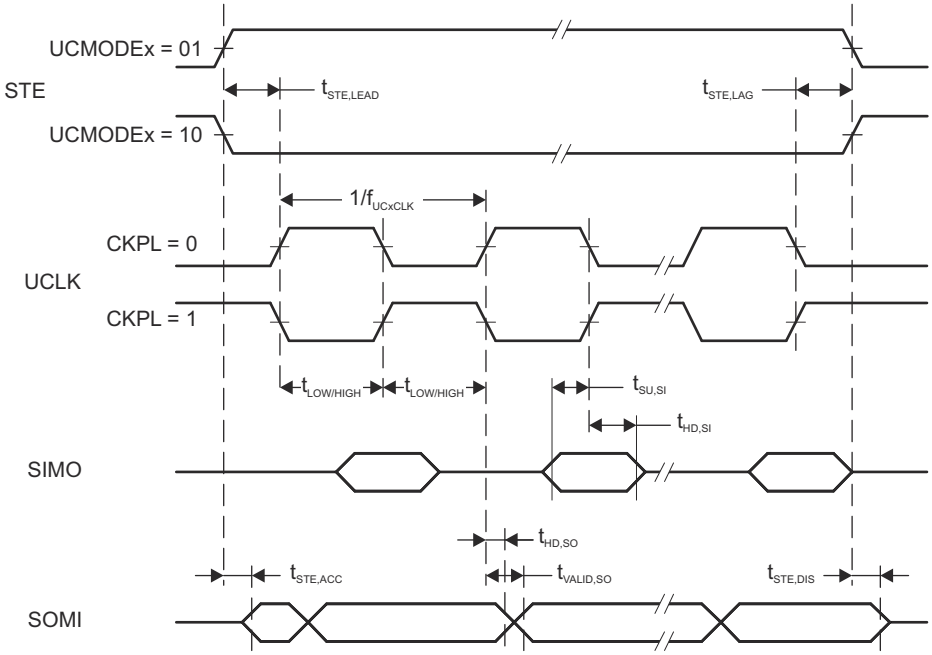


Figure 8-14. SPI Slave Mode, CKPH = 0

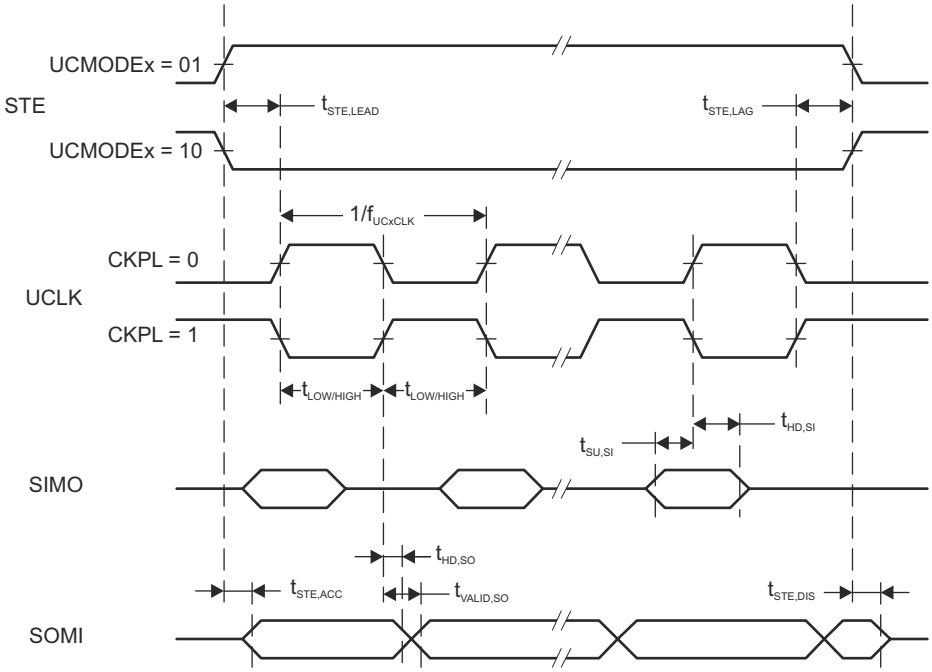


Figure 8-15. SPI Slave Mode, CKPH = 1

8.13.8.8 eUSCI (I²C Mode) Switching Characteristics

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted) (see Figure 8-16)

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
f_{eUSCI}	eUSCI input clock frequency	Internal: SMCLK or ACLK, External: UCLK, Duty cycle = 50% ±10%				16	MHz
f_{SCL}	SCL clock frequency		2.2 V, 3.0 V	0		400	kHz
$t_{HD,STA}$	Hold time (repeated) START	f_{SCL} = 100 kHz	2.2 V, 3.0 V	4.0			µs
		f_{SCL} > 100 kHz		0.6			
$t_{SU,STA}$	Setup time for a repeated START	f_{SCL} = 100 kHz	2.2 V, 3.0 V	4.7			µs
		f_{SCL} > 100 kHz		0.6			
$t_{HD,DAT}$	Data hold time		2.2 V, 3.0 V	0			ns
$t_{SU,DAT}$	Data setup time		2.2 V, 3.0 V	100			ns
$t_{SU,STO}$	Setup time for STOP	f_{SCL} = 100 kHz	2.2 V, 3.0 V	4.0			µs
		f_{SCL} > 100 kHz		0.6			
t_{BUF}	Bus free time between a STOP and START condition	f_{SCL} = 100 kHz		4.7			us
		f_{SCL} > 100 kHz		1.3			
t_{SP}	Pulse duration of spikes suppressed by input filter	UCGLITx = 0	2.2 V, 3.0 V	50		250	ns
		UCGLITx = 1		25		125	
		UCGLITx = 2		12.5		62.5	
		UCGLITx = 3		6.3		31.5	
$t_{TIMEOUT}$	Clock low time-out	UCCLTOx = 1	2.2 V, 3.0 V		27		ms
		UCCLTOx = 2			30		
		UCCLTOx = 3			33		

8.13.8.9 eUSCI (I²C Mode) Timing Diagram

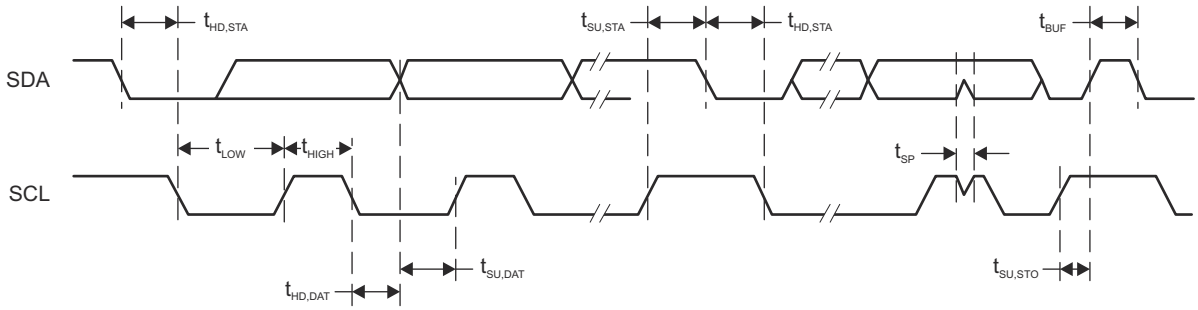


Figure 8-16. I²C Mode Timing

8.13.9 Segment LCD Controller

8.13.9.1 LCD_C Recommended Operating Conditions

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

PARAMETER		CONDITIONS	MIN	NOM	MAX	UNIT
$V_{CC,LCD\_C,CP\ en,3.6}$	Supply voltage range, charge pump enabled, $V_{LCD} \le 3.6$ V	LCDCPEN = 1, 0000b < VLCDx ≤ 1111b (charge pump enabled, $V_{LCD} \le 3.6$ V)	2.2		3.6	V
$V_{CC,LCD\_C,CP\ en,3.3}$	Supply voltage range, charge pump enabled, $V_{LCD} \le 3.3$ V	LCDCPEN = 1, 0000b < VLCDx ≤ 1100b (charge pump enabled, $V_{LCD} \le 3.3$ V)	2.0		3.6	V
$V_{CC,LCD\_C,int.\ bias}$	Supply voltage range, internal biasing, charge pump disabled	LCDCPEN = 0, VLCDEXT = 0	2.4		3.6	V
$V_{CC,LCD\_C,ext.\ bias}$	Supply voltage range, external biasing, charge pump disabled	LCDCPEN = 0, VLCDEXT = 0	2.4		3.6	V
$V_{CC,LCD\_C,VLCDEXT}$	Supply voltage range, external LCD voltage, internal or external biasing, charge pump disabled	LCDCPEN = 0, VLCDEXT = 1	2.0		3.6	V
V_{LCDCAP}	External LCD voltage at LCDCAP, internal or external biasing, charge pump disabled	LCDCPEN = 0, VLCDEXT = 1	2.4		3.6	V
C_{LCDCAP}	Capacitor value on LCDCAP when charge pump enabled	LCDCPEN = 1, VLCDx > 0000b (charge pump enabled)	$4.7_{-20\%}$	4.7	$10_{+20\%}$	µF
$f_{ACLK,in}$	ACLK input frequency range		30	32.768	40	kHz
f_{LCD}	LCD frequency range	$f_{FRAME} = (1 / (2 \times mux)) \times f_{LCD}$ with mux = 1 (static) to 8	0		1024	Hz
$f_{FRAME,4mux}$	LCD frame frequency range	$f_{FRAME,4mux}(MAX) = (1 / (2 \times 4)) \times f_{LCD}(MAX) = (1 / (2 \times 4)) \times 1024$ Hz			128	Hz
C_{Panel}	Panel capacitance	f_{LCD} = 1024 Hz, all common lines equally loaded			10000	pF
V_{R33}	Analog input voltage at R33	LCDCPEN = 0, VLCDEXT = 1	2.4		V_{CC} + 0.2	V
$V_{R23,1/3bias}$	Analog input voltage at R23	LCDREXT = 1, LCDEXTBIAS = 1, LCD2B = 0	V_{R13}	V_{R03} + 2/3 × (V_{R33} – V_{R03})	V_{R33}	V
$V_{R13,1/3bias}$	Analog input voltage at R13 with 1/3 biasing	LCDREXT = 1, LCDEXTBIAS = 1, LCD2B = 0	V_{R03}	V_{R03} + 1/3 × (V_{R33} – V_{R03})	V_{R23}	V
$V_{R13,1/2bias}$	Analog input voltage at R13 with 1/2 biasing	LCDREXT = 1, LCDEXTBIAS = 1, LCD2B = 1	V_{R03}	V_{R03} + 1/2 × (V_{R33} – V_{R03})	V_{R33}	V
V_{R03}	Analog input voltage at R03	R0EXT = 1	V_{SS}			V
$V_{LCD} – V_{R03}$	Voltage difference between V_{LCD} and R03	LCDCPEN = 0, R0EXT = 1	2.4		V_{CC} + 0.2	V
V_{LCDREF}	External LCD reference voltage applied at LCDREF	VLCDREFx = 01	0.8	1.0	1.2	V

8.13.9.2 LCD_C Electrical Characteristics

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

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
$V_{LCD,0}$	LCD voltage	VLCDx = 0000, VLCDEXT = 0	2.4 V to 3.6 V		V_{CC}		V
$V_{LCD,1}$		LCDCPEN = 1, VLCDx = 0001b	2 V to 3.6 V	2.49	2.60	2.72	
$V_{LCD,2}$		LCDCPEN = 1, VLCDx = 0010b	2 V to 3.6 V		2.66		
$V_{LCD,3}$		LCDCPEN = 1, VLCDx = 0011b	2 V to 3.6 V		2.72		
$V_{LCD,4}$		LCDCPEN = 1, VLCDx = 0100b	2 V to 3.6 V		2.78		
$V_{LCD,5}$		LCDCPEN = 1, VLCDx = 0101b	2 V to 3.6 V		2.84		
$V_{LCD,6}$		LCDCPEN = 1, VLCDx = 0110b	2 V to 3.6 V		2.90		
$V_{LCD,7}$		LCDCPEN = 1, VLCDx = 0111b	2 V to 3.6 V		2.96		
$V_{LCD,8}$		LCDCPEN = 1, VLCDx = 1000b	2 V to 3.6 V		3.02		
$V_{LCD,9}$		LCDCPEN = 1, VLCDx = 1001b	2 V to 3.6 V		3.08		
$V_{LCD,10}$		LCDCPEN = 1, VLCDx = 1010b	2 V to 3.6 V		3.14		
$V_{LCD,11}$		LCDCPEN = 1, VLCDx = 1011b	2 V to 3.6 V		3.20		
$V_{LCD,12}$		LCDCPEN = 1, VLCDx = 1100b	2 V to 3.6 V		3.26		
$V_{LCD,13}$		LCDCPEN = 1, VLCDx = 1101b	2.2 V to 3.6 V		3.32		
$V_{LCD,14}$		LCDCPEN = 1, VLCDx = 1110b	2.2 V to 3.6 V		3.38		
$V_{LCD,15}$		LCDCPEN = 1, VLCDx = 1111b	2.2 V to 3.6 V	3.32	3.44	3.6	
$V_{LCD,7,0.8}$	LCD voltage with external reference of 0.8 V	LCDCPEN = 1, VLCDx = 0111b, VLCDREFx = 01b, V_{LCDREF} = 0.8 V	2 V to 3.6 V		2.96 × 0.8 V		V
$V_{LCD,7,1.0}$	LCD voltage with external reference of 1.0 V	LCDCPEN = 1, VLCDx = 0111b, VLCDREFx = 01b, V_{LCDREF} = 1.0 V	2 V to 3.6 V		2.96 × 1.0 V		V
$V_{LCD,7,1.2}$	LCD voltage with external reference of 1.2 V	LCDCPEN = 1, VLCDx = 0111b, VLCDREFx = 01b, V_{LCDREF} = 1.2 V	2.2 V to 3.6 V		2.96 × 1.2 V		V
ΔV_{LCD}	Voltage difference between consecutive VLCDx settings	$\Delta V_{LCD} = V_{LCD,x} - V_{LCD,x-1}$ with x = 0010b to 1111b		40	60	80	mV
$I_{CC,Peak,CP}$	Peak supply currents due to charge pump activities	LCDCPEN = 1, VLCDx = 1111b external, with decoupling capacitor on DVCC supply ≥1 µF	2.2 V		600		µA
$t_{LCD,CP,on}$	Time to charge C_{LCD} when discharged	C_{LCD} = 4.7 µF, LCDCPEN = 0→1, VLCDx = 1111b	2.2 V		100	500	ms
$I_{CP,Load}$	Maximum charge pump load current	LCDCPEN = 1, VLCDx = 1111b	2.2 V	50			µA
$R_{LCD,Seg}$	LCD driver output impedance, segment lines	LCDCPEN = 0, I_{LOAD} = ±10 µA	2.2 V			10	kΩ
$R_{LCD,COM}$	LCD driver output impedance, common lines	LCDCPEN = 0, I_{LOAD} = ±10 µA	2.2 V			10	kΩ

8.13.10 ADC12_B

8.13.10.1 12-Bit ADC, Power Supply and Input Range Conditions

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

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	NOM	MAX	UNIT
$V_{(Ax)}$	Analog input voltage range(1)	All ADC12 analog input pins Ax		0		AVCC	V
$I_{(ADC12\_B)}$ single-ended mode	Operating supply current into AVCC and DVCC terminals(2) (3)	$f_{ADC12CLK}$ = MODCLK, ADC12ON = 1, ADC12PWRMD = 0, ADC12DIF = 0, REFON = 0, ADC12SHTx = 0, ADC12DIV = 0	3.0 V		145	199	µA
		$f_{ADC12CLK}$ = MODCLK, ADC12ON = 1, ADC12PWRMD = 0, ADC12DIF = 0, REFON = 0, ADC12SHTx = 0, ADC12DIV = 0	2.2 V		140	190	
$I_{(ADC12\_B)}$ differential mode	Operating supply current into AVCC and DVCC terminals(2) (3)	$f_{ADC12CLK}$ = MODCLK, ADC12ON = 1, ADC12PWRMD = 0, ADC12DIF = 1, REFON = 0, ADC12SHTx= 0, ADC12DIV = 0	3.0 V		175	245	µA
			2.2 V		170	230	
$I_{(ADC12\_B)}$ single-ended low-power mode	Operating supply current into AVCC and DVCC terminals(2) (3)	$f_{ADC12CLK}$ = MODCLK/4, ADC12ON = 1, ADC12PWRMD = 1, ADC12DIF = 0, REFON = 0, ADC12SHTx = 0, ADC12DIV = 0	3.0 V		85	125	µA
		$f_{ADC12CLK}$ = MODCLK/4, ADC12ON = 1, ADC12PWRMD = 1, ADC12DIF = 0, REFON = 0, ADC12SHTx = 0, ADC12DIV = 0	2.2 V		83	120	
$I_{(ADC12\_B)}$ differential low-power mode	Operating supply current into AVCC and DVCC terminals(2) (3)	$f_{ADC12CLK}$ = MODCLK/4, ADC12ON = 1, ADC12PWRMD = 1, ADC12DIF = 1, REFON = 0, ADC12SHTx= 0, ADC12DIV = 0	3.0 V		110	165	µA
			2.2 V		109	160	
C_I	Input capacitance	Only one terminal Ax can be selected at one time	2.2 V		10	15	pF
R_I	Input MUX ON resistance	0 V ≤ $V_{(Ax)}$ ≤ AV_{CC}	>2 V		0.5	4	kΩ
			<2 V		1	10	

(1) The analog input voltage range must be within the selected reference voltage range V_{R+} to V_{R-} for valid conversion results.
(2) The internal reference supply current is not included in current consumption parameter I(ADC12_B).
(3) Approximately 60% (typical) of the total current into the AVCC and DVCC terminal is from AVCC.

8.13.10.2 12-Bit ADC, Timing Parameters

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

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$f_{ADC12CLK}$	Frequency for specified performance	For specified performance of ADC12 linearity parameters with ADC12PWRMD = 0, If ADC12PWRMD = 1, the maximum is 1/4 of the value shown here		0.45		5.4	MHz
$f_{ADC12CLK}$	Frequency for reduced performance	Linearity parameters have reduced performance			32.768		kHz
$f_{ADC12OSC}$	Internal oscillator(3)	ADC12DIV = 0, $f_{ADC12CLK} = f_{ADC12OSC}$ from MODCLK		4	4.8	5.4	MHz
$t_{CONVERT}$	Conversion time	REFON = 0, Internal oscillator, $f_{ADC12CLK} = f_{ADC12OSC}$ from MODCLK, ADC12WINC = 0		2.6		3.5	µs
		External $f_{ADC12CLK}$ from ACLK, MCLK, or SMCLK, ADC12SSEL ≠ 0		See (2)			
$t_{ADC12ON}$	Turnon settling time of the ADC	See (1)				100	ns
$t_{ADC12OFF}$	Time ADC must be off before can be turned on again	Note: $t_{ADC12OFF}$ must be met to make sure that $t_{ADC12ON}$ time holds.		100			ns
t_{Sample}	Sampling time	R_S = 400 Ω, R_I = 4 kΩ, C_I = 15 pF, C_{pext}= 8 pF(4)	All pulse sample mode (ADC12SHP = 1) and extended sample mode (ADC12SHP = 0) with buffered reference (ADC12VRSEL = 0x1, 0x3, 0x5, 0x7, 0x9, 0xB, 0xD, 0xF)	1			µs
			Extended sample mode (ADC12SHP = 0) with unbuffered reference (ADC12VRSEL= 0x0, 0x2, 0x4, 0x6, 0xC, 0xE)	See (5)			

(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) 14 × 1 / $f_{ADC12CLK}$. If ADC12WINC = 1 then 15 × 1 / $f_{ADC12CLK}$.

(3) The ADC12OSC is sourced directly from MODOSC in the UCS.

(4) Approximately 10 Tau (τ) are needed to get an error of less than ±0.5 LSB: $t_{sample} = \ln(2^{n+2}) \times (R_S + R_I) \times (C_I + C_{pext})$, where n = ADC resolution = 12, R_S= external source resistance, C_{pext} = external parasitic capacitance.

(5) 6 × 1 / $f_{ADC12CLK}$

8.13.10.3 12-Bit ADC, Linearity Parameters

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
E_I	Integral linearity error (INL) for differential input	With external voltage reference (ADC12VRSEL = 0x2, 0x3, 0x4, 0x14, 0x15), $1.2\ V \le (V_{R+} - V_{R-}) \le AV_{CC}$			±1.8	LSB
	Integral linearity error (INL) for single-ended inputs	With external voltage reference (ADC12VRSEL = 0x2, 0x3, 0x4, 0x14, 0x15), $1.2\ V \le (V_{R+} - V_{R-}) \le AV_{CC}$			±2.2	
E_D	Differential linearity error (DNL)	With external voltage reference (ADC12VRSEL = 0x2, 0x3, 0x4, 0x14, 0x15),	–0.99		+1.0	LSB
E_O	Offset error(1) (2)	ADC12VRSEL = 0x1 without TLV calibration, TLV calibration data can be used to improve the parameter(3)		±0.5	±1.5	mV
E_G	Gain error	With internal voltage reference V_{REF} = 2.5 V (ADC12VRSEL = 0x1, 0x7, 0x9, 0xB, or 0xD)		±0.2%	±1.7%	
		With internal voltage reference V_{REF} = 1.2 V (ADC12VRSEL = 0x1, 0x7, 0x9, 0xB, or 0xD)		±0.2%	±2.5%	
		With external voltage reference without internal buffer (ADC12VRSEL = 0x2 or 0x4) without TLV calibration, V_{R+} = 2.5 V, V_{R-} = AVSS		±1	±3	LSB
		With external voltage reference with internal buffer (ADC12VRSEL = 0x3), V_{R+} = 2.5 V, V_{R-} = AVSS		±2	±27	
E_T	Total unadjusted error	With internal voltage reference V_{REF} = 2.5 V (ADC12VRSEL = 0x1, 0x7, 0x9, 0xB, or 0xD)		±0.2%	±1.8%	
		With internal voltage reference V_{REF} = 1.2 V (ADC12VRSEL = 0x1, 0x7, 0x9, 0xB, or 0xD)		±0.2%	±2.6%	
		With external voltage reference without internal buffer (ADC12VRSEL = 0x2 or 0x4) without TLV calibration, V_{R+} = 2.5 V, V_{R-} = AVSS		±1	±5	LSB
		With external voltage reference with internal buffer (ADC12VRSEL = 0x3), V_{R+} = 2.5 V, V_{R-} = AVSS		±1	±28	

(1) Offset is measured as the input voltage (at which ADC output transitions from 0 to 1) minus 0.5 LSB.
(2) Offset increases as I_R drop increases when V_{R-} is AVSS.
(3) For details, see the *Device Descriptor Table* section in the MSP430FR58xx, MSP430FR59xx, and MSP430FR6xx Family User's Guide.

8.13.10.4 12-Bit ADC, Dynamic Performance With External Reference

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Resolution	Number of no missing code output-code bits		12			bits
SNR	Signal-to-noise with differential inputs	V_{R+} = 2.5 V, V_{R-} = AV_{SS}		71		dB
	Signal-to-noise with single-ended inputs	V_{R+} = 2.5 V, V_{R-} = AV_{SS}		70		
ENOB	Effective number of bits with differential inputs(1)	V_{R+} = 2.5 V, V_{R-} = AV_{SS}		11.4		bits
	Effective number of bits with single-ended inputs(1)	V_{R+} = 2.5 V, V_{R-} = AV_{SS}		11.1		
	Effective number of bits with 32.768-kHz clock (reduced performance)(1)	Reduced performance with $f_{ADC12CLK}$ from ACLK LFXT 32.768 kHz, V_{R+} = 2.5 V, V_{R-} = AV_{SS}		10.9		

(1) ENOB = (SINAD – 1.76) / 6.02

8.13.10.5 12-Bit ADC, Dynamic Performance With Internal Reference

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Resolution	Number of no missing code output-code bits		12			bits
SNR	Signal-to-noise with differential inputs	V_{R+} = 2.5 V, V_{R-} = AV_{SS}		70		dB
	Signal-to-noise with single-ended inputs	V_{R+} = 2.5 V, V_{R-} = AV_{SS}		69		
ENOB	Effective number of bits with differential inputs(1)	V_{R+} = 2.5 V, V_{R-} = AV_{SS}		11.4		bits
	Effective number of bits with single-ended inputs(1)	V_{R+} = 2.5 V, V_{R-} = AV_{SS}		11.0		
	Effective number of bits with 32.768-kHz clock (reduced performance)(1)	Reduced performance with $f_{ADC12CLK}$ from ACLK LFXT 32.768 kHz, V_{R+} = 2.5 V, V_{R-} = AV_{SS}		10.9		

(1) ENOB = (SINAD – 1.76) / 6.02

8.13.10.6 12-Bit ADC, Temperature Sensor and Built-In $V_{1/2}$

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{SENSOR}	Temperature sensor voltage(1) (2)	ADC12ON = 1, ADC12TCMAP = 1, T_A = 0°C		700		mV
TC_{SENSOR}	See (2)	ADC12ON = 1, ADC12TCMAP = 1		2.5		mV/°C
$t_{SENSOR(sample)}$	Sample time required if ADCTCMAP = 1 and channel (MAX – 1) is selected(3)	ADC12ON = 1, ADC12TCMAP = 1, Error of conversion result ≤1 LSB	30			µs
$V_{1/2}$	AVCC voltage divider for ADC12BATMAP = 1 on MAX input channel	ADC12ON = 1, ADC12BATMAP = 1	47.5%	50%	52.5%	
$I_{V1/2}$	Current for battery monitor during sample time	ADC12ON = 1, ADC12BATMAP = 1		38	72	µA
$t_{V1/2\ (sample)}$	Sample time required if ADC12BATMAP = 1 and channel MAX is selected(4)	ADC12ON = 1, ADC12BATMAP = 1	1.7			µs

(1) The temperature sensor offset can be as much as ±30°C. TI recommends a single-point calibration to minimize the offset error of the built-in temperature sensor.

(2) The device descriptor structure contains calibration values for 30°C ±3°C and 85°C ±3°C for each of the available reference voltage levels. The sensor voltage can be computed as V_{SENSE} = TC_{SENSOR} × (Temperature, °C) + V_{SENSOR}, where TC_{SENSOR} and V_{SENSOR} can be computed from the calibration values for higher accuracy.

(3) The typical equivalent impedance of the sensor is 250 kΩ. The sample time required includes the sensor on-time, $t_{SENSOR(on)}$.

(4) The on-time $t_{V1/2(on)}$ is included in the sampling time $t_{V1/2(sample)}$; no additional on time is needed.

8.13.10.7 12-Bit ADC, External Reference

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)(1)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{R+}	Positive external reference voltage input VeREF+ or VeREF- based on ADC12VRSEL bit	$V_{R+} > V_{R-}$	1.2		AV_{CC}	V
V_{R-}	Negative external reference voltage input VeREF + or VeREF- based on ADC12VRSEL bit	$V_{R+} > V_{R-}$	0		1.2	V
$V_{R+} - V_{R-}$	Differential external reference voltage input	$V_{R+} > V_{R-}$	1.2		AV_{CC}	V
I_{VeREF+}, I_{VeREF-}	Static input current singled-ended input mode	1.2 V ≤ V_{eREF+}≤ V_{AVCC}, V_{eREF-} = 0 V $f_{ADC12CLK}$ = 5 MHz, ADC12SHTx = 1h, ADC12DIF = 0, ADC12PWRMD = 0			±10	µA
		1.2 V ≤ V_{eREF+}≤ V_{AVCC} , V_{eREF-} = 0 V $f_{ADC12CLK}$ = 5 MHz, ADC12SHTx = 8h, ADC12DIF = 0, ADC12PWRMD = 01			±2.5	
I_{VeREF+}, I_{VeREF-}	Static input current differential input mode	1.2 V ≤ V_{eREF+}≤ V_{AVCC}, V_{eREF-} = 0 V $f_{ADC12CLK}$ = 5 MHz, ADC12SHTx = 1h, ADC12DIF = 1, ADC12PWRMD = 0			±20	µA
		1.2 V ≤ V_{eREF+}≤ V_{AVCC} , V_{eREF-} = 0 V $f_{ADC12CLK}$ = 5 MHz, ADC12SHTx = 8h, ADC12DIF = 1, ADC12PWRMD = 1			±5	
I_{VeREF+}	Peak input current with single-ended input	0 V ≤ V_{eREF+} ≤ V_{AVCC}, ADC12DIF = 0			1.5	mA
I_{VeREF+}	Peak input current with differential input	0 V ≤ V_{eREF+} ≤ V_{AVCC}, ADC12DIF = 1			3	mA
$C_{VeREF+/-}$	Capacitance at VeREF+ or VeREF- terminal	See (2)	10			µF

(1) The external reference is used during ADC 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) Connect two decoupling capacitors, 10 µF and 470 nF, from VeREF+ or VeREF– to AVSS to decouple the dynamic current required for an external reference source if it is used for the ADC12_B. Also see the MSP430FR58xx, MSP430FR59xx, and MSP430FR6xx Family User's Guide.

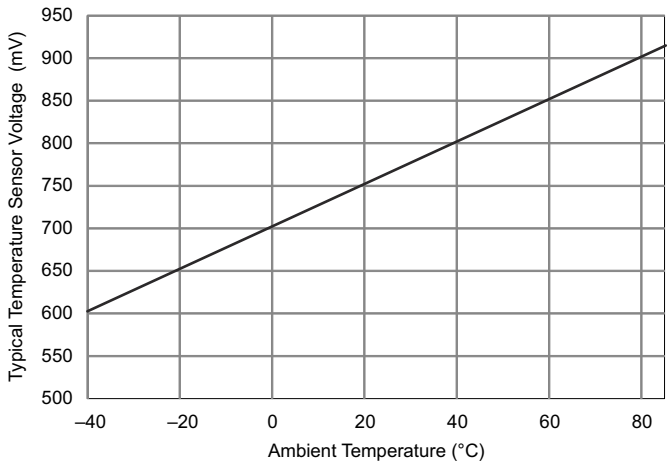


Figure 8-17. Typical Temperature Sensor Voltage

8.13.11 Reference

Section 8.13.11.1 lists the characteristics of the internal reference.

8.13.11.1 REF, Built-In Reference

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

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
V_{REF+}	Positive built-in reference voltage output	REFVSEL = {2} for 2.5 V, REFON = 1	2.7 V		2.5	±1.5%	V
		REFVSEL = {1} for 2.0 V, REFON = 1	2.2 V		2.0	±1.5%	
		REFVSEL = {0} for 1.2 V, REFON = 1	1.8 V		1.2	±1.8%	
Noise	RMS noise at VREF (3)	From 0.1 Hz to 10 Hz, REFVSEL = {0}			30	130	µV
$V_{OS\_BUF\_INT}$	VREF ADC BUF_INT buffer offset(5)	T_A = 25°C, ADC on, REFVSEL = {0}, REFON = 1, REFOUT = 0		–16		+16	mV
$V_{OS\_BUF\_EXT}$	VREF ADC BUF_EXT buffer offset(4)	T_A = 25°C, REFVSEL = {0} , REFOUT = 1, REFON = 1 or ADC on		–16		+16	mV
$AV_{CC(min)}$	AVCC minimum voltage, Positive built-in reference active	REFVSEL = {0} for 1.2 V		1.8			V
		REFVSEL = {1} for 2.0 V		2.2			
		REFVSEL = {2} for 2.5 V		2.7			
I_{REF+}	Operating supply current into AVCC terminal(1)	REFON = 1	3 V		19	26	µA
$I_{REF+\_ADC\_BUF}$	Operating supply current into AVCC terminal(1)	ADC ON, REFOUT = 0, REFVSEL = {0, 1, or 2}, ADC12PWRMD = 0	3 V		247	400	µA
		ADC ON, REFOUT = 1, REFVSEL = {0, 1, 2}, ADC12PWRMD = 0			1053	1820	
		ADC ON, REFOUT = 0, REFVSEL = {0, 1, 2}, ADC12PWRMD = 1			153	240	
		ADC ON, REFOUT = 1, REFVSEL = {0, 1, 2}, ADC12PWRMD = 1			581	1030	
		ADC OFF, REFON = 1, REFOUT = 1, REFVSEL = {0, 1, 2}			1105	1890	
$I_{O(VREF+)}$	VREF maximum load current, VREF+ terminal	REFVSEL = {0, 1, 2}, AV_{CC} = $AV_{CC(min)}$ for each reference level, REFON = REFOUT = 1		–1000		+10	µA
$\Delta V_{out}/\Delta I_{o\ (VREF+)}$	Load-current regulation, VREF+ terminal	REFVSEL = {0, 1, 2}, $I_{O(VREF+)}$ = +10 µA or –1000 µA, AV_{CC} = $AV_{CC(min)}$ for each reference level, REFON = REFOUT = 1				1500	µV/mA
$C_{VREF+/-}$	Capacitance at VREF+ and VREF- terminals	REFON = REFOUT = 1		0		100	pF
TC_{REF+}	Temperature coefficient of built-in reference	REFVSEL = {0, 1, 2}, REFON = REFOUT = 1, T_A = –40°C to 85°C(6)			24	50	ppm/K
PSRR_DC	Power supply rejection ratio (DC)	AV_{CC} = $AV_{CC\ (min)}$ to $AV_{CC(max)}$, T_A = 25°C, REFVSEL = {0, 1, 2}, REFON = REFOUT = 1			100	400	µV/V
PSRR_AC	Power supply rejection ratio (AC)	dAV_{CC}= 0.1 V at 1 kHz			3.0		mV/V
t_{SETTLE}	Settling time of reference voltage(2)	AV_{CC} = $AV_{CC\ (min)}$ to $AV_{CC(max)}$, REFVSEL = {0, 1, 2}, REFON = 0 → 1			40	80	µs
T_{buf_settle}	Settling time of ADC reference voltage buffer(2)	AV_{CC} = $AV_{CC\ (min)}$ to $AV_{CC(max)}$, REFVSEL = {0, 1, 2}, REFON = 1			0.4	2	us

(1) The internal reference current is supplied through the AVCC terminal.
(2) The condition is that the error in a conversion started after t_{REFON} is less than ±0.5 LSB.
(3) Internal reference noise affects ADC performance when ADC uses the internal reference. See Designing With the MSP430FR59xx and MSP430FR58xx ADC for details on optimizing ADC performance for your application with the choice of internal or external reference.
(4) Buffer offset affects ADC gain error and thus total unadjusted error.
(5) Buffer offset affects ADC gain error and thus total unadjusted error.
(6) Calculated using the box method: (MAX(–40°C to 85°C) – MIN(–40°C to 85°C)) / MIN(–40°C to 85°C)/(85°C – (–40°C)).

8.13.12 Comparator

Section 8.13.12.1 lists the characteristics of the comparator.

8.13.12.1 Comparator_E

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

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
I_{AVCC_COMP}	Comparator operating supply current into AVCC, excludes reference resistor ladder	CEPWRMD = 00, CEON = 1, CERSx = 00 (fast)	2.2 V, 3.0 V		12	16	µA
		CEPWRMD = 01, CEON = 1, CERSx = 00 (medium)			10	14	
		CEPWRMD = 10, CEON = 1, CERSx = 00 (slow), T_A = 30°C			0.1	0.3	
		CEPWRMD = 10, CEON = 1, CERSx = 00 (slow), T_A = 85°C			0.3	1.3	
$I_{AVCC\_COMP\_REF}$	Quiescent current of resistor ladder into AVCC, including REF module current	CEREFLx = 01, CERSx = 10, REFON = 0, CEON = 1, CEREFACC = 0	2.2 V, 3.0 V		31	38	µA
		CEREFLx = 01, CERSx = 10, REFON = 0, CEON = 1, CEREFACC = 1			16	19	
V_{REF}	Reference voltage level	CERSx = 11, CEREFLx = 01, CEREFACC = 0	1.8 V	1.152	1.2	1.248	V
		CERSx = 11, CEREFLx = 10, CEREFACC = 0	2.2 V	1.92	2.0	2.08	
		CERSx = 11, CEREFLx = 11, CEREFACC = 0	2.7 V	2.40	2.5	2.60	
		CERSx = 11, CEREFLx = 01, CEREFACC = 1	1.8 V	1.10	1.2	1.245	
		CERSx = 11, CEREFLx = 10, CEREFACC = 1	2.2 V	1.90	2.0	2.08	
		CERSx = 11, CEREFLx = 11, CEREFACC = 1	2.7 V	2.35	2.5	2.60	
V_{IC}	Common-mode input range			0		V_{CC} – 1	V
V_{OFFSET}	Input offset voltage	CEPWRMD = 00		–16		16	mV
		CEPWRMD = 01		–12		12	
		CEPWRMD = 10		–37		37	
C_{IN}	Input capacitance	CEPWRMD = 00 or CEPWRMD = 01			10		pF
		CEPWRMD = 10			10		
R_{SIN}	Series input resistance	ON (switch closed)			1	3	kΩ
		OFF (switch open)		50			MΩ
t_{PD}	Propagation delay, response time	CEPWRMD = 00, CEF = 0, Overdrive ≥ 20 mV			193	330	ns
		CEPWRMD = 01, CEF = 0, Overdrive ≥ 20 mV			230	400	
		CEPWRMD = 10, CEF = 0, Overdrive ≥ 20 mV			5	15	µs
$t_{PD,filter}$	Propagation delay with filter active	CEPWRMD = 00 or 01, CEF = 1, Overdrive ≥ 20 mV, CEFDLY = 00			700	1000	ns
		CEPWRMD = 00 or 01, CEF = 1, Overdrive ≥ 20 mV, CEFDLY = 01			1.0	1.9	µs
		CEPWRMD = 00 or 01, CEF = 1, Overdrive ≥ 20 mV, CEFDLY = 10			2.0	3.7	
		CEPWRMD = 00 or 01, CEF = 1, Overdrive ≥ 20 mV, CEFDLY = 11			4.0	7.7	

8.13.12.1 Comparator_E (continued)

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

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
t_{EN_CMP}	Comparator enable time	CEON = 0 → 1, VIN+, VIN- from pins, Overdrive ≥ 20 mV, CEPWRMD = 00			0.9	1.5	µs
		CEON = 0 → 1, VIN+, VIN- from pins, Overdrive ≥ 20 mV, CEPWRMD = 01			0.9	1.5	
		CEON = 0 → 1, VIN+, VIN- from pins, Overdrive ≥ 20 mV, CEPWRMD = 10			15	65	
$t_{EN\_CMP\_VREF}$	Comparator and reference ladder and reference voltage enable time	CEON = 0 → 1, CEREFLX = 10, CERSx = 10 or 11, CEREF0 = CEREF1 = 0x0F, REFON = 0			120	220	µs
$t_{EN\_CMP\_RL}$	Comparator and reference ladder enable time	CEON = 0 → 1, CEREFLX = 10, CERSx = 10, REFON = 1, CEREF0 = CEREF1 = 0x0F			10	30	
V_{CE_REF}	Reference voltage for a given tap	VIN = reference into resistor ladder, n = 0 to 31		VIN × (n + 0.5) / 32	VIN × (n + 1) / 32	VIN × (n + 1.5) / 32	V

8.13.13 FRAM

Section 8.13.13.1 lists the characteristics of the FRAM.

8.13.13.1 FRAM

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

PARAMETER			T_J	MIN	TYP	MAX	UNIT
	Read and write endurance			10^{15}			cycles
$t_{Retention}$	Data retention duration		25°C	100			years
			70°C	40			
			85°C	10			
I_{WRITE}	Current to write into FRAM(1)				I_{READ}		nA
I_{ERASE}	Erase current(2)				N/A(3)		nA
t_{WRITE}	Write time(4)				t_{READ}		ns
t_{READ}	Read time(5)	NWAITSx = 0			1 / f_{SYSTEM}		ns
		NWAITSx = 1			2 / f_{SYSTEM}		

(1) Writing to FRAM does not require a setup sequence or additional power when compared to reading from FRAM. The FRAM read current I_{READ} is included in the active mode current consumption, $I_{AM,FRAM}$.
(2) FRAM does not require a special erase sequence.
(3) N/A = Not applicable
(4) Writing into FRAM is as fast as reading.
(5) The maximum read (and write) speed is specified by f_{SYSTEM} using the appropriate wait state settings (NWAITSx).

8.13.14 USS

8.13.14.1 USS Recommended Operating Conditions

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
PV_{CC}	Analog supply voltage at PVCC pins for LDO operation		2.2		3.6	V
PV_{CC}	Analog supply voltage at PVCC pins for USS operation		2.2		3.6	V

8.13.14.2 USS LDO

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{CC-LDO}	Analog supply voltage at PVCC pins		2.2		3.6	V
V_{USS}	USS voltage	$0 \le I_{LOAD} \le I_{LOAD,MAX}$	1.52	1.6	1.65	V
$t_{holdoff}$	Hold off delay on power up	LBHDEL = 0		0		µs
		LBHDEL = 1		100		
		LBHDEL = 2		200		
		LBHDEL = 3		300		
$t_{time-out}$	Time-out on transition from OFF to READY			160 + $t_{holdoff}$		µs

8.13.14.3 USSXTAL

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
N_{phase_osc}	Integrated phase noise	f_{osc} = 4 MHz or 8 MHz, range = 10 kHz to 4 MHz		–74		dBc
FRQ_{XTAL}	Resonator frequency		4		8	MHz
DC_{osc}	Duty cycle		35%		65%	
I_{osc}	OSC supply current	f_{osc} = 4 MHz or 8 MHz, C_L = 18 pF, C_S = 4 pF, fully settled, ceramic resonator		180		µA
		f_{osc} = 4 MHz or 8 MHz, C_L = 12 pF (4 MHz) or 16 pF (8 MHz), C_S = 7 pF, fully settled, crystal resonator		240		
A_{osc}	Oscillation allowance	f_{osc} = 4 MHz, C_L = 18 pF, C_S = 4 pF, ceramic resonator		1500		Ω
		f_{osc} = 4 MHz, C_L = 12 pF, C_S = 7 pF, crystal resonator		1000		
		f_{osc} = 8 MHz, C_L = 18 pF, C_S = 4 pF, ceramic resonator		500		
		f_{osc} = 8 MHz, C_L = 16 pF, C_S = 7 pF, crystal resonator		350		
T_{start_osc}	Start-up time (gate)	f_{osc} = 4 MHz, crystal resonator		2.8	4.6	ms
		f_{osc} = 8 MHz, crystal resonator		1	1.9	
		f_{osc} = 4 MHz, ceramic resonator		0.14	0.17	
		f_{osc} = 8 MHz, ceramic resonator		0.08	0.12	

8.13.14.4 USS HSPLL

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
PLL_CLK_{in}	Input clock to HSPLL		4		8	MHz
PLL_CLK_{out}	Output clock from HSPLL		68		80	MHz
$LOCK_{pwr}$	Lock time from PLL power up	Reference clock = PLL_CLK_{in}, Sequence: Set USS.CTL.USSPWRUP bit = 1, then measure the time between PSQ_PLLUP (internal control signal) is set to 1 and HSPLL.CTL.PLL_LOCK is set to 1			64	cycles

8.13.14.5 USS SDHS

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

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_{sdhs}	SDHS power domain supply voltage	$V_{sdhs} = V_{uss}$		1.52	1.6	1.65	V
$I_{sdhs\_product}$	Operating supply current into AVCC and DVCC	Includes PLL, PGA, SDHS, and DTC, modulator clock = 80 MHz, output data rate = 8 Msps			5.2		mA
f_{mod}	Modulator clock			68		80	MHz
BW_{mod}	Frequency at –3-dB SNR	Modulator clock = 80 MHz, modulator only (no filter is enabled)			1.5		MHz
SNR	Signal-to-noise ratio	Bandwidth from 200 kHz to 1.5 MHz, PGA gain: a gain from the PGA gain table for the maximum SNR	100mVpp ≤ Input signal level ≤ 1000 mVpp, PVCC = 3.0 V, f_{mod} = 80 MHz, OSR = 20		45		dB
t_{MOD_Settle}	SDHS settling time (PGA + modulator)	TM2 – TM1, AUTOSSDIS = 0, 1% of settled DC level				40	µs
		TM2 – TM1, AUTOSSDIS = 1, 1% of settled DC level				40	
$DROUT_{sdhs}$	Output data rate					8	Msps

8.13.14.6 USS PHY Output Stage

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
PVCC	PHY supply voltage	PVCC = V_{CC}, PVSS = V_{SS}	2.2		3.6	V
R_{DSonT}	Output impedance of CH0OUT and CH1OUT for high and low sides	PVCC ≥ 2.5 V		3.4		Ω
R_{Term}	Termination impedance of CH0OUT and CH1OUT toward PVSS	PVCC ≥ 2.5 V		3.4		Ω
f_{MAX}	Maximum output frequency	PVCC = V_{CC} (2.5 V to 3.6 V)	4.5			MHz
C_{SUPP}	Supply buffering capacitance (low ESR type)	PVCC = V_{CC}	22	100		µF
R_{SUPP}	Series resistance to C_{SUPP}	PVCC = V_{CC}		22		Ω

8.13.14.7 USS PHY Input Stage, Multiplexer

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{IN}	Input voltage on CH0IN or CH1IN	PVCC = V_{CC}, PVSS = V_{SS}	PVSS – 0.3		1.8	V

8.13.14.8 USS PGA

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

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
PV_{cc}	Supply voltage			2.2		3.6	V
G_N	Gain(1)			–6.5		30.8	dB
V_{inr1}	Input range	2.2 V ≤ PVCC		30		800	mVpp
V_{inr2}	Input range	2.5 V ≤ PVCC		30		1000	mVpp
$V_{inrperf}$	Recommended input range for maximum performance	2.5 V ≤ PVCC		30		800	mVpp
G_{tol}	Gain tolerance	Full PGA gain range, V_{OUT} = 600 mV		–1.5		1.5	dB
G_{Tdrift}	Gain drift with temperature	Full PGA gain range, V_{OUT} = 600 mV			0.0019		dB/°C
G_{Vdrift}	Gain drift with voltage	Full PGA gain range, V_{OUT} = 600 mV			0.15		dB/V
t_{SET}	Gain settling time	Gain setting: from 0 dB to 6 dB, to ±5%			0.65	1.4	µs
DC_{offset}	DC offset (PGA and SDHS)	Full PGA gain range, measured at SDHS output			5.5		mV
DC_{drift}	DC offset drift (PGA and SDHS)	Full PGA gain range, measured at SDHS output			4.7		µV/°C
PSRR_AC	AC power supply rejection ratio	V_{CC} = 3 V + 50 mVpp × sin (2π × f_C) where f_C = 1 MHz, V_{IN} = ground, PSRR_AC = 20log(V_{OUT} / 50 mV)	PGA gain = 0 dB		–41		dB
			PGA gain = 10 dB		–37		
			PGA gain = 30 dB		–19		

(1) See the *PGA Gain* table in the MSP430FR58xx, MSP430FR59xx, and MSP430FR6xx Family User's Guide.

8.13.14.9 USS Bias Voltage Generator

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

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_{exc_bias}	Excitation bias voltage (coupling capacitors)	PVCC = V_{CC} (2.2 V to 3.6 V)	EXCBIAS = 0		200		mV
			EXCBIAS = 1		300		
			EXCBIAS = 2		400		
			EXCBIAS = 3		600		
R_{VBE}	Impedance of excitation bias generator	PVCC = V_{CC} (2.2 V to 3.6 V)	BIMP = 0		450		Ω
			BIMP = 1		850		
			BIMP = 2		1450		
			BIMP = 3		2900		
t_{SBE}	Excitation bias settling time	PVCC = V_{CC} (2.2 V to 3.6 V), to 0.1% end value, R_{ET} = 200 Ω, C_K + C_{0P} = 1 nF, BIMP = 2			20		µs
V_{pga_bias}	PGA bias voltage (coupling capacitors)	PVCC = V_{CC} (2.2 V to 3.6 V)	PGABIAS = 0		750		mV
			PGABIAS = 1		800		
			PGABIAS = 2		900		
			PGABIAS = 3		950		
R_{VBA}	Impedance of acquisition bias generator	PVCC = V_{CC} (2.2 V to 3.6 V)	BIMP = 0		500		Ω
			BIMP = 1		900		
			BIMP = 2		1500		
			BIMP = 3		2950		
t_{SBA}	Acquisition bias settling time	PVCC = V_{CC} (2.2 V to 3.6 V), to 0.1% end value, R_{ET} = 200 Ω, C_K + C_{0P} = 1 nF, BIMP = 2			22		µs

8.13.15 Emulation and Debug

Section 8.13.15.1 lists the characteristics of the JTAG and SBW interface.

8.13.15.1 JTAG and Spy-Bi-Wire Interface

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

PARAMETER		V_{CC}	MIN	TYP	MAX	UNIT
I_{JTAG}	Supply current adder when JTAG active (but not clocked)	2.2 V, 3.0 V		40	100	µA
f_{SBW}	Spy-Bi-Wire input frequency	2.2 V, 3.0 V	0		10	MHz
$t_{SBW,Low}$	Spy-Bi-Wire low clock pulse duration	2.2 V, 3.0 V	0.04		15	µs
$t_{SBW, En}$	Spy-Bi-Wire enable time (TEST high to acceptance of first clock edge)(1)	2.2 V, 3.0 V			110	µs
$t_{SBW,Rst}$	Spy-Bi-Wire return to normal operation time		15		100	µs
f_{TCK}	TCK input frequency, 4-wire JTAG(2)	2.2 V	0		16	MHz
		3.0 V	0		16	
$R_{internal}$	Internal pulldown resistance on TEST	2.2 V, 3.0 V	20	35	50	kΩ
f_{TCLK}	TCLK/MCLK frequency during JTAG access, no FRAM access (limited by f_{SYSTEM})				16	MHz
$t_{TCLK,Low/High}$	TCLK low or high clock pulse duration, no FRAM access				25	ns
$f_{TCLK,FRAM}$	TCLK/MCLK frequency during JTAG access, including FRAM access (limited by f_{SYSTEM} with no FRAM wait states)				4	MHz
$t_{TCLK,FRAM, Low/High}$	TCLK low or high clock pulse duration, including FRAM accesses				100	ns

(1) Tools that access the Spy-Bi-Wire and the BSL interfaces must wait for the $t_{SBW,En}$ time after the first transition of the TEST/SBWTCK pin (low to high), before the second transition of the pin (high to low) during the entry sequence.

(2) f_{TCK} may be restricted to meet the timing requirements of the module selected.

9 Detailed Description

9.1 Overview

The TI MSP430FR60xx family of ultra-low-power microcontrollers consists of several devices featuring different sets of peripherals. The architecture, combined with seven low-power modes, is optimized to achieve extended battery life for example in portable measurement applications. The devices features a powerful 16-bit RISC CPU, 16-bit registers, and constant generators that contribute to maximum code efficiency.

The device is an MSP430FR6xx family device with ultrasonic sensing solution (USS), low-energy accelerator (LEA), up to six 16-bit timers, up to six eUSCIs that support UART, SPI, and I^2C, a comparator, a hardware multiplier, an AES accelerator, a 6-channel DMA, an RTC module with alarm capabilities, up to 76 I/O pins, and a high-performance 12-bit ADC. The MSP430FR60xx devices also include an LCD module with contrast control for displays with up to 264 segments.

9.2 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. The peripherals can be managed with all instructions.

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.

9.3 Ultrasonic Sensing Solution (USS) Module

The USS module provides a high-precision ultrasonic sensing solution. The USS module is a sophisticated system that consists of six submodules:

- UUPS (universal USS power supply)
- HSPLL (high-speed PLL) with oscillator
- ASQ (acquisition sequencer)
- PHY (physical interface)
- PPG (programmable pulse generator) with low-output-impedance driver
- PGA (programmable gain amplifier)
- SDHS (sigma-delta high-speed ADC) with DTC (data transfer controller)

The submodules have different roles, and together they enable high-precision data acquisition in ultrasonic applications. See the dedicated chapter for each submodule in the *MSP430FR58xx, MSP430FR59xx, and MSP430FR6xx Family User's Guide*.

The USS module performs complete measurement sequence without CPU involvement to achieve ultra-low power consumption for ultrasonic metrology. Figure 9-1 shows the USS subsystem block diagram. The USS module has dedicated I/O pins without secondary functions. See the *Ultrasonic Sensing Solution (USS)* chapter in the *MSP430FR58xx, MSP430FR59xx, and MSP430FR6xx Family User's Guide* for details.

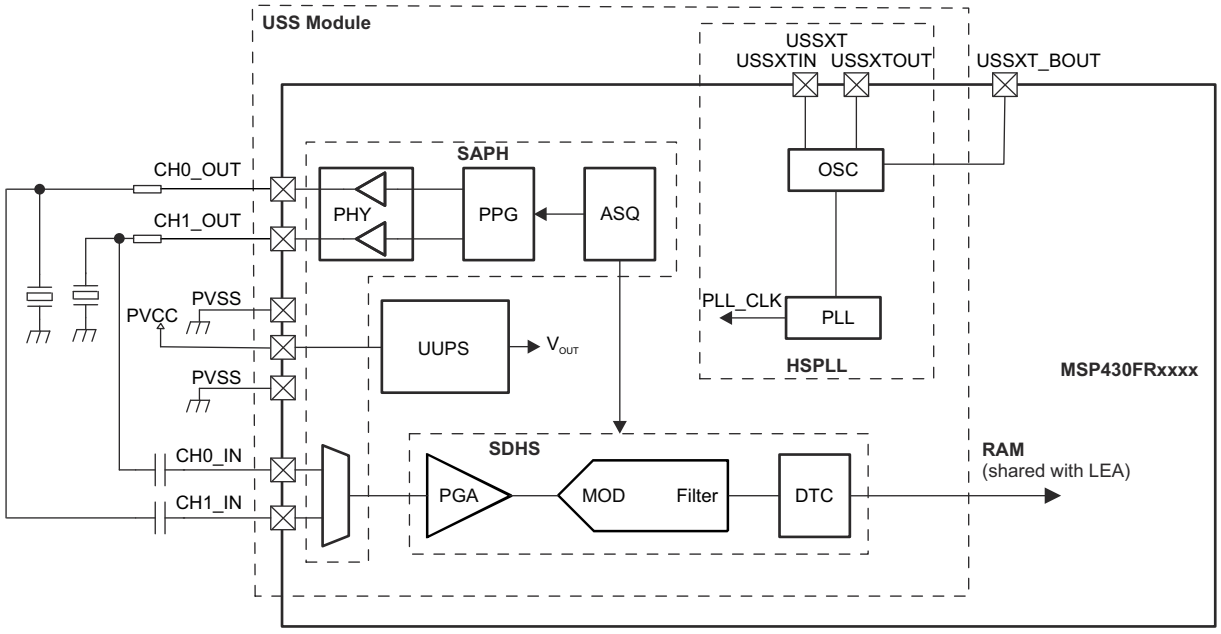


Figure 9-1. USS Subsystem Block Diagram

9.4 Low-Energy Accelerator (LEA) for Signal Processing

The LEA is a hardware engine designed for operations that involve vector-based signal processing, such as FIR, IIR, and FFT. The LEA offers fast performance and low energy consumption when performing vector-based digital signal processing computations. For performance benchmarks comparing LEA to using the CPU or other processors, see *Benchmarking the Signal Processing Capabilities of the Low-Energy Accelerator*.

The LEA requires MCLK to be operational; therefore, LEA operates only in active mode or LPM0. While the LEA is running, the LEA data operations are performed on a shared 4KB of RAM out of the 8KB of total RAM (see Table 9-45). This shared RAM can also be used by the regular application. The MSP CPU and the LEA can run simultaneously and independently unless they access the same system RAM.

Direct access to LEA registers is not supported, and TI offers the optimized Digital Signal Processing (DSP) Library for MSP Microcontrollers for the operations that the LEA module supports.

9.5 Operating Modes

The MCU has one active mode and seven software-selectable low-power modes of operation. An interrupt event can wake the device from low-power modes LPM0 to LPM4, service the request, and return to the low-power mode on return from the interrupt. LPM3.5 and LPM4.5 disable the core supply to minimize power consumption. Table 9-1 lists the operating modes and the clocks and peripherals that are available in each.

Note

XT1CLK and VLOCLK can be active during LPM4 if requested by low-frequency peripherals such as RTC or WDT.

Table 9-1. Operating Modes

MODE	AM		LPM0	LPM1	LPM2	LPM3	LPM4	LPM3.5	LPM4.5	
	ACTIVE	ACTIVE, FRAM OFF(1)	CPU OFF(2)	CPU OFF	STANDBY	STANDBY	OFF	RTC ONLY	SHUTDOWN WITH SVS	SHUTDOWN WITHOUT SVS
Maximum system clock	16 MHz		16 MHz	16 MHz	50 kHz	50 kHz	0(3)	50 kHz	0(3)	
Typical current consumption, T_A = 25°C	103 µA/MHz	65 µA/MHz	70 µA at 1 MHz	35 µA at 1 MHz	0.7 µA	0.4 µA	0.3 µA	0.25 µA	0.2 µA	0.02 µA
Typical wake-up time	N/A		instant	6 µs	6 µs	7 µs	7 µs	250 µs	250 µs	1000 µs
Wake-up events	N/A		all	all	LF, RTC, I/O, Comp	LF, RTC, I/O, Comp	I/O, Comp	RTC, I/O	I/O	
CPU	on		off	off	off	off	off	reset	reset	
USS	on		on	off	off	off	off	reset	reset	
LEA	on		on(10)	off	off	off	off	reset	reset	
FRAM	**on**	off(1)	standby or off(1)	off	off	off	off	off	off	
High-frequency peripherals	**available**		**available**	**available**	off	off	off	reset	reset	
Low-frequency peripherals	**available**		**available**	**available**	**available**	**available** (4)	off	RTC	reset	
Unclocked peripherals(5)	**available**		**available**	**available**	**available**	**available** (4)	**available** (4)	reset	reset	
MCLK	**on**		**on(10)**	**off**	off	off	off	off	off	
SMCLK	optional(6)		optional(6)	optional(6)	off	off	off	off	off	
ACLK	**on**		**on**	**on**	**on**	**on**	off	off	off	
Full retention	**yes**		**yes**	**yes**	**yes**	**yes**	**yes**	no	no	
SVS	always		always	always	optional(7)	optional(7)	optional(7)	optional(7)	on(8)	off(9)
Brownout	**always**		**always**	**always**	**always**	**always**	**always**	**always**	**always**	

(1) FRAM is disabled in the FRAM controller (FRCTL_A).
(2) Disabling the FRAM through the FRAM controller (FRCTL_A) allows the application to lower the LPM current consumption but the wake-up time increases when FRAM is accessed (for example, to fetch an interrupt vector). For a wakeup that does not involve FRAM (for example, a DMA transfer to RAM) the wake-up time is not increased.
(3) All clocks disabled
(4) See Section 9.5.2, which describes the use of peripherals in LPM3 and LPM4.
(5) *Unclocked peripherals* are peripherals that do not require a clock source to operate; for example, the comparator and REF, or the eUSCI when operated as an SPI slave.
(6) Controlled by SMCLKOFF.
(7) Activated SVS (SVSHE = 1) results in higher current consumption. SVS is not included in typical current consumption.

(8) SVSHE = 1
(9) SVSHE = 0
(10) Only while the LEA is performing a task enabled by the CPU during AM. The LEA cannot be enabled in LPM0.

9.5.1 Peripherals in Low-Power Modes

Peripherals can be in different states that affect the achievable power modes of the device. The states depend on the operational modes of the peripherals (see Table 9-2). The states are:

- A peripheral is in a "high-frequency state" if it requires or uses a clock with a "high" frequency of more than 50 kHz.
- A peripheral is in a "low-frequency state" if it requires or uses a clock with a "low" frequency of 50 kHz or less.
- A peripheral is in an "unclocked state" if it does not require or use an internal clock.

If the CPU requests a power mode that does not support the current state of all active peripherals, the device does not enter the requested power mode, but it does enter a power mode that still supports the current state of the peripherals, except if an external clock is used. If an external clock is used, the application must use the correct frequency range for the requested power mode.

Table 9-2. Peripheral States

PERIPHERAL	IN HIGH-FREQUENCY STATE(1)	IN LOW-FREQUENCY STATE(2)	IN UNCLOCKED STATE(3)
WDT	Clocked by SMCLK	Clocked by ACLK	Not applicable
DMA(4)	Not applicable	Not applicable	Waiting for a trigger
RTC_C	Not applicable	Clocked by LFXT	Not applicable
LCD_C	Not applicable	Clocked by ACLK or VLOCLK	Not applicable
Timer_A, TAx	Clocked by SMCLK or clocked by external clock >50 kHz	Clocked by ACLK or clocked by external clock ≤50 kHz	Clocked by external clock ≤50 kHz
Timer_B, TBx	Clocked by SMCLK or clocked by external clock >50 kHz	Clocked by ACLK or clocked by external clock ≤50 kHz	Clocked by external clock ≤50 kHz
eUSCI_Ax in UART mode	Clocked by SMCLK	Clocked by ACLK	Waiting for first edge of START bit
eUSCI_Ax in SPI master mode	Clocked by SMCLK	Clocked by ACLK	Not applicable
eUSCI_Ax in SPI slave mode	Clocked by external clock >50 kHz	Clocked by external clock ≤50 kHz	Clocked by external clock ≤50 kHz
eUSCI_Bx in I^2C master mode	Clocked by SMCLK or clocked by external clock >50 kHz	Clocked by ACLK or clocked by external clock ≤50 kHz	Not applicable
eUSCI_Bx in I^2C slave mode	Clocked by external clock >50 kHz	Clocked by external clock ≤50 kHz	Waiting for START condition or clocked by external clock ≤50 kHz
eUSCI_Bx in SPI master mode	Clocked by SMCLK	Clocked by ACLK	Not applicable
eUSCI_Bx in SPI slave mode	Clocked by external clock >50 kHz	Clocked by external clock ≤50 kHz	Clocked by external clock ≤50 kHz
ADC12_B	Clocked by SMCLK or by MODOSC	Clocked by ACLK	Waiting for a trigger
REF_A	Not applicable	Not applicable	Always
COMP_E	Not applicable	Not applicable	Always
CRC(5)	Not applicable	Not applicable	Not applicable
MPY(5)	Not applicable	Not applicable	Not applicable
AES(5)	Not applicable	Not applicable	Not applicable

(1) Peripherals are in a state that requires or uses a clock with a "high" frequency of more than 50 kHz
(2) Peripherals are in a state that requires or uses a clock with a "low" frequency of 50 kHz or less.
(3) Peripherals are in a state that does not require or does not use an internal clock.
(4) The DMA always transfers data in active mode but can wait for a trigger in any low-power mode. A DMA trigger during a low-power mode causes a temporary transition into active mode for the time of the transfer.
(5) This peripheral operates during active mode only and will delay the transition into a low-power mode until its operation is completed.

9.5.2 Idle Currents of Peripherals in LPM3 and LPM4

Most peripherals can be operational in LPM3 if clocked by ACLK. Some modules are operational in LPM4, because they do not require a clock to operate (for example, the comparator). Activating a peripheral in LPM3 or LPM4 increases the current consumption due to its active supply current contribution but also due to an additional idle current. To reduce the idle current adder, certain peripherals are grouped together. To achieve optimal current consumption, use modules within one group and limit the number of groups with active modules. Table 9-3 lists the peripheral groups. Modules not listed in this table are either already included in the standard LPM3 current consumption or cannot be used in LPM3 or LPM4.

The idle current adder is very small at room temperature (25°C) but increases at high temperatures (85°C); see the I_{IDLE} current parameters in Section 8 for details.

Table 9-3. Peripheral Groups

GROUP A	GROUP B	GROUP C
Timer TA1	Timer TA0	Timer TA4
Timer TA2	Timer TA3	eUSCI_A2
Timer TB0	Comparator	eUSCI_A3
eUSCI_A0	ADC12_B	eUSCI_B1
eUSCI_A1	REF_A	LCD_C
eUSCI_B0		

9.6 Interrupt Vector Table and Signatures

The interrupt vectors, the power-up start address, and signatures are in the address range 0FFFFh to 0FF80h. Figure 9-2 summarizes the content of this address range.

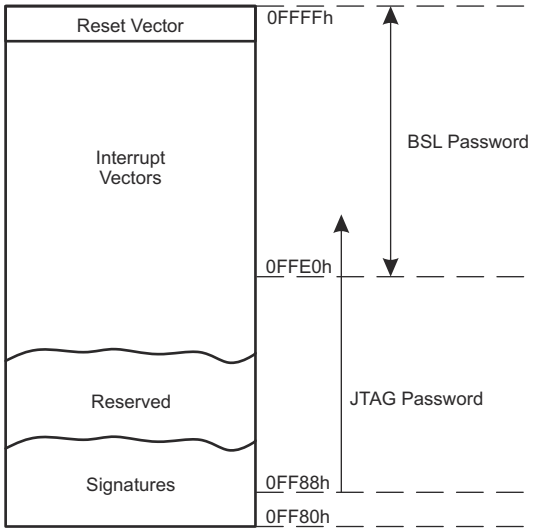


Figure 9-2. Interrupt Vectors, Signatures and Passwords

The power-up start address or reset vector is at 0FFFFh to 0FFFEh. It contains the 16-bit address pointing to the start address of the application program.

The interrupt vectors start at 0FFFDh and extend to lower addresses. Each vector contains the 16-bit address of the appropriate interrupt-handler instruction sequence. Table 9-4 shows the device-specific interrupt vector locations.

The vectors programmed into the address range from 0FFFFh to 0FFE0h are used as BSL password (if enabled by the corresponding signature).

The signatures start at 0FF80h and extend to higher addresses. Signatures are evaluated during device start-up. Table 9-5 shows the device-specific signature locations.

A JTAG password can be programmed starting from address 0FF88h and extending to higher addresses. The password can extend into the interrupt vector locations using the interrupt vector addresses as additional bits for the password. The length of the JTAG password depends on the JTAG signature.

See the *System Resets, Interrupts, and Operating Modes, System Control Module (SYS)* chapter in the *MSP430FR58xx, MSP430FR59xx, and MSP430FR6xx Family User's Guide* for details.

Table 9-4. Interrupt Sources, Flags, and Vectors

INTERRUPT SOURCE	INTERRUPT FLAG	INTERRUPT VECTOR REGISTER	SYSTEM INTERRUPT	WORD ADDRESS	PRIORITY
System Reset					
Power up, brownout, supply supervisor	SVSHIFG				
External reset $\overline{RST}$	PMMRSTIFG				
Watchdog time-out (watchdog mode)	WDTIFG				
WDT, FRCTL MPU, CS, PMM password violation	WDTPW, FRCTLPW, MPUPW, CSPW, PMMPW	SYSRSTIV(1) (2)	Reset	0FFFEh	Highest
FRAM uncorrectable bit error detection	UBDIFG				
MPU segment violation	MPUSEG1IFG, MPUSEG2IFG, MPUSEG3IFG				
Software POR, BOR	PMMPORIFG, PMMBORIFG				
System NMI					
Vacant memory access	VMAIFG				
JTAG mailbox	JMBINIFG, JMBOUTIFG				
FRAM access time error	ACCTEIFG	SYSSNIV(1) (3)	(Non)maskable	0FFFCh	
FRAM write protection error	WPIFG				
FRAM bit error detection	CBDIFG, UBDIFG				
MPU segment violation	MPUSEG1IFG, MPUSEG2IFG, MPUSEG3IFG				
User NMI					
External NMI	NMIIFG				
Oscillator fault	OFIFG	SYSUNIV(1) (3)	(Non)maskable	0FFFAh	
LEA RAM access conflict	DACCESSIFG				
Comparator_E	CEIFG, CEIIFG	CEIV(1)	Maskable	0FFF8h	
TB0	TB0CCR0.CCIFG		Maskable	0FFF6h	
TB0	TB0CCR1.CCIFG to TB0CCR6.CCIFG, TB0CTL.TBIFG	TB0IV(1)	Maskable	0FFF4h	
Watchdog timer (interval timer mode)	WDTIFG		Maskable	0FFF2h	
eUSCI_A0 receive or transmit	UCA0IFG: UCRXIFG, UCTXIFG (SPI mode) UCA0IFG: UCSTTIFG, UCTXCPTIFG, UCRXIFG, UCTXIFG (UART mode)	UCA0IV(1)	Maskable	0FFF0h	
eUSCI_B0 receive or transmit	UCB0IFG: UCRXIFG, UCTXIFG (SPI mode) UCB0IFG: UCALIFG, UCNACKIFG, UCSTTIFG, UCSTPIFG, UCRXIFG0, UCTXIFG0, UCRXIFG1, UCTXIFG1, UCRXIFG2, UCTXIFG2, UCRXIFG3, UCTXIFG3, UCCNTIFG, UCBIT9IFG (I^2C mode)	UCB0IV(1)	Maskable	0FFEEh	

Table 9-4. Interrupt Sources, Flags, and Vectors (continued)

INTERRUPT SOURCE	INTERRUPT FLAG	INTERRUPT VECTOR REGISTER	SYSTEM INTERRUPT	WORD ADDRESS	PRIORITY
ADC12_B	ADC12IFG0 to ADC12IFG31 ADC12LOIFG, ADC12INIFG, ADC12HIIFG, ADC12RDYIFG, ADC21OVIFG, ADC12TOVIFG	ADC12IV(1) (4)	Maskable	0FFECh	
TA0	TA0CCR0.CCIFG		Maskable	0FFEAh	
TA0	TA0CCR1.CCIFG, TA0CCR2.CCIFG, TA0CTL.TAIFG	TA0IV(1)	Maskable	0FFE8h	
eUSCI_A1 receive or transmit	UCA1IFG: UCRXIFG, UCTXIFG (SPI mode) UCA1IFG: UCSTTIFG, UCTXCPTIFG, UCRXIFG, UCTXIFG (UART mode)	UCA1IV(1)	Maskable	0FFE6h	
DMA	DMA0CTL.DMAIFG, DMA1CTL.DMAIFG, DMA2CTL.DMAIFG	DMAIV(1)	Maskable	0FFE4h	
TA1	TA1CCR0.CCIFG		Maskable	0FFE2h	
TA1	TA1CCR1.CCIFG, TA1CCR2.CCIFG, TA1CTL.TAIFG	TA1IV(1)	Maskable	0FFE0h	
I/O port P1	P1IFG.0 to P1IFG.7	P1IV(1)	Maskable	0FFDEh	
TA2	TA2CCR0.CCIFG		Maskable	0FFDCh	
TA2	TA2CCR1.CCIFG TA2CTL.TAIFG	TA2IV(1)	Maskable	0FFDAh	
I/O port P2	P2IFG.0 to P2IFG.7	P2IV(1)	Maskable	0FFD8h	
TA3	TA3CCR0.CCIFG		Maskable	0FFD6h	
TA3	TA3CCR1.CCIFG TA3CTL.TAIFG	TA3IV(1)	Maskable	0FFD4h	
I/O port P3	P3IFG.0 to P3IFG.7	P3IV(1)	Maskable	0FFD2h	
I/O port P4	P4IFG.0 to P4IFG.7	P4IV(1)	Maskable	0FFD0h	
LCD_C	LCD_C interrupt flags	LCDCIV(1)	Maskable	0FFCEh	
RTC_C	RTCRDYIFG, RTCTEVIFG, RTCAIFG, RT0PSIFG, RT1PSIFG, RTCOFIFG	RTCIV(1)	Maskable	0FFCCh	
AES	AESRDYIFG		Maskable	0FFCAh	
TA4	TA4CCR0.CCIFG		Maskable	0FFC8h	
TA4	TA4CCR1.CCIFG TA4CTL.TAIFG	TA4IV(1)	Maskable	0FFC6h	
I/O port P5	P5IFG.0 to P5IFG.7	P5IV(1)	Maskable	0FFC4h	
I/O port P6	P6IFG.0 to P6IFG.7	P6IV(1)	Maskable	0FFC2h	
eUSCI_A2 receive or transmit	UCA2IFG: UCRXIFG, UCTXIFG (SPI mode) UCA2IFG: UCSTTIFG, UCTXCPTIFG, UCRXIFG, UCTXIFG (UART mode)	UCA2IV(1)	Maskable	0FFC0h	
eUSCI_A3 receive or transmit	UCA3IFG: UCRXIFG, UCTXIFG (SPI mode) UCA3IFG: UCSTTIFG, UCTXCPTIFG, UCRXIFG, UCTXIFG (UART mode)	UCA3IV(1)	Maskable	0FFBEh	
eUSCI_B1 receive or transmit	UCB1IFG: UCRXIFG, UCTXIFG (SPI mode) UCB1IFG: UCALIFG, UCNACKIFG, UCSTTIFG, UCSTPIFG, UCRXIFG0, UCTXIFG0, UCRXIFG1, UCTXIFG1, UCRXIFG2, UCTXIFG2, UCRXIFG3, UCTXIFG3, UCCNTIFG, UCBIT9IFG (I^2C mode)	UCB1IV(1)	Maskable	0FFBCh	

Table 9-4. Interrupt Sources, Flags, and Vectors (continued)

INTERRUPT SOURCE	INTERRUPT FLAG	INTERRUPT VECTOR REGISTER	SYSTEM INTERRUPT	WORD ADDRESS	PRIORITY
I/O port P7	P7IFG.0 to P7IFG.7	P7IV(1)	Maskable	0FFBAh	
I/O port P8	P8IFG.0 to P8IFG.7	P8IV(1)	Maskable	0FFB8h	
I/O port P9	P9IFG.0 to P9IFG.7	P9IV(1)	Maskable	0FFB6h	
LEA	CMDIFG, SDIIFG, OORIFG, TIFG, COVLIFG	LEAIV(1)	Maskable	0FFB4h	
UUPS	PTMOUT, PREQIG	IIDX(1)	Maskable	0FFB2h	
HSPLL	PLLUNLOCK	IIDX(1)	Maskable	0FFB0h	
SAPH	DATAERR, TAMTO, SEQDN, PNGDN	IIDX(1)	Maskable	0FFAEh	
SDHS	OVF, ACQDONE, SSTRG, DTRDY, WINHI, WINLO	IIDX(1)	Maskable	0FFACh	Lowest

(1) Multiple source flags
(2) A reset is generated if the CPU tries to fetch instructions from within peripheral space.
(3) (Non)maskable: the individual interrupt enable bit can disable an interrupt event, but the general interrupt enable cannot disable it.
(4) Only on devices with ADC, otherwise reserved.

Table 9-5. Signatures

SIGNATURE	WORD ADDRESS
IP Encapsulation Signature2	0FF8Ah
IP Encapsulation Signature1(1)	0FF88h
BSL Signature2	0FF86h
BSL Signature1	0FF84h
JTAG Signature2	0FF82h
JTAG Signature1	0FF80h

(1) Must not contain 0AAAAh if used as the JTAG password.

9.7 Bootloader (BSL)

The BSL can program the FRAM or RAM using a UART serial interface (FRxxxx devices). Access to the device memory through the BSL is protected by an user-defined password. Table 9-6 lists the pins that are required for use of the BSL. BSL entry requires a specific entry sequence on the $\overline{\text{RST}}$/NMI/SBWTDIO and TEST/SBWTCK pins. For a complete description of the features of the BSL and its implementation, see the *MSP430 FRAM Devices Bootloader (BSL) User's Guide*. More information on the BSL can be found at www.ti.com/tool/mspbsl.

Table 9-6. BSL Pin Requirements and Functions

DEVICE SIGNAL	BSL FUNCTION
$\overline{\text{RST}}$/NMI/SBWTDIO	Entry sequence signal
TEST/SBWTCK	Entry sequence signal
P2.0	Devices with UART BSL (FRxxxx): Data transmit
P2.1	Devices with UART BSL (FRxxxx): Data receive
VCC	Power supply
VSS	Ground supply

9.8 JTAG Operation

9.8.1 JTAG Standard Interface

The MSP family supports the standard JTAG interface, which requires four signals for sending and receiving data. The JTAG signals are shared with general-purpose I/O. The TEST/SBWTCK pin is used to enable the JTAG signals. In addition to these signals, the $\overline{\text{RST}}$/NMI/SBWTDIO is required to interface with MSP development tools and device programmers. Table 9-7 lists the JTAG pin requirements. For further details on

interfacing to development tools and device programmers, see the *MSP430 Hardware Tools User's Guide*. For a complete description of the features of the JTAG interface and its implementation, see *MSP430 Programming With the JTAG Interface*.

Table 9-7. JTAG Pin Requirements and Functions

DEVICE SIGNAL	DIRECTION(1)	FUNCTION
PJ.3/TCK	IN	JTAG clock input
PJ.2/TMS	IN	JTAG state control
PJ.1/TDI/TCLK	IN	JTAG data input, TCLK input
PJ.0/TDO	OUT	JTAG data output
TEST/SBWTCK	IN	Enable JTAG pins
$\overline{\text{RST}}$/NMI/SBWTDIO	IN	External reset
DVCC	N/A	Power supply
DVSS	N/A	Ground supply

(1) N/A = not applicable

9.8.2 Spy-Bi-Wire (SBW) Interface

In addition to the standard JTAG interface, the MSP family supports the 2-wire SBW interface. SBW can be used to interface with MSP development tools and device programmers. Table 9-8 lists the SBW interface pin requirements. For further details on interfacing to development tools and device programmers, see the *MSP430 Hardware Tools User's Guide*. For a complete description of the features of the JTAG interface and its implementation, see *MSP430 Programming With the JTAG Interface*.

Table 9-8. SBW Pin Requirements and Functions

DEVICE SIGNAL	DIRECTION(1)	FUNCTION
TEST/SBWTCK	IN	Spy-Bi-Wire clock input
$\overline{\text{RST}}$/NMI/SBWTDIO	IN, OUT	Spy-Bi-Wire data input and output
DVCC	N/A	Power supply
DVSS	N/A	Ground supply

(1) N/A = not applicable

9.9 FRAM Controller A (FRCTL_A)

The FRAM can be programmed through the JTAG port, SBW, the BSL, or in-system by the CPU. Features of the FRAM include:

- Ultra-low-power ultra-fast-write nonvolatile memory
- Byte and word access capability
- Programmable wait state generation
- Error correction coding (ECC)

Note

Wait States

For MCLK frequencies > 8 MHz, wait states must be configured following the flow described in the "Wait State Control" section of the *FRAM Controller A (FRCTRL_A)* chapter in the *MSP430FR58xx, MSP430FR59xx, and MSP430FR6xx Family User's Guide*.

For important software design information regarding FRAM including but not limited to partitioning the memory layout according to application-specific code, constant, and data space requirements, the use of FRAM to optimize application energy consumption, and the use of the Memory Protection Unit (MPU) to maximize application robustness by protecting the program code against unintended write accesses, see *MSP430™ FRAM Technology – How To and Best Practices*.

9.10 RAM

The RAM is made up of three sectors: Sector 0 = 2KB, Sector 1 = 2KB, Sector 2 = 4KB (shared with LEA). Each sector can be individually powered down in LPM3 and LPM4 to save leakage. All data in the sector is lost when a sector is powered down.

9.11 Tiny RAM

Tiny RAM is 22 bytes of RAM in addition to the complete RAM (see Table 9-45). This memory is always available, even in LPM3 and LPM4, while the complete RAM can be powered down in LPM3 and LPM4. Tiny RAM can be used to hold data or a very small stack when the complete RAM is powered down in LPM3 and LPM4. No memory is available in LPMx.5.

9.12 Memory Protection Unit (MPU) Including IP Encapsulation

The FRAM can be protected by the MPU from inadvertent CPU execution, read access, or write access. Features of the MPU include:

- IP encapsulation with programmable boundaries in steps of 1KB (prevents reads from outside the application; for example, through JTAG or by non-IP software).
- Main memory partitioning is programmable up to three segments in steps of 1KB.
- Access rights of each segment can be individually selected (main and information memory).
- Access violation flags with interrupt capability for easy servicing of access violations.

9.13 Peripherals

Peripherals are connected to the CPU through data, address, and control buses. Peripherals can be controlled using all instructions. For complete module descriptions, see the *MSP430FR58xx, MSP430FR59xx, and MSP430FR6xx Family User's Guide*.

9.13.1 Digital I/O

Up to ten 8-bit I/O ports are implemented:

- All individual I/O bits are independently programmable.
- Any combination of input, output, and interrupt conditions is possible.
- Programmable pullup or pulldown on all ports.
- Edge-selectable interrupt and LPM3.5 and LPM4.5 wake-up input is available for all pins of ports P1 to P9.
- Read and write access to port control registers is supported by all instructions.
- Ports P1 and P2 (PA), P3 and P4 (PB), P5 and P6 (PC), P7 and P8 (PD), or P9 (PE) can be accessed byte-wise or word-wise in pairs.
- No cross currents during start-up.

Note

Configuration of Digital I/Os After BOR Reset

To prevent any cross currents during start-up of the device, all port pins are high-impedance with Schmitt triggers and their module functions disabled. To enable the I/O functionality after a BOR reset, the ports must be configured first and then the LOCKLPM5 bit must be cleared. For details, see the *Configuration After Reset* section of the *Digital I/O* chapter in the *MSP430FR58xx, MSP430FR59xx, and MSP430FR6xx Family User's Guide*.

9.13.2 Oscillator and Clock System (CS)

The clock system includes support for a 32-kHz watch-crystal oscillator XT1 (LF), an internal very-low-power low-frequency oscillator (VLO), an integrated internal digitally controlled oscillator (DCO), and a high-frequency crystal oscillator XT2 (HF). The clock system module is designed to meet the requirements of both low system cost and low power consumption. A fail-safe mechanism exists for all crystal sources. The clock system module provides the following clock signals:

- Auxiliary clock (ACLK). ACLK can be sourced from a 32-kHz watch crystal (LFXT1), the internal VLO, or a digital external low-frequency (<50-kHz) clock source.
- Main clock (MCLK), the system clock used by the CPU. MCLK can be sourced from a high-frequency crystal (HFXT2), the internal DCO, a 32-kHz watch crystal (LFXT1), the internal VLO, or a digital external clock source.
- Sub-Main clock (SMCLK), the subsystem clock used by the peripheral modules. SMCLK can be sourced by same sources made available to MCLK.

9.13.3 Power-Management Module (PMM)

The PMM includes an integrated voltage regulator that supplies the core voltage to the device . The PMM also includes supply voltage supervisor (SVS) and brownout protection. The brownout circuit provides the proper internal reset signal to the device during power on and power off. The SVS circuitry detects if the supply voltage drops below a safe level and below a user-selectable level. SVS circuitry is available on the primary and core supplies.

9.13.4 Hardware Multiplier (MPY)

The multiplication operation is supported by a dedicated peripheral module. The module performs operations with 32-, 24-, 16-, and 8-bit operands. The module supports signed multiplication, unsigned multiplication, signed multiply-and-accumulate, and unsigned multiply-and-accumulate operations.

9.13.5 Real-Time Clock (RTC_C)

The RTC_C module contains an integrated real-time clock (RTC) with the following features:

- Calendar mode with leap year correction
- General-purpose counter mode

The internal calendar compensates for months with fewer than 31 days and includes leap year correction. The RTC_C also supports flexible alarm functions and offset-calibration hardware. RTC operation is available in LPM3.5 modes to minimize power consumption.

9.13.6 Watchdog Timer (WDT_A)

The primary function of the WDT_A module is to perform a controlled system restart if 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. Table 9-9 lists the clocks that can source the WDT_A module.

Table 9-9. WDT_A Clocks

WDTSSEL	NORMAL OPERATION (WATCHDOG AND INTERVAL TIMER MODE)
00	SMCLK
01	ACLK
10	VLOCLK
11	LFMODCLK

9.13.7 System Module (SYS)

The SYS module manages many system functions within the device. These functions include power-on reset (POR) and power-up clear (PUC) handling, NMI source selection and management, reset interrupt vector generators, bootloader (BSL) entry mechanisms, and configuration management (device descriptors). The SYS module also includes a data exchange mechanism through JTAG called a JTAG mailbox that can be used in the application. Table 9-10 lists the SYS module interrupt vector registers.

Table 9-10. System Module Interrupt Vector Registers

INTERRUPT VECTOR REGISTER	ADDRESS	INTERRUPT EVENT	VALUE	PRIORITY
SYSRSTIV, System Reset	019Eh	No interrupt pending	00h	
		Brownout (BOR)	02h	Highest
		RSTIFG $\overline{\text{RST}}$/NMI (BOR)	04h	
		PMMSWBOR software BOR (BOR)	06h	
		LPMx.5 wakeup (BOR)	08h	
		Security violation (BOR)	0Ah	
		Reserved	0Ch	
		SVSHIFG SVSH event (BOR)	0Eh	
		Reserved	10h	
		Reserved	12h	
		PMMSWPOR software POR (POR)	14h	
		WDTIFG watchdog time-out (PUC)	16h	
		WDTPW password violation (PUC)	18h	
		FRCTLPW password violation (PUC)	1Ah	
		Uncorrectable FRAM bit error detection (PUC)	1Ch	
		Peripheral area fetch (PUC)	1Eh	
		PMMPW PMM password violation (PUC)	20h	
		MPUPW MPU password violation (PUC)	22h	
		CSPW CS password violation (PUC)	24h	
		MPUSEGIPIFG encapsulated IP memory segment violation (PUC)	26h	
		Reserved	28h	
		MPUSEG1IFG segment 1 memory violation (PUC)	2Ah	
		MPUSEG2IFG segment 2 memory violation (PUC)	2Ch	
		MPUSEG3IFG segment 3 memory violation (PUC)	2Eh	
		Reserved	30h to 3Eh	Lowest
SYSSNIV, System NMI	019Ch	No interrupt pending	00h	
		Reserved	02h	Highest
		Uncorrectable FRAM bit error detection	04h	
		FRAM access time error	06h	
		MPUSEGIPIFG encapsulated IP memory segment violation	08h	
		Reserved	0Ah	
		MPUSEG1IFG segment 1 memory violation	0Ch	
		MPUSEG2IFG segment 2 memory violation	0Eh	
		MPUSEG3IFG segment 3 memory violation	10h	
		VMAIFG vacant memory access	12h	
		JMBINIFG JTAG mailbox input	14h	
		JMBOUTIFG JTAG mailbox output	16h	
		Correctable FRAM bit error detection	18h	
		FRAM Write Protection Detection	1Ah	
		LEA time-out fault	1Ch	
		LEA command fault	1Eh	Lowest

Table 9-10. System Module Interrupt Vector Registers (continued)

INTERRUPT VECTOR REGISTER	ADDRESS	INTERRUPT EVENT	VALUE	PRIORITY
SYSUNIV, User NMI	019Ah	No interrupt pending	00h	
		NMIIFG NMI pin	02h	Highest
		OFIFG oscillator fault	04h	
		DACCESSIFG	06h	
		Reserved	08h	
		Reserved	0Ah to 1Eh	Lowest

9.13.8 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_B 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. Table 9-11 lists the available triggers for the DMA.

Table 9-11. DMA Trigger Assignments

TRIGGER (1)	CHANNEL 0	CHANNEL 1	CHANNEL 2	CHANNEL 3	CHANNEL 4	CHANNEL 5
0	DMAREQ	DMAREQ	DMAREQ	DMAREQ	DMAREQ	DMAREQ
1	TA0CCR0 CCIFG	TA0CCR0 CCIFG	TA0CCR0 CCIFG	TA0CCR0 CCIFG	TA0CCR0 CCIFG	TA0CCR0 CCIFG
2	TA0CCR2 CCIFG	TA0CCR2 CCIFG	TA0CCR2 CCIFG	TA0CCR2 CCIFG	TA0CCR2 CCIFG	TA0CCR2 CCIFG
3	TA1CCR0 CCIFG	TA1CCR0 CCIFG	TA1CCR0 CCIFG	TA1CCR0 CCIFG	TA1CCR0 CCIFG	TA1CCR0 CCIFG
4	TA1CCR2 CCIFG	TA1CCR2 CCIFG	TA1CCR2 CCIFG	TA1CCR2 CCIFG	TA1CCR2 CCIFG	TA1CCR2 CCIFG
5	TA2CCR0 CCIFG	TA2CCR0 CCIFG	TA2CCR0 CCIFG	TA2CCR0 CCIFG	TA2CCR0 CCIFG	TA2CCR0 CCIFG
6	TA3CCR0 CCIFG	TA3CCR0 CCIFG	TA3CCR0 CCIFG	TA3CCR0 CCIFG	TA3CCR0 CCIFG	TA3CCR0 CCIFG
7	TB0CCR0 CCIFG	TB0CCR0 CCIFG	TB0CCR0 CCIFG	TB0CCR0 CCIFG	TB0CCR0 CCIFG	TB0CCR0 CCIFG
8	TB0CCR2 CCIFG	TB0CCR2 CCIFG	TB0CCR2 CCIFG	TB0CCR2 CCIFG	TB0CCR2 CCIFG	TB0CCR2 CCIFG
9	TA4CCR0 CCIFG	TA4CCR0 CCIFG	TA4CCR0 CCIFG	TA4CCR0 CCIFG	TA4CCR0 CCIFG	TA4CCR0 CCIFG
10	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved
11	AES Trigger 0	AES Trigger 0	AES Trigger 0	AES Trigger 0	AES Trigger 0	AES Trigger 0
12	AES Trigger 1	AES Trigger 1	AES Trigger 1	AES Trigger 1	AES Trigger 1	AES Trigger 1
13	AES Trigger 2	AES Trigger 2	AES Trigger 2	AES Trigger 2	AES Trigger 2	AES Trigger 2
14	UCA0RXIFG	UCA0RXIFG	UCA0RXIFG	UCA2RXIFG	UCA2RXIFG	UCA2RXIFG
15	UCA0TXIFG	UCA0TXIFG	UCA0TXIFG	UCA2TXIFG	UCA2TXIFG	UCA2TXIFG
16	UCA1RXIFG	UCA1RXIFG	UCA1RXIFG	UCA3RXIFG	UCA3RXIFG	UCA3RXIFG
17	UCA1TXIFG	UCA1TXIFG	UCA1TXIFG	UCA3TXIFG	UCA3TXIFG	UCA3TXIFG
18	UCB0RXIFG (SPI) UCB0RXIFG0 (I^2C)	UCB0RXIFG (SPI) UCB0RXIFG0 (I^2C)	UCB0RXIFG (SPI) UCB0RXIFG0 (I^2C)	UCB1RXIFG (SPI) UCB1RXIFG0 (I^2C)	UCB1RXIFG (SPI) UCB1RXIFG0 (I^2C)	UCB1RXIFG (SPI) UCB1RXIFG0 (I^2C)
19	UCB0TXIFG (SPI) UCB0TXIFG0 (I^2C)	UCB0TXIFG (SPI) UCB0TXIFG0 (I^2C)	UCB0TXIFG (SPI) UCB0TXIFG0 (I^2C)	UCB1TXIFG (SPI) UCB1TXIFG0 (I^2C)	UCB1TXIFG (SPI) UCB1TXIFG0 (I^2C)	UCB1TXIFG (SPI) UCB1TXIFG0 (I^2C)
20	UCB0RXIFG1 (I^2C)	UCB0RXIFG1 (I^2C)	UCB0RXIFG1 (I^2C)	UCB1RXIFG1 (I^2C)	UCB1RXIFG1 (I^2C)	UCB1RXIFG1 (I^2C)
21	UCB0TXIFG1 (I^2C)	UCB0TXIFG1 (I^2C)	UCB0TXIFG1 (I^2C)	UCB1TXIFG1 (I^2C)	UCB1TXIFG1 (I^2C)	UCB1TXIFG1 (I^2C)
22	UCB0RXIFG2 (I^2C)	UCB0RXIFG2 (I^2C)	UCB0RXIFG2 (I^2C)	UCB1RXIFG2 (I^2C)	UCB1RXIFG2 (I^2C)	UCB1RXIFG2 (I^2C)
23	UCB0TXIFG2 (I^2C)	UCB0TXIFG2 (I^2C)	UCB0TXIFG2 (I^2C)	UCB1TXIFG2 (I^2C)	UCB1TXIFG2 (I^2C)	UCB1TXIFG2 (I^2C)
24	UCB0RXIFG3 (I^2C)	UCB0RXIFG3 (I^2C)	UCB0RXIFG3 (I^2C)	UCB1RXIFG3 (I^2C)	UCB1RXIFG3 (I^2C)	UCB1RXIFG3 (I^2C)
25	UCB0TXIFG3 (I^2C)	UCB0TXIFG3 (I^2C)	UCB0TXIFG3 (I^2C)	UCB1TXIFG3 (I^2C)	UCB1TXIFG3 (I^2C)	UCB1TXIFG3 (I^2C)
26	ADC12 end of conversion	ADC12 end of conversion	ADC12 end of conversion	ADC12 end of conversion	ADC12 end of conversion	ADC12 end of conversion
27	LEA ready	LEA ready	LEA ready	LEA ready	LEA ready	LEA ready
28	Reserved	Reserved	Reserved	Reserved	Reserved	Reserved
29	MPY ready	MPY ready	MPY ready	MPY ready	MPY ready	MPY ready

Table 9-11. DMA Trigger Assignments (continued)

TRIGGER (1)	CHANNEL 0	CHANNEL 1	CHANNEL 2	CHANNEL 3	CHANNEL 4	CHANNEL 5
30	DMA2IFG	DMA0IFG	DMA1IFG	DMA5IFG	DMA3IFG	DMA4IFG
31	DMAE0	DMAE0	DMAE0	DMAE0	DMAE0	DMAE0

(1) If a reserved trigger source is selected, no trigger is generated.

9.13.9 Enhanced Universal Serial Communication Interface (eUSCI)

The eUSCI modules are used for serial data communication. The eUSCI module supports synchronous communication protocols such as SPI (3- or 4-pin) and I^2C, and asynchronous communication protocols such as UART, enhanced UART with automatic baud-rate detection, and IrDA.

The eUSCI_A0, eUSCI_A1, eUSCI_A2, and eUSCI_A3 modules support SPI (3- or 4-pin), UART, enhanced UART, and IrDA.

The eUSCI_B0 and eUSCI_B1 modules support SPI (3- or 4-pin) and I^2C.

Four eUSCI_A modules and two eUSCI_B modules are implemented.

9.13.10 TA0, TA1, and TA4

TA0, TA1, and TA4 are 16-bit timers and counters (Timer_A type) with three (TA0 and TA1) or two (TA4) capture/compare registers each. Each timer can support multiple captures or compares, PWM outputs, and interval timing (see Table 9-12, Table 9-13, and Table 9-14). Each timer has extensive interrupt capabilities. Interrupts may be generated from the counter on overflow conditions and from each capture/compare register.

Table 9-12. TA0 Signal Connections

INPUT PORT PIN	DEVICE INPUT SIGNAL	MODULE INPUT SIGNAL	MODULE BLOCK	MODULE OUTPUT SIGNAL	DEVICE OUTPUT SIGNAL	OUTPUT PORT PIN
P2.4, P4.5, P5.5	TA0CLK	TACLK	Timer	N/A	N/A	
	ACLK (internal)	ACLK				
	SMCLK (internal)	SMCLK				
P2.4. P4.5, P5.5	$\overline{\text{TA0CLK}}$	INCLK				
P2.3	TA0.0	CCI0A	CCR0	TA0	TA0.0	P2.3
P2.7	TA0.0	CCI0B				P2.7
	DVSS	GND				
	DVCC	V_{CC}				
P7.4	TA0.1	CCI1A	CCR1	TA1	TA0.1	P7.4
	COUT (internal)	CCI1B				ADC12(internal)(1) ADC12SHSx = {1}
	DVSS	GND				
	DVCC	V_{CC}				
P7.7	TA0.2	CCI2A	CCR2	TA2	TA0.2	P7.7
	ACLK (internal)	CCI2B				UUPS Trigger (USSPWRUP) UUPS.CTL.USSPWRUPSEL = {2}
	DVSS	GND				
	DVCC	V_{CC}				

(1) Only on devices with ADC.

Table 9-13. TA1 Signal Connections

INPUT PORT PIN	DEVICE INPUT SIGNAL	MODULE INPUT SIGNAL	MODULE BLOCK	MODULE OUTPUT SIGNAL	DEVICE OUTPUT SIGNAL	OUTPUT PORT PIN
P2.4, P4.5	TA1CLK	TACLK	Timer	N/A	N/A	
	ACLK (internal)	ACLK				
	SMCLK (internal)	SMCLK				
P2.4. P4.5	$\overline{\text{TA1CLK}}$	INCLK				
P1.0	TA1.0	CCI0A	CCR0	TA0	TA1.0	P1.0
P9.0	TA1.0	CCI0B				P9.0
	DVSS	GND				
	DVCC	V_{CC}				
P7.5	TA1.1	CCI1A	CCR1	TA1	TA1.1	P7.5
	COUT (internal)	CCI1B				ADC12(internal)(1) ADC12SHSx = {4}
	DVSS	GND				
	DVCC	V_{CC}				
P8.4	TA1.2	CCI2A	CCR2	TA2	TA1.2	P8.4
	ACLK (internal)	CCI2B				ASQ Trigger (ASQTRIG) SAPH.ASCTL0.TRIGSEL= {2}
	DVSS	GND				
	DVCC	V_{CC}				

(1) Only on devices with ADC.

Table 9-14. TA4 Signal Connections

INPUT PORT PIN	DEVICE INPUT SIGNAL	MODULE INPUT SIGNAL	MODULE BLOCK	MODULE OUTPUT SIGNAL	DEVICE OUTPUT SIGNAL	OUTPUT PORT PIN
PJ.1,P4.6	TA4CLK	TACLK	Timer	N/A	N/A	
	ACLK (internal)	ACLK				
	SMCLK (internal)	SMCLK				
PJ.1, P4.6	$\overline{\text{TA4CLK}}$	INCLK				
P1.1	TA4.0	CCI0A	CCR0	TA0	TA4.0	P1.1
P2.5	TA4.0	CCI0B				P2.5
	DVSS	GND				
	DVCC	V_{CC}				
P7.6	TA4.1	CCI1A	CCR1	TA1	TA4.1	P7.6
P2.6	TA4.1	CCI1B				P2.6
	DVSS	GND				ADC12(internal)(1) ADC12SHSx = {7}
	DVCC	V_{CC}				

9.13.11 TA2 and TA3

TA2 and TA3 are 16-bit timers and counters (Timer_A type) with two capture/compare registers each and with internal connections only. Each timer can support multiple captures or compares, PWM outputs, and interval timing (see Table 9-15 and Table 9-16). Each timer has extensive interrupt capabilities. Interrupts may be generated from the counter on overflow conditions and from each capture/compare register.

Table 9-15. TA2 Signal Connections

DEVICE INPUT SIGNAL	MODULE INPUT NAME	MODULE BLOCK	MODULE OUTPUT SIGNAL	DEVICE OUTPUT SIGNAL
COUT (internal)	TACLK	Timer	N/A	
ACLK (internal)	ACLK			
SMCLK (internal)	SMCLK			
Reserved	INCLK			
TA3 CCR0 output (internal)	CCI0A	CCR0	TA0	TA3 CCI0A input
ACLK (internal)	CCI0B			
DVSS	GND			
DVCC	V_{CC}			
Reserved	CCI1A	CCR1	TA1	ADC12 (internal) ADC12SHSx = {5}
COUT (internal)	CCI1B			PPG Trigger (PPGTRIG) SAPH.PGCTL.TRSEL= {2}
DVSS	GND			
DVCC	V_{CC}			

Table 9-16. TA3 Signal Connections

DEVICE INPUT SIGNAL	MODULE INPUT NAME	MODULE BLOCK	MODULE OUTPUT SIGNAL	DEVICE OUTPUT SIGNAL
COUT (internal)	TACLK	Timer	N/A	
ACLK (internal)	ACLK			
SMCLK (internal)	SMCLK			
Reserved	INCLK			
TA2 CCR0 output (internal)	CCI0A	CCR0	TA0	TA2 CCI0A input
ACLK (internal)	CCI0B			
DVSS	GND			
DVCC	V_{CC}			
Reserved	CCI1A	CCR1	TA1	ADC12 (internal) ADC12SHSx = {6}
COUT (internal)	CCI1B			
DVSS	GND			
DVCC	V_{CC}			

9.13.12 TB0

TB0 is a 16-bit timer and counter (Timer_B type) with seven capture/compare registers. TB0 can support multiple captures or compares, PWM outputs, and interval timing (see Table 9-17). TB0 has extensive interrupt capabilities. Interrupts may be generated from the counter on overflow conditions and from each capture/compare register.

Table 9-17. TB0 Signal Connections

INPUT PORT PIN	DEVICE INPUT SIGNAL	MODULE INPUT SIGNAL	MODULE BLOCK	MODULE OUTPUT SIGNAL	DEVICE OUTPUT SIGNAL	OUTPUT PORT PIN
P2.4, P4.6	TB0CLK	TBCLK	Timer	N/A	N/A	
	ACLK (internal)	ACLK				
	SMCLK (internal)	SMCLK				
P2.4, P4.6	$\overline{\text{TB0CLK}}$	INCLK				
P7.2	TB0.0	CCI0A	CCR0	TB0	TB0.0	P7.2
P3.0	TB0.0	CCI0B				P3.0
	DVSS	GND				ADC12 (internal) ADC12SHSx = {2}
	DVCC	V_{CC}				
P7.3	TB0.1	CCI1A	CCR1	TB1	TB0.1	P7.3
	COUT (internal)	CCI1B				P3.1
	DVSS	GND				ADC12 (internal) ADC12SHSx = {3}
	DVCC	V_{CC}				
P8.0	TB0.2	CCI2A	CCR2	TB2	TB0.2	P8.0
	ACLK (internal)	CCI2B				P3.2
	DVSS	GND				
	DVCC	V_{CC}				
P8.1	TB0.3	CCI3A	CCR3	TB3	TB0.3	P8.1
P3.3	TB0.3	CCI3B				P3.3
	DVSS	GND				
	DVCC	V_{CC}				
P1.4	TB0.4	CCI4A	CCR4	TB4	TB0.4	P1.4
P3.5	TB0.4	CCI4B				P3.5
	DVSS	GND				
	DVCC	V_{CC}				
P1.5	TB0.5	CCI5A	CCR5	TB5	TB0.5	P1.5
P3.6	TB0.5	CCI5B				P3.6
	DVSS	GND				
	DVCC	V_{CC}				
PJ.3	TB0.6	CCI6A	CCR6	TB6	TB0.6	PJ.3
P3.7	TB0.6	CCI6B				P3.7
	DVSS	GND				
	DVCC	V_{CC}				

9.13.13 ADC12_B

The ADC12_B module supports fast 12-bit analog-to-digital conversions with differential and single-ended inputs. The module implements a 12-bit SAR core, sample select control, a reference generator, and a conversion result buffer. A window comparator with lower and upper limits allows CPU-independent result monitoring with three window comparator interrupt flags.

Table 9-18 lists the external trigger sources.

Table 9-18. ADC12_B Trigger Signal Connections

ADC12SHSx		CONNECTED TRIGGER SOURCE
BINARY	DECIMAL	
000	0	Software (ADC12SC)
001	1	TA0 CCR1 output
010	2	TB0 CCR0 output
011	3	TB0 CCR1 output
100	4	TA1 CCR1 output
101	5	TA2 CCR1 output
110	6	TA3 CCR1 output
111	7	TA4 CCR1 output

Table 9-19 lists the available multiplexing between internal and external analog inputs.

Table 9-19. ADC12_B External and Internal Signal Mapping

CONTROL BIT IN ADC12CTL3 REGISTER	EXTERNAL ADC INPUT (CONTROL BIT = 0)	INTERNAL ADC INPUT (CONTROL BIT = 1)
ADC12BATMAP	A31	Battery monitor
ADC12TCMAP	A30	Temperature sensor
ADC12CH0MAP	A29	N/A(1)
ADC12CH1MAP	A28	N/A(1)
ADC12CH2MAP	A27	N/A(1)
ADC12CH3MAP	A26	N/A(1)

(1) N/A = No internal signal is available on this device.

9.13.14 USS

Table 9-20 lists the available UUPS triggers.

Table 9-20. UUPS Trigger Signal Connections

UUPS.CTL.USSPWRUPSEL BINARY	CONNECTED TRIGGER SOURCE
00	Software (UUPS.CTL.USSPWRUP)
01	RTC (any enabled interrupt events)
10	TA0 CCR2 output
11	P1.7

Table 9-21 lists the available PPG triggers.

Table 9-21. PPG Trigger Signal Connections

SAPH.PGCTL.TRSEL BINARY	CONNECTED TRIGGER SOURCE
00	Software (SAPH.PPGTRIG.PPGTRIG)
01	ASQ (Acquisition Sequencer)
10	TA2 CCR1 output
11	Reserved

Table 9-22 lists the available ASQ triggers.

Table 9-22. ASQ Trigger Signal Connections

SAPH.ASCTL0.TRIGSEL BINARY	CONNECTED TRIGGER SOURCE
00	Software (SAPH.ASQTRIG.ASQTRIG)
01	PSQ (Power Sequencer)
10	TA1 CCR2 output
11	Reserved

9.13.15 Comparator_E

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

9.13.16 CRC16

The CRC16 module produces a signature based on a sequence of entered data values and can be used for data checking purposes. The CRC16 module signature is based on the CRC-CCITT standard.

9.13.17 CRC32

The CRC32 module produces a signature based on a sequence of entered data values and can be used for data checking purposes. The CRC32 module signature is based on the ISO 3309 standard.

9.13.18 AES256 Accelerator

The AES accelerator module performs encryption and decryption of 128-bit data with 128-, 192-, or 256-bit keys according to the Advanced Encryption Standard (AES) (FIPS PUB 197) in hardware.

9.13.19 True Random Seed

The device descriptor information (TLV) section contains a 128-bit true random seed that can be used to implement a deterministic random number generator.

9.13.20 Shared Reference (REF)

The REF module generates critical reference voltages that can be used by the various analog peripherals in the device.

9.13.21 LCD_C

The LCD_C driver generates the segment and common signals required to drive a liquid crystal display (LCD). The LCD_C controller has dedicated data memories to hold segment drive information. Common and segment signals are generated as defined by the mode. Static and 2-mux to 8-mux LCDs are supported. The module can provide an LCD voltage independent of the supply voltage with its integrated charge pump. It is possible to control the level of the LCD voltage and thus contrast by software. The module also provides an automatic blinking capability for individual segments in static, 2-, 3-, and 4-mux modes.

To reduce system noise, the charge pump can be temporarily disabled. Table 9-23 lists the available automatic charge pump disable options.

Table 9-23. LCD Automatic Charge Pump Disable Bits (LCDCPDISx)

CONTROL BIT	DESCRIPTION
LCDCPDIS0	LCD charge pump disable during ADC12 conversion 0b = LCD charge pump not automatically disabled during conversion. 1b = LCD charge pump automatically disabled during conversion.
LCDCPDIS1 to LCDCPDIS7	No functionality.

9.13.22 Embedded Emulation

9.13.22.1 Embedded Emulation Module (EEM) (S Version)

The EEM supports real-time in-system debugging. The S version of the EEM has the following features:

- Three hardware triggers or breakpoints on memory access
- One hardware trigger or breakpoint on CPU register write access
- Up to four hardware triggers that can be combined to form complex triggers or breakpoints
- One cycle counter
- Clock control on module level

9.13.22.2 EnergyTrace++ Technology

The devices implement circuitry to support EnergyTrace++ technology. The EnergyTrace++ technology lets the user observe information about the internal states of the microcontroller. These states include the CPU Program Counter (PC), the on or off status of the peripherals and system clocks (regardless of the clock source), and the low-power mode currently in use. These states can always be read by a debug tool, even when the microcontroller sleeps in LPMx.5 modes.

The activity of the following modules can be observed:

- LEA is running
- MPY is calculating.
- WDT is counting.
- RTC is counting.
- ADC: a sequence, sample, or conversion is active.
- REF: REFBG or REFGEN active and BG in static mode.
- COMP is on.
- AES is encrypting or decrypting.
- eUSCI_A0 is transferring (receiving or transmitting) data.
- eUSCI_A1 is transferring (receiving or transmitting) data.
- eUSCI_A2 is transferring (receiving or transmitting) data.
- eUSCI_A3 is transferring (receiving or transmitting) data.
- eUSCI_B0 is transferring (receiving or transmitting) data.

- eUSCI_B1 is transferring (receiving or transmitting) data.
- TB0 is counting.
- TA0 is counting.
- TA1 is counting.
- TA2 is counting.
- TA3 is counting.
- TA4 is counting.
- LCD_C is running.
- USS status

9.14 Input/Output Diagrams

9.14.1 Port Function Select Registers (PySEL1 , PySEL0)

Port pins are multiplexed with peripheral module functions as described in the *MSP430FR58xx, MSP430FR59xx, and MSP430FR6xx Family User's Guide*. The functions of each port pin are controlled by its port function select registers, PySEL1 and PySEL0, where y = port number. The bits in the registers are mapped to the pins in the port. The primary module function, secondary module function, and tertiary module function of the pins are determined by the configuration of the PySEL1.x and PySEL0.x bits (see Table 9-24). For example, P1SEL1.0 and P1SEL0.0 determine the primary module function, secondary module function, and tertiary module function of the P1.0 pin, which is in port 1. The module functions may also require the PxDIR bits to be configured according to the direction needed for the module function.

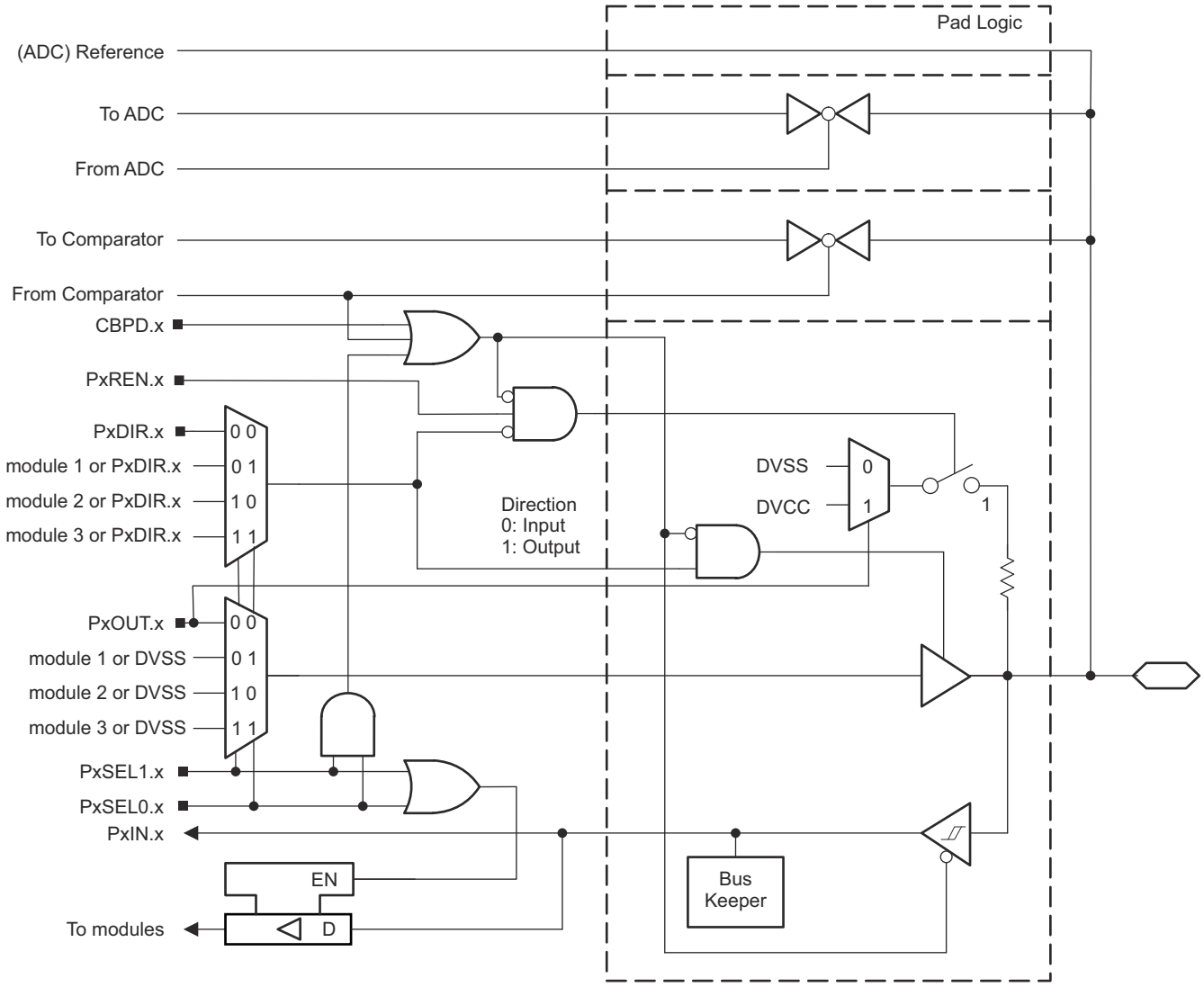
Table 9-24. I/O Function Selection

I/O FUNCTIONS	PySEL1.x	PySEL0.x
General-purpose I/O is selected	0	0
Primary module function is selected	0	1
Secondary module function is selected	1	0
Tertiary module function is selected	1	1

See the port pin function tables in the following sections for the configurations of the function and direction for each pin.

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

Figure 9-3 shows the port diagram. Table 9-25 summarizes the selection of the pin function.



Functional representation only.

Figure 9-3. Port P1 (P1.0 to P1.1) Diagram

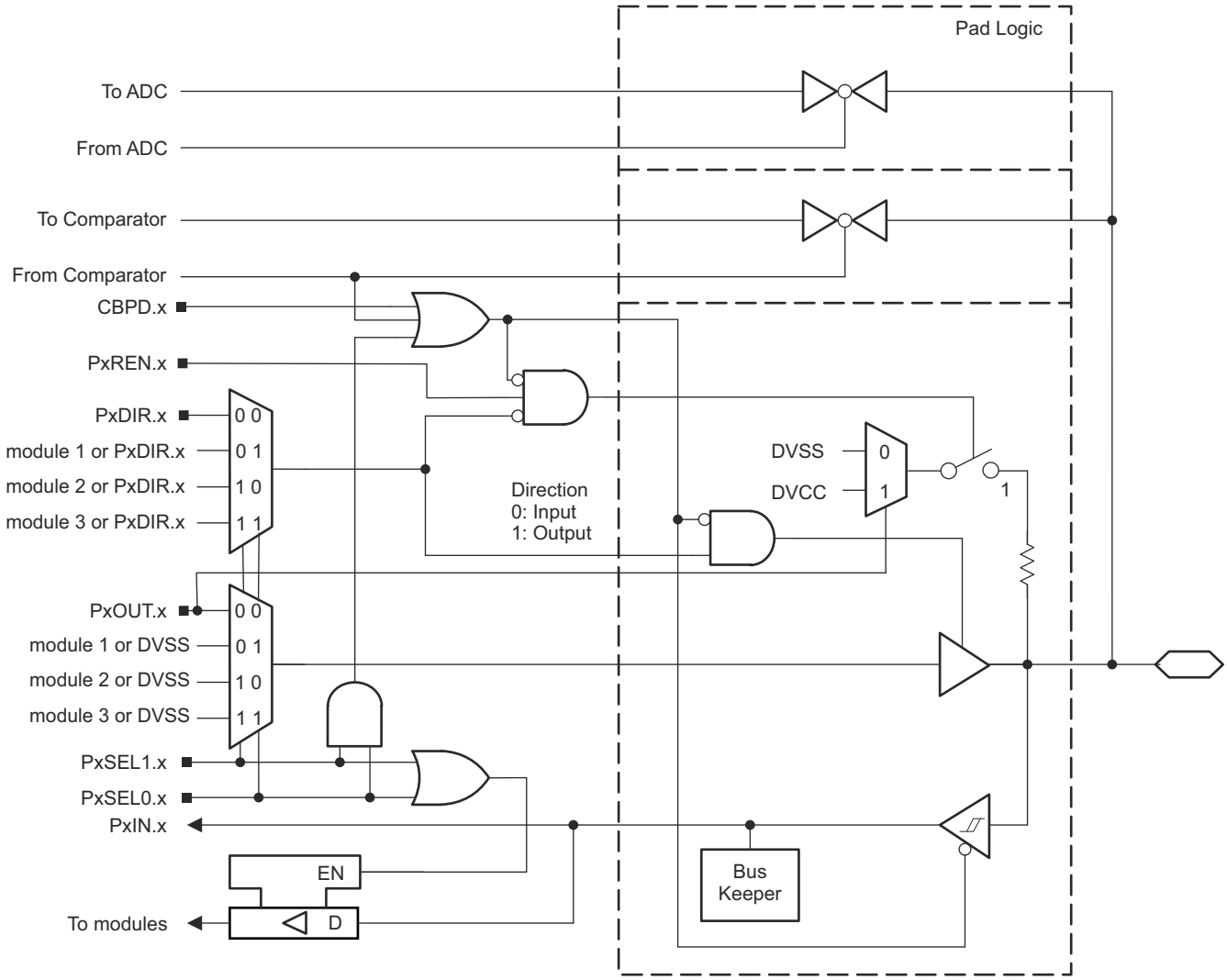
Table 9-25. Port P1 (P1.0 to P1.1) Pin Functions

PIN NAME (P1.x)	x	FUNCTION	CONTROL BITS AND SIGNALS[1]		
			P1DIR.x	P1SEL1.x	P1SEL0.x
P1.0/UCA1CLK/TA1.0/A0/C0/ VREF-/ VeREF-	0	P1.0 (I/O)	0 = Input, 1 = Output	0	0
		UCA1CLK	X[4]	0	1
		TA1.CCI0A	0	1	0
		TA1.0	1		
		A0, C0, VREF-, VeREF-[2] [3]	X	1	1
P1.1/UCA1STE/TA4.0/A1/C1/ VREF+/ VeREF+	1	P1.1 (I/O)	0 = Input, 1 = Output	0	0
		UCA1STE	X[4]	0	1
		TA4.CCI0A	0	1	0
		TA4.0	1		
		A1, C1, VREF+, VeREF+[2] [3]	X	1	1

(1) X = Don't care
(2) Setting P1SEL1.x and P1SEL0.x disables the output driver and the input Schmitt trigger to prevent parasitic cross currents when applying analog signals.
(3) Setting the CEPDx bit of the comparator disables the output driver and the input Schmitt trigger to prevent parasitic cross currents when applying analog signals. Selecting the Cx input pin to the comparator multiplexer with the input select bits in the comparator module automatically disables output driver and input buffer for that pin, regardless of the state of the associated CEPDx bit.
(4) Direction controlled by eUSCI_A1 module.

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

Figure 9-4 shows the port diagram. Table 9-26 summarizes the selection of the pin function.



Functional representation only.

Figure 9-4. Port P1 (P1.2 to P1.7) Diagram

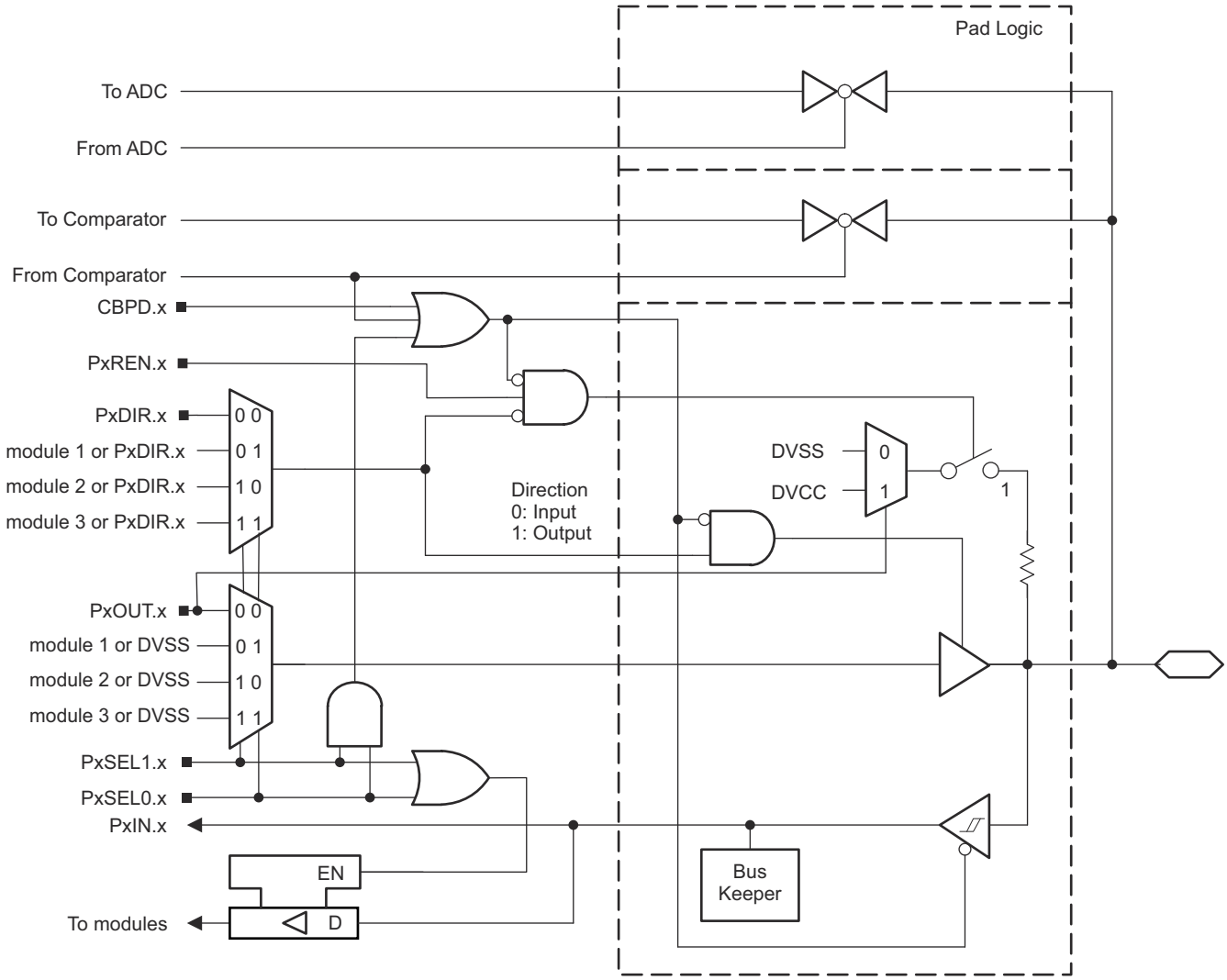
Table 9-26. Port P1 (P1.2 to P1.7) Pin Functions

PIN NAME (P1.x)	x	FUNCTION	CONTROL BITS AND SIGNALS(1)		
			P1DIR.x	P1SEL1.x	P1SEL0.x
P1.2/UCA1SIMO/UCA1TXD/A8/C8	2	P1.2 (I/O)	0 = Input, 1 = Output	0	0
		UCA1SIMO/UCA1TXD	X(2)	0	1
		N/A	0	1	0
		Internally tied to DVSS	1		
		A8, C8(3) (4)	X	1	1
P1.3/UCA1SOMI/UCA1RXD/A9/C9	3	P1.3 (I/O)	0 = Input, 1 = Output	0	0
		UCA1SOMI/UCA1RXD	X(2)	0	1
		N/A	0	1	0
		Internally tied to DVSS	1		
		A9, C9(3) (4)	X	1	1
P1.4/TB0.4/UCB0STE/A2/C2	4	P1.4 (I/O)	0 = Input, 1 = Output	0	0
		TB0.CCI4A	0	0	1
		TB0.4	1		
		UCB0STE	X(1)	1	0
		A2, C2(3) (4)	X	1	1
P1.5/TB0.5/UCB0CLK/A3/C3	5	P1.5(I/O)	0 = Input, 1 = Output	0	0
		TB0.CCI5A	0	0	1
		TB0.5	1		
		UCB0CLK	X(1)	1	0
		A3, C3(3) (4)	X	1	1
P1.6/UCB0SIMO/UCB0SDA/A4/C4	6	P1.6(I/O)	0 = Input, 1 = Output	0	0
		N/A	0	0	1
		Internally tied to DVSS	1		
		UCB0SIMO/UCB0SDA	X(1)	1	0
		A4, C4(3) (4)	X	1	1
P1.7/USSTRG/UCB0SOMI/UCB0SCL/ A5/C5	7	P1.7(I/O)	0 = Input, 1 = Output	0	0
		USSTRG (independent function)	0	X	1
				1	X
		Internally tied to DVSS	1	0	1
		UCB0SOMI/UCB0SCL	X(1)	1	0
		A5, C5(3) (4)	X	1	1

(1) Direction controlled by eUSCI_B0 module.
(2) Direction controlled by eUSCI_A1 module.
(3) Setting P1SEL1.x and P1SEL0.x disables the output driver and the input Schmitt trigger to prevent parasitic cross currents when applying analog signals.
(4) Setting the CEPDx bit of the comparator disables the output driver and the input Schmitt trigger to prevent parasitic cross currents when applying analog signals. Selecting the Cx input pin to the comparator multiplexer with the input select bits in the comparator module automatically disables output driver and input buffer for that pin, regardless of the state of the associated CEPDx bit.

9.14.4 Port P2 (P2.0 to P2.3) Input/Output With Schmitt Trigger

Figure 9-5 shows the port diagram. Table 9-27 summarizes the selection of the pin function.



Functional representation only.

Figure 9-5. Port P2 (P2.0 to P2.3) Diagram

Table 9-27. Port P2 (P2.0 to P2.3) Pin Functions

PIN NAME (P2.x)	x	FUNCTION	CONTROL BITS AND SIGNALS[1]		
			P2DIR.x	P2SEL1.x	P2SEL0.x
P2.0/UCA0SIMO/UCA0TXD/A6/C6	0	P2.0 (I/O)	0 = Input, 1 = Output	0	0
		N/A	0	0	1
		Internally tied to DVSS	1		
		UCA0SIMO/UCA0TXD	X[1]	1	0
		A6, C6[2] [3]	X	1	1
P2.1/UCA0SOMI/UCA0RXD/A7/C7	1	P2.1 (I/O)	0 = Input, 1 = Output	0	0
		N/A	0	0	1
		Internally tied to DVSS	1		
		UCA0SOMI/UCA0RXD	X[1]	1	0
		A7, C7[2] [3]	X	1	1
P2.2/COUT/UCA0CLK/A14/C14	2	P2.2 (I/O)	0 = Input, 1 = Output	0	0
		N/A	0	0	1
		COUT	1		
		UCA0CLK	X[1]	1	0
		A14, C14[2] [3]	X	1	1
P2.3/TA0.0/UCA0STE/A15/C15	3	P2.3(I/O)	0 = Input, 1 = Output	0	0
		TA0.CCI0A	0	0	1
		TA0.0	1		
		UCA0STE	X[1]	1	0
		A15, C15[2] [3]	X	1	1

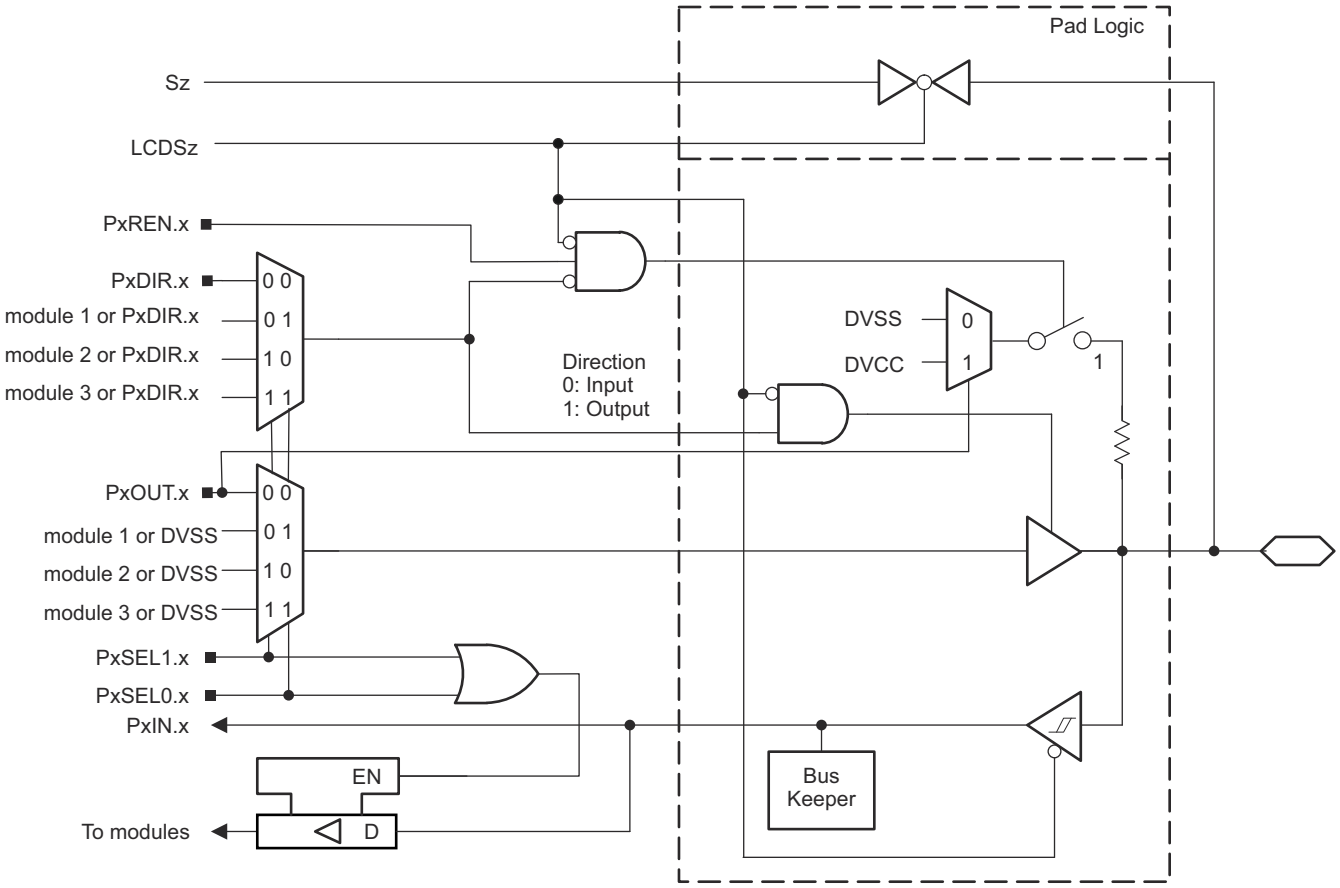
(1) Direction controlled by eUSCI_A0 module.

(2) Setting P2SEL1.x and P2SEL0.x disables the output driver and the input Schmitt trigger to prevent parasitic cross currents when applying analog signals.

(3) Setting the CEPDx bit of the comparator disables the output driver and the input Schmitt trigger to prevent parasitic cross currents when applying analog signals. Selecting the Cx input pin to the comparator multiplexer with the input select bits in the comparator module automatically disables output driver and input buffer for that pin, regardless of the state of the associated CEPDx bit.

9.14.5 Port P2 (P2.4 to P2.7) Input/Output With Schmitt Trigger

Figure 9-6 shows the port diagram. Table 9-28 summarizes the selection of the pin function.



Functional representation only.

Figure 9-6. Port P2 (P2.4 to P2.7) Diagram

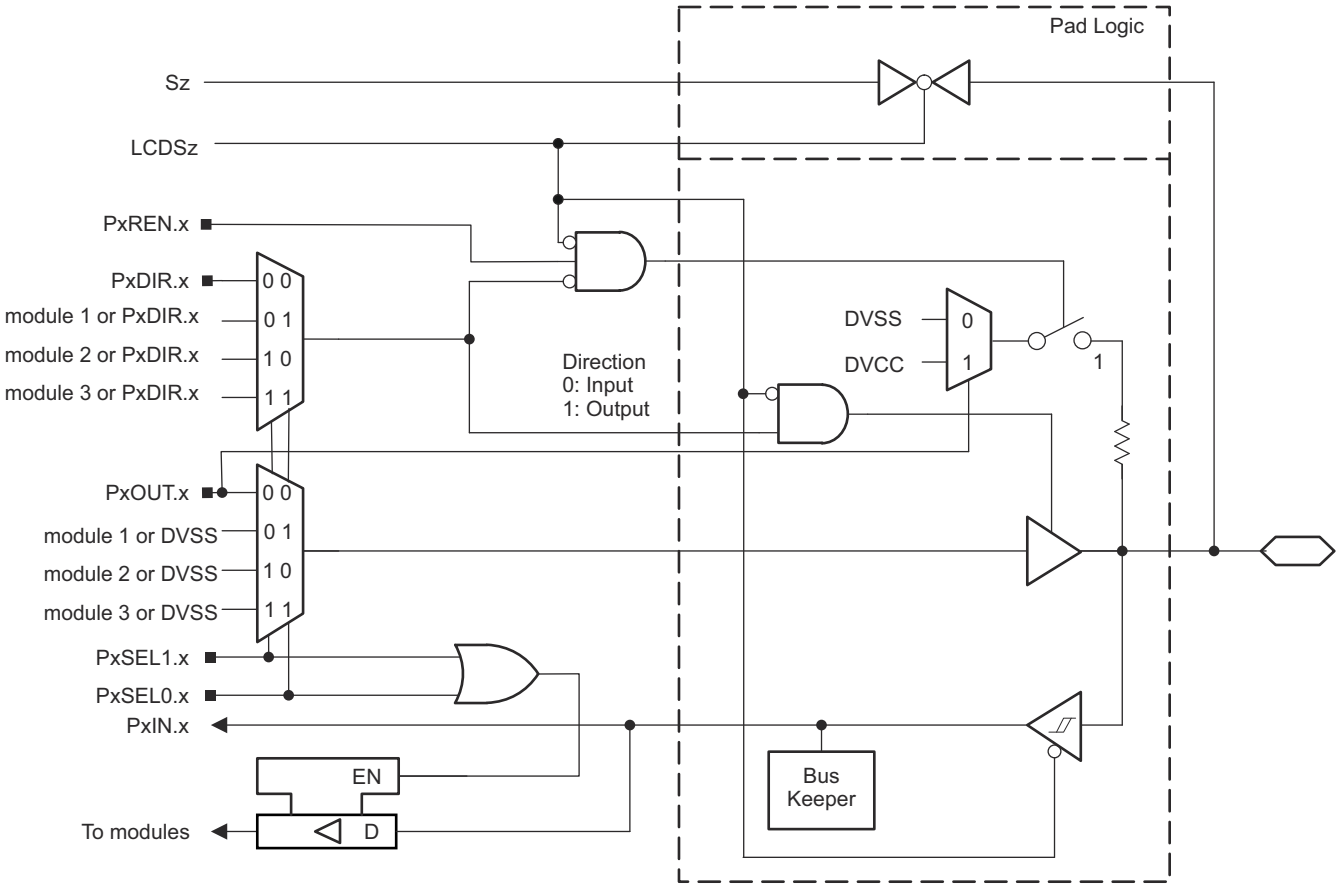
Table 9-28. Port P2 (P2.4 to P2.7) Pin Functions

PIN NAME (P2.x)	x	FUNCTION	CONTROL BITS OR SIGNALS (1)			
			P2DIR.x	P2SEL1.x	P2SEL0.x	LCDSz
P2.4/TA0LCK/TB0CLK/TA1CLK/ LCDS32	4	P2.4 (I/O)	0 = Input, 1 = Output	0	0	0
		TA0LCK	0	0	1	0
		Internally tied to DVSS	1			
		TB0LCK	0	1	0	0
		Internally tied to DVSS	1			
		TA1LCK	0	1	1	0
		Internally tied to DVSS	1			
		Sz (1)	X	X	X	1
P2.5/TA4.0/LCDS31	5	P2.5 (I/O)	0 = Input, 1 = Output	0	0	0
		N/A	0	0	1	0
		Internally tied to DVSS	1			
		TA4.CCI0B	0	1	0	0
		TA4.0	1			
		N/A	0	1	1	0
		Internally tied to DVSS	1			
		Sz (1)	X	X	X	1
P2.6/TA4.1/LCDS30	6	P2.6 (I/O)	0 = Input, 1 = Output	0	0	0
		N/A	0	0	1	0
		Internally tied to DVSS	1			
		TA4.CCI1B	0	1	0	0
		TA4.1	1			
		N/A	0	1	1	0
		Internally tied to DVSS	1			
		Sz (1)	X	X	X	1
P2.7/TA0.0/LCDS21	7	P2.7 (I/O)	0 = Input, 1 = Output	0	0	0
		N/A	0	0	1	0
		Internally tied to DVSS	1			
		TA0.CCI0B	0	1	0	0
		TA0.0	1			
		N/A	0	1	1	0
		Internally tied to DVSS	1			
		Sz (1)	X	X	X	1

(1) Associated LCD segment is package dependent. Refer to the pin diagrams and signal descriptions in Section 7.

9.14.6 Port P3 (P3.0 to P3.7) Input/Output With Schmitt Trigger

Figure 9-7 shows the port diagram. Table 9-29 summarizes the selection of the pin function.



Functional representation only.

Figure 9-7. Port P3 (P3.0 to P3.7) Diagram

Table 9-29. Port P3 (P3.0 to P3.7) Pin Functions

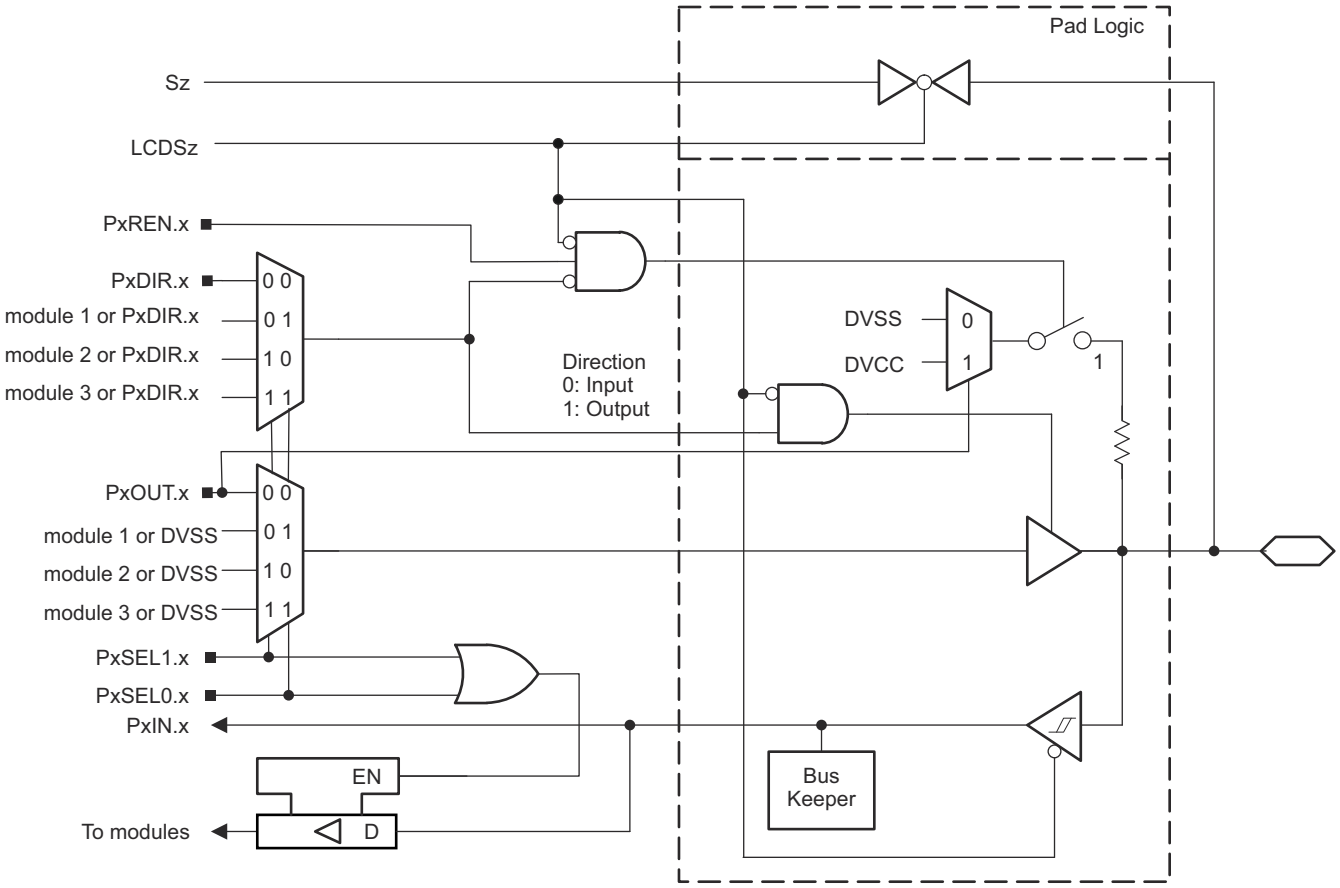
PIN NAME (P3.x)	x	FUNCTION	CONTROL BITS OR SIGNALS (1)			
			P3DIR.x	P3SEL1.x	P3SEL0.x	LCDSz
P3.0/TB0.0/LCDS29	0	P3.0 (I/O)	0 = Input, 1 = Output	0	0	0
		N/A	0	0	1	0
		Internally tied to DVSS	1			
		TB0.CCI0B	0	1	0	0
		TB0.0	1			
		N/A	0	1	1	0
		Internally tied to DVSS	1			
		Sz (1)	X	X	X	1
P3.1/TB0.1/LCDS28	1	P3.1 (I/O)	0 = Input, 1 = Output	0	0	0
		N/A	0	0	1	0
		Internally tied to DVSS	1			
		N/A	0	1	0	0
		TB0.1	1			
		N/A	0	1	1	0
		Internally tied to DVSS	1			
		Sz (1)	X	X	X	1
P3.2/TB0.2/LCDS27	2	P3.2 (I/O)	0 = Input, 1 = Output	0	0	0
		N/A	0	0	1	0
		Internally tied to DVSS	1			
		N/A	0	1	0	0
		TB0.2	1			
		N/A	0	1	1	0
		Internally tied to DVSS	1			
		Sz (1)	X	X	X	1
P3.3/TB0.3/LCDS26	3	P3.3 (I/O)	0 = Input, 1 = Output	0	0	0
		N/A	0	0	1	0
		Internally tied to DVSS	1			
		TB0.CCI3B	0	1	0	0
		TB0.3	1			
		N/A	0	1	1	0
		Internally tied to DVSS	1			
		Sz (1)	X	X	X	1
P3.4/TB0OUTH/LCDS25	4	P3.4 (I/O)	0 = Input, 1 = Output	0	0	0
		N/A	0	0	1	0
		Internally tied to DVSS	1			
		TB0OUTH	0	1	0	0
		Internally tied to DVSS	1			
		N/A	0	1	1	0
		Internally tied to DVSS	1			
		Sz (1)	X	X	X	1

Table 9-29. Port P3 (P3.0 to P3.7) Pin Functions (continued)

PIN NAME (P3.x)	x	FUNCTION	CONTROL BITS OR SIGNALS (1)			
			P3DIR.x	P3SEL1.x	P3SEL0.x	LCDSz
P3.5/TB0.4/LCDS24	5	P3.5 (I/O)	0 = Input, 1 = Output	0	0	0
		N/A	0	0	1	0
		Internally tied to DVSS	1			
		TB0.CCI4B	0	1	0	0
		TB0.4	1			
		N/A	0	1	1	0
		Internally tied to DVSS	1			
		Sz (1)	X	X	X	1
P3.6/TB0.5/LCDS23	6	P3.6 (I/O)	0 = Input, 1 = Output	0	0	0
		N/A	0	0	1	0
		Internally tied to DVSS	1			
		TB0.CCI5B	0	1	0	0
		TB0.5	1			
		N/A	0	1	1	0
		Internally tied to DVSS	1			
		Sz (1)	X	X	X	1
P3.7/TB0.6/LCDS22	7	P3.7 (I/O)	0 = Input, 1 = Output	0	0	0
		N/A	0	0	1	0
		Internally tied to DVSS	1			
		TB0.CCI6B	0	1	0	0
		TB0.6	1			
		N/A	0	1	1	0
		Internally tied to DVSS	1			
		Sz (1)	X	X	X	1

9.14.7 Port P4 (P4.0 to P4.7) Input/Output With Schmitt Trigger

Figure 9-8 shows the port diagram. Table 9-30 summarizes the selection of the pin function.



Functional representation only.

Figure 9-8. Port P4 (P4.0 to P4.7) Diagram

Table 9-30. Port P4 (P4.0 to P4.7) Pin Functions

PIN NAME (P4.x)	x	FUNCTION	CONTROL BITS OR SIGNALS (1)			
			P4DIR.x	P4SEL1.x	P4SEL0.x	LCDSz
P4.0/RTCCLK/LCDS16	0	P4.0 (I/O)	0 = Input, 1 = Output	0	0	0
		N/A	0	0	1	0
		Internally tied to DVSS	1			
		N/A	0	1	0	0
		RTCCLK	1			
		N/A	0	1	1	0
		Internally tied to DVSS	1			
		Sz (1)	X	X	X	1

Table 9-30. Port P4 (P4.0 to P4.7) Pin Functions (continued)

PIN NAME (P4.x)	x	FUNCTION	CONTROL BITS OR SIGNALS (1)			
			P4DIR.x	P4SEL1.x	P4SEL0.x	LCDSz
P4.1/UCA0CLK/LCDS15	1	P4.1 (I/O)	0 = Input, 1 = Output	0	0	0
		UCA0CLK	X(1)	0	1	0
		N/A	0	1	0	0
		Internally tied to DVSS	1			
		N/A	0	1	1	0
		Internally tied to DVSS	1			
		Sz (1)	X	X	X	1
P4.2/UCA0STE/LCDS14	2	P4.2 (I/O)	0 = Input, 1 = Output	0	0	0
		UCA0STE	X(1)	0	1	0
		N/A	0	1	0	0
		Internally tied to DVSS	1			
		N/A	0	1	1	0
		Internally tied to DVSS	1			
		Sz (1)	X	X	X	1
P4.3/UCA0SIMO/UCA0TXD/LCDS13	3	P4.3 (I/O)	0 = Input, 1 = Output	0	0	0
		UCA0SIMO/UCA0TXD	X(1)	0	1	0
		N/A	0	1	0	0
		Internally tied to DVSS	1			
		N/A	0	1	1	0
		Internally tied to DVSS	1			
		Sz (1)	X	X	X	1
P4.4/UCA0SOMI/UCA0RXD/ LCDS12	4	P4.4 (I/O)	0 = Input, 1 = Output	0	0	0
		UCA0SOMI/UCA0RXD	X(1)	0	1	0
		N/A	0	1	0	0
		Internally tied to DVSS	1			
		N/A	0	1	1	0
		Internally tied to DVSS	1			
		Sz (1)	X	X	X	1
P4.5/TA0LCK/TA1CLK/LCDS11	5	P4.5 (I/O)	0 = Input, 1 = Output	0	0	0
		TA0CLK	0	0	1	0
		Internally tied to DVSS	1			
		TA1CLK	0	1	0	0
		Internally tied to DVSS	1			
		N/A	0	1	1	0
		Internally tied to DVSS	1			
		Sz (1)	X	X	X	1

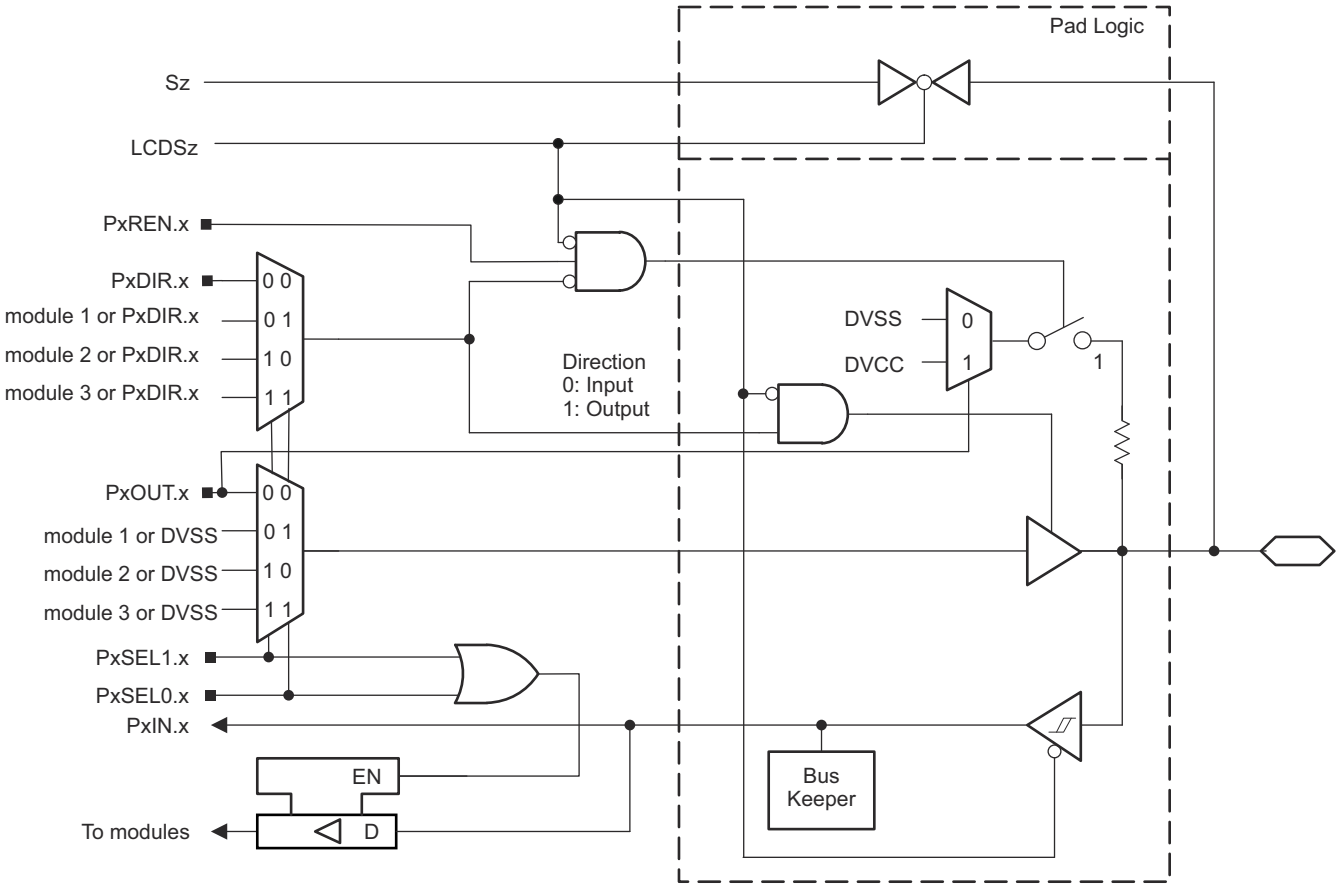
Table 9-30. Port P4 (P4.0 to P4.7) Pin Functions (continued)

PIN NAME (P4.x)	x	FUNCTION	CONTROL BITS OR SIGNALS (1)			
			P4DIR.x	P4SEL1.x	P4SEL0.x	LCDSz
P4.6/TB0CLK/TA4CLK/LCDS10	6	P4.6 (I/O)	0 = Input, 1 = Output	0	0	0
		TB0CLK	0	0	1	0
		Internally tied to DVSS	1			
		TA4CLK	0	1	0	0
		Internally tied to DVSS	1			
		N/A	0	1	1	0
		Internally tied to DVSS	1			
		Sz (1)	X	X	X	1
P4.7/DMAE0/LCDS9	7	P4.7 (I/O)	0 = Input, 1 = Output	0	0	0
		N/A	0	0	1	0
		Internally tied to DVSS	1			
		DMAE0	0	1	0	0
		Internally tied to DVSS	1			
		N/A	0	1	1	0
		Internally tied to DVSS	1			
		Sz (1)	X	X	X	1

(1) Direction controlled by eUSCI_A0 module.

9.14.8 Port P5 (P5.0 to P5.7) Input/Output With Schmitt Trigger

Figure 9-9 shows the port diagram. Table 9-31 summarizes the selection of the pin function.



Functional representation only.

Figure 9-9. Port P5 (P5.0 to P5.7) Diagram

Table 9-31. Port P5 (P5.0 to P5.7) Pin Functions

PIN NAME (P5.x)	x	FUNCTION	CONTROL BITS OR SIGNALS[1]			
			P5DIR.x	P5SEL1.x	P5SEL0.x	LCDSz
P5.0/UCA2SIMO/UCA2TXD/LCDS8	0	P5.0 (I/O)	0 = Input, 1 = Output	0	0	0
		N/A	0	0	1	0
		Internally tied to DVSS	1			
		UCA2SIMO/UCA2TXD	X[4]	1	0	0
		N/A	0	1	1	0
		Internally tied to DVSS	1			
		Sz[3]	X	X	X	1
P5.1/UCA2SOMI/UCA2RXD/LCDS7	1	P5.1 (I/O)	0 = Input, 1 = Output	0	0	0
		N/A	0	0	1	0
		Internally tied to DVSS	1			
		UCA2SOMI/UCA2RXD	X[4]	1	0	0
		N/A	0	1	1	0
		Internally tied to DVSS	1			
		Sz[3]	X	X	X	1

Table 9-31. Port P5 (P5.0 to P5.7) Pin Functions (continued)

PIN NAME (P5.x)	x	FUNCTION	CONTROL BITS OR SIGNALS[1]			
			P5DIR.x	P5SEL1.x	P5SEL0.x	LCDSz
P5.2/UCA2CLK/LCDS6	2	P5.2 (I/O)	0 = Input, 1 = Output	0	0	0
		N/A	0	0	1	0
		Internally tied to DVSS	1			
		UCA2CLK	X[4]	1	0	0
		N/A	0	1	1	0
		Internally tied to DVSS	1			
		Sz[3]	X	X	X	1
P5.3/UCA2STE/LCDS5	3	P5.3 (I/O)	0 = Input, 1 = Output	0	0	0
		N/A	0	0	1	0
		Internally tied to DVSS	1			
		UCA2STE	X[4]	1	0	0
		N/A	0	1	1	0
		Internally tied to DVSS	1			
		Sz[3]	X	X	X	1
P5.4/UCB1CLK/LCDS4	4	P5.4 (I/O)	0 = Input, 1 = Output	0	0	0
		N/A	0	0	1	0
		Internally tied to DVSS	1			
		UCB1CLK	X[2]	1	0	0
		N/A	0	1	1	0
		Internally tied to DVSS	1			
		Sz [3]	X	X	X	1
P5.5/TA0CLK/UCB1SIMO/ UCB1SDA/LCDS3	5	P5.5 (I/O)	0 = Input, 1 = Output	0	0	0
		TA0CLK	0	0	1	0
		Internally tied to DVSS	1			
		UCB1SIMO/UCB1SDA	X[2]	1	0	0
		N/A	0	1	1	0
		Internally tied to DVSS	1			
		Sz [3]	X	X	X	1
P5.6/UCB1SOMI/UCB1SCL/LCDS2	6	P5.6 (I/O)	0 = Input, 1 = Output	0	0	0
		N/A	0	0	1	0
		Internally tied to DVSS	1			
		UCB1SOMI/UCB1SCL	X[2]	1	0	0
		N/A	0	1	1	0
		Internally tied to DVSS	1			
		Sz [3]	X	X	X	1

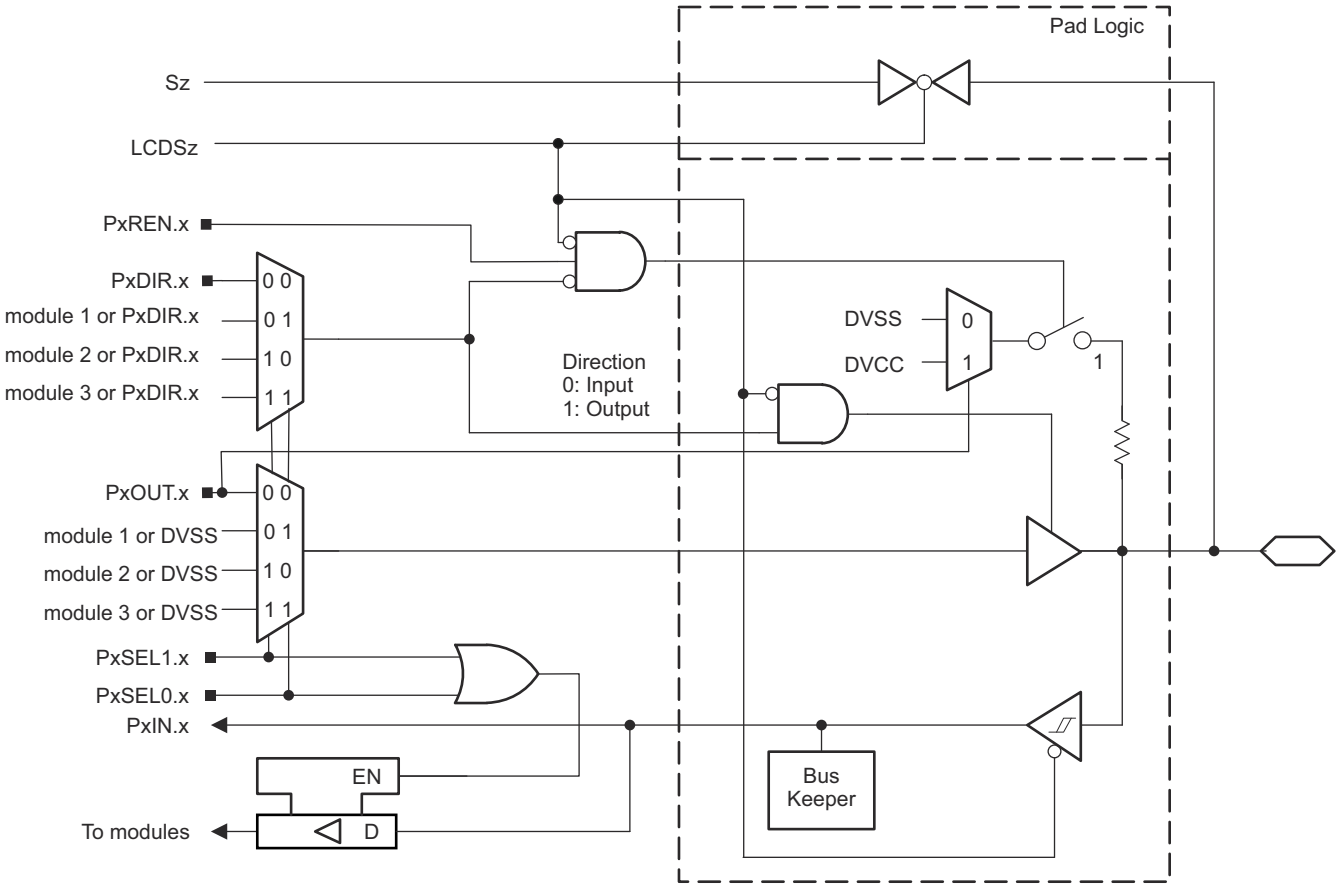
Table 9-31. Port P5 (P5.0 to P5.7) Pin Functions (continued)

PIN NAME (P5.x)	x	FUNCTION	CONTROL BITS OR SIGNALS(1)			
			P5DIR.x	P5SEL1.x	P5SEL0.x	LCDSz
P5.7/UCB1STE/LCDS1	7	P5.7 (I/O)	0 = Input, 1 = Output	0	0	0
		N/A	0	0	1	0
		Internally tied to DVSS	1			
		UCB1STE	X(2)	1	0	0
		N/A	0	1	1	0
		Internally tied to DVSS	1			
		Sz (3)	X	X	X	1

(1) X = Don't care
(2) Direction controlled by eUSCI_B1 module.
(3) Associated LCD segment is package dependent. Refer to the pin diagrams and signal descriptions in Section 7.
(4) Direction controlled by eUSCI_A2 module.

9.14.9 Port P6 (P6.0) Input/Output With Schmitt Trigger

Figure 9-10 shows the port diagram. Table 9-32 summarizes the selection of the pin function.



Functional representation only.

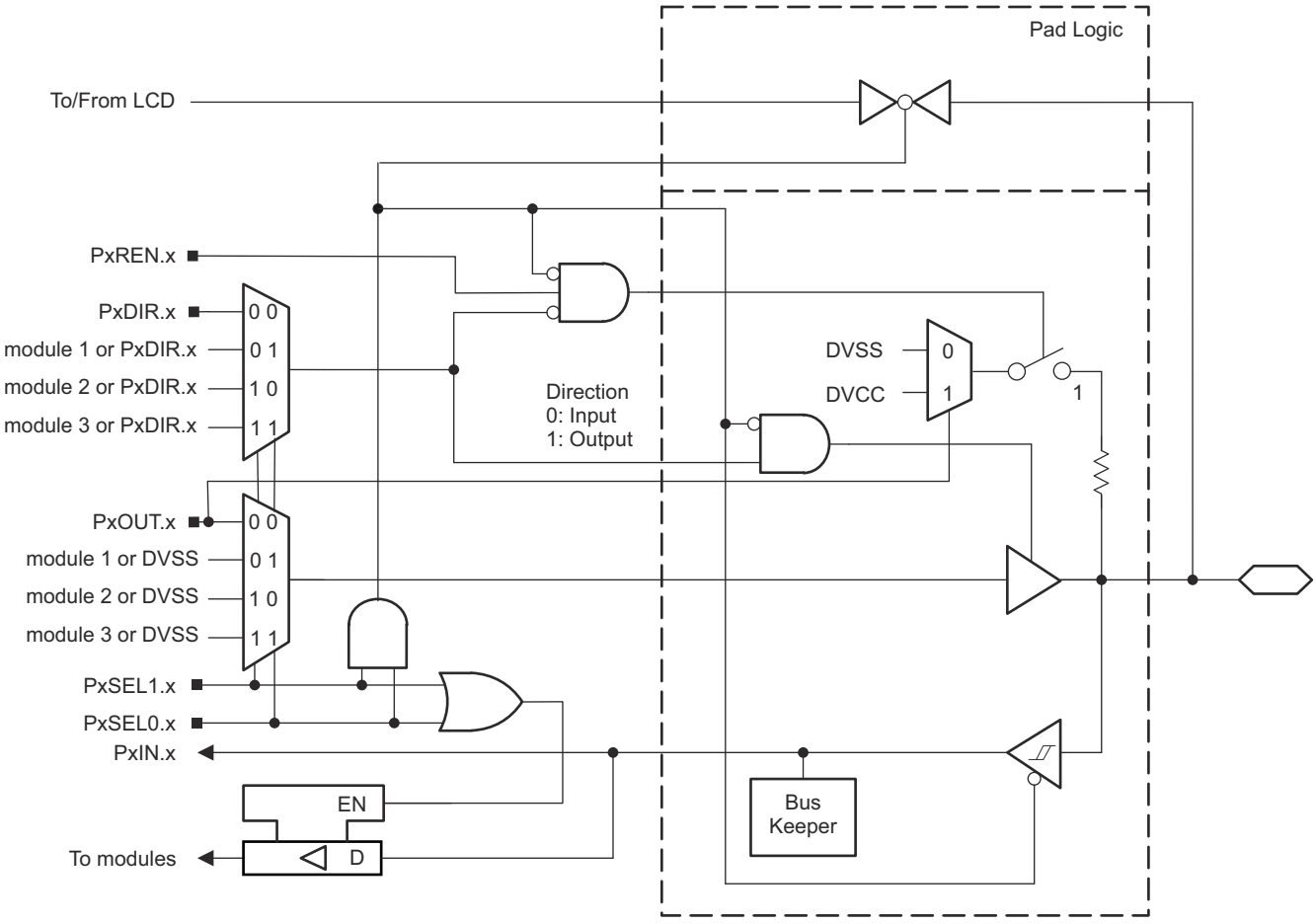
Figure 9-10. Port P6 (P6.0) Diagram

Table 9-32. Port P6 (P6.0) Pin Functions

PIN NAME (P6.x)	x	FUNCTION	CONTROL BITS OR SIGNALS (1)			
			P6DIR.x	P6SEL1.x	P6SEL0.x	LCDSz
P6.0/COUT/LCDS0	0	P6.0 (I/O)	0 = Input, 1 = Output	0	0	0
		N/A	0	0	1	0
		Internally tied to DVSS	1			
		N/A	0	1	0	0
		COUT	1			
		N/A	0	1	1	0
		Internally tied to DVSS	1			
		Sz (1)	X	X	X	1

9.14.10 Port P6 (P6.1 to P6.5) Input/Output With Schmitt Trigger

Figure 9-11 shows the port diagram. Table 9-33 summarizes the selection of the pin function.



Functional representation only.

Figure 9-11. Port P6 (P6.1 to P6.5) Diagram

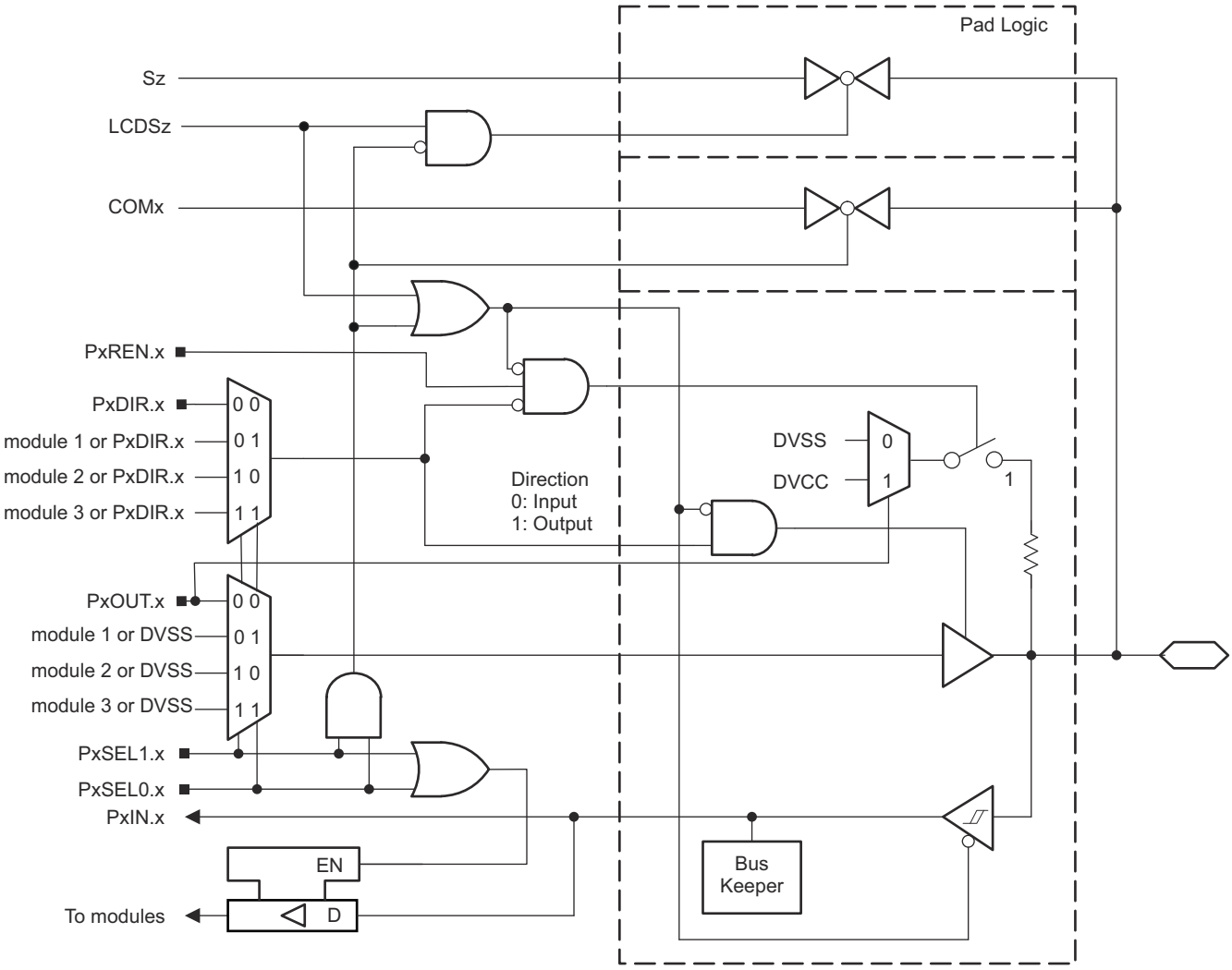
Table 9-33. Port P6 (P6.1 to P6.5) Pin Functions

PIN NAME (P6.x)	x	FUNCTION	CONTROL BITS OR SIGNALS (1)		
			P6DIR.x	P6SEL1.x	P6SEL0.x
P6.1/R03	1	P6.1 (I/O)	0 = Input, 1 = Output	0	0
		N/A	0	0	1
		Internally tied to DVSS	1		
		N/A	0	1	0
		Internally tied to DVSS	1		
		R03 (1)	X	1	1
P6.2/R13/LCDREF	2	P6.2 (I/O)	0 = Input, 1 = Output	0	0
		N/A	0	0	1
		Internally tied to DVSS	1		
		N/A	0	1	0
		Internally tied to DVSS	1		
		R13/LCDREF (1)	X	1	1
P6.3/R23	3	P6.3 (I/O)	0 = Input, 1 = Output	0	0
		N/A	0	0	1
		Internally tied to DVSS	1		
		N/A	0	1	0
		Internally tied to DVSS	1		
		R23 (1)	X	1	1
P6.4/COM0	4	P6.4 (I/O)	0 = Input, 1 = Output	0	0
		N/A	0	0	1
		Internally tied to DVSS	1		
		N/A	0	1	0
		Internally tied to DVSS	1		
		COM0 (1)	X	1	1
P6.5/COM1	5	P6.5 (I/O)	0 = Input, 1 = Output	0	0
		N/A	0	0	1
		Internally tied to DVSS	1		
		N/A	0	1	0
		Internally tied to DVSS	1		
		COM1 (1)	X	1	1

(1) Setting P6SEL1.x and P6SEL0.x disables the output driver and the input Schmitt trigger to prevent parasitic cross currents when applying analog signals.

9.14.11 Port P6 (P6.6 and P6.7) Input/Output With Schmitt Trigger

Figure 9-12 shows the port diagram. Table 9-34 summarizes the selection of the pin function.



Functional representation only.

Figure 9-12. Port P6 (P6.6 and P6.7) Diagram

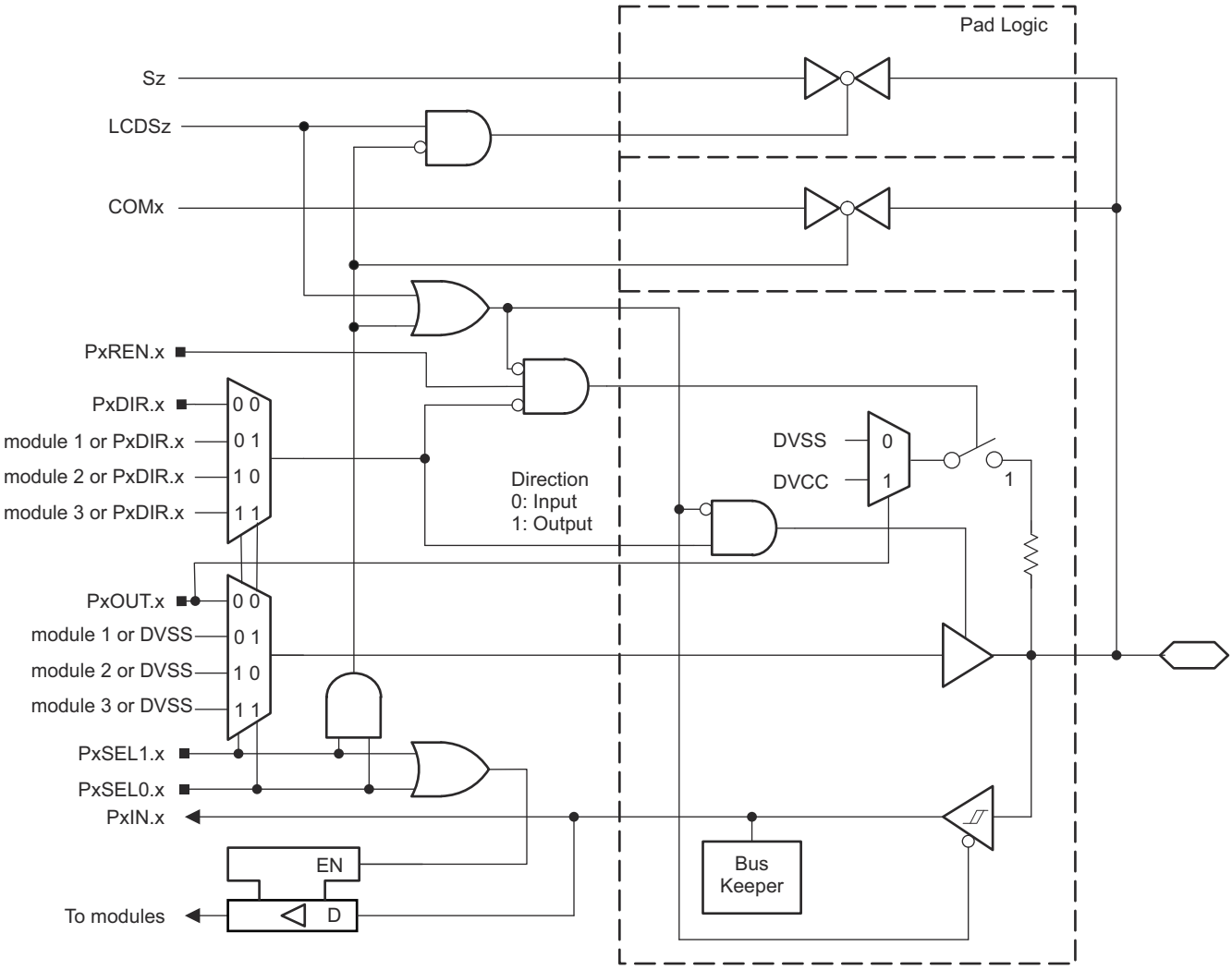
Table 9-34. Port P6 (P6.6 to P6.7) Pin Functions

PIN NAME (P6.x)	x	FUNCTION	CONTROL BITS OR SIGNALS (1)			
			P6DIR.x	P6SEL1.x	P6SEL0.x	LCDSz
P6.6/COM2/LCDS38	6	P6.6(I/O)	0 = Input, 1 = Output	0	0	0
		N/A	0	0	1	0
		Internally tied to DVSS	1			
		N/A	0	1	0	0
		Internally tied to DVSS	1			
		COM2(1)	X	1	1	0
		Sz (1)	X	X	0	1
				0	X	
P6.7/COM3/LCDS37	7	P6.7(I/O)	0 = Input, 1 = Output	0	0	0
		N/A	0	0	1	0
		Internally tied to DVSS	1			
		N/A	0	1	0	0
		Internally tied to DVSS	1			
		COM3(1)	X	1	1	0
		Sz (1)	X	X	0	1
				0	X	

(1) X = Don't care

9.14.12 Port P7 (P7.0 to P7.3) Input/Output With Schmitt Trigger

Figure 9-13 shows the port diagram. Table 9-35 summarizes the selection of the pin function.



Functional representation only.

Figure 9-13. Port P7 (P7.0 to P7.3) Diagram

Table 9-35. Port P7 (P7.0 to P7.3) Pin Functions

PIN NAME (P7.x)	x	FUNCTION	CONTROL BITS OR SIGNALS[1]			
			P7DIR.x	P7SEL1.x	P7SEL0.x	LCDSz
P7.0/UCA2SIMO/UCA2TXD/ ACLK/ COM4/LCDS36	0	P7.0(I/O)	0 = Input, 1 = Output	0	0	0
		UCA2SIMO/UCA2TXD	X[2]	0	1	0
		N/A	0	1	0	0
		ACLK	1			
		COM4[1]	X	1	1	0
		Sz [1]	X	X	0	1
				0	X	
P7.1/UCA2SOMI/UCA2RXD/ SMCLK/COM5/LCDS35	1	P7.1(I/O)	0 = Input, 1 = Output	0	0	0
		UCA2SOMI/UCA2RXD	X[2]	0	1	0
		N/A	0	1	0	0
		SMCLK	1			
		COM5[1]	X	1	1	0
		Sz [1]	X	X	0	1
				0	X	
P7.2/UCA2CLK/TB0.0/COM6/ LCDS34	2	P7.2(I/O)	0 = Input, 1 = Output	0	0	0
		UCA2CLK	X[2]	0	1	0
		TB0.CCI0A	0	1	0	0
		TB0.0	1			
		COM6[1]	X	1	1	0
		Sz [1]	X	X	0	1
				0	X	
P7.3/UCA2STE/TB0.1/COM7/ LCDS33	3	P7.3(I/O)	0 = Input, 1 = Output	0	0	0
		UCA2STE	X[2]	0	1	0
		TB0.CCI1A	0	1	0	0
		TB0.1	1			
		COM7[1]	X	1	1	0
		Sz [1]	X	X	0	1
				0	X	

(1) X = Don't care
(2) Direction controlled by eUSCI_A2 module.

9.14.13 Port P7 (P7.4 to P7.7) Input/Output With Schmitt Trigger

Figure 9-14 shows the port diagram. Table 9-36 summarizes the selection of the pin function.

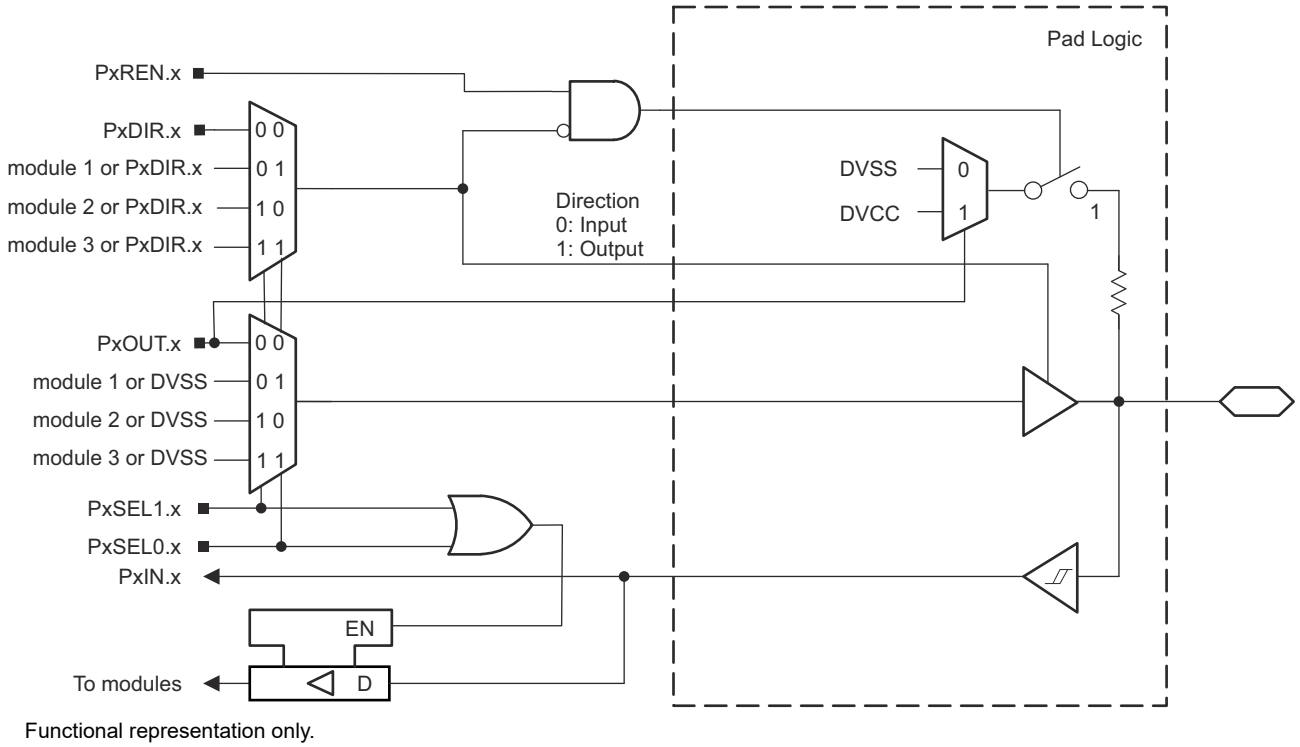


Figure 9-14. Port P7 (P7.6 and P7.7) Diagram

Table 9-36. Port P7 (P7.6 to P7.7) Pin Functions

PIN NAME (P7.x)	x	FUNCTION	CONTROL BITS OR SIGNALS[1]		
			P7DIR.x	P7SEL1.x	P7SEL0.x
P7.4/TA0.1	4	P7.4(I/O)	0 = Input, 1 = Output	0	0
		TA0.CCI1A	0	0	1
		TA0.1	1		
		N/A	0	1	0
		Internally tied to DVSS	1		
		N/A	0	1	1
		Internally tied to DVSS	1		
P7.5/TA1.1	5	P7.5(I/O)	0 = Input, 1 = Output	0	0
		TA1.CCI1A	0	0	1
		TA1.1	1		
		N/A	0	1	0
		Internally tied to DVSS	1		
		N/A	0	1	1
		Internally tied to DVSS	1		
P7.6/TA4.1/DMAE0/COUT	6	P7.6(I/O)	0 = Input, 1 = Output	0	0
		TA4.CCI1A	0	0	1
		TA4.1	1		
		DMAE0	0	1	0
		Internally tied to DVSS	1		
		N/A	0	1	1
		COUT	1		
P7.7/TA0.2/TB0OUTH/COUT	7	P7.7(I/O)	0 = Input, 1 = Output	0	0
		TA0.CCI2A	0	0	1
		TA0.2	1		
		TB0OUTH	0	1	0
		Internally tied to DVSS	1		
		N/A	0	1	1
		COUT	1		

(1) X = Don't care

9.14.14 Port P8 (P8.0 to P8.3) Input/Output With Schmitt Trigger

Figure 9-15 shows the port diagram. Table 9-37 summarizes the selection of the pin function.

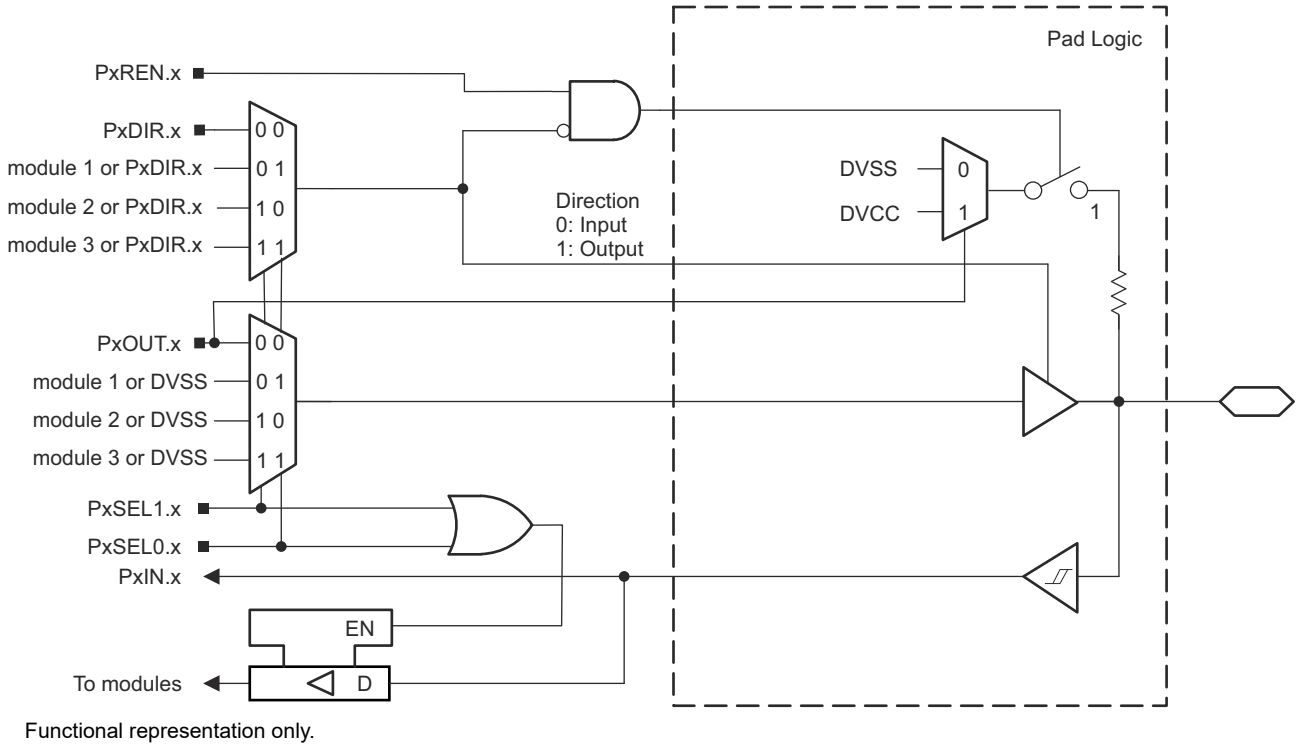


Figure 9-15. Port P8 (P8.0 to P8.3) Diagram

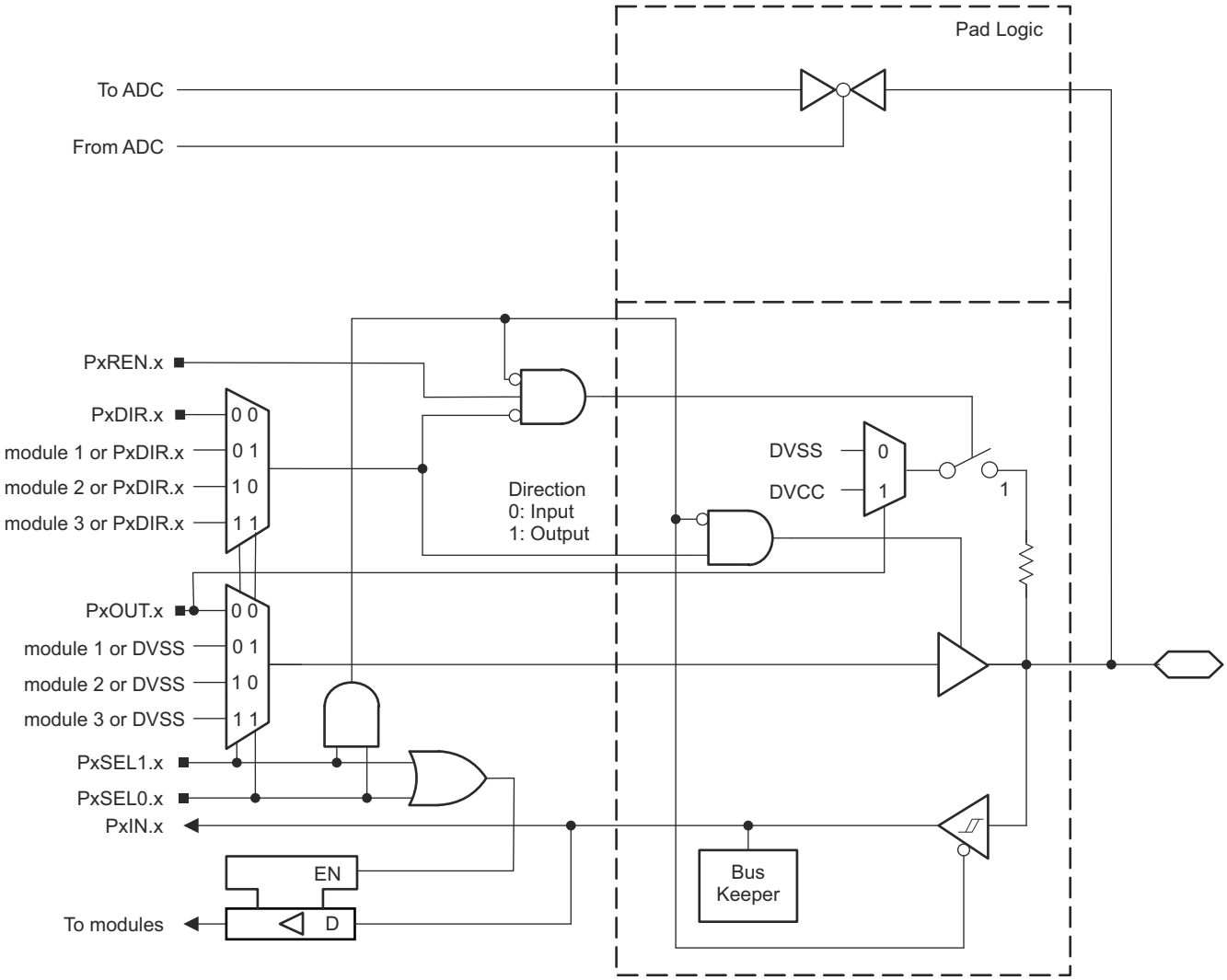
Table 9-37. Port P8 (P8.0 to P8.3) Pin Functions

PIN NAME (P8.x)	x	FUNCTION	CONTROL BITS OR SIGNALS[1]		
			P8DIR.x	P8SEL1.x	P8SEL0.x
P8.0/UCA3STE/TB0.2/DMAE0	0	P8.0(I/O)	0 = Input, 1 = Output	0	0
		UCA3STE	X[2]	0	1
		TB0.CCI2A	0	1	0
		TB0.2	1		
		DMAE0	0	1	1
		Internally tied to DVSS	1		
P8.1/UCA3CLK/TB0.3/TB0OUTH	1	P8.1(I/O)	0 = Input, 1 = Output	0	0
		UCA3CLK	X[2]	0	1
		TB0.CCI3A	0	1	0
		TB0.3	1		
		TB0OUTH	0	1	1
		Internally tied to DVSS	1		
P8.2/UCA3SOMI/UCA3RXD/MCLK	2	P8.2(I/O)	0 = Input, 1 = Output	0	0
		UCA3SOMI/UCA3RXD	X[2]	0	1
		N/A	0	1	0
		MCLK	1		
		N/A	0	1	1
		Internally tied to DVSS	1		
P8.3/UCA3SIMO/UCA3TXD/RTCCLK	3	P8.3(I/O)	0 = Input, 1 = Output	0	0
		UCA3SIMO/UCA3TXD	X[2]	0	1
		N/A	0	1	0
		RTCCLK	1		
		N/A	0	1	1
		Internally tied to DVSS	1		

(1) X = Don't care
(2) Direction controlled by eUSCI_A3 module.

9.14.15 Port P8 (P8.4 to P8.7) Input/Output With Schmitt Trigger

Figure 9-16 shows the port diagram. Table 9-38 summarizes the selection of the pin function.



Functional representation only.

Figure 9-16. Port P8 (P8.4 to P8.7) Diagram

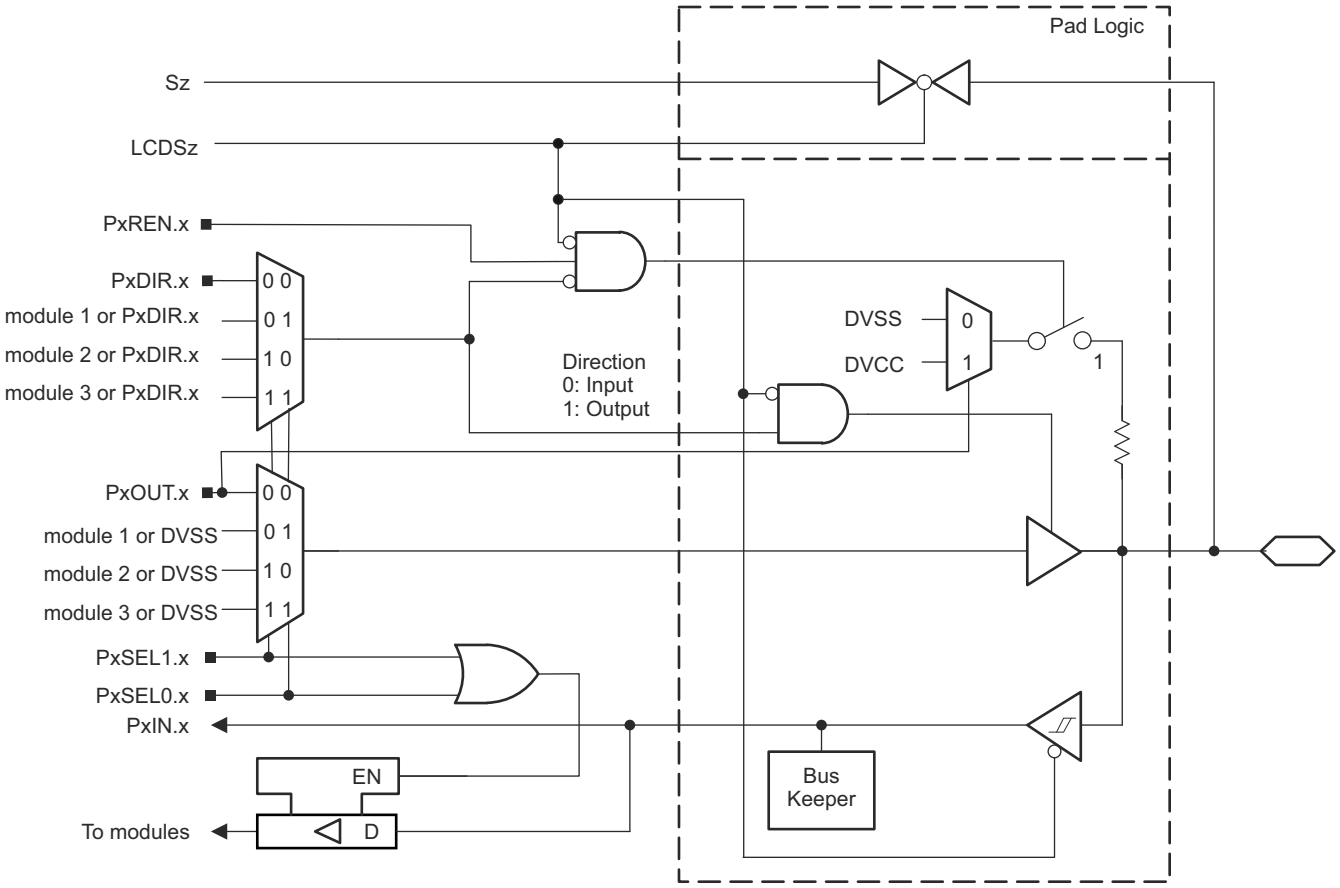
Table 9-38. Port P8 (P8.4 to P8.7) Pin Functions

PIN NAME (P8.x)	x	FUNCTION	CONTROL BITS OR SIGNALS[1]		
			P8DIR.x	P8SEL1.x	P8SEL0.x
P8.4/UCB1CLK/TA1.2/A10	4	P8.4(I/O)	0 = Input, 1 = Output	0	0
		UCB1CLK	X[2]	0	1
		TA1.CCI2A	0	1	0
		TA1.2	1		
		A10[3]	X	1	1
P8.5/UCB1SIMO/UCB1SDA/A11	5	P8.5(I/O)	0 = Input, 1 = Output	0	0
		UCB1SIMO/UCB1SDA	X[2]	0	1
		N/A	0	1	0
		Internally tied to DVSS	1		
		A11[3]	X	1	1
P8.6/UCB1SOMI/UCB1SCL/A12	6	P8.6(I/O)	0 = Input, 1 = Output	0	0
		UCB1SOMI/UCB1SCL	X[2]	0	1
		N/A	0	1	0
		Internally tied to DVSS	1		
		A12[3]	X	1	1
P8.7/UCB1STE/USSXT_BOUT/A13	7	P8.7(I/O)	0 = Input, 1 = Output	0	0
		UCB1STE	X[2]	0	1
		N/A	0	1	0
		USSXT_BOUT[4]	1		
		A13[3]	X	1	1

(1) X = Don't care
(2) Direction controlled by eUSCI_B1 module.
(3) Setting P8SEL1.x and P8SEL0.x disables the output driver and the input Schmitt trigger to prevent parasitic cross currents when applying analog signals.
(4) USSXTHSPLL.PLLXTLCTL.XTOUTOFF bit must also be set to 0.

9.14.16 Port P9 (P9.0 to P9.3) Input/Output With Schmitt Trigger

Figure 9-17 shows the port diagram. Table 9-39 summarizes the selection of the pin function.



Functional representation only.

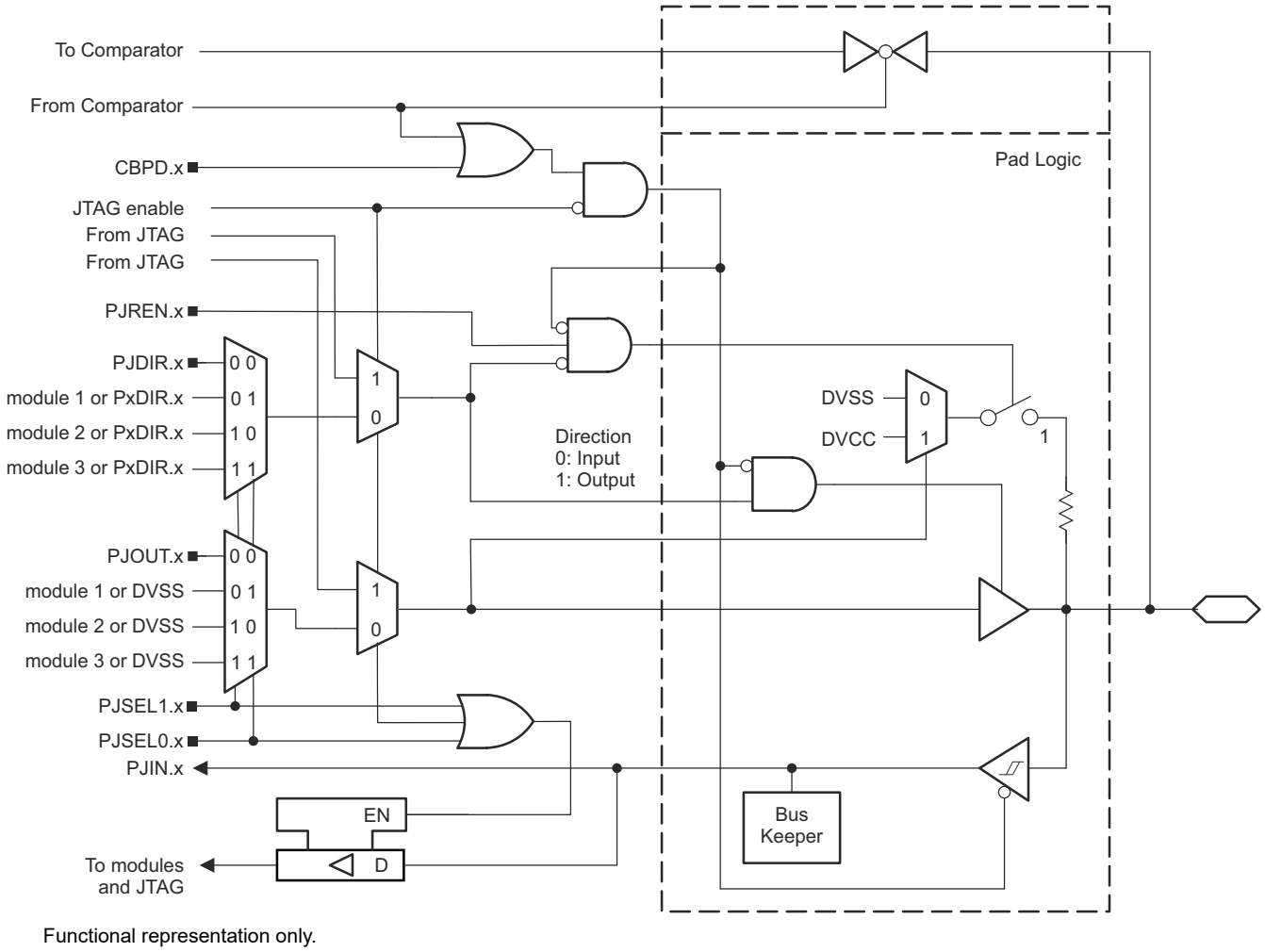
Figure 9-17. Port P9 (P9.0 to P9.3) Diagram

Table 9-39. Port P9 (P9.0 to P9.3) Pin Functions

PIN NAME (P9.x)	x	FUNCTION	CONTROL BITS OR SIGNALS (1)			
			P9DIR.x	P9SEL1.x	P9SEL0.x	LCDSz
P9.0/TA1.0/LCDS20	0	P9.0 (I/O)	0 = Input, 1 = Output	0	0	0
		TA1.CCI0B	0	0	1	0
		TA1.0	1			
		N/A	0	1	0	0
		Internally tied to DVSS	1			
		N/A	0	1	1	0
		Internally tied to DVSS	1			
		Sz (1)	X	X	X	1
P9.1/SMCLK/LCDS19	1	P9.1 (I/O)	0 = Input, 1 = Output	0	0	0
		N/A	0	0	1	0
		Internally tied to DVSS	1			
		N/A	0	1	0	0
		SMCLK	1			
		N/A	0	1	1	0
		Internally tied to DVSS	1			
		Sz (1)	X	X	X	1
P9.2/MCLK/LCDS18	2	P9.2 (I/O)	0 = Input, 1 = Output	0	0	0
		N/A	0	0	1	0
		Internally tied to DVSS	1			
		N/A	0	1	0	0
		MCLK	1			
		N/A	0	1	1	0
		Internally tied to DVSS	1			
		Sz (1)	X	X	X	1
P9.3/ACLK/LCDS17	3	P9.3 (I/O)	0 = Input, 1 = Output	0	0	0
		N/A	0	0	1	0
		Internally tied to DVSS	1			
		N/A	0	1	0	0
		ACLK	1			
		N/A	0	1	1	0
		Internally tied to DVSS	1			
		Sz (1)	X	X	X	1

9.14.17 Port PJ (PJ.0 to PJ.3) JTAG Pins TDO, TMS, TCK, TDI/TCLK, Input/Output With Schmitt Trigger

Figure 9-18 shows the port diagram. Table 9-40 summarizes the selection of the pin function.



Functional representation only.

Figure 9-18. Port PJ (PJ.0 to PJ.3) Diagram

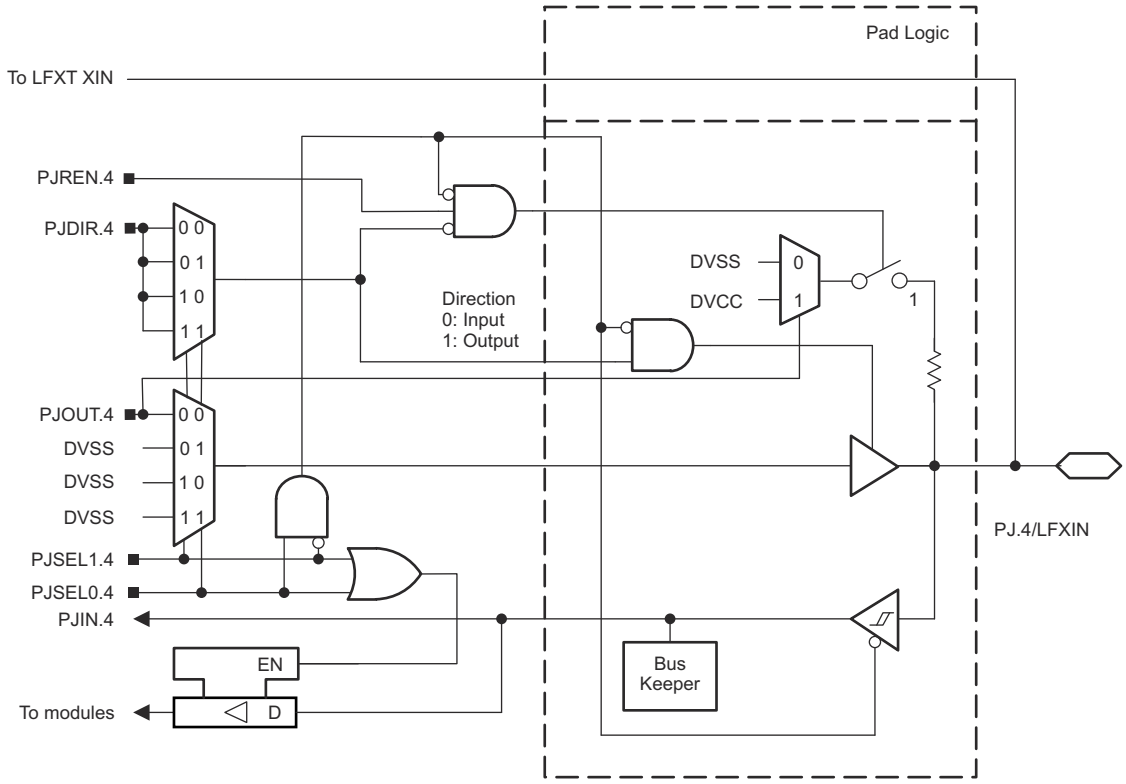
Table 9-40. Port PJ (PJ.0 to PJ.3) Pin Functions

PIN NAME (PJ.x)	x	FUNCTION	CONTROL BITS/ SIGNALS[1]			
			PJDIR.x	PJSEL1.x	PJSEL0.x	CEPDx (Cx)
PJ.0/TDO/ACLK/SRSCG1/ DMAE0/C10	0	PJ.0 (I/O)[2]	0 = Input, 1 = Output	0	0	0
		TDO[3]	X	X	X	0
		N/A	0	0	1	0
		ACLK	1			
		N/A	0	1	0	0
		CPU Status Register Bit SCG1	1			
		DMAE0	0	1	1	0
		Internally tied to DVSS	1			
		C10[5]	X	X	X	1
PJ.1/TDI/TCLK/SMCLK/ SRSCG0/TA4CLK/C11	1	PJ.1 (I/O)[2]	0 = Input, 1 = Output	0	0	0
		TDI/TCLK[3] [4]	X	X	X	0
		N/A	0	0	1	0
		SMCLK	1			
		N/A	0	1	0	0
		CPU Status Register Bit SCG0	1			
		TA4CLK	0	1	1	0
		Internally tied to DVSS	1			
		C11[5]	X	X	X	1
PJ.2/TMS/MCLK/ SROSCOFF/TB0OUTH/C12	2	PJ.2 (I/O)[2]	I: 0; O: 1	0	0	0
		TMS[3] [4]	X	X	X	0
		N/A	0	0	1	0
		MCLK	1			
		N/A	0	1	0	0
		CPU Status Register Bit OSCOFF	1			
		TB0OUTH	0	1	1	0
		Internally tied to DVSS	1			
		C12[5]	X	X	X	1
PJ.3/TCK/RTCCLK/ SRCPUOFF/TB0.6/C13	3	PJ.3 (I/O)[2]	I: 0; O: 1	0	0	0
		TCK[3] [4]	X	X	X	0
		N/A	0	0	1	0
		RTCCLK	1			
		N/A	0	1	0	0
		CPU Status Register Bit CPUOFF	1			
		TB0.CCI6A	0	1	1	0
		TB0.6	1			
		C13[5]	X	X	X	1

(1) X = Don't care
(2) Default condition
(3) The pin direction is controlled by the JTAG module. JTAG mode selection is made through the SYS module or by the Spy-Bi-Wire four-wire entry sequence. Neither PJSEL1.x and PJSEL0.x nor CEPDx bits have an effect in these cases.
(4) In JTAG mode, pullups are activated automatically on TMS, TCK, and TDI/TCLK. PJREN.x are don't care.
(5) Setting the CEPDx bit of the comparator disables the output driver and the input Schmitt trigger to prevent parasitic cross currents when applying analog signals. Selecting the Cx input pin to the comparator multiplexer with the input select bits in the comparator module automatically disables The output driver and input buffer for that pin, regardless of the state of the associated CEPDx bit.

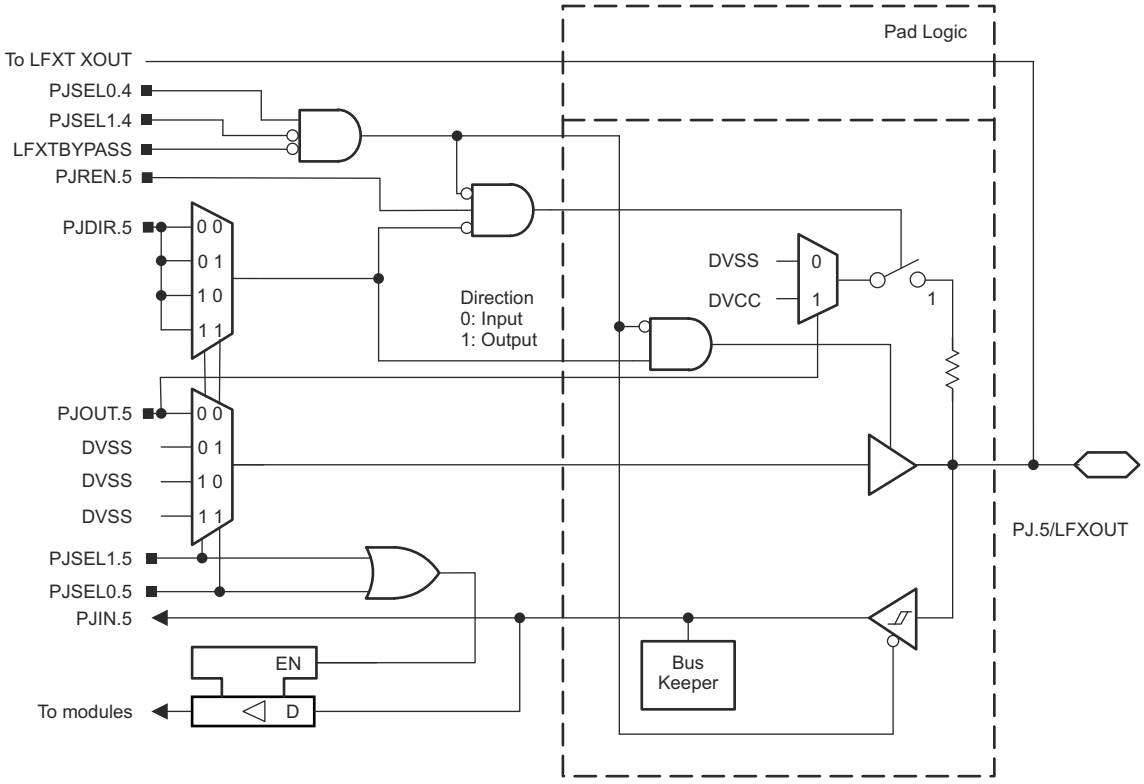
9.14.18 Port PJ (PJ.4 and PJ.5) Input/Output With Schmitt Trigger

Figure 9-19 and Figure 9-20 show the port diagrams. Table 9-41 summarizes the selection of the pin function.



Functional representation only.

Figure 9-19. Port PJ (PJ.4) Diagram



Functional representation only.

Figure 9-20. Port PJ (PJ.5) Diagram

Table 9-41. Port PJ (PJ.4 and PJ.5) Pin Functions

PIN NAME (PJ.x)	x	FUNCTION	CONTROL BITS AND SIGNALS[1]					
			PJDIR.x	PJSEL1.5	PJSEL0.5	PJSEL1.4	PJSEL0.4	LFXT BYPASS
PJ.4/LFXIN	4	PJ.4 (I/O)	I: 0; O: 1	X	X	0	0	X
		N/A	0	X	X	1	X	X
		Internally tied to DVSS	1					
		LFXIN crystal mode[2]	X	X	X	0	1	0
		LFXIN bypass mode[2]	X	X	X	0	1	1
PJ.5/LFXOUT	5	PJ.5 (I/O)	I: 0; O: 1	0	0	0	0	0
						1	X	
						X	X	1[3]
		N/A	0	see[1]	see[1]	0	0	0
						1	X	
						X	X	1[3]
		Internally tied to DVSS	1	see[1]	see[1]	0	0	0
						1	X	
						X	X	1[3]
		LFXOUT crystal mode[2]	X	X	X	0	1	0

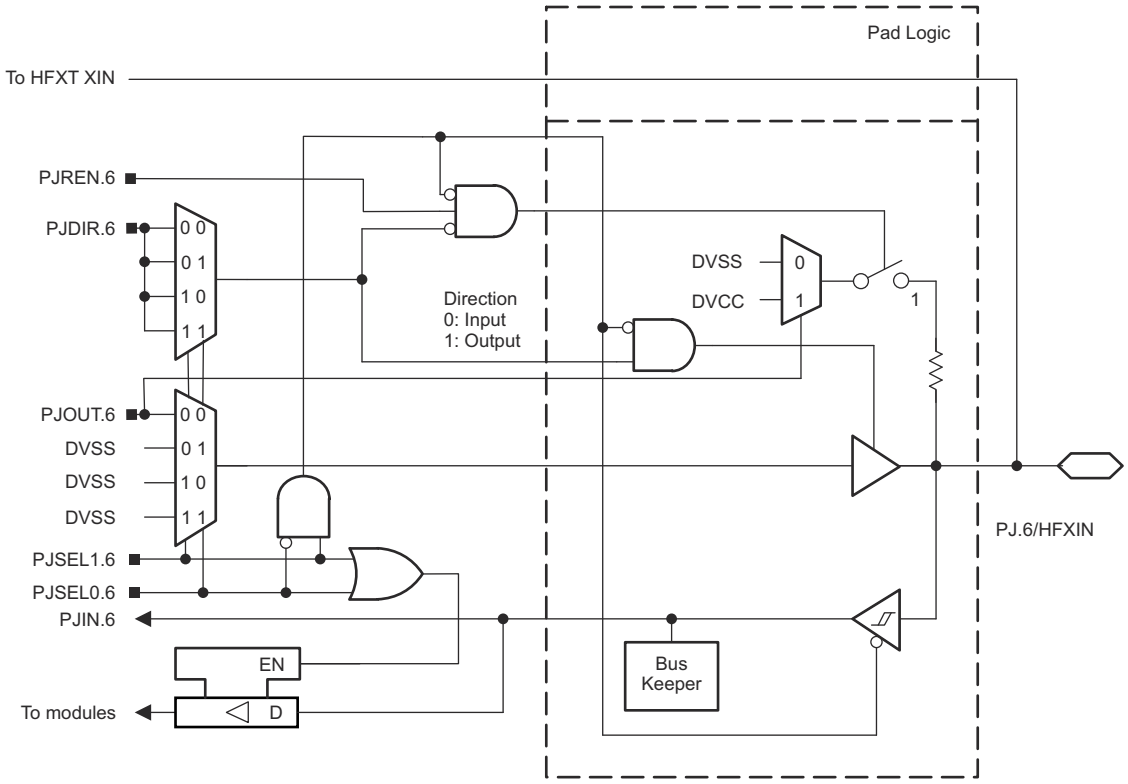
(1) If PJSEL0.5 = 1 or PJSEL1.5 = 1, the general-purpose I/O functionality is disabled. No input function is available. Configured as output, the pin is actively pulled to zero.

(2) If PJSEL1.4 = 0 and PJSEL0.4 = 1, the general-purpose I/O is disabled. When LFXTBYPASS = 0, PJ.4 and PJ.5 are configured for crystal operation and PJSEL1.5 and PJSEL0.5 are don't care. When LFXTBYPASS = 1, PJ.4 is configured for bypass operation and PJ.5 is configured as general-purpose I/O.

(3) When PJ.4 is configured in bypass mode, PJ.5 is configured as general-purpose I/O.

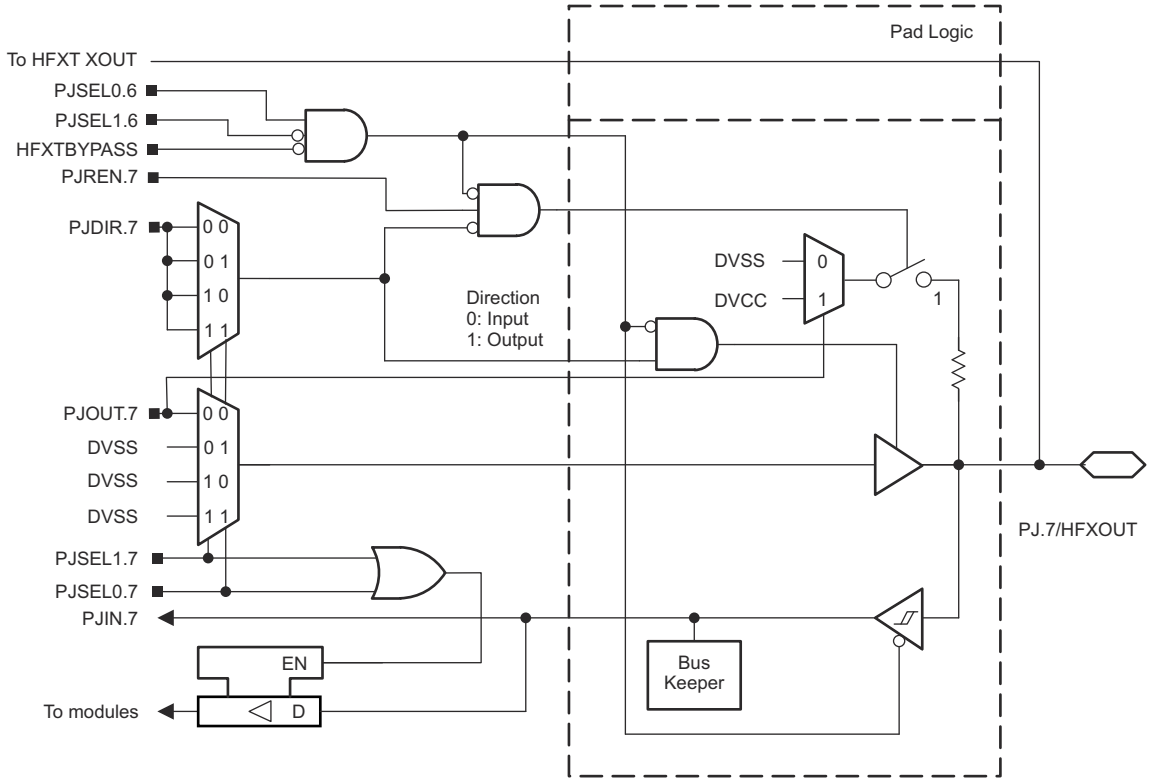
9.14.19 Port PJ (PJ.6 and PJ.7) Input/Output With Schmitt Trigger

Figure 9-21 and Figure 9-22 show the port diagrams. Table 9-42 summarizes the selection of the pin function.



Functional representation only.

Figure 9-21. Port PJ (PJ.6) Diagram



Functional representation only.

Figure 9-22. Port PJ (PJ.7) Diagram

Table 9-42. Port PJ (PJ.6 and PJ.7) Pin Functions

PIN NAME (PJ.x)	x	FUNCTION	CONTROL BITS AND SIGNALS[1]					
			PJDIR.x	PJSEL1.7	PJSEL0.7	PJSEL1.6	PJSEL0.6	HFXTBYPASS
PJ.6/HFXIN	6	PJ.6 (I/O)	I: 0; O: 1	X	X	0	0	X
		N/A	0	X	X	1	X	X
		Internally tied to DVSS	1					
		HFXIN crystal mode[2]	X	X	X	0	1	0
		HFXIN bypass mode[2]	X	X	X	0	1	1
PJ.7/HFXOUT	7	PJ.7 (I/O)[1]	I: 0; O: 1	0	0	0	0	0
						1	X	
						X	X	1[3]
		N/A	0	see [1]	see [1]	0	0	0
						1	X	
						X	X	1[3]
		Internally tied to DVSS	1	see [1]	see [1]	0	0	0
						1	X	
						X	X	1[3]
		HFXOUT crystal mode[2]	X	X	X	0	1	0

(1) With PJSEL0.7 = 1 or PJSEL1.7 =1 the general-purpose I/O functionality is disabled. No input function is available. Configured as output the pin is actively pulled to zero.

(2) Setting PJSEL1.6 = 0 and PJSEL0.6 = 1 causes the general-purpose I/O to be disabled. When HFXTBYPASS = 0, PJ.6 and PJ.7 are configured for crystal operation and PJSEL1.6 and PJSEL0.7 are do not care. When HFXTBYPASS = 1, PJ.6 is configured for bypass operation and PJ.7 is configured as general-purpose I/O.

(3) When PJ.6 is configured in bypass mode, PJ.7 is configured as general-purpose I/O.

9.15 Device Descriptors (TLV)

Table 9-43 lists the Device IDs.

Table 9-43. Device IDs

DEVICE	PACKAGE	DEVICE ID	
		01A05h	01A04h
MSP430FR6007	PZ	83h	2Eh
MSP430FR6005	PZ	83h	2Fh

Table 9-44 lists the contents of the device descriptor tag-length-value (TLV) structure.

Table 9-44. Device Descriptors

	DESCRIPTION	MSP430FR60xx (UART BSL)(1)	
		ADDRESS	VALUE
Info Block	Info length	01A00h	06h
	CRC length	01A01h	06h
	CRC value	01A02h	Per unit
		01A03h	Per unit
	Device ID	01A04h	See Table 9-43.
		01A05h	
	Hardware revision	01A06h	Per unit
	Firmware revision	01A07h	Per unit
Die Record	Die record tag	01A08h	08h
	Die record length	01A09h	0Ah
	Lot/wafer ID	01A0Ah	Per unit
		01A0Bh	Per unit
		01A0Ch	Per unit
		01A0Dh	Per unit
	Die X position	01A0Eh	Per unit
		01A0Fh	Per unit
	Die Y position	01A10h	Per unit
		01A11h	Per unit
	Test results	01A12h	Per unit
		01A13h	Per unit

Table 9-44. Device Descriptors (continued)

	DESCRIPTION	MSP430FR60xx (UART BSL)[1]	
		ADDRESS	VALUE
ADC12 Calibration	ADC12 calibration tag	01A14h	11h
	ADC12 calibration length	01A15h	10h
	ADC gain factor[2]	01A16h	Per unit
		01A17h	Per unit
	ADC offset[3]	01A18h	Per unit
		01A19h	Per unit
	ADC 1.2-V reference temperature sensor 30°C	01A1Ah	Per unit
		01A1Bh	Per unit
	ADC 1.2-V reference temperature sensor 85°C	01A1Ch	Per unit
		01A1Dh	Per unit
	ADC 2.0-V reference temperature sensor 30°C	01A1Eh	Per unit
		01A1Fh	Per unit
	ADC 2.0-V reference temperature sensor 85°C	01A20h	Per unit
		01A21h	Per unit
	ADC 2.5-V reference temperature sensor 30°C	01A22h	Per unit
		01A23h	Per unit
	ADC 2.5-V reference temperature sensor 85°C	01A24h	Per unit
		01A25h	Per unit
REF Calibration	REF calibration tag	01A26h	12h
	REF calibration length	01A27h	06h
	REF 1.2-V reference	01A28h	Per unit
		01A29h	Per unit
	REF 2.0-V reference	01A2Ah	Per unit
		01A2Bh	Per unit
	REF 2.5-V reference	01A2Ch	Per unit
		01A2Dh	Per unit
Random Number	128-bit random number tag	01A2Eh	15h
	Random number length	01A2Fh	10h
	128-bit random number[4]	01A30h	Per unit
		01A31h	Per unit
		01A32h	Per unit
		01A33h	Per unit
		01A34h	Per unit
		01A35h	Per unit
		01A36h	Per unit
		01A37h	Per unit
		01A38h	Per unit
		01A39h	Per unit
		01A3Ah	Per unit
		01A3Bh	Per unit
		01A3Ch	Per unit
		01A3Dh	Per unit
		01A3Eh	Per unit
		01A3Fh	Per unit

Table 9-44. Device Descriptors (continued)

	DESCRIPTION	MSP430FR60xx (UART BSL)(1)	
		ADDRESS	VALUE
BSL Configuration	BSL tag	01A40h	1Ch
	BSL length	01A41h	02h
	BSL interface	01A42h	00h
	BSL interface configuration	01A43h	00h

(1) NA = Not applicable, Per unit = content can differ from device to device

(2) ADC gain: The gain correction factor is measured at room temperature using a 2.5-V external voltage reference without internal buffer (ADC12VRSEL = 0x2, 0x4, or 0xE). Other settings (for example, using internal reference) can result in different correction factors.

(3) ADC offset: the offset correction factor is measured at room temperature using ADC12VRSEL= 0x2 or 0x4, an external reference, V_{R+} = external 2.5 V, V_{R-} = AVSS.

(4) 128-bit random number: The random number is generated during production test using the Microsoft® CryptGenRandom() function.

9.16 Memory Map

Table 9-45 summarizes the memory organization for all device variants.

Table 9-45. Memory Organization (1) (2)

		MSP430FR6007	MSP430FR6005
Memory (FRAM)	Total Size	256KB	128KB
Main: interrupt vectors and signatures		00FFFFh to 00FF80h	00FFFFh to 00FF80h
Main: code memory		043FFFh to 004000h	0023FFFh to 004000h
RAM (shared with LEA)	Size	4KB	4KB
(Sector 2)		(003BFFh to 002C00h)	(003BFFh to 002C00h)
Block 0		003BFFh to 002C00h	003BFFh to 002C00h
System RAM	Size	4KB	4KB
(Sector 1)		(002BFFh to 002400h)	(002BFFh to 002400h)
(Sector 0)		(0023FFh to 001C00h)	(0023FFh to 001C00h)
Main: base location		002BFFh to 001C00h	002BFFh to 001C00h
Main: interrupt vectors		003BFFh to 003B80h	003BFFh to 003B80h
Device descriptor info (TLV) (FRAM)	Size	256 bytes 001AFFh to 001A00h	256 bytes 001AFFh to 001A00h
TI calibration and configuration (FRAM)	Size	256 bytes 0019FFh to 001900h	256 bytes 0019FFh to 001900h
Bootloader (BSL) memory (ROM)	BSL 3	512 bytes 0017FFh to 001600h	512 bytes 0017FFh to 001600h
	BSL 2	512 bytes 0015FFh to 001400h	512 bytes 0015FFh to 001400h
	BSL 1	512 bytes 0013FFh to 001200h	512 bytes 0013FFh to 001200h
	BSL 0	512 bytes 0011FFh to 001000h	512 bytes 0011FFh to 001000h
Peripherals	Size	4KB 000FFFh to 000020h	4KB 000FFFh to 000020h
Tiny RAM	Size	22 bytes 000001Fh to 00000Ah	22 bytes 000001Fh to 00000Ah
Reserved	Size	10 bytes 000009h to 000000h	10 bytes 000009h to 000000h

(1) N/A = Not available
(2) All address space not listed is considered vacant memory.

9.16.1 Peripheral File Map

For complete module register descriptions, see the *MSP430FR58xx, MSP430FR59xx, and MSP430FR6xx Family User's Guide*. Table 9-46 lists the base and end addresses of the registers for each peripheral.

Table 9-46. Peripherals

MODULE NAME	BASE ADDRESS	END ADDRESS
Special Functions (see Table 9-47)	0100h	011Fh
PMM (see Table 9-48)	0120h	013Fh
FRAM Control (see Table 9-49)	0140h	014Fh
CRC (see Table 9-50)	0150h	0157h
RAM Control (see Table 9-51)	0158h	0159h
Watchdog (see Table 9-52)	015Ch	015Dh
CS (see Table 9-53)	0160h	016Fh
SYS (see Table 9-54)	0180h	019Fh

Table 9-46. Peripherals (continued)

MODULE NAME	BASE ADDRESS	END ADDRESS
Shared Reference (see Table 9-55)	01B0h	01B1h
Digital I/O (see Table 9-56)	0200h	033Fh
TA0 (see Table 9-57)	0340h	036Fh
TA1 (see Table 9-58)	0380h	03AFh
TB0 (see Table 9-59)	03C0h	03EFh
TA2 (see Table 9-60)	0400h	042Fh
TA3 (see Table 9-61)	0440h	046Fh
RTC_C (see Table 9-62)	04A0h	04BFh
32-Bit Hardware Multiplier (see Table 9-63)	04C0h	04EFh
DMA (see Table 9-64)	0500h	056Fh
MPU Control (see Table 9-65)	05A0h	05AFh
eUSCI_A0 (see Table 9-66)	05C0h	05DFh
eUSCI_A1 (see Table 9-67)	05E0h	05FFh
eUSCI_A2 (see Table 9-68)	0600h	061Fh
eUSCI_A3 (see Table 9-69)	0620h	063Fh
eUSCI_B0 (see Table 9-70)	0640h	066Fh
eUSCI_B1 (see Table 9-71)	0680h	06AFh
TA4 (see Table 9-72)	07C0h	07EFh
ADC12_B (see Table 9-73)	0800h	089Fh
Comparator E (see Table 9-74)	08C0h	08CFh
CRC32 (see Table 9-75)	0980h	09AFh
AES256 (see Table 9-76)	09C0h	09CFh
LCD_C (see Table 9-77)	0A00h	0A5Fh
LEA (see Table 9-78)	0A80h	0AFFh
SAPH (see Table 9-79)	0E00h	0E7Fh
SDHS (see Table 9-80)	0E80h	0EBFh
UUPS (see Table 9-81)	0EC0h	0EDFh
HSPLL (see Table 9-82)	0EE0h	0EFFh

Table 9-47. Special Functions Registers

REGISTER DESCRIPTION	ACRONYM	ADDRESS
Interrupt Enable	SFRIE1	0100h
Interrupt Flag	SFRIFG1	0102h
Reset Pin Control	SFRRPCR	0104h

Table 9-48. PMM Registers

REGISTER DESCRIPTION	ACRONYM	ADDRESS
PMM Control 0	PMMCTL0	0120h
PMM Interrupt Flag	PMMIFG	012Ah
Power Mode 5 Control 0	PM5CTL0	0130h

Table 9-49. FRAM Control Registers

REGISTER DESCRIPTION	ACRONYM	ADDRESS
FRAM Controller A Control 0	FRCTL0	0140h
General Control 0	GCCTL0	0144h
General Control 1	GCCTL1	0146h

Table 9-50. CRC Registers

REGISTER DESCRIPTION	ACRONYM	ADDRESS
CRC Data In	CRCDI	0150h
CRC Data In Reverse Byte	CRCDIRB	0152h
CRC Initialization and Result	CRCINIRES	0154h
CRC Result Reverse	CRCRESR	0156h

Table 9-51. RAM Control Registers

REGISTER DESCRIPTION	ACRONYM	ADDRESS
RAM Controller Control 0	RCCTL0	0158h
RAM Controller Control 1	RCCTL1	015Ah

Table 9-52. Watchdog Registers

REGISTER DESCRIPTION	ACRONYM	ADDRESS
Watchdog Timer Control	WDTCTL	015Ch

Table 9-53. CS Registers

REGISTER DESCRIPTION	ACRONYM	ADDRESS
Clock System Control 0	CSCTL0	0160h
Clock System Control 1	CSCTL1	0162h
Clock System Control 2	CSCTL2	0164h
Clock System Control 3	CSCTL3	0166h
Clock System Control 4	CSCTL4	0168h
Clock System Control 5	CSCTL5	016Ah
Clock System Control 6	CSCTL6	016Ch

Table 9-54. SYS Registers

REGISTER DESCRIPTION	ACRONYM	ADDRESS
System Control	SYSCTL	0180h
JTAG Mailbox Control	SYSJMBC	0186h
JTAG Mailbox Input	SYSJMBI0	0188h
JTAG Mailbox Input	SYSJMBI1	018Ah
JTAG Mailbox Output	SYSJMBO0	018Ch
JTAG Mailbox Output	SYSJMBO1	018Eh
User NMI Vector Generator	SYSUNIV	019Ah
System NMI Vector Generator	SYSSNIV	019Ch
Reset Vector Generator	SYSRSTIV	019Eh

Table 9-55. Shared Reference Registers

REGISTER DESCRIPTION	ACRONYM	ADDRESS
REF Control 0	REFCTL0	01B0h

Table 9-56. Digital I/O Registers

REGISTER DESCRIPTION	ACRONYM	ADDRESS
Port A Input	PAIN	0200h
Port 1 Input	P1IN	0200h
Port 2 Input	P2IN	0201h
Port A Output	PAOUT	0202h
Port 1 Output	P1OUT	0202h
Port 2 Output	P2OUT	0203h
Port A Direction	PADIR	0204h
Port 1 Direction	P1DIR	0204h
Port 2 Direction	P2DIR	0205h
Port A Resistor Enable	PAREN	0206h
Port 1 Resistor Enable	P1REN	0206h
Port 2 Resistor Enable	P2REN	0207h
Port A Select 0	PASEL0	020Ah
Port 1 Select 0	P1SEL0	020Ah
Port 2 Select 0	P2SEL0	020Bh
Port A Select 1	PASEL1	020Ch
Port 1 Select 1	P1SEL1	020Ch
Port 2 Select 1	P2SEL1	020Dh
Port 1 Interrupt Vector	P1IV	020Eh
Port A Complement Select	PASELC	0216h
Port 1 Complement Select	P1SELC	0216h
Port 2 Complement Select	P2SELC	0217h
Port A Interrupt Edge Select	PAIES	0218h
Port 1 Interrupt Edge Select	P1IES	0218h
Port 2 Interrupt Edge Select	P2IES	0219h
Port A Interrupt Enable	PAIE	021Ah
Port 1 Interrupt Enable	P1IE	021Ah
Port 2 Interrupt Enable	P2IE	021Bh
Port A Interrupt Flag	PAIFG	021Ch
Port 1 Interrupt Flag	P1IFG	021Ch

Table 9-56. Digital I/O Registers (continued)

REGISTER DESCRIPTION	ACRONYM	ADDRESS
Port 2 Interrupt Flag	P2IFG	021Dh
Port 2 Interrupt Vector	P2IV	021Eh
Port B Input	PBIN	0220h
Port 3 Input	P3IN	0220h
Port 4 Input	P4IN	0221h
Port B Output	PBOUT	0222h
Port 3 Output	P3OUT	0222h
Port 4 Output	P4OUT	0223h
Port B Direction	PBDIR	0224h
Port 3 Direction	P3DIR	0224h
Port 4 Direction	P4DIR	0225h
Port B Resistor Enable	PBREN	0226h
Port 3 Resistor Enable	P3REN	0226h
Port 4 Resistor Enable	P4REN	0227h
Port B Select 0	PBSEL0	022Ah
Port 3 Select 0	P3SEL0	022Ah
Port 4 Select 0	P4SEL0	022Bh
Port B Select 1	PBSEL1	022Ch
Port 3 Select 1	P3SEL1	022Ch
Port 4 Select 1	P4SEL1	022Dh
Port 3 Interrupt Vector	P3IV	022Eh
Port B Complement Select	PBSELC	0236h
Port 3 Complement Select	P3SELC	0236h
Port 4 Complement Select	P4SELC	0237h
Port B Interrupt Edge Select	PBIES	0238h
Port 3 Interrupt Edge Select	P3IES	0238h
Port 4 Interrupt Edge Select	P4IES	0239h
Port B Interrupt Enable	PBIE	023Ah
Port 3 Interrupt Enable	P3IE	023Ah
Port 4 Interrupt Enable	P4IE	023Bh
Port B Interrupt Flag	PBIFG	023Ch
Port 3 Interrupt Flag	P3IFG	023Ch
Port 4 Interrupt Flag	P4IFG	023Dh
Port 4 Interrupt Vector	P4IV	023Eh
Port C Input	PCIN	0240h
Port 5 Input	P5IN	0240h
Port 6 Input	P6IN	0241h
Port C Output	PCOUT	0242h
Port 5 Output	P5OUT	0242h
Port 6 Output	P6OUT	0243h
Port C Direction	PCDIR	0244h
Port 5 Direction	P5DIR	0244h
Port 6 Direction	P6DIR	0245h
Port C Resistor Enable	PCREN	0246h
Port 5 Resistor Enable	P5REN	0246h

Table 9-56. Digital I/O Registers (continued)

REGISTER DESCRIPTION	ACRONYM	ADDRESS
Port 6 Resistor Enable	P6REN	0247h
Port C Select 0	PCSEL0	024Ah
Port 5 Select 0	P5SEL0	024Ah
Port 6 Select 0	P6SEL0	024Bh
Port C Select 1	PCSEL1	024Ch
Port 5 Select 1	P5SEL1	024Ch
Port 6 Select 1	P6SEL1	024Dh
Port 5 Interrupt Vector	P5IV	024Eh
Port C Complement Select	PCSELC	0256h
Port 5 Complement Select	P5SELC	0256h
Port 6 Complement Select	P6SELC	0257h
Port C Interrupt Edge Select	PCIES	0258h
Port 5 Interrupt Edge Select	P5IES	0258h
Port 6 Interrupt Edge Select	P6IES	0259h
Port C Interrupt Enable	PCIE	025Ah
Port 5 Interrupt Enable	P5IE	025Ah
Port 6 Interrupt Enable	P6IE	025Bh
Port C Interrupt Flag	PCIFG	025Ch
Port 5 Interrupt Flag	P5IFG	025Ch
Port 6 Interrupt Flag	P6IFG	025Dh
Port 6 Interrupt Vector	P6IV	025Eh
Port D Input	PDIN	0260h
Port 7 Input	P7IN	0260h
Port 8 Input	P8IN	0261h
Port D Output	PDOUT	0262h
Port 7 Output	P7OUT	0262h
Port 8 Output	P8OUT	0263h
Port D Direction	PDDIR	0264h
Port 7 Direction	P7DIR	0264h
Port 8 Direction	P8DIR	0265h
Port D Resistor Enable	PDREN	0266h
Port 7 Resistor Enable	P7REN	0266h
Port 8 Resistor Enable	P8REN	0267h
Port D Select 0	PDSEL0	026Ah
Port 7 Select 0	P7SEL0	026Ah
Port 8 Select 0	P8SEL0	026Bh
Port D Select 1	PDSEL1	026Ch
Port 7 Select 1	P7SEL1	026Ch
Port 8 Select 1	P8SEL1	026Dh
Port 7 Interrupt Vector	P7IV	026Eh
Port D Complement Select	PDSELC	0276h
Port 7 Complement Select	P7SELC	0276h
Port 8 Complement Select	P8SELC	0277h
Port D Interrupt Edge Select	PDIES	0278h
Port 7 Interrupt Edge Select	P7IES	0278h

Table 9-56. Digital I/O Registers (continued)

REGISTER DESCRIPTION	ACRONYM	ADDRESS
Port 8 Interrupt Edge Select	P8IES	0279h
Port D Interrupt Enable	PDIE	027Ah
Port 7 Interrupt Enable	P7IE	027Ah
Port 8 Interrupt Enable	P8IE	027Bh
Port D Interrupt Flag	PDIFG	027Ch
Port 7 Interrupt Flag	P7IFG	027Ch
Port 8 Interrupt Flag	P8IFG	027Dh
Port 8 Interrupt Vector	P8IV	027Eh
Port E Input	PEIN	0280h
Port 9 Input	P9IN	0280h
Port E Output	PEOUT	0282h
Port 9 Output	P9OUT	0282h
Port E Direction	PEDIR	0284h
Port 9 Direction	P9DIR	0284h
Port E Resistor Enable	PEREN	0286h
Port 9 Resistor Enable	P9REN	0286h
Port E Select 0	PESEL0	028Ah
Port 9 Select 0	P9SEL0	028Ah
Port E Select 1	PESEL1	028Ch
Port 9 Select 1	P9SEL1	028Ch
Port 9 Interrupt Vector	P9IV	028Eh
Port E Complement Select	PESELC	0296h
Port 9 Complement Select	P9SELC	0296h
Port E Interrupt Edge Select	PEIES	0298h
Port 9 Interrupt Edge Select	P9IES	0298h
Port E Interrupt Enable	PEIE	029Ah
Port 9 Interrupt Enable	P9IE	029Ah
Port E Interrupt Flag	PEIFG	029Ch
Port 9 Interrupt Flag	P9IFG	029Ch
Port J Input	PJIN	0320h
Port J Output	PJOUT	0322h
Port J Direction	PJDIR	0324h
Port J Resistor Enable	PJREN	0326h
Port J Select 0	PJSEL0	032Ah
Port J Select 1	PJSEL1	032Ch
Port J Complement Select	PJSELC	0336h

Table 9-57. TA0 Registers

REGISTER DESCRIPTION	ACRONYM	ADDRESS
Timer_A0 Control	TA0CTL	0340h
Timer_A0 Capture/Compare Control	TA0CCTL0	0342h
Timer_A0 Capture/Compare Control	TA0CCTL1	0344h
Timer_A0 Capture/Compare Control	TA0CCTL2	0346h
Timer_A0 Counter	TA0R	0350h
Timer_A0 Capture/Compare	TA0CCR0	0352h
Timer_A0 Capture/Compare	TA0CCR1	0354h
Timer_A0 Capture/Compare	TA0CCR2	0356h
Timer_A0 Expansion 0	TA0EX0	0360h
Timer_A0 Interrupt Vector	TA0IV	036Eh

Table 9-58. TA1 Registers

REGISTER DESCRIPTION	ACRONYM	ADDRESS
Timer_A1 Control	TA1CTL	0380h
Timer_A1 Capture/Compare Control	TA1CCTL0	0382h
Timer_A1 Capture/Compare Control	TA1CCTL1	0384h
Timer_A1 Capture/Compare Control	TA1CCTL2	0386h
Timer_A1 Counter	TA1R	0390h
Timer_A1 Capture/Compare	TA1CCR0	0392h
Timer_A1 Capture/Compare	TA1CCR1	0394h
Timer_A1 Capture/Compare	TA1CCR2	0396h
Timer_A1 Expansion 0	TA1EX0	03A0h
Timer_A1 Interrupt Vector	TA1IV	03AEh

Table 9-59. TB0 Registers

REGISTER DESCRIPTION	ACRONYM	ADDRESS
Timer_B0 Control	TB0CTL	03C0h
Timer_B0 Capture/Compare Control	TB0CCTL0	03C2h
Timer_B0 Capture/Compare Control	TB0CCTL1	03C4h
Timer_B0 Capture/Compare Control	TB0CCTL2	03C6h
Timer_B0 Capture/Compare Control	TB0CCTL3	03C8h
Timer_B0 Capture/Compare Control	TB0CCTL4	03CAh
Timer_B0 Capture/Compare Control	TB0CCTL5	03CCh
Timer_B0 Capture/Compare Control	TB0CCTL6	03CEh
Timer_B0 Counter	TB0R	03D0h
Timer_B0 Capture/Compare	TB0CCR0	03D2h
Timer_B0 Capture/Compare	TB0CCR1	03D4h
Timer_B0 Capture/Compare	TB0CCR2	03D6h
Timer_B0 Capture/Compare	TB0CCR3	03D8h
Timer_B0 Capture/Compare	TB0CCR4	03DAh
Timer_B0 Capture/Compare	TB0CCR5	03DCh
Timer_B0 Capture/Compare	TB0CCR6	03DEh
Timer_B0 Expansion 0	TB0EX0	03E0h
Timer_B0 Interrupt Vector	TB0IV	03EEh

Table 9-60. TA2 Registers

REGISTER DESCRIPTION	ACRONYM	ADDRESS
Timer_A2 Control	TA2CTL	0400h
Timer_A2 Capture/Compare Control	TA2CCTL0	0402h
Timer_A2 Capture/Compare Control	TA2CCTL1	0404h
Timer_A2 Counter	TA2R	0410h
Timer_A2 Capture/Compare	TA2CCR0	0412h
Timer_A2 Capture/Compare	TA2CCR1	0414h
Timer_A2 Expansion 0	TA2EX0	0420h
Timer_A2 Interrupt Vector	TA2IV	042Eh

Table 9-61. TA3 Registers

REGISTER DESCRIPTION	ACRONYM	ADDRESS
Timer_A3 Control	TA3CTL	0440h
Timer_A3 Capture/Compare Control	TA3CCTL0	0442h
Timer_A3 Capture/Compare Control	TA3CCTL1	0444h
Timer_A3 Counter	TA3R	0450h
Timer_A3 Capture/Compare	TA3CCR0	0452h
Timer_A3 Capture/Compare	TA3CCR1	0454h
Timer_A3 Expansion 0	TA3EX0	0460h
Timer_A3 Interrupt Vector	TA3IV	046Eh

Table 9-62. RTC_C Registers

REGISTER DESCRIPTION	ACRONYM	ADDRESS
Real-Time Clock Control 0	RTCCTL0	04A0h
Real-Time Clock Control 1, 3	RTCCTL13	04A2h
Real-Time Clock Offset Calibration	RTCOCAL	04A4h
Real-Time Clock Temperature Compensation	RTCTCMP	04A6h
Real-Time Clock Prescale Timer 0 Control	RTCPS0CTL	04A8h
Real-Time Clock Prescale Timer 1 Control	RTCPS1CTL	04AAh
Real-Time Clock Prescale Timer Counter	RTCPS	04ACh
Prescale Timer 0 Counter Value	RT0PS	04ACh
Prescale Timer 1 Counter Value	RT1PS	04ADh
Real-Time Clock Interrupt Vector	RTCIV	04AEh
Real-Time Clock Seconds and Minutes	RTCTIM0	04B0h
Real-Time Clock Hour, Day of Week	RTCTIM1	04B2h
Real-Time Clock Date	RTCDATE	04B4h
Real-Time Clock Year	RTCYEAR	04B6h
Real-Time Clock Minute and Hour	RTCAMINHR	04B8h
Real-Time Clock Alarm Day of Week and Day	RTCADOWDAY	04BAh
Binary-to-BCD Conversion	BIN2BCD	04BCh
BCD-to-Binary Conversion	BCD2BIN	04BEh

Table 9-63. 32-Bit Hardware Multiplier Registers

REGISTER DESCRIPTION	ACRONYM	ADDRESS
16-bit operand one – multiply	MPY	04C0h
16-bit operand one – signed multiply	MPYS	04C2h
16-bit operand one – multiply accumulate	MAC	04C4h
16-bit operand one – signed multiply accumulate	MACS	04C6h
16-bit operand two	OP2	04C8h
16x16-bit result low word	RESLO	04CAh
16x16-bit result high word	RESHI	04CCh
16x16-bit sum extension	SUMEXT	04CEh
32-bit operand 1 – multiply – low word	MPY32L	04D0h
32-bit operand 1 – multiply – high word	MPY32H	04D2h
32-bit operand 1 – signed multiply – low word	MPYS32L	04D4h
32-bit operand 1 – signed multiply – high word	MPYS32H	04D6h
32-bit operand 1 – multiply accumulate – low word	MAC32L	04D8h
32-bit operand 1 – multiply accumulate – high word	MAC32H	04DAh
32-bit operand 1 – signed multiply accumulate – low word	MACS32L	04DCh
32-bit operand 1 – signed multiply accumulate – high word	MACS32H	04DEh
32-bit operand 2 – low word	OP2L	04E0h
32-bit operand 2 – high word	OP2H	04E2h
32x32-bit result 0 – least significant word	RES0	04E4h
32x32-bit result 1	RES1	04E6h
32x32-bit result 2	RES2	04E8h
32x32-bit result 3 – most significant word	RES3	04EAh
MPY32 control 0	MPY32CTL0	04ECh

Table 9-64. DMA Registers

REGISTER DESCRIPTION	ACRONYM	ADDRESS
DMA Control 0	DMACTL0	0500h
DMA Control 1	DMACTL1	0502h
DMA Control 2	DMACTL2	0504h
DMA Control 4	DMACTL4	0508h
DMA Interrupt Vector	DMAIV	050Eh
DMA Channel 0 Control	DMA0CTL	0510h
DMA Channel 0 Source Address	DMA0SA	0512h
DMA Channel 0 Destination Address	DMA0DA	0516h
DMA Channel 0 Transfer Size	DMA0SZ	051Ah
DMA Channel 1 Control	DMA1CTL	0520h
DMA Channel 1 Source Address	DMA1SA	0522h
DMA Channel 1 Destination Address	DMA1DA	0526h
DMA Channel 1 Transfer Size	DMA1SZ	052Ah
DMA Channel 2 Control	DMA2CTL	0530h
DMA Channel 2 Source Address	DMA2SA	0532h
DMA Channel 2 Destination Address	DMA2DA	0536h
DMA Channel 2 Transfer Size	DMA2SZ	053Ah
DMA Channel 3 Control	DMA3CTL	0540h
DMA Channel 3 Source Address	DMA3SA	0542h
DMA Channel 3 Destination Address	DMA3DA	0546h
DMA Channel 3 Transfer Size	DMA3SZ	054Ah
DMA Channel 4 Control	DMA4CTL	0550h
DMA Channel 4 Source Address	DMA4SA	0552h
DMA Channel 4 Destination Address	DMA4DA	0556h
DMA Channel 4 Transfer Size	DMA4SZ	055Ah
DMA Channel 5 Control	DMA5CTL	0560h
DMA Channel 5 Source Address	DMA5SA	0562h
DMA Channel 5 Destination Address	DMA5DA	0566h
DMA Channel 5 Transfer Size	DMA5SZ	056Ah

Table 9-65. MPU Control Registers

REGISTER DESCRIPTION	ACRONYM	ADDRESS
Memory Protection Unit Control 0	MPUCTL0	05A0h
Memory Protection Unit Control 1	MPUCTL1	05A2h
Memory Protection Unit Segmentation Border 2 Register	MPUSEGB2	05A4h
Memory Protection Unit Segmentation Border 1 Register	MPUSEGB1	05A6h
Memory Protection Unit Segmentation Access Management Register	MPUSAM	05A8h
Memory Protection Unit IP Control 0 Register	MPUIPC0	05AAh
Memory Protection Unit IP Encapsulation Segment Border 2 Register	MPUIPSEGB2	05ACh
Memory Protection Unit IP Encapsulation Segment Border 1 Register	MPUIPSEGB1	05AEh

Table 9-66. eUSCI_A0 Registers

REGISTER DESCRIPTION	ACRONYM	ADDRESS
eUSCI_A0 Control Word Register 0	UCA0CTLW0	05C0h
eUSCI_A0 Control Word Register 1	UCA0CTLW1	05C2h
eUSCI_A0 Baud Rate Control Word	UCA0BRW	05C6h
eUSCI_A0 Modulation Control Word	UCA0MCTLW	05C8h
eUSCI_A0 Status Register	UCA0STATW	05CAh
eUSCI_A0 Receive Buffer	UCA0RXBUF	05CCh
eUSCI_A0 Transmit Buffer	UCA0TXBUF	05CEh
eUSCI_A0 Auto Baud Rate Control	UCA0ABCTL	05D0h
eUSCI_A0 IrDA Control Word	UCA0IRCTL	05D2h
eUSCI_A0 Interrupt Enable	UCA0IE	05DAh
eUSCI_A0 Interrupt Flag	UCA0IFG	05DCh
eUSCI_A0 Interrupt Vector	UCA0IV	05DEh

Table 9-67. eUSCI_A1 Registers

REGISTER DESCRIPTION	ACRONYM	ADDRESS
eUSCI_A1 Control Word Register 0	UCA1CTLW0	05E0h
eUSCI_A1 Control Word Register 1	UCA1CTLW1	05E2h
eUSCI_A1 Baud Rate Control Word	UCA1BRW	05E6h
eUSCI_A1 Modulation Control Word	UCA1MCTLW	05E8h
eUSCI_A1 Status Register	UCA1STATW	05EAh
eUSCI_A1 Receive Buffer	UCA1RXBUF	05ECh
eUSCI_A1 Transmit Buffer	UCA1TXBUF	05EEh
eUSCI_A1 Auto Baud Rate Control	UCA1ABCTL	05F0h
eUSCI_A1 IrDA Control Word	UCA1IRCTL	05F2h
eUSCI_A1 Interrupt Enable	UCA1IE	05FAh
eUSCI_A1 Interrupt Flag	UCA1IFG	05FCh
eUSCI_A1 Interrupt Vector	UCA1IV	05FEh

Table 9-68. eUSCI_A2 Registers

REGISTER DESCRIPTION	ACRONYM	ADDRESS
eUSCI_A2 Control Word Register 0	UCA2CTLW0	0600h
eUSCI_A2 Control Word Register 1	UCA2CTLW1	0602h
eUSCI_A2 Baud Rate Control Word	UCA2BRW	0606h
eUSCI_A2 Modulation Control Word	UCA2MCTLW	0608h
eUSCI_A2 Status Register	UCA2STATW	060Ah
eUSCI_A2 Receive Buffer	UCA2RXBUF	060Ch
eUSCI_A2 Transmit Buffer	UCA2TXBUF	060Eh
eUSCI_A2 Auto Baud Rate Control	UCA2ABCTL	0610h
eUSCI_A2 IrDA Control Word	UCA2IRCTL	0612h
eUSCI_A2 Interrupt Enable	UCA2IE	061Ah
eUSCI_A2 Interrupt Flag	UCA2IFG	061Ch
eUSCI_A2 Interrupt Vector	UCA2IV	061Eh

Table 9-69. eUSCI_A3 Registers

REGISTER DESCRIPTION	ACRONYM	ADDRESS
eUSCI_A3 Control Word Register 0	UCA3CTLW0	0620h
eUSCI_A3 Control Word Register 1	UCA3CTLW1	0622h
eUSCI_A3 Baud Rate Control Word	UCA3BRW	0626h
eUSCI_A3 Modulation Control Word	UCA3MCTLW	0628h
eUSCI_A3 Status Register	UCA3STATW	062Ah
eUSCI_A3 Receive Buffer	UCA3RXBUF	062Ch
eUSCI_A3 Transmit Buffer	UCA3TXBUF	062Eh
eUSCI_A3 Auto Baud Rate Control	UCA3ABCTL	0630h
eUSCI_A3 IrDA Control Word	UCA3IRCTL	0632h
eUSCI_A3 Interrupt Enable	UCA3IE	063Ah
eUSCI_A3 Interrupt Flag	UCA3IFG	063Ch
eUSCI_A3 Interrupt Vector	UCA3IV	063Eh

Table 9-70. eUSCI_B0 Registers

REGISTER DESCRIPTION	ACRONYM	ADDRESS
eUSCI_B0 Control Word Register 0	UCB0CTLW0	0640h
eUSCI_B0 Control Word Register 1	UCB0CTLW1	0642h
eUSCI_B0 Baud Rate Control Word	UCB0BRW	0646h
eUSCI_B0 Status Register	UCB0STATW	0648h
eUSCI_B0 Byte Counter Threshold	UCB0TBCNT	064Ah
eUSCI_B0 Receive Buffer	UCB0RXBUF	064Ch
eUSCI_B0 Transmit Buffer	UCB0TXBUF	064Eh
eUSCI_B0 I2C Own Address 0	UCB0I2COA0	0654h
eUSCI_B0 I2C Own Address 1	UCB0I2COA1	0656h
eUSCI_B0 I2C Own Address 2	UCB0I2COA2	0658h
eUSCI_B0 I2C Own Address 3	UCB0I2COA3	065Ah
eUSCI_B0 I2C Received Address	UCB0ADDRX	065Ch
eUSCI_B0 I2C Address Mask	UCB0ADDMASK	065Eh
eUSCI_B0 I2C Slave Address	UCB0I2CSA	0660h
eUSCI_B0 Interrupt Enable	UCB0IE	066Ah
eUSCI_B0 Interrupt Flag	UCB0IFG	066Ch
eUSCI_B0 Interrupt Vector	UCB0IV	066Eh

Table 9-71. eUSCI_B1 Registers

REGISTER DESCRIPTION	ACRONYM	ADDRESS
eUSCI_B1 Control Word Register 0	UCB1CTLW0	0680h
eUSCI_B1 Control Word Register 1	UCB1CTLW1	0682h
eUSCI_B1 Baud Rate Control Word	UCB1BRW	0686h
eUSCI_B1 Status Register	UCB1STATW	0688h
eUSCI_B1 Byte Counter Threshold	UCB1TBCNT	068Ah
eUSCI_B1 Receive Buffer	UCB1RXBUF	068Ch
eUSCI_B1 Transmit Buffer	UCB1TXBUF	068Eh
eUSCI_B1 I2C Own Address 0	UCB1I2COA0	0694h
eUSCI_B1 I2C Own Address 1	UCB1I2COA1	0696h
eUSCI_B1 I2C Own Address 2	UCB1I2COA2	0698h
eUSCI_B1 I2C Own Address 3	UCB1I2COA3	069Ah
eUSCI_B1 I2C Received Address	UCB1ADDRX	069Ch
eUSCI_B1 I2C Address Mask	UCB1ADDMASK	069Eh
eUSCI_B1 I2C Slave Address	UCB1I2CSA	06A0h
eUSCI_B1 Interrupt Enable	UCB1IE	06AAh
eUSCI_B1 Interrupt Flag	UCB1IFG	06ACh
eUSCI_B1 Interrupt Vector	UCB1IV	06AEh

Table 9-72. TA4 Registers

REGISTER DESCRIPTION	ACRONYM	ADDRESS
Timer_A4 Control	TA4CTL	07C0h
Timer_A4 Capture/Compare Control	TA4CCTL0	07C2h
Timer_A4 Capture/Compare Control	TA4CCTL1	07C4h
Timer_A4 Counter	TA4R	07D0h
Timer_A4 Capture/Compare	TA4CCR0	07D2h
Timer_A4 Capture/Compare	TA4CCR1	07D4h
Timer_A4 Expansion 0	TA4EX0	07E0h
Timer_A4 Interrupt Vector	TA4IV	07EEh

Table 9-73. ADC12_B Registers

REGISTER DESCRIPTION	ACRONYM	ADDRESS
ADC12_B Control 0	ADC12CTL0	0800h
ADC12_B Control 1	ADC12CTL1	0802h
ADC12_B Control 2	ADC12CTL2	0804h
ADC12_B Control 3	ADC12CTL3	0806h
ADC12_B Window Comparator Low Threshold Register	ADC12LO	0808h
ADC12_B Window Comparator High Threshold Register	ADC12HI	080Ah
ADC12_B Interrupt Flag 0	ADC12IFGR0	080Ch
ADC12_B Interrupt Flag 1	ADC12IFGR1	080Eh
ADC12_B Interrupt Flag 2	ADC12IFGR2	0810h
ADC12_B Interrupt Enable 0	ADC12IER0	0812h
ADC12_B Interrupt Enable 1	ADC12IER1	0814h
ADC12_B Interrupt Enable 2	ADC12IER2	0816h
ADC12_B Interrupt Vector	ADC12IV	0818h
ADC12_B Memory Control 0	ADC12MCTL0	0820h
ADC12_B Memory Control 1	ADC12MCTL1	0822h
ADC12_B Memory Control 2	ADC12MCTL2	0824h
ADC12_B Memory Control 3	ADC12MCTL3	0826h
ADC12_B Memory Control 4	ADC12MCTL4	0828h
ADC12_B Memory Control 5	ADC12MCTL5	082Ah
ADC12_B Memory Control 6	ADC12MCTL6	082Ch
ADC12_B Memory Control 7	ADC12MCTL7	082Eh
ADC12_B Memory Control 8	ADC12MCTL8	0830h
ADC12_B Memory Control 9	ADC12MCTL9	0832h
ADC12_B Memory Control 10	ADC12MCTL10	0834h
ADC12_B Memory Control 11	ADC12MCTL11	0836h
ADC12_B Memory Control 12	ADC12MCTL12	0838h
ADC12_B Memory Control 13	ADC12MCTL13	083Ah
ADC12_B Memory Control 14	ADC12MCTL14	083Ch
ADC12_B Memory Control 15	ADC12MCTL15	083Eh
ADC12_B Memory Control 16	ADC12MCTL16	0840h
ADC12_B Memory Control 17	ADC12MCTL17	0842h
ADC12_B Memory Control 18	ADC12MCTL18	0844h
ADC12_B Memory Control 19	ADC12MCTL19	0846h
ADC12_B Memory Control 20	ADC12MCTL20	0848h
ADC12_B Memory Control 21	ADC12MCTL21	084Ah
ADC12_B Memory Control 22	ADC12MCTL22	084Ch
ADC12_B Memory Control 23	ADC12MCTL23	084Eh
ADC12_B Memory Control 24	ADC12MCTL24	0850h
ADC12_B Memory Control 25	ADC12MCTL25	0852h
ADC12_B Memory Control 26	ADC12MCTL26	0854h
ADC12_B Memory Control 27	ADC12MCTL27	0856h
ADC12_B Memory Control 28	ADC12MCTL28	0858h
ADC12_B Memory Control 29	ADC12MCTL29	085Ah
ADC12_B Memory Control 30	ADC12MCTL30	085Ch
ADC12_B Memory Control 31	ADC12MCTL31	085Eh

Table 9-73. ADC12_B Registers (continued)

REGISTER DESCRIPTION	ACRONYM	ADDRESS
ADC12_B Memory 0	ADC12MEM0	0860h
ADC12_B Memory 1	ADC12MEM1	0862h
ADC12_B Memory 2	ADC12MEM2	0864h
ADC12_B Memory 3	ADC12MEM3	0866h
ADC12_B Memory 4	ADC12MEM4	0868h
ADC12_B Memory 5	ADC12MEM5	086Ah
ADC12_B Memory 6	ADC12MEM6	086Ch
ADC12_B Memory 7	ADC12MEM7	086Eh
ADC12_B Memory 8	ADC12MEM8	0870h
ADC12_B Memory 9	ADC12MEM9	0872h
ADC12_B Memory 10	ADC12MEM10	0874h
ADC12_B Memory 11	ADC12MEM11	0876h
ADC12_B Memory 12	ADC12MEM12	0878h
ADC12_B Memory 13	ADC12MEM13	087Ah
ADC12_B Memory 14	ADC12MEM14	087Ch
ADC12_B Memory 15	ADC12MEM15	087Eh
ADC12_B Memory 16	ADC12MEM16	0880h
ADC12_B Memory 17	ADC12MEM17	0882h
ADC12_B Memory 18	ADC12MEM18	0884h
ADC12_B Memory 19	ADC12MEM19	0886h
ADC12_B Memory 20	ADC12MEM20	0888h
ADC12_B Memory 21	ADC12MEM21	088Ah
ADC12_B Memory 22	ADC12MEM22	088Ch
ADC12_B Memory 23	ADC12MEM23	088Eh
ADC12_B Memory 24	ADC12MEM24	0890h
ADC12_B Memory 25	ADC12MEM25	0892h
ADC12_B Memory 26	ADC12MEM26	0894h
ADC12_B Memory 27	ADC12MEM27	0896h
ADC12_B Memory 28	ADC12MEM28	0898h
ADC12_B Memory 29	ADC12MEM29	089Ah
ADC12_B Memory 30	ADC12MEM30	089Ch
ADC12_B Memory 31	ADC12MEM31	089Eh

Table 9-74. Comparator_E Registers

REGISTER DESCRIPTION	ACRONYM	ADDRESS
Comparator Control Register 0	CECTL0	08C0h
Comparator Control Register 1	CECTL1	08C2h
Comparator Control Register 2	CECTL2	08C4h
Comparator Control Register 3	CECTL3	08C6h
Comparator Interrupt Control	CEINT	08CCh
Comparator Interrupt Vector Word	CEIV	08CEh

Table 9-75. CRC32 Registers

REGISTER DESCRIPTION	ACRONYM	ADDRESS
CRC32 Data Input Word 0	CRC32DIW0	0980h
CRC32 Data Input Word 1	CRC32DIW1	0982h
CRC32 Data In Reverse Word 1	CRC32DIRBW1	0984h
CRC32 Data In Reverse Word 0	CRC32DIRBW0	0986h
CRC32 Initialization and Result Word 0	CRC32INIRESW0	0988h
CRC32 Initialization and Result Word 1	CRC32INIRESW1	098Ah
CRC32 Result Reverse Word 1	CRC32RESRW1	098Ch
CRC32 Result Reverse Word 0	CRC32RESRW0	098Eh
CRC16 Data Input	CRC16DIW0	0990h
CRC16 Data In Reverse	CRC16DIRBW0	0996h
CRC16 Init and Result	CRC16INIRESW0	0998h
CRC16 Result Reverse	CRC16RESRW0	099Eh

Table 9-76. AES256 Registers

REGISTER DESCRIPTION	ACRONYM	ADDRESS
AES Accelerator Control 0	AESACTL0	09C0h
AES Accelerator Control 1	AESACTL1	09C2h
AES Accelerator Status	AESASTAT	09C4h
AES Accelerator Key	AESAKEY	09C6h
AES Accelerator Data In	AESADIN	09C8h
AES Accelerator Data Out	AESADOUT	09CAh
AES Accelerator XORed Data In	AESAXDIN	09CCh
AES Accelerator XORed Data In	AESAXIN	09CEh

Table 9-77. LCD_C Registers

REGISTER DESCRIPTION	ACRONYM	ADDRESS
LCD_C control 0	LCDCCTL0	0A00h
LCD_C control 1	LCDCCTL1	0A02h
LCD_C blinking control	LCDCBLKCTL	0A04h
LCD_C memory control	LCDCMEMCTL	0A06h
LCD_C Voltage Control	LCDCVCTL	0A08h
LCD_C port control 0	LCDCPCTL0	0A0Ah
LCD_C port control 1	LCDCPCTL1	0A0Ch
LCD_C port control 2 (≥256 segments)	LCDCPCTL2	0A0Eh
LCD_C port control 3 (384 segments)	LCDCPCTL3	0A10h
LCD_C charge pump control	LCDCCPCTL	0A12h
LCD_C interrupt vector	LCDCIV	0A1Eh
LCDMX = 0 ... 4		
LCD memory 1	LCDM1	0A20h
LCD memory 2	LCDM2	0A21h
LCD memory 3	LCDM3	0A22h
LCD memory 4	LCDM4	0A23h
LCD memory 5	LCDM5	0A24h
LCD memory 6	LCDM6	0A25h
LCD memory 7	LCDM7	0A26h
LCD memory 8	LCDM8	0A27h
LCD memory 9	LCDM9	0A28h
LCD memory 10	LCDM10	0A29h
LCD memory 11	LCDM11	0A2Ah
LCD memory 12	LCDM12	0A2Bh
LCD memory 13	LCDM13	0A2Ch
LCD memory 14	LCDM14	0A2Dh
LCD memory 15	LCDM15	0A2Eh
LCD memory 16	LCDM16	0A2Fh
LCD memory 17	LCDM17	0A30h
LCD memory 18	LCDM18	0A31h
LCD memory 19	LCDM19	0A32h
LCD memory 20	LCDM20	0A33h
LCD blinking memory 1	LCDM33_LCDBM1	0A40h
LCD blinking memory 2	LCDM34_LCDBM2	0A41h
LCD blinking memory 3	LCDM35_LCDBM3	0A42h
LCD blinking memory 4	LCDM36_LCDBM4	0A43h
LCD blinking memory 5	LCDM37_LCDBM5	0A44h
LCD blinking memory 6	LCDM38_LCDBM6	0A45h
LCD blinking memory 7	LCDM39_LCDBM7	0A46h
LCD blinking memory 8	LCDM40_LCDBM8	0A47h
LCD blinking memory 9	LCDM41_LCDBM9	0A48h
LCD blinking memory 10	LCDM42_LCDBM10	0A49h
LCD blinking memory 11	LCDM43_LCDBM11	0A4Ah
LCD blinking memory 11	LCDM44_LCDBM12	0A4Bh
LCD blinking memory 13	LCDM45_LCDBM13	0A4Ch

Table 9-77. LCD_C Registers (continued)

REGISTER DESCRIPTION	ACRONYM	ADDRESS
LCD blinking memory 14	LCDM46_LCDBM14	0A4Dh
LCD blinking memory 15	LCDM47_LCDBM15	0A4Eh
LCD blinking memory 16	LCDM48_LCDBM16	0A4Fh
LCD blinking memory 17	LCDM49_LCDBM17	0A50h
LCD blinking memory 18	LCDM50_LCDBM18	0A51h
LCD blinking memory 19	LCDM51_LCDBM19	0A52h
LCD blinking memory 20	LCDM52_LCDBM20	0A53h
LCDMX = 5 ... 8		
LCD memory 1	LCDM1	0A20h
LCD memory 2	LCDM2	0A21h
LCD memory 3	LCDM3	0A22h
LCD memory 4	LCDM4	0A23h
LCD memory 5	LCDM5	0A24h
LCD memory 6	LCDM6	0A25h
LCD memory 7	LCDM7	0A26h
LCD memory 8	LCDM8	0A27h
LCD memory 9	LCDM9	0A28h
LCD memory 10	LCDM10	0A29h
LCD memory 11	LCDM11	0A2Ah
LCD memory 12	LCDM12	0A2Bh
LCD memory 13	LCDM13	0A2Ch
LCD memory 14	LCDM14	0A2Dh
LCD memory 15	LCDM15	0A2Eh
LCD memory 16	LCDM16	0A2Fh
LCD memory 17	LCDM17	0A30h
LCD memory 18	LCDM18	0A31h
LCD memory 19	LCDM19	0A32h
LCD memory 20	LCDM20	0A33h
LCD memory 21	LCDM21	0A34h
LCD memory 22	LCDM22	0A35h
LCD memory 23	LCDM23	0A36h
LCD memory 24	LCDM24	0A37h
LCD memory 25	LCDM25	0A38h
LCD memory 26	LCDM26	0A39h
LCD memory 27	LCDM27	0A3Ah
LCD memory 28	LCDM28	0A3Bh
LCD memory 29	LCDM29	0A3Ch
LCD memory 30	LCDM30	0A3Dh
LCD memory 31	LCDM31	0A3Eh
LCD memory 32	LCDM32	0A3Fh
LCD memory 33	LCDM33_LCDBM1	0A40h
LCD memory 34	LCDM34_LCDBM2	0A41h
LCD memory 35	LCDM35_LCDBM3	0A42h
LCD memory 36	LCDM36_LCDBM4	0A43h

Table 9-78. LEA Registers

REGISTER DESCRIPTION	ACRONYM	ADDRESS
LEA Capability Register	LEACAP	0A80h
Configuration Register 0	LEACNF0	0A84h
Configuration Register 1	LEACNF1	0A88h
Configuration Register 2	LEACNF2	0A8Ch
Memory Bottom Register	LEAMB	0A90h
Memory Top Register	LEAMT	0A94h
Code Memory Access	LEACMA	0A98h
Code Memory Control	LEACMCTL	0A9Ch
LEA Command Status	LEACMDSTAT	0AA8h
LEA Source 1 Status	LEAS1STAT	0AACh
LEA Source 0 Status	LEAS0STAT	0AB0h
LEA Result Status	LEADSTSTAT	0AB4h
PM Control Register	LEAPMCTL	0AC0h
PM Result Register	LEAPMDST	0AC4h
PM Source 1 Register	LEAPMS1	0AC8h
PM Source 0 Register	LEAPMS0	0ACCh
PM Command Buffer	LEAPMCB	0AD0h
Interrupt Flag and Set	LEAIFGSET	0AF0h
Interrupt Enable	LEAIE	0AF4h
Interrupt Flag and Clear	LEAIFG	0AF8h
Interrupt Vector	LEAIV	0AFCh

Table 9-79. SAPH Registers

REGISTER DESCRIPTION	ACRONYM	ADDRESS
Interrupt Index	SAPHIIDX	0E00h
Masked Interrupt Satus	SAPHMIS	0E02h
Raw Interrupt Status	SAPHRIS	0E04h
Interrupt Mask	SAPHIMSC	0E06h
Interrupt Clear	SAPHICR	0E08h
Interrupt Set	SAPHISR	0E0Ah
Module-Descriptor Low Word	SAPHDESCLO	0E0Ch
Module-Descriptor High Word	SAPHDESCHI	0E0Eh
Key	SAPHKEY	0E10h
Physical Interface Output Control #0	SAPHOCTL0	0E12h
Physical Interface Output Control #1	SAPHOCTL1	0E14h
Physical Interface Output Function Select	SAPHOSEL	0E16h
Channel 0 Pull UpTrim	SAPHCH0PUT	0E20h
Channel 0 Pull DownTrim	SAPHCH0PDT	0E22h
Channel 0 Termination Trim	SAPHCH0TT	0E24h
Channel 1 Pull UpTrim	SAPHCH1PUT	0E26h
Channel 1 Pull DownTrim	SAPHCH1PDT	0E28h
Channel 1 Termination Trim	SAPHCH1TT	0E2Ah
Mode Configuration Register	SAPHMCNF	0E2Ch
Trim Access Control	SAPHTACTL	0E2Eh
Physical Interface Input Control #0	SAPHICTL0	0E30h
Bias Control	SAPHBCTL	0E34h
PPG Count	SAPHPGC	0E40h
Pulse Generator Low Period	SAPHPGLPER	0E42h
Pulse Generator High Period	SAPHPGHPER	0E44h
PPG Control	SAPHPGCTL	0E46h
PPG Software Trigger	SAPHPPGTRIG	0E48h
A-SEQ control 0	SAPHASCTL0	0E60h
A-SEQ control 1	SAPHASCTL1	0E62h
ASQ Software Trigger	SAPHASQTRIG	0E64h
ASQ ping output polarity	SAPHAPOL	0E66h
ASQ ping pause level	SAPHAPLEV	0E68h
ASQ ping pause impedance	SAPHAPHIZ	0E6Ah
A-SEQ start to 1st ping	SAPHATM_A	0E6Eh
ASQ start to ADC arm	SAPHATM_B	0E70h
Count for the TIMEMARK C Event	SAPHATM_C	0E72h
ASQ start to ADC trig	SAPHATM_D	0E74h
ASQ start to restart	SAPHATM_E	0E76h
ASQ start to time-out	SAPHATM_F	0E78h
Time Base Control	SAPHTBCTL	0E7Ah
Acquisition Timer Low Part	SAPHATIMLO	0E7Ch
Acquisition Timer High Part	SAPHATIMHI	0E7Eh

Table 9-80. SDHS Registers

REGISTER DESCRIPTION	ACRONYM	ADDRESS
Interrupt Index Register	SDHSIIDX	0E80h
Masked Interrupt Status and Clear Register	SDHSMIS	0E82h
Raw Interrupt Status	SDHSRIS	0E84h
Interrupt Mask Register	SDHSIMSC	0E86h
Interrupt Clear	SDHSICR	0E88h
Interrupt Set Register	SDHSISR	0E8Ah
SDHS Descriptor Register L	SDHSDESCLO	0E8Ch
SDHS Descriptor Register H	SDHSDESCHI	0E8Eh
SDHS Control Register 0	SDHSCTL0	0E90h
SDHS Control Register 1	SDHSCTL1	0E92h
SDHS Control Register 2	SDHSCTL2	0E94h
SDHS Control Register 3	SDHSCTL3	0E96h
SDHS Control Register 4	SDHSCTL4	0E98h
SDHS Control Register 5	SDHSCTL5	0E9Ah
SDHS Control Register 6	SDHSCTL6	0E9Ch
SDHS Control Register 7	SDHSCTL7	0E9Eh
SDHS Data Converstion Register	SDHSDT	0EA2h
SDHS Window Comparator High Threshold Register	SDHSWINHITH	0EA4h
SDHS Window Comparator Low Threshold Register	SDHSWINLOTH	0EA6h
DTC destination address	SDHSDTCDA	0EA8h

Table 9-81. UUPS Registers

REGISTER DESCRIPTION	ACRONYM	ADDRESS
Interrupt Index Register	UUPSIIDX	0EC0h
Masked Interrupt Status	UUPSMIS	0EC2h
Raw Interrupt Status	UUPSRIS	0EC4h
Interrupt Mask Register	UUPSIMSC	0EC6h
Interrupt Clear	UUPSICR	0EC8h
Interrupt Flag Set	UUPSISR	0ECAh
UUPS Descriptor Register L	UUPSDESCLO	0ECCh
UUPS Descriptor Register H	UUPSDESCHI	0ECEh
UUPS Control	UUPSCTL	0ED0h

Table 9-82. HSPLL Registers

REGISTER DESCRIPTION	ACRONYM	ADDRESS
Interrupt Index Register	HSPLLIIDX	0EE0h
Masked Interrupt Status	HSPLLMIS	0EE2h
Raw Interrupt Status	HSPLLRIS	0EE4h
Interrupt Mask Register	HSPLLIMSC	0EE6h
Interrupt Flag Clear	HSPLLICR	0EE8h
Interrupt Flag Set	HSPLLISR	0EEAh
HSPLL Descriptor Register L	HSPLLDESCLO	0EECh
HSPLL Descriptor Register H	HSPLLDESCHI	0EEEh
HSPLL Control Register	HSPLLCTL	0EF0h
USSXT Control Register	HSPLLUSSXTLCTL	0EF2h

9.17 Identification

9.17.1 Revision Identification

The device revision information is shown as part of the top-side marking on the device package. The device-specific errata sheet describes these markings. For links to the errata sheets for the devices in this data sheet, see Section 11.4.

The hardware revision is also stored in the Device Descriptor structure in the Info Block section. For details on this value, see the "Hardware Revision" entries in the Device Descriptor structure (see Section 9.15).

9.17.2 Device Identification

The device type can be identified from the top-side marking on the device package. The device-specific errata sheet describes these markings. For links to the errata sheets for the devices in this data sheet, see Section 11.4.

A device identification value is also stored in the Device Descriptor structure in the Info Block section. For details on this value, see the "Device ID" entries in the Device Descriptor structure (see Section 9.15).

9.17.3 JTAG Identification

Programming through the JTAG interface, including reading and identifying the JTAG ID, is described in *MSP430 Programming With the JTAG Interface*.

10 Applications, Implementation, and Layout

Note

Information in the following Applications section is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

10.1 Device Connection and Layout Fundamentals

This section describes the recommended guidelines when designing with the MSP MCU. These guidelines are to make sure that the device has proper connections for powering, programming, debugging, and optimum analog performance.

10.1.1 Power Supply Decoupling and Bulk Capacitors

TI recommends connecting a combination of a 1-µF plus a 100-nF low-ESR ceramic decoupling capacitor to each AVCC and DVCC pin (see Figure 10-1). Higher-value capacitors may be used but can affect supply rail ramp-up time. Decoupling capacitors must be placed as close as possible to the pins that they decouple (within a few millimeters). Additionally, TI recommends separated grounds with a single-point connection for better noise isolation from digital to analog circuits on the board and to achieve high analog accuracy.

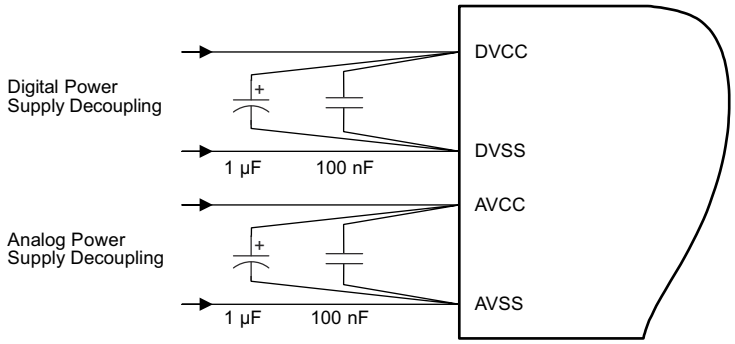


Figure 10-1. Power Supply Decoupling

For PVCC and PVSS, TI recommends connecting a combination of a 1-µF plus a 22-µF low-ESR ceramic decoupling capacitor between the PVCC and PVSS pins and a serial 22-Ω resistor to filter low-frequency noise on the supply line (see Figure 10-2).

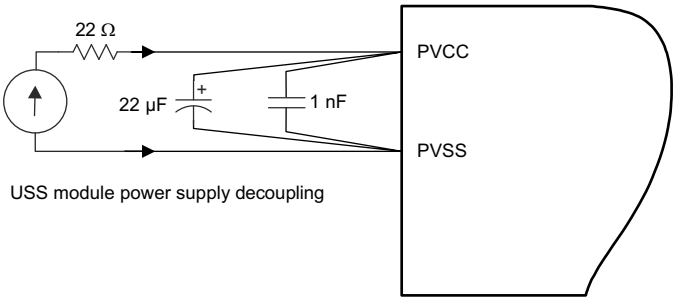


Figure 10-2. Power Supply Decoupling for PVCC and PVSS

10.1.2 External Oscillator (HFXT and LFXT)

Depending on the device variant (see Section 6), the device can support a low-frequency crystal (32 kHz) on the LFXT pins, a high-frequency crystal on the HFXT pins, or both. External bypass capacitors for the crystal oscillator pins are required.

It is also possible to apply digital clock signals to the LFXIN and HFXIN input pins that meet the specifications of the respective oscillator if the appropriate LFXTBYPASS or HFXTBYPASS mode is selected. In this case, the associated LFXOUT and HFXOUT pins can be used for other purposes. If they are left unused, they must be terminated according to Section 7.6.

Figure 10-3 shows a typical connection diagram.

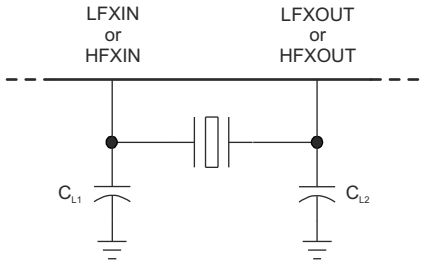


Figure 10-3. Typical Crystal Connection

See *MSP430 32-kHz Crystal Oscillators* for more information on selecting, testing, and designing a crystal oscillator with the MSP MCUs.

10.1.3 USS Oscillator (USSXT)

Depending on the device variant (see Section 6), the device with USS module supports a high-frequency crystal on the USSXT pins. External bypass capacitors for the crystal oscillator pins are required. Serially connect a 22-Ω resistor close to the USSXTOUT pin (see Figure 10-4). The USSXT does not support bypass mode, so it is not possible to apply digital clock signals to the USSXTIN pin. Never connect the USSXTIN pin to a power supply line (AVCC, DVCC, or PVCC). If the USSXT pins are not used, terminate them according to Section 7.6.

Figure 10-4 shows a typical connection diagram.

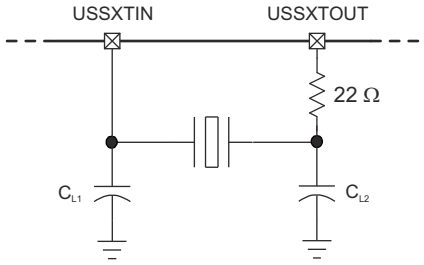


Figure 10-4. Typical Crystal Connection

Consider the following items for the USSXT layout:

- Keep the trace of USSXTIN and USSXTOUT as short as possible. If one must be longer than the other, keep USSXTIN shorter, because USSXTIN is more sensitive to EMI.
- Make the ground shield open ended without making a loop.
- Use a ground plane to reduce the impedance of the ground trace.
- If USSXT_BOUT is used, keep coupling to USSXTIN and CH0_IN to a minimum.
- If USSXT_BOUT is feeding other clock or device inputs, apply a small capacitor (10 pF) as the line termination load at the end of the line. This avoids reflection artifacts on sensitive inputs (for example, HFXTIN).

Figure 10-5 shows the recommended PCB layout.

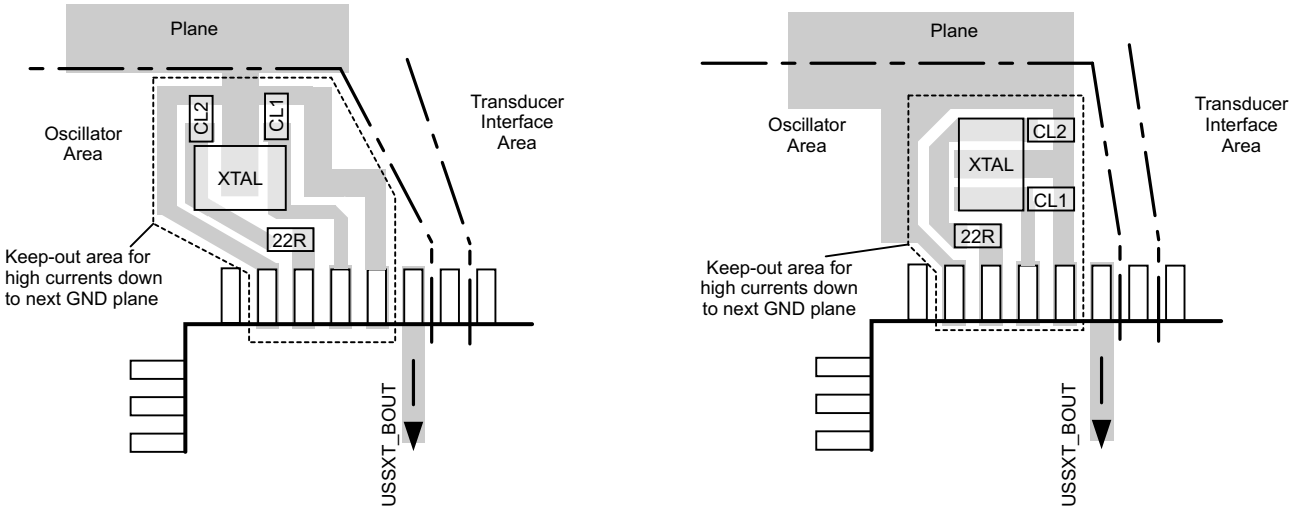


Figure 10-5. USSXT PCB Layout Recommendation

10.1.4 Transducer Connection to the USS Module

Figure 10-6 shows a typical connection of two transducers to the USS output and input pins. TI recommends 1% error tolerance for the external termination resistors (Rterm0 and Rterm1) and the AC coupling capacitors (Cac0 and Cac1). Typical value of the termination resistors is in the range of 150 to 400 Ω, the AC coupling capacitors are 1 to 2 nF. Actual values should be determined to meet the requirements of each application.

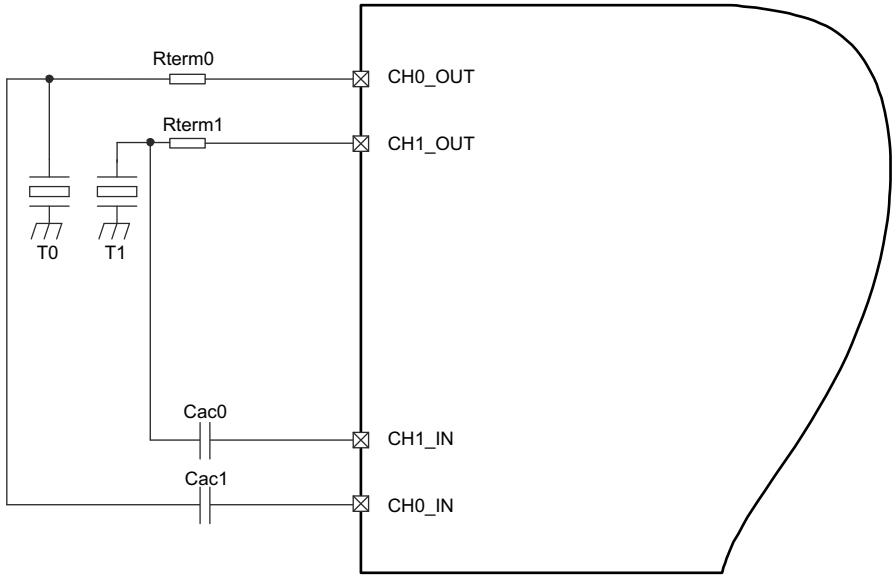


Figure 10-6. Typical Transducer Connection

10.1.5 Charge Pump Control of Input Multiplexer

Figure 10-7 shows the control logic of the charge pump control of the input multiplexer of CHx_IN. The charge pump is enabled as long the SAPH_AMCNF.CPEO is high and during the arming of the SDHS. Use the CPDA bit to control the CP during data acquisition.

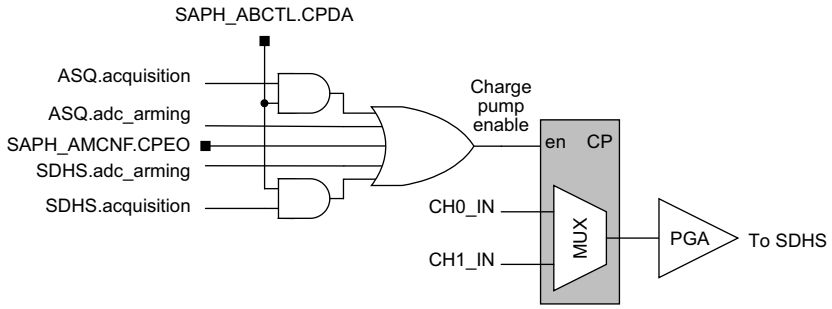


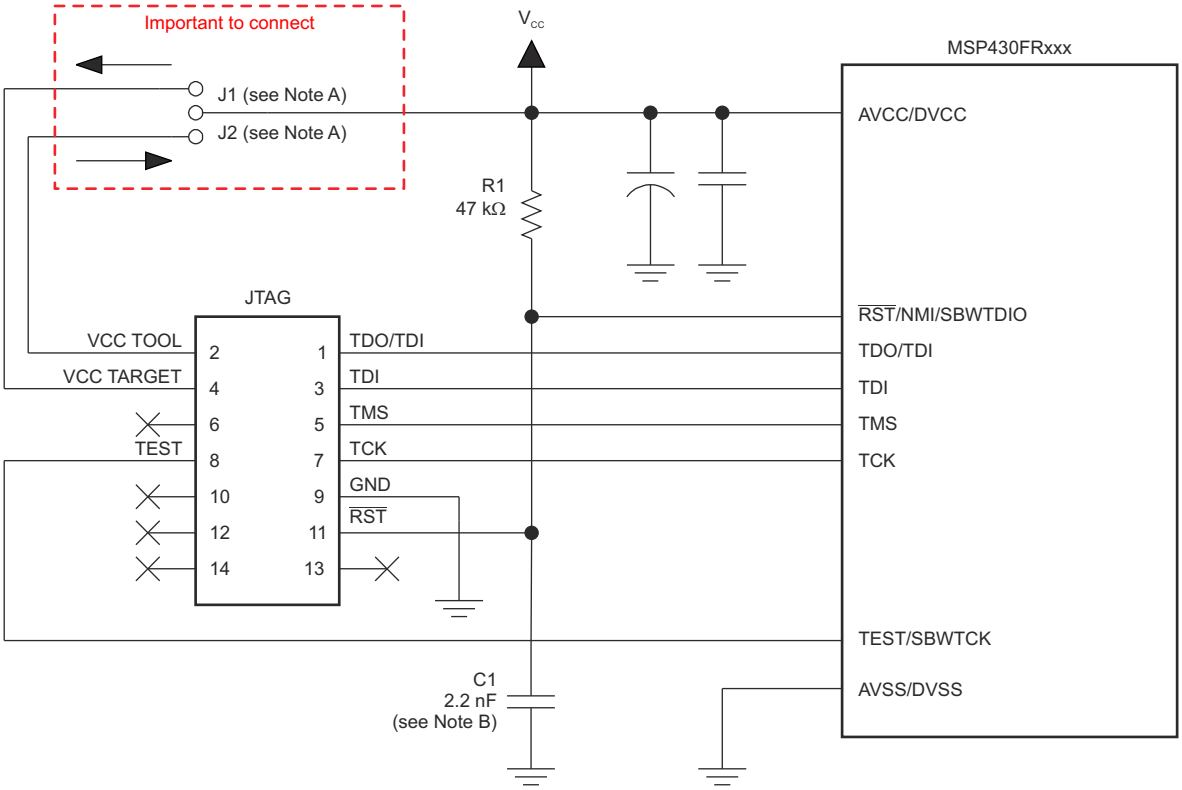
Figure 10-7. Control Of Input Multiplexer

10.1.6 JTAG

With the proper connections, the debugger and a hardware JTAG interface (such as the MSP-FET or MSP-FET430UIF) can be used to program and debug code on the target board. In addition, the connections also support the MSP-GANG production programmers, thus providing an easy way to program prototype boards, if desired. Figure 10-8 shows the connections between the 14-pin JTAG connector and the target device required to support in-system programming and debugging for 4-wire JTAG communication. Figure 10-9 shows the connections for 2-wire JTAG mode (Spy-Bi-Wire).

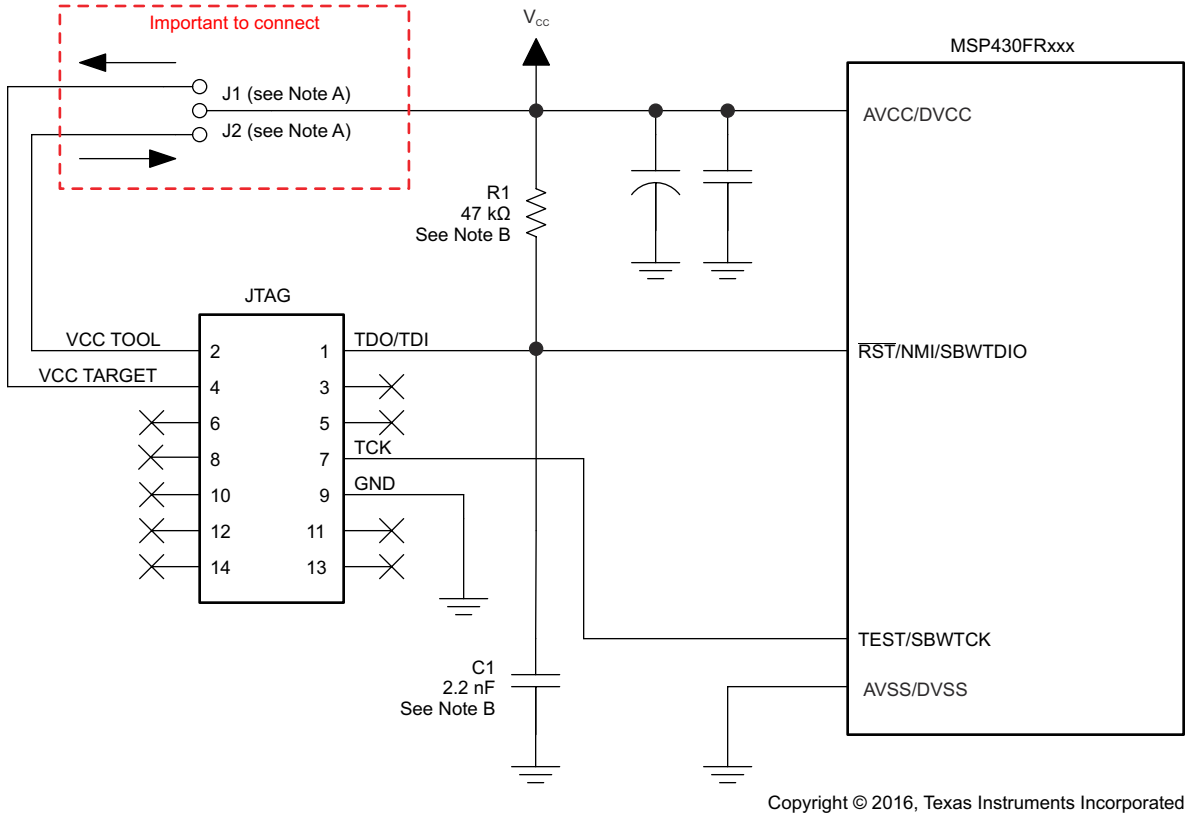
The connections for the MSP-FET and MSP-FET430UIF interface modules and the MSP-GANG are identical. Both can supply V_{CC} to the target board (through pin 2). In addition, the MSP-FET and MSP-FET430UIF interface modules and MSP-GANG have a V_{CC} sense feature that, if used, requires an alternate connection (pin 4 instead of pin 2). The V_{CC} sense feature senses the local V_{CC} present on the target board (that is, a battery or other local power supply) and adjusts the output signals accordingly. Figure 10-8 and Figure 10-9 show a jumper block that supports both scenarios of supplying V_{CC} to the target board. If this flexibility is not required, the desired V_{CC} connections may be hard-wired to eliminate the jumper block. Pins 2 and 4 must not be connected at the same time.

For additional design information regarding the JTAG interface, see the *MSP430 Hardware Tools User's Guide*.



A. If a local target power supply is used, make connection J1. If power from the debug or programming adapter is used, make connection J2.
B. The upper limit for C1 is 2.2 nF when using current TI tools.

Figure 10-8. Signal Connections for 4-Wire JTAG Communication



A. Make connection J1 if a local target power supply is used, or make connection J2 if the target is powered from the debug or programming adapter.
B. The device RST/NMI/SBWTDIO pin is used in 2-wire mode for bidirectional communication with the device during JTAG access, and any capacitance that is attached to this signal may affect the ability to establish a connection with the device. The upper limit for C1 is 2.2 nF when using current TI tools.

Figure 10-9. Signal Connections for 2-Wire JTAG Communication (Spy-Bi-Wire)

10.1.7 Reset

The reset pin can be configured as a reset function (default) or as an NMI function in the SFRRPCR register.

In reset mode, the RST/NMI pin is active low, and a pulse applied to this pin that meets the reset timing specifications generates a BOR-type device reset.

Setting SYSNMI causes the RST/NMI pin to be configured as an external NMI source. The external NMI is edge sensitive, and its edge is selectable by SYSNMIIES. Setting the NMIIE enables the interrupt of the external NMI. When an external NMI event occurs, the NMIIFG is set.

The RST/NMI pin can have either a pullup or pulldown that is enabled or not. SYSRSTUP selects either pullup or pulldown, and SYSRSTRE causes the pullup (default) or pulldown to be enabled (default) or not. If the RST/NMI pin is unused, it is required either to select and enable the internal pullup or to connect an external 47-kΩ pullup resistor to the RST/NMI pin with a 2.2-nF pulldown capacitor. The pulldown capacitor should not exceed 2.2 nF when using devices with Spy-Bi-Wire interface in Spy-Bi-Wire mode or in 4-wire JTAG mode with TI tools like FET interfaces or GANG programmers.

See the *MSP430FR58xx, MSP430FR59xx, and MSP430FR6xx Family User's Guide* for more information on the referenced control registers and bits.

10.1.8 Unused Pins

For details on the connection of unused pins, see Section 7.6.

10.1.9 General Layout Recommendations

- Proper grounding and short traces for external crystal to reduce parasitic capacitance. See *MSP430 32-kHz Crystal Oscillators* for recommended layout guidelines.
- Proper bypass capacitors on DVCC, AVCC, and reference pins if used.
- Avoid routing any high-frequency signal close to an analog signal line. For example, keep digital switching signals such as PWM or JTAG signals away from the oscillator circuit.
- Proper ESD level protection should be considered to protect the device from unintended high-voltage electrostatic discharge. See *MSP430 System-Level ESD Considerations* for guidelines.

10.1.10 Do's and Don'ts

TI recommends powering AVCC and DVCC pins from the same source. At a minimum, during power up, power down, and device operation, the voltage difference between AVCC and DVCC must not exceed the limits specified in Section 8.1. Exceeding the specified limits may cause malfunction of the device including erroneous writes to RAM and FRAM.

10.2 Peripheral- and Interface-Specific Design Information

10.2.1 ADC12_B Peripheral

10.2.1.1 Partial Schematic

Figure 10-10 shows the recommended connections for the reference input pins.

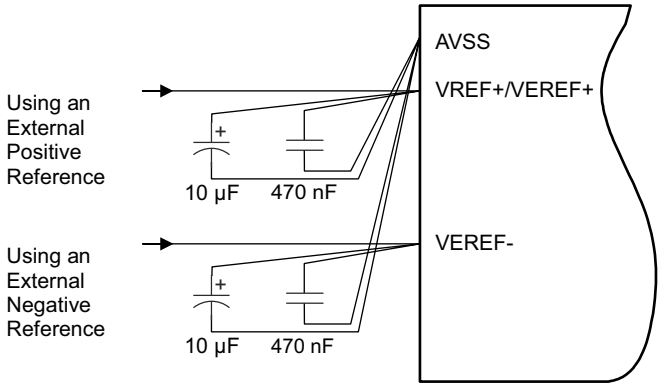


Figure 10-10. ADC12_B Grounding and Noise Considerations

10.2.1.2 Design Requirements

As with any high-resolution ADC, appropriate printed-circuit-board layout and grounding techniques should be followed to eliminate ground loops, unwanted parasitic effects, and noise.

Ground loops are formed when return current from the ADC flows through paths that are common with other analog or digital circuitry. If care is not taken, this current can generate small unwanted offset voltages that can add to or subtract from the reference or input voltages of the ADC. The general guidelines in Section 10.1.1 combined with the connections shown in Figure 10-10 prevent these offsets.

In addition to grounding, ripple and noise spikes on the power-supply lines that are caused by digital switching or switching power supplies can corrupt the conversion result. A noise-free design using separate analog and digital ground planes with a single-point connection is recommend to achieve high accuracy.

Figure 10-10 shows the recommended decoupling circuit when an external voltage reference is used. The internal reference module has a maximum drive current as specified in the $I_{O(VREF+)}$ specification of the REF module.

The reference voltage must be a stable voltage for accurate measurements. The capacitor values that are selected in the general guidelines filter out the high- and low-frequency ripple before the reference voltage enters the device. In this case, the 10-µF capacitor buffers the reference pin and filter any low-frequency ripple. A 470-nF bypass capacitor filters out any high-frequency noise.

10.2.1.3 Detailed Design Procedure

For additional design information, see *Designing With the MSP430FR58xx, FR59xx, FR68xx, and FR69xx ADC*.

10.2.1.4 Layout Guidelines

Component that are shown in the partial schematic (see Figure 10-10) should be placed as close as possible to the respective device pins. Avoid long traces, because they add additional parasitic capacitance, inductance, and resistance on the signal.

Avoid routing analog input signals close to a high-frequency pin (for example, a high-frequency PWM), because the high-frequency switching can be coupled into the analog signal.

If differential mode is used for the ADC12_B, the analog differential input signals must be routed closely together to minimize the effect of noise on the resulting signal.

10.2.2 LCD_C Peripheral

10.2.2.1 Partial Schematic

Required LCD connections greatly vary by the type of display that is used (static or multiplexed), whether external or internal biasing is used, and whether the on-chip charge pump is employed. Also, there is a fair amount of flexibility as to how the segment (Sx) and common (COMx) signals are connected to the MCU, which can provide unique benefits. Because LCD connections are application-specific, it is difficult to provide a single one-fits-all schematic. However, for examples and how-to circuit design guidance, see *Designing With MSP430™ MCUs and Segment LCDs*.

10.2.2.2 Design Requirements

Due to the flexibility of the LCD_C peripheral module to accommodate various segment-based LCDs, selecting the correct display for the application in combination with determining specific design requirements is often an iterative process. TI strongly recommends reviewing the LCD_C peripheral module chapter in the *MSP430FR58xx, MSP430FR59xx, and MSP430FR6xx Family User's Guide* and *Designing With MSP430™ MCUs and Segment LCDs* during the initial design requirements and decision process.

10.2.2.3 Detailed Design Procedure

A major component in designing the LCD solution is determining the exact connections between the LCD_C peripheral module and the display. Two basic design processes can be employed for this step, although in reality often a balanced co-design approach is recommended:

- PCB layout-driven design, optimizing signal routing
- Software-driven design, focusing on optimizing computational overhead

For a detailed discussion of the design procedure as well as for design information regarding the LCD controller input voltage selection including internal and external options, contrast control, and bias generation, see *Designing With MSP430™ MCUs and Segment LCDs* and the *LCD_C Controller* chapter in the *MSP430FR58xx, MSP430FR59xx, and MSP430FR6xx Family User's Guide*.

10.2.2.4 Layout Guidelines

LCD segment (Sx) and common (COMx) signal traces are continuously switching while the LCD is enabled and should, therefore, be kept away from sensitive analog signals such as ADC inputs to prevent any noise coupling. TI recommends keeping the LCD signal traces on one side of the PCB grouped together in a bus-like fashion. A ground plane beneath the LCD traces and guard traces alongside the LCD traces can provide shielding.

If the internal charge pump of the LCD module is used, place the externally provided capacitor on the LCDCAP pin as close as possible to the MCU. Connect the capacitor to the device using a short and direct trace and also have a solid connection to the ground plane that supplies the V_{SS} pins of the MCU.

For an example layouts and a more in-depth discussion, see *Designing With MSP430™ MCUs and Segment LCDs*.

11 Device and Documentation Support

11.1 Getting Started and Next Steps

For more information on the MSP family of microcontrollers and the tools and libraries that are available to help with your development, visit the MSP430™ ultra-low-power sensing & measurement MCUs overview.

11.2 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

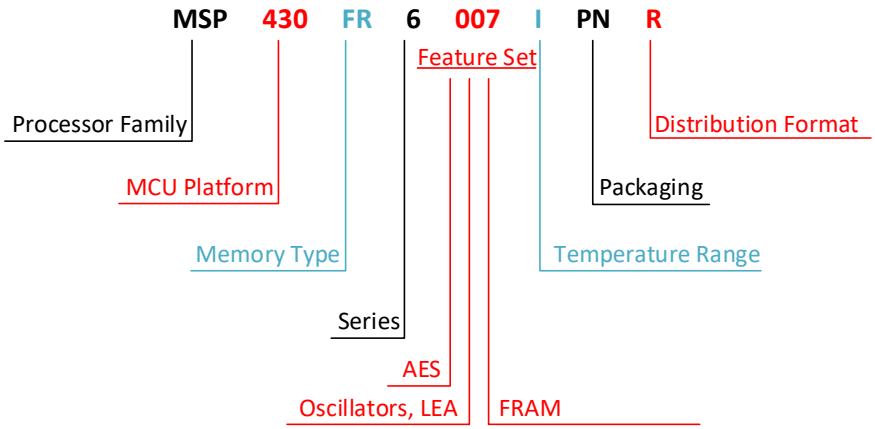
XMS devices are shipped against the following disclaimer:

"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 11-1 provides a legend for reading the complete device name.



Processor Family	MSP = Mixed-Signal Processor XMS = Experimental Silicon		
Platform	430 = MSP430 16-Bit Low-Power Platform		
Memory Type	FR = FRAM		
Series	6 = FRAM 6 Series Up to 16 MHz with LCD		
Feature Sets	**First Digit: Feature** 0 = AES	**Second Digit: Oscillators, LEA** 0 = HFXT + LFXT + LEA + USS	**Third Digit: FRAM (KB)** 7 = 256 5 = 128
Temperature Range	I = -40°C to 85°C		
Packaging	http://www.ti.com/packaging		
Optional: Distribution Format	T = Small reel R = Large reel No Marking = Tube or Tray		

Figure 11-1. Device Nomenclature

11.3 Tools and Software

Table 11-1 lists the debug features supported by these microcontrollers. See the Code Composer Studio™ IDE for MSP430 User's Guide for details on the available features. For further usage information, see the following documents:

Advanced Debugging Using the Enhanced Emulation Module (EEM) With Code Composer Studio™ IDE

MSP430™ Advanced Power Optimizations: ULP Advisor™ Software and EnergyTrace™ Technology

Table 11-1. Hardware Features

MSP ARCHITECTURE	4-WIRE JTAG	2-WIRE JTAG	BREAK-POINTS (N)	RANGE BREAK-POINTS	CLOCK CONTROL	STATE SEQUENCER	TRACE BUFFER	LPMx.5 DEBUGGING SUPPORT	EnergyTrace++
MSP430Xv2	Yes	Yes	3	Yes	Yes	No	No	Yes	Yes

Design Kits and Evaluation Modules

MSP430FR6047 Ultrasonic Sensing Evaluation Module

The EVM430-FR6047 evaluation kit is a development platform that can be used to evaluate the performance of the MSP430FR6007 for ultrasonic sensing applications (for example, smart water meters).

MSP-TS430PZ100E 100-pin Target Development Board

The MSP-TS430PZ100E is a stand-alone 100-pin ZIF socket target board used to program and debug the MSP430 MCU in-system through the JTAG interface or the Spy Bi-Wire (2-wire JTAG) protocol.

Software

MSP430Ware™ Software

MSP430Ware software is a collection of code examples, data sheets, and other design resources for all MSP430 devices delivered in a convenient package. In addition to providing a complete collection of existing MSP430 design resources, MSP430Ware software also includes a high-level API called MSP430 Driver Library. This library makes it easy to program MSP430 hardware. MSP430Ware software is available as a component of Code Composer Studio IDE or as a stand-alone package.

MSP430FR604x(1), MSP430FR603x(1) Code Examples

C Code examples are available for every MSP device that configures each of the integrated peripherals for various application needs.

MSP Driver Library

Driver Library's abstracted API keeps you above the bits and bytes of the MSP430 hardware by providing easy-to-use function calls. Thorough documentation is delivered through a helpful API Guide, which includes details on each function call and the recognized parameters. Developers can use Driver Library functions to write complete projects with minimal overhead.

MSP EnergyTrace™ Technology

EnergyTrace technology for MSP430 microcontrollers is an energy-based code analysis tool that measures and displays the energy profile of the application and helps to optimize it for ultra-low-power consumption.

ULP (Ultra-Low Power) Advisor

ULP Advisor™ software is a tool for guiding developers to write more efficient code to fully use the unique ultra-low power features of MSP430 and MSP432 microcontrollers. Aimed at both experienced and new microcontroller developers, ULP Advisor checks your code against a thorough ULP checklist to squeeze every last nano amp out of your application. At build time, ULP Advisor provides notifications and remarks on areas of your code that can be further optimized for lower power.

Fixed-Point Math Library for MSP MCUs

The MSP IQmath and Qmath Libraries are a collection of highly optimized and high-precision mathematical functions for C programmers to seamlessly port a floating-point algorithm into fixed-point code on MSP430 and MSP432 devices. These routines are typically used in computationally intensive real-time applications where optimal execution speed, high accuracy, and ultra-low energy are critical. By using the IQmath and Qmath libraries, it is possible to achieve execution speeds considerably faster and energy consumption considerably lower than equivalent code written using floating-point math.

Floating-Point Math Library for MSP430™ MCUs

Continuing to innovate in the low power and low cost microcontroller space, TI brings you MSPMATHLIB. Leveraging the intelligent peripherals of our devices, this floating point math library of scalar functions brings you up to 26x better performance. Mathlib is easy to integrate into your designs. This library is free and is integrated in both Code Composer Studio and IAR IDEs. Read the user's guide for an in depth look at the math library and relevant benchmarks.

Development Tools

Code Composer Studio™ Integrated Development Environment for MSP Microcontrollers

The Code Composer Studio integrated development environment (IDE) supports TI's Microcontroller and Embedded Processors portfolio. The Code Composer Studio IDE comprises a suite of tools used to develop and debug embedded applications. It includes an optimizing C/C++ compiler, source code editor, project build environment, debugger, profiler, and many other features. The intuitive IDE provides a single user interface taking you through each step of the application development flow. Familiar tools and interfaces allow users to get started faster than ever before. The Code Composer Studio IDE combines the advantages of the Eclipse software framework with advanced embedded debug capabilities from TI resulting in a compelling feature-rich development environment for embedded developers.

Command-Line Programmer

MSP Flasher is an open-source shell-based interface for programming MSP microcontrollers through a FET programmer or eZ430 using JTAG or Spy-Bi-Wire (SBW) communication. MSP Flasher can download binary files (.txt or .hex) files directly to the MSP microcontroller without an IDE.

MSP MCU Programmer and Debugger

The MSP-FET is a powerful emulation development tool – often called a debug probe – which allows users to quickly begin application development on MSP low-power microcontrollers (MCU). Creating MCU software usually requires downloading the resulting binary program to the MSP device for validation and debugging. The MSP-FET provides a debug communication pathway between a host computer and the target MSP. Furthermore, the MSP-FET also provides a Backchannel UART connection between the computer's USB interface and the MSP UART. This affords the MSP programmer a convenient method for communicating serially between the MSP and a terminal running on the computer. The MSP-FET also supports loading programs (often called firmware) to the MSP target using the BSL through the UART and I^2C communication protocols.

MSP-GANG Production Programmer

The MSP Gang Programmer is an MSP430 or MSP432 device programmer that can program up to eight identical MSP430 or MSP432 Flash or FRAM devices at the same time. The MSP Gang Programmer connects to a host PC using a standard RS-232 or USB connection and provides flexible programming options that allow the user to fully customize the process. The MSP Gang Programmer is provided with an expansion board, called the Gang Splitter, that implements the interconnections between the MSP Gang Programmer and multiple target devices. Eight cables are provided that connect the expansion board to eight target devices (through JTAG or Spy-Bi-Wire connectors). The programming can be done with a PC or as a stand-alone device. A PC-side graphical user interface is also available and is DLL-based.

11.4 Documentation Support

The following documents describe the MSP430FR600x MCUs. Copies of these documents are available on the Internet at www.ti.com.

Receiving Notification of Document Updates

To receive notification of documentation updates—including silicon errata—go to the product folder for your device on ti.com (for example, MSP430FR6007). In the upper-right corner, click the "Alert me" button. This registers you to receive a weekly digest of product information that has changed (if any). For change details, check the revision history of any revised document.

Errata

MSP430FR6007 Device Erratasheet

Describes the known exceptions to the functional specifications.

MSP430FR6005 Device Erratasheet

Describes the known exceptions to the functional specifications.

User's Guides

MSP430FR58xx, MSP430FR59xx, and MSP430FR6xx Family User's Guide

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

MSP430™ FRAM Devices Bootloader (BSL) User's Guide

The bootloader (BSL) on MSP430 microcontrollers (MCUs) lets users communicate with embedded memory in the MSP430 MCU during the prototyping phase, final production, and in service. Both the programmable memory (FRAM memory) and the data memory (RAM) can be modified as required.

MSP430™ Programming With the JTAG Interface

This document describes the functions that are required to erase, program, and verify the memory module of the MSP430 flash-based and FRAM-based microcontroller families using the JTAG communication port. In addition, it describes how to program the JTAG access security fuse that is available on all MSP430 devices. This document describes device access using both the standard 4-wire JTAG interface and the 2-wire JTAG interface, which is also referred to as Spy-Bi-Wire (SBW).

MSP430™ Hardware Tools User's Guide

This manual describes the hardware of the TI MSP-FET430 Flash Emulation Tool (FET). The FET is the program development tool for the MSP430 ultra-low-power microcontroller.

Application Reports

MSP430™ 32-kHz Crystal Oscillators

Selection of the correct crystal, correct load circuit, and proper board layout are important for a stable crystal oscillator. This application report summarizes crystal oscillator function and explains the parameters to select the correct crystal for MSP430 ultra-low-power operation. In addition, hints and examples for correct board layout are given. The document also contains detailed information on the possible oscillator tests to ensure stable oscillator operation in mass production.

MSP430™ System-Level ESD Considerations

System-level ESD has become increasingly demanding with silicon technology scaling towards lower voltages and the need for designing cost-effective and ultra-low-power components. This application report addresses different ESD topics to help board designers and OEMs understand and design robust system-level designs. A few real-world system-level ESD protection design examples and their results are also discussed.

11.5 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.

Linked content is provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

11.6 Trademarks

MSP430Ware™, MSP430™, EnergyTrace™, ULP Advisor™, Code Composer Studio™, and TI E2E™ are trademarks of Texas Instruments.
Arm® and Cortex® are registered trademarks of Arm Limited.
Microsoft® is a registered trademark of Microsoft Corporation.
All trademarks are the property of their respective owners.

11.7 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.

11.8 Export Control Notice

Recipient agrees to not knowingly export or re-export, directly or indirectly, any product or technical data (as defined by the U.S., EU, and other Export Administration Regulations) including software, or any controlled product restricted by other applicable national regulations, received from disclosing party under nondisclosure obligations (if any), or any direct product of such technology, to any destination to which such export or re-export is restricted or prohibited by U.S. or other applicable laws, without obtaining prior authorization from U.S. Department of Commerce and other competent Government authorities to the extent required by those laws.

11.9 Glossary

TI Glossary This glossary lists and explains terms, acronyms, and definitions.

12 Mechanical, Packaging, and Orderable 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
MSP430FR6005IPZ	ACTIVE	LQFP	PZ	100	90	RoHS & Green	NIPDAU	Level-3-260C-168 HR	-40 to 85	FR6005	Samples
MSP430FR6005IPZR	ACTIVE	LQFP	PZ	100	1000	RoHS & Green	NIPDAU	Level-3-260C-168 HR	-40 to 85	FR6005	Samples
MSP430FR6007IPZ	ACTIVE	LQFP	PZ	100	90	RoHS & Green	NIPDAU	Level-3-260C-168 HR	-40 to 85	FR6007	Samples
MSP430FR6007IPZR	ACTIVE	LQFP	PZ	100	1000	RoHS & Green	NIPDAU	Level-3-260C-168 HR	-40 to 85	FR6007	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.

continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals.
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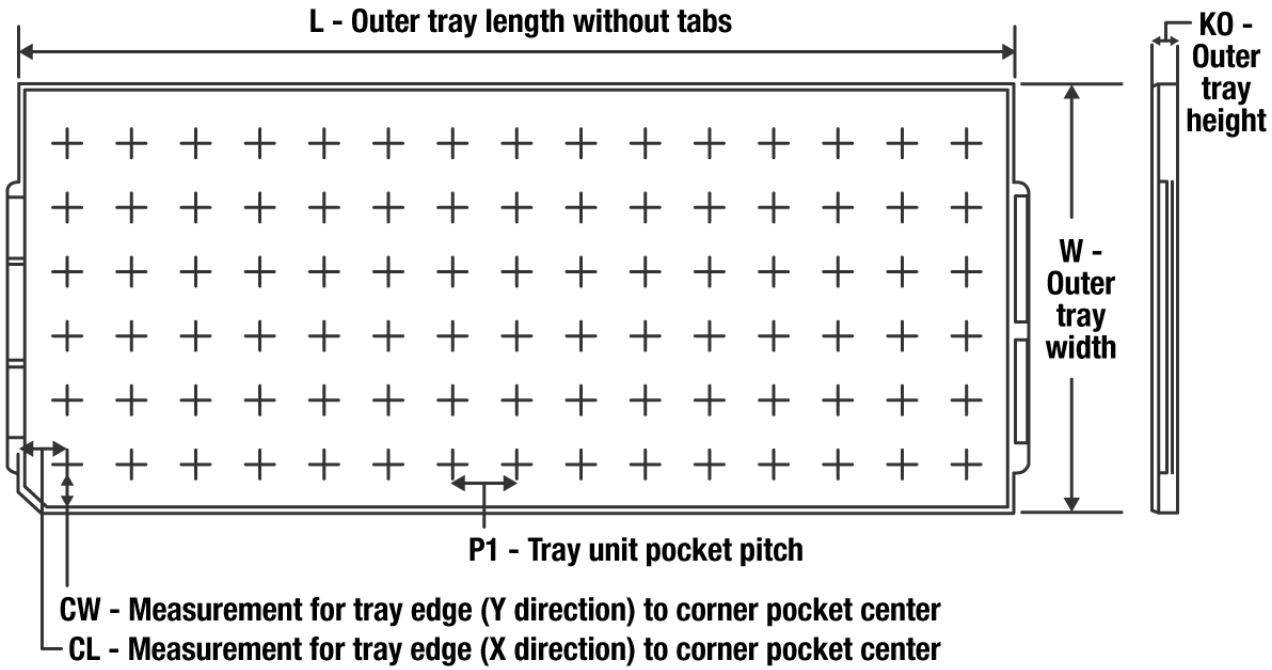
TRAY



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)
MSP430FR6005IPZ	PZ	LQFP	100	90	6 x 15	150	315	135.9	7620	20.3	15.4	15.45
MSP430FR6007IPZ	PZ	LQFP	100	90	6 x 15	150	315	135.9	7620	20.3	15.4	15.45

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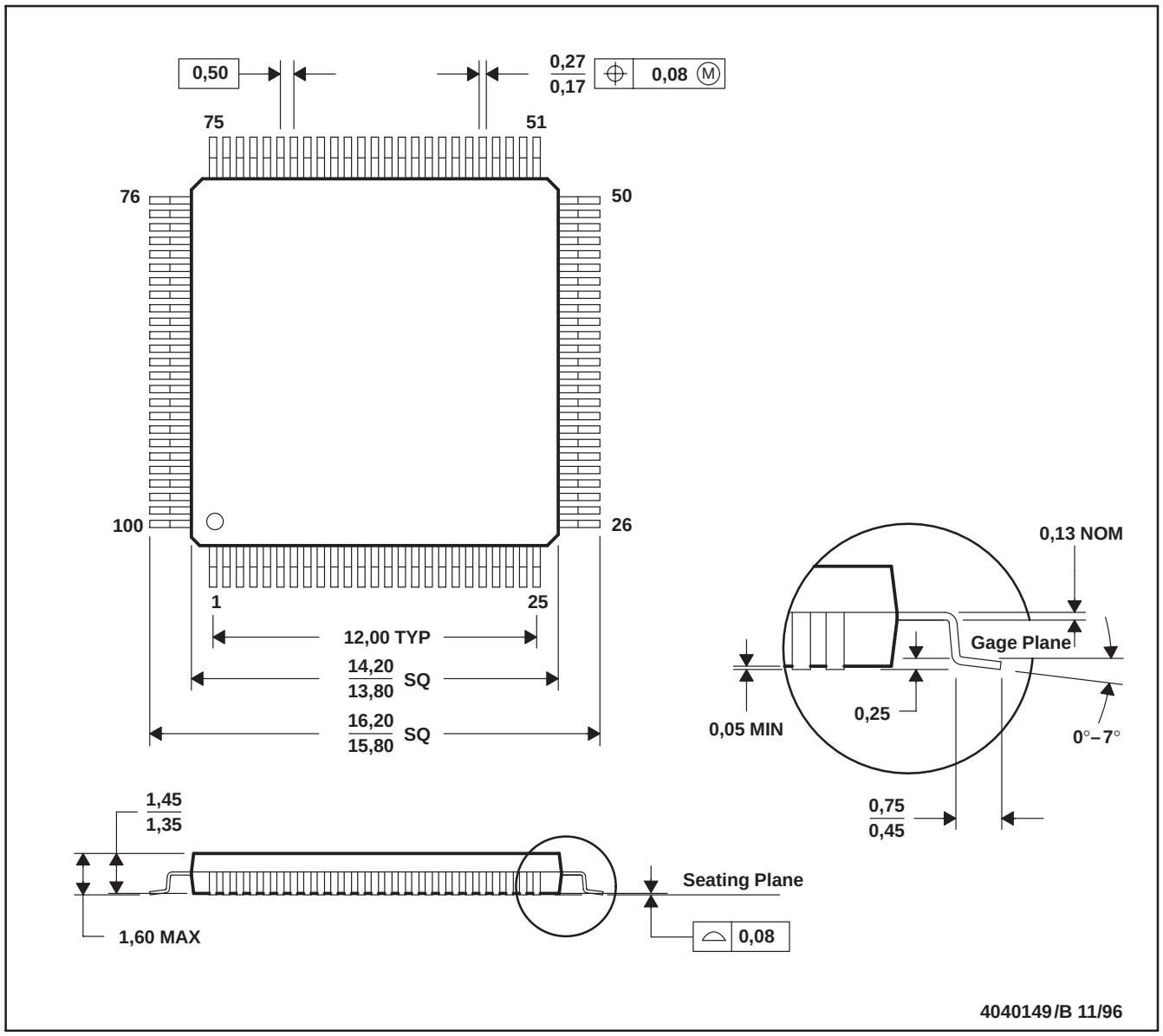
PZ (S-PQFP-G100) **PLASTIC QUAD FLATPACK**



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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