SLAS578B – NOVEMBER 2007 – REVISED MAY 2008

- **Low Supply-Voltage Range, 1.8 V to 3.6 V**
- **Ultra-Low Power Consumption:**
  - **Active Mode: 200 μA at 1 MHz, 2.2 V**
  - **Standby Mode: 0.7 μA**
  - **Off Mode (RAM Retention): 0.1 μA**
- **Ultra-Fast Wake-Up From Standby Mode in Less Than 1 μs**
- **16-Bit RISC Architecture, 62.5-ns Instruction Cycle Time**
- **Basic Clock Module Configurations:**
  - **Internal Frequencies up to 16 MHz With Four Calibrated Frequencies to ±1%**
  - **Internal Very Low-Power Low-Frequency Oscillator**
  - **32-kHz Crystal**
  - **High-Frequency Crystal up to 16 MHz**
  - **Resonator**
  - **External Digital Clock Source**
  - **External Resistor**
- **16-Bit Timer0_A3 With Three Capture/Compare Registers**
- **16-Bit Timer1_A2 With Two Capture/Compare Registers**
- **On-Chip Comparator for Analog Signal Compare Function or Slope Analog-to-Digital (A/D) Conversion**
- **10-Bit, 200-ksps A/D Converter With Internal Reference, Sample-and-Hold, Autoscan, and Data Transfer Controller**
- **Universal Serial Communication Interface**
  - **Enhanced UART Supporting Auto Baudrate Detection (LIN)**
  - **IrDA Encoder and Decoder**
  - **Synchronous SPI**
  - **I^2C™**
- **Brownout Detector**
- **Serial Onboard Programming, No External Programming Voltage Needed, Programmable Code Protection by Security Fuse**
- **Bootstrap Loader in Flash Devices**
- **On-Chip Emulation Module**
- **Family Members Include:**
  MSP430F2132
  - **8KB + 256B Flash Memory**
  - **512B RAM**

  MSP430F2122
  - **4KB + 256B Flash Memory**
  - **512B RAM**

  MSP430F2112
  - **2kB + 256B Flash Memory**
  - **256B RAM**
- **Available in 28-Pin TSSOP and 32-Pin QFN (See Available Options)**
- **For Complete Module Descriptions, See the *MSP430x2xx Family User's Guide*, Literature Number SLAU144**

description

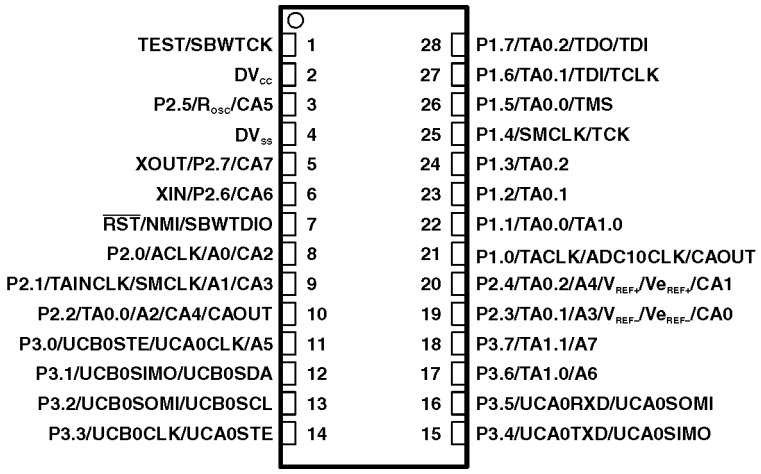
The Texas Instruments MSP430 family of ultra-low-power microcontrollers consists of several devices featuring different sets of peripherals targeted for various applications. The architecture, combined with five low-power modes, is optimized to achieve extended battery life in portable measurement applications.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

The MSP430F21x2 series is an ultra-low-power microcontroller with two built-in 16-bit timers, a fast 10-bit A/D converter with integrated reference and a data transfer controller (DTC), a comparator, built-in communication capability using the universal serial communication interface, and up to 24 I/O pins.

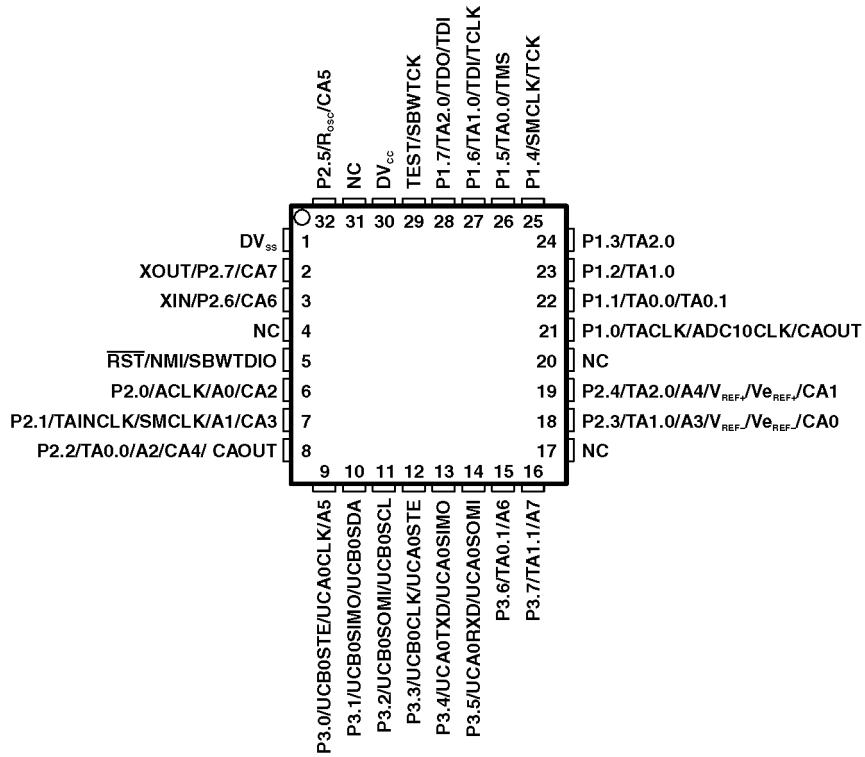
AVAILABLE OPTIONS

T_A	PACKAGED DEVICES	
	PLASTIC 28-PIN TSSOP (PW)	PLASTIC 32-PIN QFN (RHB)
–40°C to 85°C	MSP430F2112IPW	MSP430F2112IRHB
	MSP430F2122IPW	MSP430F2122IRHB
	MSP430F2132IPW	MSP430F2132IRHB
–40°C to 105°C	MSP430F2112TPW	MSP430F2112TRHB
	MSP430F2122TPW	MSP430F2122TRHB
	MSP430F2132TPW	MSP430F2132TRHB

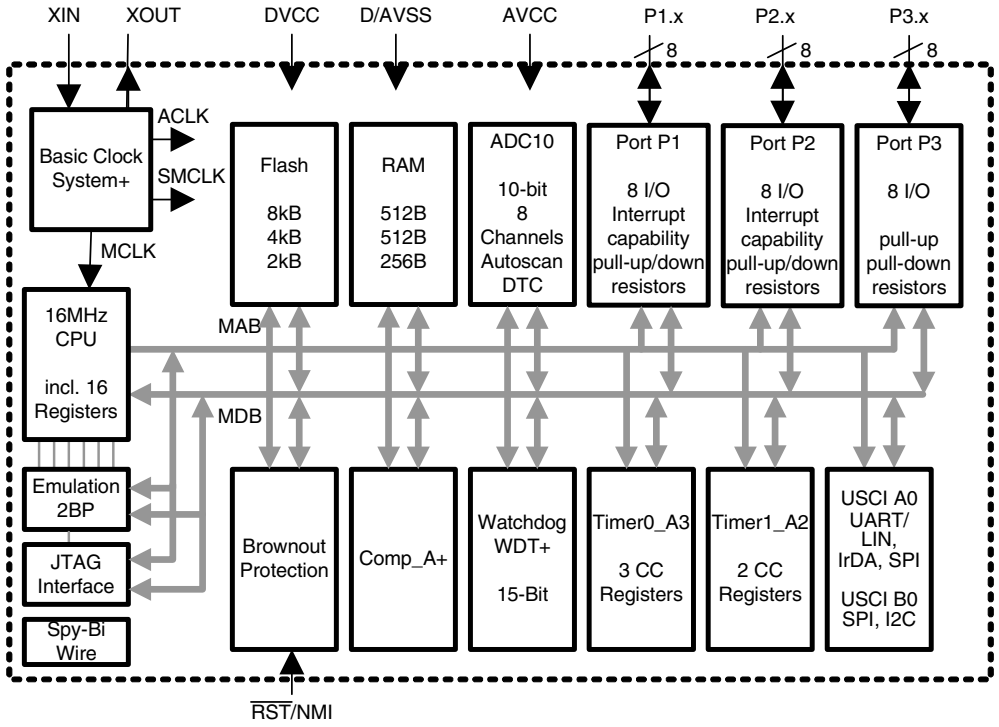
pin designation, PW package



pin designation, RHB package



functional block diagram



Terminal Functions

TERMINAL			I/O	DESCRIPTION
NAME	28-Pin PW	32-Pin RHB		
P1.0/TACLK/ ADC10CLK/CAOUT	21	21	I/O	General-purpose digital I/O pin Timer0_A3, clock signal TACLK input Timer1_A2, clock signal TACLK input ADC10, conversion clock Comparator_A+ output
P1.1/TA0.0/TA1.0	22	22	I/O	General-purpose digital I/O pin Timer0_A3, capture: CCI0A input, compare: Out0 Output Timer1_A2, capture: CCI0A input
P1.2/TA0.1	23	23	I/O	General-purpose digital I/O pin Timer0_A3, capture: CCI1A input, compare: Out1 Output
P1.3/TA0.2	24	24	I/O	General-purpose digital I/O pin Timer0_A3, capture: CCI2A input, compare: Out2 Output
P1.4/SMCLK/TCK	25	25	I/O	General-purpose digital I/O pin SMCLK signal output Test Clock input for device programming and test
P1.5/TA0.0/TMS	26	26	I/O	General-purpose digital I/O pin Timer0_A3, compare: Out0 Output JTAG test mode select, input terminal for device programming and test
P1.6/TA0.1/TDI/TCLK	27	27	I/O	General-purpose digital I/O pin Timer0_A3, compare: Out1 Output JTAG test data input or test clock input in programming an test
P1.7/TA0.2/TDO/TDI	28	28	I/O	General-purpose digital I/O pin Timer0_A3, compare: Out2 Output JTAG test data output terminal or test data input in programming an test
P2.0/ACLK/A0/CA2	8	6	I/O	General-purpose digital I/O pin ACLK signal output ADC10 analog input A0 Comparator_A+ input
P2.1/TAINCLK/ SMCLK/A1/CA3	9	7	I/O	General-purpose digital I/O pin SMCLK signal output Timer0_A3, clock signal TACLK input Timer1_A2, clock signal TACLK input ADC10 analog input A1 Comparator_A+ input
P2.2/TA0.0/A2/CA4/ CAOUT	10	8	I/O	General-purpose digital I/O pin Timer0_A3, capture: CCI0B input, compare: Out0 Output ADC10 analog input A2 Comparator_A+ input Comparator_A+ output
P2.3/TA0.1/A3/ V_{REF-}/Ve_{REF-}/CA0	19	18	I/O	General-purpose digital I/O pin Timer0_A3, compare: Out1 Output ADC10 analog input A3 / negative reference Comparator_A+ input
P2.4/TA0.2/A4/ V_{REF+}/Ve_{REF+}/CA1	20	19	I/O	General-purpose digital I/O pin Timer0_A3, compare: Out2 Output ADC10 analog input A4 / positive reference Comparator_A+ input

Terminal Functions (continued)

TERMINAL			I/O	DESCRIPTION
NAME	28-Pin PW	32-Pin RHB		
XIN/P2.6/CA6	6	3	I/O	Input terminal of crystal oscillator General-purpose digital I/O pin Comparator_A+ input
XOUT/P2.7/CA7	5	2	I/O	Output terminal of crystal oscillator General-purpose digital I/O pin Comparator_A+ input
P3.0/UCB0STE/ UCA0CLK/A5	11	9	I/O	General-purpose digital I/O pin USCI_B0 slave transmit enable/USCI_A0 clock input/output ADC10 analog input A5
P3.1/UCB0SIMO/ UCB0SDA	12	10	I/O	General-purpose digital I/O pin USCI_B0 slave in/master out in SPI mode, SDA I^2C data in I^2C mode
P3.2/UCB0SOMI/ UCB0SCL	13	11	I/O	General-purpose digital I/O pin USCI_B0 slave out/master in in SPI mode, SCL I^2C clock in I^2C mode
P3.3/UCB0CLK/ UCA0STE	14	12	I/O	General-purpose digital I/O USCI_B0 clock input/output, USCI_A0 slave transmit enable
P3.4/UCA0TXD/ UCA0SIMO	15	13	I/O	General-purpose digital I/O pin USCI_A0 transmit data output in UART mode, slave data in/master out in SPI mode
P3.5/UCA0RXD/ UCA0SOMI	16	14	I/O	General-purpose digital I/O pin USCI_A0 receive data input in UART mode, slave data out/master in in SPI mode
P3.6/TA1.0/A6	17	15	I/O	General-purpose digital I/O pin Timer1_A2, capture: CCI0B input, compare: Out0 Output ADC10 analog input A6
P3.7/TA1.1/A7	18	16	I/O	General-purpose digital I/O pin Timer1_A2, capture: CCI1A input, compare: Out1 Output ADC10 analog input A7
$\overline{\text{RST}}$/NMI/SBWTDIO	7	5	I	Reset or nonmaskable interrupt input Spy-Bi-Wire test data input/output during programming and test
TEST/SBWTCK	1	29	I	Selects test mode for JTAG pins on Port1. The device protection fuse is connected to TEST.
P2.5/R_{OSC}/CA5	3	32	I/O	General-purpose digital I/O pin Input for external resistor defining the DCO nominal frequency Comparator_A+ input
DV_{CC}	2	30		Digital supply voltage
DV_{SS}	4	1		Digital supply voltage
NC	NA	4, 17, 20, 31		Not connected internally. Connection to V_{SS} is recommended.
QFN Pad	NA	NA	NA	QFN package pad (RHB package only). Connection to DV_{SS} is recommended.

short-form description

CPU

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

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

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

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

instruction set

The instruction set consists of 51 instructions with three formats and seven address modes. Each instruction can operate on word and byte data. Table 1 shows examples of the three types of instruction formats; the address modes are listed in Table 2.

Table 1. Instruction Word Formats

Dual operands, source-destination	e.g., ADD R4,R5	R4 + R5 ---> R5
Single operands, destination only	e.g., CALL R8	PC -->(TOS), R8--> PC
Relative jump, un/conditional	e.g., JNE	Jump-on-equal bit = 0

Table 2. Address Mode Descriptions

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

NOTE: S = source D = destination

operating modes

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

The following six operating modes can be configured by software:

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

interrupt vector addresses

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

INTERRUPT SOURCE	INTERRUPT FLAG	SYSTEM INTERRUPT	WORD ADDRESS	PRIORITY
Power-up External reset Watchdog Flash key violation PC out of range (see Note 1)	PORIFG RSTIFG WDTIFG KEYV (see Note 2)	Reset	0xFFFE	31, highest
NMI Oscillator fault Flash memory access violation	NMIIFG OFIFG ACCVIFG (see Notes 2 and 6)	(Non)maskable (Non)maskable (Non)maskable	0xFFFC	30
Timer1_A2	TA1CCR0 CCIFG (see Note 3)	Maskable	0xFFFA	29
Timer1_A2	TA1CCR1 CCIFG, TA1CTL TAIFG (see Notes 2 and 3)	Maskable	0xFFF8	28
Comparator_A+	CAIFG	Maskable	0xFFF6	27
Watchdog timer	WDTIFG	Maskable	0xFFF4	26
Timer0_A3	TA0CCR0 CCIFG (see Note 3)	Maskable	0xFFF2	25
Timer0_A3	TA0CCR1 CCIFG, TA0CCR2 CCIFG, TA0CTL TAIFG (see Notes 2 and 3)	Maskable	0xFFF0	24
USCI_A0/USCI_B0 receive USCI_B0 I2C status	UCA0RXIFG, UCB0RXIFG (see Note 2 and 4)	Maskable	0xFFEE	23
USCI_A0/USCI_B0 transmit USCI_B0 I2C receive/transmit	UCA0TXIFG, UCB0TXIFG (see Note 2 and 5)	Maskable	0xFFEC	22
ADC10	ADC10IFG (see Note 3)	Maskable	0xFFEA	21
			0xFFE8	20
I/O port P2 (eight flags)	P2IFG.0 to P2IFG.7 (see Notes 2 and 3)	Maskable	0xFFE6	19
I/O port P1 (eight flags)	P1IFG.0 to P1IFG.7 (see Notes 2 and 3)	Maskable	0xFFE4	18
			0xFFE2	17
			0xFFE0	16
(See Note 7)			0xFFDE	15
(See Note 8)			0xFFDC to 0xFFC0	14 to 0, lowest

NOTES:
1. A reset is executed if the CPU tries to fetch instructions from within the module register memory address range (0x0000 to 0x01FF).
2. Multiple source flags.
3. Interrupt flags are located in the module.
4. In SPI mode: UCB0RXIFG. In I2C mode: UCALIFG, UCNACKIFG, ICSTTIFG, UCSTPIFG.
5. In UART/SPI mode: UCB0TXIFG. In I2C mode: UCB0RXIFG, UCB0TXIFG.
6. (Non)maskable: the individual interrupt-enable bit can disable an interrupt event, but the general interrupt enable cannot.
7. This location is used as bootstrap loader security key (BSLSKEY).
   A 0xAA55 at this location disables the BSL completely.
   A zero (0h) disables the erasure of the flash if an invalid password is supplied.
8. The interrupt vectors at addresses 0xFFDC to 0xFFC0 are not used in this device and can be used for regular program code if necessary.

special function registers

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

interrupt enable 1 and 2

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

WDTIE Watchdog timer interrupt enable. Inactive if watchdog mode is selected. Active if watchdog timer is configured in interval timer mode.

OFIE Oscillator fault enable

NMIIE (Non)maskable interrupt enable

ACCVIE Flash access violation interrupt enable

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

UCA0RXIE USCI_A0 receive interrupt enable

UCA0TXIE USCI_A0 transmit interrupt enable

UCB0RXIE USCI_B0 receive interrupt enable

UCB0TXIE USCI_B0 transmit interrupt enable

interrupt flag register 1 and 2

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

WDTIFG Set on watchdog timer overflow or security key violation.
Reset on V_{CC} power-up or a reset condition at $\overline{RST}$/NMI pin in reset mode.

OFIFG Flag set on oscillator fault

RSTIFG External reset interrupt flag. Set on a reset condition at $\overline{RST}$/NMI pin in reset mode. Reset on V_{CC} power up

PORIFG Power-on interrupt flag. Set on V_{CC} power-up.

NMIIFG Set via $\overline{RST}$/NMI pin

Address	7	6	5	4	3	2	1	0
03h					UCB0TX IFG	UCB0RX IFG	UCA0TX IFG	UCA0RX IFG
					rw-1	rw-0	rw-1	rw-0

UCA0RXIFG USCI_A0 receive interrupt flag

UCA0TXIFG USCI_A0 transmit interrupt flag

UCB0RXIFG USCI_B0 receive interrupt flag

UCB0TXIFG USCI_B0 transmit interrupt flag

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

memory organization

		MSP430F2112	MSP430F2122	MSP430F2132
Memory Main: interrupt vector Main: code memory	Size Flash Flash	2 KB 0xFFFF to 0xFFC0 0xFFFF to 0xF800	4 KB 0xFFFF to 0xFFC0 0xFFFF to 0xF000	8 KB 0xFFFF to 0xFFC0 0xFFFF to 0xE000
Information memory	Size Flash	256 Byte 0x10FFh to 0x1000	256 Byte 0x10FFh to 0x1000	256 Byte 0x10FFh to 0x1000
Boot memory	Size ROM	1 KB 0x0FFF to 0x0C00	1 KB 0x0FFF to 0x0C00	1 KB 0x0FFF to 0x0C00
RAM	Size	256 B 0x02FF to 0x0200	512 Byte 0x03FF to 0x0200	512 Byte 0x03FF to 0x0200
Peripherals	16-bit 8-bit 8-bit SFR	0x01FF to 0x0100 0x00FF to 0x0010 0x000F to 0x0000	0x01FF to 0x0100 0x00FF to 0x0010 0x000F to 0x0000	0x01FF to 0x0100 0x00FF to 0x0010 0x000F to 0x0000

bootstrap loader (BSL)

The MSP430 BSL enables users to program the flash memory or RAM using a UART serial interface. Access to the MSP430 memory via the BSL is protected by user-defined password. For complete description of the features of the BSL and its implementation, see the application report *Features of the MSP430 Bootstrap Loader*, literature number SLAA089.

BSL FUNCTION	28-PIN PW PACKAGE PINS	32-PIN RHB PACKAGE PINS
Data transmit	22 – P1.1	22 – P1.1
Data receive	10 – P2.2	8 – P2.2

flash memory

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

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

peripherals

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

oscillator and system clock

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

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

The DCO settings to calibrate the DCO output frequency are stored in the information memory segment A.

calibration data stored in information memory segment A

Calibration data is stored for both the DCO and for ADC10 organized in a tag-length-value structure.

TAGS USED BY THE ADC CALIBRATION TAGS			
NAME	ADDRESS	VALUE	DESCRIPTION
TAG_DCO_30	0x10F6	0x01	DCO frequency calibration at V_{CC} = 3 V and T_A = 30°C at calibration
TAG_ADC10_1	0x10DA	0x10	ADC10_1 calibration tag
TAG_EMPTY	-	0xFE	Identifier for empty memory areas

LABELS USED BY THE ADC CALIBRATION TAGS			
LABEL	CONDITION AT CALIBRATION / DESCRIPTION	SIZE	ADDRESS OFFSET
CAL_ADC_25T85	INCHx = 0x1010, REF2_5 = 1, T_A = 85°C	word	0x000E
CAL_ADC_25T30	INCHx = 0x1010, REF2_5 = 1, T_A = 30°C	word	0x000C
CAL_ADC_25VREF_FACTOR	REF2_5 = 1, T_A = 30°C, I_{VREF+} = 1 mA	word	0x000A
CAL_ADC_15T85	INCHx = 0x1010, REF2_5 = 0, T_A = 85°C	word	0x0008
CAL_ADC_15T30	INCHx = 0x1010, REF2_5 = 0, T_A = 30°C	word	0x0006
CAL_ADC_15VREF_FACTOR	REF2_5 = 0, T_A = 30°C, I_{VREF+} = 0.5 mA	word	0x0004
CAL_ADC_OFFSET	External V_{REF} = 1.5 V, $f_{ADC10CLK}$ = 5 MHz	word	0x0002
CAL_ADC_GAIN_FACTOR	External V_{REF} = 1.5 V, $f_{ADC10CLK}$ = 5 MHz	word	0x0000
CAL_BC1_1MHz	-	byte	0x0007
CAL_DCO_1MHz	-	byte	0x0006
CAL_BC1_8MHz	-	byte	0x0005
CAL_DCO_8MHz	-	byte	0x0004
CAL_BC1_12MHz	-	byte	0x0003
CAL_DCO_12MHz	-	byte	0x0002
CAL_BC1_16MHz	-	byte	0x0001
CAL_DCO_16MHz	-	byte	0x0000

brownout

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

digital I/O

There are three 8-bit I/O ports implemented—ports P1 through P3:

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

The MSP430F21x2 devices provides up to 24 total port I/O pins available externally. See the device pinout for more information.

watchdog timer + (WDT+)

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

ADC10

The ADC10 module supports fast, 10-bit analog-to-digital conversions. The module implements a 10-bit SAR core, sample select control, reference generator, and data transfer controller (DTC), for automatic conversion result handling, allowing ADC samples to be converted and stored without any CPU intervention.

Comparator_A+

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

Timer0_A3

Timer0_A3 is a 16-bit timer/counter with three capture/compare registers. Timer0_A3 can support multiple capture/compares, PWM outputs, and interval timing. Timer0_A3 also has extensive interrupt capabilities. Interrupts may be generated from the counter on overflow conditions and from each of the capture/compare registers.

TIMER0_A3 SIGNAL CONNECTIONS

INPUT PIN NUMBER		DEVICE INPUT SIGNAL	MODULE INPUT NAME	MODULE BLOCK	MODULE OUTPUT SIGNAL	OUTPUT PIN NUMBER	
28-PIN PW	32-PIN RHB					28-PIN PW	32-PIN RHB
21 – P1.0	21 – P1.0	TACLK	TACLK	Timer	NA		
		ACLK	ACLK				
		SMCLK	SMCLK				
9 – P2.1	7 – P2.1	TAINCLK	INCLK				
22 – P1.1	22 – P1.1	TA0	CCI0A	CCR0	TA0	22 – P1.1	22 – P1.1
10 – P2.2	8 – P2.2	TA0	CCI0B			26 – P1.5	26 – P1.5
		DV_{SS}	GND			10 – P2.2	8 – P2.2
		DV_{CC}	V_{CC}			ADC10 (internal)	ADC10 (internal)
23 – P1.2	23 – P1.2	TA1	CCI1A	CCR1	TA1	23 – P1.2	23 – P1.2
		CAOUT (internal)	CCI1B			27 – P1.6	27 – P1.6
		DV_{SS}	GND			19 - P2.3	18 – P2.3
		DV_{CC}	V_{CC}			ADC10 (internal)	ADC10 (internal)
24 – P1.3	24 – P1.3	TA2	CCI2A	CCR2	TA2	24 – P1.3	24 – P1.3
		ACLK (internal)	CCI2B			28 – P1.7	28 – P1.7
		DV_{SS}	GND			20 - P2.4	19 – P2.4
		DV_{CC}	V_{CC}			ADC10 (internal)	ADC10 (internal)

Timer1_A2

Timer1_A2 is a 16-bit timer/counter with two capture/compare registers. Timer1_A2 can support multiple capture/compares, PWM outputs, and interval timing. Timer1_A2 also has extensive interrupt capabilities. Interrupts may be generated from the counter on overflow conditions and from each of the capture/compare registers.

TIMER1_A2 SIGNAL CONNECTIONS							
INPUT PIN NUMBER		DEVICE INPUT SIGNAL	MODULE INPUT NAME	MODULE BLOCK	MODULE OUTPUT SIGNAL	OUTPUT PIN NUMBER	
28-PIN PW	32-PIN RHB					28-PIN PW	32-PIN RHB
21 – P1.0	21 – P1.0	TACLK	TACLK	Timer	NA		
		ACLK	ACLK				
		SMCLK	SMCLK				
9 – P2.1	7 – P2.1	TAINCLK	INCLK				
22 – P1.1	22 – P1.1	TA0	CCI0A	CCR0	TA0	17 – P3.6	15 – P3.6
17 – P3.6	15 – P3.6	TA0	CCI0B				
		DV_{SS}	GND				
		DV_{CC}	V_{CC}				
18 – P3.7	16 – P3.7	TA1	CCI1A	CCR1	TA1	18 – P3.7	16 – P3.7
		CAOUT (internal)	CCI1B				
		DV_{SS}	GND				
		DV_{CC}	V_{CC}				

universal serial communications interface (USCI)

The USCI module is used for serial data communication. The USCI module supports synchronous communication protocols such as SPI (3 or 4 pin) and I2C, and asynchronous communication protocols such as UART, enhanced UART with automatic baudrate detection (LIN), and IrDA. Not all packages support the USCI functionality.

USCI_A0 provides support for SPI (3 or 4 pin), UART, enhanced UART, and IrDA.

USCI_B0 provides support for SPI (3 or 4 pin) and I2C.

peripheral file map

PERIPHERALS WITH WORD ACCESS			
ADC10	ADC data transfer start address	ADC10SA	0x01BC
	ADC memory	ADC10MEM	0x01B4
	ADC control register 1	ADC10CTL1	0x01B2
	ADC control register 0	ADC10CTL0	0x01B0
	ADC analog enable 0	ADC10AE0	0x004A
	ADC analog enable 1	ADC10AE1	0x004B
	ADC data transfer control register 1	ADC10DTC1	0x0049
	ADC data transfer control register 0	ADC10DTC0	0x0048
Timer0_A3	Capture/compare register	TA0CCR2	0x0176
	Capture/compare register	TA0CCR1	0x0174
	Capture/compare register	TA0CCR0	0x0172
	Timer0_A3 register	TA0R	0x0170
	Capture/compare control	TA0CCTL2	0x0166
	Capture/compare control	TA0CCTL1	0x0164
	Capture/compare control	TA0CCTL0	0x0162
	Timer0_A3 control	TA0CTL	0x0160
	Timer0_A3 interrupt vector	TA0IV	0x012E
Timer1_A2	Capture/compare register	TA1CCR1	0x0194
	Capture/compare register	TA1CCR0	0x0192
	Timer1_A2 register	TA1R	0x0190
	Capture/compare control	TA1CCTL1	0x0184
	Capture/compare control	TA1CCTL0	0x0182
	Timer1_A2 control	TA1CTL	0x0180
	Timer1_A2 interrupt vector	TA1IV	0x011E
Flash Memory	Flash control 3	FCTL3	0x012C
	Flash control 2	FCTL2	0x012A
	Flash control 1	FCTL1	0x0128
Watchdog Timer+	Watchdog/timer control	WDTCTL	0x0120
PERIPHERALS WITH BYTE ACCESS			
USCI_B0	USCI_B0 transmit buffer	UCB0TXBUF	0x06F
	USCI_B0 receive buffer	UCB0RXBUF	0x06E
	USCI_B0 status	UCB0STAT	0x06D
	USCI B0 I2C Interrupt enable	UCB0CIE	0x06C
	USCI_B0 bit rate control 1	UCB0BR1	0x06B
	USCI_B0 bit rate control 0	UCB0BR0	0x06A
	USCI_B0 control 1	UCB0CTL1	0x069
	USCI_B0 control 0	UCB0CTL0	0x068
	USCI_B0 I2C slave address	UCB0SA	0x011A
	USCI_B0 I2C own address	UCB0OA	0x0118
USCI_A0 (28-pin and 32-pin version only)	USCI_A0 transmit buffer	UCA0TXBUF	0x0067
	USCI_A0 receive buffer	UCA0RXBUF	0x0066
	USCI_A0 status	UCA0STAT	0x0065
	USCI_A0 modulation control	UCA0MCTL	0x0064
	USCI_A0 baud rate control 1	UCA0BR1	0x0063
	USCI_A0 baud rate control 0	UCA0BR0	0x0062
	USCI_A0 control 1	UCA0CTL1	0x0061
	USCI_A0 control 0	UCA0CTL0	0x0060
	USCI_A0 IrDA receive control	UCA0IRRCTL	0x005F
	USCI_A0 IrDA transmit control	UCA0IRTCTL	0x005E
	USCI_A0 auto baud rate control	UCA0ABCTL	0x005D
Comparator_A+	Comparator_A port disable	CAPD	0x005B
	Comparator_A control2	CACTL2	0x005A
	Comparator_A control1	CACTL1	0x0059

PERIPHERALS WITH BYTE ACCESS (continued)			
Basic Clock System+	Basic clock system control 3	BCSCTL3	0x0053
	Basic clock system control 2	BCSCTL2	0x0058
	Basic clock system control 1	BCSCTL1	0x0057
	DCO clock frequency control	DCOCTL	0x0056
Port P3	Port P3 resistor enable	P3REN	0x0010
	Port P3 selection	P3SEL	0x001B
	Port P3 direction	P3DIR	0x001A
	Port P3 output	P3OUT	0x0019
	Port P3 input	P3IN	0x0018
Port P2	Port P2 selection 2	P2SEL2	0x0042
	Port P2 resistor enable	P2REN	0x002F
	Port P2 selection	P2SEL	0x002E
	Port P2 interrupt enable	P2IE	0x002D
	Port P2 interrupt edge select	P2IES	0x002C
	Port P2 interrupt flag	P2IFG	0x002B
	Port P2 direction	P2DIR	0x002A
	Port P2 output	P2OUT	0x0029
	Port P2 input	P2IN	0x0028
Port P1	Port P1 selection 2 register	P1SEL2	0x0041
	Port P1 resistor enable	P1REN	0x0027
	Port P1 selection	P1SEL	0x0026
	Port P1 interrupt enable	P1IE	0x0025
	Port P1 interrupt edge select	P1IES	0x0024
	Port P1 interrupt flag	P1IFG	0x0023
	Port P1 direction	P1DIR	0x0022
	Port P1 output	P1OUT	0x0021
	Port P1 input	P1IN	0x0020
Special Function	SFR interrupt flag 2	IFG2	0x0003
	SFR interrupt flag 1	IFG1	0x0002
	SFR interrupt enable 2	IE2	0x0001
	SFR interrupt enable 1	IE1	0x0000

absolute maximum ratings (see Note 1)

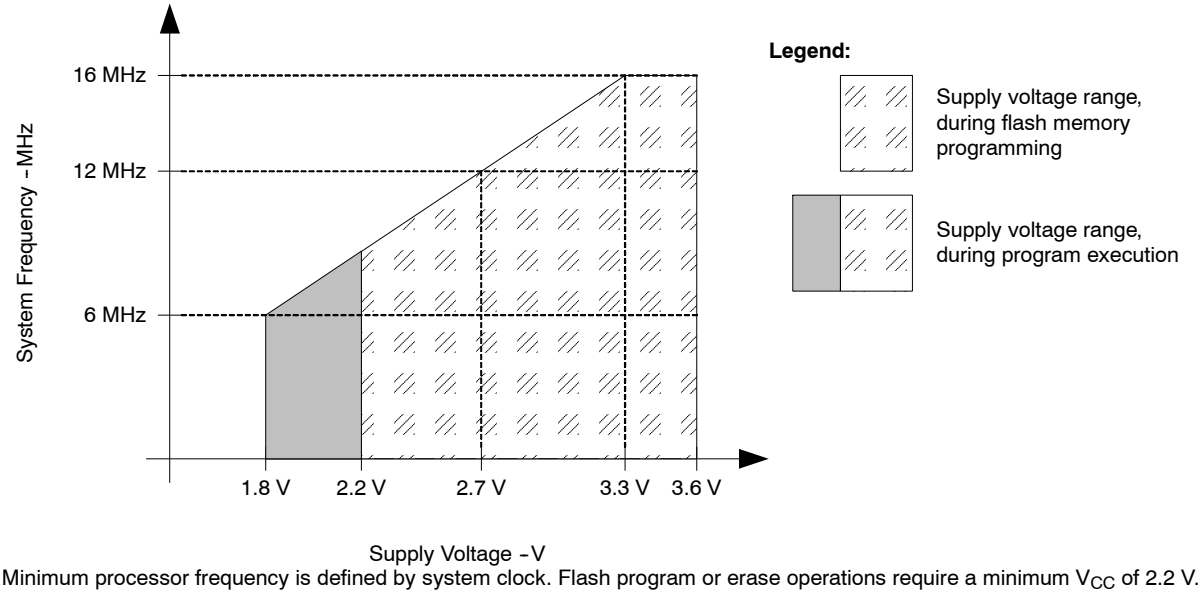
Voltage applied at V_{CC} to V_{SS} . . . . . –0.3 V to + 4.1 V
Voltage applied to any pin (see Note 2) . . . . . –0.3 V to V_{CC}+0.3 V
Diode current at any device terminal . . . . . ±2 mA
Storage temperature (unprogrammed device, see Note 3) . . . . . –55°C to 150°C
Storage temperature (programmed device, see Note 3) . . . . . –40°C to 105°C

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

recommended operating conditions

PARAMETER		MIN	NOM	MAX	UNITS
Supply voltage during program execution, V_{CC}	$AV_{CC} = DV_{CC} = V_{CC}$ (see Note 1)	1.8		3.6	V
Supply voltage during flash memory programming, V_{CC}	$AV_{CC} = DV_{CC} = V_{CC}$ (see Note 1)	2.2		3.6	V
Supply voltage, V_{SS}	$AV_{SS} = DV_{SS} = V_{SS}$	0.0		0.0	V
Operating free-air temperature range, T_A	I version	–40		85	°C
	T version	–40		105	
Processor frequency $f_{SYSYTEM}$ (Maximum MCLK frequency) (see Notes 1, 2 and Figure 1)	V_{CC} = 1.8 V, Duty cycle = 50% ±10%	dc		6	MHz
	V_{CC} = 2.7 V, Duty cycle = 50% ±10%	dc		12	
	$V_{CC} \geq$ 3.3 V, Duty cycle = 50% ±10%	dc		16	

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



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

Figure 1. Operating Area

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

active mode supply current (into V_{CC}) excluding external current (see Notes 1 and 2)

PARAMETER		TEST CONDITIONS	T_A	V_{CC}	MIN	TYP	MAX	UNIT
$I_{AM, 1MHz}$	Active mode (AM) current (1MHz)	$f_{DCO} = f_{MCLK} = f_{SMCLK} = 1MHz$, $f_{ACLK} = 32,768Hz$, Program executes from flash, BCSCTL1 = CALBC1_1MHZ, DCOCTL = CALDCO_1MHZ, CPUOFF = 0, SCG0 = 0, SCG1 = 0, OSCOFF = 0		2.2 V		200	250	µA
				3 V		300	350	
$I_{AM, 1MHz}$	Active mode (AM) current (1MHz)	$f_{DCO} = f_{MCLK} = f_{SMCLK} = 1MHz$, $f_{ACLK} = 32,768Hz$, Program executes in RAM, BCSCTL1 = CALBC1_1MHZ, DCOCTL = CALDCO_1MHZ, CPUOFF = 0, SCG0 = 0, SCG1 = 0, OSCOFF = 0		2.2 V		160		µA
				3 V		260		
$I_{AM, 4kHz}$	Active mode (AM) current (4kHz)	$f_{MCLK} = f_{SMCLK} =$ $f_{ACLK} = 32,768Hz/8 = 4,096Hz$, $f_{DCO} = 0Hz$, Program executes in flash, SELMx = 11, SELS = 1, DIVMx = DIVSx = DIVAx = 11, CPUOFF = 0, SCG0 = 1, SCG1 = 0, OSCOFF = 0	–40°C to 85°C	2.2 V		2	5	µA
			105°C				6	
			–40°C to 85°C	3 V		3	7	
			105°C				9	
$I_{AM,100kHz}$	Active mode (AM) current (100kHz)	$f_{MCLK} = f_{SMCLK} = f_{DCO(0, 0)} \approx 100kHz$, $f_{ACLK} = 0Hz$, Program executes in flash, RSELx = 0, DCOx = 0, CPUOFF = 0, SCG0 = 0, SCG1 = 0, OSCOFF = 1	–40°C to 85°C	2.2 V		60	85	µA
			105°C				90	
			–40°C to 85°C	3 V		72	95	
			105°C				100	

NOTES: 1. All inputs are tied to 0 V or V_{CC}. Outputs do not source or sink any current.
2. The currents are characterized with a Micro Crystal CC4V-T1A SMD crystal with a load capacitance of 9 pF. The internal and external load capacitance is chosen to closely match the required 9 pF.

typical characteristics – active mode supply current (into DV_{CC} + AV_{CC})

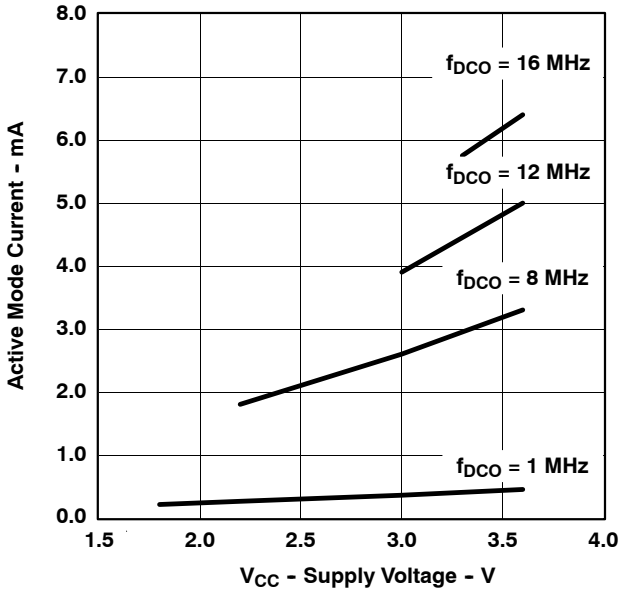


Figure 2. Active Mode Current vs V_{CC}, T_A = 25°C

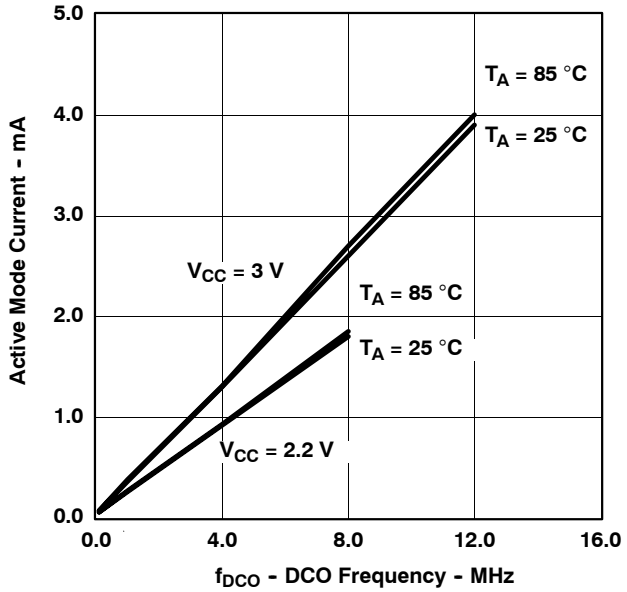


Figure 3. Active Mode Current vs DCO Frequency

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

low-power mode supply currents (into V_{CC}) excluding external current (see Notes 1 and 2)

PARAMETER		TEST CONDITIONS	T_A	V_{CC}	MIN	TYP	MAX	UNIT
$I_{LPM0, 1MHz}$	Low-power mode 0 (LPM0) current, see Note 3	f_{MCLK} = 0 MHz, $f_{SMCLK} = f_{DCO}$ = 1 MHz, f_{ACLK} = 32,768 Hz, BCSCTL1 = CALBC1_1MHZ, DCOCTL = CALDCO_1MHZ, CPUOFF = 1, SCG0 = 0, SCG1 = 0, OSCOFF = 0	-40°C to 85°C	2.2 V		32	45	µA
			105°C				49	
			-40°C to 85°C	3 V		55	70	
			105°C				74	
$I_{LPM0, 100kHz}$	Low-power mode 0 (LPM0) current, see Note 3	f_{MCLK} = 0 MHz, $f_{SMCLK} = f_{DCO(0, 0)} \approx$ 100 kHz, f_{ACLK} = 0Hz, RSELx = 0, DCOx = 0, CPUOFF = 1, SCG0 = 0, SCG1 = 0, OSCOFF = 1	-40°C to 85°C	2.2 V		20	27	µA
			105°C				31	
			-40°C to 85°C	3 V		31	42	
			105°C				46	
I_{LPM2}	Low-power mode 2 (LPM2) current, see Note 4	$f_{MCLK} = f_{SMCLK}$ = 0 MHz, f_{DCO} = 1 MHz, f_{ACLK} = 32,768 Hz, BCSCTL1 = CALBC1_1MHZ, DCOCTL = CALDCO_1MHZ, CPUOFF = 1, SCG0 = 0, SCG1 = 1, OSCOFF = 0	-40°C to 85°C	2.2 V		13	16	µA
			105°C				20	
			-40°C to 85°C	3 V		20	25	
			105°C				31	
$I_{LPM3,LFXT1}$	Low-power mode 3 (LPM3) current, see Note 4	$f_{DCO} = f_{MCLK} = f_{SMCLK}$ = 0 MHz, f_{ACLK} = 32,768 Hz, CPUOFF = 1, SCG0 = 1, SCG1 = 1, OSCOFF = 0	-40°C to 85°C	2.2 V		0.7	1.2	µA
			85°C			1.6	2.3	
			105°C			3	6	
			-40°C to 85°C	3 V		0.9	1.2	
			85°C			1.6	2.8	
			105°C			3	7	
$I_{LPM3,VLO}$	Low-power mode 3 current, (LPM3) see Note 4	$f_{DCO} = f_{MCLK} = f_{SMCLK}$ = 0 MHz, f_{ACLK} from internal LF oscillator (VLO), CPUOFF = 1, SCG0 = 1, SCG1 = 1, OSCOFF = 0	-40°C	2.2 V		0.25	0.7	µA
			25°C			0.3	0.7	
			85°C			1.2	1.9	
			105°C			2	5	
			-40°C to 85°C	3 V		0.7	0.8	
			85°C			1.4	2.1	
			105°C			2.5	6	
I_{LPM4}	Low-power mode 4 (LPM4) current, see Note 5	$f_{DCO} = f_{MCLK} = f_{SMCLK}$ = 0 MHz, f_{ACLK} = 0 Hz, CPUOFF = 1, SCG0 = 1, SCG1 = 1, OSCOFF = 1	-40°C	2.2 V/ 3 V		0.1	0.5	µA
			25°C			0.1	0.5	
			85°C			0.8	1.5	
			105°C			2	4	

NOTES: 1. All inputs are tied to 0 V or V_{CC}. Outputs do not source or sink any current.
2. The currents are characterized with a Micro Crystal CC4V-T1A SMD crystal with a load capacitance of 9 pF. The internal and external load capacitance is chosen to closely match the required 9 pF.
3. Current for brownout and WDT clocked by SMCLK included.
4. Current for brownout and WDT clocked by ACLK included.
5. Current for brownout included.

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

typical characteristics – LPM4 current

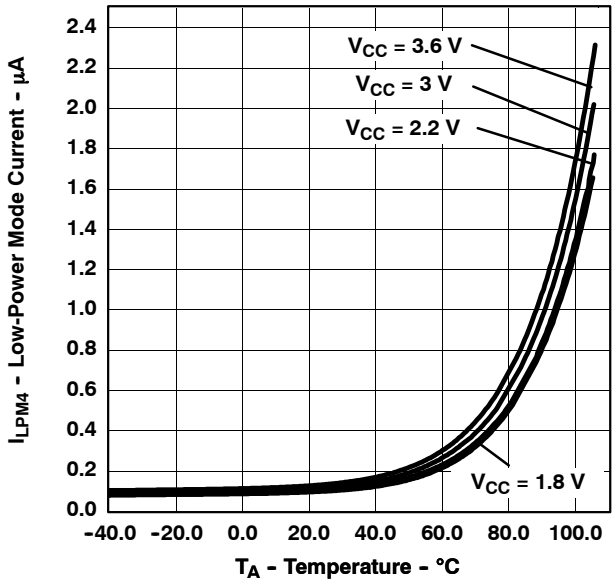


Figure 4. I_{LPM4} – LPM4 Current vs Temperature

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

Schmitt-trigger inputs – Ports P1, P2, P3, JTAG, $\overline{\text{RST}}$/NMI, and XIN (see Note 1)

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
V_{IT+}	Positive-going input threshold voltage			0.45		0.75	V_{CC}
			2.2 V	1.00		1.65	V
			3 V	1.35		2.25	
V_{IT-}	Negative-going input threshold voltage			0.25		0.55	V_{CC}
			2.2 V	0.55		1.20	V
			3 V	0.75		1.65	
V_{hys}	Input voltage hysteresis (V_{IT+} – V_{IT-})		2.2 V	0.2		1.0	V
			3 V	0.3		1.0	
R_{Pull}	Pullup/pulldown resistor	For pullup: $V_{IN} = V_{SS}$; For pulldown: $V_{IN} = V_{CC}$		20	35	50	kΩ
C_I	Input capacitance	$V_{IN} = V_{SS}$ or V_{CC}			5		pF

NOTE 1: XIN only in bypass mode

inputs – Ports P1, P2

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
$t_{(int)}$	External interrupt timing	Port P1, P2: P1.x to P2.x, External trigger pulse width to set interrupt flag (see Note 2)	2.2 V/3 V	20			ns

NOTE 2: An external signal sets the interrupt flag every time the minimum interrupt pulse width $t_{(int)}$ is met. It may be set with trigger signals shorter than $t_{(int)}$.

leakage current – Ports P1, P2 and P3

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
$I_{lkg(Px.x)}$	High-impedance leakage current	See Notes 1 and 2	2.2 V/3 V			±50	nA

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

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

outputs – Ports P1, P2 and P3

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

NOTES: 1. The maximum total current, I_{OHmax} and I_{OLmax}, for all outputs combined, should not exceed ±12 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 ±48 mA to hold the maximum voltage drop specified.

output frequency – Ports P1, P2 and P3

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
$f_{Px.y}$	Port output frequency (with load)	P1.4/SMCLK, C_L = 20 pF, R_L = 1 kΩ (see Note 1 and 2)	2.2 V			7.5	MHz
			3 V			12	MHz
f_{Port_CLK}	Clock output frequency	P2.0/ACLK, P1.4/SMCLK, C_L = 20 pF (see Note 2)	2.2 V			7.5	MHz
			3 V			16	MHz

NOTES: 1. A resistive divider with 2 × 0.5 kΩ between V_{CC} and V_{SS} is used as load. The output is connected to the center tap of the divider.
2. The output voltage reaches at least 10% and 90% V_{CC} at the specified toggle frequency.

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

typical characteristics – outputs

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

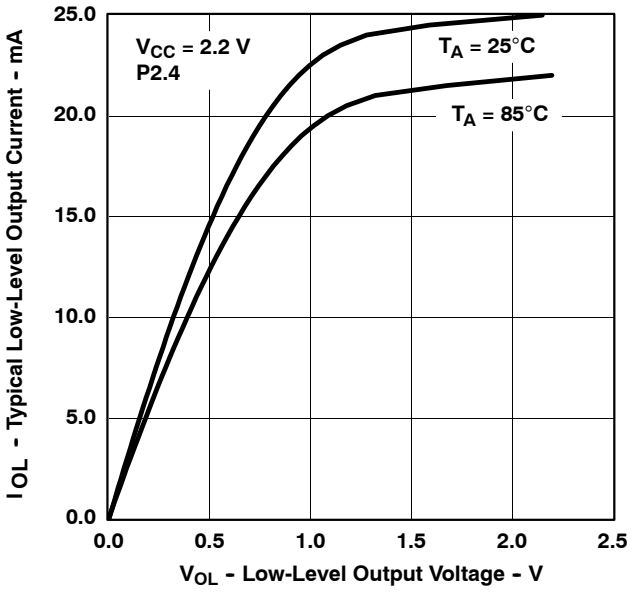


Figure 5

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

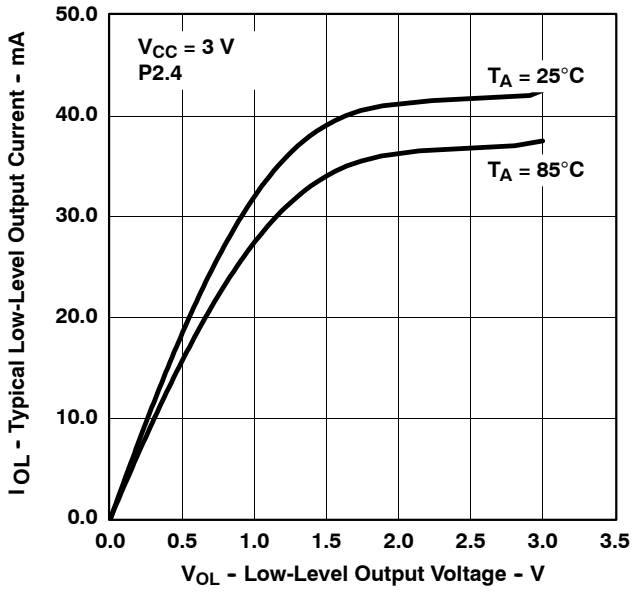


Figure 6

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

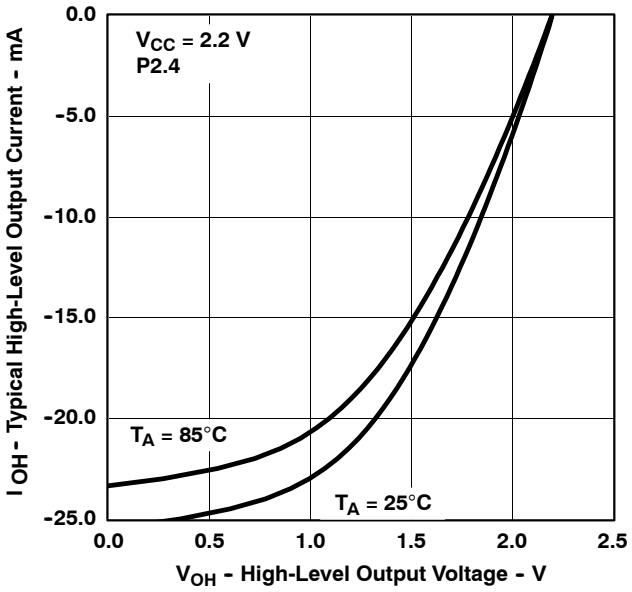


Figure 7

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

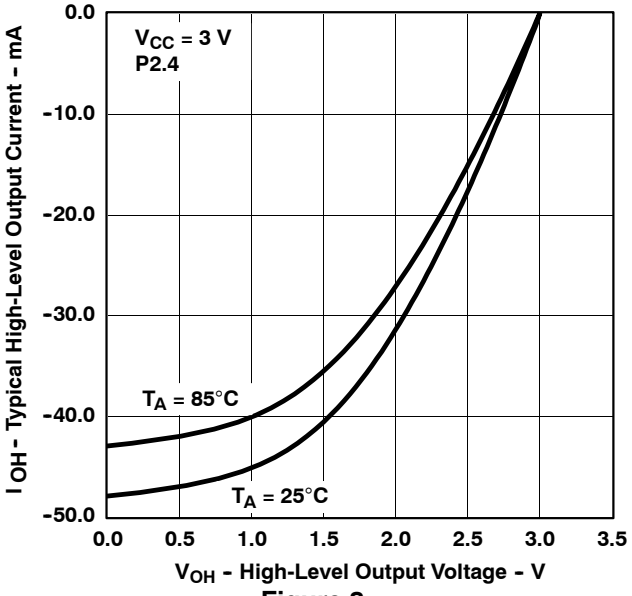


Figure 8

NOTE: One output loaded at a time.

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

POR/brownout reset (BOR) (see Notes 1 and 2)

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
$V_{CC(start)}$	See Figure 9	$dV_{CC}/dt \le 3$ V/s		$0.7 \times V_{(B\_IT-)}$			V
$V_{(B\_IT-)}$	See Figure 9 through Figure 11	$dV_{CC}/dt \le 3$ V/s				1.71	V
$V_{hys(B\_IT-)}$	See Figure 9	$dV_{CC}/dt \le 3$ V/s		70	130	210	mV
$t_{d(BOR)}$	See Figure 9					2000	μs
$t_{(reset)}$	Pulse length needed at $\overline{RST}$/NMI pin to accepted reset internally		2.2 V/3 V	2			μs

NOTES: 1. The current consumption of the brownout module is already included in the I_{CC} current consumption data. The voltage level $V_{(B\_IT-)} + V_{hys(B\_IT-)}$ is ≤ 1.8V.

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

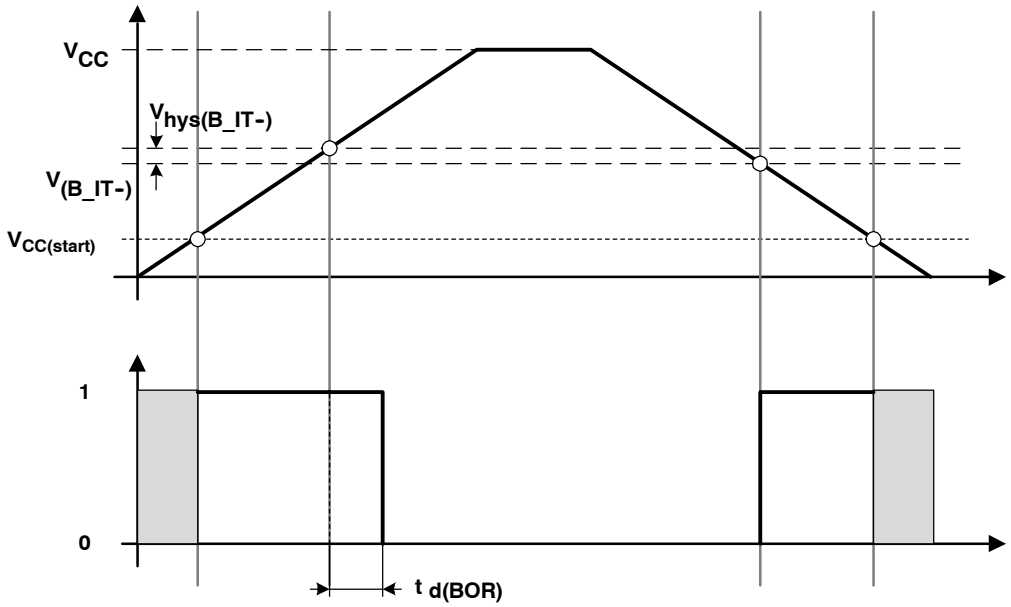


Figure 9. POR/Brownout Reset (BOR) vs Supply Voltage

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

typical characteristics – POR/brownout reset (BOR)

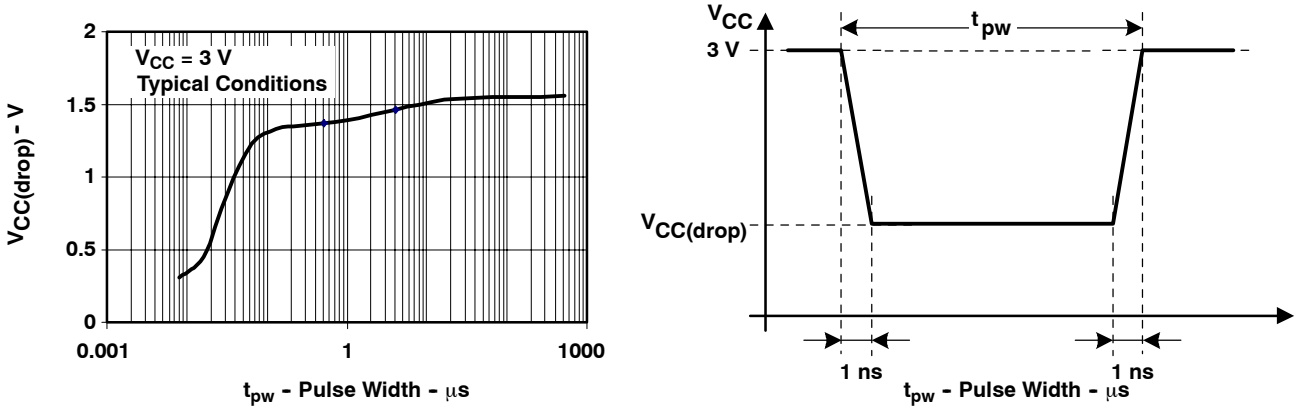


Figure 10. $V_{CC(drop)}$ Level With a Square Voltage Drop to Generate a POR/Brownout Signal

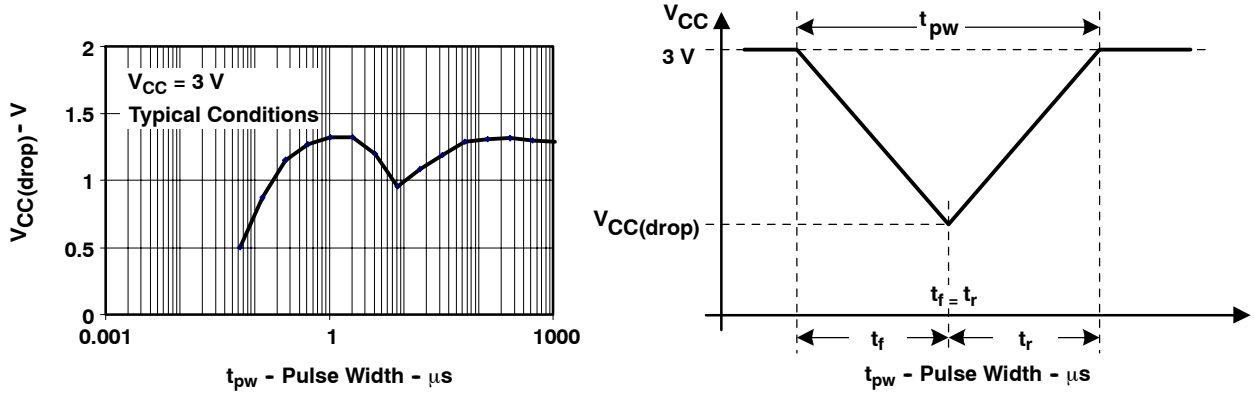


Figure 11. $V_{CC(drop)}$ Level With a Triangle Voltage Drop to Generate a POR/Brownout Signal

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

main DCO characteristics

- All ranges selected by RSELx overlap with RSELx + 1; e.g., RSELx = 0 overlaps RSELx = 1, and RSELx = 14 overlaps RSELx = 15.
- DCO control bits DCOx have a step size as defined by parameter S_{DCO}.
- Modulation control bits MODx select how often $f_{DCO(RSEL,DCO+1)}$ is used within the period of 32 DCOCLK cycles. The frequency $f_{DCO(RSEL,DCO)}$ is used for the remaining cycles. The frequency is an average equal to:

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

DCO frequency

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

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

calibrated DCO frequencies – tolerance at calibration

PARAMETER		TEST CONDITIONS	T_A	V_{CC}	MIN	TYP	MAX	UNIT
Frequency tolerance at calibration			25°C	3 V	–1	±0.2	+1	%
$f_{CAL(1MHz)}$	1-MHz calibration value	BCSCTL1 = CALBC1_1MHZ, DCOCTL = CALDCO_1MHZ, Gating time = 5 ms	25°C	3 V	0.990	1	1.010	MHz
$f_{CAL(8MHz)}$	8-MHz calibration value	BCSCTL1 = CALBC1_8MHZ, DCOCTL = CALDCO_8MHZ, Gating time = 5 ms	25°C	3 V	7.920	8	8.080	MHz
$f_{CAL(12MHz)}$	12-MHz calibration value	BCSCTL1 = CALBC1_12MHZ, DCOCTL = CALDCO_12MHZ, Gating time = 5 ms	25°C	3 V	11.88	12	12.12	MHz
$f_{CAL(16MHz)}$	16-MHz calibration value	BCSCTL1 = CALBC1_16MHZ, DCOCTL = CALDCO_16MHZ, Gating time = 2 ms	25°C	3 V	15.84	16	16.16	MHz

calibrated DCO frequencies – tolerance over temperature 0°C – +85°C

PARAMETER		TEST CONDITIONS	T_A	V_{CC}	MIN	TYP	MAX	UNIT
1-MHz tolerance over temperature			0°C to 85°C	3 V	–2.5	±0.5	+2.5	%
8-MHz tolerance over temperature			0°C to 85°C	3 V	–2.5	±1	+2.5	%
12-MHz tolerance over temperature			0°C to 85°C	3 V	–2.5	±1	+2.5	%
16-MHz tolerance over temperature			0°C to 85°C	3 V	–3	±2	+3	%
$f_{CAL(1MHz)}$	1-MHz calibration value	BCSCTL1 = CALBC1_1MHZ, DCOCTL = CALDCO_1MHZ, Gating time: 5ms	0°C to 85°C	2.2 V	0.970	1	1.030	MHz
				3 V	0.975	1	1.025	MHz
				3.6 V	0.970	1	1.030	MHz
$f_{CAL(8MHz)}$	8-MHz calibration value	BCSCTL1 = CALBC1_8MHZ, DCOCTL = CALDCO_8MHZ, Gating time = 5 ms	0°C to 85°C	2.2 V	7.760	8	8.400	MHz
				3 V	7.800	8	8.200	MHz
				3.6 V	7.600	8	8.240	MHz
$f_{CAL(12MHz)}$	12-MHz calibration value	BCSCTL1 = CALBC1_12MHZ, DCOCTL = CALDCO_12MHZ, Gating time = 5 ms	0°C to 85°C	2.2 V	11.64	12	12.36	MHz
				3 V	11.64	12	12.36	MHz
				3.6 V	11.64	12	12.36	MHz
$f_{CAL(16MHz)}$	16-MHz calibration value	BCSCTL1 = CALBC1_16MHZ, DCOCTL = CALDCO_16MHZ, Gating time = 2 ms	0°C to 85°C	3 V	15.52	16	16.48	MHz
				3.6 V	15.00	16	16.48	MHz

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

calibrated DCO frequencies – tolerance over supply voltage V_{CC}

PARAMETER		TEST CONDITIONS	T_A	V_{CC}	MIN	TYP	MAX	UNIT
1-MHz tolerance over V_{CC}			25°C	1.8 V to 3.6 V	-3	±2	+3	%
8-MHz tolerance over V_{CC}			25°C	1.8 V to 3.6 V	-3	±2	+3	%
12-MHz tolerance over V_{CC}			25°C	2.2 V to 3.6 V	-3	±2	+3	%
16-MHz tolerance over V_{CC}			25°C	3 V to 3.6 V	-6	±2	+3	%
$f_{CAL(1MHz)}$	1-MHz calibration value	BCSCTL1 = CALBC1_1MHZ, DCOCTL = CALDCO_1MHZ, Gating time = 5 ms	25°C	1.8 V to 3.6 V	0.970	1	1.030	MHz
$f_{CAL(8MHz)}$	8-MHz calibration value	BCSCTL1 = CALBC1_8MHZ, DCOCTL = CALDCO_8MHZ, Gating time = 5 ms	25°C	1.8 V to 3.6 V	7.760	8	8.240	MHz
$f_{CAL(12MHz)}$	12-MHz calibration value	BCSCTL1 = CALBC1_12MHZ, DCOCTL = CALDCO_12MHZ, Gating time = 5 ms	25°C	2.2 V to 3.6 V	11.64	12	12.36	MHz
$f_{CAL(16MHz)}$	16-MHz calibration value	BCSCTL1 = CALBC1_16MHZ, DCOCTL = CALDCO_16MHZ, Gating time = 2 ms	25°C	3 V to 3.6 V	15.00	16	16.48	MHz

calibrated DCO frequencies – overall tolerance

PARAMETER		TEST CONDITIONS	T_A	V_{CC}	MIN	TYP	MAX	UNIT
1-MHz tolerance overall			-40°C to 105°C	1.8 V to 3.6 V	-5	±2	+5	%
8-MHz tolerance overall			-40°C to 105°C	1.8 V to 3.6 V	-5	±2	+5	%
12-MHz tolerance overall			-40°C to 105°C	2.2 V to 3.6 V	-5	±2	+5	%
16-MHz tolerance overall			-40°C to 105°C	3 V to 3.6 V	-6	±3	+6	%
$f_{CAL(1MHz)}$	1-MHz calibration value	BCSCTL1 = CALBC1_1MHZ, DCOCTL = CALDCO_1MHZ, Gating time = 5 ms	-40°C to 105°C	1.8 V to 3.6 V	0.950	1	1.050	MHz
$f_{CAL(8MHz)}$	8-MHz calibration value	BCSCTL1 = CALBC1_8MHZ, DCOCTL = CALDCO_8MHZ, Gating time = 5 ms	-40°C to 105°C	1.8 V to 3.6 V	7.600	8	8.400	MHz
$f_{CAL(12MHz)}$	12-MHz calibration value	BCSCTL1 = CALBC1_12MHZ, DCOCTL = CALDCO_12MHZ, Gating time = 5 ms	-40°C to 105°C	2.2 V to 3.6 V	11.40	12	12.60	MHz
$f_{CAL(16MHz)}$	16-MHz calibration value	BCSCTL1 = CALBC1_16MHZ, DCOCTL = CALDCO_16MHZ, Gating time = 2 ms	-40°C to 105°C	3 V to 3.6 V	15.00	16	17.00	MHz

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

typical characteristics – calibrated DCO frequency

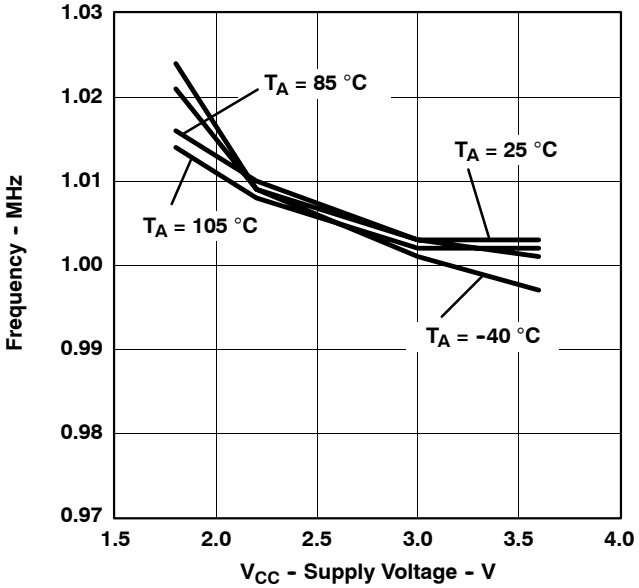


Figure 12. Calibrated 1 MHz Frequency vs V_{CC}

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

wake-up from lower power modes (LPM3/4)

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

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

typical characteristics – DCO clock wake-up time from LPM3/4

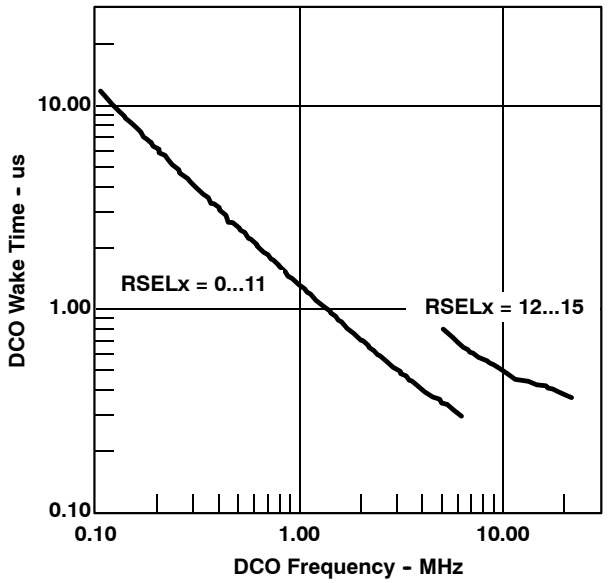


Figure 13. Clock Wake-Up Time From LPM3 vs DCO Frequency

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

DCO with external resistor R_{OSC} (see Note)

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

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

typical characteristics – DCO with external resistor R_{OSC}

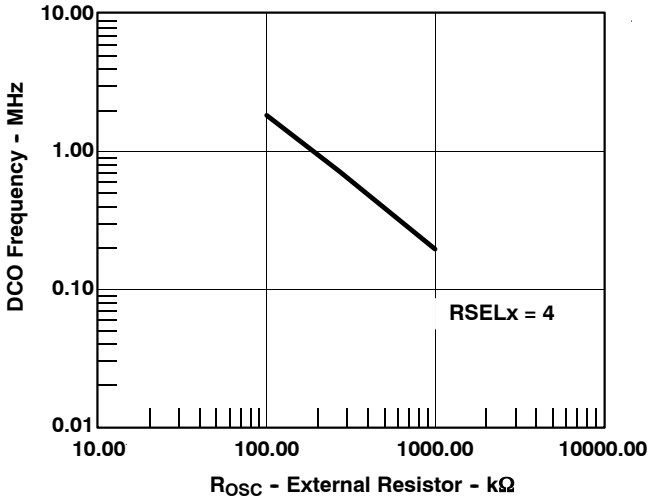


Figure 14. DCO Frequency vs R_{OSC}, V_{CC} = 2.2 V, T_A = 25°C

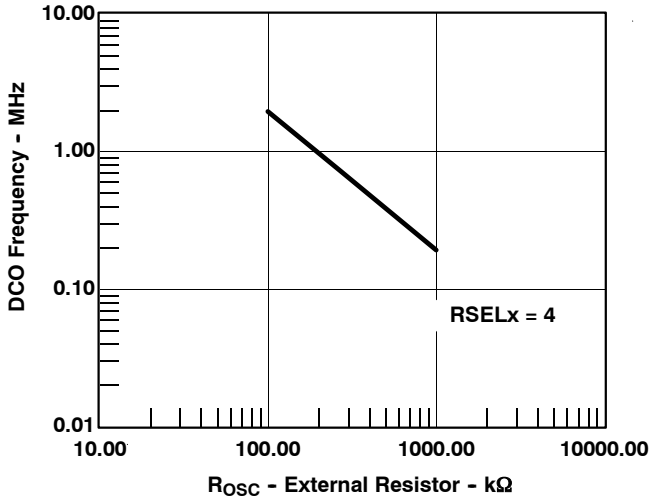


Figure 15. DCO Frequency vs R_{OSC}, V_{CC} = 3 V, T_A = 25°C

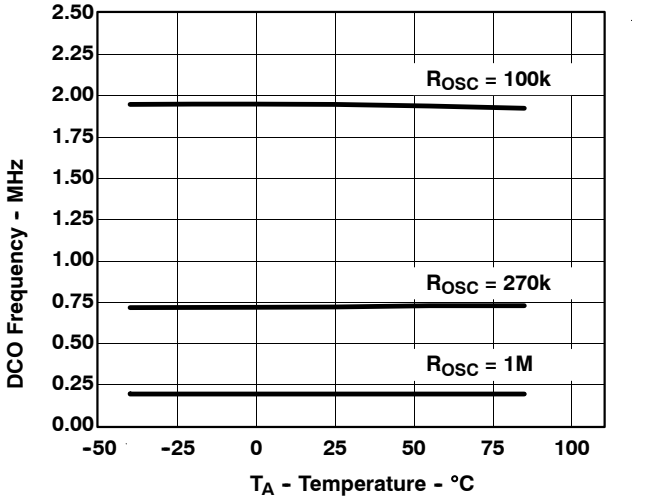


Figure 16. DCO Frequency vs Temperature, V_{CC} = 3 V

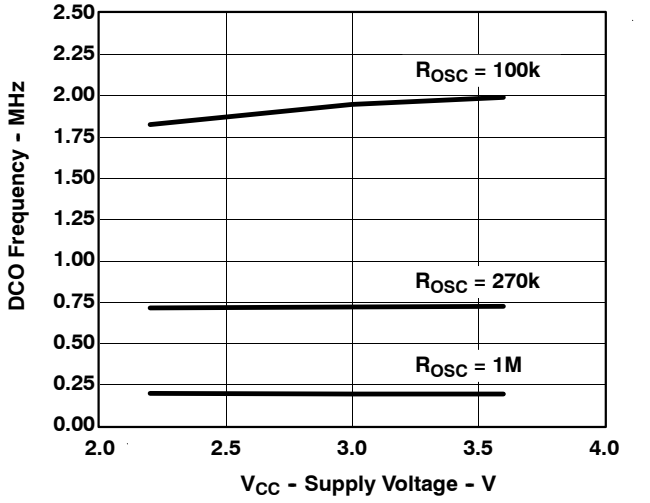


Figure 17. DCO Frequency vs V_{CC}, T_A = 25°C

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

crystal oscillator, LFXT1, low frequency modes (see Note 4)

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
$f_{LFXT1,LF}$	LFXT1 oscillator crystal frequency, LF mode 0, 1	XTS = 0, LFXT1Sx = 0 or 1	1.8 V to 3.6 V		32,768		Hz
$f_{LFXT1,LF,logic}$	LFXT1 oscillator logic level square wave input frequency, LF mode	XTS = 0, XCAPx = 0, LFXT1Sx = 3	1.8 V to 3.6 V	10,000	32,768	50,000	Hz
OA_{LF}	Oscillation allowance for LF crystals	XTS = 0, LFXT1Sx = 0, $f_{LFXT1,LF}$ = 32,768 kHz, $C_{L,eff}$ = 6 pF			500		kΩ
		XTS = 0, LFXT1Sx = 0, $f_{LFXT1,LF}$ = 32,768 kHz, $C_{L,eff}$ = 12 pF			200		
$C_{L,eff}$	Integrated effective load capacitance, LF mode (see Note 1)	XTS = 0, XCAPx = 0			1		pF
		XTS = 0, XCAPx = 1			5.5		
		XTS = 0, XCAPx = 2			8.5		
		XTS = 0, XCAPx = 3			11		
Duty cycle	LF mode	XTS = 0, Measured at P2.0/ACLK, $f_{LFXT1,LF}$ = 32,768Hz	2.2 V/3 V	30	50	70	%
$f_{Fault,LF}$	Oscillator fault frequency, LF mode (see Note 3)	XTS = 0, XCAPx = 0. LFXT1Sx = 3 (see Note 2)	2.2 V/3 V	10		10,000	Hz

NOTES: 1. Includes parasitic bond and package capacitance (approximately 2 pF per pin).
Since the PCB adds additional capacitance it is recommended to verify the correct load by measuring the ACLK frequency. For a correct setup the effective load capacitance should always match the specification of the used crystal.
2. Measured with logic level input frequency but also applies to operation with crystals.
3. Frequencies below the MIN specification set the fault flag, frequencies above the MAX specification do not set the fault flag, and frequencies in between might set the flag.
4. To improve EMI on the LFXT1 oscillator the following guidelines should be observed.
   - Keep the trace between the device and the crystal as short as possible.
   - Design a good ground plane around the oscillator pins.
   - Prevent crosstalk from other clock or data lines into oscillator pins XIN and XOUT.
   - Avoid running PCB traces underneath or adjacent to the XIN and XOUT pins.
   - Use assembly materials and praxis to avoid any parasitic load on the oscillator XIN and XOUT pins.
   - If conformal coating is used, ensure that it does not induce capacitive/resistive leakage between the oscillator pins.
   - Do not route the XOUT line to the JTAG header to support the serial programming adapter as shown in other documentation. This signal is no longer required for the serial programming adapter.

internal very low power, low frequency oscillator (VLO)

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
f_{VLO}	VLO frequency	T_A = –40°C to 85°C	2.2 V/3 V	4	12	20	kHz
		T_A = 105°C	2.2 V/3 V			22	kHz
df_{VLO}/dT	VLO frequency temperature drift	See Note 1	2.2 V/3 V		0.5		%/°C
df_{VLO}/dV_{CC}	VLO frequency supply voltage drift	See Note 2	1.8V to 3.6V		4		%/V

NOTES: 1. Calculated using the box method:
I Version: (MAX(–40°C to 85°C) – MIN(–40°C to 85°C))/MIN(–40°C to 85°C)/(85°C – (–40°C))
T Version: (MAX(–40°C to 105_C) – MIN(–40°C to 105_C))/MIN(–40°C to 105_C)/(105_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)

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

crystal oscillator, LFXT1, high frequency modes (see Note 5)

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
$f_{LFXT1,HF0}$	LFXT1 oscillator crystal frequency, HF mode 0	XTS = 1, XCAPx = 0, LFXT1Sx = 0	1.8 V to 3.6 V	0.4		1	MHz
$f_{LFXT1,HF1}$	LFXT1 oscillator crystal frequency, HF mode 1	XTS = 1, XCAPx = 0, LFXT1Sx = 1	1.8 V to 3.6 V	1		4	MHz
$f_{LFXT1,HF2}$	LFXT1 oscillator crystal frequency, HF mode 2	XTS = 1, XCAPx = 0, LFXT1Sx = 2	1.8 V to 3.6 V	2		10	MHz
			2.2 V to 3.6 V	2		12	MHz
			3 V to 3.6 V	2		16	MHz
$f_{LFXT1,HF,logic}$	LFXT1 oscillator logic level square wave input frequency, HF mode	XTS = 1, XCAPx = 0, LFXT1Sx = 3	1.8 V to 3.6 V	0.4		10	MHz
			2.2 V to 3.6 V	0.4		12	MHz
			3 V to 3.6 V	0.4		16	MHz
OA_{HF}	Oscillation allowance for HF crystals (see Figure 18 and Figure 19)	XTS = 1, XCAPx = 0, LFXT1Sx = 0, $f_{LFXT1,HF}$ = 1 MHz, $C_{L,eff}$ = 15 pF			2700		Ω
		XTS = 1, XCAPx = 0, LFXT1Sx = 1, $f_{LFXT1,HF}$ = 4 MHz, $C_{L,eff}$ = 15 pF			800		Ω
		XTS = 1, XCAPx = 0, LFXT1Sx = 2, $f_{LFXT1,HF}$ = 16 MHz, $C_{L,eff}$ = 15 pF			300		Ω
$C_{L,eff}$	Integrated effective load capacitance, HF mode (see Note 1)	XTS = 1, XCAPx = 0 (see Note 2)			1		pF
Duty cycle	HF mode	XTS = 1, XCAPx = 0, Measured at P2.0/ACLK, $f_{LFXT1,HF}$ = 10 MHz	2.2 V/3 V	40	50	60	%
		XTS = 1, XCAPx = 0, Measured at P2.0/ACLK, $f_{LFXT1,HF}$ = 16 MHz	2.2 V/3 V	40	50	60	%
$f_{Fault,HF}$	Oscillator fault frequency, HF mode (see Note 4)	XTS = 1, XCAPx = 0, LFXT1Sx = 3 (see Notes 3)	2.2 V/3 V	30		300	kHz

NOTES:
1. Includes parasitic bond and package capacitance (approximately 2 pF per pin).
   Since the PCB adds additional capacitance it is recommended to verify the correct load by measuring the ACLK frequency. For a correct setup the effective load capacitance should always match the specification of the used crystal.
2. Requires external capacitors at both terminals. Values are specified by crystal manufacturers.
3. Measured with logic level input frequency but also applies to operation with crystals.
4. Frequencies below the MIN specification set the fault flag, frequencies above the MAX specification do not set the fault flag, and frequencies in between might set the flag.
5. To improve EMI on the LFXT1 oscillator the following guidelines should be observed.
   - Keep the trace between the device and the crystal as short as possible.
   - Design a good ground plane around the oscillator pins.
   - Prevent crosstalk from other clock or data lines into oscillator pins XIN and XOUT.
   - Avoid running PCB traces underneath or adjacent to the XIN and XOUT pins.
   - Use assembly materials and praxis to avoid any parasitic load on the oscillator XIN and XOUT pins.
   - If conformal coating is used, ensure that it does not induce capacitive/resistive leakage between the oscillator pins.
   - Do not route the XOUT line to the JTAG header to support the serial programming adapter as shown in other documentation. This signal is no longer required for the serial programming adapter.

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

typical characteristics – LFXT1 oscillator in HF mode (XTS = 1)

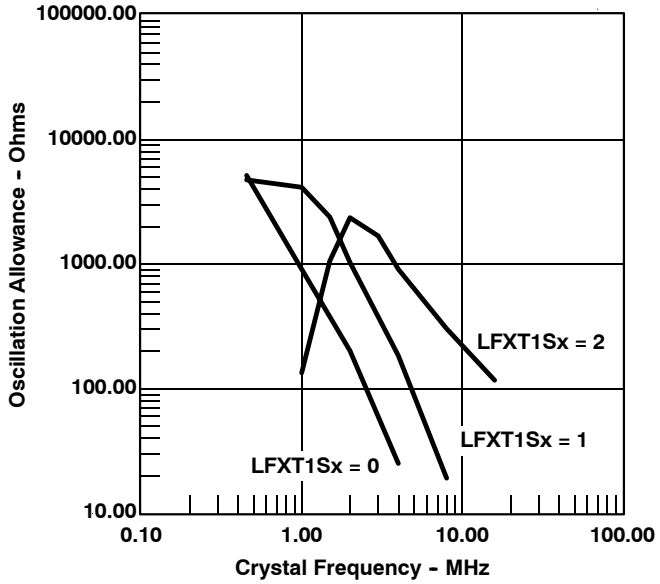


Figure 18. Oscillation Allowance vs Crystal Frequency, $C_{L,eff}$ = 15 pF, T_A = 25°C

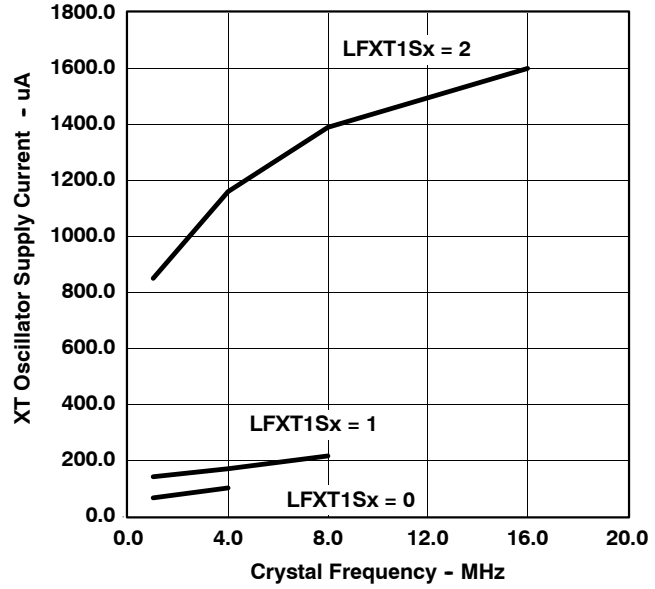


Figure 19. XT Oscillator Supply Current vs Crystal Frequency, $C_{L,eff}$ = 15 pF, T_A = 25°C

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

Timer0_A3

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
f_{TA}	Timer0_A3 clock frequency	Internal: SMCLK, ACLK, External: TACLK, INCLK, Duty cycle = 50% ± 10%	2.2 V			10	MHz
			3 V			16	
$t_{TA,cap}$	Timer0_A3, capture timing	TA0.0, TA0.1, TA0.2	2.2 V/3 V	20			ns

Timer1_A2

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
f_{TB}	Timer1_A2 clock frequency	Internal: SMCLK, ACLK, External: TACLK, INCLK, Duty cycle = 50% ± 10%	2.2 V			10	MHz
			3 V			16	
$t_{TB,cap}$	Timer1_A2, capture timing	TA1.0, TA1.1	2.2 V/3 V	20			ns

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

USCI (UART mode)

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
f_{USCI}	USCI input clock frequency	Internal: SMCLK, ACLK, External: UCLK, Duty cycle = 50% ± 10%				f_{SYSTEM}	MHz
$f_{max,BITCLK}$	Maximum BITCLK clock frequency (equals baudrate in MBaud) (see Note 1)		2.2V /3 V	2			MHz
t_τ	UART receive deglitch time (see Note 2)		2.2 V	50	150		ns
			3 V	50	100		ns

NOTES: 1. The DCO wake-up time must be considered in LPM3/4 for baudrates above 1 MHz.
2. Pulses on the UART receive input (UCxRX) shorter than the UART receive deglitch time are suppressed. To ensure that pulses are correctly recognized their width should exceed the maximum specification of the deglitch time.

USCI (SPI master mode) (see Figure 20 and Figure 21)

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

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

USCI (SPI slave mode) (see Figure 22 and Figure 23)

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

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

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

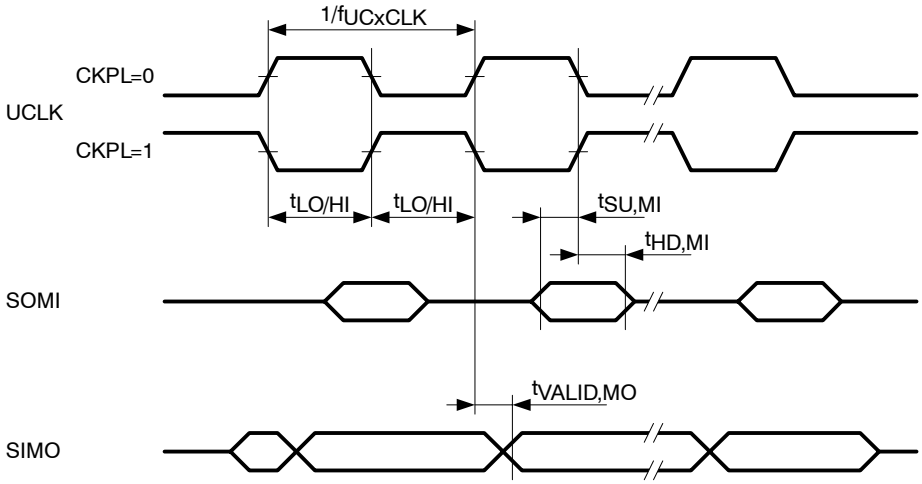


Figure 20. SPI Master Mode, CKPH = 0

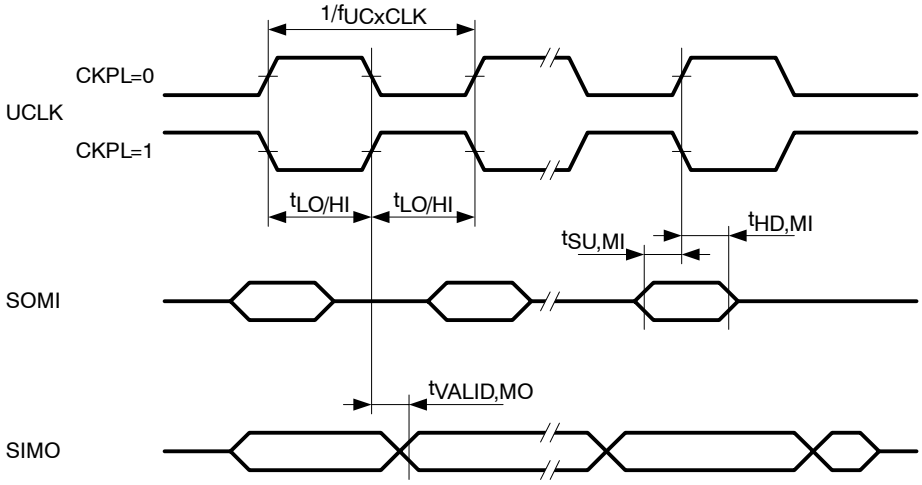


Figure 21. SPI Master Mode, CKPH = 1

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

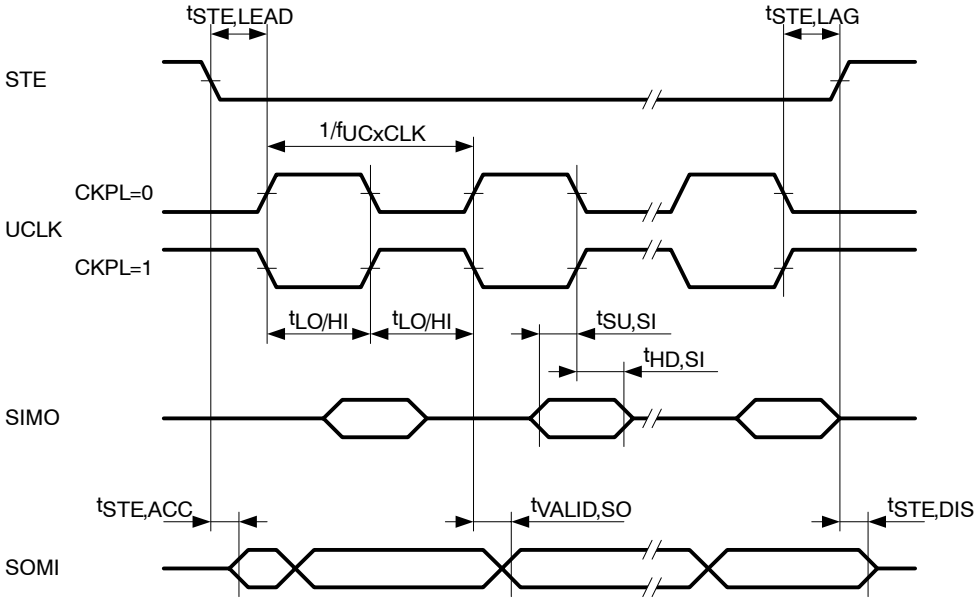


Figure 22. SPI Slave Mode, CKPH = 0

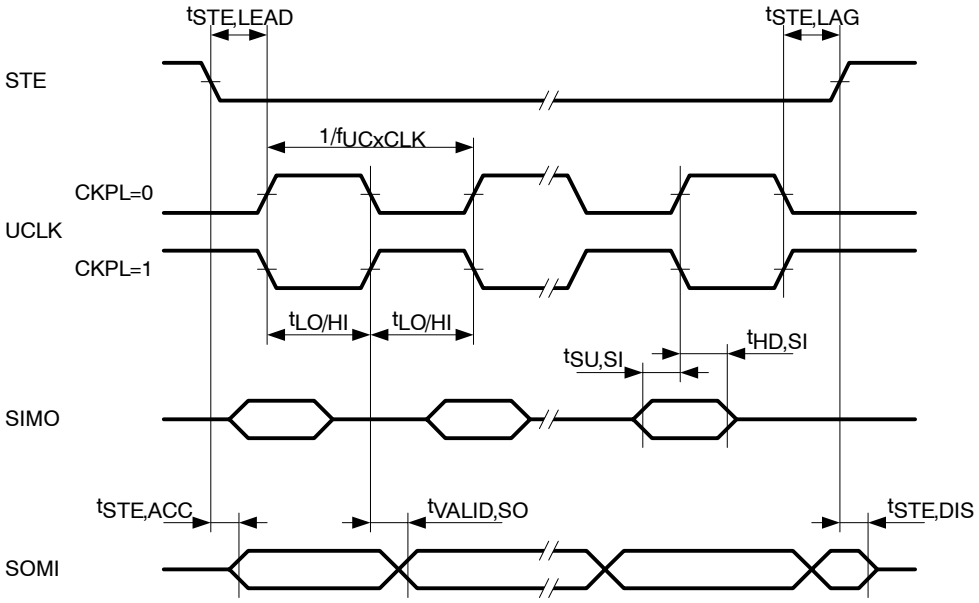


Figure 23. SPI Slave Mode, CKPH = 1

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

USCI (I2C mode) (see Figure 24)

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
f_{USCI}	USCI input clock frequency	Internal: SMCLK, ACLK, External: UCLK, Duty Cycle = 50% ± 10%				f_{SYSTEM}	MHz
f_{SCL}	SCL clock frequency		2.2 V/3 V	0		400	kHz
$t_{HD,STA}$	Hold time (repeated) start	$f_{SCL} \le 100kHz$	2.2 V/3 V	4.0			us
		$f_{SCL} > 100kHz$	2.2 V/3 V	0.6			us
$t_{SU,STA}$	Setup time for a repeated start	$f_{SCL} \le 100kHz$	2.2 V/3 V	4.7			us
		$f_{SCL} > 100kHz$	2.2 V/3 V	0.6			us
$t_{HD,DAT}$	Data hold time		2.2 V/3 V	0			ns
$t_{SU,DAT}$	Data setup time		2.2 V/3 V	250			ns
$t_{SU,STO}$	Setup time for stop		2.2 V/3 V	4.0			us
t_{SP}	Pulse width of spikes suppressed by input filter		2.2 V	50	150	600	ns
			3 V	50	100	600	ns

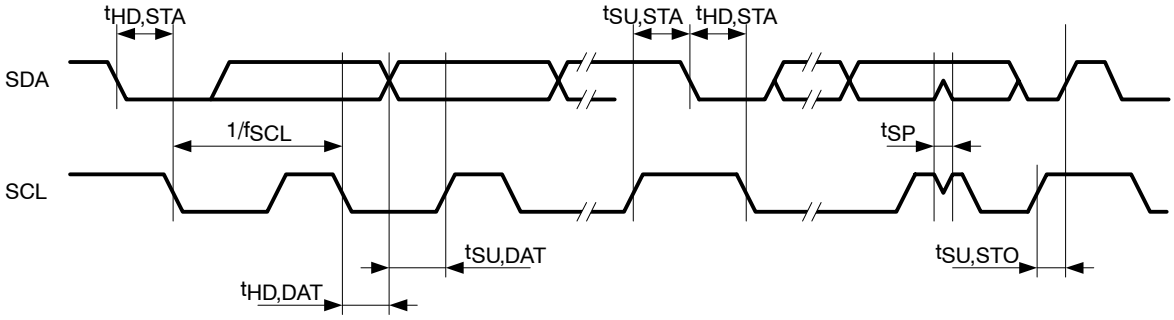


Figure 24. I2C Mode Timing

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

Comparator_A+ (see Note 1)

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
$I_{(DD)}$		CAON = 1, CARSEL = 0, CAREF = 0	2.2 V		25	40	μA
			3 V		45	60	
$I_{(Refladder/RefDiode)}$		CAON = 1, CARSEL = 0, CAREF = 1/2/3, No load at P1.0/CA0 and P1.1/CA1	2.2 V		30	50	μA
			3 V		45	71	
$V_{(IC)}$	Common-mode input voltage	CAON = 1	2.2 V/3 V	0		V_{CC}–1	V
$V_{(Ref025)}$	$\frac{\text{Voltage @ 0.25 } V_{CC}\text{ node}}{V_{CC}}$	PCA0 = 1, CARSEL = 1, CAREF = 1, No load at P1.0/CA0 and P1.1/CA1	2.2 V/3 V	0.23	0.24	0.25	
$V_{(Ref050)}$	$\frac{\text{Voltage @ 0.5}V_{CC}\text{ node}}{V_{CC}}$	PCA0 = 1, CARSEL = 1, CAREF = 2, No load at P1.0/CA0 and P1.1/CA1	2.2 V/3 V	0.47	0.48	0.5	
$V_{(RefVT)}$	See Figure 28 and Figure 29	PCA0 = 1, CARSEL = 1, CAREF = 3, No load at P1.0/CA0 and P1.1/CA1, T_A = 85°C	2.2 V	390	480	540	mV
			3 V	400	490	550	
$V_{(offset)}$	Offset voltage	See Note 2	2.2 V/3 V	–30		30	mV
V_{hys}	Input hysteresis	CAON = 1	2.2 V/3 V	0	0.7	1.4	mV
$t_{(response)}$	Response time (low to high and high to low) (see Note 3)	T_A = 25°C, Overdrive 10 mV, Without filter: CAF = 0 (see Note 3, Figure 25 and Figure 26)	2.2 V	80	165	300	ns
			3 V	70	120	240	
		T_A = 25°C, Overdrive 10 mV, With filter: CAF = 1 (see Note 3, Figure 25 and Figure 26)	2.2 V	1.4	1.9	2.8	μs
			3 V	0.9	1.5	2.2	

NOTES: 1. The leakage current for the Comparator_A+ terminals is identical to $I_{lkg(Px.x)}$ specification.
2. The input offset voltage can be cancelled by using the CAEX bit to invert the Comparator_A+ inputs on successive measurements. The two successive measurements are then summed together.
3. Response time measured at P2.2/TA0.0/A2/CA4/CAOUT. If the Comparator_A+ is enabled a settling time of 60 ns (typical) is added to the response time.

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

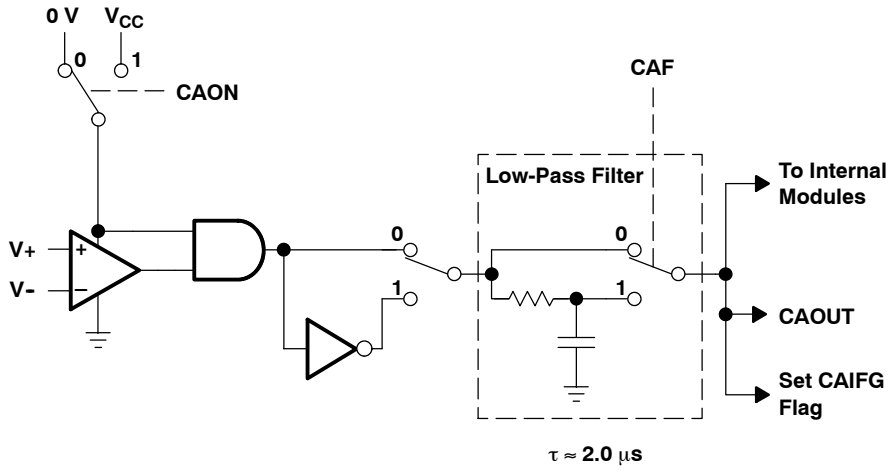


Figure 25. Block Diagram of Comparator_A+ Module

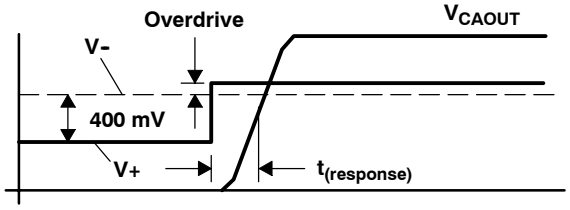


Figure 26. Overdrive Definition

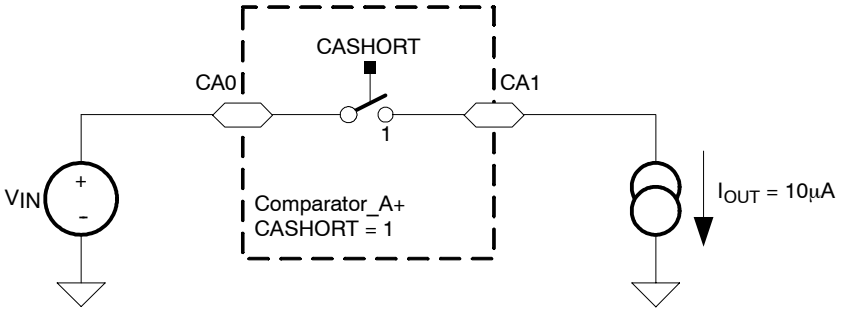


Figure 27. Comparator_A+ Short Resistance Test Condition

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

typical characteristics – Comparator_A+

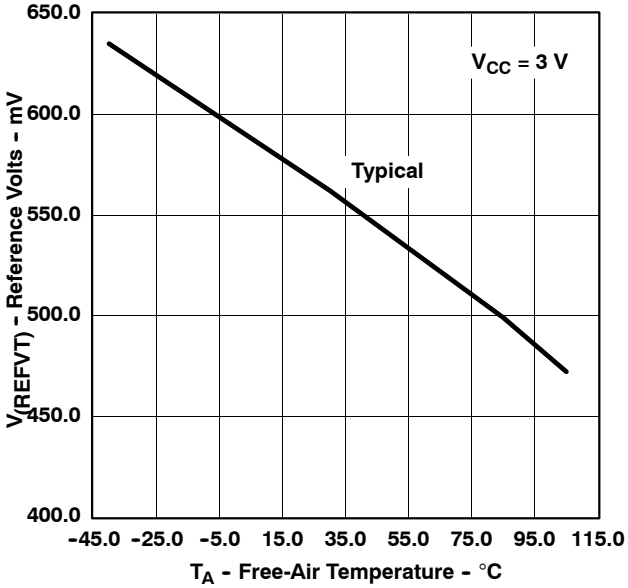


Figure 28. $V_{(RefVT)}$ vs Temperature, V_{CC} = 3 V

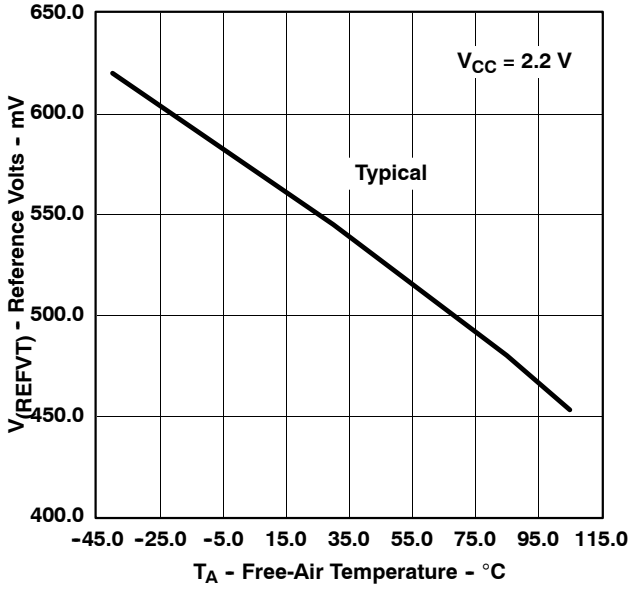


Figure 29. $V_{(RefVT)}$ vs Temperature, V_{CC} = 2.2 V

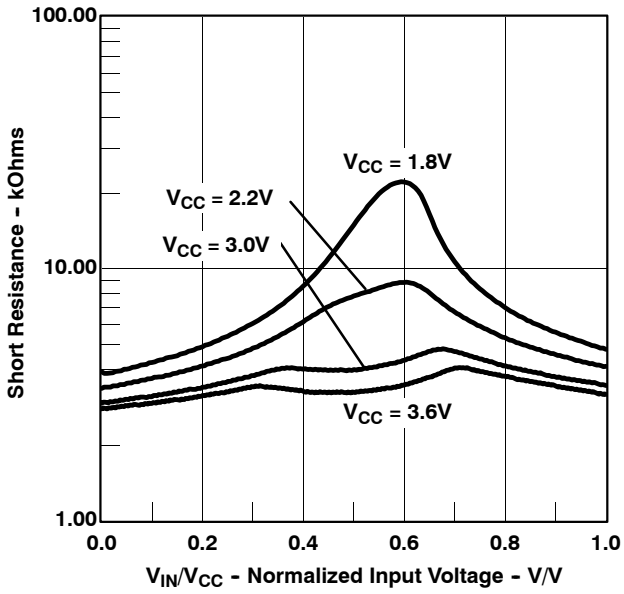


Figure 30. Short Resistance vs V_{IN}/V_{CC}

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

10-bit ADC, power supply and input range conditions (see Note 1)

PARAMETER		TEST CONDITIONS	T_A	VCC	MIN	TYP	MAX	UNIT
V_{CC}	Analog supply voltage range	V_{SS} = 0 V			2.2		3.6	V
V_{Ax}	Analog input voltage range (see Note 2)	All Ax terminals, Analog inputs selected in ADC10AE register			0		V_{CC}	V
I_{ADC10}	ADC10 supply current (see Note 3)	$f_{ADC10CLK}$ = 5 MHz, ADC10ON = 1, REFON = 0 ADC10SHT0 = 1, ADC10SHT1 = 0, ADC10DIV = 0	I: –40°C to 85°C T: –40°C to105°C	2.2 V		0.52	1.05	mA
				3 V		0.6	1.2	
I_{REF+}	Reference supply current, reference buffer disabled (see Note 4)	$f_{ADC10CLK}$ = 5 MHz, ADC10ON = 0, REF2_5V = 0, REFON = 1, REFOUT = 0	I: –40°C to 85°C T: –40°C to105°C	2.2 V/3 V		0.25	0.4	mA
		$f_{ADC10CLK}$ = 5 MHz, ADC10ON = 0, REF2_5V = 1, REFON = 1, REFOUT = 0	I: –40°C to 85°C T: –40°C to105°C	3 V				mA
$I_{REFB,0}$	Reference buffer supply current with ADC10SR = 0 (see Note 4)	$f_{ADC10CLK}$ = 5 MHz, ADC10ON = 0, REFON = 1, REF2_5V = 0, REFOUT = 1, ADC10SR = 0	–40°C to 85°C	2.2 V/3 V		1.1	1.4	mA
			105°C	2.2 V/3 V			1.8	mA
$I_{REFB,1}$	Reference buffer supply current with ADC10SR = 1 (see Note 4)	$f_{ADC10CLK}$ = 5 MHz, ADC10ON = 0, REFON = 1, REF2_5V = 0, REFOUT = 1, ADC10SR = 1	–40°C to 85°C	2.2 V/3 V		0.5	0.7	mA
			105°C	2.2 V/3 V			0.8	mA
C_I	Input capacitance	Only one terminal Ax selected at a time	I: –40°C to 85°C T: –40°C to105°C				27	pF
R_I	Input MUX ON resistance	$0V \le V_{Ax} \le V_{CC}$	I: –40°C to 85°C T: –40°C to105°C	2.2 V/3 V			2000	Ω

NOTES: 1. The leakage current is defined in the leakage current table with Px.x/Ax parameter.
2. The analog input voltage range must be within the selected reference voltage range V_{R+} to V_{R-} for valid conversion results.
3. The internal reference supply current is not included in current consumption parameter I_{ADC10}.
4. The internal reference current is supplied via terminal V_{CC}. Consumption is independent of the ADC10ON control bit, unless a conversion is active. The REFON bit enables the built-in reference to settle before starting an A/D conversion.

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

10-bit ADC, built-in voltage reference

PARAMETER		TEST CONDITIONS		T_A	V_{CC}	MIN	TYP	MAX	UNIT
$V_{CC,REF+}$	Positive built-in reference analog supply voltage range	$I_{VREF+} \le 1$ mA, REF2_5V = 0				2.2			V
		$I_{VREF+} \le 0.5$ mA, REF2_5V = 1				2.8			
		$I_{VREF+} \le 1$ mA, REF2_5V = 1				2.9			
V_{REF+}	Positive built-in reference voltage	$I_{VREF+} \le I_{VREF+}$max, REF2_5V = 0			2.2 V/ 3 V	1.41	1.5	1.59	V
		$I_{VREF+} \le I_{VREF+}$max, REF2_5V = 1			3 V	2.35	2.5	2.65	V
$I_{LD,VREF+}$	Maximum V_{REF+} load current				2.2 V			±0.5	mA
					3 V			±1	
	V_{REF+} load regulation	I_{VREF+} = 500 μA ± 100 μA, Analog input voltage $V_{Ax} \approx 0.75$ V, REF2_5V = 0			2.2 V/ 3 V			±2	LSB
		I_{VREF+} = 500 μA ± 100 μA, Analog input voltage $V_{Ax} \approx 1.25$ V, REF2_5V = 1			3 V			±2	LSB
	V_{REF+} load regulation response time	I_{VREF+} = 100 μA→900 μA, $V_{Ax} \approx 0.5 \times V_{REF+}$, Error of conversion result ≤ 1 LSB	ADC10SR = 0		3 V			400	ns
			ADC10SR = 1		3V			2000	
C_{VREF+}	Max. capacitance at pin V_{REF+} (see Note 1)	$I_{VREF+} \le \pm 1$ mA, REFON = 1, REFOUT = 1			2.2 V/ 3 V			100	pF
TC_{REF+}	Temperature coefficient	I_{VREF+} = const. with 0 mA ≤ I_{VREF+} ≤ 1 mA (see Note 3)		-40°C to 85°C	2.2 V/ 3 V			±100	ppm/°C
				85°C to 105°C	2.2 V/ 3 V			±110	ppm/°C
t_{REFON}	Settling time of internal reference voltage (see Note 2)	I_{VREF+} = 0.5 mA, REF2_5V = 0, REFON = 0 → 1			3.6 V			30	μs
$t_{REFBURST}$	Settling time of reference buffer (see Note 2)	I_{VREF+} = 0.5 mA, REF2_5V = 0, REFON = 1, REFBURST = 1	ADC10SR = 0		2.2 V			1	μs
			ADC10SR = 1		2.2 V			2.5	
		I_{VREF+} = 0.5 mA, REF2_5V = 1, REFON = 1, REFBURST = 1	ADC10SR = 0		3 V			2	μs
			ADC10SR = 1		3 V			4.5	

NOTES: 1. The capacitance applied to the internal buffer operational amplifier, if switched to terminal P2.4/TA2/A4/V_{REF+}/V_{eREF+} (REFOUT = 1), must be limited; the reference buffer may become unstable, otherwise.
2. The condition is that the error in a conversion started after t_{REFON} or t_{RefBuf} is less than ±0.5 LSB.
3. Calculated using the box method: ((MAX(V_{REF}(T)) – MIN(V_{REF}(T))) / MIN(V_{REF}(T)) / (T_{MAX} – T_{MIN})

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

10-bit ADC, external reference (see Note 1)

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
V_{eREF+}	Positive external reference input voltage range (see Note 2)	$V_{eREF+} > V_{eREF-}$, SREF1 = 1, SREF0 = 0		1.4		V_{CC}	V
		$V_{eREF-} \le V_{eREF+} \le (V_{CC} - 0.15\ V)$ SREF1 = 1, SREF0 = 1 (see Note 3)		1.4		3.0	
V_{eREF-}	Negative external reference input voltage range (see Note 4)	$V_{eREF+} > V_{eREF-}$		0		1.2	V
ΔV_{eREF}	Differential external reference input voltage range $\Delta V_{eREF} = V_{eREF+} - V_{eREF-}$	$V_{eREF+} > V_{eREF-}$ (see Note 5)		1.4		V_{CC}	V
I_{VeREF+}	Static input current into V_{eREF+}	$0V \le V_{eREF+} \le V_{CC}$, SREF1 = 1, SREF0 = 0	2.2 V/3 V			±1	µA
		$0V \le V_{eREF+} \le (V_{CC} - 0.15\ V) \le 3\ V$, SREF1 = 1, SREF0 = 1 (see Note 3)	2.2 V/3 V			0	
I_{VeREF-}	Static input current into V_{eREF-}	$0V \le V_{eREF-} \le V_{CC}$	2.2 V/3 V			±1	µA

NOTES:
1. The external reference is used during conversion to charge and discharge the capacitance array. The input capacitance, C_I, is also the dynamic load for an external reference during conversion. The dynamic impedance of the reference supply should follow the recommendations on analog-source impedance to allow the charge to settle for 10-bit accuracy.
2. The accuracy limits the minimum positive external reference voltage. Lower reference voltage levels may be applied with reduced accuracy requirements.
3. Under this condition the external reference is internally buffered. The reference buffer is active and requires the reference buffer supply current I_{REFB}. The current consumption can be limited to the sample and conversion period with REBURST = 1.
4. The accuracy limits the maximum negative external reference voltage. Higher reference voltage levels may be applied with reduced accuracy requirements.
5. The accuracy limits the minimum external differential reference voltage. Lower differential reference voltage levels may be applied with reduced accuracy requirements.

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

10-bit ADC, timing parameters

PARAMETER		TEST CONDITIONS		V_{CC}	MIN	TYP	MAX	UNIT
$f_{ADC10CLK}$	ADC10 input clock frequency	For specified performance of ADC10 linearity parameters	ADC10SR = 0	2.2 V/3 V	0.45		6.3	MHz
			ADC10SR = 1	2.2 V/3 V	0.45		1.5	
$f_{ADC10OSC}$	ADC10 built-in oscillator frequency	ADC10DIVx = 0, ADC10SSELx = 0 $f_{ADC10CLK} = f_{ADC10OSC}$		2.2 V/3 V	3.7		6.3	MHz
$t_{CONVERT}$	Conversion time	ADC10 built-in oscillator, ADC10SSELx = 0 $f_{ADC10CLK} = f_{ADC10OSC}$		2.2 V/3 V	2.06		3.51	µs
		$f_{ADC10CLK}$ from ACLK, MCLK or SMCLK: ADC10SSELx ≠ 0			13× ADC10DIV× $1/f_{ADC10CLK}$			µs
$t_{ADC10ON}$	Turn on settling time of the ADC	See Note 1					100	ns

NOTE 1: The condition is that the error in a conversion started after $t_{ADC10ON}$ is less than ±0.5 LSB. The reference and input signals are already settled.

10-bit ADC, linearity parameters

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
E_I	Integral linearity error		2.2 V/3 V			±1	LSB
E_D	Differential linearity error		2.2 V/3 V			±1	LSB
E_O	Offset error	Source impedance R_S < 100 Ω	2.2 V/3 V			±1	LSB
E_G	Gain error	SREFx = 010, Unbuffered external reference; V_{eREF+} = 1.5 V	2.2 V		±1.1	±2	LSB
		SREFx = 010, Unbuffered external reference; V_{eREF+} = 2.5 V	3 V		±1.1	±2	LSB
		SREFx = 011, Buffered external reference (see Note 2), V_{eREF+} = 1.5 V	2.2 V		±1.1	±4	LSB
		SREFx = 011, Buffered external reference (see Note 2), V_{eREF+} = 2.5 V	3 V		±1.1	±3	LSB
E_T	Total unadjusted error	SREFx = 010, Unbuffered external reference; V_{eREF+} = 1.5 V	2.2 V		±2	±5	LSB
		SREFx = 010, Unbuffered external reference; V_{eREF+} = 2.5 V	3 V		±2	±5	LSB
		SREFx = 011, Buffered external reference (see Note 2), V_{eREF+} = 1.5 V	2.2 V		±2	±7	LSB
		SREFx = 011, Buffered external reference (see Note 2), V_{eREF+} = 2.5 V	3 V		±2	±6	LSB

NOTE 2: The reference buffer's offset adds to the gain and total unadjusted error.

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

10-bit ADC, temperature sensor and built-in V_{MID}

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
I_{SENSOR}	Temperature sensor supply current (see Note 1)	REFON = 0, INCHx = 0Ah, ADC10ON = 1, T_A = 25°C	2.2 V		40	120	µA
			3 V		60	160	
TC_{SENSOR}		ADC10ON = 1, INCHx = 0Ah (see Note 2)	2.2 V/3 V		3.55		mV/°C
$V_{Offset,Sensor}$	Sensor offset voltage	ADC10ON = 1, INCHx = 0Ah (see Note 2)		–100		100	mV
V_{Sensor}	Sensor output voltage (see Note 3)	Temperature sensor voltage at T_A = 105°C (T version only)	2.2 V/3 V	1265	1365	1465	mV
		Temperature sensor voltage at T_A = 85°C	2.2 V/3 V	1195	1295	1395	mV
		Temperature sensor voltage at T_A = 25°C	2.2 V/3 V	985	1085	1185	mV
		Temperature sensor voltage at T_A = 0°C	2.2 V/3 V	895	995	1095	
$t_{Sensor(sample)}$	Sample time required if channel 10 is selected (see Note 4)	ADC10ON = 1, INCHx = 0Ah, Error of conversion result ≤ 1 LSB	2.2 V/3 V	30			µs
I_{VMID}	Current into divider at channel11 (see Note 5)	ADC10ON = 1, INCHx = 0Bh,	2.2 V			NA	µA
			3 V			NA	
V_{MID}	V_{CC} divider at channel 11	ADC10ON = 1, INCHx = 0Bh, V_{MID} is ≈0.5 x V_{CC}	2.2 V	1.06	1.1	1.14	V
			3 V	1.46	1.5	1.54	
$t_{VMID(sample)}$	Sample time required if channel 11 is selected (see Note 6)	ADC10ON = 1, INCHx = 0Bh, Error of conversion result ≤ 1 LSB	2.2 V	1400			ns
			3 V	1220			

NOTES:
1. The sensor current I_{SENSOR} is consumed if (ADC10ON = 1 and REFON = 1), or (ADC10ON = 1 and INCH = 0Ah and sample signal is high). When REFON = 1, I_{SENSOR} is included in I_{REF+}. When REFON = 0, I_{SENSOR} applies during conversion of the temperature sensor input (INCH = 0Ah).
2. The following formula can be used to calculate the temperature sensor output voltage:
   $V_{Sensor,typ} = TC_{Sensor}$ (273 + T [°C]) + $V_{Offset,sensor}$ [mV] or
   $V_{Sensor,typ} = TC_{Sensor}$ T [°C] + $V_{Sensor}(T_A = 0°C)$ [mV]
3. Results based on characterization and/or production test, not TC_{Sensor} or $V_{Offset,sensor}$.
4. The typical equivalent impedance of the sensor is 51 kΩ. The sample time required includes the sensor-on time $t_{SENSOR(on)}$.
5. No additional current is needed. The V_{MID} is used during sampling.
6. The on-time $t_{VMID(on)}$ is included in the sampling time $t_{VMID(sample)}$; no additional on time is needed.

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

flash memory

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

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

RAM

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{(RAMh)}$	RAM retention supply voltage (see Note)	CPU halted	1.6			V

NOTE: This parameter defines the minimum supply voltage V_{CC} when the data in RAM remains unchanged. No program execution should happen during this supply voltage condition.

JTAG and Spy-Bi-Wire interface

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
f_{SBW}	Spy-Bi-Wire input frequency		2.2 V/3 V	0		20	MHz
$t_{SBW,Low}$	Spy-Bi-Wire low clock pulse length		2.2 V/3 V	0.025		15	us
$t_{SBW,En}$	Spy-Bi-Wire enable time, TEST high to acceptance of first clock edge (see Note 1)		2.2 V/3 V			1	us
$t_{SBW,Ret}$	Spy-Bi-Wire return to normal operation time		2.2 V/3 V	15		100	us
f_{TCK}	TCK input frequency (see Note 2)		2.2 V	0		5	MHz
			3 V	0		10	MHz
$R_{Internal}$	Internal pulldown resistance on TEST		2.2 V/3 V	25	60	90	kΩ

NOTES: 1. Tools accessing the Spy-Bi-Wire interface need to wait for the maximum $t_{SBW,En}$ time after pulling the TEST/SBWCLK pin high before applying the first SBWCLK clock edge.
2. f_{TCK} may be restricted to meet the timing requirements of the module selected.

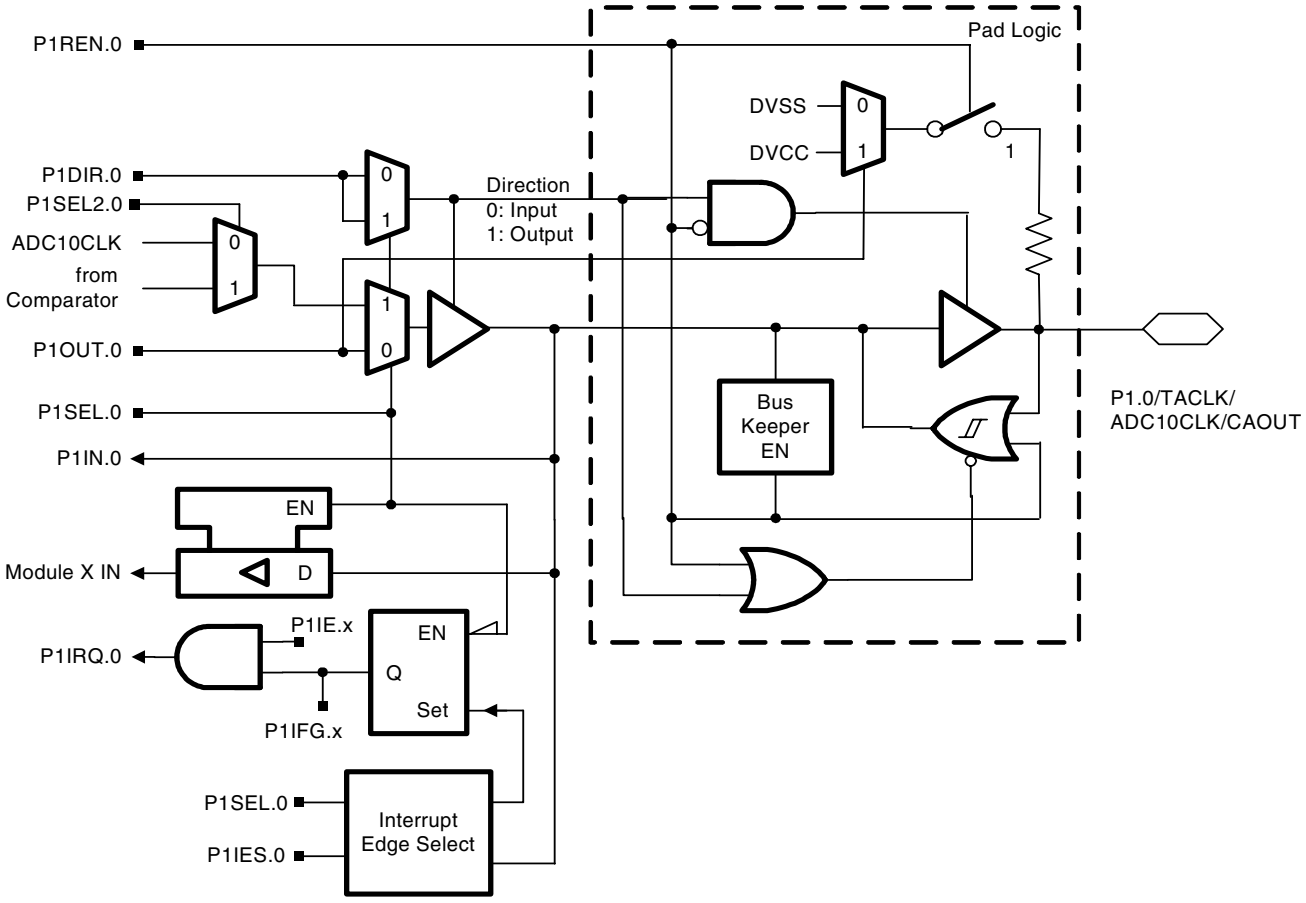
JTAG fuse (see Note)

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

NOTE: Once the fuse is blown, no further access to the MSP430 JTAG/Test and emulation features is possible. The JTAG block is switched to bypass mode.

APPLICATION INFORMATION

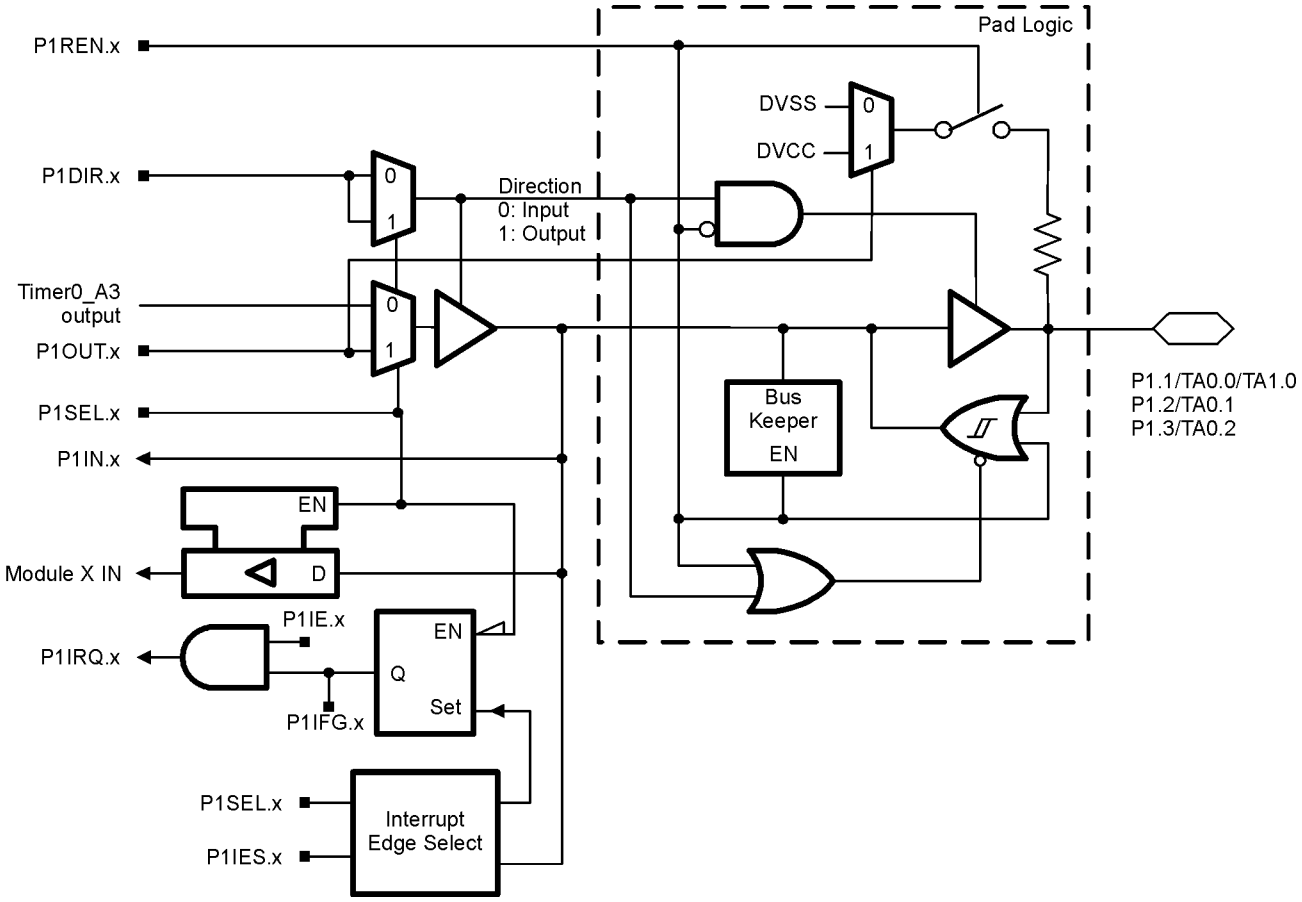
Port P1 pin schematic: P1.0, input/output with Schmitt trigger



Port P1 (P1.0) pin functions

PIN NAME (P1.x)	x	FUNCTION	CONTROL BITS / SIGNALS		
			P1DIR.x	P1SEL.x	P1SEL2.x
P1.0/TACLK/ ADC10CLK/CAOUT	0	P1.0 (I/O)	I: 0, O: 1	0	0
		Timer0_A3.TACLK, Timer1_A2.TACLK	0	1	0
		ADC10CLK	1	1	0
		CAOUT	1	1	1

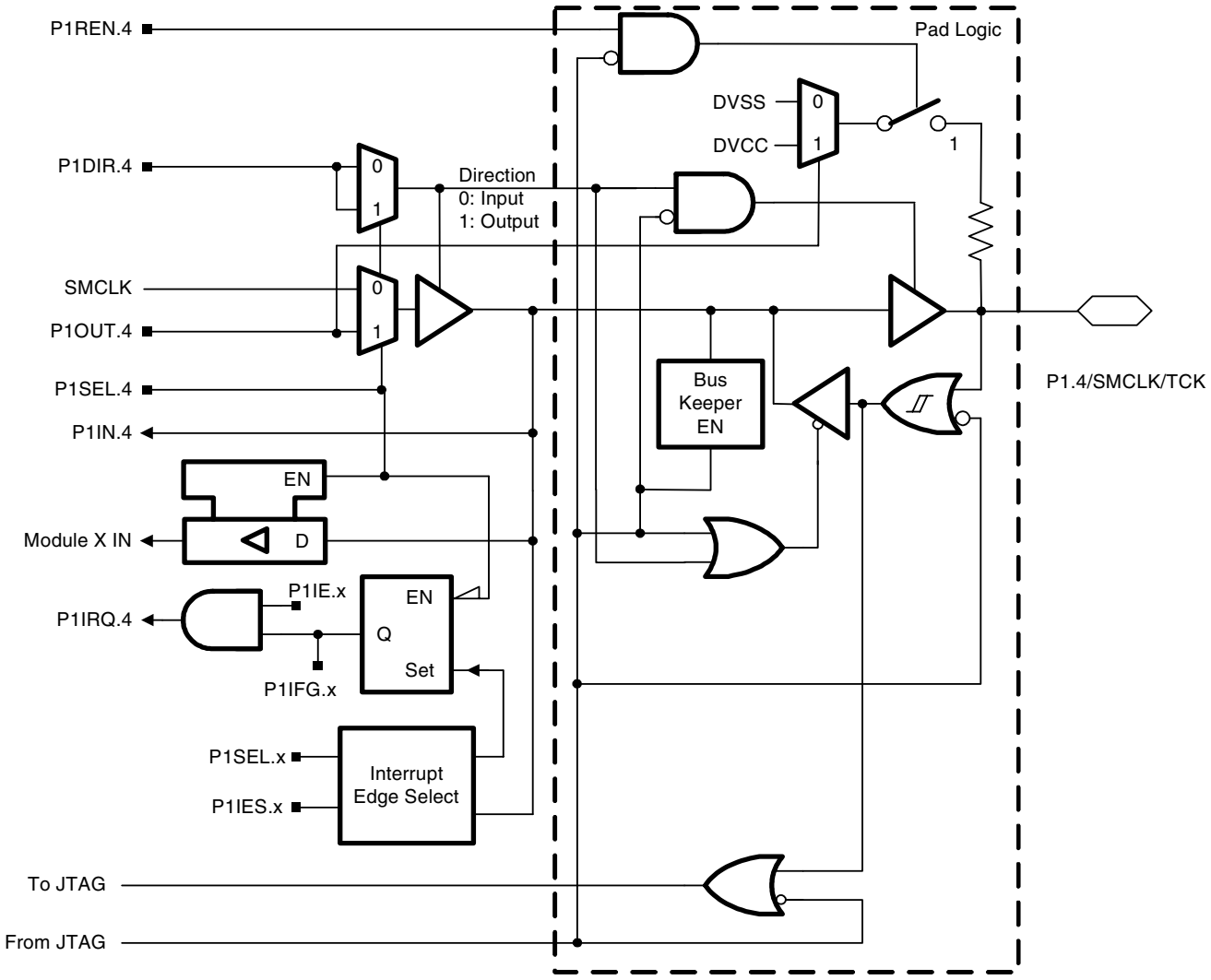
Port P1 pin schematic: P1.1 to P1.3, input/output with Schmitt trigger



Port P1 (P1.1 to P1.3) pin functions

PIN NAME (P1.x)	x	FUNCTION	CONTROL BITS / SIGNALS		
			P1DIR.x	P1SEL.x	P1SEL2.x
P1.1/TA0.0/TA1.0	1	P1.1 (I/O)	I: 0; O: 1	0	0
		Timer0_A3.CCI0A, Timer1_A2.CCI0A	0	1	0
		Timer0_A3.TA0	1	1	0
P1.2/TA0.1	2	P1.2 (I/O)	I: 0; O: 1	0	0
		Timer0_A3.CCI0A	0	1	0
		Timer0_A3.TA0	1	1	0
P1.3/TA0.2	3	P1.3 (I/O)	I: 0; O: 1	0	0
		Timer0_A3.CCI0A	0	1	0
		Timer0_A3.TA0	1	1	0

Port P1 pin schematic: P1.4

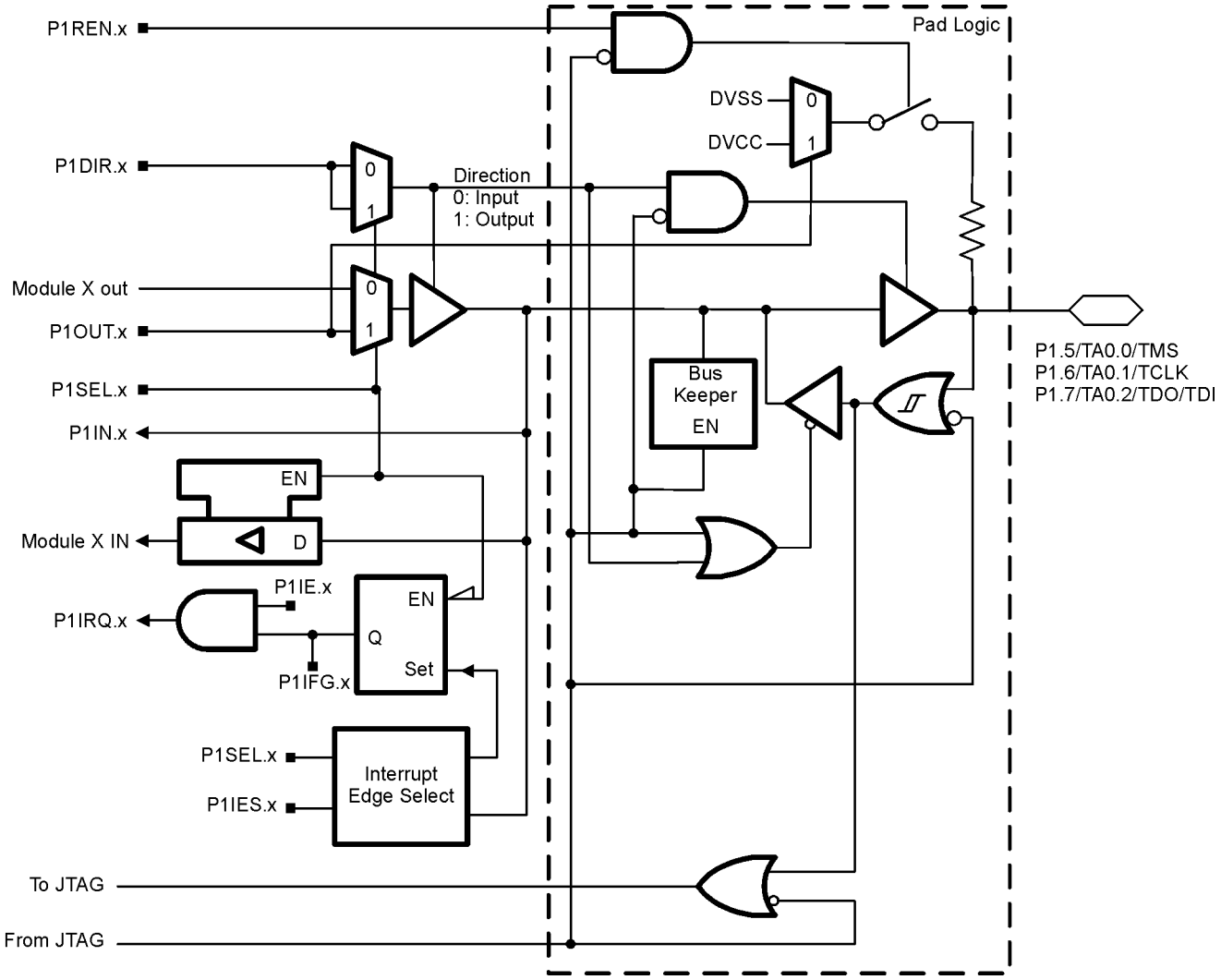


Port P1 (P1.4) pin functions

PIN NAME (P1.x)	x	FUNCTION	CONTROL BITS / SIGNALS		
			P1DIR.x	P1SEL.x P1SEL2.x = 0	JTAG Mode
P1.4/SMCLK/TCK	4	P1.4 (I/O)	I: 0; O: 1	0	0
		SMCLK	1	1	0
		TCK (see Note 1)	X	X	1

NOTES: 1. In JTAG Mode the internal pullup/pulldown resistors are disabled.
2. X: Don't care.

Port P1 pin schematic: P1.5 to P1.7

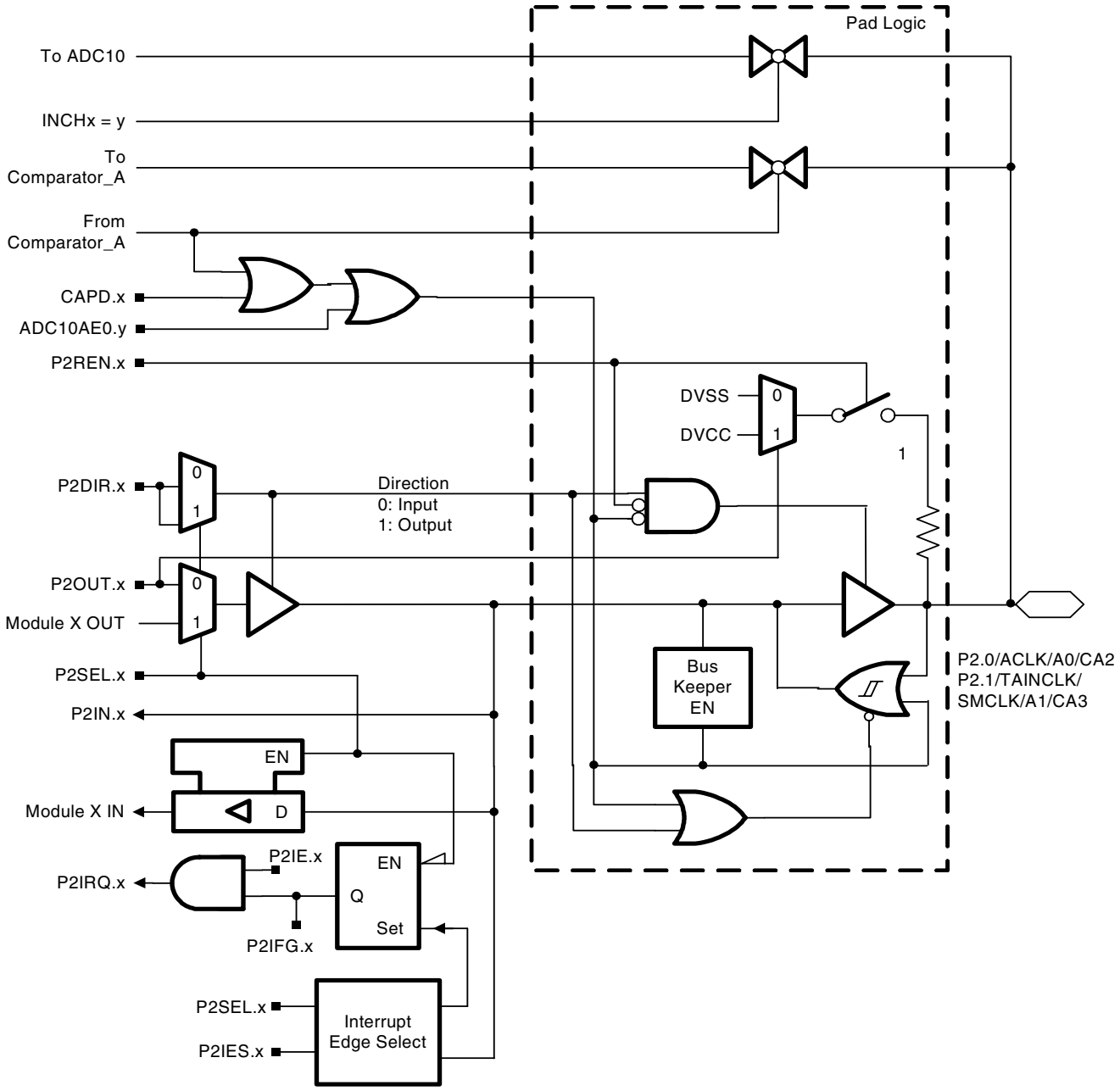


Port P1 (P1.5 to P1.7) pin functions

PIN NAME (P1.x)	x	FUNCTION	CONTROL BITS / SIGNALS		
			P1DIR.x	P1SEL.x P1SEL2.x = 0	JTAG Mode
P1.5/TA0.0/TMS	5	P1.5 (I/O)	I: 0; O: 1	0	0
		Timer0_A3.TA0	1	1	0
		TMS (see Note 1)	X	X	1
P1.6/TA0.1/ TDI/TCLK	6	P1.6 (I/O)	I: 0; O: 1	0	0
		Timer0_A3.TA1	1	1	0
		Timer0_A3.CCI0B	0	1	0
		TDI/TCLK (see Note 1)	X	X	1
P1.7/TA0.2/TDO/TDI	7	P1.6 (I/O)	I: 0; O: 1	0	0
		Timer0_A3.TA2	1	1	0
		TDO/TDI (see Note 1)	X	X	1

NOTES: 1. In JTAG Mode the internal pullup/pulldown resistors are disabled.
2. X: Don’t care.

Port P2 pin schematic: P2.0 and P2.1, input/output with Schmitt trigger

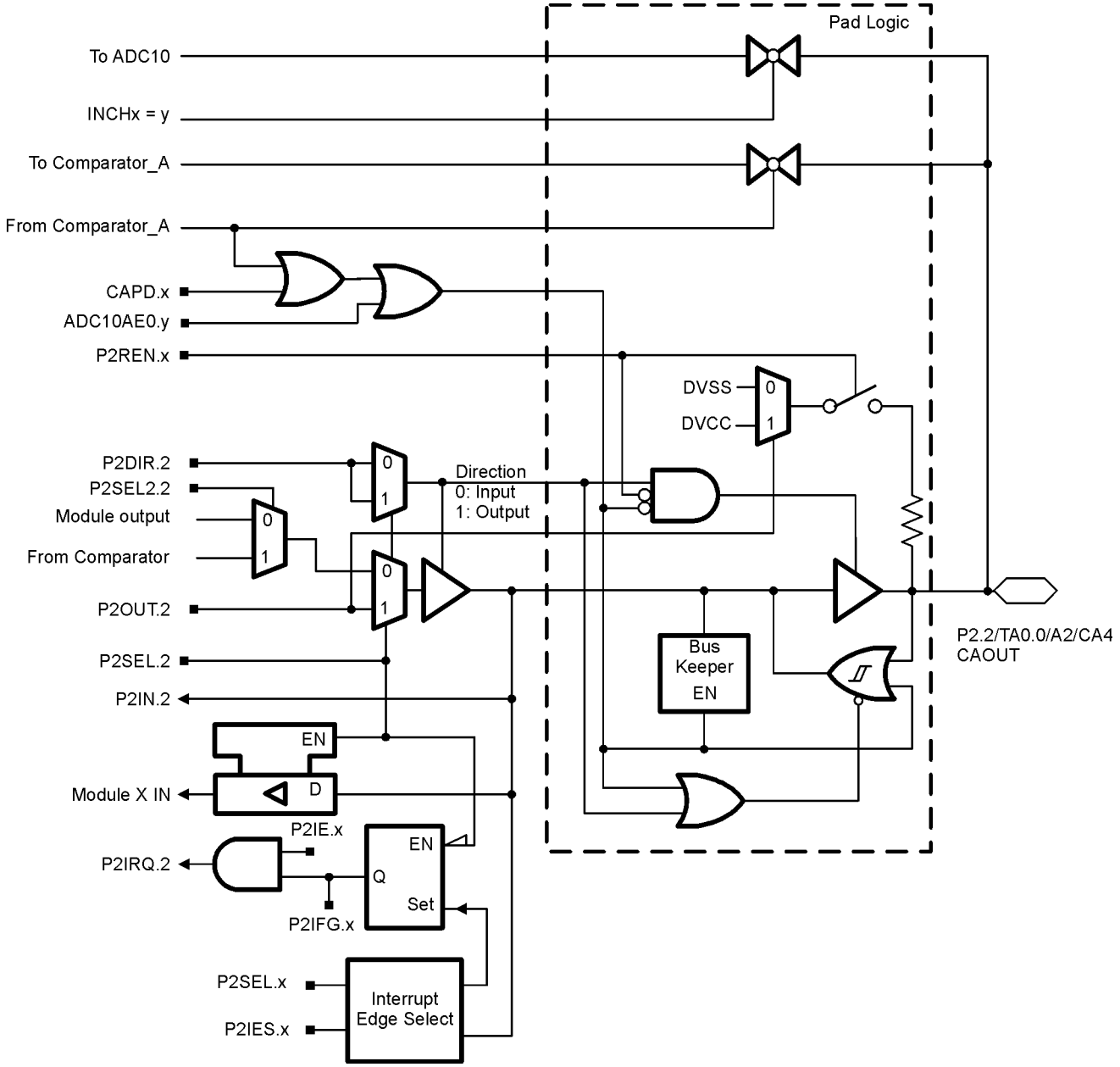


Port P2 (P2.0 and P2.1) pin functions

PIN NAME (P2.x)	x	FUNCTION	CONTROL BITS / SIGNALS			
			ADC10AE0.y	CAPD.x	P2DIR.x	P2SEL.x P2SEL2.x = 0
P2.0/ACLK/A0/CA2	0	P2.0 (I/O)	0	0	I: 0; O: 1	0
		ACLK	0	0	1	1
		A0	1	0	X	X
		CA2	0	1	X	X
P2.1/TAINCLK/ SMCLK/A1/CA3	1	P2.1 (I/O)	0	0	I: 0; O: 1	0
		Timer0_A3.TAINCLK, Timer1_A2.TAINCLK	0	0	0	1
		SMCLK	0	0	1	1
		A1	1	0	X	X
		CA3	0	1	X	X

NOTE: X: Don’t care.

Port P2 pin schematic: P2.2, input/output with Schmitt trigger

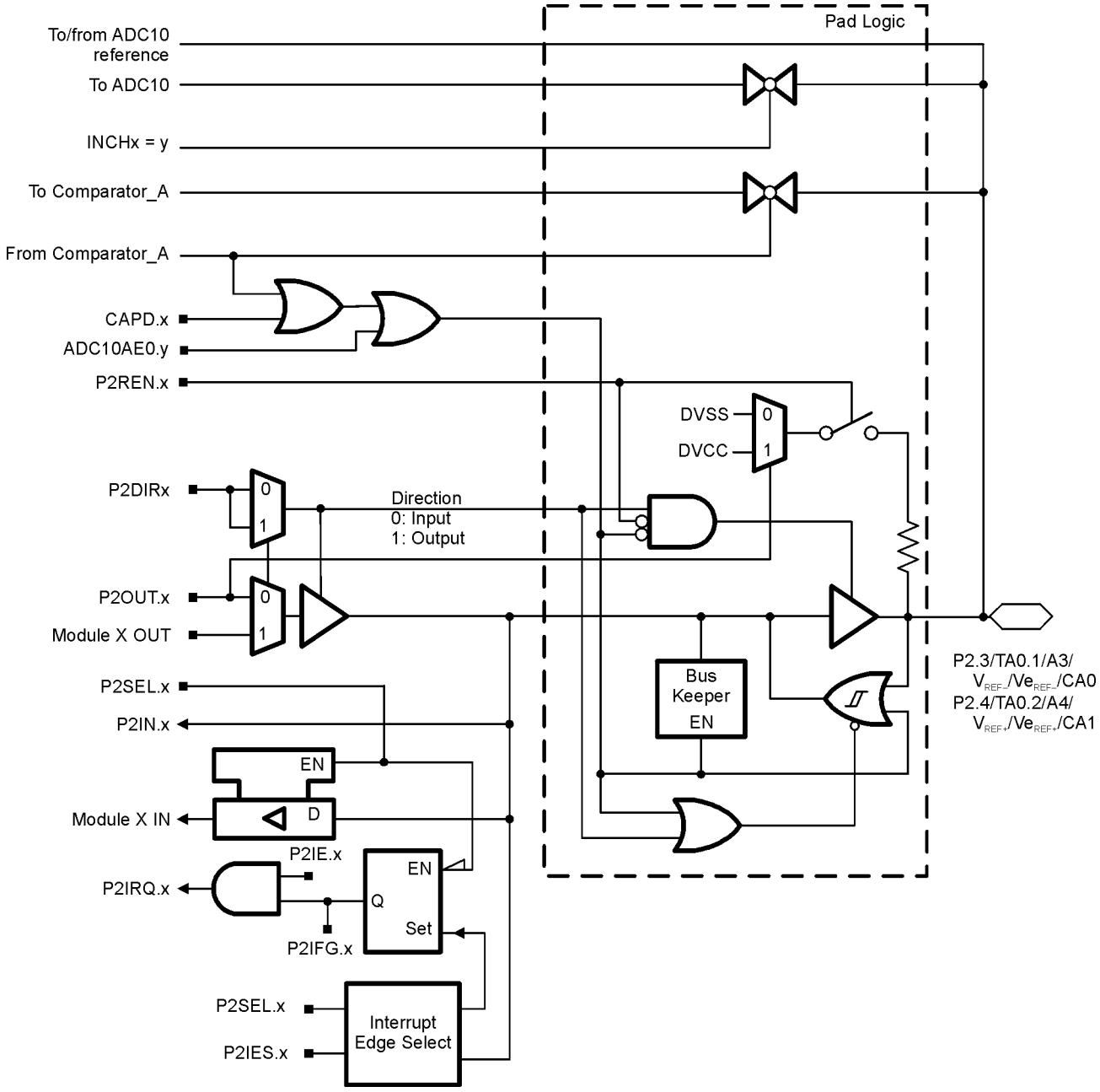


Port P2 (P2.2) pin functions

PIN NAME (P2.x)	x	FUNCTION	CONTROL BITS / SIGNALS				
			ADC10AE0.x	CAPD.x	P2DIR.x	P2SEL.x	P2SEL2.x
P2.2/TA0.0/A2/CA4/ CAOUT	2	P2.0 (I/O)	0	0	I: 0; O: 1	0	0
		Timer0_A3.TA0	0	0	1	1	0
		Timer0_A3.CCI0B	0	0	0	1	0
		A2	1	0	X	X	X
		CA4	0	1	X	X	X
		CAOUT	0	0	1	1	1

NOTE: X: Don’t care.

Port P2 pin schematic: P2.3 and P2.4, input/output with Schmitt trigger

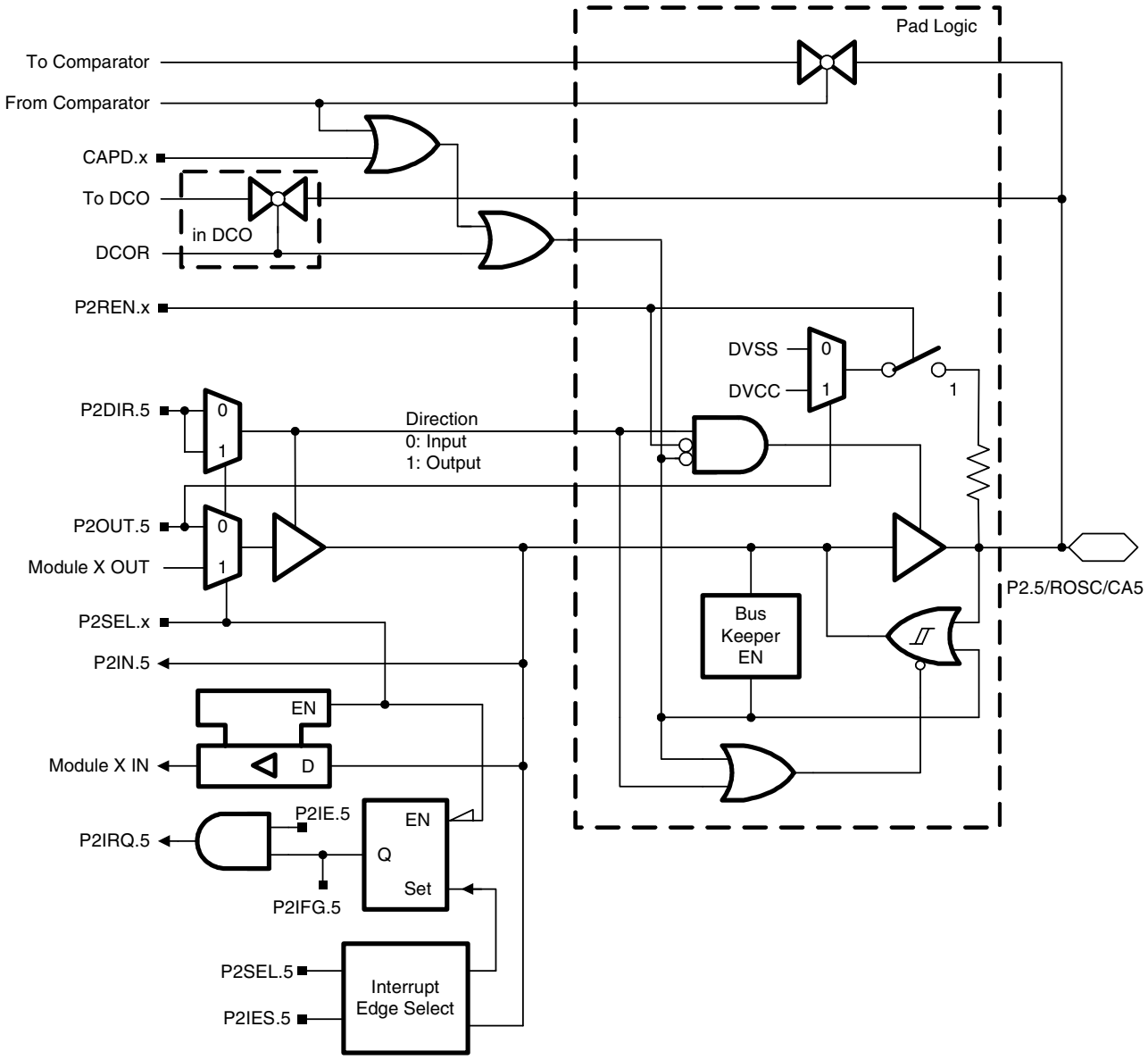


Port P2 (P2.3 and P2.4) pin functions

PIN NAME (P2.x)	x	FUNCTION	CONTROL BITS / SIGNALS			
			ADC10AE0.y	CAPD.x	P2DIR.x	P2SEL.x P2SEL2.x = 0
P2.3/TA0.1/A3/ V_{Ref-}/Ve_{Ref-}/CA0	3	P2.3 (I/O)	0	0	I: 0; O: 1	0
		Timer0_A3.TA1	0	0	1	1
		A3/V_{Ref-}/Ve_{Ref-}	1	0	X	X
		CA0	0	1	X	X
P2.4/TA0.2/A4/ V_{Ref+}/Ve_{Ref+}/CA1	4	P2.4 (I/O)	0	0	I: 0; O: 1	0
		Timer0_A3.TA2	0	0	1	1
		A4/V_{Ref+}/Ve_{Ref+}	1	0	X	X
		CA1	0	1	X	X

NOTE: X: Don’t care.

Port P2 pin schematic: P2.5, input/output with Schmitt trigger

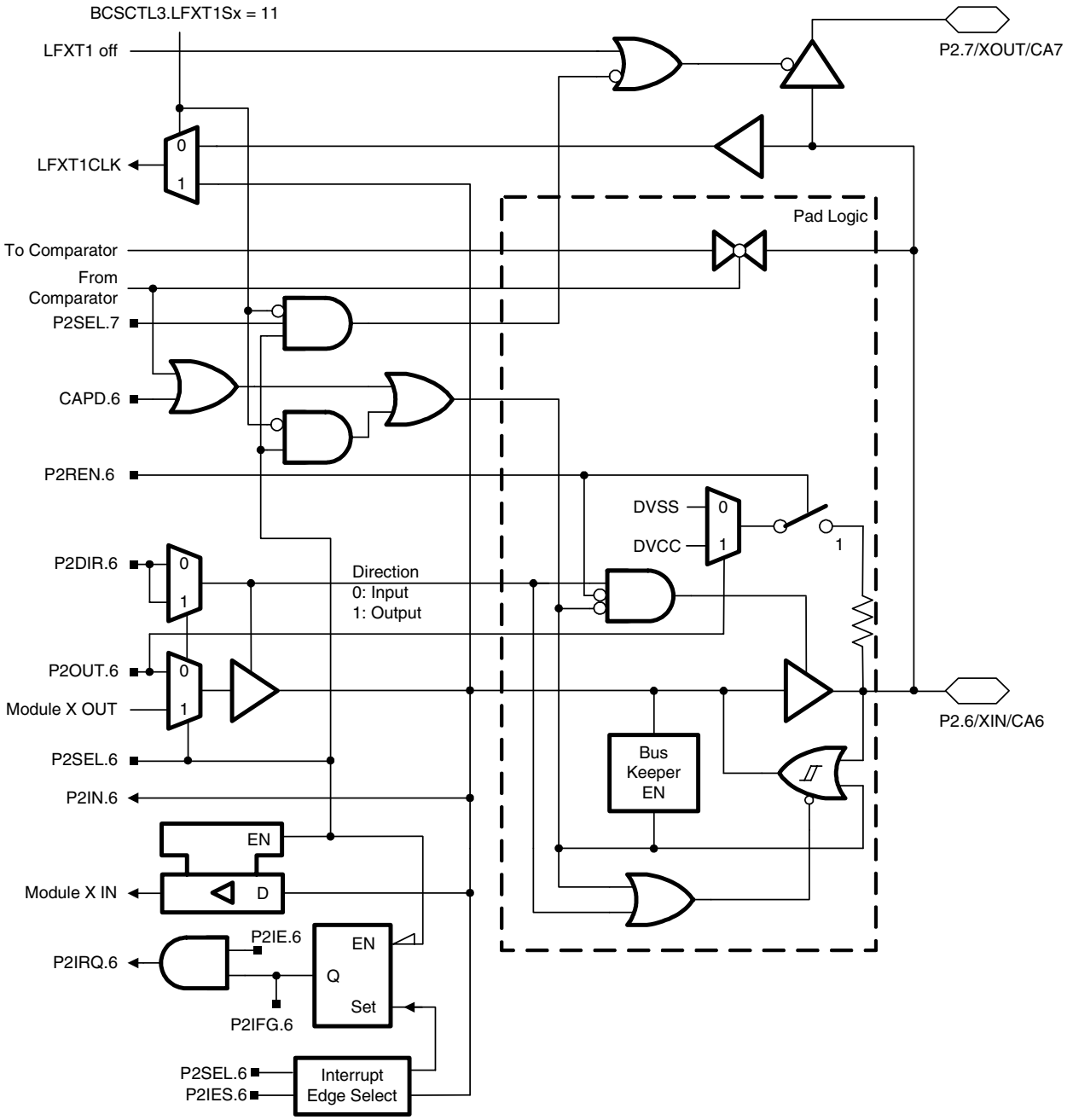


Port P2 (P2.5) pin functions

PIN NAME (P2.x)	x	FUNCTION	CONTROL BITS / SIGNALS			
			CAPD.5	DCOR	P2DIR.5	P2SEL.5 P2SEL2.x = 0
P2.5/R_{OSC}/CA5	5	P2.5 (I/O)	0	0	I: 0, O: 1	0
		R_{OSC}	0	1	X	X
		DV_{SS}	0	0	1	1
		CA5 (see Note 2)	1	0	X	X

NOTES: 1. X: Don't care.
2. Setting the CAPD.x bit disables the output driver as well as the input to prevent parasitic cross currents when applying analog signals. Selecting the CAx input to the comparator multiplexer with the P2CAx bits automatically disables the input buffer for that pin, regardless of the state of the associated CAPD.x bit.

Port P2 pin schematic: P2.6, input/output with Schmitt trigger

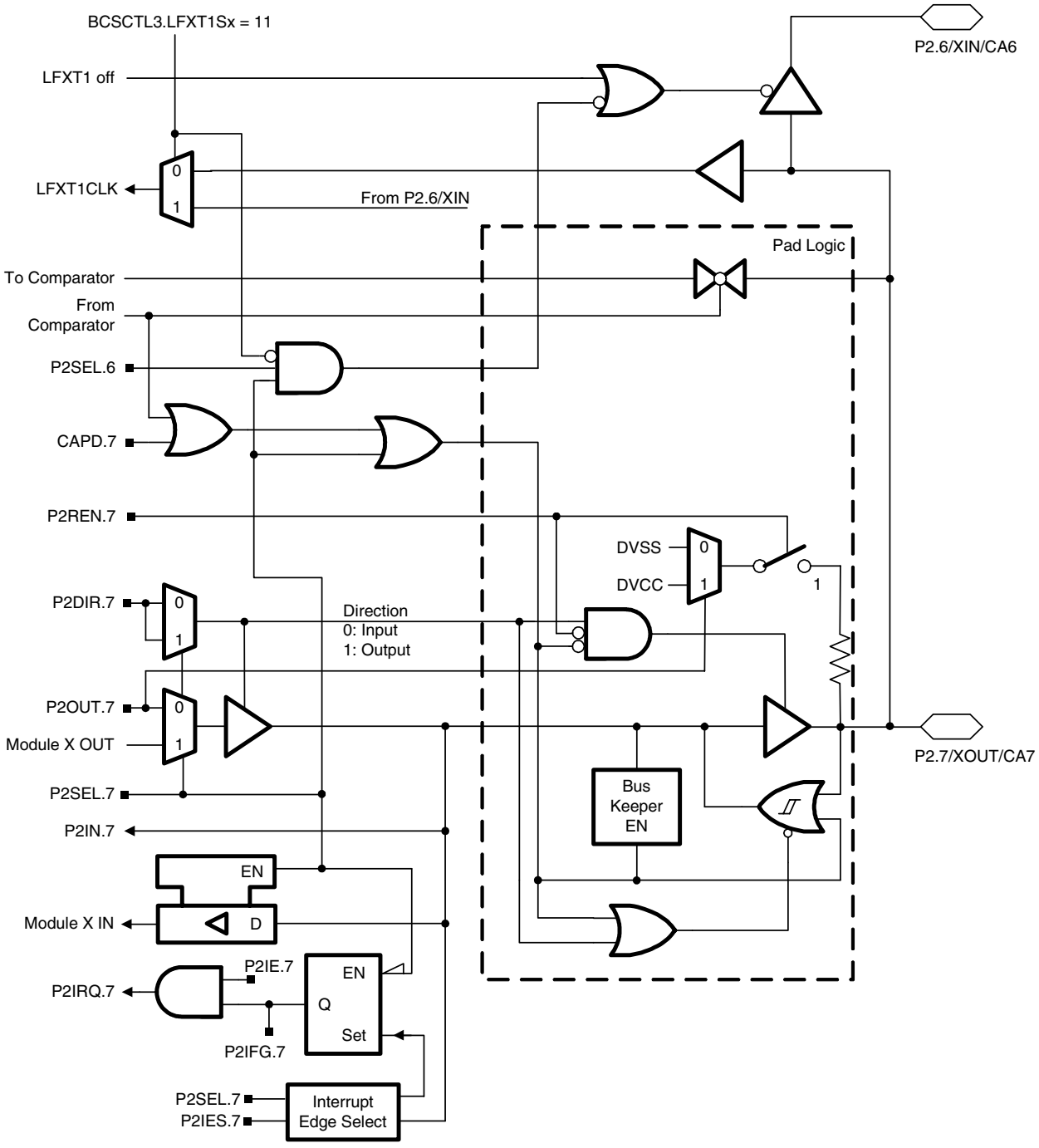


Port P2.6 pin functions

Pin Name (P2.x)	x	FUNCTION	CONTROL BITS / SIGNALS		
			CAPD.6	P2DIR.6	P2SEL.6 P2SEL2.x = 0
P2.6/XIN/CA6	6	P2.6 (I/O)	0	I: 0; O: 1	0
		XIN (default)	X	1	1
		CA6 (see Note 2)	1	X	0

NOTES: 1. X: Don't care.
2. Setting the CAPD.x bit disables the output driver as well as the input to prevent parasitic cross currents when applying analog signals. Selecting the CAx input to the comparator multiplexer with the P2CAx bits automatically disables the input buffer for that pin, regardless of the state of the associated CAPD.x bit.

Port P2 pin schematic: P2.7, input/output with Schmitt trigger

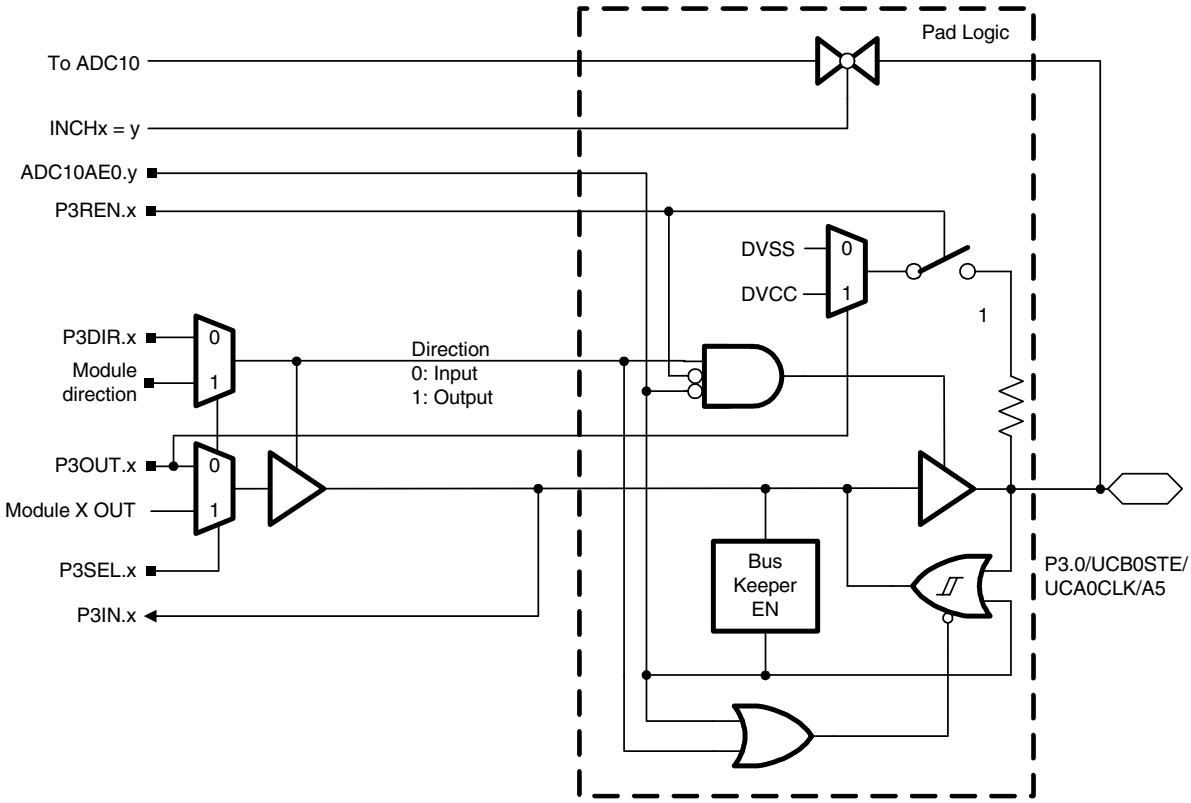


Port P2.7 pin functions

PIN NAME (P2.x)	x	FUNCTION	CONTROL BITS / SIGNALS		
			CAPD.7	P2DIR.7	P2SEL.7 P2SEL2.x = 0
P2.7/XOUT/CA7	7	P2.7 (I/O)	0	I: 0, O: 1	0
		XOUT (default)	X	1	1
		CA7 (see Note 2)	1	X	0

NOTES: 1. X: Don't care.
2. Setting the CAPD.x bit disables the output driver as well as the input to prevent parasitic cross currents when applying analog signals. Selecting the CAx input to the comparator multiplexer with the P2CAx bits automatically disables the input buffer for that pin, regardless of the state of the associated CAPD.x bit.

Port P3 pin schematic: P3.0, input/output with Schmitt trigger

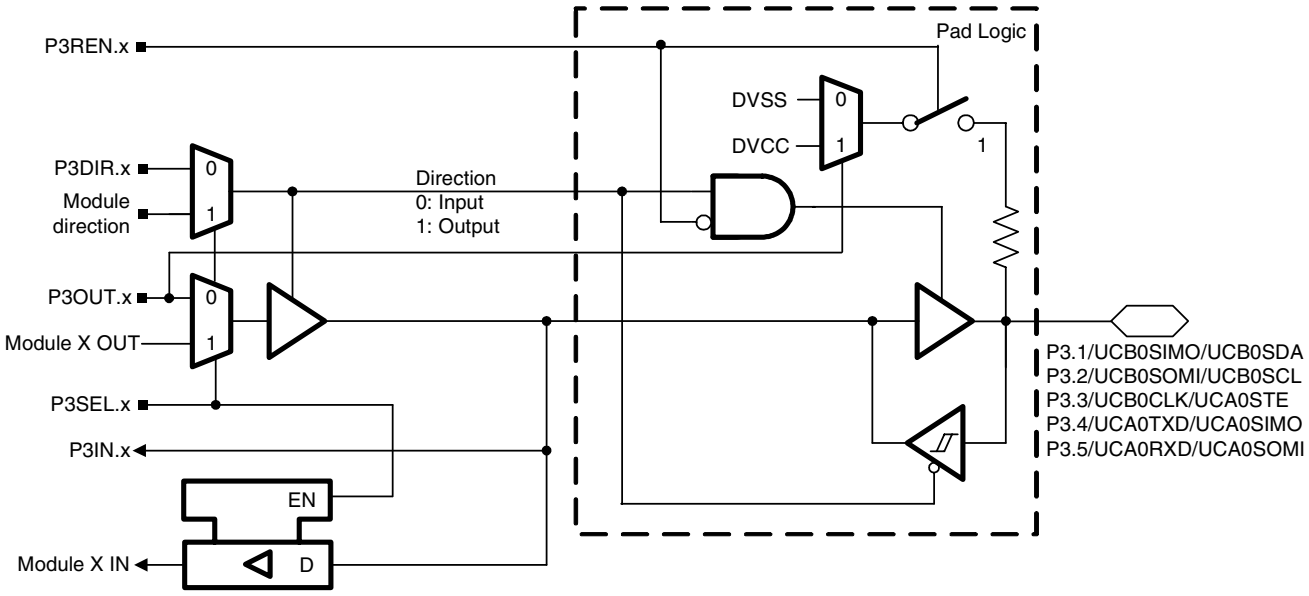


Port P3.0 pin functions

PIN NAME (P3.x)	x	FUNCTION	CONTROL BITS / SIGNALS		
			ADC10AE0.y	P3DIR.x	P3SEL.x P3SEL2.x = 0
P3.0/UCB0STE/ UCA0CLK/A5	0	P3.0 (I/O)	0	I: 0; O: 1	0
		UCB0STE/UCA0CLK (see Notes 1 and 2)	0	X	1
		A5 (see Notes 1 and 2)	1	X	X

NOTES: 1. X: Don't care.
2. The pin direction is controlled by the USCI module.
3. If the I2C functionality is selected, the output drives only the logical 0 to V_{SS} level.

Port P3 pin schematic: P3.1 to P3.5, input/output with Schmitt trigger

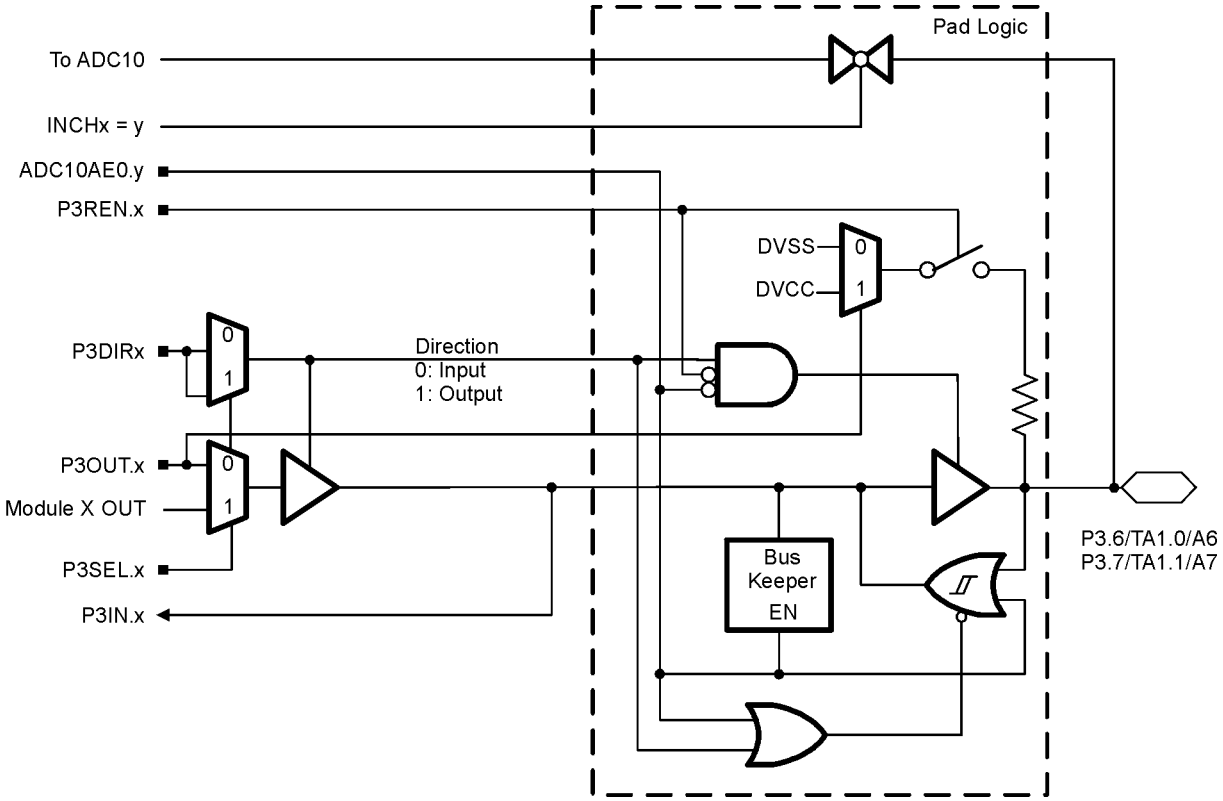


Port P3 (P3.1 to P3.5) pin functions

PIN NAME (P3.x)	x	FUNCTION	CONTROL BITS / SIGNALS	
			P3DIR.x	P3SEL.x P3SEL2.x = 0
P3.1/UCB0SIMO/ UCB0SDA	1	P3.1 (I/O)	I: 0; O: 1	0
		UCB0SIMO/UCB0SDA (see Notes 1, 2 and 3)	X	1
P3.2/UCB0SOMI/ UCB0SCL	2	P3.2 (I/O)	I: 0; O: 1	0
		UCB0SOMI/UCB0SCL (see Notes 1, 2 and 3)	X	1
P3.3/UCB0CLK/ UCA0STE	3	P3.3 (I/O)	I: 0; O: 1	0
		UCB0CLK/UCA0STE (see Notes 1 and 2)	X	1
P3.4/UCA0TXD/ UCA0SIMO	4	P3.4 (I/O)	I: 0; O: 1	0
		UCA0TXD/UCA0SIMO (see Notes 1 and 2)	X	1
P3.5/UCA0RXD/ UCA0SOMI	5	P3.5 (I/O)	I: 0; O: 1	0
		UCA0RXD/UCA0SOMI (see Notes 1 and 2)	X	1

NOTES: 1. X: Don't care.
2. The pin direction is controlled by the USCI module.
3. In case the I2C functionality is selected the output drives only the logical 0 to V_{SS} level.

Port P3 pin schematic: P3.6 to P3.7, input/output with Schmitt trigger



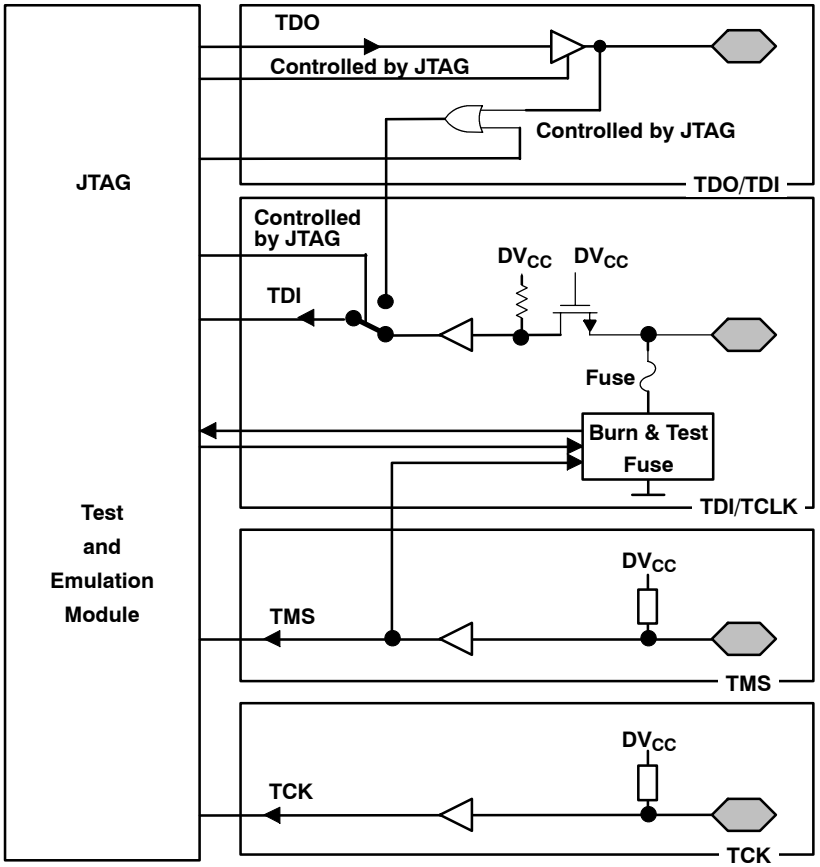
Port P3 (P3.6 and P3.7) pin functions

PIN NAME (P3.x)	x	FUNCTION	ADC10AE0.y	P3DIR.x	P3SEL.x P3SEL2 = 0
P3.6/TA1.0/A6	6	P3.6 (I/O)	0	I: 0; O: 1	0
		Timer1_A2.TA0	0	1	1
		Timer1_A2.CCI0B	0	0	1
		A6	1	X	X
P3.7/TA1.1/A7	7	P3.7 (I/O)	0	I: 0; O: 1	0
		Timer1_A2.TA1	0	1	1
		Timer1_A2.CCI1A	0	0	1
		A7	1	X	X

NOTES: 1. X: Don't care.

APPLICATION INFORMATION

JTAG pins: TMS, TCK, TDI/TCLK, TDO/TDI, input/output with Schmitt trigger



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

APPLICATION INFORMATION

JTAG fuse check mode

MSP430F21x2 devices that have the fuse on the TDI/TCLK terminal have a fuse-check mode that tests the continuity of the fuse the first time the JTAG port is accessed after a power-on reset (POR). When activated, a fuse-check current, I_{TF}, of 1 mA at 3 V or 2.5 mA at 5 V can flow from the TDI/TCLK pin to ground if the fuse is not burned. Care must be taken to avoid accidentally activating the fuse-check mode and increasing overall system power consumption.

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

The fuse-check current flows only when the fuse-check mode is active and the TMS pin is in a low state (see Figure 31). Therefore, the additional current flow can be prevented by holding the TMS pin high (default condition).

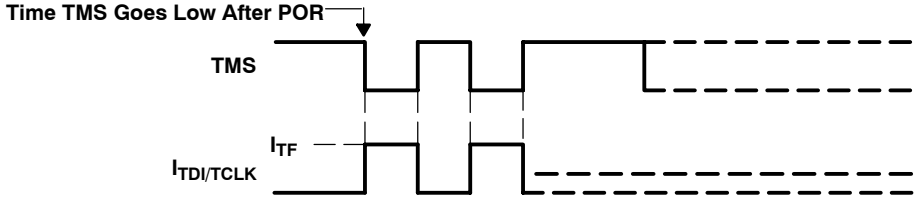


Figure 31. Fuse Check Mode Current

Data Sheet Revision History

LITERATURE NUMBER	SUMMARY
SLAS578	PRODUCT PREVIEW data sheet release
SLAS578A	PRODUCTION DATA data sheet release
SLAS578B	Corrected timer pin names throughout: TA0_0 changed to TA0.0, TA0_1 changed to TA1.0, TA1_0 changed to TA0.1, TA2_0 changed to TA0.2, TA1_1 changed to TA1.1

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)
MSP430F2112IPW	ACTIVE	TSSOP	PW	28	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
MSP430F2112IPWR	ACTIVE	TSSOP	PW	28	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
MSP430F2112IRHBR	ACTIVE	QFN	RHB	32	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
MSP430F2112IRHBT	ACTIVE	QFN	RHB	32	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
MSP430F2112TPW	ACTIVE	TSSOP	PW	28	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
MSP430F2112TPWR	ACTIVE	TSSOP	PW	28	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
MSP430F2112TRHB	PREVIEW	QFN	RHB	32		TBD	Call TI	Call TI
MSP430F2112TRHBR	ACTIVE	QFN	RHB	32	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
MSP430F2112TRHBT	ACTIVE	QFN	RHB	32	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
MSP430F2122IPW	ACTIVE	TSSOP	PW	28	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
MSP430F2122IPWR	ACTIVE	TSSOP	PW	28	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
MSP430F2122IRHB	PREVIEW	QFN	RHB	32		TBD	Call TI	Call TI
MSP430F2122IRHBR	ACTIVE	QFN	RHB	32	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
MSP430F2122IRHBT	ACTIVE	QFN	RHB	32	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
MSP430F2122TPW	ACTIVE	TSSOP	PW	28	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
MSP430F2122TPWR	ACTIVE	TSSOP	PW	28	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
MSP430F2122TRHB	PREVIEW	QFN	RHB	32		TBD	Call TI	Call TI
MSP430F2122TRHBR	ACTIVE	QFN	RHB	32	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
MSP430F2122TRHBT	ACTIVE	QFN	RHB	32	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
MSP430F2132IPW	ACTIVE	TSSOP	PW	28	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
MSP430F2132IPWR	ACTIVE	TSSOP	PW	28	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
MSP430F2132IRHBR	ACTIVE	QFN	RHB	32	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
MSP430F2132IRHBT	ACTIVE	QFN	RHB	32	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
MSP430F2132TPW	ACTIVE	TSSOP	PW	28	50	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
MSP430F2132TPWR	ACTIVE	TSSOP	PW	28	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
MSP430F2132TRHBR	ACTIVE	QFN	RHB	32	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR

Orderable Device	Status [1]	Package Type	Package Drawing	Pins	Package Qty	Eco Plan [2]	Lead/Ball Finish	MSL Peak Temp [3]
MSP430F2132TRHBT	ACTIVE	QFN	RHB	32	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR

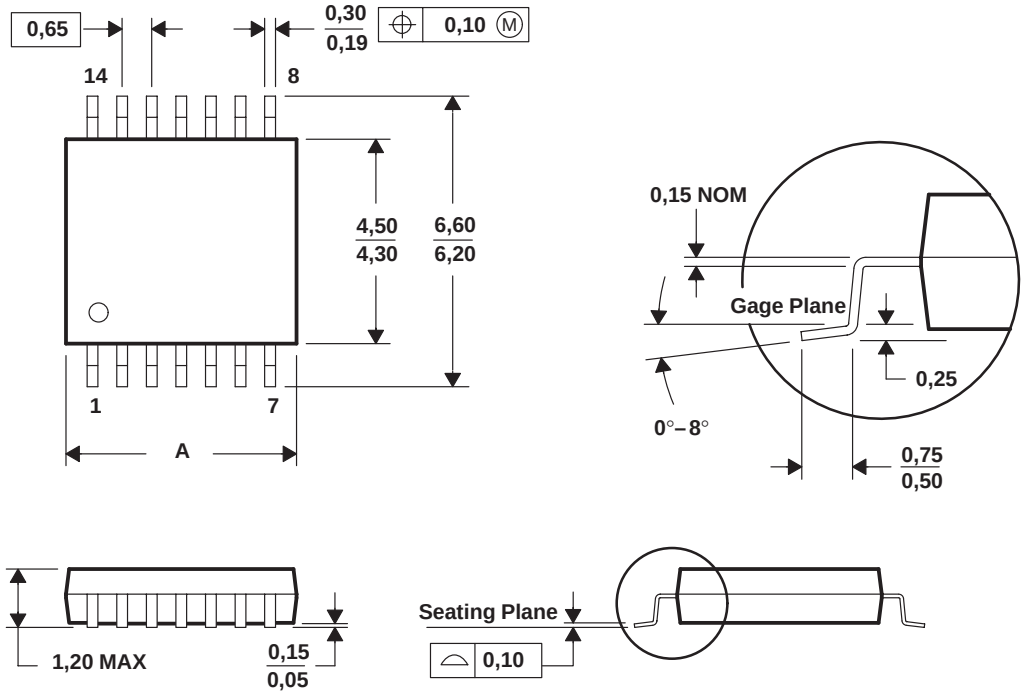
[1] The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, 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] Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

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

PW (R-PDSO-G)** **PLASTIC SMALL-OUTLINE PACKAGE**

14 PINS SHOWN

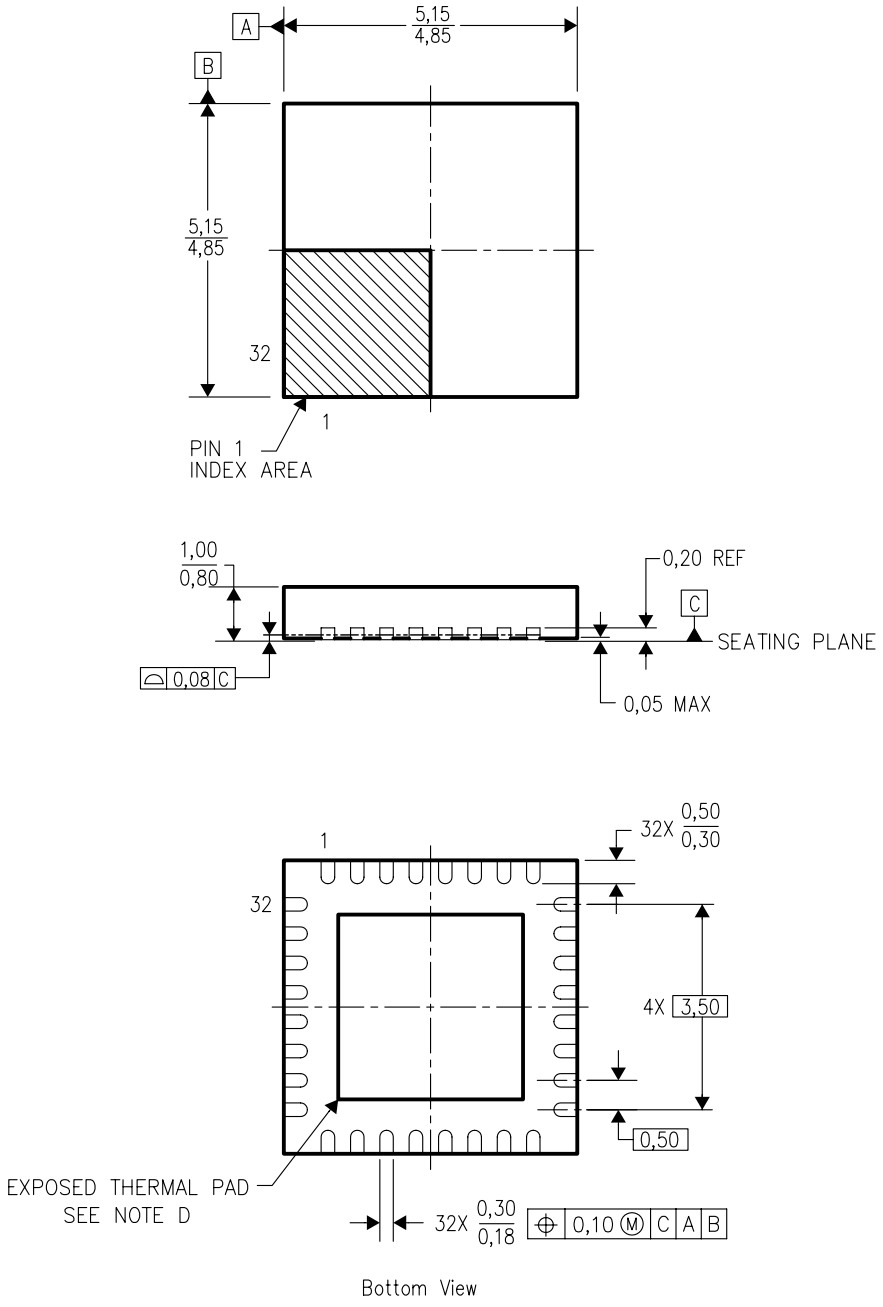


DIM \ PINS **	8	14	16	20	24	28
A MAX	3,10	5,10	5,10	6,60	7,90	9,80
A MIN	2,90	4,90	4,90	6,40	7,70	9,60

4040064/F 01/97

NOTES: A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion not to exceed 0,15.
D. Falls within JEDEC MO-153

RHB (S–PQFP–N32) PLASTIC QUAD FLATPACK



4204326/C xx/04

NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. QFN (Quad Flatpack No–Lead) Package configuration.
D The Package thermal pad must be soldered to the board for thermal and mechanical performance. See product data sheet for details regarding the exposed thermal pad dimensions.
E. Falls within JEDEC MO–220.

THERMAL PAD MECHANICAL DATA

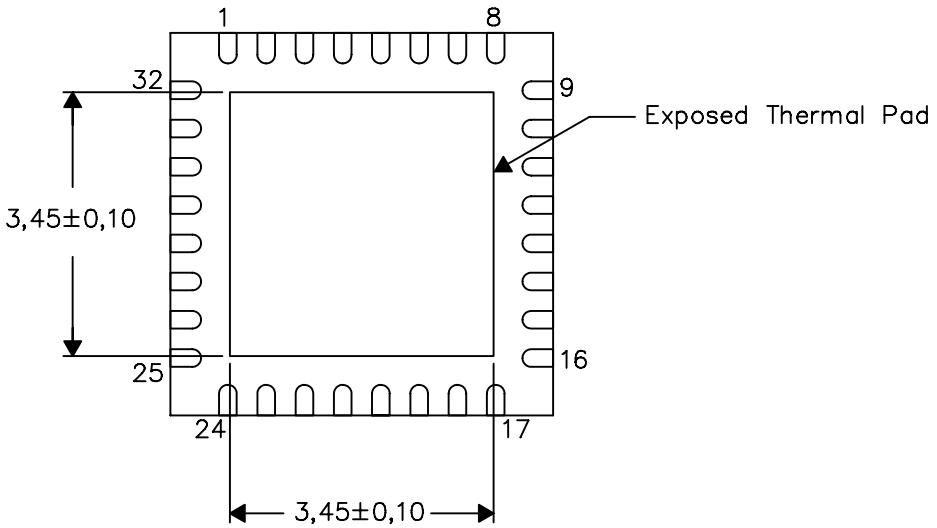
RHB (S–PVQFN–N32)

THERMAL INFORMATION

This package incorporates an exposed thermal pad that is designed to be attached directly to an external heatsink. The thermal pad must be soldered directly to the printed circuit board (PCB). After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For information on the Quad Flatpack No–Lead (QFN) package and its advantages, refer to Application Report, QFN/SON PCB Attachment, Texas Instruments Literature No. SLUA271. This document is available at www.ti.com.

The exposed thermal pad dimensions for this package are shown in the following illustration.

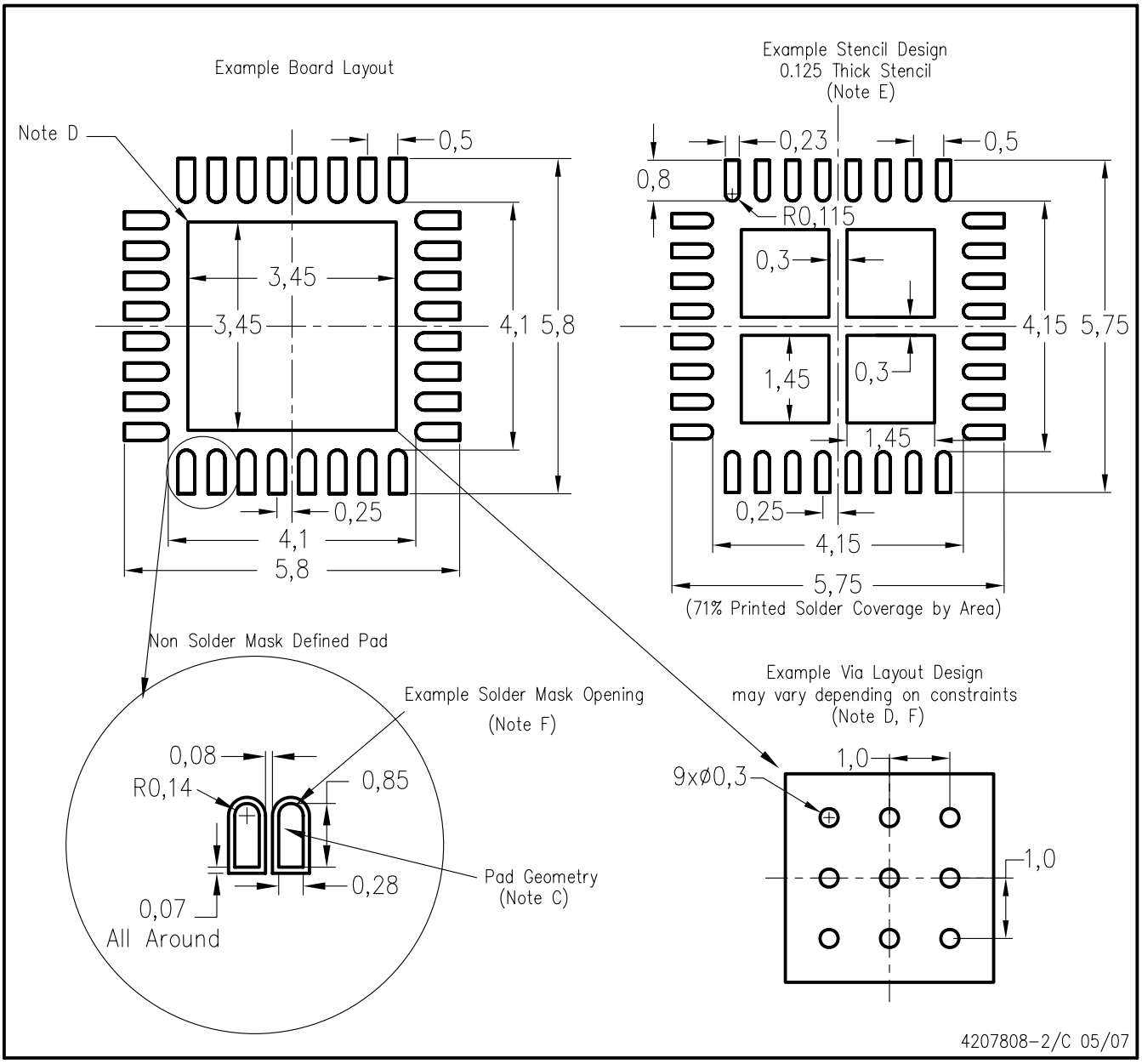


Bottom View

NOTE: All linear dimensions are in millimeters

Exposed Thermal Pad Dimensions

RHB (S–PQFP–N32)



NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Publication IPC–7351 is recommended for alternate designs.
D. This package is designed to be soldered to a thermal pad on the board. Refer to Application Note, Quad Flat–Pack Packages, Texas Instruments Literature No. SCBA017, SLUA271, and also the Product Data Sheets for specific thermal information, via requirements, and recommended board layout. These documents are available at www.ti.com <http://www.ti.com>.
E. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC 7525 for stencil design considerations.
F. Customers should contact their board fabrication site for recommended solder mask tolerances and via tenting recommendations for vias placed in the thermal pad.

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products		**Applications**	
Amplifiers	amplifier.ti.com	Audio	www.ti.com/audio
Data Converters	dataconverter.ti.com	Automotive	www.ti.com/automotive
DSP	dsp.ti.com	Broadband	www.ti.com/broadband
Clocks and Timers	www.ti.com/clocks	Digital Control	www.ti.com/digitalcontrol
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Military	www.ti.com/military
Power Mgmt	power.ti.com	Optical Networking	www.ti.com/opticalnetwork
Microcontrollers	microcontroller.ti.com	Security	www.ti.com/security
RFID	www.ti-rfid.com	Telephony	www.ti.com/telephony
RF/IF and ZigBee® Solutions	www.ti.com/lprf	Video & Imaging	www.ti.com/video
		Wireless	www.ti.com/wireless

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265