- **Low Supply-Voltage Range, 2.7 V . . . 3.6 V**
- **Ultralow-Power Consumption:**
  - **Active Mode: 400 μA at 1 MHz, 3.0 V**
  - **Standby Mode: 1.1 μA**
  - **Off Mode (RAM Retention): 0.1 μA**
- **Five Power-Saving Modes**
- **Wake-Up From Standby Mode in 6 μs**
- **Frequency-Locked Loop, FLL+**
- **16-Bit RISC Architecture, 125-ns Instruction Cycle Time**
- **Embedded Signal Processing for Single-Phase Energy Metering with Integrated Analog Front-End and Temperature Sensor (ESP430CE1)**
- **16-Bit Timer_A With Three Capture/Compare Registers**
- **Integrated LCD Driver for 128 Segments**
- **Serial Communication Interface (USART), Asynchronous UART or Synchronous SPI selectable by software.**
- **Basic Timer to support Real Time Clocks**
- **Brownout Detector**
- **Supply Voltage Supervisor/Monitor With Programmable Level Detection**
- **Serial Onboard Programming, No External Programming Voltage Needed Programmable Code Protection by Security Fuse**
- **Bootstrap Loader in Flash Devices**
- **Family Members Include:**
  - **MSP430FE423:**
    8KB + 256B Flash Memory,
    256B RAM
  - **MSP430FE425:**
    16KB + 256B Flash Memory,
    512B RAM
  - **MSP430FE427:**
    32KB + 256B Flash Memory,
    1KB RAM
- **Available in 64-Pin Quad Flat Pack (QFP)**
- **For Complete Module Descriptions, Refer to the MSP430x4xx Family User's Guide, Literature Number SLAU056**

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description

The Texas Instruments MSP430 family of ultralow power microcontrollers consist of several devices featuring different sets of peripherals targeted for various applications. The architecture, combined with five low power modes is optimized to achieve extended battery life in portable measurement applications. The device features a powerful 16-bit RISC CPU, 16-bit registers, and constant generators that attribute to maximum code efficiency. The digitally controlled oscillator (DCO) allows wake-up from low-power modes to active mode in less than 6μs.

The MSP430xE42x series are microcontroller configurations with three independent 16-bit sigma−delta A/D converters and embedded signal processor core used to measure and calculate single-phase energy in both 2 and 3 wire configurations. Also included is a built-in 16-bit timer, 128 LCD segment drive capability, and 14 I/O pins.

Typical applications include 2-wire and 3-wire single-phase energy metering including tamper-resistant meter implementations.

AVAILABLE OPTIONS

T_A	PACKAGED DEVICES
	PLASTIC 64-PIN QFP (PM)
−40°C to 85°C	MSP430FE423IPM MSP430FE425IPM MSP430FE427IPM

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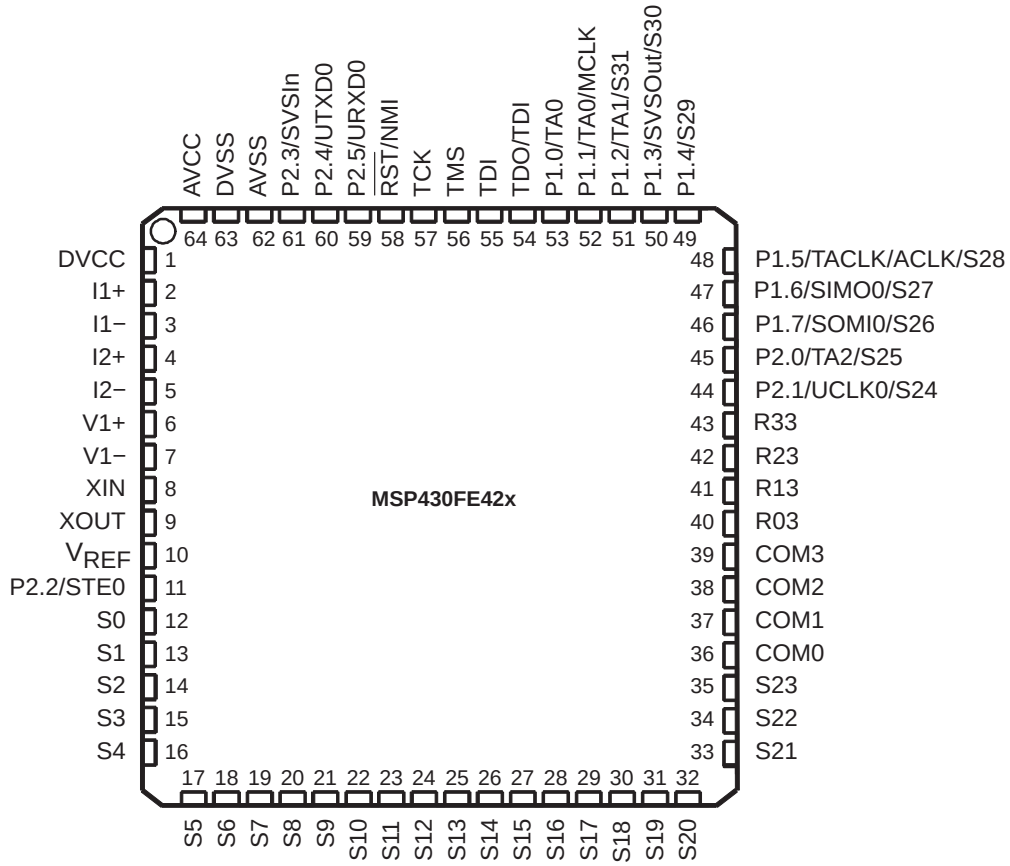
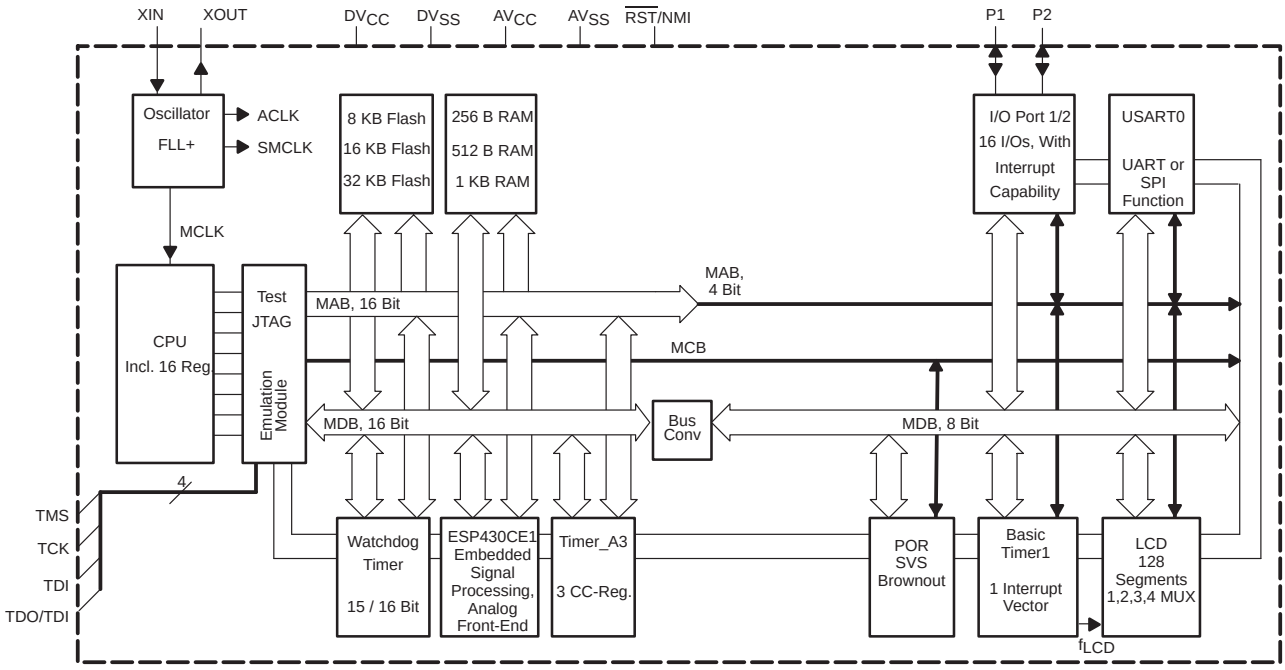
pin designation, MSP430FE42x



functional block diagram



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MSP430FE42x Terminal Functions

TERMINAL PN NAME	TERMINAL PN NO.	I/O	DESCRIPTION
DV_{CC}	1		Digital supply voltage, positive terminal. Supplies all digital parts
I_1+	2	I	Current 1 positive analog input
I_1-	3	I	Current 1 negative analog input
I_2+	4	I	Current 2 positive analog input
I_2-	5	I	Current 2 negative analog input
V_1+	6	I	Voltage 1 positive analog input
V_1-	7	I	Voltage 1 negative analog input
XIN	8	I	Input port for crystal oscillator XT1. Standard or watch crystals can be connected.
XOUT	9	O	Output terminal of crystal oscillator XT1
V_{REF}	10	I/O	Input for an external reference voltage / internal reference voltage output (can be used as mid-voltage)
P2.2/STE0	11	I/O	General-purpose digital I/O / slave transmit enable—USART0/SPI mode
S0	12	O	LCD segment output 0
S1	13	O	LCD segment output 1
S2	14	O	LCD segment output 2
S3	15	O	LCD segment output 3
S4	16	O	LCD segment output 4
S5	17	O	LCD segment output 5
S6	18	O	LCD segment output 6
S7	19	O	LCD segment output 7
S8	20	O	LCD segment output 8
S9	21	O	LCD segment output 9
S10	22	O	LCD segment output 10
S11	23	O	LCD segment output 11
S12	24	O	LCD segment output 12
S13	25	O	LCD segment output 13
S14	26	O	LCD segment output 14
S15	27	O	LCD segment output 15
S16	28	O	LCD segment output 16
S17	29	O	LCD segment output 17
S18	30	O	LCD segment output 18
S19	31	O	LCD segment output 19
S20	32	O	LCD segment output 20
S21	33	O	LCD segment output 21
S22	34	O	LCD segment output 22
S23	35	O	LCD segment output 23
COM0	36	O	Common output, COM0−3 are used for LCD backplanes.
COM1	37	O	Common output, COM0−3 are used for LCD backplanes.
COM2	38	O	Common output, COM0−3 are used for LCD backplanes.
COM3	39	O	Common output, COM0−3 are used for LCD backplanes.
R03	40	I	Input port of fourth positive (lowest) analog LCD level (V5)

MSP430FE42x Terminal Functions (Continued)

TERMINAL		I/O	DESCRIPTION
PN NAME	NO.		
R13	41	I	Input port of third most positive analog LCD level (V4 or V3)
R23	42	I	Input port of second most positive analog LCD level (V2)
R33	43	O	Output port of most positive analog LCD level (V1)
P2.1/UCLK0/S24	44	I/O	General-purpose digital I/O / external clock input-USART0/UART or SPI mode, clock output—USART0/SPI mode / LCD segment output 24 (See Note 1)
P2.0/TA2/S25	45	I/O	General-purpose digital I/O / Timer_A Capture: CCI2A input, Compare: Out2 output / LCD segment output 25 (See Note 1)
P1.7/SOMI0/S26	46	I/O	General-purpose digital I/O / slave out/master in of USART0/SPI mode / LCD segment output 26 (See Note 1)
P1.6/SIMO0/S27	47	I/O	General-purpose digital I/O / slave in/master out of USART0/SPI mode / LCD segment output 27 (See Note 1)
P1.5/TACLK/ ACLK/S28	48	I/O	General-purpose digital I/O / Timer_A and SD16 clock signal TACLK input / ACLK output (divided by 1, 2, 4, or 8) / LCD segment output 28 (See Note 1)
P1.4/S29	49	I/O	General-purpose digital I/O / LCD segment output 29 (See Note 1)
P1.3/SVSOut/ S30	50	I/O	General-purpose digital I/O / SVS: output of SVS comparator / LCD segment output 30 (See Note 1)
P1.2/TA1/S31	51	I/O	General-purpose digital I/O / Timer_A, Capture: CCI1A, CCI1B input, Compare: Out1 output / LCD segment output 31 (See Note 1)
P1.1/TA0/MCLK	52	I/O	General-purpose digital I/O / Timer_A, Capture: CCI0B input / MCLK output. Note: TA0 is only an input on this pin.
P1.0/TA0	53	I/O	General-purpose digital I/O / Timer_A, Capture: CCI0A input, Compare: Out0 output
TDO/TDI	54	I/O	Test data output port. TDO/TDI data output or programming data input terminal
TDI	55	I	Test data input. TDI is used as a data input port. The device protection fuse is connected to TDI.
TMS	56	I	Test mode select. TMS is used as an input port for device programming and test.
TCK	57	I	Test clock. TCK is the clock input port for device programming and test.
$\overline{\text{RST}}$/NMI	58	I	Reset input or nonmaskable interrupt input port
P2.5/URXD0	59	I/O	General-purpose digital I/O / receive data in—USART0/UART mode
P2.4/UTXD0	60	I/O	General-purpose digital I/O / transmit data out—USART0/UART mode
P2.3/SVSIn	61	I/O	General-purpose digital I/O / Analog input to brownout, supply voltage supervisor
AV_{SS}	62		Analog supply voltage, negative terminal. Supplies SD16, SVS, brownout, oscillator, FLL+, and LCD resistive divider circuitry.
DV_{SS}	63		Digital supply voltage, negative terminal. Supplies all digital parts, except those which are supplied via AV_{CC}/AV_{SS}.
AV_{CC}	64		Analog supply voltage, positive terminal. Supplies SD16, SVS, brownout, oscillator, FLL+, and LCD resistive divider circuitry; must not power up prior to DV_{CC}.

NOTE 1: LCD function selected automatically when applicable LCD module control bits are set, not with PxSEL bits.

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short-form description

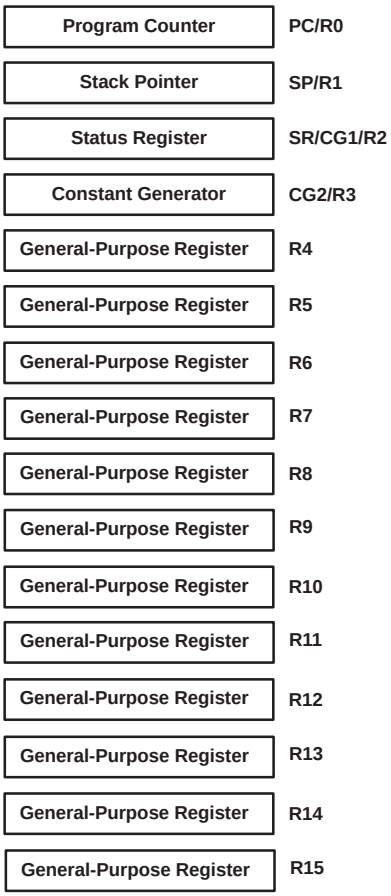
CPU

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

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

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

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



instruction set

The instruction set consists of 51 instructions with three formats and seven address modes. Each instruction can operate on word and byte data. Table 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

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operating modes

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

The following six operating modes can be configured by software:

- Active mode AM;
  - All clocks are active
- Low-power mode 0 (LPM0);
  - CPU is disabled
    ACLK and SMCLK remain active. MCLK is disabled
    FLL+ Loop control remains active
- Low-power mode 1 (LPM1);
  - CPU is disabled
    FLL+ Loop control is disabled
    ACLK and SMCLK remain active. MCLK is disabled
- Low-power mode 2 (LPM2);
  - CPU is disabled
    MCLK and FLL+ loop control and DCOCLK are disabled
    DCO's dc-generator remains enabled
    ACLK remains active
- Low-power mode 3 (LPM3);
  - CPU is disabled
    MCLK, FLL+ loop control, and DCOCLK are disabled
    DCO's dc-generator is disabled
    ACLK remains active
- Low-power mode 4 (LPM4);
  - CPU is disabled
    ACLK is disabled
    MCLK, FLL+ loop control, and DCOCLK are disabled
    DCO's dc-generator is disabled
    Crystal oscillator is stopped

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interrupt vector addresses

The interrupt vectors and the power-up starting address are located in the ROM with an address range 0FFFFh − 0FFE0h. The vector contains the 16-bit address of the appropriate interrupt-handler instruction sequence.

INTERRUPT SOURCE	INTERRUPT FLAG	SYSTEM INTERRUPT	WORD ADDRESS	PRIORITY
Power-up External Reset Watchdog Flash memory PC Out-of-Range (see Note 4)	WDTIFG KEYV (see Note 1)	Reset	0FFFEh	15, highest
NMI Oscillator Fault Flash memory access violation	NMIIFG (see Notes 1 and 3) OFIFG (see Notes 1 and 3) ACCVIFG (see Notes 1 and 3)	(Non)maskable (Non)maskable (Non)maskable	0FFFCh	14
ESP430	MBCTL_OUTxIFG, MBCTL_INxIFG (see Notes 1 and 2)	Maskable	0FFFAh	13
SD16	SD16CCTLx_OVIFG, SD16CCTLx_IFG (see Notes 1 and 2)	Maskable	0FFF8h	12
			0FFF6h	11
Watchdog Timer	WDTIFG	Maskable	0FFF4h	10
USART0 Receive	URXIFG0	Maskable	0FFF2h	9
USART0 Transmit	UTXIFG0	Maskable	0FFF0h	8
			0FFEEh	7
Timer_A3	TACCR0 CCIFG (see Note 2)	Maskable	0FFECh	6
Timer_A3	TACCR1 and TACCR2 CCIFGs, and TACTL TAIFG (see Notes 1 and 2)	Maskable	0FFEAh	5
I/O port P1 (eight flags)	P1IFG.0 (see Notes 1 and 2) To P1IFG.7 (see Notes 1 and 2)	Maskable	0FFE8h	4
			0FFE6h	3
			0FFE4h	2
I/O port P2 (eight flags)	P2IFG.0 (see Notes 1 and 2) To P2IFG.7 (see Notes 1 and 2)	Maskable	0FFE2h	1
Basic Timer1	BTIFG	Maskable	0FFE0h	0, lowest

NOTES: 1. Multiple source flags
2. Interrupt flags are located in the module.
3. (Non)maskable: the individual interrupt-enable bit can disable an interrupt event, but the general interrupt-enable cannot.
4. A reset is generated if the CPU tries to fetch instructions from within the module register memory address range (0h-01FFh).

special function registers

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

interrupt enable 1 and 2

Address	7	6	5	4	3	2	1	0
0h	UTXIE0	URXIE0	ACCVIE	NMIIE			OFIE	WDTIE
	rw–0	rw–0	rw–0	rw–0			rw–0	rw–0

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

OFIE: Oscillator-fault-interrupt enable

NMIIE: Nonmaskable-interrupt enable

ACCVIE: Flash access violation interrupt enable

URXIE0: USART0, UART, and SPI receive-interrupt enable

UTXIE0: USART0, UART, and SPI transmit-interrupt enable

Address	7	6	5	4	3	2	1	0
1h	BTIE							
	rw-0							

BTIE: Basic Timer1 interrupt enable

interrupt flag register 1 and 2

Address	7	6	5	4	3	2	1	0
02h	UTXIFG0	URXIFG0		NMIIFG			OFIFG	WDTIFG
	rw–1	rw–0		rw–0			rw–1	rw–0

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

OFIFG: Flag set on oscillator fault

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

URXIFG0: USART0, UART, and SPI receive flag

UTXIFG0: USART0, UART, and SPI transmit flag

Address	7	6	5	4	3	2	1	0
3h	BTIFG							
	rw-0							

BTIFG: Basic Timer1 interrupt flag

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module enable registers 1 and 2

Address	7	6	5	4	3	2	1	0
04h	UTXE0	URXE0 USPIE0						
	rw–0	rw–0						

URXE0: USART0, UART mode receive enable

UTXE0: USART0, UART mode transmit enable

USPIE0: USART0, SPI mode transmit and receive enable

Address	7	6	5	4	3	2	1	0
05h								

Legend: rw: **Bit Can Be Read and Written**
rw-0: **Bit Can Be Read and Written. It Is Reset by PUC.**
SFR Bit Not Present in Device

memory organization

		MSP430FE423	MSP430FE425	MSP430FE427
Memory	Size	8KB	16KB	32KB
Interrupt vector	Flash	0FFFFh − 0FFE0h	0FFFFh − 0FFE0h	0FFFFh − 0FFE0h
Code memory	Flash	0FFFFh − 0E000h	0FFFFh − 0C000h	0FFFFh − 08000h
Information memory	Size	256 Byte 010FFh − 01000h	256 Byte 010FFh − 01000h	256 Byte 010FFh − 01000h
Boot memory	Size	1kB 0FFFh − 0C00h	1kB 0FFFh − 0C00h	1kB 0FFFh − 0C00h
RAM	Size	256 Byte 02FFh − 0200h	512 Byte 03FFh − 0200h	1KB 05FFh − 0200h
Peripherals	16-bit	01FFh − 0100h	01FFh − 0100h	01FFh − 0100h
	8-bit	0FFh − 010h	0FFh − 010h	0FFh − 010h
	8-bit SFR	0Fh − 00h	0Fh − 00h	0Fh − 00h

bootstrap loader (BSL)

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

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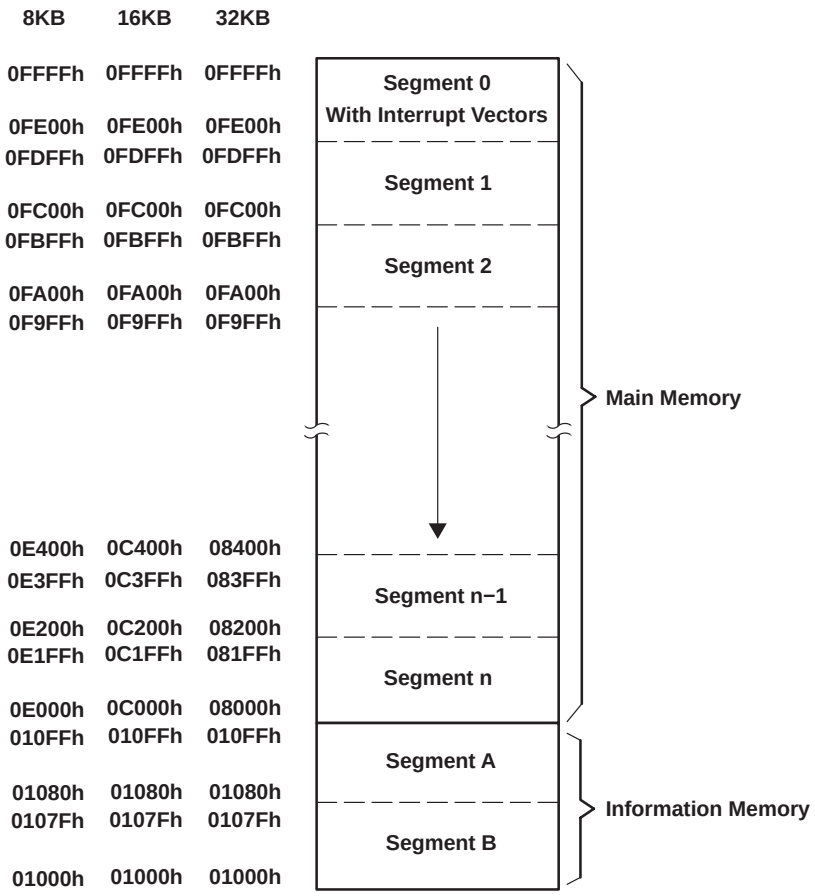
flash memory

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

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

flash memory (continued)



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peripherals

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

oscillator and system clock

The clock system in the MSP430FE42x family of devices is supported by the FLL+ module that includes support for a 32768-Hz watch crystal oscillator, an internal digitally-controlled oscillator (DCO) and a high frequency crystal oscillator. The FLL+ clock module is designed to meet the requirements of both low system cost and low-power consumption. The FLL+ features a digital frequency locked loop (FLL) hardware which in conjunction with a digital modulator stabilizes the DCO frequency to a programmable multiple of the watch crystal frequency. The internal DCO provides a fast turn-on clock source and stabilizes in less than 6 μs. The FLL+ module provides the following clock signals:

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

brownout, supply voltage supervisor

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

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

digital I/O

There are two 8-bit I/O ports implemented—ports P1 and P2 (only six P2 I/O signals are available on external pins):

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

NOTE:
Six bits of port P2, P2.0 to P2.5, are available on external pins - but all control and data bits for port P2 are implemented.

Basic Timer1

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

LCD drive

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

WDT+ watchdog timer

The primary function of the watchdog timer (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.

timer_A3

Timer_A3 is a 16-bit timer/counter with three capture/compare registers. Timer_A3 can support multiple capture/compares, PWM outputs, and interval timing. Timer_A3 also has extensive interrupt capabilities. Interrupts may be generated from the counter on overflow conditions and from each of the capture/compare registers.

Timer_A3 Signal Connections				
Input Pin Number	**Device Input Signal**	**Module Input Name**	**Module Output Signal**	**Output Pin Number**
48 - P1.5	TACLK	TACLK	NA	
	ACLK	ACLK		
	SMCLK	SMCLK		
48 - P1.5	$\overline{\text{TACLK}}$	INCLK		
53 - P1.0	TA0	CCI0A	TA0	53 - P1.0
52 - P1.1	TA0	CCI0B		
	DVss	GND		
	DV_{CC}	V_{CC}		
51 - P1.2	TA1	CCI1A	TA1	51 - P1.2
51 - P1.2	TA1	CCI1B		
	DVss	GND		
	DV_{CC}	V_{CC}		
45 - P2.0	TA2	CCI2A	TA2	45 - P2.0
	ACLK (internal)	CCI2B		
	DVss	GND		
	DV_{CC}	V_{CC}		

USART0

The MSP430FE42x devices have one hardware universal synchronous/asynchronous receive transmit (USART0) peripheral module that is used for serial data communication. The USART supports synchronous SPI (3 or 4 pin) and asynchronous UART communication protocols, using double-buffered transmit and receive channels.

ESP430CE1

The ESP430CE1 module integrates a hardware multiplier, three independent 16-bit Sigma-Delta A/D converters (SD16) and an embedded signal processor (ESP430). The ESP430CE1 module measures 2 or 3-wire, single-phase energy and automatically calculates parameters which are made available to the MSP430 CPU. The module can be calibrated and initialized to accurately calculate energy, power factor, etc for a wide range of metering sensor configurations.

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peripheral file map

PERIPHERALS WITH WORD ACCESS			
Watchdog	Watchdog Timer control	WDTCTL	0120h
Timer_A3	Timer_A interrupt vector	TAIV	012Eh
	Timer_A control	TACTL	0160h
	Capture/compare control 0	TACCTL0	0162h
	Capture/compare control 1	TACCTL1	0164h
	Capture/compare control 2	TACCTL2	0166h
	Reserved		0168h
	Reserved		016Ah
	Reserved		016Ch
	Reserved		016Eh
	Timer_A register	TAR	0170h
	Capture/compare register 0	TACCR0	0172h
	Capture/compare register 1	TACCR1	0174h
	Capture/compare register 2	TACCR2	0176h
	Reserved		0178h
	Reserved		017Ah
	Reserved		017Ch
	Reserved		017Eh
Multiply (ESP430CE1)	Sum extend	SUMEXT	013Eh
	Result high word	RESHI	013Ch
	Result low word	RESLO	013Ah
	Second operand	OP2	0138h
	Multiply signed + accumulate/operand1	MACS	0136h
	Multiply + accumulate/operand1	MAC	0134h
	Multiply signed/operand1	MPYS	0132h
	Multiply unsigned/operand1	MPY	0130h
Flash	Flash control 3	FCTL3	012Ch
	Flash control 2	FCTL2	012Ah
	Flash control 1	FCTL1	0128h
SD16 (ESP430CE1) (see also: Peripherals with Byte Access)	General Control	SD16CTL	0100h
	Channel 0 Control	SD16CCTL0	0102h
	Channel 1 Control	SD16CCTL1	0104h
	Channel 2 Control	SD16CCTL2	0106h
	Reserved		0108h
	Reserved		010Ah
	Reserved		010Ch
	Reserved		010Eh
	Reserved		0110h
	Reserved		0112h

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PERIPHERALS WITH WORD ACCESS			
SD16 (continued)	Reserved		0114h
	Reserved		0116h
	Reserved		0118h
	Reserved		011Ah
	Reserved		011Ch
	Reserved		011Eh
ESP430 (ESP430CE1)	ESP430 Control	ESPCTL	0150h
	Mailbox Control	MBCTL	0152h
	Mailbox In 0	MBIN0	0154h
	Mailbox In 1	MBIN1	0156h
	Mailbox Out 0	MBOUT0	0158h
	Mailbox Out 1	MBOUT1	015Ah
	ESP430 Return Value 0	RET0	01C0h
	:	:	:
	ESP430 Return Value 31	RET31	01FEh

PERIPHERALS WITH BYTE ACCESS			
SD16 (ESP430CE1) (see also: Peripherals with Word Access)	Channel 0 Input Control	SD16INCTL0	0B0h
	Channel 1 Input Control	SD16INCTL1	0B1h
	Channel 2 Input Control	SD16INCTL2	0B2h
	Reserved		0B3h
	Reserved		0B4h
	Reserved		0B5h
	Reserved		0B6h
	Reserved (VREF Trimming 0)	(SD16TRIM0)	0B7h
	Reserved		0B8h
	Reserved		0B9h
	Reserved		0BAh
	Reserved		0BBh
	Reserved		0BCh
	Reserved		0BDh
	Reserved		0BEh
	Reserved (VREF Trimming 1)	(SD16TRIM1)	0BFh
LCD	LCD memory 20	LCDM20	0A4h
	:	:	:
	LCD memory 16	LCDM16	0A0h
	LCD memory 15	LCDM15	09Fh
	:	:	:
	LCD memory 1	LCDM1	091h
	LCD control and mode	LCDCTL	090h

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peripheral file map (continued)

PERIPHERALS WITH BYTE ACCESS (CONTINUED)			
USART0	Transmit buffer	U0TXBUF	077h
	Receive buffer	U0RXBUF	076h
	Baud rate	U0BR1	075h
	Baud rate	U0BR0	074h
	Modulation control	U0MCTL	073h
	Receive control	U0RCTL	072h
	Transmit control	U0TCTL	071h
	USART control	U0CTL	070h
Brownout, SVS	SVS control register	SVSCTL	056h
FLL+ Clock	FLL+ Control1	FLL_CTL1	054h
	FLL+ Control0	FLL_CTL0	053h
	System clock frequency control	SCFQCTL	052h
	System clock frequency integrator	SCFI1	051h
	System clock frequency integrator	SCFI0	050h
Basic Timer1	BT counter2	BTCNT2	047h
	BT counter1	BTCNT1	046h
	BT control	BTCTL	040h
Port P2	Port P2 selection	P2SEL	02Eh
	Port P2 interrupt enable	P2IE	02Dh
	Port P2 interrupt-edge select	P2IES	02Ch
	Port P2 interrupt flag	P2IFG	02Bh
	Port P2 direction	P2DIR	02Ah
	Port P2 output	P2OUT	029h
	Port P2 input	P2IN	028h
Port P1	Port P1 selection	P1SEL	026h
	Port P1 interrupt enable	P1IE	025h
	Port P1 interrupt-edge select	P1IES	024h
	Port P1 interrupt flag	P1IFG	023h
	Port P1 direction	P1DIR	022h
	Port P1 output	P1OUT	021h
	Port P1 input	P1IN	020h
Special Functions	SFR module enable 2	ME2	005h
	SFR module enable 1	ME1	004h
	SFR interrupt flag 2	IFG2	003h
	SFR interrupt flag 1	IFG1	002h
	SFR interrupt enable2	IE2	001h
	SFR interrupt enable1	IE1	000h

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absolute maximum ratings†

Voltage applied at V_{CC} to V_{SS} (see Note 1) . . . . . −0.3 V to + 4.1 V
Voltage applied to any pin (referenced to V_{SS}) (see Note 1) . . . . . −0.3 V to V_{CC} + 0.3 V
Diode current at any device terminal . . . . . ±2 mA
Storage temperature (unprogrammed device) . . . . . −55°C to 150°C
Storage temperature (programmed device) . . . . . −40°C to 85°C

† 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.

NOTE 1: All voltages referenced to V_{SS}.

recommended operating conditions

PARAMETER			MIN	NOM	MAX	UNITS
Supply voltage during program execution V_{CC} (AV_{CC} = DV_{CC} = V_{CC})		MSP430FE42x	1.8		3.6	V
Supply voltage during programming flash memory, V_{CC} (AV_{CC} = DV_{CC} = V_{CC})		MSP430FE42x	2.7		3.6	V
Supply voltage, V_{SS} (AV_{SS} = DV_{SS} = V_{SS})			0		0	V
Operating free-air temperature range, T_A		MSP430FE42x	−40		85	°C
LFXT1 crystal frequency, $f_{(LFXT1)}$ (see Note 2)	LF selected, XTS_FLL=0	Watch crystal		32768		Hz
	XT1 selected, XTS_FLL=1	Ceramic resonator	450		8000	kHz
	XT1 selected, XTS_FLL=1	Crystal	1000		8000	kHz
Processor frequency (signal MCLK), $f_{(System)}$		V_{CC} = 2.7 V	DC		6	MHz
		V_{CC} = 3.6 V	DC		8	
Flash-timing-generator frequency, $f_{(FTG)}$		MSP430FE42x	257		476	kHz
Cumulative program time, $t_{(CPT)}$ (see Note 3)		V_{CC} = 2.7 V/3.6 V MSP430FE42x			3	ms
Cumulative mass erase time, $t_{(CMEras)}$ (see Note 4)		V_{CC} = 2.7 V/3.6 V MSP430FE42x	200			ms
Low-level input voltage (TCK, TMS, TDI, $\overline{RST}$/NMI), V_{IL} (excluding XIN, XOUT)		V_{CC} = 3 V	V_{SS}		V_{SS} + 0.6	V
High-level input voltage (TCK, TMS, TDI, $\overline{RST}$/NMI), V_{IH} (excluding XIN, XOUT)		V_{CC} = 3 V	0.8 × V_{CC}		V_{CC}	V
Input levels at XIN and XOUT	$V_{IL(XIN, XOUT)}$	V_{CC} = 2.7 V/3 V XTS_FLL=1	V_{SS}		0.2×V_{CC}	V
	$V_{IH(XIN, XOUT)}$		0.8×V_{CC}		V_{CC}	

NOTES: 1. The minimum operating supply voltage is defined according to the trip point where POR is going active by decreasing supply voltage. POR is going inactive when the supply voltage is raised above minimum supply voltage plus the hysteresis of the SVS circuitry.
2. The LFXT1 oscillator in LF-mode requires a watch crystal.
3. The cumulative program time must not be exceeded during a block-write operation.
4. The mass-erase duration generated by the flash timing generator is at least 11.1 ms. The cumulative mass-erase time needed is 200 ms. This can be achieved by repeating the mass-erase operation until the cumulative mass-erase time is met (a minimum of 19 cycles may be required).

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

supply current into AV_{CC} + DV_{CC} excluding external current, (see Note 1)

PARAMETER		TEST CONDITIONS		MIN	NOM	MAX	UNIT
$I_{(AM)}$	Active mode, $f_{(MCLK)} = f_{(SMCLK)}$ = 1 MHz, $f_{(ACLK)}$ = 32,768 Hz, XTS_FLL = 0	T_A = −40°C to 85°C	V_{CC} = 3 V		400	550	µA
$I_{(LPM0)}$	Low-power mode, (LPM0) FN_8=FN_4=FN_3=FN_2=0	T_A = −40°C to 85°C	V_{CC} = 3 V		55	70	µA
$I_{(LPM2)}$	Low-power mode, (LPM2) (see Note 3)	T_A = −40°C to 85°C	V_{CC} = 3 V		17	22	µA
$I_{(LPM3)}$	Low-power mode, (LPM3) (see Notes 2 and 3)	T_A = −40°C	V_{CC} = 3 V		1.8	2.2	µA
		T_A = 25°C			1.6	1.9	
		T_A = 60°C			2.5	3.5	
		T_A = 85°C			4.2	7.5	
$I_{(LPM4)}$	Low-power mode, (LPM4) (see Note 3)	T_A = −40°C	V_{CC} = 3 V		0.1	0.5	µA
		T_A = 25°C			0.1	0.5	
		T_A = 85°C			1.9	3.5	

NOTES: 1. All inputs are tied to 0 V or V_{CC}. Outputs do not source or sink any current. The current consumption in LPM2, LPM3, and LPM4 are measured with active Basic Timer1 and LCD (ACLK selected).
The current consumption of the ESP430CE1 and the SVS module are specified in the respective sections.
2. The LPM3 currents are characterized with a KDS Daishinku DT−38 (6 pF) crystal.
3. LPMx currents measured with WDT+ disabled.

current consumption of active mode versus system frequency, F version

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

current consumption of active mode versus supply voltage, F version

$$I_{(AM)} = I_{(AM)\ [3\ V]} + 140\ \mu A/V \times (V_{CC} - 3\ V)$$

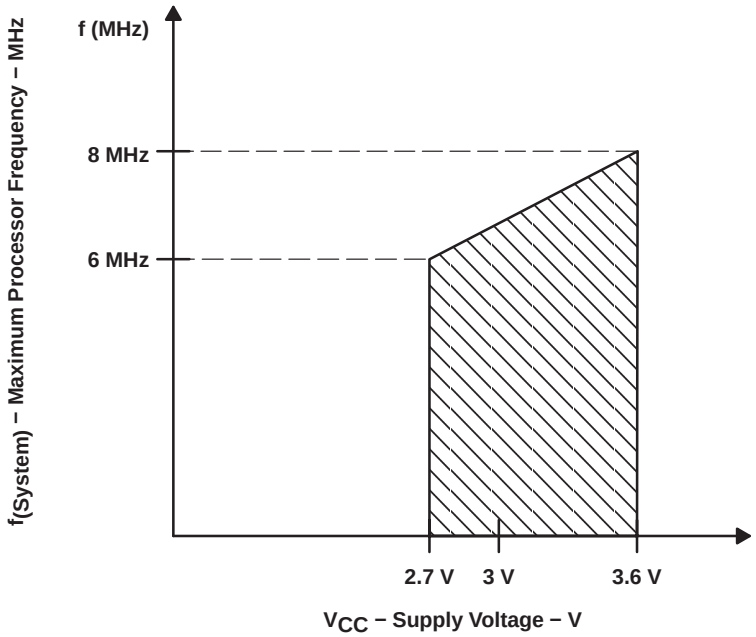

Figure 1. Frequency vs Supply Voltage

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

Schmitt-trigger inputs − Ports P1 and P2; $\overline{\text{RST}}$/NMI; JTAG: TCK, TMS, TDI, TDO

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{IT+}	Positive-going input threshold voltage	V_{CC} = 3 V	1.5		1.9	V
V_{IT-}	Negative-going input threshold voltage	V_{CC} = 3 V	0.9		1.3	V
V_{hys}	Input voltage hysteresis ($V_{IT+} - V_{IT-}$)	V_{CC} = 3 V	0.45		1	V

outputs − Ports P1 and P2

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

NOTES: 1. The maximum total current, $I_{OH(max)}$ and $I_{OL(max)}$, for all outputs combined, should not exceed ±12 mA to satisfy the maximum specified voltage drop.
2. The maximum total current, $I_{OH(max)}$ and $I_{OL(max)}$, for all outputs combined, should not exceed ±24 mA to satisfy the maximum specified voltage drop.

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

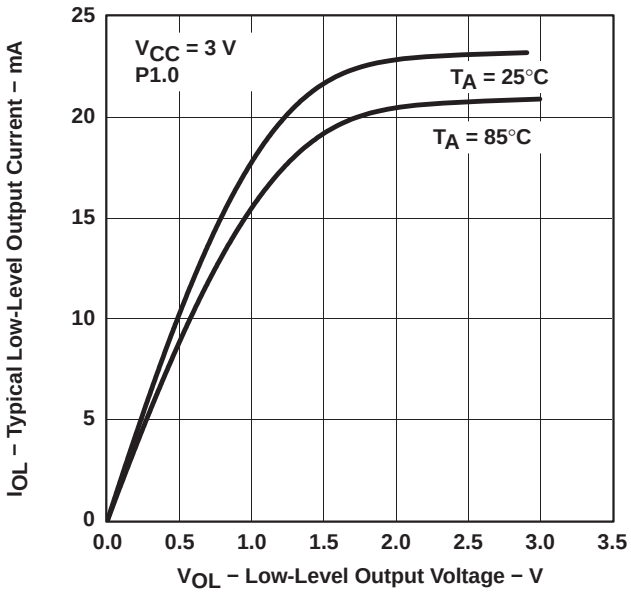

Figure 2

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

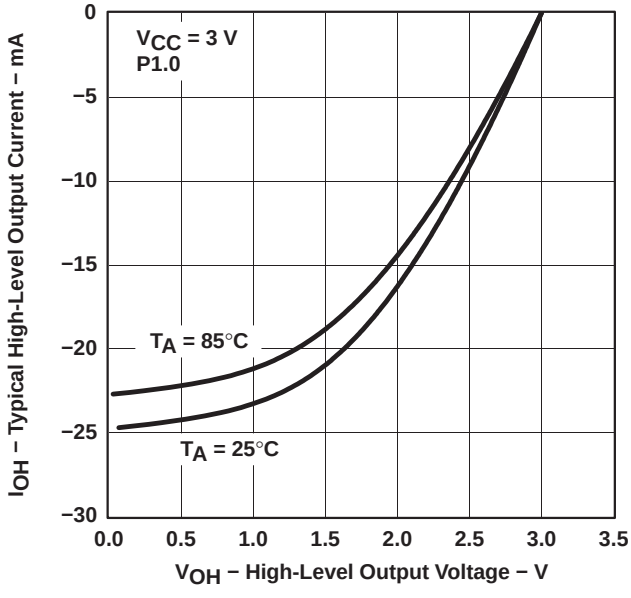

Figure 3

NOTE: One output loaded at a time

PRODUCT PREVIEW

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

inputs Px.x, TAx

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
$t_{(int)}$	External interrupt timing	Port P1, P2: P1.x to P2.x, External trigger signal for the interrupt flag, (see Note 1)	3 V	1.5			cycle
			3 V	50			ns
$t_{(cap)}$	Timer_A, capture timing	TAx, (see Note 2)	3 V	1.5			cycle
			3 V	50			ns
$f_{(TAext)}$	Timer_A clock frequency externally applied to pin	TACLK, INCLK $t_{(H)} = t_{(L)}$	3 V			10	MHz
$f_{(TAint)}$	Timer_A clock frequency	SMCLK or ACLK signal selected	3 V			10	MHz

NOTES: 1. The external signal sets the interrupt flag every time the minimum $t_{(int)}$ cycle and time parameters are met. It may be set even with trigger signals shorter than $t_{(int)}$. Both the cycle and timing specifications must be met to ensure the flag is set. $t_{(int)}$ is measured in MCLK cycles.

2. The external capture signal triggers the capture event every time the minimum $t_{(cap)}$ cycle and time parameters are met. A capture may be triggered with capture signals even shorter than $t_{(cap)}$. Both the cycle and timing specifications must be met to ensure a correct capture of the 16-bit timer value and to ensure the flag is set.

output frequency

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$f_{Px.y}$	$(1 \le x \le 2,\ 0 \le y \le 7)$	C_L = 20 pF, I_L = ± 1.5mA	V_{CC} = 3 V	DC		7.5	MHz
f_{ACLK}, f_{MCLK}, f_{SMCLK}	P1.1/TA0/MCLK, P1.5/TACLK/ACLK	C_L = 20 pF	V_{CC} = 3 V			12	MHz
t_{Xdc}	Duty cycle of output frequency	P1.5/TACLK/ACLK, C_L = 20 pF V_{CC} = 3 V	$f_{ACLK} = f_{LFXT1} = f_{XT1}$	40%		60%	
			$f_{ACLK} = f_{LFXT1} = f_{LF}$	30%		70%	
			$f_{ACLK} = f_{LFXT1}$		50%		
		P1.1/TA0/MCLK, C_L = 20 pF, V_{CC} = 3 V	$f_{MCLK} = f_{XT1}$	40%		60%	
			$f_{MCLK} = f_{DCOCLK}$	50%− 15 ns	50%	50%+ 15 ns	

wake-up LPM3 (see Note 1)

PARAMETER		TEST CONDITIONS	MIN	NOM	MAX	UNIT
$t_{(LPM3)}$	Delay time	V_{CC} = 3 V			6	µs

NOTE 1: The delay time $t_{(LPM3)}$ is independent of the system frequency and V_{CC}.

leakage current (see Note 1)

PARAMETER			TEST CONDITIONS		MIN	NOM	MAX	UNIT
$I_{lkg(P1.x)}$	Leakage current	Port P1	Port 1: $V_{(P1.x)}$ (see Note 2)	V_{CC} = 3 V			±50	nA
$I_{lkg(P2.x)}$		Port P2	Port 2: $V_{(P2.x)}$ (see Note 2)				±50	

NOTES: 1. The leakage current is measured with V_{SS} or V_{CC} applied to the corresponding pin(s), unless otherwise noted.

2. The port pin must be selected as an input.

RAM (see Note 1)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
VRAMh	CPU halted (see Note 1)	1.6			V

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

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

LCD

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$V_{(33)}$	Analog voltage	Voltage at R33	V_{CC} = 3 V	2.5		V_{CC} +0.2	V
$V_{(23)}$		Voltage at R23			$(V_{33}-V_{03}) \times 2/3 + V_{03}$		
$V_{(13)}$		Voltage at R13			$(V_{(33)}-V_{(03)}) \times 1/3 + V_{(03)}$		
$V_{(33)} - V_{(03)}$		Voltage at R33/R03		2.5		V_{CC} +0.2	
$I_{(R03)}$	Input leakage	R03 = V_{SS}	No load at all segment and common lines, V_{CC} = 3 V			±20	nA
$I_{(R13)}$		R13 = $V_{CC}/3$				±20	
$I_{(R23)}$		R23 = $2 \times V_{CC}/3$				±20	
$V_{(Sxx0)}$	Segment line voltage	$I_{(Sxx)}$ = −3 µA,	V_{CC} = 3 V	$V_{(03)}$		$V_{(03)}$ − 0.1	V
$V_{(Sxx1)}$				$V_{(13)}$		$V_{(13)}$ − 0.1	
$V_{(Sxx2)}$				$V_{(23)}$		$V_{(23)}$ − 0.1	
$V_{(Sxx3)}$				$V_{(33)}$		$V_{(33)}$ + 0.1	

USART0 (see Note 1)

PARAMETER		TEST CONDITIONS	MIN	NOM	MAX	UNIT
$t_{(\tau)}$	USART0: deglitch time	V_{CC} = 3 V	150	280	500	ns

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

POR brownout, reset (see Notes 1 and 2)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{d(BOR)}$	Brownout				2000	µs
$V_{CC(start)}$		$dV_{CC}/dt \le 3$ V/s (see Figure 4)		$0.7 \times V_{(B\_IT-)}$		V
$V_{(B\_IT-)}$		$dV_{CC}/dt \le 3$ V/s (see Figure 4, Figure 5, Figure 6)			1.71	V
$V_{hys(B\_IT-)}$		$dV_{CC}/dt \le 3$ V/s (see Figure 4)	70	130	180	mV
$t_{(reset)}$		Pulse length needed at $\overline{RST}$/NMI pin to accepted reset internally, V_{CC} = 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 ≤ 1.8 V.

2. During power up, the CPU begins code execution following a period of $t_{d(BOR)}$ after $V_{CC} = V_{(B\_IT-)} + V_{hys(B\_IT-)}$. The default FLL+ settings must not be changed until $V_{CC} \ge V_{CC(min)}$. See the *MSP430x4xx Family User's Guide* (SLAU056) for more information on the brownout/SVS circuit.

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

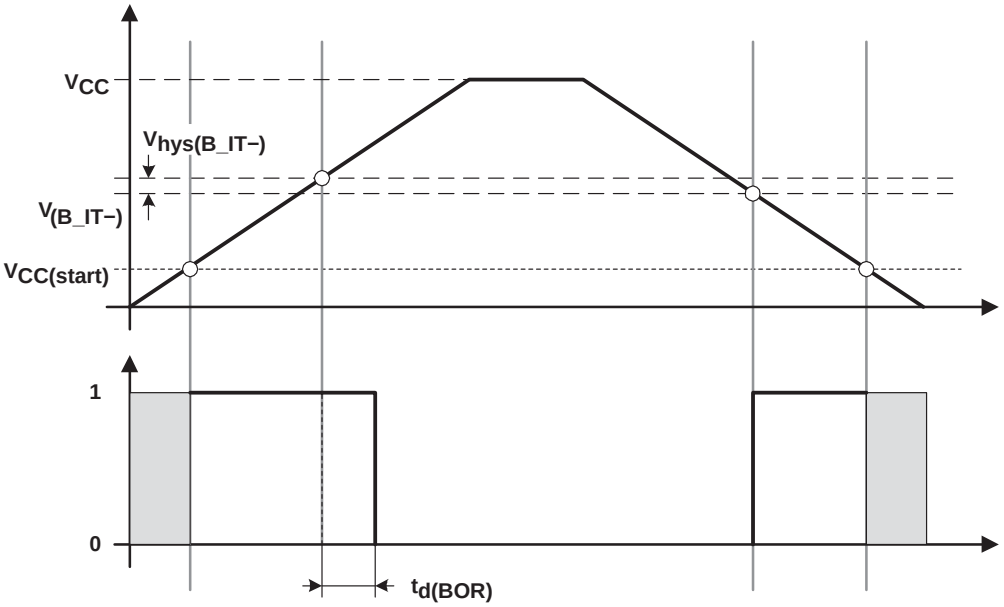

Figure 4. POR/Brownout Reset (BOR) vs Supply Voltage

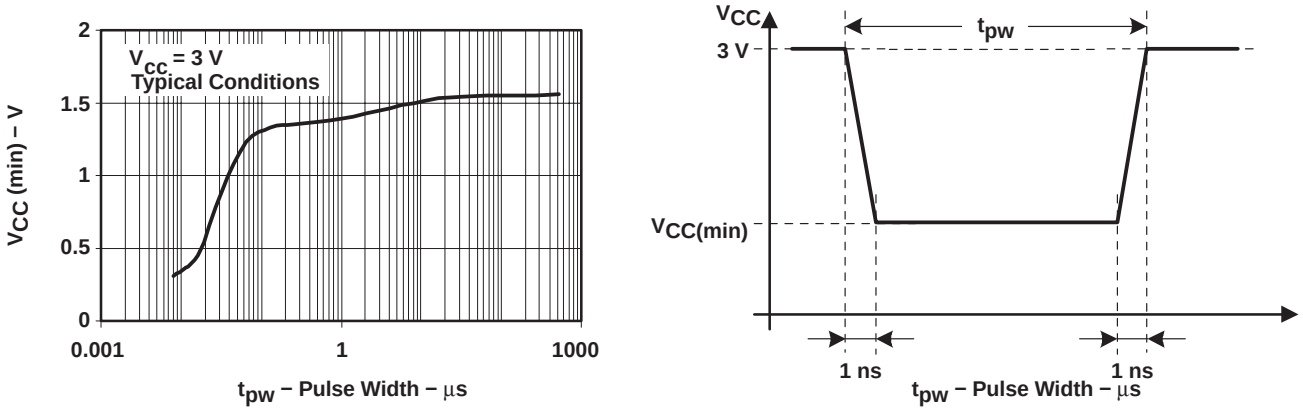

Figure 5. $V_{CC(min)}$ Level With a Square Voltage Drop to Generate a POR/Brownout Signal

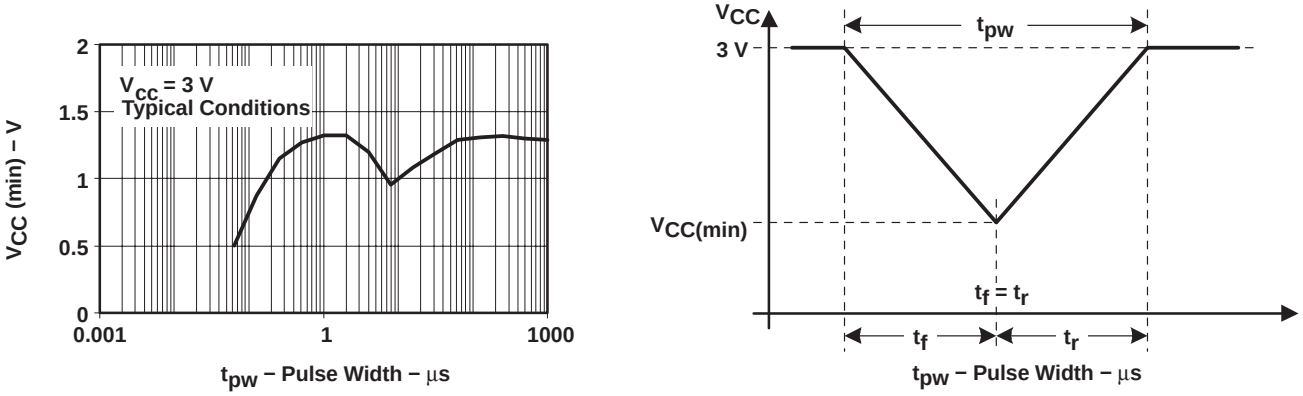

Figure 6. $V_{CC(min)}$ Level With a Triangle Voltage Drop to Generate a POR/Brownout Signal

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

SVS (supply voltage supervisor/monitor) (see Note 1)

PARAMETER	TEST CONDITIONS		MIN	NOM	MAX	UNIT
$t_{(SVSR)}$	dV_{CC}/dt > 30 V/ms (see Figure 7)		5		150	µs
	$dV_{CC}/dt \le$ 30 V/ms				2000	µs
$t_{d(SVSon)}$	SVSon, switch from VLD=0 to VLD ≠ 0, V_{CC} = 3 V		20		150	µs
t_{settle}	VLD ≠ 0‡				12	µs
$V_{(SVSstart)}$	VLD ≠ 0, $V_{CC}/dt \le$ 3 V/s (see Figure 7)			1.55	1.7	V
$V_{hys(B\_IT-)}$	$V_{CC}/dt \le$ 3 V/s (see Figure 7)	VLD = 1	70	120	155	mV
		VLD = 2 .. 14	$V_{(SVS\_IT-)}$ x 0.004		$V_{(SVS\_IT-)}$ x 0.008	
	$V_{CC}/dt \le$ 3 V/s (see Figure 7), external voltage applied on P2.3	VLD = 15	4.4		10.4	mV
$V_{(SVS\_IT-)}$	$V_{CC}/dt \le$ 3 V/s (see Figure 7)	VLD = 1	1.8	1.9	2.05	V
		VLD = 2	1.94	2.1	2.25	
		VLD = 3	2.05	2.2	2.37	
		VLD = 4	2.14	2.3	2.48	
		VLD = 5	2.24	2.4	2.6	
		VLD = 6	2.33	2.5	2.71	
		VLD = 7	2.46	2.65	2.86	
		VLD = 8	2.58	2.8	3	
		VLD = 9	2.69	2.9	3.13	
		VLD = 10	2.83	3.05	3.29	
		VLD = 11	2.94	3.2	3.42	
		VLD = 12	3.11	3.35	3.61†	
		VLD = 13	3.24	3.5	3.76†	
		VLD = 14	3.43	3.7†	3.99†	
	$V_{CC}/dt \le$ 3 V/s (see Figure 7), external voltage applied on P2.3	VLD = 15	1.1	1.2	1.3	
$I_{CC(SVS)}$ (see Note 1)	VLD ≠ 0, V_{CC} = 2.2 V/3 V			10	15	µA

† The recommended operating voltage range is limited to 3.6 V.

‡ t_{settle} is the settling time that the comparator o/p needs to have a stable level after VLD is switched VLD ≠ 0 to a different VLD value somewhere between 2 and 15. The overdrive is assumed to be > 50 mV.

NOTE 1: The current consumption of the SVS module is not included in the I_{CC} current consumption data.

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

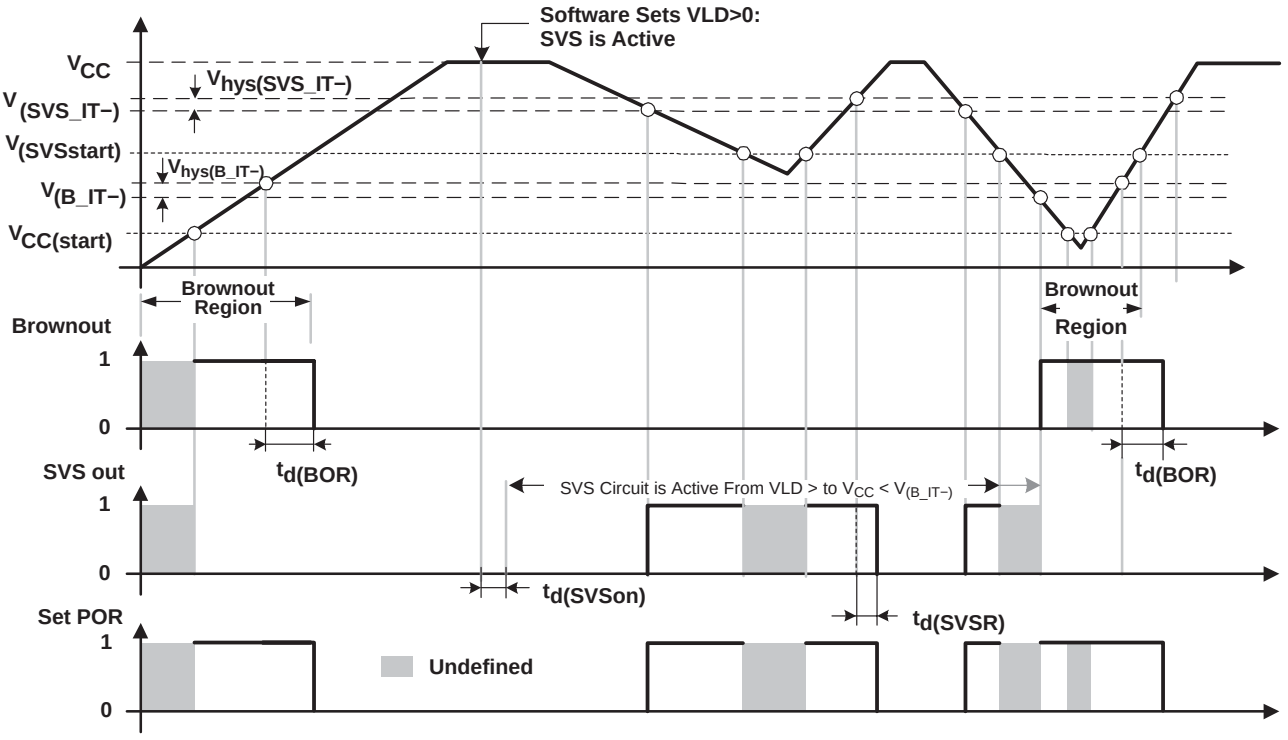

Figure 7. SVS Reset (SVSR) vs Supply Voltage

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

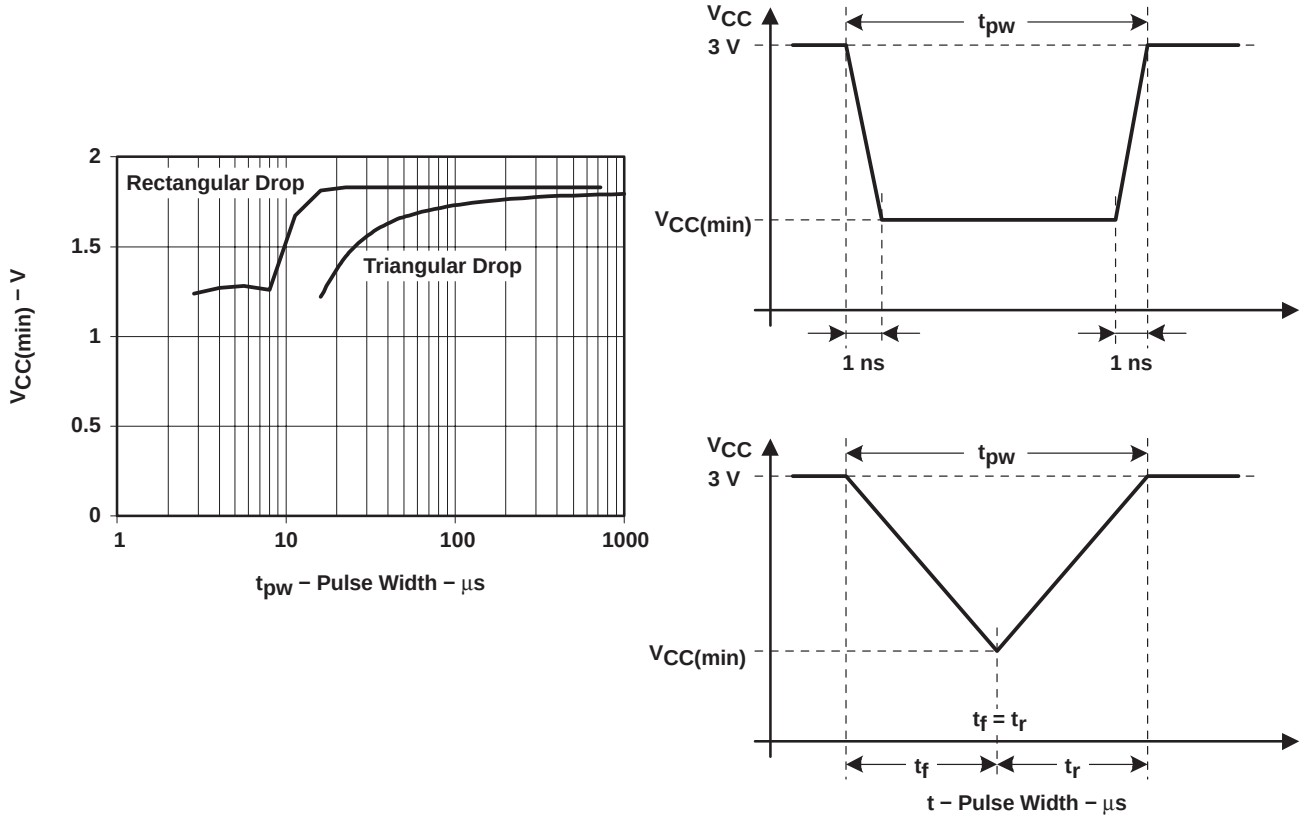

Figure 8. $V_{CC(min)}$ With a Square Voltage Drop and a Triangle Voltage Drop to Generate an SVS Signal

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

DCO

PARAMETER	TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
$f_{(DCOCLK)}$	$N_{(DCO)}$=01E0h, FN_8=FN_4=FN_3=FN_2=0, D = 2, DCOPLUS= 0	3 V		1		MHz
$f_{(DCO2)}$	FN_8=FN_4=FN_3=FN_2=0 , DCO+ = 1	3 V	0.3	0.7	1.3	MHz
$f_{(DCO27)}$	FN_8=FN_4=FN_3=FN_2=0, DCO+ = 1, (see Note 1)	3 V	2.7	6.1	11.3	MHz
$f_{(DCO2)}$	FN_8=FN_4=FN_3=0, FN_2=1; DCO+ = 1	3 V	0.8	1.5	2.5	MHz
$f_{(DCO27)}$	FN_8=FN_4=FN_3=0, FN_2=1; DCO+ = 1, (see Note 1)	3 V	6.5	12.1	20	MHz
$f_{(DCO2)}$	FN_8=FN_4=0, FN_3= 1, FN_2=x; DCO+ = 1	3 V	1.3	2.2	3.5	MHz
$f_{(DCO27)}$	FN_8=FN_4=0, FN_3= 1, FN_2=x;, DCO+ = 1, (see Note 1)	3 V	10.3	17.9	28.5	MHz
$f_{(DCO2)}$	FN_8=0, FN_4= 1, FN_3= FN_2=x; DCO+ = 1	3 V	2.1	3.4	5.2	MHz
$f_{(DCO27)}$	FN_8=0, FN_4=1, FN_3= FN_2=x; DCO+ = 1, (see Note 1)	3 V	16	26.6	41	MHz
$f_{(DCO2)}$	FN_8=1, FN_4=FN_3=FN_2=x; DCO+ = 1	3 V	4.2	6.3	9.2	MHz
$f_{(DCO27)}$	FN_8=1,FN_4=FN_3=FN_2=x,DCO+ = 1, (see Note 1)	3 V	30	46	70	MHz
S	$f_{(NDCO)+1} = f_{(NDCO)}$	2 < TAP ≤ 20	1.06		1.13	
		TAP > 20	1.1		1.17	
D_t	Temperature drift, $N_{(DCO)}$ = 01E0h, FN_8=FN_4=FN_3=FN_2=0 D = 2, DCO+ = 0, (see Note 2)	3 V	–0.2	–0.3	–0.4	%/°C
D_V	Drift with V_{CC} variation, $N_{(DCO)}$ = 01E0h, FN_8=FN_4=FN_3=FN_2=0 D = 2, DCO+ = 0 (see Note 2)		0	5	15	%/V

NOTES: 1. Do not exceed the maximum system frequency.
2. This parameter is not production tested.

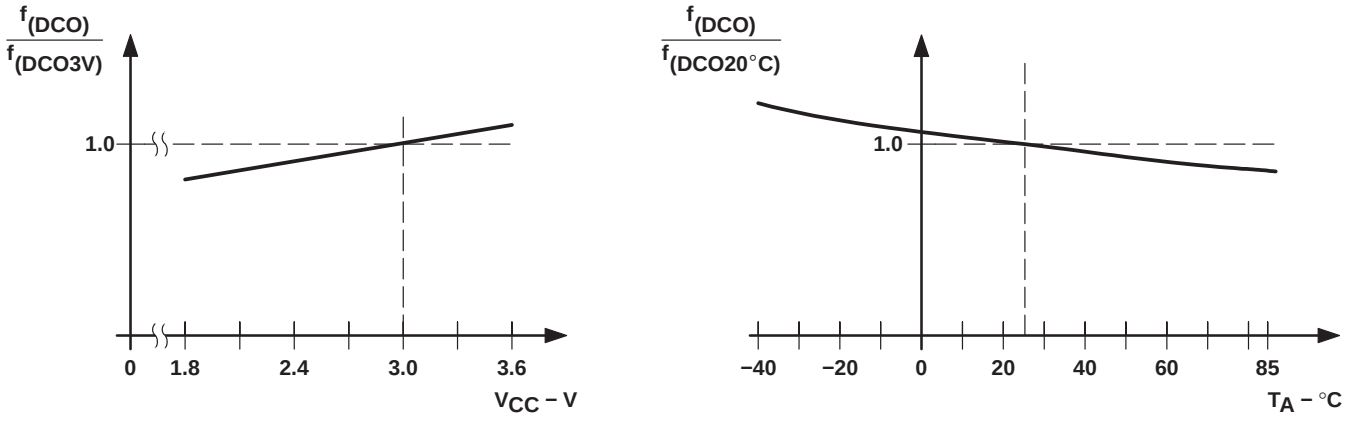


Figure 9. DCO Frequency vs Supply Voltage V_{CC} and vs Ambient Temperature

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

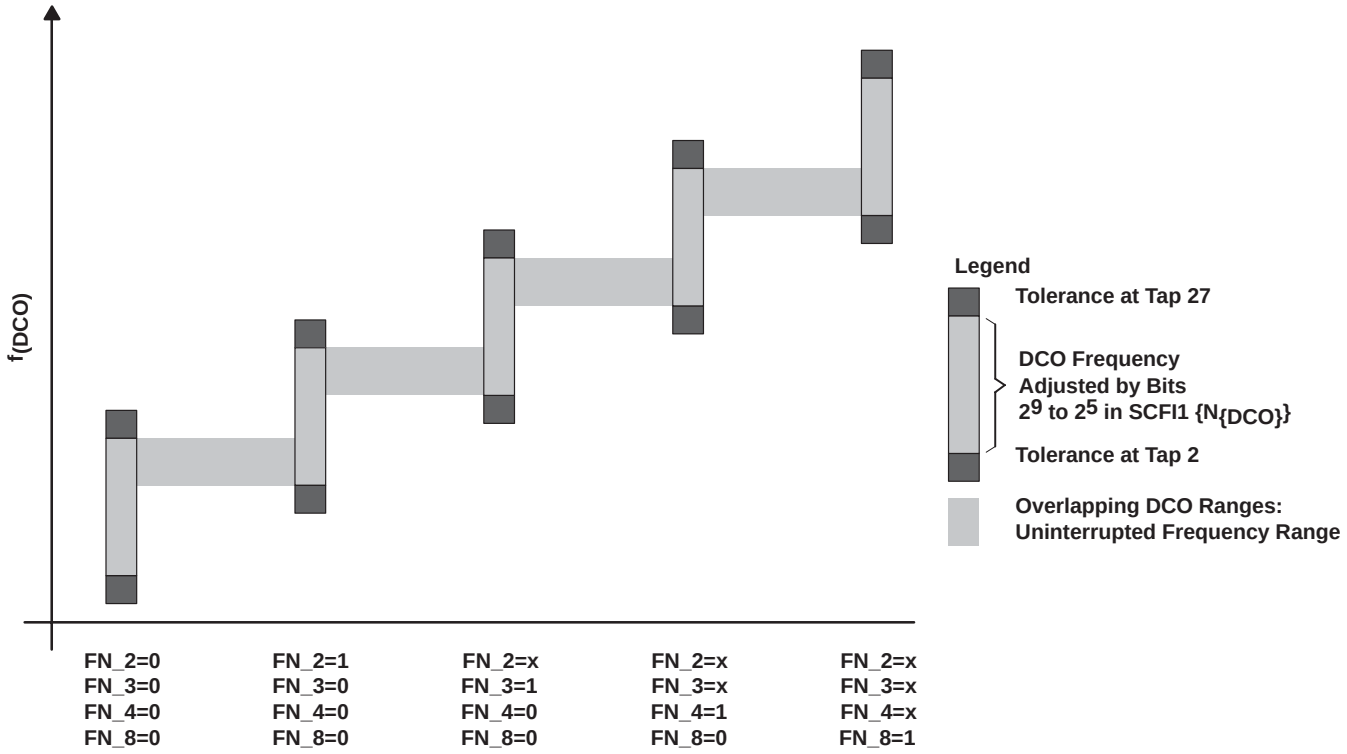


Figure 10. Five Overlapping DCO Ranges Controlled by FN_x Bits

crystal oscillator, LFXT1 oscillator (see Notes 1 and 2)

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
C_{XIN}	Integrated input capacitance	OSCCAP = 0	3 V		0		pF
		OSCCAP = 1	3 V		10		
		OSCCAP = 2	3 V		14		
		OSCCAP = 3	3 V		18		
C_{XOUT}	Integrated output capacitance	OSCCAP = 0	3 V		0		pF
		OSCCAP = 1	3 V		10		
		OSCCAP = 2	3 V		14		
		OSCCAP = 3	3 V		18		

NOTES: 1. The parasitic capacitance from the package and board may be estimated to be 2pF. The effective load capacitor for the crystal is (C_{XIN} x C_{XOUT}) / (C_{XIN} + C_{XOUT}). It is independent of XTS_FLL .

2. To improve EMI on the low-power LFXT1 oscillator, particularly in the LF mode (32 kHz), the following guidelines must be observe:
   - Keep as short a trace as possible between the 'FE42x and the crystal.
   - Design a good ground plane around oscillator pins.
   - Prevent crosstalk from other clock or data lines into oscillator pins XIN and XOUT.
   - Avoid running PCB traces underneath or adjacent to XIN an 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.

PRODUCT PREVIEW

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

ESP430CE1, power supply

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
AV_{CC}	Analog supply voltage	$AV_{CC} = DV_{CC}$ $AV_{SS} = DV_{SS} = 0V$		2.7		3.6	V
$I_{ESP430CE1}$	Total Digital & Analog supply current (ESP430 and SD16, active)	LP = 0, f_{MCLK} = 4MHz, $f_{SD16} = f_{MCLK}/4$, REFON = 1, VMIDON = 0	GAIN(V): 1, GAIN(I1): 1, I2: off		2.0	2.7	mA
			GAIN(V): 1, GAIN(I1): 32, I2: off		2.5	3.4	
			GAIN(V): 1, GAIN(I1): 1, GAIN(I2): 1		2.5	3.4	
			GAIN(V): 1, GAIN(I1): 32, GAIN(I2): 32		3.5	4.9	
		LP = 1, f_{MCLK} = 2MHz, $f_{SD16} = f_{MCLK}/4$, REFON = 1, VMIDON = 0	GAIN(V): 1, GAIN(I1): 1, I2: off		1.5	2.1	mA
			GAIN(V): 1, GAIN(I1): 32, I2: off		1.5	2.1	
			GAIN(V): 1, GAIN(I1): 1, GAIN(I2): 1		2.0	2.8	
			GAIN(V): 1, GAIN(I1): 32, GAIN(I2): 32		2.0	2.8	
f_{MAINS}	Mains frequency range			33		80	Hz
f_{SD16}	Analog front-end input clock frequency	LP = 0 (Low power mode disabled)		TBD	1	TBD	MHz
		LP = 1 (Low power mode enabled)		TBD	0.5	TBD	

ESP430CE1, analog front-end input range (see Note 1)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{IN(MAX)}$	Maximum differential input range for specified performance (see Note 2)	GAIN = 1, REFON = 1		±500		mV
		GAIN = 2, REFON = 1		±250		
		GAIN = 4, REFON = 1		±125		
		GAIN = 8, REFON = 1		±62		
		GAIN = 16, REFON = 1		±31		
		GAIN = 32, REFON = 1		±15		
$Z_{IN,GND}$	Input impedance (input to AV_{SS})	f_{SD16} = 1MHz, GAIN = 1		500		kΩ
		f_{SD16} = 1MHz, GAIN = 32	67	100		
$Z_{IN,DIFF}$	Input impedance (IN+ to IN−)	f_{SD16} = 1MHz, GAIN = 1		1000		kΩ
		f_{SD16} = 1MHz, GAIN = 32	133	200		
$V_{IN,ABS}$	Absolute input voltage range		AV_{SS} - 1.0V		AV_{CC}	V
I_{Lkg}	Leakage current				TBD	nA

NOTES: 1. All parameters pertain to each analog input channel: I1+, I1−, I2+ I2−, V1+, and V1−.
2. The analog input range depends on the reference voltage applied to V_{REF}. If V_{REF} is sourced externally, the full-scale range is defined by $V_{FSR+} = +(V_{REF}/2)/GAIN$ and $V_{FSR-} = -(V_{REF}/2)/GAIN$. The analog input range should not exceed 80% of V_{FSR+} or V_{FSR-}.

PRODUCT PREVIEW

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

ESP430CE1, analog front-end performance (f_{SD16} = 1MHz, OSR = 256, REFON = 1)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
SINAD	Signal-to-Noise + Distortion Ratio	GAIN = 1, Signal Amplitude = 500mV		85		dB
		GAIN = 2, Signal Amplitude = 250mV		83		
		GAIN = 4, Signal Amplitude = 125mV		79		
		GAIN = 8, Signal Amplitude = 62mV		76		
		GAIN = 16, Signal Amplitude = 31mV		72		
		GAIN = 32, Signal Amplitude = 15mV		67		

ESP430CE1, analog front-end temperature sensor

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
TC_{Sensor}	Sensor temperature coefficient			1.257 −3%	1.257	1.257 +3%	mV/K
$V_{Offset,sensor}$	Sensor offset voltage			−16		16	mV
V_{Sensor}	Sensor output voltage	Values given are calculated based on the test results for TC_{Sensor} (See Note 1)	85°C	421	450	480	mV
			25°C	347	375	402	
			0°C	317	343	369	

NOTES: 1. The following formulas can be used to calculate the temperrature sensor output volatge:
$V_{Sensor,typ} = TC_{Sensor}$ (273 + T [°C]) [mV]
$V_{Sensor,min} = TC_{Sensor}$ (1−3%)(273 + T [°C]) − 16 [mV]
$V_{Sensor,max} = TC_{Sensor}$ (1+3%)(273 + T [°C]) + 16 [mV]

ESP430CE1, analog front-end reference voltage

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{REF}	Internal reference output voltage	REFON = 1, VMIDON = 0	1.06	1.18	1.30	V
		REFON = 1, VMIDON = 1		1.18		
I_{REF}	Reference supply current	REFON = 1, VMIDON = 0		0.25		mA
	Reference supply + buffer quiescent current	REFON = 1, VMIDON = 1		0.55		
C_{VREF}	V_{REF} load capacitance	REFON = 1, VMIDON = 0 (see Note 1)		100		nF
		REFON = 1, VMIDON = 1	470			
I_{LOAD}	V_{REF} maximum load current	REFON = 1, VMIDON = 0		200		nA
		REFON = 1, VMIDON = 1		1		mA
V_{REG}	V_{REF} output voltage vs. load current	REFON = 1, VMIDON = 1, I_{LOAD} = 0 to 1mA	−15		+15	mV
TC	Temperature coefficient	REFON = 1		20	50	ppm/K
V_{REF}	External reference input voltage range	REFON = 0	1.0	1.25	1.5	V

NOTES: 1. There is no capacitance required on V_{REF} when VMIDON = 0. However, a capacitance of at least 100nF is recommended to reduce any reference voltage noise.

PRODUCT PREVIEW

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

JTAG, program memory and fuse

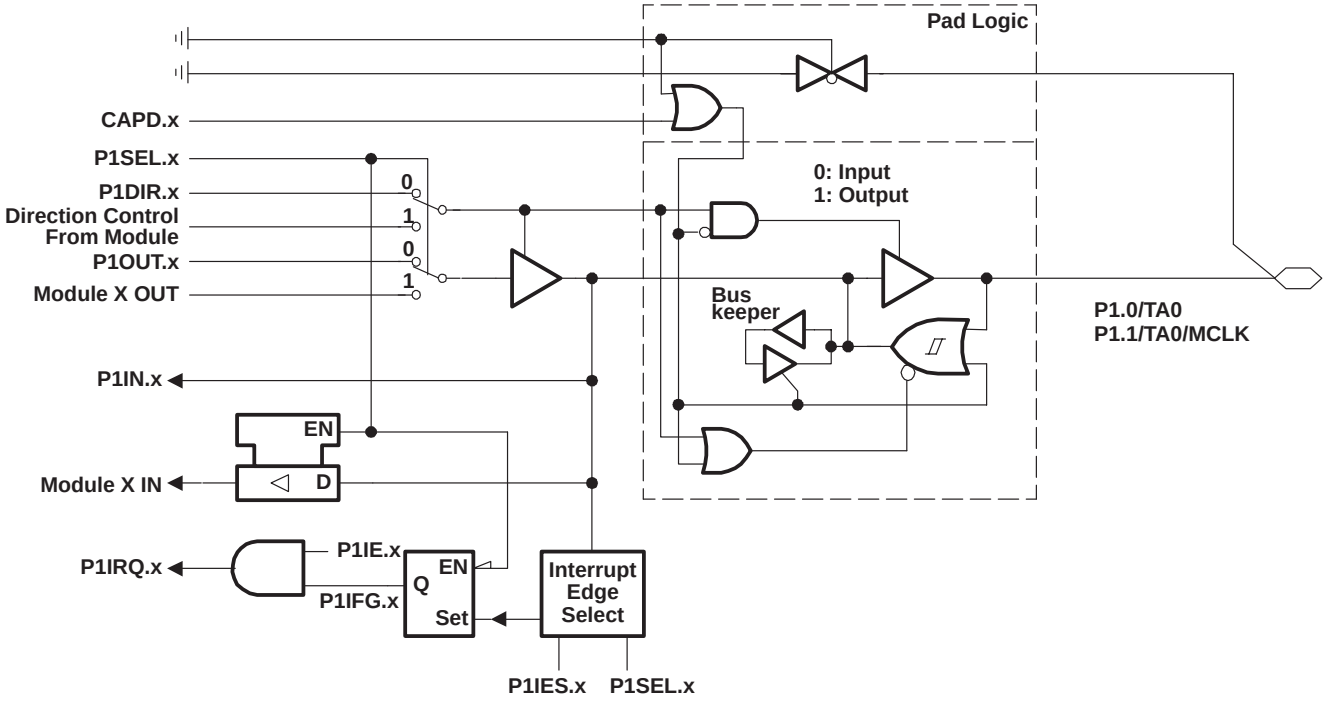
PARAMETER		TEST CONDITIONS	V_{CC}	MIN	NOM	MAX	UNIT
$f_{(TCK)}$	JTAG/Test (see Note 4)	TCK frequency	2.2 V	DC		5	MHz
			3 V	DC		10	
$R_{Internal}$		Pullup resistors on TMS, TCK, TDI (see Note 1)	2.2 V/ 3V	25	60	90	kΩ
$V_{CC(FB)}$	JTAG/fuse (see Note 2)	Supply voltage during fuse-blow condition, $T_{(A)}$ = 25°C		2.5			V
V_{FB}		Fuse-blow voltage, F versions (see Note 3)		6.0		7.0	V
I_{FB}		Supply current on TDI with fuse blown				100	mA
		Time to blow the fuse				1	ms
$I_{(DD-PGM)}$	F-versions only (see Note 5)	Current from DV_{CC} when programming is active	2.7 V/3.6 V		3	5	mA
$I_{(DD-Erase)}$		Current from DV_{CC} when erase is active	2.7 V/3.6 V		3	5	mA
Erase Cycles	F-versions only			10^4	10^5		cycles
$t_{(retention)}$	F-versions only	Data retention T_J = 25°C		100			years

NOTES: 1. TMS, TDI, and TCK pull-up resistors are implemented in all F versions.
2. Once the fuse is blown, no further access to the MSP430 JTAG/Test feature is possible. The JTAG block is switched to bypass mode.
3. The voltage required to blow the fuse is applied to the TDI pin.
4. $f_{(TCK)}$ may be restricted to meet the timing requirements of the module selected.
5. Duration of the program/erase cycle is determined by $f_{(FTG)}$ applied to the flash timing controller. It can be calculated as follows:
   $t_{(word\ write)} = 35 \times 1/f_{(FTG)}$
   $t_{(block\ write,\ byte\ 0)} = 30 \times 1/f_{(FTG)}$
   $t_{(block\ write,\ bytes\ 1–63)} = 20 \times 1/f_{(FTG)}$
   $t_{(block\ write\ end\ sequence)} = 6 \times 1/f_{(FTG)}$
   $t_{(mass\ erase)} = 5297 \times 1/f_{(FTG)}$
   $t_{(segment\ erase)} = 4819 \times 1/f_{(FTG)}$

PRODUCT PREVIEW

input/output schematic

Port P1, P1.0 to P1.1, input/output with Schmitt-trigger



NOTE: $0 \le x \le 1$.
Port Function is Active if CAPD.x = 0

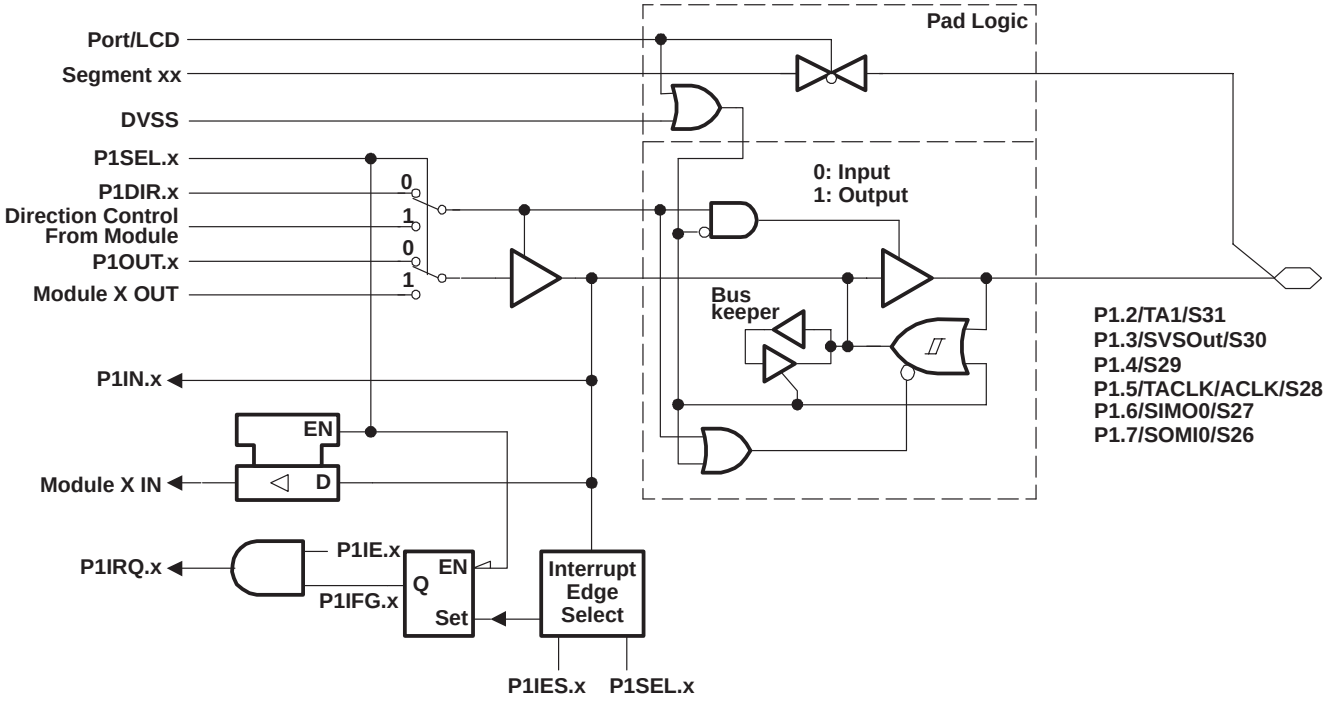
PnSEL.x	PnDIR.x	Direction Control From Module	PnOUT.x	Module X OUT	PnIN.x	Module X IN	PnIE.x	PnIFG.x	PnIES.x	CAPD.x
P1SEL.0	P1DIR.0	P1DIR.0	P1OUT.0	Out0 Sig.†	P1IN.0	CCI0A†	P1IE.0	P1IFG.0	P1IES.0	DVSS
P1SEL.1	P1DIR.1	P1DIR.1	P1OUT.1	MCLK	P1IN.1	CCI0B†	P1IE.1	P1IFG.1	P1IES.1	DVSS

† Timer_A3

PRODUCT PREVIEW

input/output schematic (continued)

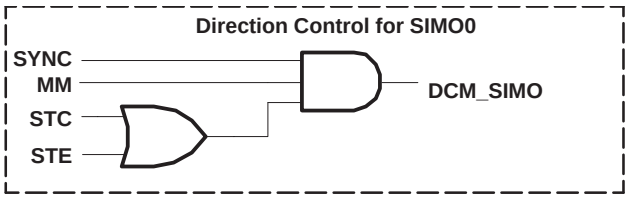
Port P1, P1.2 to P1.7, input/output with Schmitt-trigger

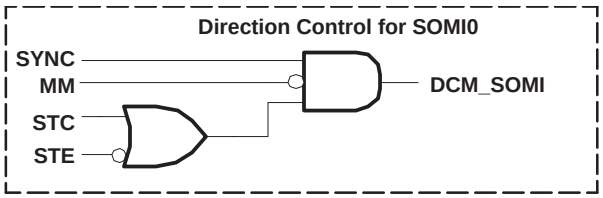


NOTE: $2 \le x \le 7$.
Port Function is Active if Port/LCD = 0

PnSEL.x	PnDIR.x	Direction Control From Module	PnOUT.x	Module X OUT	PnIN.x	Module X IN	PnIE.x	PnIFG.x	PnIES.x	Port/LCD	Segment
P1SEL.2	P1DIR.2	P1DIR.2	P1OUT.2	Out1 Sig.†	P1IN.2	CCI1A†	P1IE.2	P1IFG.2	P1IES.2	0: LCDM < 0E0h 1: LCDM ≥ 0E0h	S31
P1SEL.3	P1DIR.3	P1DIR.3	P1OUT.3	SVSOut	P1IN.3	unused	P1IE.3	P1IFG.3	P1IES.3		S30
P1SEL.4	P1DIR.4	P1DIR.4	P1OUT.4	DVSS	P1IN.4	unused	P1IE.4	P1IFG.4	P1IES.4		S29
P1SEL.5	P1DIR.5	P1DIR.5	P1OUT.5	ACLK	P1IN.5	TACLK†	P1IE.5	P1IFG.5	P1IES.5		S28
P1SEL.6	P1DIR.6	DCM_SIMO	P1OUT.6	SIMO0(o)‡	P1IN.6	SIMO0(i)‡	P1IE.6	P1IFG.6	P1IES.6	0: LCDM < 0C0h 1: LCDM ≥ 0C0h	S27
P1SEL.7	P1DIR.7	DCM_SOMI	P1OUT.7	SOMI0(o)‡	P1IN.7	SOMI0(i)‡	P1IE.7	P1IFG.7	P1IES.7		S26

† Timer_A3
‡ USART0

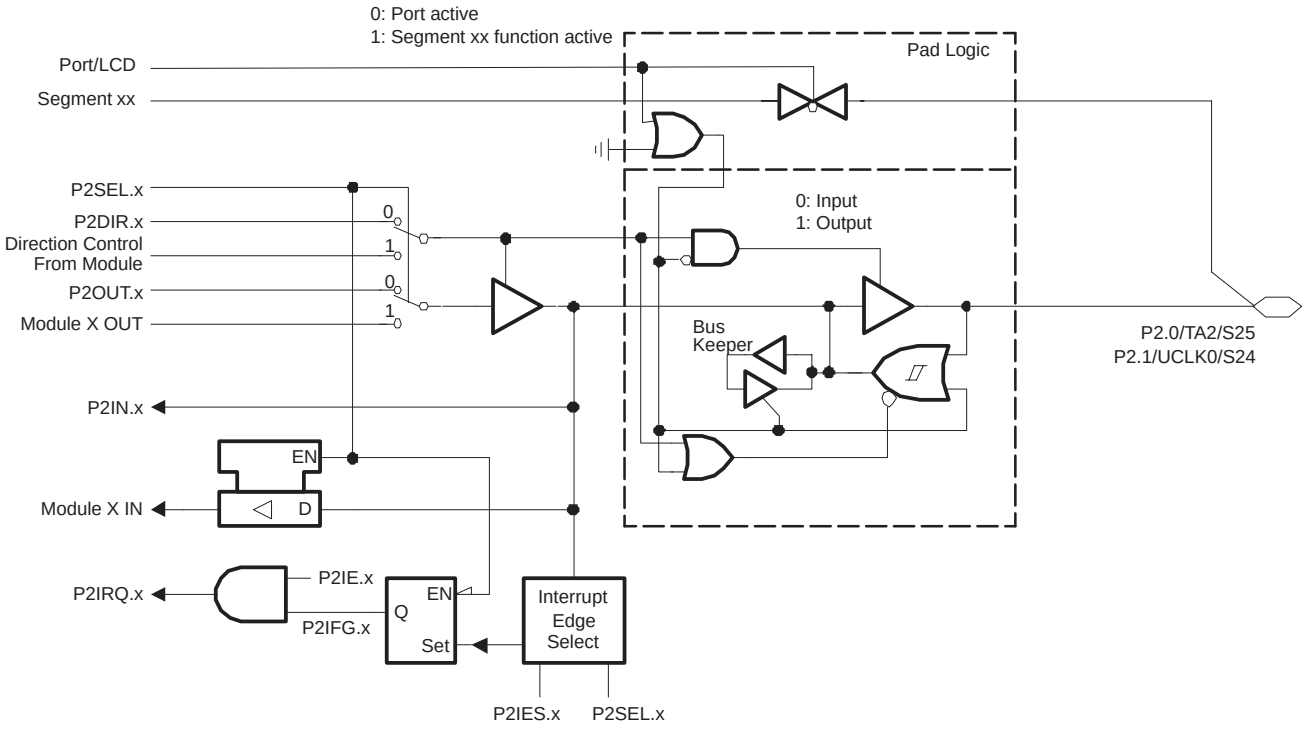




PRODUCT PREVIEW

input/output schematic (continued)

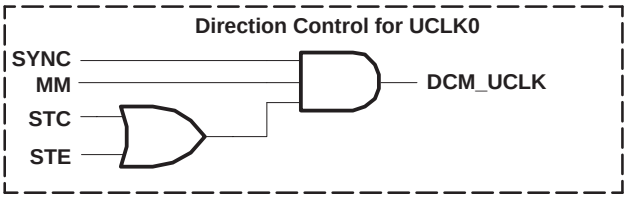
port P2, P2.0 to P2.1, input/output with Schmitt-trigger



NOTE: $0 \le x \le 1$.
Port Function is Active if Port/LCD = 0

PnSel.x	PnDIR.x	Dir. Control from module	PnOUT.x	Module X OUT	PnIN.x	Module X IN	PnIE.x	PnIFG.x	PnIES.x	Port/LCD	Segment
P2Sel.0	P2DIR.0	P2DIR.0	P2OUT.0	Out2sig.†	P2IN.0	CCI2A †	P2IE.0	P2IFG.0	P2IES.0	0: LCDM < 0E0h	S25
P2Sel.1	P2DIR.1	DCM_UCLK	P2OUT.1	UCLK0(o)‡	P2IN.1	UCLK0(i)‡	P2IE.1	P2IFG.1	P2IES.1	1: LCDM ≥ 0E0h	S24

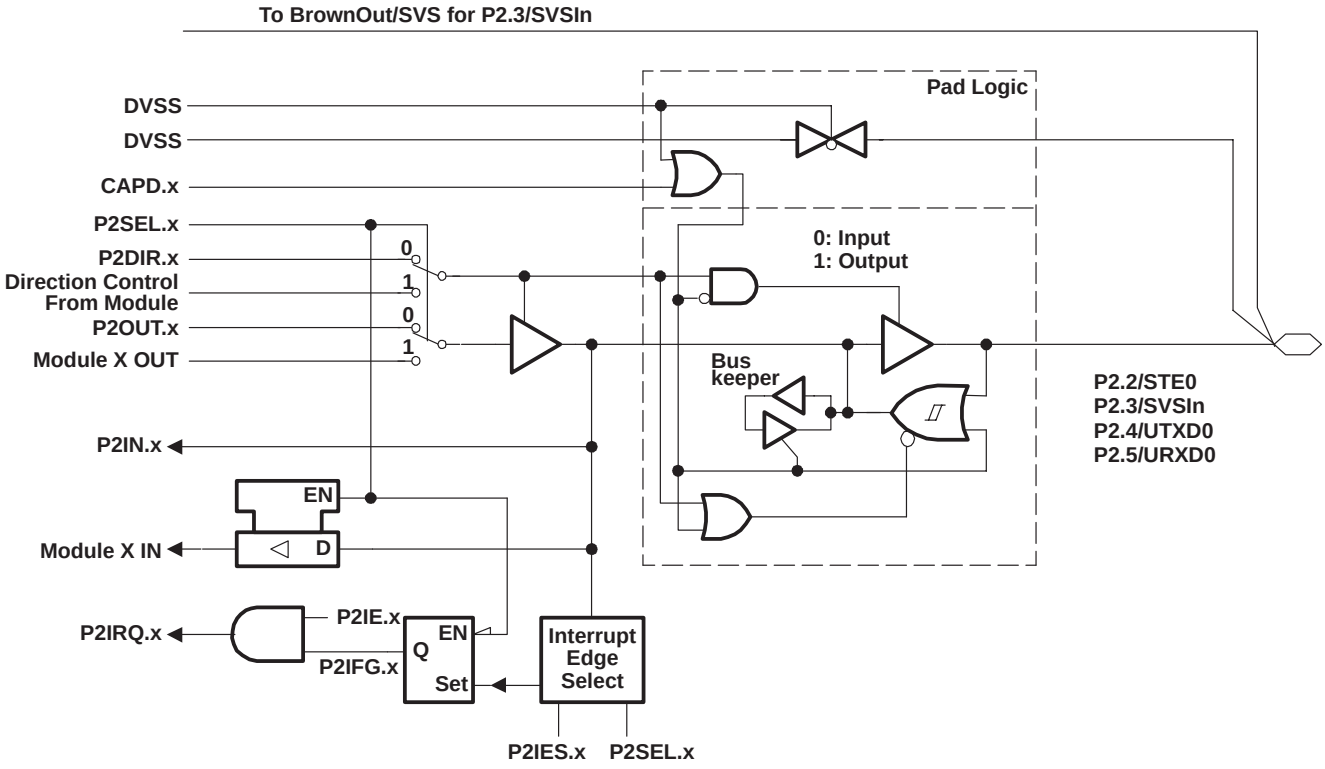
† Timer_A3
‡ USART0



PRODUCT PREVIEW

input/output schematic (continued)

port P2, P2.2 to P2.5, input/output with Schmitt-trigger



NOTE: $2 \le x \le 5$
Port function is active if CAPD.x = 0

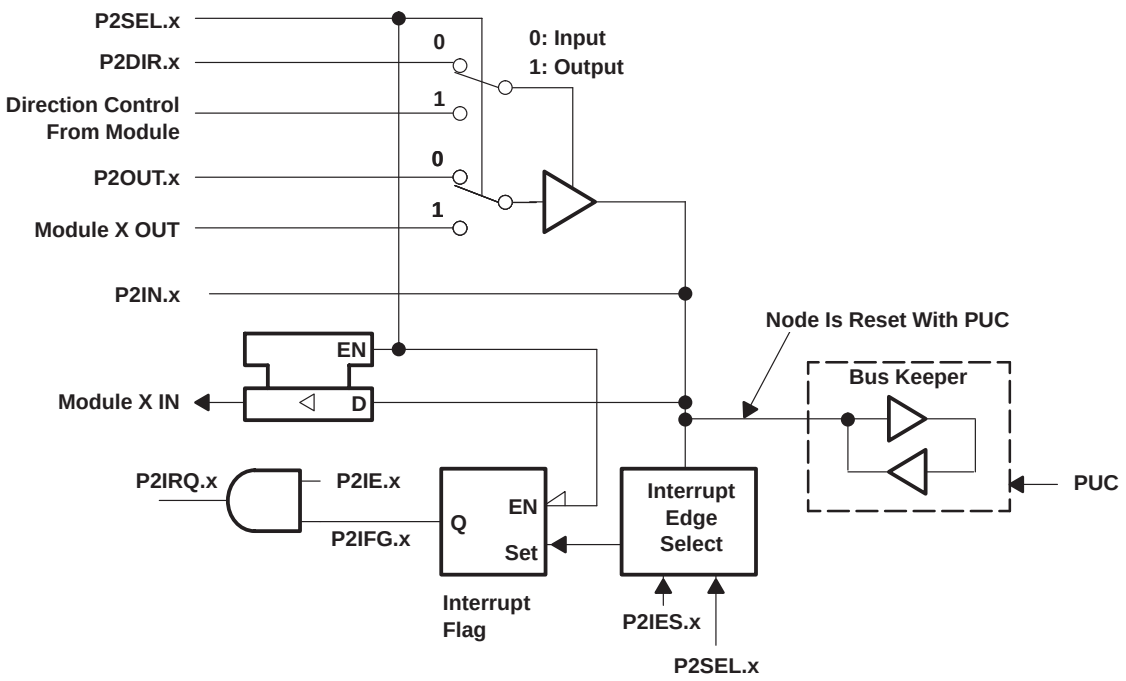
PnSEL.x	PnDIR.x	Direction Control From Module	PnOUT.x	Module X OUT	PnIN.x	Module X IN	PnIE.x	PnIFG.x	PnIES.x	CAPD.x
P2SEL.2	P2DIR.2	DVSS	P2OUT.2	DVSS	P2IN.2	STE0†	P2IE.2	P2IFG.2	P2IES.2	DVSS
P2SEL.3	P2DIR.3	P2DIR.3	P2OUT.3	DVSS	P2IN.3	unused	P2IE.3	P2IFG.3	P2IES.3	SVSCTL VLD = 1111b
P2SEL.4	P2DIR.4	DVCC	P2OUT.4	UTXD0†	P2IN.4	unused	P2IE.4	P2IFG.4	P2IES.4	DVSS
P2SEL.5	P2DIR.5	DVSS	P2OUT.5	DVSS	P2IN.5	URXD0†	P2IE.5	P2IFG.5	P2IES.5	DVSS

† USART0

PRODUCT PREVIEW

input/output schematic (continued)

Port P2, unbonded bits P2.6 and P2.7



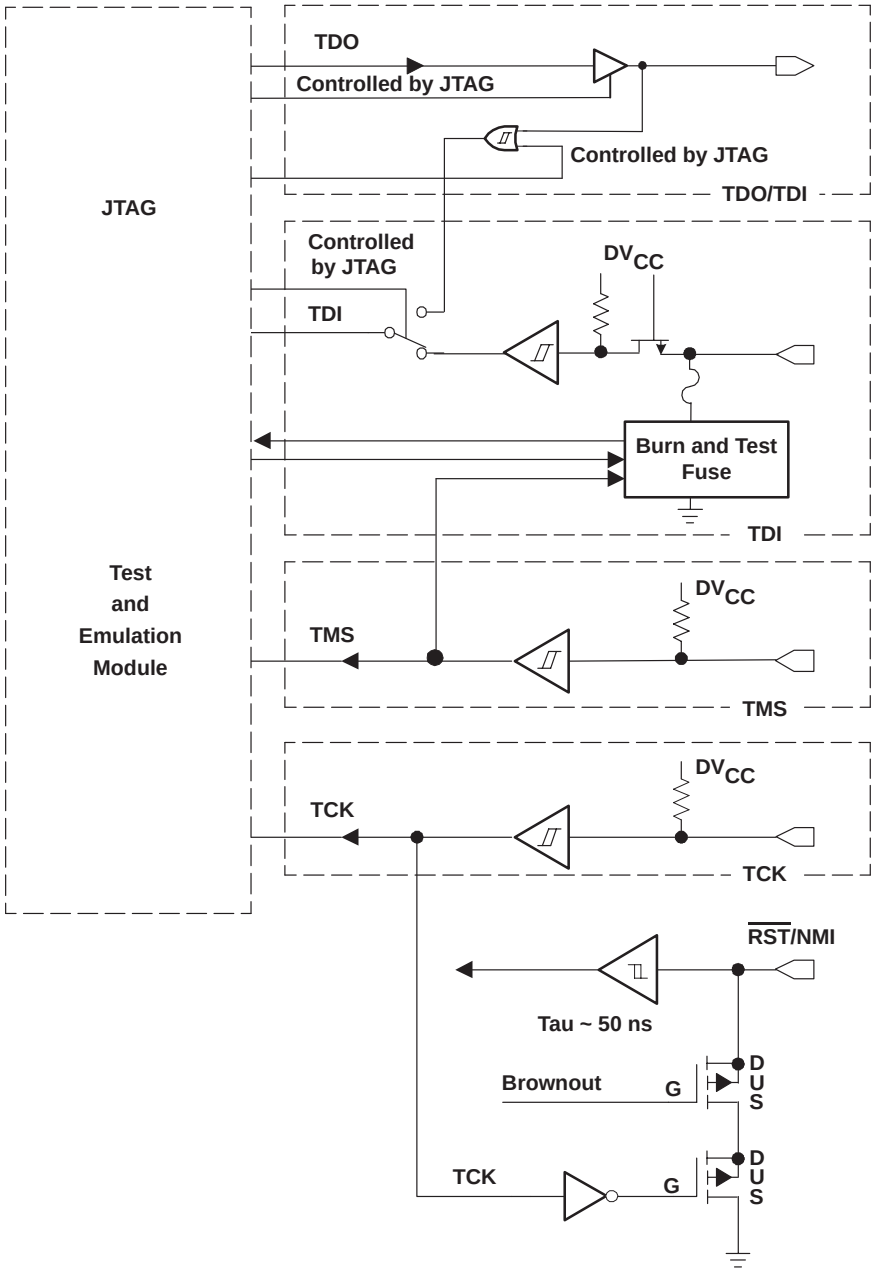
NOTE: x = Bit/identifier, 6 to 7 for port P2 without external pins

P2Sel.x	P2DIR.x	DIRECTION CONTROL FROM MODULE	P2OUT.x	MODULE X OUT	P2IN.x	MODULE X IN	P2IE.x	P2IFG.x	P2IES.x
P2Sel.6	P2DIR.6	P2DIR.6	P2OUT.6	DV_{SS}	P2IN.6	unused	P2IE.6	P2IFG.6	P2IES.6
P2Sel.7	P2DIR.7	P2DIR.7	P2OUT.7	DV_{SS}	P2IN.7	unused	P2IE.7	P2IFG.7	P2IES.7

NOTE: Unbonded bits 6 and 7 of port P2 can be used as interrupt flags. Only software can affect the interrupt flags. They work as software interrupts.

PRODUCT PREVIEW

JTAG pins TMS, TCK, TDI, TDO/TDI, input/output with Schmitt-trigger or output



PRODUCT PREVIEW

JTAG fuse check mode

MSP430 devices that have the fuse on the TDI 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 1.8 mA at 3 V can flow from the TDI pin to ground if the fuse is not burned. Care must be taken to avoid accidentally activating the fuse check mode and increasing overall system power consumption.

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

The fuse check current only flows when the fuse check mode is active and the TMS pin is in a low state (see Figure 11). Therefore, the additional current flow can be prevented by holding the TMS pin high (default condition).

The JTAG pins are terminated internally, and therefore do not require external termination.

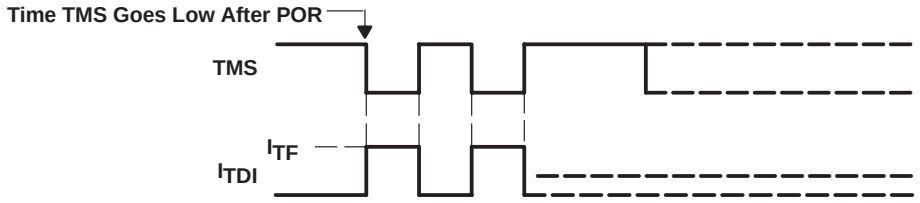
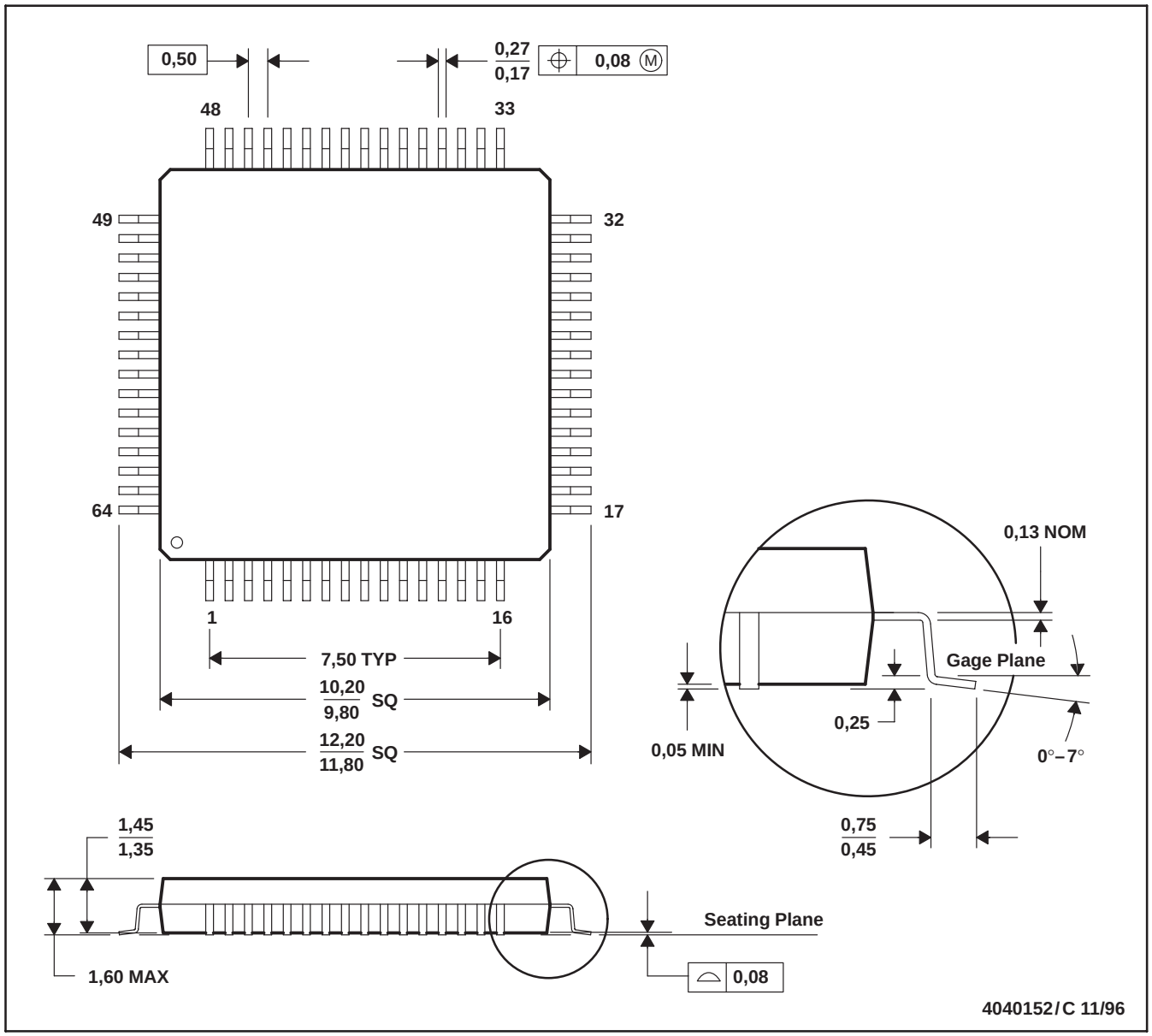


Figure 11. Fuse Check Mode Current, MSP430FE42x

PRODUCT PREVIEW

PM (S-PQFP-G64) **PLASTIC QUAD FLATPACK**



NOTES: A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Falls within JEDEC MS-026
D. May also be thermally enhanced plastic with leads connected to the die pads.

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