- **Low Supply Voltage Range: 1.8 V to 3.6 V**
- **Ultralow-Power Consumption:**
  - **Active Mode: 400 μA at 1 MHz, 2.2 V**
  - **Standby Mode: 1.3 μA**
  - **Off Mode (RAM Retention): 0.22 μA**
- **Five Power-Saving Modes**
- **Wake-Up From Standby Mode in Less Than 6 μs**
- **16-Bit RISC Architecture, Extended Memory, 125-ns Instruction Cycle Time**
- **Three Channel Internal DMA**
- **12-Bit A/D Converter With Internal Reference, Sample-and-Hold and Autoscan Feature (MSP430x461x only)**
- **16-Bit Timer_A With Three Capture/Compare Registers**
- **16-Bit Timer_B With Seven Capture/Compare-With-Shadow Registers**
- **On-Chip Comparator**
- **Supply Voltage Supervisor/Monitor With Programmable Level Detection**
- **Basic Timer With Real Time Clock Feature**
- **Integrated LCD Driver up to 160 Segments With Regulated Charge Pump**
- **Serial Communication Interface (USART1), Select Asynchronous UART or Synchronous SPI by Software**
- **Universal Serial Communication Interface**
  - **Enhanced UART Supporting Auto-Baudrate Detection**
  - **IrDA Encoder and Decoder**
  - **Synchronous SPI**
  - **I2C™**
- **Serial Onboard Programming, Programmable Code Protection by Security Fuse**
- **Brownout Detector**
- **Family Members Include:**
  - **MSP430x4616, MSP430x46161†:**
    92KB+256B Flash or ROM Memory
    4KB RAM
  - **MSP430x4617, MSP430x46171†:**
    92KB+256B Flash or ROM Memory,
    8KB RAM
  - **MSP430x4618, MSP430x46181†:**
    116KB+256B Flash or ROM Memory,
    8KB RAM
  - **MSP430x4619, MSP430x46191†:**
    120KB+256B Flash or ROM Memory,
    4KB RAM
- **For Complete Module Descriptions, Refer to the *MSP430x4xx Family User's Guide***

† The MSP430F461x1 devices are identical to the MSP430F461x devices, with the exception that the ADC12 module is not implemented.

description

The Texas Instruments MSP430 family of ultralow-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 devices feature 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 6 μs.

The MSP430x461x(1) series are microcontroller configurations with two 16-bit timers, a high-performance 12-bit A/D converter (MSP430x461x only), one universal serial communication interface (USCI), one universal synchronous/asynchronous communication interface (USART), DMA, 80 I/O pins, and a liquid crystal display (LCD) driver with regulated charge pump.

Typical applications for this device include portable medical applications and e-meter applications.

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage. ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications. These devices have limited built-in ESD protection.

Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

AVAILABLE OPTIONS[†]

T_A	PACKAGED DEVICES[‡]	
	PLASTIC 100-PIN TQFP (PZ)	
–40°C to 85°C	MSP430F4616IPZ	MSP430F46161IPZ
	MSP430F4617IPZ	MSP430F46171IPZ
	MSP430F4618IPZ	MSP430F46181IPZ
	MSP430F4619IPZ	MSP430F46191IPZ

† For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI web site at www.ti.com.

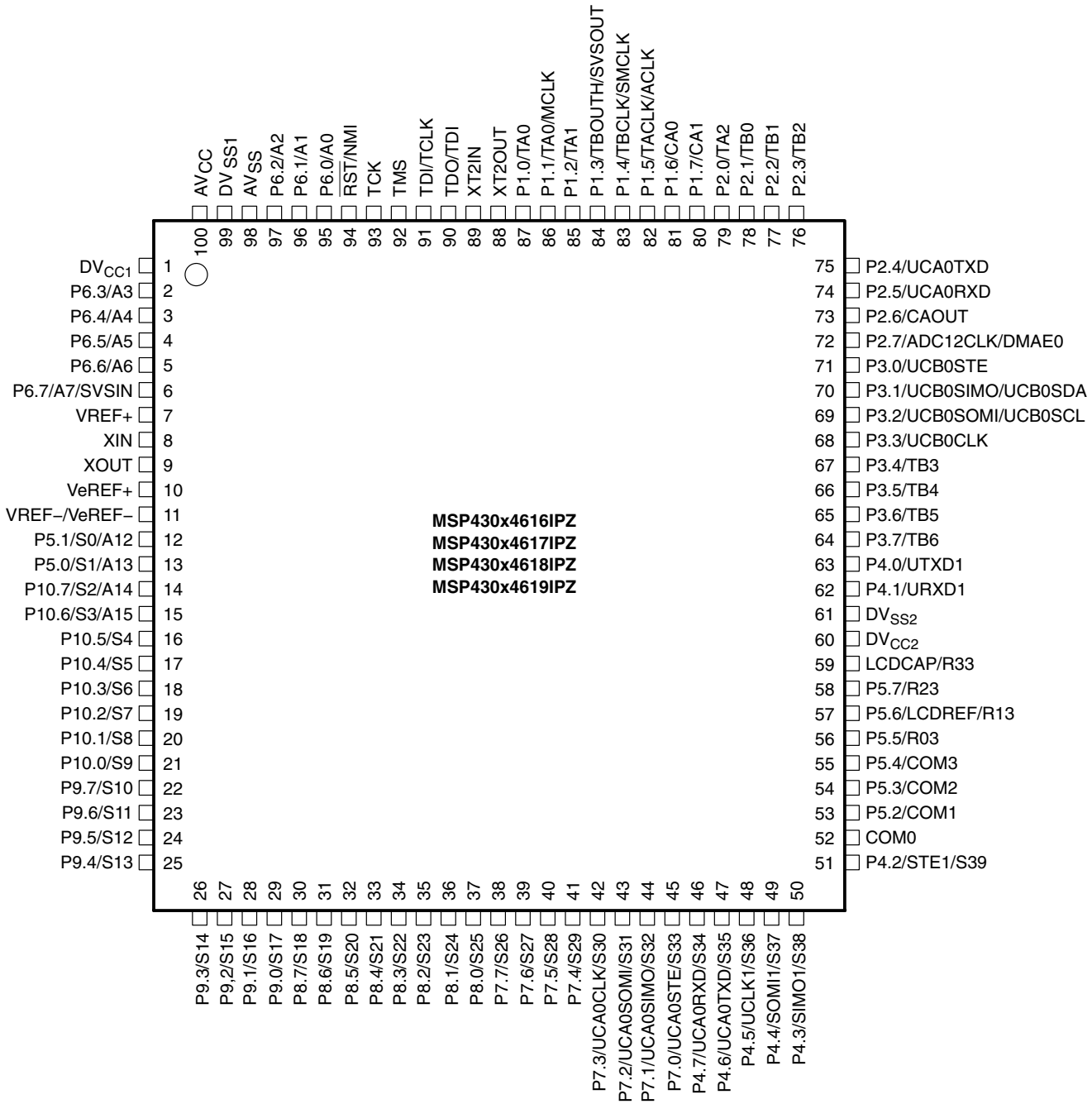
‡ Package drawings, thermal data, and symbolization are available at www.ti.com/packaging.

DEVELOPMENT TOOL SUPPORT

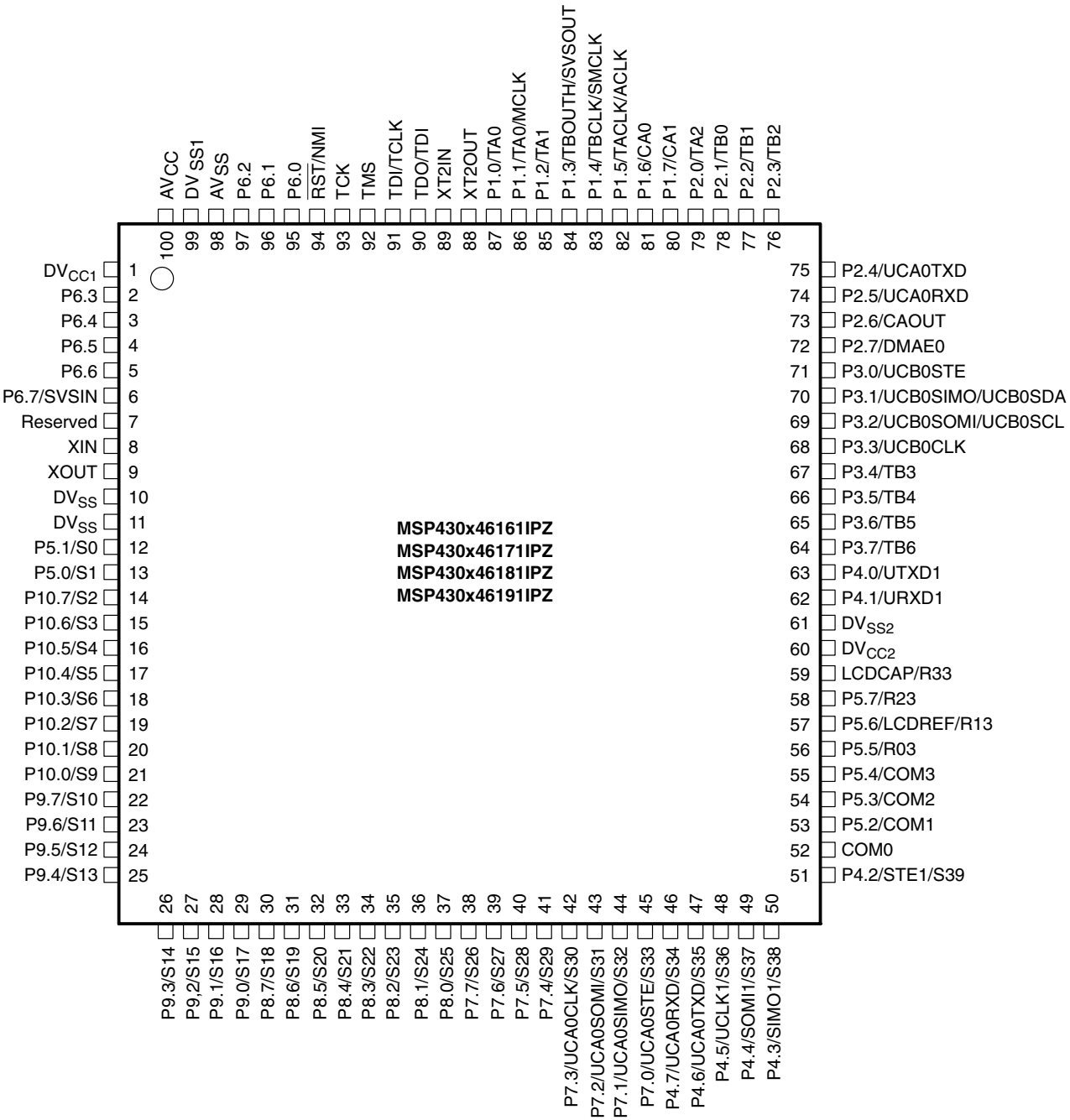
All MSP430 microcontrollers include an Embedded Emulation Module (EEM) allowing advanced debugging and programming through easy to use development tools. Recommended hardware options include the following:

- Debugging and Programming Interface
  - MSP-FET430UIF (USB)
  - MSP-FET430PIF (Parallel Port)
- Debugging and Programming Interface with Target Board
  - MSP-FET430U100
- Stand-Alone Target Board
  - MSP-TS430PZ100
- Production Programmer
  - MSP-GANG430

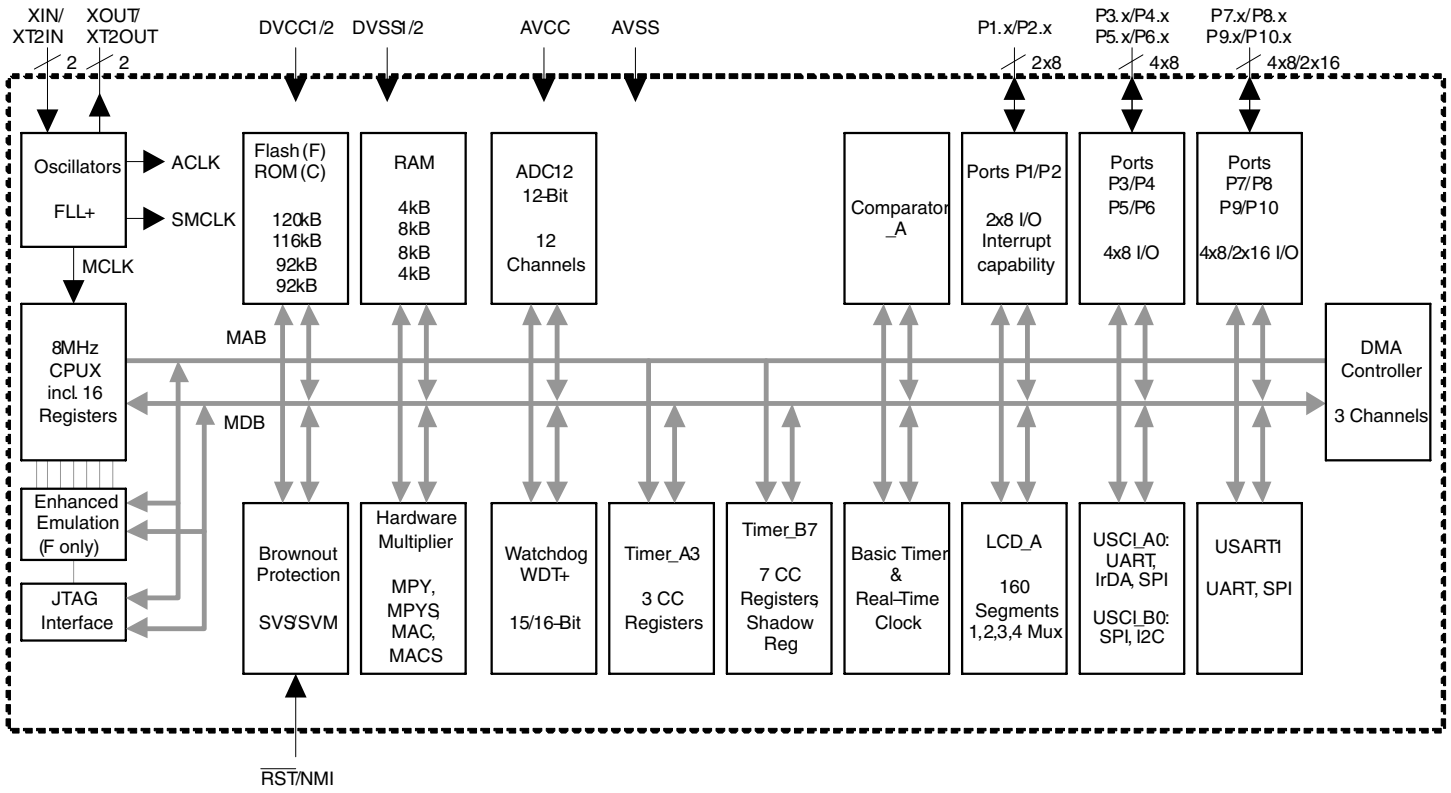
pin designation, MSP430x461xIPZ



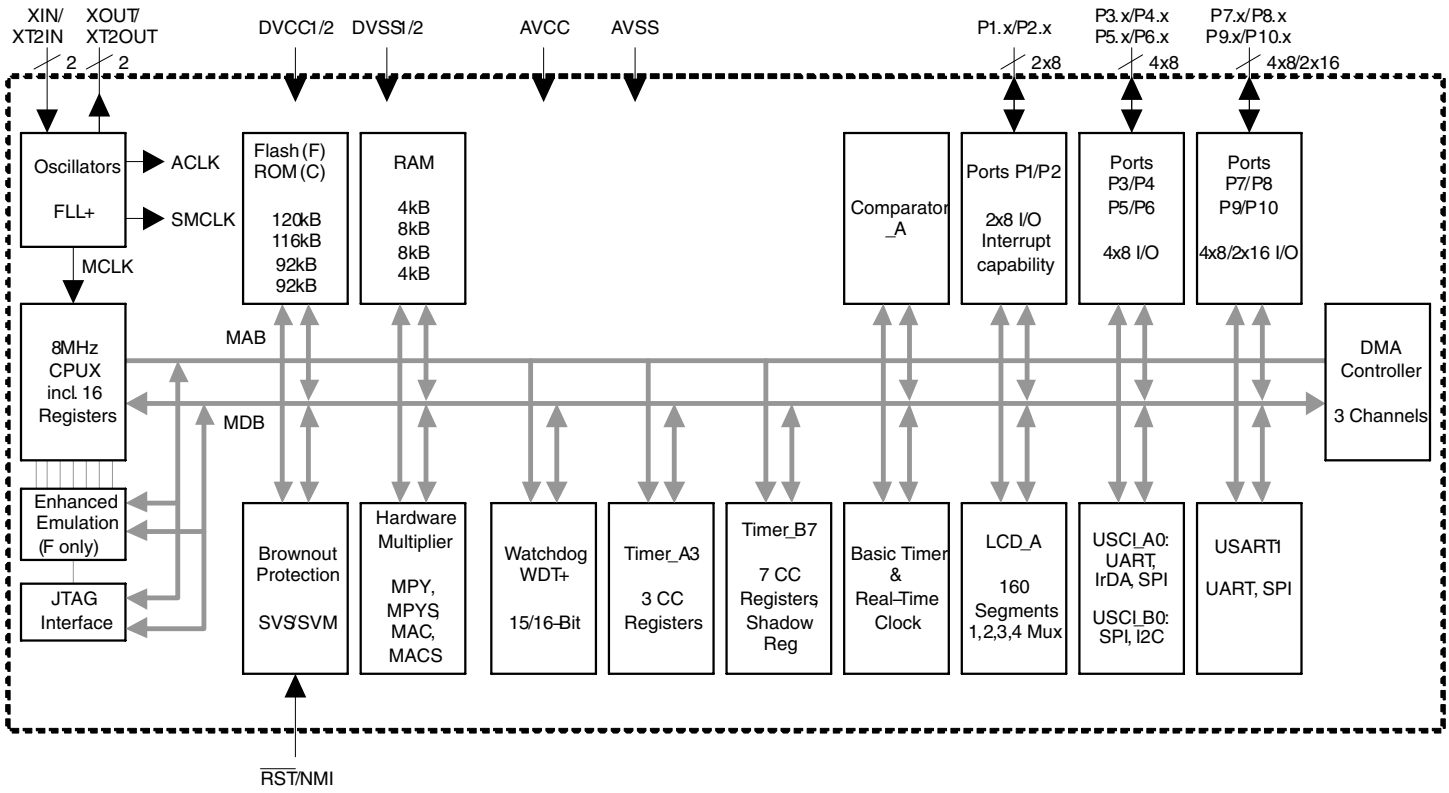
pin designation, MSP430x461x1IPZ



MSP430x461x functional block diagram



MSP430x461x1 functional block diagram



MSP430x461x Terminal Functions

TERMINAL NAME	TERMINAL NO.	I/O	DESCRIPTION
DV_{CC1}	1		Digital supply voltage, positive terminal
P6.3/A3	2	I/O	General-purpose digital I/O / analog input a3—12-bit ADC
P6.4/A4	3	I/O	General-purpose digital I/O / analog input a4—12-bit ADC
P6.5/A5	4	I/O	General-purpose digital I/O / analog input a5—12-bit ADC
P6.6/A6	5	I/O	General-purpose digital I/O / analog input a6—12-bit ADC
P6.7/A7/SVSIN	6	I/O	General-purpose digital I/O / analog input a7—12-bit ADC / analog input to brownout, supply voltage supervisor
V_{REF+}	7	O	Output of positive terminal of the reference voltage in the ADC
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
Ve_{REF+}	10	I/O	Input for an external reference voltage to the ADC
V_{REF-}/Ve_{REF-}	11	I	Negative terminal for the ADC reference voltage for both sources, the internal reference voltage, or an external applied reference voltage
P5.1/S0/A12 (see Note 1)	12	I/O	General-purpose digital I/O / LCD segment output 0 / analog input a12 – 12–bit ADC
P5.0/S1/A13 (see Note 1)	13	I/O	General-purpose digital I/O / LCD segment output 1 / analog input a13 – 12–bit ADC
P10.7/S2/A14 (see Note 1)	14	I/O	General-purpose digital I/O / LCD segment output 2 / analog input a14 – 12–bit ADC
P10.6/S3/A15 (see Note 1)	15	I/O	General-purpose digital I/O / LCD segment output 3 / analog input a15 – 12–bit ADC
P10.5/S4	16	I/O	General-purpose digital I/O / LCD segment output 4
P10.4/S5	17	I/O	General-purpose digital I/O / LCD segment output 5
P10.3/S6	18	I/O	General-purpose digital I/O / LCD segment output 6
P10.2/S7	19	I/O	General-purpose digital I/O / LCD segment output 7
P10.1/S8	20	I/O	General-purpose digital I/O / LCD segment output 8
P10.0/S9	21	I/O	General-purpose digital I/O / LCD segment output 9
P9.7/S10	22	I/O	General-purpose digital I/O / LCD segment output 10
P9.6/S11	23	I/O	General-purpose digital I/O / LCD segment output 11
P9.5/S12	24	I/O	General-purpose digital I/O / LCD segment output 12
P9.4/S13	25	I/O	General-purpose digital I/O / LCD segment output 13
P9.3/S14	26	I/O	General-purpose digital I/O / LCD segment output 14
P9.2/S15	27	I/O	General-purpose digital I/O / LCD segment output 15
P9.1/S16	28	I/O	General-purpose digital I/O / LCD segment output 16
P9.0/S17	29	I/O	General-purpose digital I/O / LCD segment output 17
P8.7/S18	30	I/O	General-purpose digital I/O / LCD segment output 18
P8.6/S19	31	I/O	General-purpose digital I/O / LCD segment output 19
P8.5/S20	32	I/O	General-purpose digital I/O / LCD segment output 20
P8.4/S21	33	I/O	General-purpose digital I/O / LCD segment output 21
P8.3/S22	34	I/O	General-purpose digital I/O / LCD segment output 22

NOTE 1: Segments S0 through S3 are disabled when the LCD charge pump feature is enabled (LCDCPEN = 1) and cannot be used together with the LCD charge pump. In addition, when using segments S0 through S3 with an external LCD voltage supply, $V_{LCD} \le AV_{CC}$.

Terminal Functions (Continued)

TERMINAL		I/O	DESCRIPTION
NAME	NO.		
P8.2/S23	35	I/O	General-purpose digital I/O / LCD segment output 23
P8.1/S24	36	I/O	General-purpose digital I/O / LCD segment output 24
P8.0/S25	37	I/O	General-purpose digital I/O / LCD segment output 25
P7.7/S26	38	I/O	General-purpose digital I/O / LCD segment output 26
P7.6/S27	39	I/O	General-purpose digital I/O / LCD segment output 27
P7.5/S28	40	I/O	General-purpose digital I/O / LCD segment output 28
P7.4/S29	41	I/O	General-purpose digital I/O / LCD segment output 29
P7.3/UCA0CLK/S30	42	I/O	General-purpose digital I/O / external clock input – USCI_A0/UART or SPI mode, clock output – USCI_A0/SPI mode / LCD segment 30
P7.2/UCA0SOMI/S31	43	I/O	General-purpose digital I/O / slave out/master in of USCI_A0/SPI mode / LCD segment output 31
P7.1/UCA0SIMO/S32	44	I/O	General-purpose digital I/O / slave in/master out of USCI_A0/SPI mode / LCD segment output 32
P7.0/UCA0STE/S33	45	I/O	General-purpose digital I/O / slave transmit enable—USCI_A0/SPI mode / LCD segment output 33
P4.7/UCA0RXD/S34	46	I/O	General-purpose digital I/O / receive data in – USCI_A0/UART or IrDA mode / LCD segment output 34
P4.6/UCA0TXD/S35	47	I/O	General-purpose digital I/O / transmit data out – USCI_A0/UART or IrDA mode / LCD segment output 35
P4.5/UCLK1/S36	48	I/O	General-purpose digital I/O / external clock input – USART1/UART or SPI mode, clock output – USART1/SPI MODE / LCD segment output 36
P4.4/SOMI1/S37	49	I/O	General-purpose digital I/O / slave out/master in of USART1/SPI mode / LCD segment output 37
P4.3/SIMO1/S38	50	I/O	General-purpose digital I/O / slave in/master out of USART1/SPI mode / LCD segment output 38
P4.2/STE1/S39	51	I/O	General-purpose digital I/O / slave transmit enable—USART1/SPI mode / LCD segment output 39
COM0	52	O	COM0–3 are used for LCD backplanes.
P5.2/COM1	53	I/O	General-purpose digital I/O / common output, COM0–3 are used for LCD backplanes.
P5.3/COM2	54	I/O	General-purpose digital I/O / common output, COM0–3 are used for LCD backplanes.
P5.4/COM3	55	I/O	General-purpose digital I/O / common output, COM0–3 are used for LCD backplanes.
P5.5/R03	56	I/O	General-purpose digital I/O / Input port of lowest analog LCD level (V5)
P5.6/LCDREF/R13	57	I/O	General-purpose digital I/O / External reference voltage input for regulated LCD voltage / Input port of third most positive analog LCD level (V4 or V3)
P5.7/R23	58	I/O	General-purpose digital I/O / Input port of second most positive analog LCD level (V2)
LCDCAP/R33	59	I	LCD capacitor connection / Input/output port of most positive analog LCD level (V1)
DV_{CC2}	60		Digital supply voltage, positive terminal
DV_{SS2}	61		Digital supply voltage, negative terminal
P4.1/URXD1	62	I/O	General-purpose digital I/O / receive data in—USART1/UART mode
P4.0/UTXD1	63	I/O	General-purpose digital I/O / transmit data out—USART1/UART mode
P3.7/TB6	64	I/O	General-purpose digital I/O / Timer_B7 CCR6. Capture: CCI6A/CCI6B input, compare: Out6 output
P3.6/TB5	65	I/O	General-purpose digital I/O / Timer_B7 CCR5. Capture: CCI5A/CCI5B input, compare: Out5 output
P3.5/TB4	66	I/O	General-purpose digital I/O / Timer_B7 CCR4. Capture: CCI4A/CCI4B input, compare: Out4 output

Terminal Functions (Continued)

TERMINAL		I/O	DESCRIPTION
NAME	NO.		
P3.4/TB3	67	I/O	General-purpose digital I/O / Timer_B7 CCR3. Capture: CCI3A/CCI3B input, compare: Out3 output
P3.3/UCB0CLK	68	I/O	General-purpose digital I/O / external clock input—USCI_B0/UART or SPI mode, clock output—USCI_B0/SPI mode
P3.2/UCB0SOMI/ UCB0SCL	69	I/O	General-purpose digital I/O / slave out/master in of USCI_B0/SPI mode /I2C clock—USCI_B0/I2C mode
P3.1/UCB0SIMO/ UCB0SDA	70	I/O	General-purpose digital I/O / slave in/master out of USCI_B0/SPI mode, I2C data—USCI_B0/I2C mode
P3.0/UCB0STE	71	I/O	General-purpose digital I/O / slave transmit enable—USCI_B0/SPI mode
P2.7/ADC12CLK/ DMAE0	72	I/O	General-purpose digital I/O / conversion clock—12-bit ADC / DMA Channel 0 external trigger
P2.6/CAOUT	73	I/O	General-purpose digital I/O / Comparator_A output
P2.5/UCA0RXD	74	I/O	General-purpose digital I/O / receive data in—USCI_A0/UART or IrDA mode
P2.4/UCA0TXD	75	I/O	General-purpose digital I/O / transmit data out—USCI_A0/UART or IrDA mode
P2.3/TB2	76	I/O	General-purpose digital I/O / Timer_B7 CCR2. Capture: CCI2A/CCI2B input, compare: Out2 output
P2.2/TB1	77	I/O	General-purpose digital I/O / Timer_B7 CCR1. Capture: CCI1A/CCI1B input, compare: Out1 output
P2.1/TB0	78	I/O	General-purpose digital I/O / Timer_B7 CCR0. Capture: CCI0A/CCI0B input, compare: Out0 output
P2.0/TA2	79	I/O	General-purpose digital I/O / Timer_A Capture: CCI2A input, compare: Out2 output
P1.7/CA1	80	I/O	General-purpose digital I/O / Comparator_A input
P1.6/CA0	81	I/O	General-purpose digital I/O / Comparator_A input
P1.5/TACLK/ACLK	82	I/O	General-purpose digital I/O / Timer_A, clock signal TACLK input / ACLK output (divided by 1, 2, 4, or 8)
P1.4/TBCLK/SMCLK	83	I/O	General-purpose digital I/O / input clock TBCLK—Timer_B7 / submain system clock SMCLK output
P1.3/TBOUTH/SVSOUT	84	I/O	General-purpose digital I/O / switch all PWM digital output ports to high impedance—Timer_B7 TB0 to TB6 / SVS: output of SVS comparator
P1.2/TA1	85	I/O	General-purpose digital I/O / Timer_A, Capture: CCI1A input, compare: Out1 output
P1.1/TA0/MCLK	86	I/O	General-purpose digital I/O / Timer_A. Capture: CCI0B input / MCLK output. Note: TA0 is only an input on this pin / BSL receive
P1.0/TA0	87	I/O	General-purpose digital I/O / Timer_A. Capture: CCI0A input, compare: Out0 output / BSL transmit
XT2OUT	88	O	Output terminal of crystal oscillator XT2
XT2IN	89	I	Input port for crystal oscillator XT2. Only standard crystals can be connected.
TDO/TDI	90	I/O	Test data output port. TDO/TDI data output or programming data input terminal
TDI/TCLK	91	I	Test data input or test clock input. The device protection fuse is connected to TDI/TCLK.
TMS	92	I	Test mode select. TMS is used as an input port for device programming and test.
TCK	93	I	Test clock. TCK is the clock input port for device programming and test.
$\overline{\text{RST}}$/NMI	94	I	Reset input or nonmaskable interrupt input port
P6.0/A0	95	I/O	General-purpose digital I/O / analog input a0—12-bit ADC
P6.1/A1	96	I/O	General-purpose digital I/O / analog input a1—12-bit ADC
P6.2/A2	97	I/O	General-purpose digital I/O / analog input a2—12-bit ADC
AV_{SS}	98		Analog supply voltage, negative terminal. Supplies SVS, brownout, oscillator, comparator_A, port 1
DV_{SS1}	99		Digital supply voltage, negative terminal
AV_{CC}	100		Analog supply voltage, positive terminal. Supplies SVS, brownout, oscillator, comparator_A, port 1; must not power up prior to DV_{CC1}/DV_{CC2}.

MSP430x461x1 Terminal Functions

TERMINAL NAME	TERMINAL NO.	I/O	DESCRIPTION
DV_{CC1}	1		Digital supply voltage, positive terminal
P6.3	2	I/O	General-purpose digital I/O
P6.4	3	I/O	General-purpose digital I/O
P6.5	4	I/O	General-purpose digital I/O
P6.6	5	I/O	General-purpose digital I/O
P6.7/SVSIN	6	I/O	General-purpose digital I/O / analog input to brownout, supply voltage supervisor
Reserved	7	O	Reserved, do not connect externally
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
DV_{SS}	10	I/O	Connect to DV_{SS}
DV_{SS}	11	I	Connect to DV_{SS}
P5.1/S0 (see Note 2)	12	I/O	General-purpose digital I/O / LCD segment output 0
P5.0/S1 (see Note 2)	13	I/O	General-purpose digital I/O / LCD segment output 1
P10.7/S2 (see Note 2)	14	I/O	General-purpose digital I/O / LCD segment output 2
P10.6/S3 (see Note 2)	15	I/O	General-purpose digital I/O / LCD segment output 3
P10.5/S4	16	I/O	General-purpose digital I/O / LCD segment output 4
P10.4/S5	17	I/O	General-purpose digital I/O / LCD segment output 5
P10.3/S6	18	I/O	General-purpose digital I/O / LCD segment output 6
P10.2/S7	19	I/O	General-purpose digital I/O / LCD segment output 7
P10.1/S8	20	I/O	General-purpose digital I/O / LCD segment output 8
P10.0/S9	21	I/O	General-purpose digital I/O / LCD segment output 9
P9.7/S10	22	I/O	General-purpose digital I/O / LCD segment output 10
P9.6/S11	23	I/O	General-purpose digital I/O / LCD segment output 11
P9.5/S12	24	I/O	General-purpose digital I/O / LCD segment output 12
P9.4/S13	25	I/O	General-purpose digital I/O / LCD segment output 13
P9.3/S14	26	I/O	General-purpose digital I/O / LCD segment output 14
P9.2/S15	27	I/O	General-purpose digital I/O / LCD segment output 15
P9.1/S16	28	I/O	General-purpose digital I/O / LCD segment output 16
P9.0/S17	29	I/O	General-purpose digital I/O / LCD segment output 17
P8.7/S18	30	I/O	General-purpose digital I/O / LCD segment output 18
P8.6/S19	31	I/O	General-purpose digital I/O / LCD segment output 19
P8.5/S20	32	I/O	General-purpose digital I/O / LCD segment output 20
P8.4/S21	33	I/O	General-purpose digital I/O / LCD segment output 21
P8.3/S22	34	I/O	General-purpose digital I/O / LCD segment output 22

NOTE 2: Segments S0 through S3 are disabled when the LCD charge pump feature is enabled (LCDCPEN = 1) and cannot be used together with the LCD charge pump. In addition, when using segments S0 through S3 with an external LCD voltage supply, $V_{LCD} \le AV_{CC}$.

Terminal Functions (Continued)

TERMINAL		I/O	DESCRIPTION
NAME	NO.		
P8.2/S23	35	I/O	General-purpose digital I/O / LCD segment output 23
P8.1/S24	36	I/O	General-purpose digital I/O / LCD segment output 24
P8.0/S25	37	I/O	General-purpose digital I/O / LCD segment output 25
P7.7/S26	38	I/O	General-purpose digital I/O / LCD segment output 26
P7.6/S27	39	I/O	General-purpose digital I/O / LCD segment output 27
P7.5/S28	40	I/O	General-purpose digital I/O / LCD segment output 28
P7.4/S29	41	I/O	General-purpose digital I/O / LCD segment output 29
P7.3/UCA0CLK/S30	42	I/O	General-purpose digital I/O / external clock input – USCI_A0/UART or SPI mode, clock output – USCI_A0/SPI mode / LCD segment 30
P7.2/UCA0SOMI/S31	43	I/O	General-purpose digital I/O / slave out/master in of USCI_A0/SPI mode / LCD segment output 31
P7.1/UCA0SIMO/S32	44	I/O	General-purpose digital I/O / slave in/master out of USCI_A0/SPI mode / LCD segment output 32
P7.0/UCA0STE/S33	45	I/O	General-purpose digital I/O / slave transmit enable—USCI_A0/SPI mode / LCD segment output 33
P4.7/UCA0RXD/S34	46	I/O	General-purpose digital I/O / receive data in – USCI_A0/UART or IrDA mode / LCD segment output 34
P4.6/UCA0TXD/S35	47	I/O	General-purpose digital I/O / transmit data out – USCI_A0/UART or IrDA mode / LCD segment output 35
P4.5/UCLK1/S36	48	I/O	General-purpose digital I/O / external clock input – USART1/UART or SPI mode, clock output – USART1/SPI MODE / LCD segment output 36
P4.4/SOMI1/S37	49	I/O	General-purpose digital I/O / slave out/master in of USART1/SPI mode / LCD segment output 37
P4.3/SIMO1/S38	50	I/O	General-purpose digital I/O / slave in/master out of USART1/SPI mode / LCD segment output 38
P4.2/STE1/S39	51	I/O	General-purpose digital I/O / slave transmit enable—USART1/SPI mode / LCD segment output 39
COM0	52	O	COM0–3 are used for LCD backplanes.
P5.2/COM1	53	I/O	General-purpose digital I/O / common output, COM0–3 are used for LCD backplanes.
P5.3/COM2	54	I/O	General-purpose digital I/O / common output, COM0–3 are used for LCD backplanes.
P5.4/COM3	55	I/O	General-purpose digital I/O / common output, COM0–3 are used for LCD backplanes.
P5.5/R03	56	I/O	General-purpose digital I/O / Input port of lowest analog LCD level (V5)
P5.6/LCDREF/R13	57	I/O	General-purpose digital I/O / External reference voltage input for regulated LCD voltage / Input port of third most positive analog LCD level (V4 or V3)
P5.7/R23	58	I/O	General-purpose digital I/O / Input port of second most positive analog LCD level (V2)
LCDCAP/R33	59	I	LCD capacitor connection / Input/output port of most positive analog LCD level (V1)
DV_{CC2}	60		Digital supply voltage, positive terminal
DV_{SS2}	61		Digital supply voltage, negative terminal
P4.1/URXD1	62	I/O	General-purpose digital I/O / receive data in—USART1/UART mode
P4.0/UTXD1	63	I/O	General-purpose digital I/O / transmit data out—USART1/UART mode
P3.7/TB6	64	I/O	General-purpose digital I/O / Timer_B7 CCR6. Capture: CCI6A/CCI6B input, compare: Out6 output
P3.6/TB5	65	I/O	General-purpose digital I/O / Timer_B7 CCR5. Capture: CCI5A/CCI5B input, compare: Out5 output
P3.5/TB4	66	I/O	General-purpose digital I/O / Timer_B7 CCR4. Capture: CCI4A/CCI4B input, compare: Out4 output

Terminal Functions (Continued)

TERMINAL		I/O	DESCRIPTION
NAME	NO.		
P3.4/TB3	67	I/O	General-purpose digital I/O / Timer_B7 CCR3. Capture: CCI3A/CCI3B input, compare: Out3 output
P3.3/UCB0CLK	68	I/O	General-purpose digital I/O / external clock input—USCI_B0/UART or SPI mode, clock output—USCI_B0/SPI mode
P3.2/UCB0SOMI/ UCB0SCL	69	I/O	General-purpose digital I/O / slave out/master in of USCI_B0/SPI mode /I2C clock—USCI_B0/I2C mode
P3.1/UCB0SIMO/ UCB0SDA	70	I/O	General-purpose digital I/O / slave in/master out of USCI_B0/SPI mode, I2C data—USCI_B0/I2C mode
P3.0/UCB0STE	71	I/O	General-purpose digital I/O / slave transmit enable—USCI_B0/SPI mode
P2.7/ADC12CLK/ DMAE0	72	I/O	General-purpose digital I/O / conversion clock—12-bit ADC / DMA Channel 0 external trigger
P2.6/CAOUT	73	I/O	General-purpose digital I/O / Comparator_A output
P2.5/UCA0RXD	74	I/O	General-purpose digital I/O / receive data in—USCI_A0/UART or IrDA mode
P2.4/UCA0TXD	75	I/O	General-purpose digital I/O / transmit data out—USCI_A0/UART or IrDA mode
P2.3/TB2	76	I/O	General-purpose digital I/O / Timer_B7 CCR2. Capture: CCI2A/CCI2B input, compare: Out2 output
P2.2/TB1	77	I/O	General-purpose digital I/O / Timer_B7 CCR1. Capture: CCI1A/CCI1B input, compare: Out1 output
P2.1/TB0	78	I/O	General-purpose digital I/O / Timer_B7 CCR0. Capture: CCI0A/CCI0B input, compare: Out0 output
P2.0/TA2	79	I/O	General-purpose digital I/O / Timer_A Capture: CCI2A input, compare: Out2 output
P1.7/CA1	80	I/O	General-purpose digital I/O / Comparator_A input
P1.6/CA0	81	I/O	General-purpose digital I/O / Comparator_A input
P1.5/TACLK/ACLK	82	I/O	General-purpose digital I/O / Timer_A, clock signal TACLK input / ACLK output (divided by 1, 2, 4, or 8)
P1.4/TBCLK/SMCLK	83	I/O	General-purpose digital I/O / input clock TBCLK—Timer_B7 / submain system clock SMCLK output
P1.3/TBOUTH/SVSOUT	84	I/O	General-purpose digital I/O / switch all PWM digital output ports to high impedance—Timer_B7 TB0 to TB6 / SVS: output of SVS comparator
P1.2/TA1	85	I/O	General-purpose digital I/O / Timer_A, Capture: CCI1A input, compare: Out1 output
P1.1/TA0/MCLK	86	I/O	General-purpose digital I/O / Timer_A. Capture: CCI0B input / MCLK output. Note: TA0 is only an input on this pin / BSL receive
P1.0/TA0	87	I/O	General-purpose digital I/O / Timer_A. Capture: CCI0A input, compare: Out0 output / BSL transmit
XT2OUT	88	O	Output terminal of crystal oscillator XT2
XT2IN	89	I	Input port for crystal oscillator XT2. Only standard crystals can be connected.
TDO/TDI	90	I/O	Test data output port. TDO/TDI data output or programming data input terminal
TDI/TCLK	91	I	Test data input or test clock input. The device protection fuse is connected to TDI/TCLK.
TMS	92	I	Test mode select. TMS is used as an input port for device programming and test.
TCK	93	I	Test clock. TCK is the clock input port for device programming and test.
$\overline{\text{RST}}$/NMI	94	I	Reset input or nonmaskable interrupt input port
P6.0	95	I/O	General-purpose digital I/O
P6.1	96	I/O	General-purpose digital I/O
P6.2	97	I/O	General-purpose digital I/O
AV_{SS}	98		Analog supply voltage, negative terminal. Supplies SVS, brownout, oscillator, comparator_A, port 1
DV_{SS1}	99		Digital supply voltage, negative terminal
AV_{CC}	100		Analog supply voltage, positive terminal. Supplies SVS, brownout, oscillator, comparator_A, port 1; must not power up prior to DV_{CC1}/DV_{CC2}.

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.

The MSP430x461x(1) device family uses the MSP430X CPU and is completely backward compatible with the MSP430 CPU. For a complete description of the MSP430X CPU, see the *MSP430x4xx Family User's Guide*.

instruction set

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

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

interrupt vector addresses

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

Table 3. Interrupt Sources, Flags, and Vectors

INTERRUPT SOURCE	INTERRUPT FLAG	SYSTEM INTERRUPT	WORD ADDRESS	PRIORITY
Power-Up External Reset Watchdog Flash Memory	WDTIFG KEYV (see Note 1 and 5)	Reset	0FFFEh	31, highest
NMI Oscillator Fault Flash Memory Access Violation	NMIIFG (see Notes 1 and 3) OFIFG (see Notes 1 and 3) ACCVIFG (see Notes 1, 2, and 5)	(Non)maskable (Non)maskable (Non)maskable	0FFFCh	30
Timer_B7	TBCCR0 CCIFG0 (see Note 2)	Maskable	0FFFAh	29
Timer_B7	TBCCR1 CCIFG1 ... TBCCR6 CCIFG6, TBIFG (see Notes 1 and 2)	Maskable	0FFF8h	28
Comparator_A	CAIFG	Maskable	0FFF6h	27
Watchdog Timer+	WDTIFG	Maskable	0FFF4h	26
USCI_A0/USCI_B0 Receive	UCA0RXIFG, UCB0RXIFG (see Note 1)	Maskable	0FFF2h	25
USCI_A0/USCI_B0 Transmit	UCA0TXIFG, UCB0TXIFG (see Note 1)	Maskable	0FFF0h	24
ADC12 (see Note 6)	ADC12IFG (see Notes 1 and 2)	Maskable	0FFEEh	23
Timer_A3	TACCR0 CCIFG0 (see Note 2)	Maskable	0FFECh	22
Timer_A3	TACCR1 CCIFG1 and TACCR2 CCIFG2, TAIFG (see Notes 1 and 2)	Maskable	0FFEAh	21
I/O Port P1 (Eight Flags)	P1IFG.0 to P1IFG.7 (see Notes 1 and 2)	Maskable	0FFE8h	20
USART1 Receive	URXIFG1	Maskable	0FFE6h	19
USART1 Transmit	UTXIFG1	Maskable	0FFE4h	18
I/O Port P2 (Eight Flags)	P2IFG.0 to P2IFG.7 (see Notes 1 and 2)	Maskable	0FFE2h	17
Basic Timer1/RTC	BTIFG	Maskable	0FFE0h	16
DMA	DMA0IFG, DMA1IFG, DMA2IFG (see Notes 1 and 2)	Maskable	0FFDEh	15
Reserved	Reserved	Maskable	0FFDCh	14
Reserved	Reserved (see Note 4)		0FFDAh	13
			...	...
			0FFC0h	0, lowest

NOTES: 1. Multiple source flags
2. Interrupt flags are located in the module.
3. A reset is generated if the CPU tries to fetch instructions from within the module register memory address range (0h to 01FFh). (Non)maskable: the individual interrupt-enable bit can disable an interrupt event, but the general-interrupt enable cannot disable it.
4. The interrupt vectors at addresses 0FFDAh to 0FFC0h are not used in this device and can be used for regular program code if necessary.
5. Access and key violations, KEYV and ACCVIFG, only applicable to F devices.
6. ADC12 is not implemented in MSP430x461x1 devices.

special function registers (SFRs)

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

interrupt enable 1 and 2

Address	7	6	5	4	3	2	1	0
0h			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 as a general-purpose timer.
OFIE	Oscillator-fault-interrupt enable
NMIIE	Nonmaskable-interrupt enable
ACCVIE	Flash access violation interrupt enable

Address	7	6	5	4	3	2	1	0
01h	BTIE		UTXIE1	URXIE1	UCB0TXIE	UCB0RXIE	UCA0TXIE	UCA0RXIE
	rw–0		rw–0	rw–0	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
URXIE1	USART1 UART and SPI receive-interrupt enable
UTXIE1	USART1 UART and SPI transmit-interrupt enable
BTIE	Basic timer interrupt enable

interrupt flag register 1 and 2

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

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

OFIFG: Flag set on oscillator fault

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

Address	7	6	5	4	3	2	1	0
03h	BTIFG		UTXIFG1	URXIFG1	UCB0TXIFG	UCB0RXIFG	UCA0TXIFG	UCA0RXIFG
	rw–0		rw–1	rw–0	rw–0	rw–0	rw–0	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

URXIFG0: USART1: UART and SPI receive flag

UTXIFG0: USART1: UART and SPI transmit flag

BTIFG: Basic timer flag

module enable registers 1 and 2

Address	7	6	5	4	3	2	1	0
04h								

Address	7	6	5	4	3	2	1	0
05h			UTXE1	URXE1 USPIE1				
			rw–0	rw–0				

URXE1: USART1: UART mode receive enable

UTXE1: USART1: UART mode transmit enable

USPIE1: USART1: SPI mode transmit and receive enable

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

		MSP430F4616 MSP430F46161	MSP430F4617 MSP430F46171	MSP430F4618 MSP430F46181	MSP430F4619 MSP430F46191
Memory Main: interrupt vector Main: code memory	Size Flash Flash	92KB 0FFFFh – 0FFC0h 018FFFh – 002100h	92KB 0FFFFh – 0FFC0h 019FFFh – 003100h	116KB 0FFFFh – 0FFC0h 01FFFFh – 003100h	120KB 0FFFFh – 0FFC0h 01FFFFh – 002100h
RAM (Total) Extended Mirrored	Size Size Size	4KB 020FFh – 01100h 2KB 020FFh – 01900h 2KB 018FFh – 01100h	8KB 030FFh – 01100h 6KB 030FFh – 01900h 2KB 018FFh – 01100h	8KB 030FFh – 01100h 6KB 030FFh – 01900h 2KB 018FFh – 01100h	4KB 020FFh – 01100h 2KB 020FFh – 01900h 2KB 018FFh – 01100h
Information memory	Size Flash	256 Byte 010FFh – 01000h	256 Byte 010FFh – 01000h	256 Byte 010FFh – 01000h	256 Byte 010FFh – 01000h
Boot memory	Size ROM	1KB 0FFFh – 0C00h	1KB 0FFFh – 0C00h	1KB 0FFFh – 0C00h	1KB 0FFFh – 0C00h
RAM (mirrored at 018FFh – 01100h)	Size	2KB 09FFh – 0200h	2KB 09FFh – 0200h	2KB 09FFh – 0200h	2KB 09FFh – 0200h
Peripherals	16 bit 8 bit 8-bit SFR	01FFh – 0100h 0FFh – 010h 0Fh – 00h	01FFh – 0100h 0FFh – 010h 0Fh – 00h	01FFh – 0100h 0FFh – 010h 0Fh – 00h	01FFh – 0100h 0FFh – 010h 0Fh – 00h

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. A bootstrap loader security key is provided at address 0FFBEh to disable the BSL completely or to disable the erasure of the flash if an invalid password is supplied. The BSL is optional for ROM-based devices. 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.

BSLKEY	DESCRIPTION
00000h	Erasure of flash disabled if an invalid password is supplied
0AA55h	BSL disabled
any other value	BSL enabled

BSL FUNCTION	PZ PACKAGE PINS
Data Transmit	87/A7 – P1.0
Data Receive	86/E7 – P1.1

flash memory

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

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

peripherals

Peripherals are connected to the CPU through data, address, and control buses and can be handled using all instructions. For complete module descriptions, see the *MSP430x4xx Family User's Guide*, literature number SLAU056.

DMA controller

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

oscillator and system clock

The clock system in the MSP430x461x(1) family of devices is supported by the FLL+ module, which includes support for a 32768-Hz watch crystal oscillator, an internal digitally controlled oscillator (DCO), and a high frequency crystal oscillator. The FLL+ clock module is designed to meet the requirements of both low system cost and low power consumption. The FLL+ features digital frequency locked loop (FLL) hardware that, in conjunction with a digital modulator, stabilizes the DCO frequency to a programmable multiple of the watch crystal frequency. The internal DCO provides a fast turn-on clock source and stabilizes in less than 6 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 subsystem 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 ten 8-bit I/O ports implemented—ports P1 through P10:

- All individual I/O bits are independently programmable.
- Any combination of input, output, and interrupt conditions is possible.
- Edge-selectable interrupt input capability for all the eight bits of ports P1 and P2.
- Read/write access to port-control registers is supported by all instructions.
- Ports P7/P8 and P9/P10 can be accessed word-wise as ports PA and PB respectively.

Basic Timer1 and Real-Time Clock (RTC)

The Basic Timer1 has two independent 8-bit timers that can be cascaded to form a 16-bit timer/counter. Both timers can be read and written by software. Basic Timer1 is extended to provide an integrated real-time clock (RTC). An internal calendar compensates for months with less than 31 days and includes leap-year correction.

LCD_A drive with regulated charge pump

The LCD_A driver generates the segment and common signals required to drive an LCD display. The LCD_A 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. The module can provide a LCD voltage independent of the supply voltage with its integrated charge pump. Furthermore it is possible to control the level of the LCD voltage and, thus, contrast by software.

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.

universal serial communication interface (USCI)

The USCI modules are used for serial data communication. The USCI module supports synchronous communication protocols like SPI (3 or 4 pin), I2C and asynchronous communication protocols like UART, enhanced UART with automatic baudrate detection, and IrDA.

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

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

USART1

The hardware universal synchronous/asynchronous receive transmit (USART) peripheral module 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.

hardware multiplier

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

Timer_A3

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

TIMER_A3 SIGNAL CONNECTIONS					
INPUT PIN NUMBER	DEVICE INPUT SIGNAL	MODULE INPUT NAME	MODULE BLOCK	MODULE OUTPUT SIGNAL	OUTPUT PIN NUMBER
PZ					PZ
82/B9 - P1.5	TACLK	TACLK	Timer	NA	
	ACLK	ACLK			
	SMCLK	SMCLK			
82/B9 - P1.5	$\overline{\text{TACLK}}$	INCLK			
87/A7 - P1.0	TA0	CCI0A	CCR0	TA0	87/A7 - P1.0
86/E7 - P1.1	TA0	CCI0B			
	DV_{SS}	GND			
	DV_{CC}	V_{CC}			
85/D7 - P1.2	TA1	CCI1A	CCR1	TA1	85/D7 - P1.2
	CAOUT (internal)	CCI1B			ADC12 (internal)
	DV_{SS}	GND			
	DV_{CC}	V_{CC}			
79/A10 - P2.0	TA2	CCI2A	CCR2	TA2	79/A10 - P2.0
	ACLK (internal)	CCI2B			
	DV_{SS}	GND			
	DV_{CC}	V_{CC}			

Timer_B7

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

TIMER_B7 SIGNAL CONNECTIONS					
INPUT PIN NUMBER	DEVICE INPUT SIGNAL	MODULE INPUT NAME	MODULE BLOCK	MODULE OUTPUT SIGNAL	OUTPUT PIN NUMBER
PZ					PZ
83/B8 - P1.4	TBCLK	TBCLK	Timer	NA	
	ACLK	ACLK			
	SMCLK	SMCLK			
83/B8 - P1.4	$\overline{\text{TBCLK}}$	INCLK			
78/D8 - P2.1	TB0	CCI0A	CCR0	TB0	78/D8 - P2.1
78/D8 - P2.1	TB0	CCI0B			ADC12 (internal)
	DV_{SS}	GND			
	DV_{CC}	V_{CC}			
77/E8 - P2.2	TB1	CCI1A	CCR1	TB1	77/E8 - P2.2
77/E8 - P2.2	TB1	CCI1B			ADC12 (internal)
	DV_{SS}	GND			
	DV_{CC}	V_{CC}			
76/A11 - P2.3	TB2	CCI2A	CCR2	TB2	76/A11 - P2.3
76/A11 - P2.3	TB2	CCI2B			
	DV_{SS}	GND			
	DV_{CC}	V_{CC}			
67/E12 - P3.4	TB3	CCI3A	CCR3	TB3	67/E12 - P3.4
67/E12 - P3.4	TB3	CCI3B			
	DV_{SS}	GND			
	DV_{CC}	V_{CC}			
66/G9 - P3.5	TB4	CCI4A	CCR4	TB4	66/G9 - P3.5
66/G9 - P3.5	TB4	CCI4B			
	DV_{SS}	GND			
	DV_{CC}	V_{CC}			
65/F11 - P3.6	TB5	CCI5A	CCR5	TB5	65/F11 - P3.6
65/F11 - P3.6	TB5	CCI5B			
	DV_{SS}	GND			
	DV_{CC}	V_{CC}			
64/F12 - P3.7	TB6	CCI6A	CCR6	TB6	64/F12 - P3.7
	ACLK (internal)	CCI6B			
	DV_{SS}	GND			
	DV_{CC}	V_{CC}			

Comparator_A

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

ADC12 (MSP430x461x Only)

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

peripheral file map

PERIPHERALS WITH WORD ACCESS			
Watchdog+	Watchdog timer control	WDTCTL	0120h
Timer_B7	Capture/compare register 6	TBCCR6	019Eh
	Capture/compare register 5	TBCCR5	019Ch
	Capture/compare register 4	TBCCR4	019Ah
	Capture/compare register 3	TBCCR3	0198h
	Capture/compare register 2	TBCCR2	0196h
	Capture/compare register 1	TBCCR1	0194h
	Capture/compare register 0	TBCCR0	0192h
	Timer_B register	TBR	0190h
	Capture/compare control 6	TBCCTL6	018Eh
	Capture/compare control 5	TBCCTL5	018Ch
	Capture/compare control 4	TBCCTL4	018Ah
	Capture/compare control 3	TBCCTL3	0188h
	Capture/compare control 2	TBCCTL2	0186h
	Capture/compare control 1	TBCCTL1	0184h
	Capture/compare control 0	TBCCTL0	0182h
	Timer_B control	TBCTL	0180h
	Timer_B interrupt vector	TBIV	011Eh
Timer_A3	Capture/compare register 2	TACCR2	0176h
	Capture/compare register 1	TACCR1	0174h
	Capture/compare register 0	TACCR0	0172h
	Timer_A register	TAR	0170h
	Capture/compare control 2	TACCTL2	0166h
	Capture/compare control 1	TACCTL1	0164h
	Capture/compare control 0	TACCTL0	0162h
	Timer_A control	TACTL	0160h
	Timer_A interrupt vector	TAIV	012Eh
Hardware Multiplier	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 (F devices only)	Flash control 3	FCTL3	012Ch
	Flash control 2	FCTL2	012Ah
	Flash control 1	FCTL1	0128h

peripheral file map (continued)

PERIPHERALS WITH WORD ACCESS (CONTINUED)			
DMA	DMA module control 0	DMACTL0	0122h
	DMA module control 1	DMACTL1	0124h
	DMA interrupt vector	DMAIV	0126h
DMA Channel 0	DMA channel 0 control	DMA0CTL	01D0h
	DMA channel 0 source address	DMA0SA	01D2h
	DMA channel 0 destination address	DMA0DA	01D6h
	DMA channel 0 transfer size	DMA0SZ	01DAh
DMA Channel 1	DMA channel 1 control	DMA1CTL	01DCh
	DMA channel 1 source address	DMA1SA	01DEh
	DMA channel 1 destination address	DMA1DA	01E2h
	DMA channel 1 transfer size	DMA1SZ	01E6h
DMA Channel 2	DMA channel 2 control	DMA2CTL	01E8h
	DMA channel 2 source address	DMA2SA	01EAh
	DMA channel 2 destination address	DMA2DA	01EEh
	DMA channel 2 transfer size	DMA2SZ	01F2h

peripheral file map (continued)

PERIPHERALS WITH WORD ACCESS (CONTINUED)			
ADC12 See also *Peripherals With Byte Access* (MSP430x461x only)	Conversion memory 15	ADC12MEM15	015Eh
	Conversion memory 14	ADC12MEM14	015Ch
	Conversion memory 13	ADC12MEM13	015Ah
	Conversion memory 12	ADC12MEM12	0158h
	Conversion memory 11	ADC12MEM11	0156h
	Conversion memory 10	ADC12MEM10	0154h
	Conversion memory 9	ADC12MEM9	0152h
	Conversion memory 8	ADC12MEM8	0150h
	Conversion memory 7	ADC12MEM7	014Eh
	Conversion memory 6	ADC12MEM6	014Ch
	Conversion memory 5	ADC12MEM5	014Ah
	Conversion memory 4	ADC12MEM4	0148h
	Conversion memory 3	ADC12MEM3	0146h
	Conversion memory 2	ADC12MEM2	0144h
	Conversion memory 1	ADC12MEM1	0142h
	Conversion memory 0	ADC12MEM0	0140h
	Interrupt-vector-word register	ADC12IV	01A8h
	Inerrupt-enable register	ADC12IE	01A6h
	Inerrupt-flag register	ADC12IFG	01A4h
	Control register 1	ADC12CTL1	01A2h
	Control register 0	ADC12CTL0	01A0h
Port PA	Port PA selection	PASEL	03Eh
	Port PA direction	PADIR	03Ch
	Port PA output	PAOUT	03Ah
	Port PA input	PAIN	038h
Port PB	Port PB selection	PBSEL	00Eh
	Port PB direction	PBDIR	00Ch
	Port PB output	PBOUT	00Ah
	Port PB input	PBIN	008h

peripheral file map (continued)

PERIPHERALS WITH BYTE ACCESS			
LCD_A	LCD Voltage Control 1	LCDAVCTL1	0AFh
	LCD Voltage Control 0	LCDAVCTL0	0AEh
	LCD Voltage Port Control 1	LCDAPCTL1	0ADh
	LCD Voltage Port Control 0	LCDAPCTL0	0ACh
	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
ADC12 (Memory control registers require byte access) (MSP430x461x only)	ADC memory-control register 15	ADC12MCTL15	08Fh
	ADC memory-control register 14	ADC12MCTL14	08Eh
	ADC memory-control register 13	ADC12MCTL13	08Dh
	ADC memory-control register 12	ADC12MCTL12	08Ch
	ADC memory-control register 11	ADC12MCTL11	08Bh
	ADC memory-control register 10	ADC12MCTL10	08Ah
	ADC memory-control register 9	ADC12MCTL9	089h
	ADC memory-control register 8	ADC12MCTL8	088h
	ADC memory-control register 7	ADC12MCTL7	087h
	ADC memory-control register 6	ADC12MCTL6	086h
	ADC memory-control register 5	ADC12MCTL5	085h
	ADC memory-control register 4	ADC12MCTL4	084h
	ADC memory-control register 3	ADC12MCTL3	083h
	ADC memory-control register 2	ADC12MCTL2	082h
	ADC memory-control register 1	ADC12MCTL1	081h
	ADC memory-control register 0	ADC12MCTL0	080h
USART1	Transmit buffer	U1TXBUF	07Fh
	Receive buffer	U1RXBUF	07Eh
	Baud rate	U1BR1	07Dh
	Baud rate	U1BR0	07Ch
	Modulation control	U1MCTL	07Bh
	Receive control	U1RCTL	07Ah
	Transmit control	U1TCTL	079h
	USART control	U1CTL	078h

peripheral file map (continued)

PERIPHERALS WITH BYTE ACCESS (CONTINUED)			
USCI	USCI I2C Slave Address	UCBI2CSA	011Ah
	USCI I2C Own Address	UCBI2COA	0118h
	USCI Synchronous Transmit Buffer	UCBTXBUF	06Fh
	USCI Synchronous Receive Buffer	UCBRXBUF	06Eh
	USCI Synchronous Status	UCBSTAT	06Dh
	USCI I2C Interrupt Enable	UCBI2CIE	06Ch
	USCI Synchronous Bit Rate 1	UCBBR1	06Bh
	USCI Synchronous Bit Rate 0	UCBBR0	06Ah
	USCI Synchronous Control 1	UCBCTL1	069h
	USCI Synchronous Control 0	UCBCTL0	068h
	USCI Transmit Buffer	UCATXBUF	067h
	USCI Receive Buffer	UCARXBUF	066h
	USCI Status	UCASTAT	065h
	USCI Modulation Control	UCAMCTL	064h
	USCI Baud Rate 1	UCABR1	063h
	USCI Baud Rate 0	UCABR0	062h
	USCI Control 1	UCACTL1	061h
	USCI Control 0	UCACTL0	060h
	USCI IrDA Receive Control	UCAIRRCTL	05Fh
	USCI IrDA Transmit Control	UCAIRTCTL	05Eh
	USCI LIN Control	UCAABCTL	05Dh
Comparator_A	Comparator_A port disable	CAPD	05Bh
	Comparator_A control 2	CACTL2	05Ah
	Comparator_A control 1	CACTL1	059h
BrownOUT, SVS	SVS control register (Reset by brownout signal)	SVSCTL	056h
FLL+Clock	FLL+ Control 1	FLL_CTL1	054h
	FLL+ Control 0	FLL_CTL0	053h
	System clock frequency control	SCFQCTL	052h
	System clock frequency integrator	SCFI1	051h
	System clock frequency integrator	SCFI0	050h
RTC (Basic Timer 1)	Real Time Clock Year High Byte	RTCYEARH	04Fh
	Real Time Clock Year Low Byte	RTCYEARL	04Eh
	Real Time Clock Month	RTCMON	04Dh
	Real Time Clock Day of Month	RTCDAY	04Ch
	Basic Timer1 Counter 2	BTCNT2	047h
	Basic Timer1 Counter 1	BTCNT1	046h
	Real Time Counter 4	RTCNT4	045h
	(Real Time Clock Day of Week)	(RTCDOW)	
	Real Time Counter 3	RTCNT3	044h
	(Real Time Clock Hour)	(RTCHOUR)	
	Real Time Counter 2	RTCNT2	043h
	(Real Time Clock Minute)	(RTCMIN)	
	Real Time Counter 1	RTCNT1	042h
	(Real Time Clock Second)	(RTCSEC)	
	Real Time Clock Control	RTCCTL	041h
	Basic Timer1 Control	BTCTL	040h

peripheral file map (continued)

PERIPHERALS WITH BYTE ACCESS (CONTINUED)			
Port P10	Port P10 selection	P10SEL	00Fh
	Port P10 direction	P10DIR	00Dh
	Port P10 output	P10OUT	00Bh
	Port P10 input	P10IN	009h
Port P9	Port P9 selection	P9SEL	00Eh
	Port P9 direction	P9DIR	00Ch
	Port P9 output	P9OUT	00Ah
	Port P9 input	P9IN	008h
Port P8	Port P8 selection	P8SEL	03Fh
	Port P8 direction	P8DIR	03Dh
	Port P8 output	P8OUT	03Bh
	Port P8 input	P8IN	039h
Port P7	Port P7 selection	P7SEL	03Eh
	Port P7 direction	P7DIR	03Ch
	Port P7 output	P7OUT	03Ah
	Port P7 input	P7IN	038h
Port P6	Port P6 selection	P6SEL	037h
	Port P6 direction	P6DIR	036h
	Port P6 output	P6OUT	035h
	Port P6 input	P6IN	034h
Port P5	Port P5 selection	P5SEL	033h
	Port P5 direction	P5DIR	032h
	Port P5 output	P5OUT	031h
	Port P5 input	P5IN	030h
Port P4	Port P4 selection	P4SEL	01Fh
	Port P4 direction	P4DIR	01Eh
	Port P4 output	P4OUT	01Dh
	Port P4 input	P4IN	01Ch
Port P3	Port P3 selection	P3SEL	01Bh
	Port P3 direction	P3DIR	01Ah
	Port P3 output	P3OUT	019h
	Port P3 input	P3IN	018h
Port P2	Port P2 selection	P2SEL	02Eh
	Port P2 interrupt enable	P2IE	02Dh
	Port P2 interrupt-edge select	P2IES	02Ch
	Port P2 interrupt flag	P2IFG	02Bh
	Port P2 direction	P2DIR	02Ah
	Port P2 output	P2OUT	029h
	Port P2 input	P2IN	028h
Port P1	Port P1 selection	P1SEL	026h
	Port P1 interrupt enable	P1IE	025h
	Port P1 interrupt-edge select	P1IES	024h
	Port P1 interrupt flag	P1IFG	023h
	Port P1 direction	P1DIR	022h
	Port P1 output	P1OUT	021h
	Port P1 input	P1IN	020h

peripheral file map (continued)

PERIPHERALS WITH BYTE ACCESS (CONTINUED)			
Special functions	SFR module enable 2	ME2	005h
	SFR module enable 1	ME1	004h
	SFR interrupt flag 2	IFG2	003h
	SFR interrupt flag 1	IFG1	002h
	SFR interrupt enable 2	IE2	001h
	SFR interrupt enable 1	IE1	000h

absolute maximum ratings over operating free-air temperature (unless otherwise noted)†

Voltage range applied at V_{CC} to V_{SS} . . . . . –0.3 V to 4.1 V
Voltage range applied to any pin (see Note) . . . . . –0.3 V to V_{CC} + 0.3 V
Diode current at any device terminal . . . . . ±2 mA
Storage temperature range, T_{stg}: Unprogrammed device . . . . . –55°C to 150°C
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: 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.

recommended operating conditions

			MIN	NOM	MAX	UNITS
Supply voltage during program execution (see Note 1), V_{CC} (AV_{CC} = $DV_{CC1/2}$ = V_{CC})		MSP430x461x(1)	1.8		3.6	V
Supply voltage during flash memory programming (see Note 1), V_{CC} (AV_{CC} = $DV_{CC1/2}$ = V_{CC})		MSP430F461x(1)	2.7		3.6	V
Supply voltage during program execution, SVS enabled and PORON = 1 (see Note 1 and Note 2), V_{CC} (AV_{CC} = $DV_{CC1/2}$ = V_{CC})		MSP430x461x(1)	2		3.6	V
Supply voltage (see Note 1), V_{SS} (AV_{SS} = $DV_{SS1/2}$ = V_{SS})			0		0	V
Operating free-air temperature range, T_A		MSP430x461x(1)	–40		85	°C
LFXT1 crystal frequency, $f_{(LFXT1)}$ (see Note 2)	LF selected, XTS_FLL = 0	Watch crystal		32.768		kHz
	XT1 selected, XTS_FLL = 1	Ceramic resonator	450		8000	
	XT1 selected, XTS_FLL = 1	Crystal	1000		8000	
XT2 crystal frequency, $f_{(XT2)}$		Ceramic resonator	450		8000	kHz
		Crystal	1000		8000	
Processor frequency (signal MCLK), $f_{(System)}$		V_{CC} = 1.8 V	DC		3.0	MHz
		V_{CC} = 2.0 V	DC		4.6	
		V_{CC} = 3.6 V	DC		8.0	

NOTES: 1. It is recommended to power AV_{CC} and DV_{CC} from the same source. A maximum difference of 0.3 V between AV_{CC} and DV_{CC} can be tolerated during power up and operation.
2. The minimum operating supply voltage is defined according to the trip point where POR is going active by decreasing the supply voltage. POR is going inactive when the supply voltage is raised above the minimum supply voltage plus the hysteresis of the SVS circuitry.
3. In LF mode, the LFXT1 oscillator requires a watch crystal. In XT1 mode, LFXT1 accepts a ceramic resonator or a crystal.

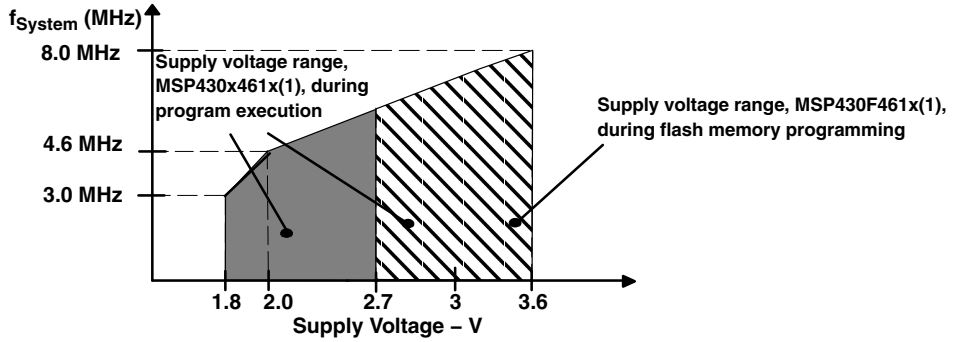


Figure 1. Frequency vs Supply Voltage, Typical Characteristic

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

supply current into AV_{CC} + DV_{CC} excluding external current

PARAMETER			TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
$I_{(AM)}$	Active mode (see Note 1 and Note 4) $f_{(MCLK)} = f_{(SMCLK)}$ = 1 MHz, $f_{(ACLK)}$ = 32,768 Hz XTS=0, SELM=(0,1) (F461x(1): Program executes from flash)	C461x(1)	T_A = –40°C to 85°C	2.2 V		280	370	µA
				3 V		470	580	
		F461x(1)	T_A = –40°C to 85°C	2.2 V		400	480	µA
				3 V		600	740	
$I_{(LPM0)}$	Low-power mode (LPM0) (see Note 1 and Note 4)	x461x(1)	T_A = –40°C to 85°C	2.2 V		45	70	µA
				3 V		75	110	
$I_{(LPM2)}$	Low-power mode (LPM2), $f_{(MCLK)} = f_{(SMCLK)}$ = 0 MHz, $f_{(ACLK)}$ = 32,768 Hz, SCG0 = 0 (see Note 2 and Note 4)		T_A = –40°C to 85°C	2.2 V		11	20	µA
				3 V		17	24	
$I_{(LPM3)}$	Low-power mode (LPM3) $f_{(MCLK)} = f_{(SMCLK)}$ = 0 MHz, $f_{(ACLK)}$ = 32,768 Hz, SCG0 = 1 Basic Timer1 enabled, ACLK selected LCD_A enabled, LCDCPEN = 0; (static mode; $f_{LCD} = f_{(ACLK)}$ /32) (see Note 2 and Note 3 and Note 4)		T_A = –40°C	2.2 V		1.3	4.0	µA
			T_A = 25°C			1.3	4.0	
			T_A = 60°C			2.22	6.5	
			T_A = 85°C			6.5	15.0	
			T_A = –40°C	3 V		1.9	5.0	
			T_A = 25°C			1.9	5.0	
			T_A = 60°C			2.5	7.5	
			T_A = 85°C			7.5	18.0	
$I_{(LPM3)}$	Low-power mode (LPM3) $f_{(MCLK)} = f_{(SMCLK)}$ = 0 MHz, $f_{(ACLK)}$ = 32,768 Hz, SCG0 = 1 Basic Timer1 enabled, ACLK selected LCD_A enabled, LCDCPEN = 0; (4–mux mode; $f_{LCD} = f_{(ACLK)}$ /32) (see Note 2 and Note 3 and Note 4)		T_A = –40°C	2.2 V		1.5	5.5	µA
			T_A = 25°C			1.5	5.5	
			T_A = 60°C			2.8	7.0	
			T_A = 85°C			7.2	17.0	
			T_A = –40°C	3 V		2.5	6.5	
			T_A = 25°C			2.5	6.5	
			T_A = 60°C			3.2	8.0	
			T_A = 85°C			8.5	20.0	
$I_{(LPM4)}$	Low-power mode (LPM4) $f_{(MCLK)}$ = 0 MHz, $f_{(SMCLK)}$ = 0 MHz, $f_{(ACLK)}$ = 0 Hz, SCG0 = 1 (see Note 2 and Note 4)		T_A = –40°C	2.2 V		0.13	1.0	µA
			T_A = 25°C			0.22	1.0	
			T_A = 60°C			0.9	2.5	
			T_A = 85°C			4.3	12.5	
			T_A = –40°C	3 V		0.13	1.6	
			T_A = 25°C			0.3	1.6	
			T_A = 60°C			1.1	3.0	
			T_A = 85°C			5.0	15.0	

NOTES: 1. Timer_B is clocked by $f_{(DCOCLK)} = f_{(DCO)}$ = 1 MHz. All inputs are tied to 0 V or to V_{CC}. Outputs do not source or sink any current.
2. All inputs are tied to 0 V or to V_{CC}. Outputs do not source or sink any current.
3. The LPM3 currents are characterized with a Micro Crystal CC4V–T1A (9 pF) crystal and OSCCAPx = 1h.
4. Current for brownout included.

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:

$$I_{(AM)} = I_{(AM)\ [3\ V]} + 200\ \mu A/V \times (V_{CC} - 3\ V)$$

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

Schmitt-trigger inputs – Ports P1 to P10, $\overline{\text{RST}}$/NMI, JTAG (TCK, TMS, TDI/TCLK, TDO/TDI)

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

inputs Px.x, TAx, TBx

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)	2.2 V	62			ns
			3 V	50			
$t_{(cap)}$	Timer_A, Timer_B capture timing	TA0, TA1, TA2 TB0, TB1, TB2, TB3, TB4, TB5, TB6	2.2 V	62			ns
			3 V	50			
$f_{(TAext)}$	Timer_A, Timer_B clock frequency externally applied to pin	TACLK, TBCLK, INCLK: $t_{(H)} = t_{(L)}$	2.2 V			8	MHz
$f_{(TBext)}$			3 V			10	
$f_{(TAint)}$	Timer_A, Timer_B clock frequency	SMCLK or ACLK signal selected	2.2 V			8	MHz
$f_{(TBint)}$			3 V			10	

NOTES: 1. The external signal sets the interrupt flag every time the minimum $t_{(int)}$ parameters are met. It may be set even with trigger signals shorter than $t_{(int)}$.

leakage current – Ports P1 to P10 (see Note 1)

PARAMETER			TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
$I_{lkg(Px.y)}$	Leakage current	Port Px	$V_{(Px.y)}$ (see Note 2) $(1 \le x \le 10,\ 0 \le y \le 7)$	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 port pin must be selected as input.

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

outputs – Ports P1 to P10

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
V_{OH}	High-level output voltage	$I_{OH(max)}$ = –1.5 mA (see Note 1)	2.2 V	V_{CC}–0.25		V_{CC}	V
		$I_{OH(max)}$ = –6 mA (see Note 2)	2.2 V	V_{CC}–0.6		V_{CC}	
		$I_{OH(max)}$ = –1.5 mA (see Note 1)	3 V	V_{CC}–0.25		V_{CC}	
		$I_{OH(max)}$ = –6 mA (see Note 2)	3 V	V_{CC}–0.6		V_{CC}	
V_{OL}	Low-level output voltage	$I_{OL(max)}$ = 1.5 mA (see Note 1)	2.2 V	V_{SS}		V_{SS}+0.25	V
		$I_{OL(max)}$ = 6 mA (see Note 2)	2.2 V	V_{SS}		V_{SS}+0.6	
		$I_{OL(max)}$ = 1.5 mA, (see Note 1)	3 V	V_{SS}		V_{SS}+0.25	
		$I_{OL(max)}$ = 6 mA (see Note 2)	3 V	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 ±48 mA to satisfy the maximum specified voltage drop.

output frequency

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$f_{(Px.y)}$	(1 ≤ x ≤ 10, 0 ≤ y ≤ 7)	C_L = 20 pF, I_L = ±1.5 mA	V_{CC} = 2.2 V	DC		10	MHz
			V_{CC} = 3 V	DC		12	MHz
$f_{(MCLK)}$, $f_{(SMCLK)}$	P1.1/TA0/MCLK, P1.4/TBCLK/SMCLK,	C_L = 20 pF	V_{CC} = 2.2 V			10	MHz
$f_{(ACLK)}$	P1.5/TACLK/ACLK		V_{CC} = 3 V	DC		12	MHz
$t_{(Xdc)}$	Duty cycle of output frequency	P1.5/TACLK/ACLK, C_L = 20 pF, V_{CC} = 2.2 V / 3 V	$f_{(ACLK)} = f_{(LFXT1)} = f_{(XT1)}$	40%		60%	
			$f_{(ACLK)} = f_{(LFXT1)} = f_{(LF)}$	30%		70%	
			$f_{(ACLK)} = f_{(LFXT1)}$		50%		
		P1.1/TA0/MCLK, C_L = 20 pF, V_{CC} = 2.2 V / 3 V	$f_{(MCLK)} = f_{(XT1)}$	40%		60%	
			$f_{(MCLK)} = f_{(DCOCLK)}$	50%– 15 ns	50%	50%+ 15 ns	
		P1.4/TBCLK/SMCLK, C_L = 20 pF, V_{CC} = 2.2 V / 3 V	$f_{(SMCLK)} = f_{(XT2)}$	40%		60%	
			$f_{(SMCLK)} = f_{(DCOCLK)}$	50%– 15 ns	50%	50%+ 15 ns	

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

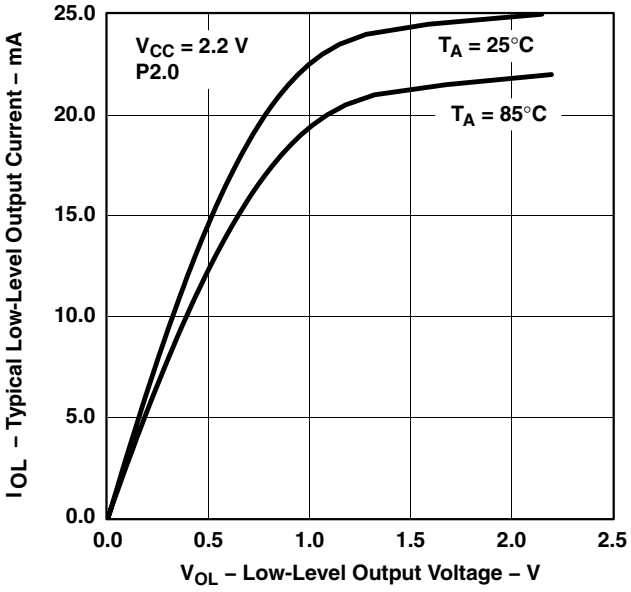


Figure 2

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

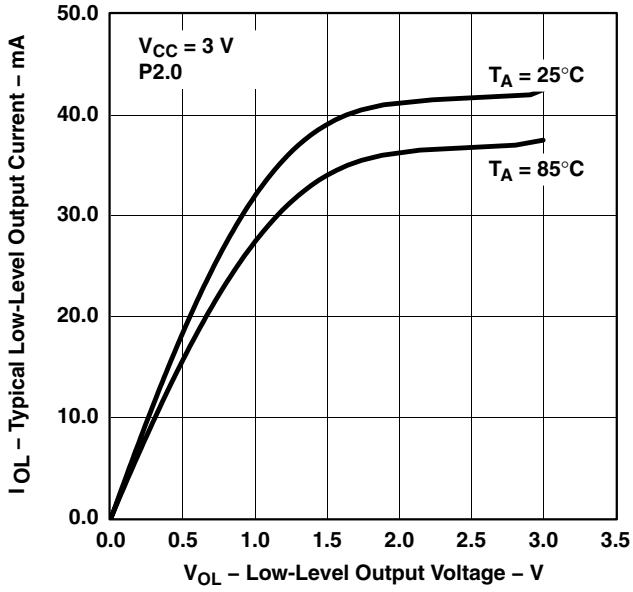


Figure 3

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

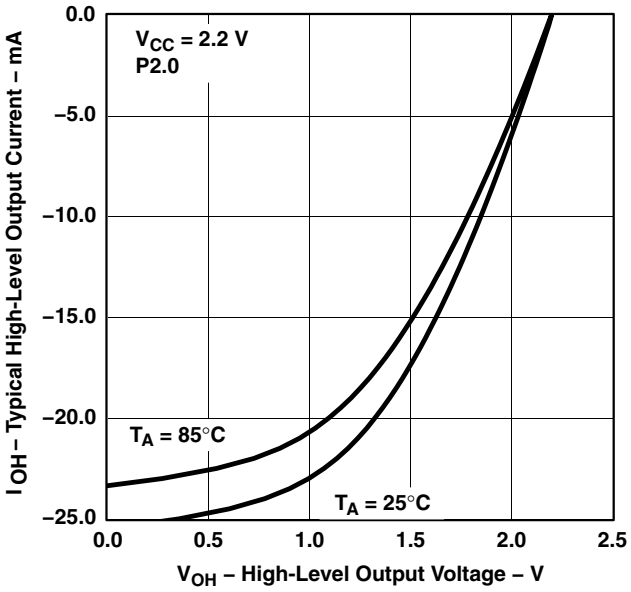


Figure 4

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

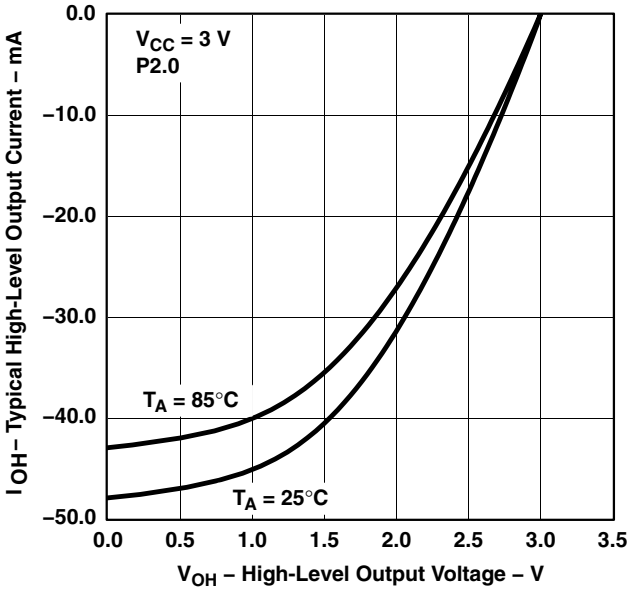


Figure 5

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

wake-up LPM3

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

RAM

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 program memory RAM remain unchanged. No program execution should take place during this supply voltage condition.

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

LCD_A

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
$V_{CC(LCD)}$	Supply voltage (see Note 2)	Charge pump enabled (LCDCPEN = 1; VLCDx > 0000)		2.2		3.6	V
$I_{CC(LCD)}$	Supply current (see Note 2)	$V_{LCD(typ)}$=3 V; LCDCPEN = 1, VLCDx= 1000; all segments on, $f_{LCD} = f_{ACLK}/32$, no LCD connected (see Note 4) T_A = 25°C	2.2 V		3		µA
C_{LCD}	Capacitor on LCDCAP (see Note 1 and Note 3)	Charge pump enabled (LCDCPEN = 1; VLCDx > 0000)		4.7			µF
f_{LCD}	LCD frequency					1.1	kHz
V_{LCD}	LCD voltage (see Note 3)	VLCDx = 0000			V_{CC}		V
		VLCDx = 0001			2.60		
		VLCDx = 0010			2.66		
		VLCDx = 0011			2.72		
		VLCDx = 0100			2.78		
		VLCDx = 0101			2.84		
		VLCDx = 0110			2.90		
		VLCDx = 0111			2.96		
		VLCDx = 1000			3.02		
		VLCDx = 1001			3.08		
		VLCDx = 1010			3.14		
		VLCDx = 1011			3.20		
		VLCDx = 1100			3.26		
		VLCDx = 1101			3.32		
		VLCDx = 1110			3.38		
		VLCDx = 1111			3.44	3.60	
R_{LCD}	LCD driver output impedance	V_{LCD}=3 V; CPEN = 1; VLCDx = 1000, I_{LOAD} = ± 10 µA	2.2 V			10	kΩ

NOTES: 1. Enabling the internal charge pump with an external capacitor smaller than the minimum specified might damage the device.
2. Refer to the supply current specifications $I_{(LPM3)}$ for additional current specifications with the LCD_A module active.
3. Segments S0 through S3 are disabled when the LCD charge pump feature is enabled (LCDCPEN = 1) and cannot be used together with the LCD charge pump. In addition, when using segments S0 through S3 with an external LCD voltage supply, $V_{LCD} \le AV_{CC}$.
4. Connecting an actual display will increase the current consumption depending on the size of the LCD.

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

Comparator_A (see Note 1)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$I_{(CC)}$		CAON=1, CARSEL=0, CAREF=0	V_{CC} = 2.2 V		25	40	µA
			V_{CC} = 3 V		45	60	
$I_{(Refladder/RefDiode)}$		CAON=1, CARSEL=0, CAREF=1/2/3, No load at P1.6/CA0 and P1.7/CA1	V_{CC} = 2.2 V		30	50	µA
			V_{CC} = 3 V		45	71	
$V_{(Ref025)}$	$\frac{\text{Voltage @ 0.25 } V_{CC} \text{ node}}{V_{CC}}$	PCA0=1, CARSEL=1, CAREF=1, No load at P1.6/CA0 and P1.7/CA1	V_{CC} = 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 P1.6/CA0 and P1.7/CA1	V_{CC} = 2.2V / 3 V	0.47	0.48	0.5	
$V_{(RefVT)}$		PCA0=1, CARSEL=1, CAREF=3, No load at P1.6/CA0 and P1.7/CA1; T_A = 85°C	V_{CC} = 2.2 V	390	480	540	mV
			V_{CC} = 3 V	400	490	550	
V_{IC}	Common-mode input voltage range	CAON=1	V_{CC} = 2.2 V / 3 V	0		V_{CC}–1	V
V_p–V_S	Offset voltage	See Note 2	VCC = 2.2 V / 3 V	–30		30	mV
V_{hys}	Input hysteresis	CAON = 1	V_{CC} = 2.2 V / 3 V	0	0.7	1.4	mV
$t_{(response\ LH)}$		T_A = 25°C, Overdrive 10 mV, without filter: CAF = 0	V_{CC} = 2.2 V	160	210	300	ns
			V_{CC} = 3 V	80	150	240	
		T_A = 25°C Overdrive 10 mV, with filter: CAF = 1	V_{CC} = 2.2 V	1.4	1.9	3.4	µs
			V_{CC} = 3 V	0.9	1.5	2.6	
$t_{(response\ HL)}$		T_A = 25°C Overdrive 10 mV, without filter: CAF = 0	V_{CC} = 2.2 V	130	210	300	ns
			V_{CC} = 3 V	80	150	240	
		T_A = 25°C, Overdrive 10 mV, with filter: CAF = 1	V_{CC} = 2.2 V	1.4	1.9	3.4	µs
			V_{CC} = 3 V	0.9	1.5	2.6	

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.

typical characteristics

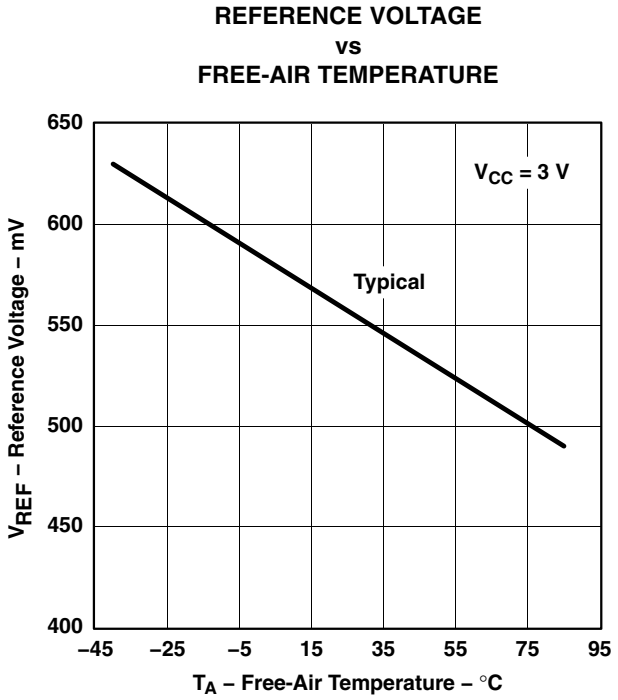


Figure 6. $V_{(RefVT)}$ vs Temperature

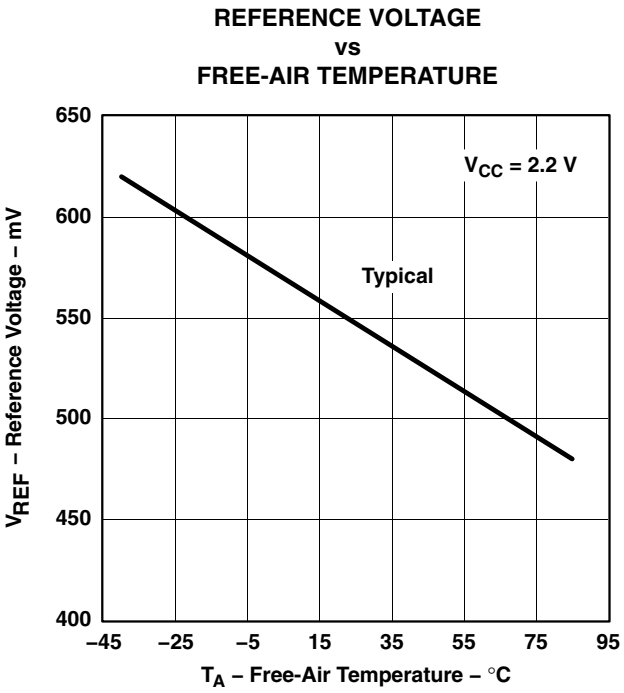


Figure 7. $V_{(RefVT)}$ vs Temperature

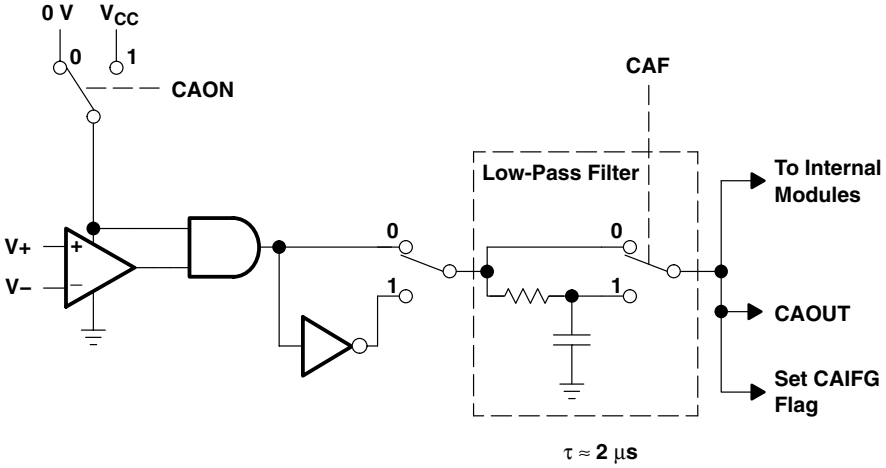


Figure 8. Block Diagram of Comparator_A Module

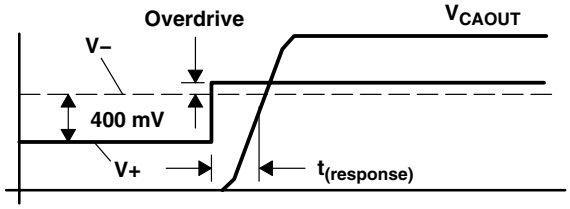


Figure 9. Overdrive Definition

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

POR/brownout reset (BOR) (see Note 1)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{d(BOR)}$	Brownout (see Notes 2 and 3)				2000	µs
$V_{CC(start)}$		$dV_{CC}/dt \le 3$ V/s (see Figure 10)		$0.7 \times V_{(B\_IT-)}$		V
$V_{(B\_IT-)}$		$dV_{CC}/dt \le 3$ V/s (see Figure 10 through Figure 12)			1.79	V
$V_{hys(B\_IT-)}$		$dV_{CC}/dt \le 3$ V/s (see Figure 10)	70	130	210	mV
$t_{(reset)}$		Pulse length needed at $\overline{RST}$/NMI pin to accepted reset internally, V_{CC} = 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.
2. The voltage level $V_{(B\_IT-)} + V_{hys(B\_IT-)}$ is ≤ 1.89V.
3. 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 $V_{CC} \ge V_{CC(min)}$, where $V_{CC(min)}$ is the minimum supply voltage for the desired operating frequency. See the *MSP430x4xx Family User's Guide* for more information on the brownout/SVS circuit.

typical characteristics

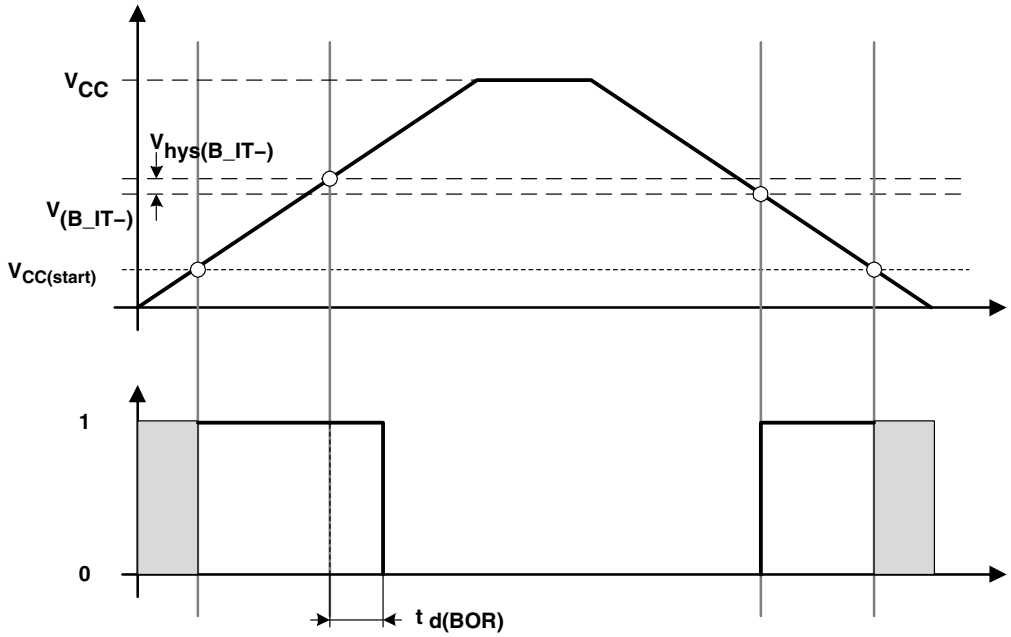


Figure 10. POR/Brownout Reset (BOR) vs Supply Voltage

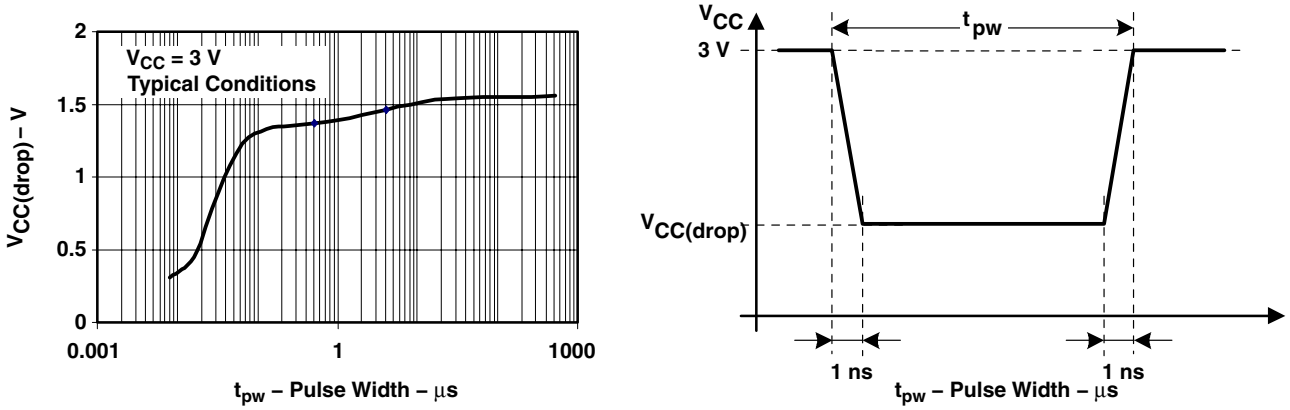


Figure 11. $V_{CC(drop)}$ Level With a Square Voltage Drop to Generate a POR/Brownout Signal

typical characteristics (continued)

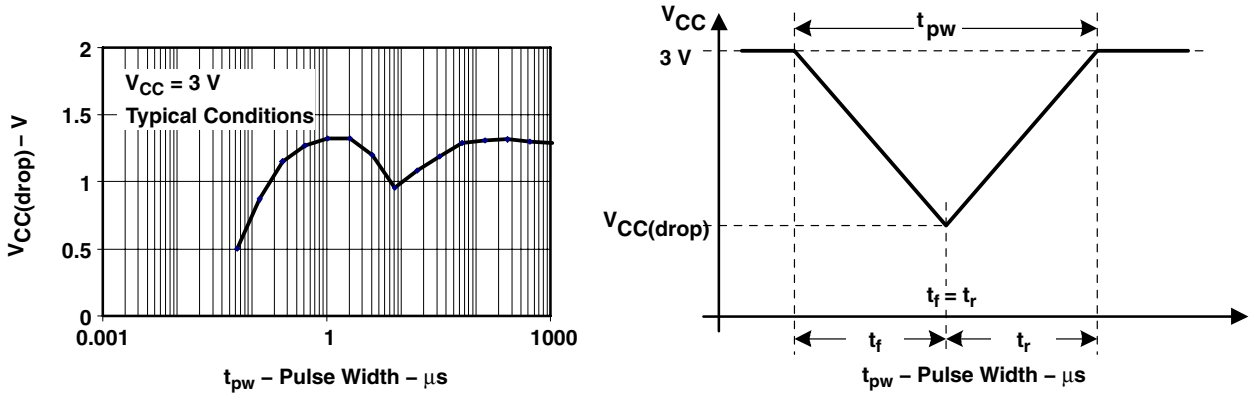


Figure 12. $V_{CC(drop)}$ Level With a Triangle Voltage Drop to Generate a POR/Brownout Signal

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

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

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
$t_{(SVSR)}$	dV_{CC}/dt > 30 V/ms (see Figure 13)		5		150	µs
	$dV_{CC}/dt \le$ 30 V/ms				2000	
$t_{d(SVSon)}$	SVS on, 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 13)			1.55	1.7	V
$V_{hys(SVS\_IT-)}$	$V_{CC}/dt \le$ 3 V/s (see Figure 13)	VLD = 1	70	120	155	mV
		VLD = 2 .. 14	$V_{(SVS\_IT-)}$ x 0.001		$V_{(SVS\_IT-)}$ x 0.016	
	$V_{CC}/dt \le$ 3 V/s (see Figure 13), external voltage applied on A7	VLD = 15	4.4		20	mV
$V_{(SVS\_IT-)}$	$V_{CC}/dt \le$ 3 V/s (see Figure 13)	VLD = 1	1.8	1.9	2.05	V
		VLD = 2	1.94	2.1	2.23	
		VLD = 3	2.05	2.2	2.35	
		VLD = 4	2.14	2.3	2.46	
		VLD = 5	2.24	2.4	2.58	
		VLD = 6	2.33	2.5	2.69	
		VLD = 7	2.46	2.65	2.84	
		VLD = 8	2.58	2.8	2.97	
		VLD = 9	2.69	2.9	3.10	
		VLD = 10	2.83	3.05	3.26	
		VLD = 11	2.94	3.2	3.39	
		VLD = 12	3.11	3.35	3.58†	
		VLD = 13	3.24	3.5	3.73†	
		VLD = 14	3.43	3.7†	3.96†	
	$V_{CC}/dt \le$ 3 V/s (see Figure 13), external voltage applied on A7	VLD = 15	1.1	1.2	1.3	
$I_{CC(SVS)}$ (see Note 4)	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 4: The current consumption of the SVS module is not included in the I_{CC} current consumption data.

typical characteristics

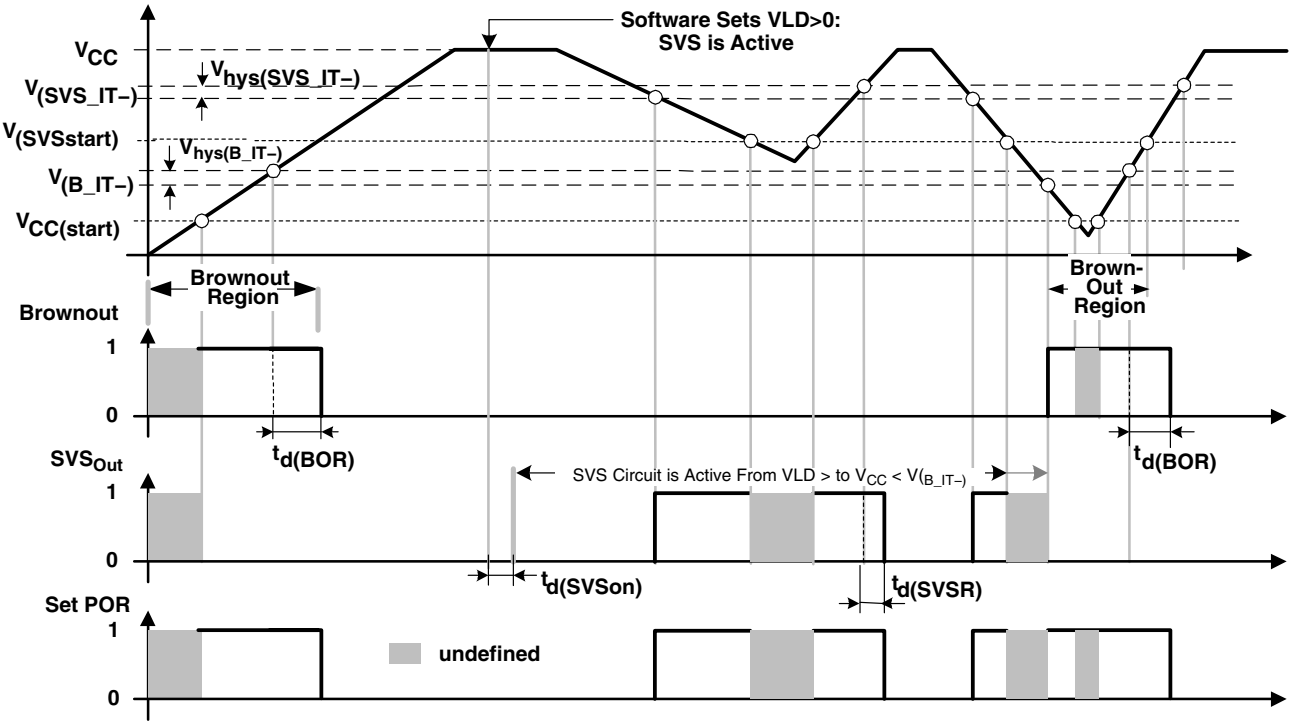


Figure 13. SVS Reset (SVSR) vs Supply Voltage

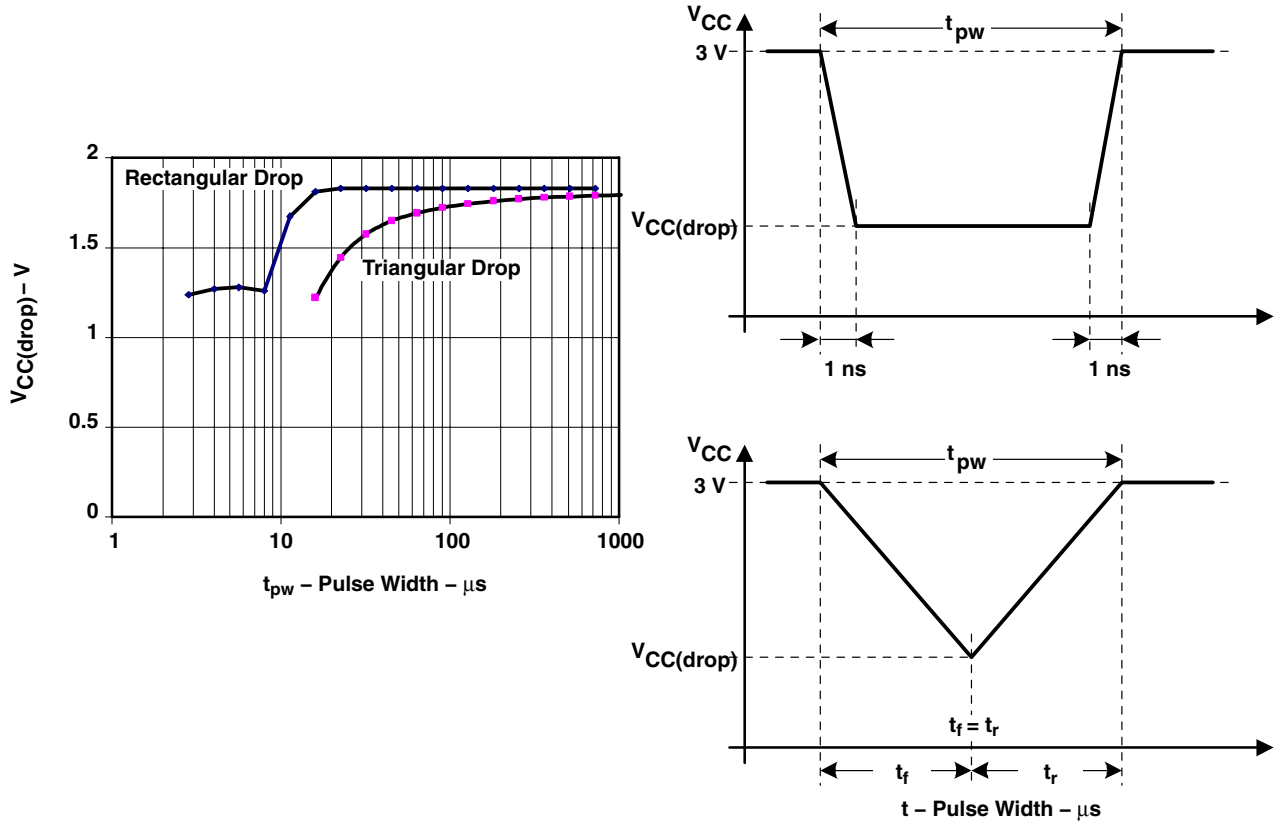


Figure 14. $V_{CC(drop)}$ With a Square Voltage Drop and a Triangle Voltage Drop to Generate an SVS Signal

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

DCO

PARAMETER	TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
$f_{(DCOCLK)}$	$N_{(DCO)}$=01Eh, FN_8=FN_4=FN_3=FN_2=0, D = 2; DCOPLUS= 0	2.2 V/3 V		1		MHz
$f_{(DCO=2)}$	FN_8=FN_4=FN_3=FN_2=0 ; DCOPLUS = 1	2.2 V	0.3	0.65	1.25	MHz
		3 V	0.3	0.7	1.3	
$f_{(DCO=27)}$	FN_8=FN_4=FN_3=FN_2=0; DCOPLUS = 1	2.2 V	2.5	5.6	10.5	MHz
		3 V	2.7	6.1	11.3	
$f_{(DCO=2)}$	FN_8=FN_4=FN_3=0, FN_2=1; DCOPLUS = 1	2.2 V	0.7	1.3	2.3	MHz
		3 V	0.8	1.5	2.5	
$f_{(DCO=27)}$	FN_8=FN_4=FN_3=0, FN_2=1; DCOPLUS = 1	2.2 V	5.7	10.8	18	MHz
		3 V	6.5	12.1	20	
$f_{(DCO=2)}$	FN_8=FN_4=0, FN_3= 1, FN_2=x; DCOPLUS = 1	2.2 V	1.2	2	3	MHz
		3 V	1.3	2.2	3.5	
$f_{(DCO=27)}$	FN_8=FN_4=0, FN_3= 1, FN_2=x; DCOPLUS = 1	2.2 V	9	15.5	25	MHz
		3 V	10.3	17.9	28.5	
$f_{(DCO=2)}$	FN_8=0, FN_4= 1, FN_3= FN_2=x; DCOPLUS = 1	2.2 V	1.8	2.8	4.2	MHz
		3 V	2.1	3.4	5.2	
$f_{(DCO=27)}$	FN_8=0, FN_4=1, FN_3= FN_2=x; DCOPLUS = 1	2.2 V	13.5	21.5	33	MHz
		3 V	16	26.6	41	
$f_{(DCO=2)}$	FN_8=1, FN_4=FN_3=FN_2=x; DCOPLUS = 1	2.2 V	2.8	4.2	6.2	MHz
		3 V	4.2	6.3	9.2	
$f_{(DCO=27)}$	FN_8=1,FN_4=FN_3=FN_2=x; DCOPLUS = 1	2.2 V	21	32	46	MHz
		3 V	30	46	70	
S_n	Step size between adjacent DCO taps: $S_n = f_{DCO(Tap\ n+1)} / f_{DCO(Tap\ n)}$ (see Figure 16 for taps 21 to 27)	1 < TAP ≤ 20	1.06		1.11	
		TAP = 27	1.07		1.17	
D_t	Temperature drift, $N_{(DCO)}$ = 01Eh, FN_8=FN_4=FN_3=FN_2=0 D = 2; DCOPLUS = 0	2.2 V	–0.2	–0.3	–0.4	%/°C
		3 V	–0.2	–0.3	–0.4	
D_V	Drift with V_{CC} variation, $N_{(DCO)}$ = 01Eh, FN_8=FN_4=FN_3=FN_2=0 D = 2; DCOPLUS = 0		0	5	15	%/V

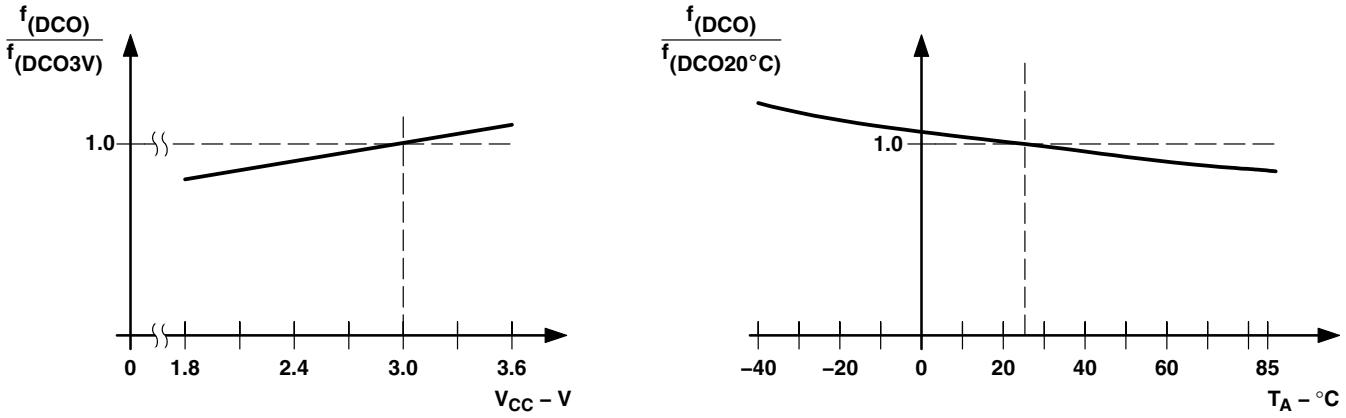


Figure 15. DCO Frequency vs Supply Voltage V_{CC} and vs Ambient Temperature

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

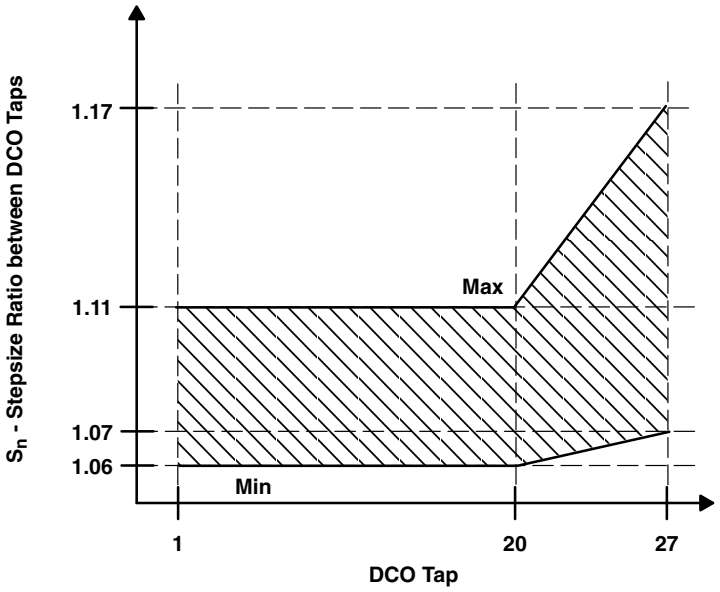


Figure 16. DCO Tap Step Size

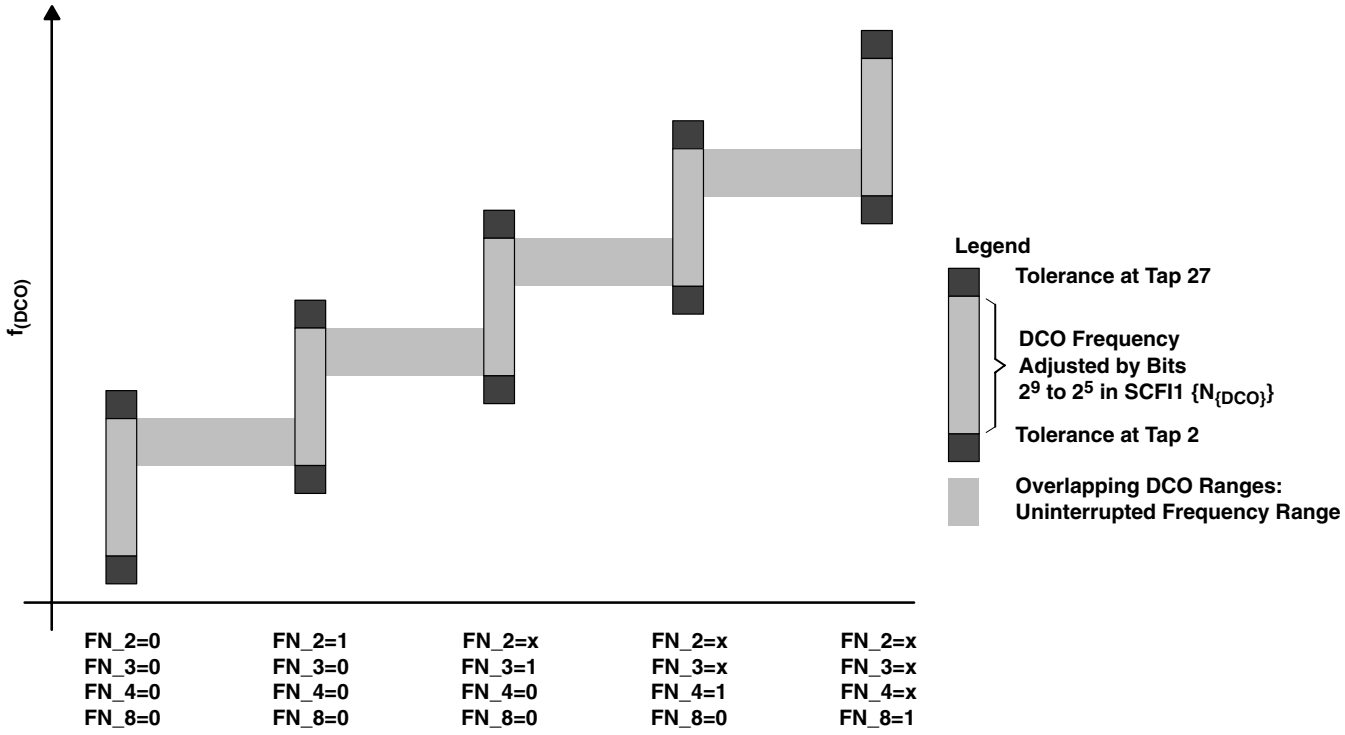


Figure 17. Five Overlapping DCO Ranges Controlled by FN_x Bits

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

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

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
C_{XIN}	Integrated input capacitance (see Note 4)	OSCCAPx = 0h	2.2 V / 3 V		0		pF
		OSCCAPx = 1h	2.2 V / 3 V		10		
		OSCCAPx = 2h	2.2 V / 3 V		14		
		OSCCAPx = 3h	2.2 V / 3 V		18		
C_{XOUT}	Integrated output capacitance (see Note 4)	OSCCAPx = 0h	2.2 V / 3 V		0		pF
		OSCCAPx = 1h	2.2 V / 3 V		10		
		OSCCAPx = 2h	2.2 V / 3 V		14		
		OSCCAPx = 3h	2.2 V / 3 V		18		
V_{IL}	Input levels at XIN	See Note 3	2.2 V/3 V	V_{SS}		$0.2 \times V_{CC}$	V
V_{IH}				$0.8 \times V_{CC}$		V_{CC}	

NOTES: 1. The parasitic capacitance from the package and board may be estimated to be 2 pF. The effective load capacitor for the crystal is (C_{XIN} x C_{XOUT}) / (C_{XIN} + C_{XOUT}). This is independent of XTS_FLL.
2. To improve EMI on the low-power LFXT1 oscillator, particularly in the LF mode (32 kHz), the following guidelines should be observed.
   - Keep the trace between the MSP430 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.
3. Applies only when using an external logic-level clock source. XTS_FLL must be set. Not applicable when using a crystal or resonator.
4. External capacitance is recommended for precision real-time clock applications; OSCCAPx = 0h.

crystal oscillator, XT2 oscillator (see Note 1)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
C_{XT2IN}	Integrated input capacitance	V_{CC} = 2.2 V/3 V		2		pF
C_{XT2OUT}	Integrated output capacitance	V_{CC} = 2.2 V/3 V		2		pF
V_{IL}	Input levels at XT2IN	V_{CC} = 2.2 V/3 V (see Note 2)	V_{SS}		$0.2 \times V_{CC}$	V
V_{IH}			$0.8 \times V_{CC}$		V_{CC}	V

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

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_{BITCLK}	BITCLK clock frequency (equals Baudrate in MBaud)		2.2V /3 V			1	MHz
t_τ	UART receive deglitch time (see Note 1)		2.2 V	50	150	600	ns
			3 V	50	100	600	

NOTE 1: 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 18 and Figure 19)

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			
$t_{HD,MI}$	SOMI input data hold time		2.2 V	0			ns
			3 V	0			
$t_{VALID,MO}$	SIMO output data valid time	UCLK edge to SIMO valid; C_L = 20 pF	2.2 V			30	ns
			3 V			20	

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

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

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

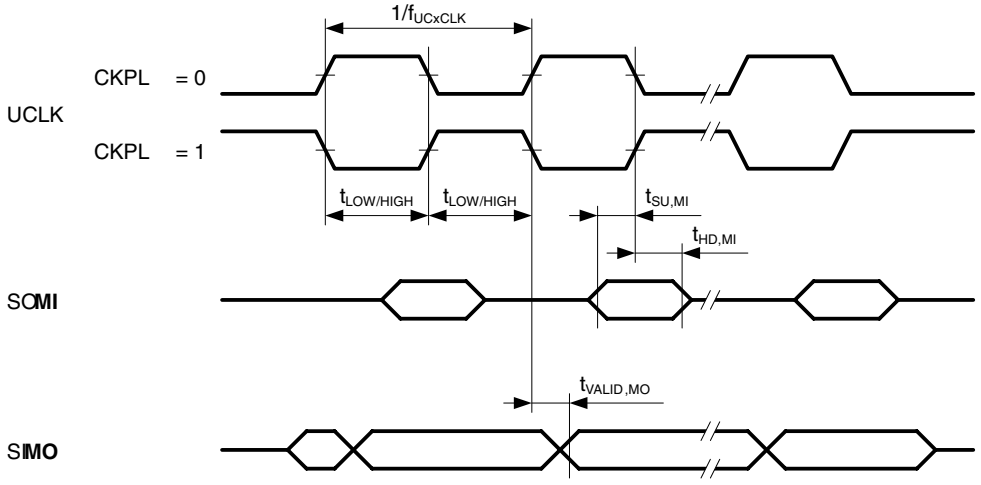


Figure 18. SPI Master Mode, CKPH = 0

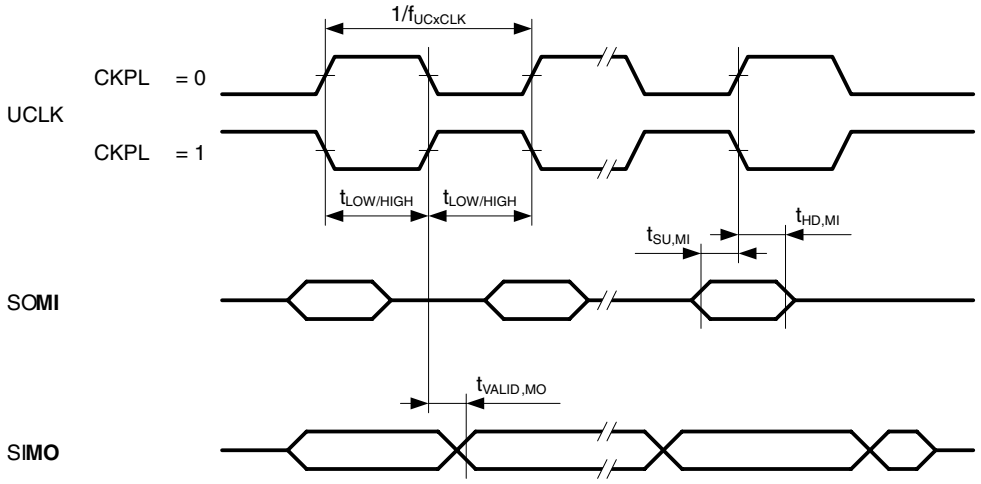


Figure 19. SPI Master Mode, CKPH = 1

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

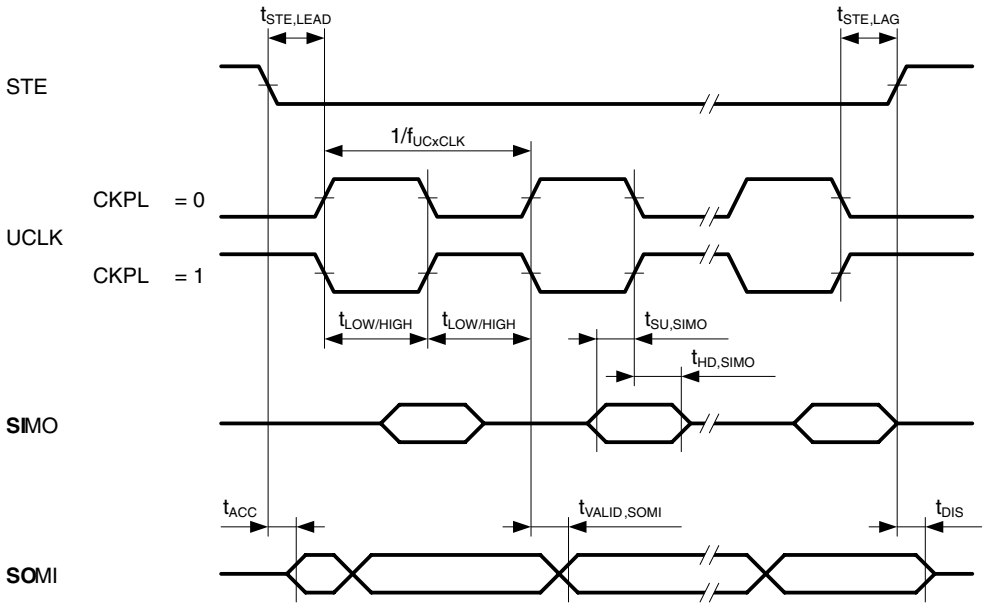


Figure 20. SPI Slave Mode, CKPH = 0

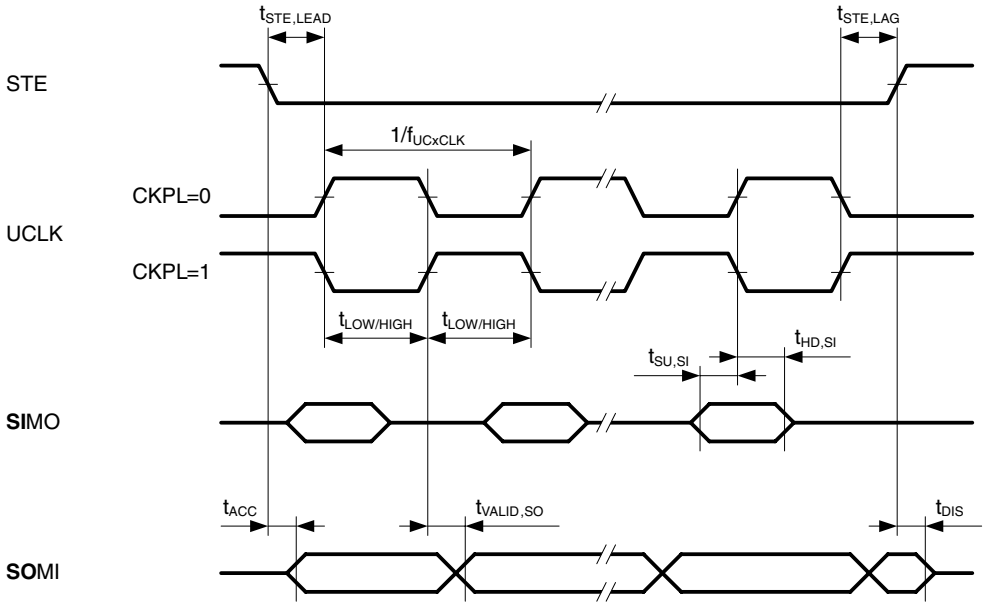


Figure 21. SPI Slave Mode, CKPH = 1

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

USCI (I2C mode) (see Figure 22)

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	$f_{SCL} \le 100$kHz	2.2 V/3 V	4.0			µs
		$f_{SCL} > 100$kHz	2.2 V/3 V	0.6			
$t_{SU,STA}$	Set–up time for a repeated START	$f_{SCL} \le 100$kHz	2.2 V/3 V	4.7			µs
		$f_{SCL} > 100$kHz	2.2 V/3 V	0.6			
$t_{HD,DAT}$	Data hold time		2.2 V/3 V	0			ns
$t_{SU,DAT}$	Data set–up time		2.2 V/3 V	250			ns
$t_{SU,STO}$	Set–up time for STOP		2.2 V/3 V	4.0			µs
t_{SP}	Pulse width of spikes suppressed by input filter		2.2 V	50	150	600	ns
			3 V	50	100	600	

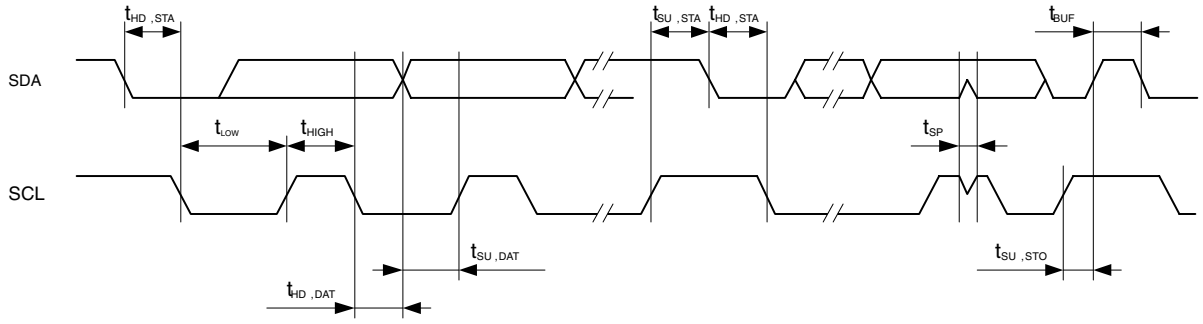


Figure 22. I2C Mode Timing

USART1 (see Note 1)

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
$t_{(\tau)}$	USART1 deglitch time	SYNC = 0, UART mode	2.2 V	200	430	800	ns
		SYNC = 0, UART mode	3 V	150	280	500	

NOTE 1: The signal applied to the USART1 receive signal/terminal (URXD1) should meet the timing requirements of $t_{(\tau)}$ to ensure that the URXS flip-flop is set. The URXS flip-flop is set with negative pulses meeting the minimum-timing condition of $t_{(\tau)}$. 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 URXD1 line.

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

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

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

NOTES: 1. The leakage current is defined in the leakage current table with Ax parameter.
2. The analog input voltage range must be within the selected reference voltage range V_{R+} to V_{R-} for valid conversion results.
3. The internal reference supply current is not included in current consumption parameter I_{ADC12}.
4. The internal reference current is supplied via terminal AV_{CC}. Consumption is independent of the ADC12ON control bit, unless a conversion is active. The REFON bit enables to settle the built-in reference before starting an A/D conversion.

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

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_{eREF+}	Positive external reference voltage input	$V_{eREF+} > V_{REF-}/V_{eREF-}$ (see Note 2)		1.4		V_{AVCC}	V
V_{REF-}/V_{eREF-}	Negative external reference voltage input	$V_{eREF+} > V_{REF-}/V_{eREF-}$ (see Note 3)		0		1.2	V
$(V_{eREF+} - V_{REF-}/V_{eREF-})$	Differential external reference voltage input	$V_{eREF+} > V_{REF-}/V_{eREF-}$ (see Note 4)		1.4		V_{AVCC}	V
I_{VeREF+}	Input leakage current	$0V \le V_{eREF+} \le V_{AVCC}$	V_{CC} = 2.2 V/3 V			±1	µA
$I_{VREF-/VeREF-}$	Input leakage current	$0V \le V_{eREF-} \le V_{AVCC}$	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 12-bit accuracy.
2. The accuracy limits the minimum positive external reference voltage. Lower reference voltage levels may be applied with reduced accuracy requirements.
3. The accuracy limits the maximum negative external reference voltage. Higher reference voltage levels may be applied with reduced accuracy requirements.
4. The accuracy limits minimum external differential reference voltage. Lower differential reference voltage levels may be applied with reduced accuracy requirements.

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

12-bit ADC, built-in reference

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
V_{REF+}	Positive built-in reference voltage output	REF2_5V = 1 for 2.5 V, I_{VREF+}max ≤ I_{VREF+}≤ I_{VREF+}min	3 V	2.4	2.5	2.6	V
		REF2_5V = 0 for 1.5 V, I_{VREF+}max ≤ I_{VREF+}≤ I_{VREF+}min	2.2 V/3 V	1.44	1.5	1.56	
$AV_{CC(min)}$	AV_{CC} minimum voltage, Positive built-in reference active	REF2_5V = 0, I_{VREF+}max ≤ I_{VREF+} ≤ I_{VREF+}min		2.2			V
		REF2_5V = 1, I_{VREF+}min ≥ I_{VREF+} ≥ –0.5mA		2.8			
		REF2_5V = 1, I_{VREF+}min ≥ I_{VREF+} ≥ –1mA		2.9			
I_{VREF+}	Load current out of V_{REF+} terminal		2.2 V	0.01		–0.5	mA
			3 V	0.01		–1	
$I_{L(VREF)+}$	Load-current regulation V_{REF+} terminal	I_{VREF+} = 500 μA +/– 100 μA, Analog input voltage ~0.75 V; REF2_5V = 0	2.2 V			±2	LSB
			3 V			±2	
		I_{VREF+} = 500 μA ± 100 μA, Analog input voltage ~1.25 V, REF2_5V = 1	3 V			±2	LSB
$I_{DL(VREF)+}$	Load current regulation V_{REF+} terminal	I_{VREF+} =100 μA → 900 μA, C_{VREF+}=5 μF, ax ~0.5 x V_{REF+}, Error of conversion result ≤ 1 LSB	3 V			20	ns
C_{VREF+}	Capacitance at pin V_{REF+} (see Note 1)	REFON =1, 0 mA ≤ I_{VREF+} ≤ I_{VREF+}max	2.2 V/3 V	5	10		μF
T_{REF+}	Temperature coefficient of built-in reference	I_{VREF+} is a constant in the range of 0 mA ≤ I_{VREF+} ≤ 1 mA	2.2 V/3 V			±100	ppm/°C
t_{REFON}	Settle time of internal reference voltage (see Figure 23 and Note 2)	I_{VREF+} = 0.5 mA, C_{VREF+} = 10 μF, V_{REF+} = 1.5 V, V_{AVCC} = 2.2 V				17	ms

NOTES: 1. The internal buffer operational amplifier and the accuracy specifications require an external capacitor. All INL and DNL tests uses two capacitors between pins V_{REF+} and AV_{SS} and $V_{REF–}/V_{eREF–}$ and AV_{SS}: 10 μF tantalum and 100 nF ceramic.

2. The condition is that the error in a conversion started after t_{REFON} is less than ±0.5 LSB. The settling time depends on the external capacitive load.

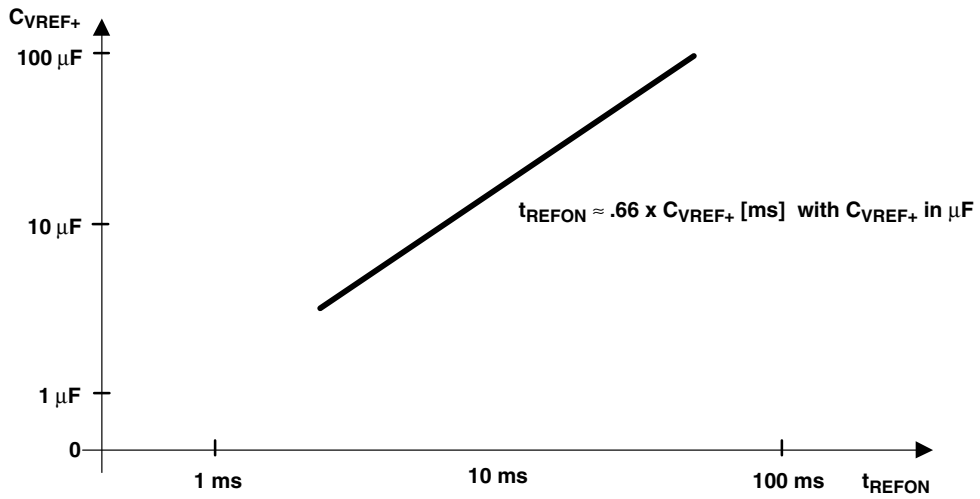


Figure 23. Typical Settling Time of Internal Reference t_{REFON} vs External Capacitor on V_{REF+}

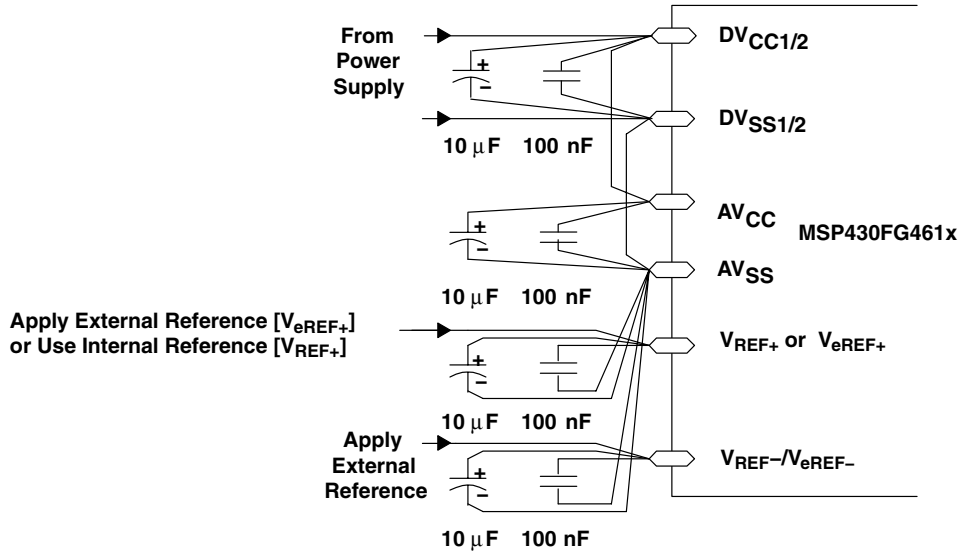


Figure 24. Supply Voltage and Reference Voltage Design V_{REF-}/V_{eREF-} External Supply

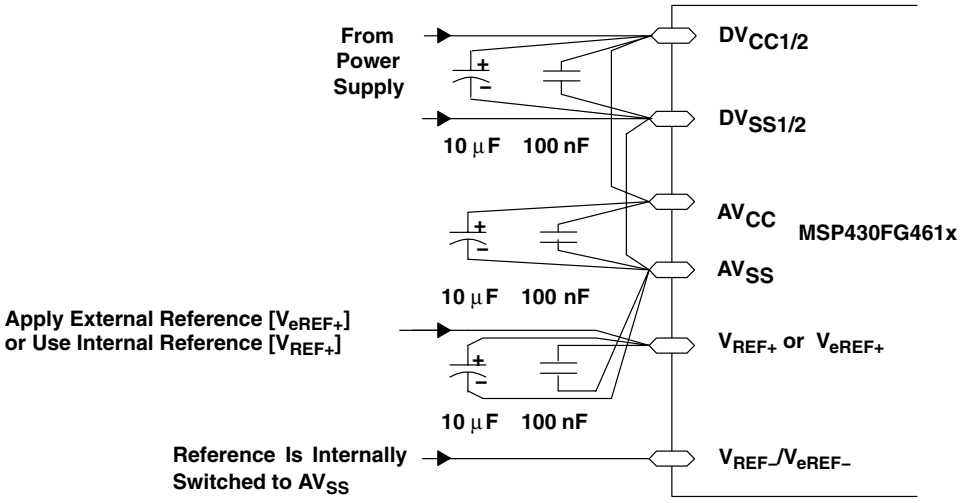


Figure 25. Supply Voltage and Reference Voltage Design V_{REF-}/V_{eREF-} = AV_{SS}, Internally Connected

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

12-bit ADC, timing parameters

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

NOTES: 1. The condition is that the error in a conversion started after $t_{ADC12ON}$ is less than ±0.5 LSB. The reference and input signal are already settled.

2. Approximately ten Tau (τ) are needed to get an error of less than ±0.5 LSB:
$t_{Sample} = \ln(2^{n+1}) \times (R_S + R_I) \times C_I + 800$ ns where n = ADC resolution = 12, R_S = external source resistance.

12-bit ADC, linearity parameters

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

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

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

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
I_{SENSOR}	Operating supply current into AV_{CC} terminal (see Note 1)	REFON = 0, INCH = 0Ah, ADC12ON=NA, T_A = 25°C	2.2 V		40	120	µA
			3 V		60	160	
V_{SENSOR}	See Note 2	ADC12ON = 1, INCH = 0Ah, T_A = 0°C	2.2 V/ 3 V		986		mV
TC_{SENSOR}		ADC12ON = 1, INCH = 0Ah	2.2 V/ 3 V		3.55±3%		mV/°C
$t_{SENSOR(sample)}$	Sample time required if channel 10 is selected (see Note 3)	ADC12ON = 1, INCH = 0Ah, Error of conversion result ≤ 1 LSB	2.2 V	30			µs
			3 V	30			
I_{VMID}	Current into divider at channel 11 (see Note 4)	ADC12ON = 1, INCH = 0Bh	2.2 V			NA	µA
			3 V			NA	
V_{MID}	AV_{CC} divider at channel 11	ADC12ON = 1, INCH = 0Bh, V_{MID} is ~0.5 x V_{AVCC}	2.2 V		1.1	1.1±0.04	V
			3 V		1.5	1.50±0.04	
$t_{VMID(sample)}$	Sample time required if channel 11 is selected (see Note 5)	ADC12ON = 1, INCH = 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 (ADC12ON = 1 and REFON=1), or (ADC12ON=1 AND INCH=0Ah and sample signal is high). When REFON = 1, I_{SENSOR} is already included in I_{REF+}.
2. The temperature sensor offset can be as much as ±20°C. A single-point calibration is recommended in order to minimize the offset error of the built-in temperature sensor.
3. The typical equivalent impedance of the sensor is 51 kΩ. The sample time required includes the sensor-on time $t_{SENSOR(on)}$
4. No additional current is needed. The V_{MID} is used during sampling.
5. The on-time $t_{VMID(on)}$ is included in the sampling time $t_{VMID(sample)}$; no additional on time is needed.

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

flash memory

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
$V_{CC(PGM/ERASE)}$	Program and Erase supply voltage			2.7		3.6	V
f_{FTG}	Flash Timing Generator frequency			257		476	kHz
I_{PGM}	Supply current from DV_{CC} during program		2.7 V/3.6 V		3	5	mA
I_{ERASE}	Supply current from DV_{CC} during erase	See Note 3	2.7 V/3.6 V		3	7	mA
$I_{GMERASE}$	Supply current from DV_{CC} during global mass erase	See Note 4	2.7 V/3.6 V		6	14	mA
t_{CPT}	Cumulative program time	See Note 1	2.7 V/3.6 V			10	ms
$t_{CMErase}$	Cumulative mass erase time		2.7 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 1st byte or word				25		
$t_{Block, 1-63}$	Block program time for each additional byte or word				18		
$t_{Block, End}$	Block program end-sequence wait time				6		
$t_{Mass Erase}$	Mass erase time				10593		
$t_{Global Mass Erase}$	Global mass erase time				10593		
$t_{Seg Erase}$	Segment erase time				4819		

NOTES: 6. The cumulative program time must not be exceeded during a block-write operation. This parameter is only relevant if the block write feature is used.
2. These values are hardwired into the Flash Controller's state machine ($t_{FTG} = 1/f_{FTG}$).
3. Lower 64-KB or upper 64-KB Flash memory erased.
4. All Flash memory erased.

JTAG interface

PARAMETER		TEST CONDITIONS	V_{CC}	MIN	TYP	MAX	UNIT
f_{TCK}	TCK input frequency	See Note 1	2.2 V	0		5	MHz
			3 V	0		10	MHz
$R_{Internal}$	Internal pull-up resistance on TMS, TCK, TDI/TCLK	See Note 2	2.2 V/ 3 V	25	60	90	kΩ

NOTES: 1. f_{TCK} may be restricted to meet the timing requirements of the module selected.
2. TMS, TDI/TCLK, and TCK pull-up resistors are implemented in all versions.

JTAG fuse (see Note 1)

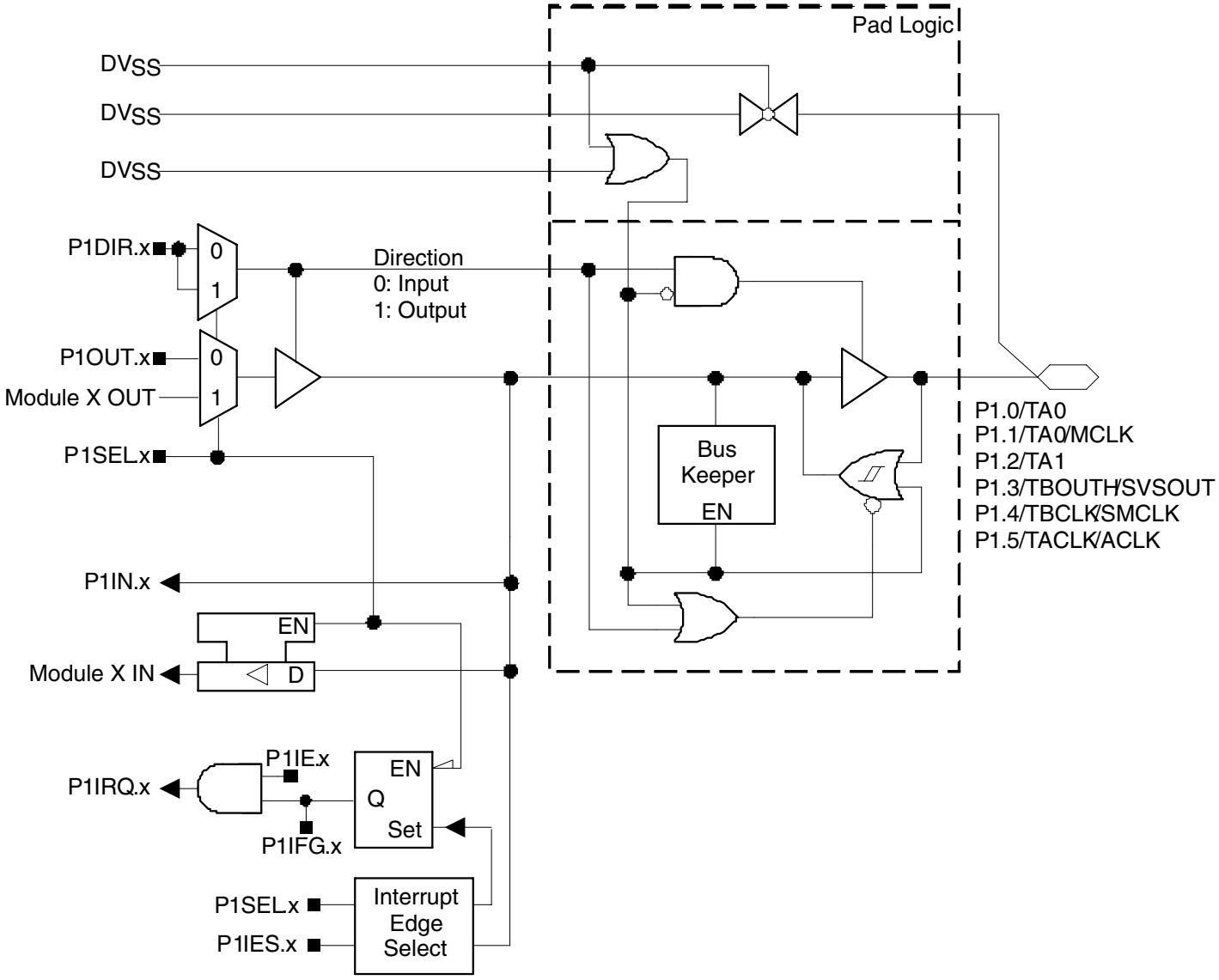
PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{CC(FB)}$	Supply voltage during fuse-blow condition	T_A = 25°C	2.5			V
V_{FB}	Voltage level on TDI/TCLK for fuse-blow: F versions		6		7	V
I_{FB}	Supply current into TDI/TCLK during fuse blow				100	mA
t_{FB}	Time to blow fuse				1	ms

NOTE 1: 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

input/output schematics

port P1, P1.0 to P1.5, input/output with Schmitt trigger

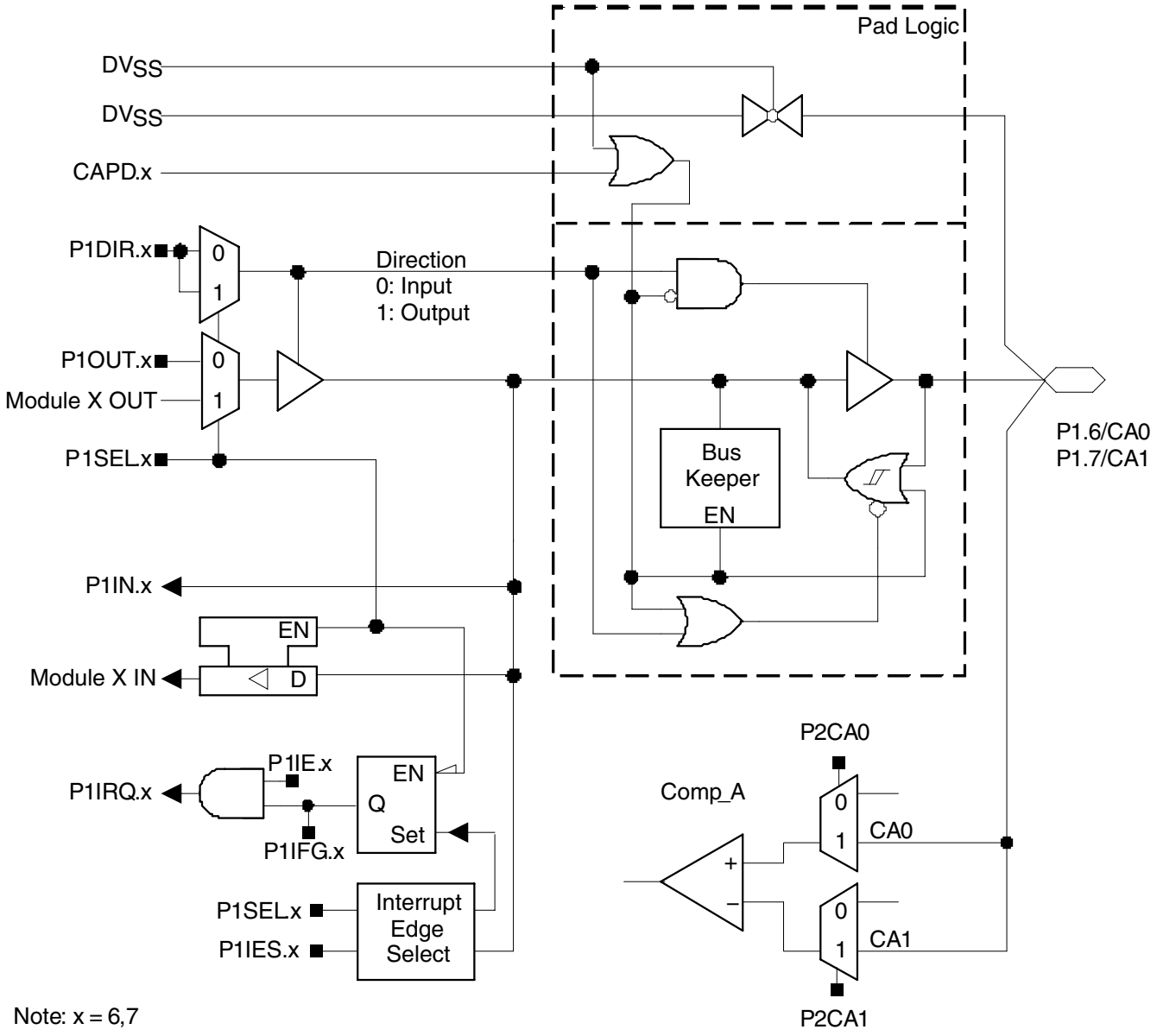


Note: x = 0,1,2,3,4,5

port P1 (P1.0 to P1.5) pin functions

PIN NAME (P1.X)	X	FUNCTION	CONTROL BITS / SIGNALS	
			P1DIR.x	P1SEL.x
P1.0/TA0	0	P1.0 (I/O)	I: 0; O: 1	0
		Timer_A3.CCI0A	0	1
		Timer_A3.TA0	1	1
P1.1/TA0/MCLK	1	P1.1 (I/O)	I: 0; O: 1	0
		Timer_A3.CCI0B	0	1
		MCLK	1	1
P1.2/TA1	2	P1.2 (I/O)	I: 0; O: 1	0
		Timer_A3.CCI1A	0	1
		Timer_A3.TA1	1	1
P1.3/TBOUTH/SVSOUT	3	P1.3 (I/O)	I: 0; O: 1	0
		Timer_B7.TBOUTH	0	1
		SVSOUT	1	1
P1.4/TBCLK/SMCLK	4	P1.4 (I/O)	I: 0; O: 1	0
		Timer_B7.TBCLK	0	1
		SMCLK	1	1
P1.5/TACLK/ACLK	5	P1.5 (I/O)	I: 0; O: 1	0
		Timer_A3.TACLK	0	1
		ACLK	1	1

port P1, P1.6, P1.7, input/output with Schmitt trigger



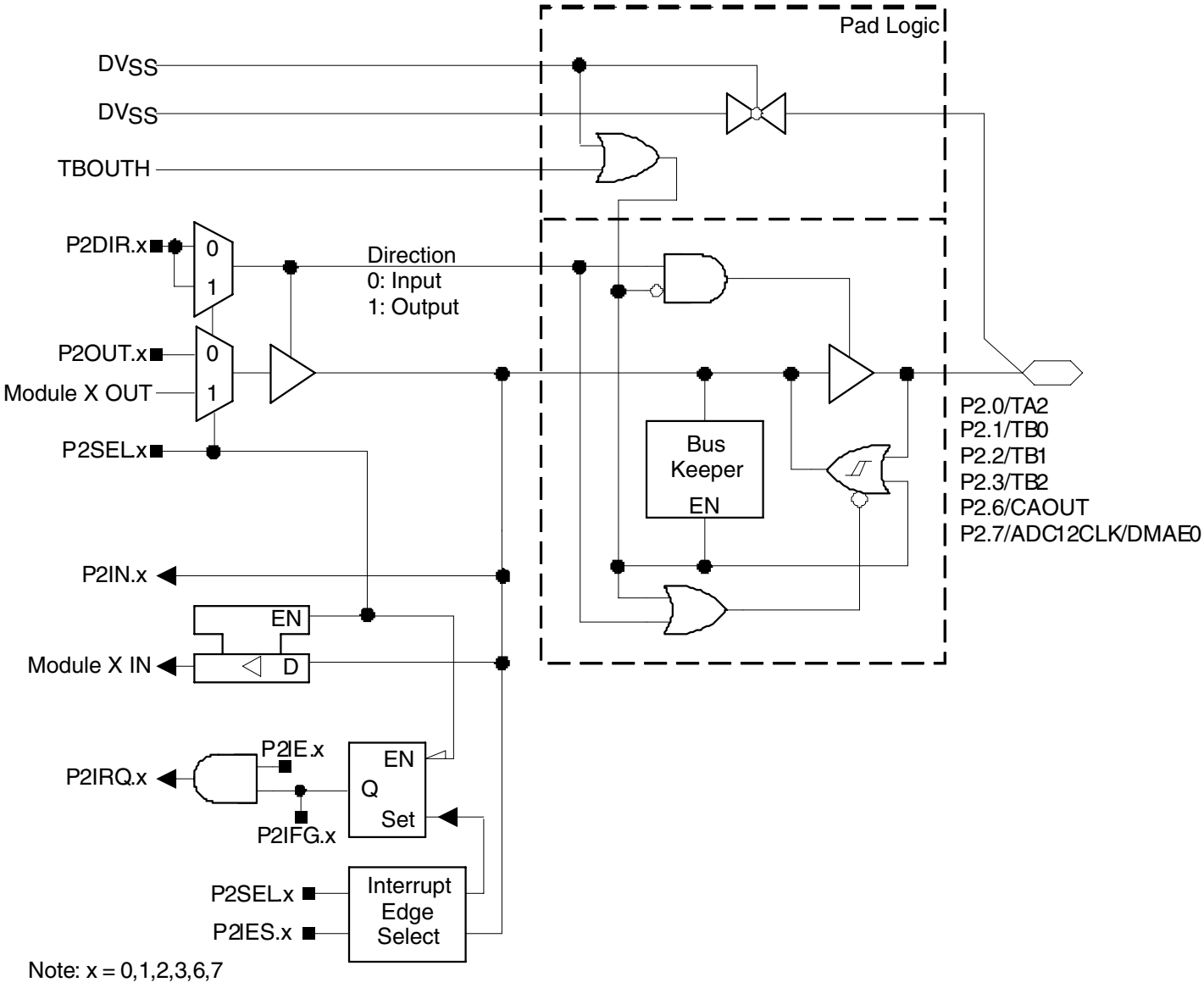
Note: x = 6,7

port P1 (P1.6 and P1.7) pin functions

PIN NAME (P1.X)	X	FUNCTION	CONTROL BITS / SIGNALS		
			CAPD.x	P1DIR.x	P1SEL.x
P1.6/CA0	6	P1.6 (I/O)	0	I: 0; O: 1	0
		CA0	1	X	X
P1.7/CA1	7	P1.7 (I/O)	0	I: 0; O: 1	0
		CA1	1	X	X

NOTE 1: X: Don't care.

port P2, P2.0 to P2.3, P2.6 to P2.7, input/output with Schmitt trigger

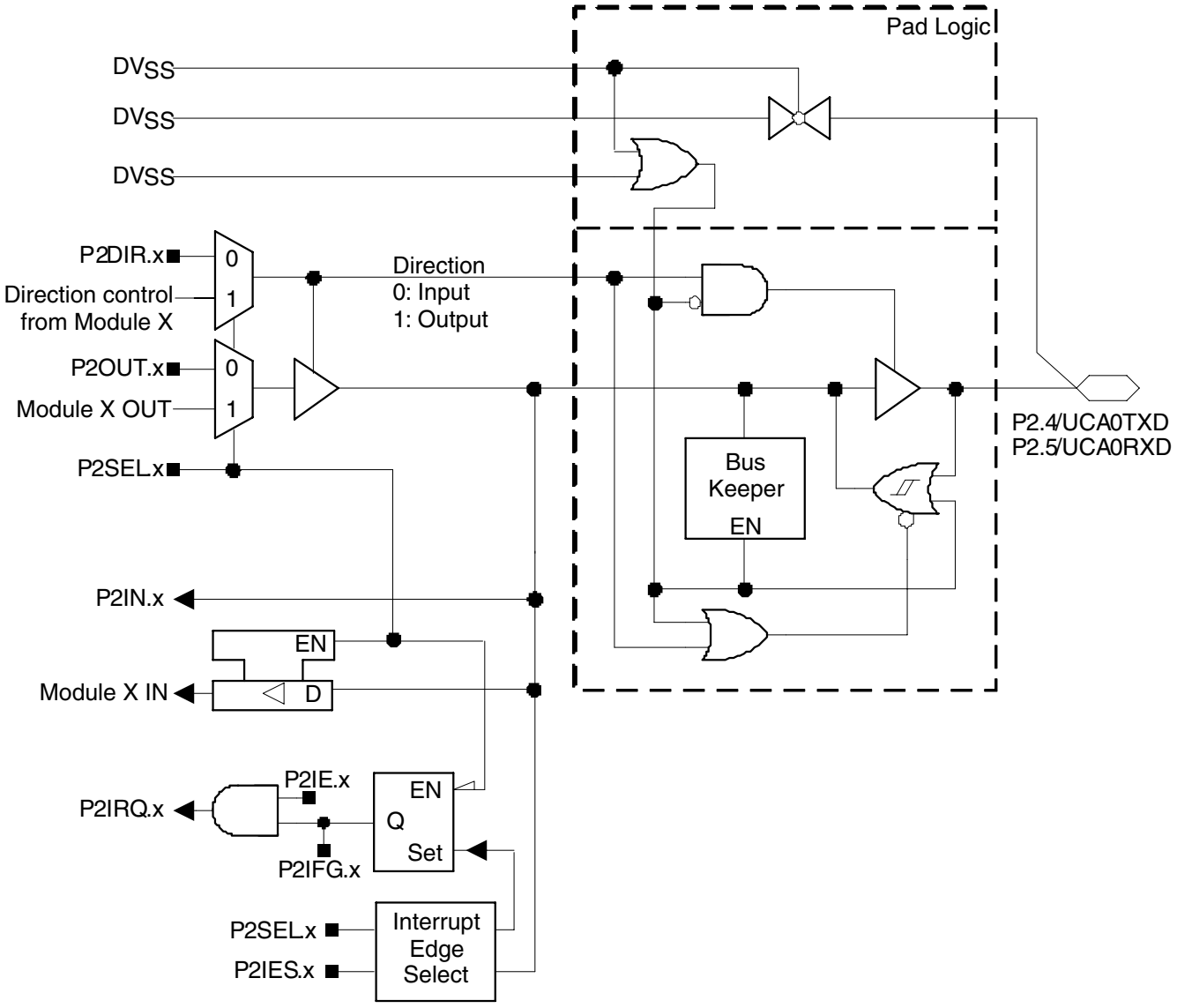


port P2 (P2.0, P2.1, P2.2, P2.3, P2.6 and P2.7) pin functions

PIN NAME (P2.X)	X	FUNCTION	CONTROL BITS / SIGNALS	
			P2DIR.x	P2SEL.x
P2.0/TA2	0	P2.0 (I/O)	I: 0; O: 1	0
		Timer_A3.CCI2A	0	1
		Timer_A3.TA2	1	1
P2.1/TB0	1	P2.1 (I/O)	I: 0; O: 1	0
		Timer_B7.CCI0A and Timer_B7.CCI0B	0	1
		Timer_B7.TB0 (see Note 1)	1	1
P2.2/TB1	2	P2.2 (I/O)	I: 0; O: 1	0
		Timer_B7.CCI1A and Timer_B7.CCI1B	0	1
		Timer_B7.TB1 (see Note 1)	1	1
P2.3/TB3	3	P2.3 (I/O)	I: 0; O: 1	0
		Timer_B7.CCI2A and Timer_B7.CCI2B	0	1
		Timer_B7.TB3 (see Note 1)	1	1
P2.6/CAOUT	6	P2.6 (I/O)	I: 0; O: 1	0
		CAOUT	1	1
P2.7/ADC12CLK/DMAE0	7	P2.7 (I/O)	I: 0; O: 1	0
		ADC12CLK (MSP430F461x only)	1	1
		DMAE0	0	1

NOTE 1: Setting TBOUTH causes all Timer_B outputs to be set to high impedance.

port P2, P2.4 to P2.5, input/output with Schmitt trigger



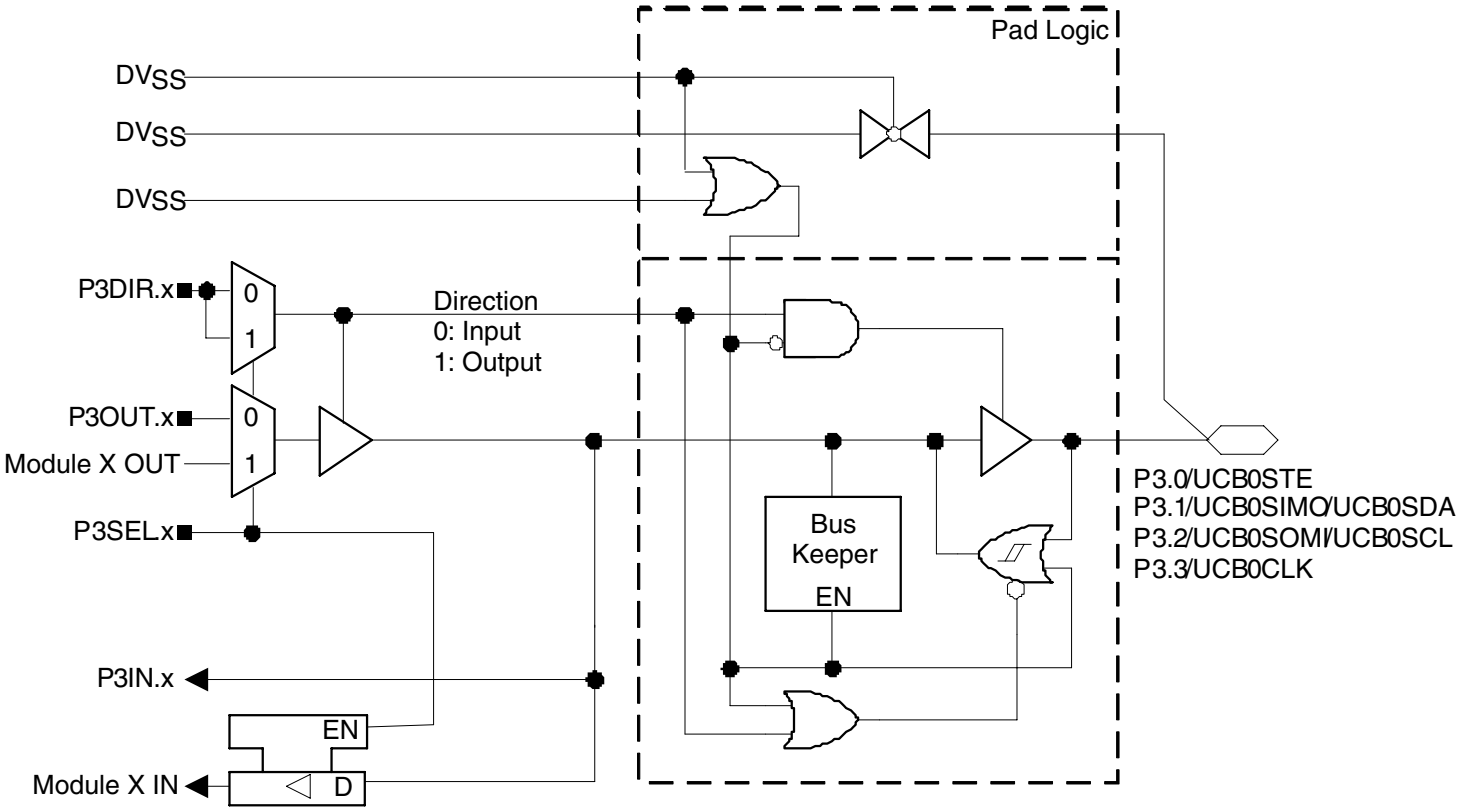
Note: x = 4,5

port P2 (P2.4 and P2.5) pin functions

PIN NAME (P2.X)	X	FUNCTION	CONTROL BITS / SIGNALS	
			P2DIR.x	P2SEL.x
P2.4/UCA0TXD	4	P2.4 (I/O)	I: 0; O: 1	0
		USCI_A0.UCA0TXD (see Note 1, 2)	X	1
P2.5/UCA0RXD	5	P2.5 (I/O)	I: 0; O: 1	0
		USCI_A0.UCA0RXD (see Note 1, 2)	X	1

NOTES: 1. X: Don't care.
2. When in USCI mode, P2.4 is set to output, P2.5 is set to input.

port P3, P3.0 to P3.3, input/output with Schmitt trigger



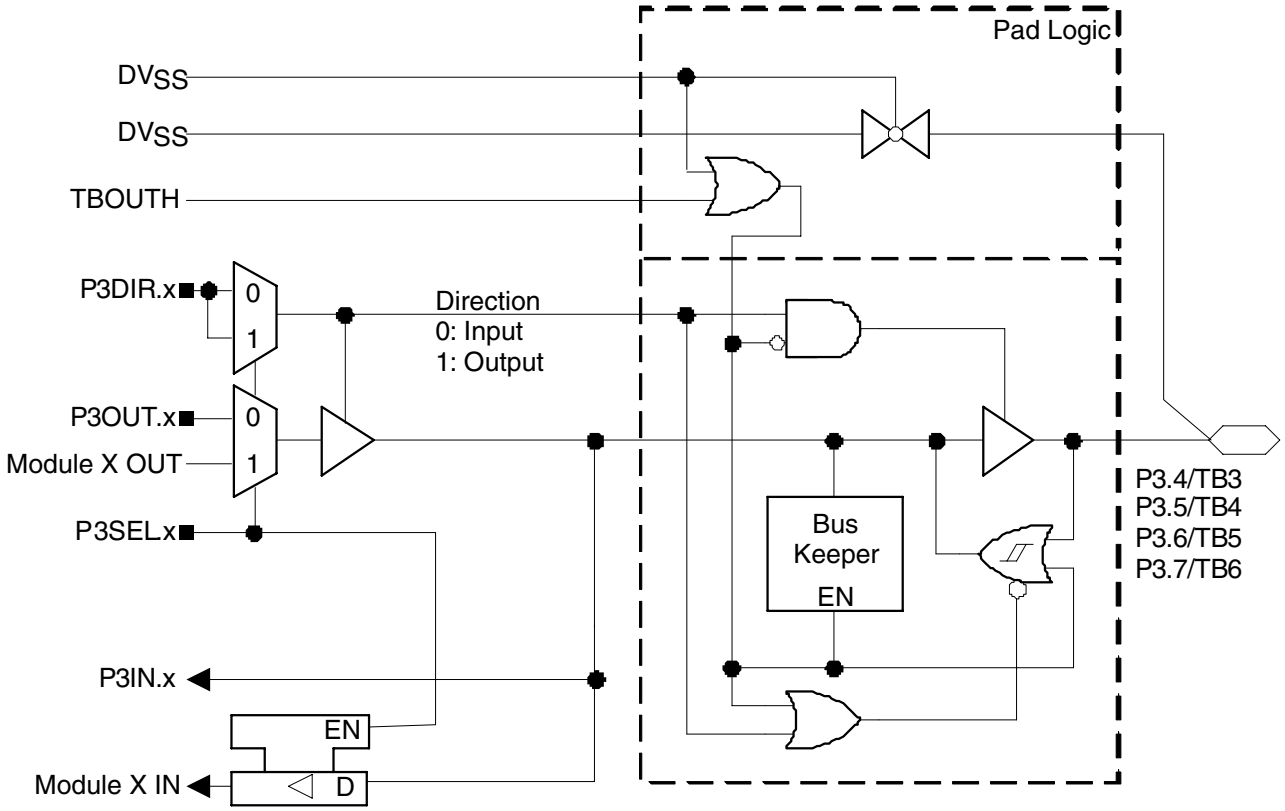
Note: x = 0,1,2,3

port P3 (P3.0 to P3.3) pin functions

PIN NAME (P3.X)	X	FUNCTION	CONTROL BITS / SIGNALS	
			P3DIR.x	P3SEL.x
P3.0/UCB0STE	0	P3.0 (I/O)	I: 0; O: 1	0
		UCB0STE (see Notes 1, 2)	X	1
P3.1/UCB0SIMO/ UCB0SDA	1	P3.1 (I/O)	I: 0; O: 1	0
		UCB0SIMO/UCB0SDA (see Notes 1, 2, 3)	X	1
P3.2/UCB0SOMI/ UCB0SCL	2	P3.2 (I/O)	I: 0; O: 1	0
		UCB0SOMI/UCB0SCL (see Notes 1, 2, 3)	X	1
P3.3/UCB0CLK	3	P3.3 (I/O)	I: 0; O: 1	0
		UCB0CLK (see Notes 1, 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, P3.4 to P3.7, input/output with Schmitt trigger



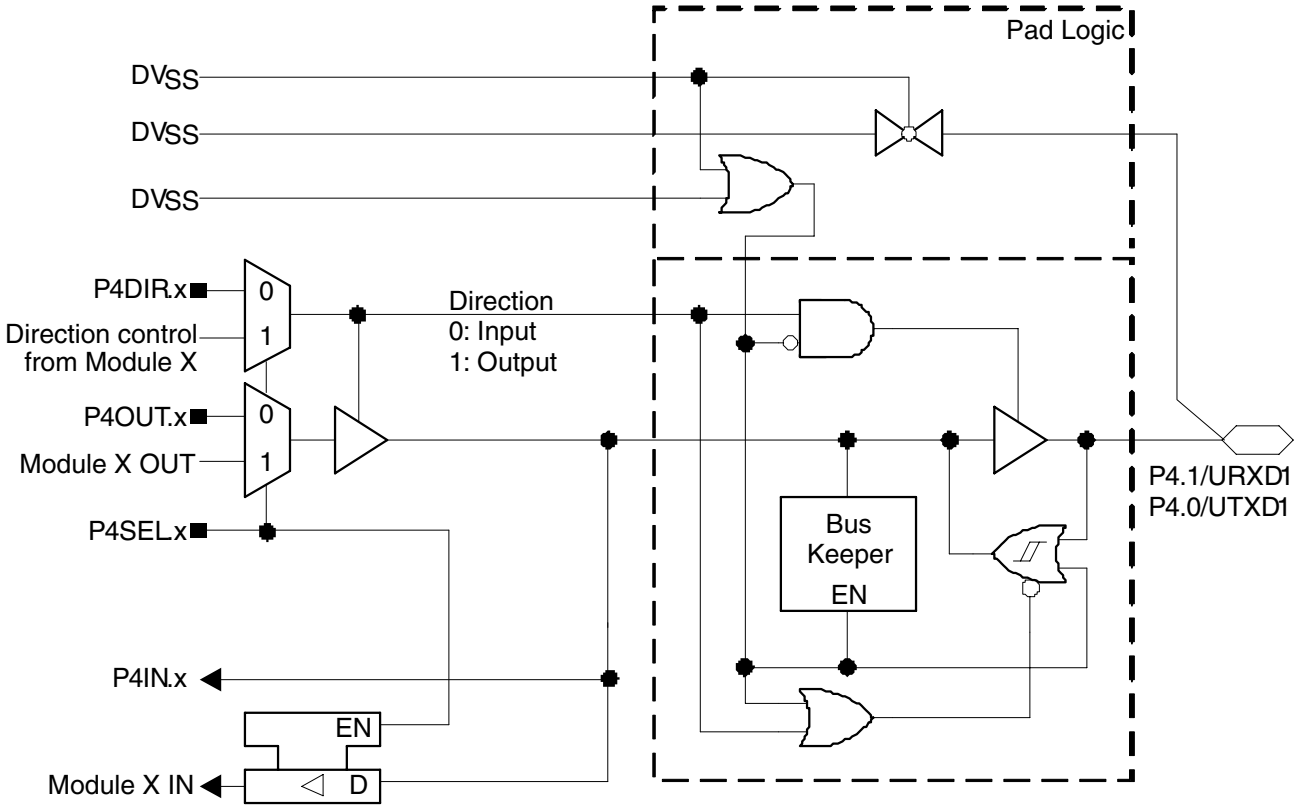
Note: x = 4,5,6,7

port P3 (P3.4 to P3.7) pin functions

PIN NAME (P3.X)	X	FUNCTION	CONTROL BITS / SIGNALS	
			P3DIR.x	P3SEL.x
P3.4/TB3	4	P3.4 (I/O)	I: 0; O: 1	0
		Timer_B7.CCI3A and Timer_B7.CCI3B	0	1
		Timer_B7.TB3 (see Note 1)	1	1
P3.5/TB4	5	P3.5 (I/O)	I: 0; O: 1	0
		Timer_B7.CCI4A and Timer_B7.CCI4B	0	1
		Timer_B7.TB4 (see Note 1)	1	1
P3.6/TB5	6	P3.6 (I/O)	I: 0; O: 1	0
		Timer_B7.CCI5A and Timer_B7.CCI5B	0	1
		Timer_B7.TB5 (see Note 1)	1	1
P3.7/TB6	7	P3.7 (I/O)	I: 0; O: 1	0
		Timer_B7.CCI6A and Timer_B7.CCI6B	0	1
		Timer_B7.TB6 (see Note 1)	1	1

NOTE 1: Setting TBOUTH causes all Timer_B outputs to be set to high impedance.

port P4, P4.0 to P4.1, input/output with Schmitt trigger



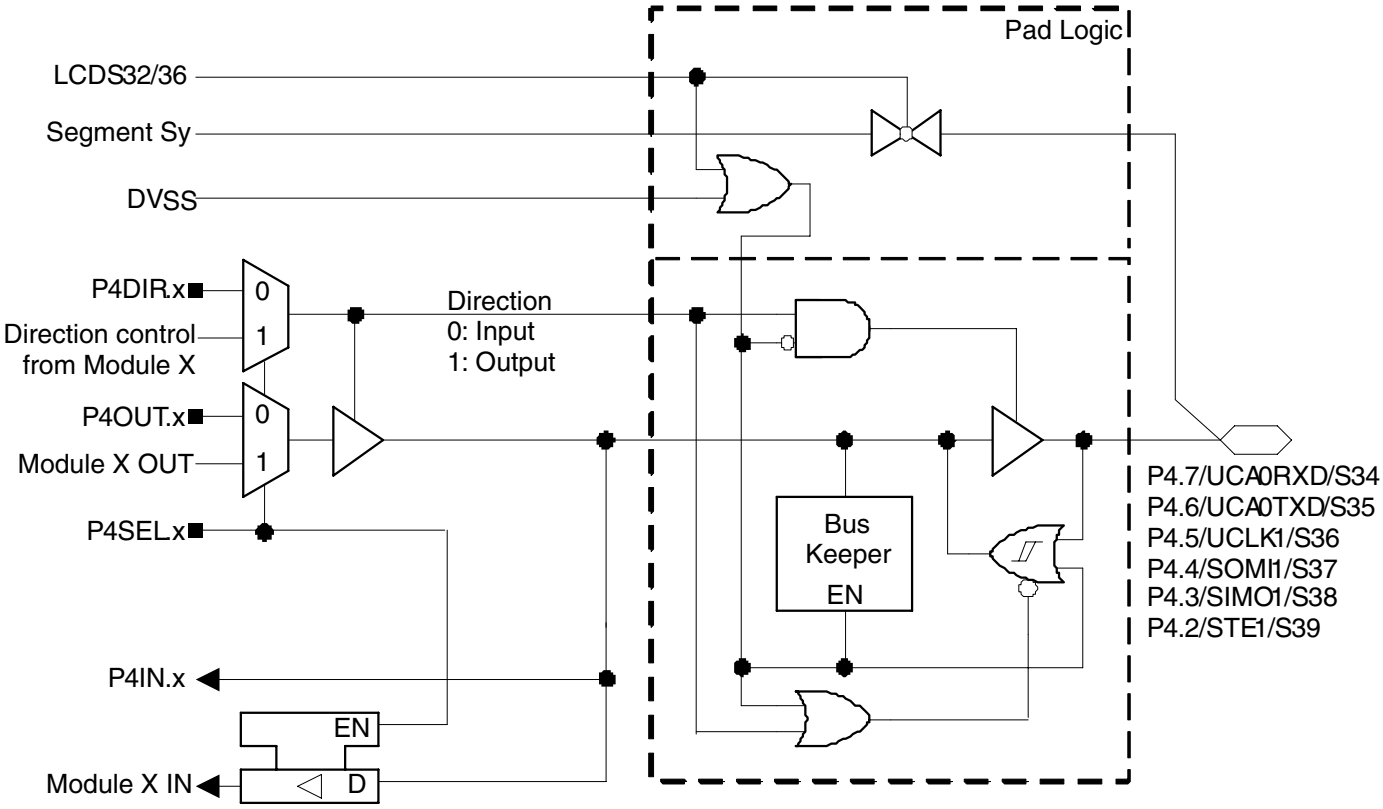
Note: x = 0,1

port P4 (P4.0 to P4.1) pin functions

PIN NAME (P4.X)	X	FUNCTION	CONTROL BITS / SIGNALS	
			P4DIR.x	P4SEL.x
P4.0/UTXD1	0	P4.0 (I/O)	I: 0; O: 1	0
		USART1.UTXD1 (see Notes 1, 2)	X	1
P4.1/URXD1	1	P4.1 (I/O)	I: 0; O: 1	0
		USART1.URXD1 (see Notes 1, 2)	X	1

NOTES: 1. X: Don't care.
2. When in USART1 mode, P4.0 is set to output, P4.1 is set to input.

port P4, P4.2 to P4.7, input/output with Schmitt trigger



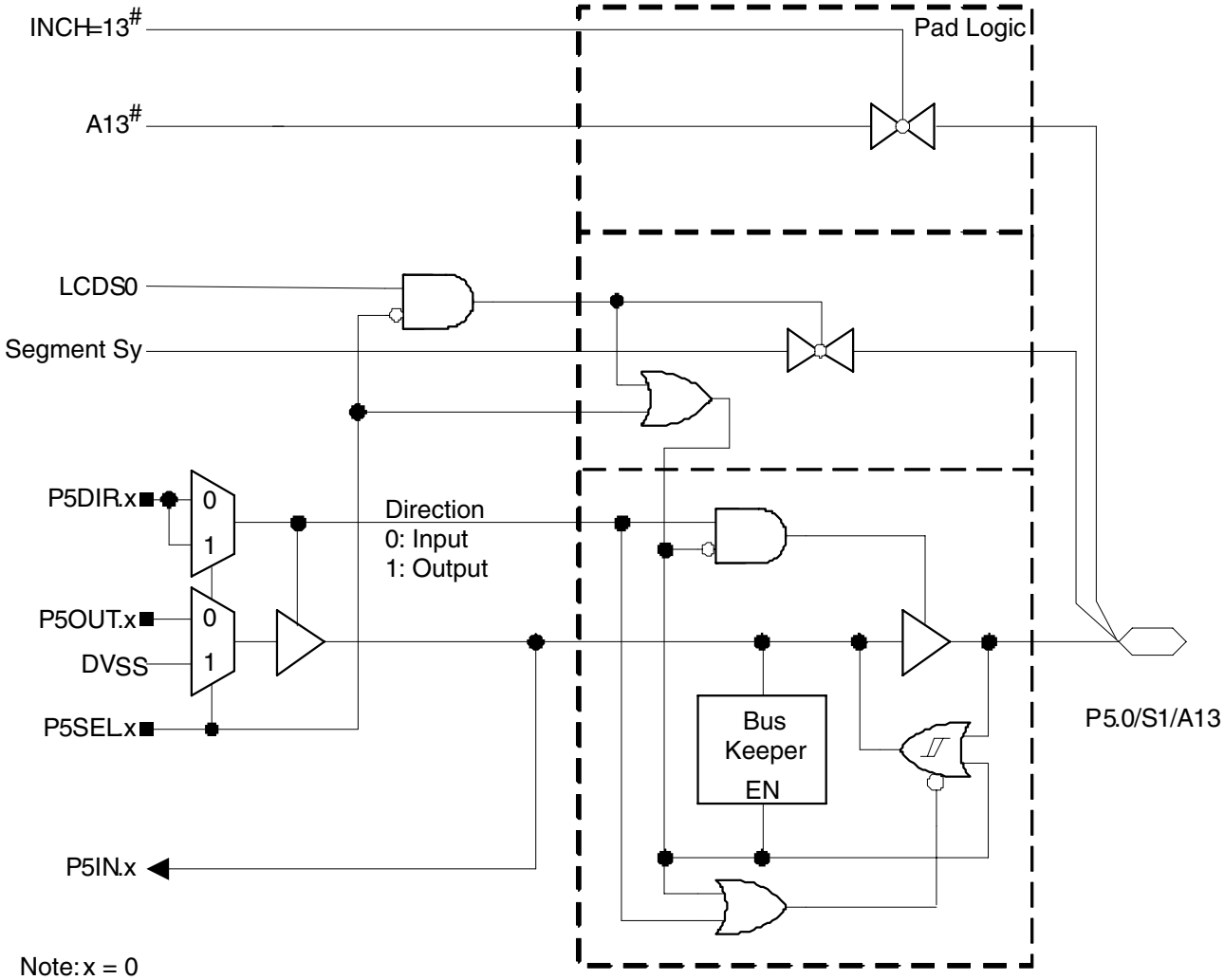
Note : x = 2,3,4,5,6,7
y = 34,35,36,37,38,39

port P4 (P4.2 to P4.5) pin functions

PIN NAME (P4.X)	X	FUNCTION	CONTROL BITS / SIGNALS		
			P4DIR.x	P4SEL.x	LCDS36
P4.2/STE1/S39	2	P4.2 (I/O)	I: 0; O: 1	0	0
		USART1.STE1	X	1	0
		S39 (see Note 1)	X	X	1
P4.3/SIMO/S38	3	P4.3 (I/O)	I: 0; O: 1	0	0
		USART1.SIMO1 (see Notes 1, 2)	X	1	0
		S38 (see Note 1)	X	X	1
P4.4/SOMI/S37	4	P4.4 (I/O)	I: 0; O: 1	0	0
		USART1.SOMI1 (see Notes 1, 2)	X	1	0
		S37 (see Note 1)	X	X	1
P4.5/SOMI/S36	5	P4.5 (I/O)	I: 0; O: 1	0	0
		USART1.UCLK1 (see Notes 1, 2)	X	1	0
		S36 (see Note 1)	X	X	1
P4.6/UCA0TXD/S35	6	P4.6 (I/O)	I: 0; O: 1	0	0
		USCI_A0.UCA0TXD (see Notes 1, 3)	X	1	0
		S35 (see Note 1)	X	X	1
P4.7/UCA0RXD/S34	7	P4.7 (I/O)	I: 0; O: 1	0	0
		USCI_A0.UCA0RXD (see Notes 1, 3)	X	1	0
		S34 (see Note 1)	X	X	1

NOTES: 1. X: Don't care.
2. The pin direction is controlled by the USART1 module.
3. When in USCI mode, P4.6 is set to output, P4.7 is set to input.

port P5, P5.0, input/output with Schmitt trigger



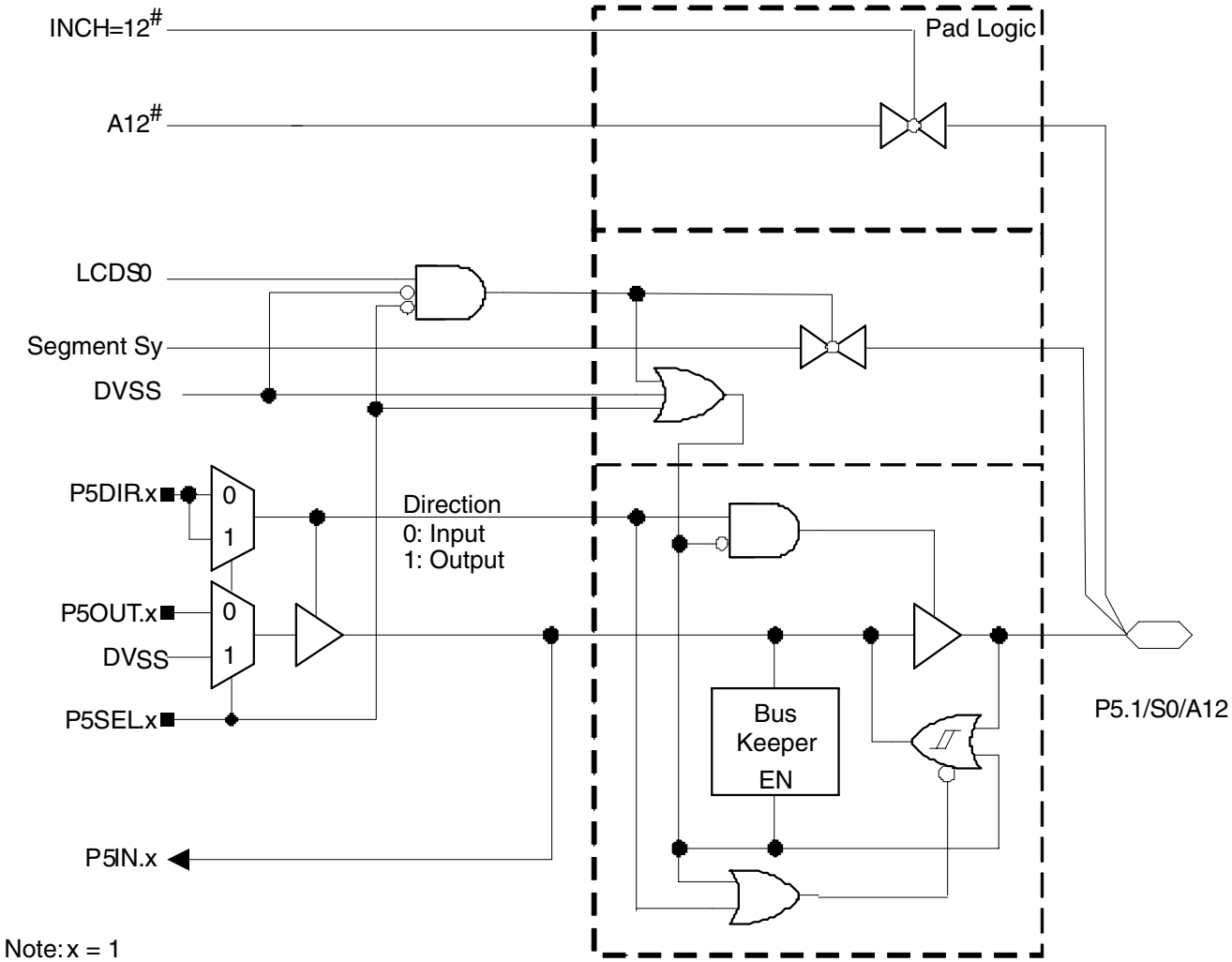
Note: x = 0
y = 1
# = Signal from or to ADC12
(MSP430x461x only)

port P5 (P5.0) pin functions

PIN NAME (P5.X)	X	FUNCTION	CONTROL BITS / SIGNALS			
			P5DIR.x	P5SEL.x	INCHx	LCDS0
P5.0/S1/A13	0	P5.0 (I/O) (see Note 1)	I: 0; O: 1	0	X	0
		A13 (MSP430x461x only, see Notes 1, 3)	X	1	13	X
		S1 enabled (see Note 1)	X	0	X	1
		S1 disabled (see Note 1)	X	1	X	1

NOTES: 1. X: Don't care.
2. N/A: Not available or not applicable.
3. Setting the P5SEL.x bit disables the output driver as well as the input Schmitt trigger to prevent parasitic cross currents when applying analog signals.

port P5, P5.1, input/output with Schmitt trigger



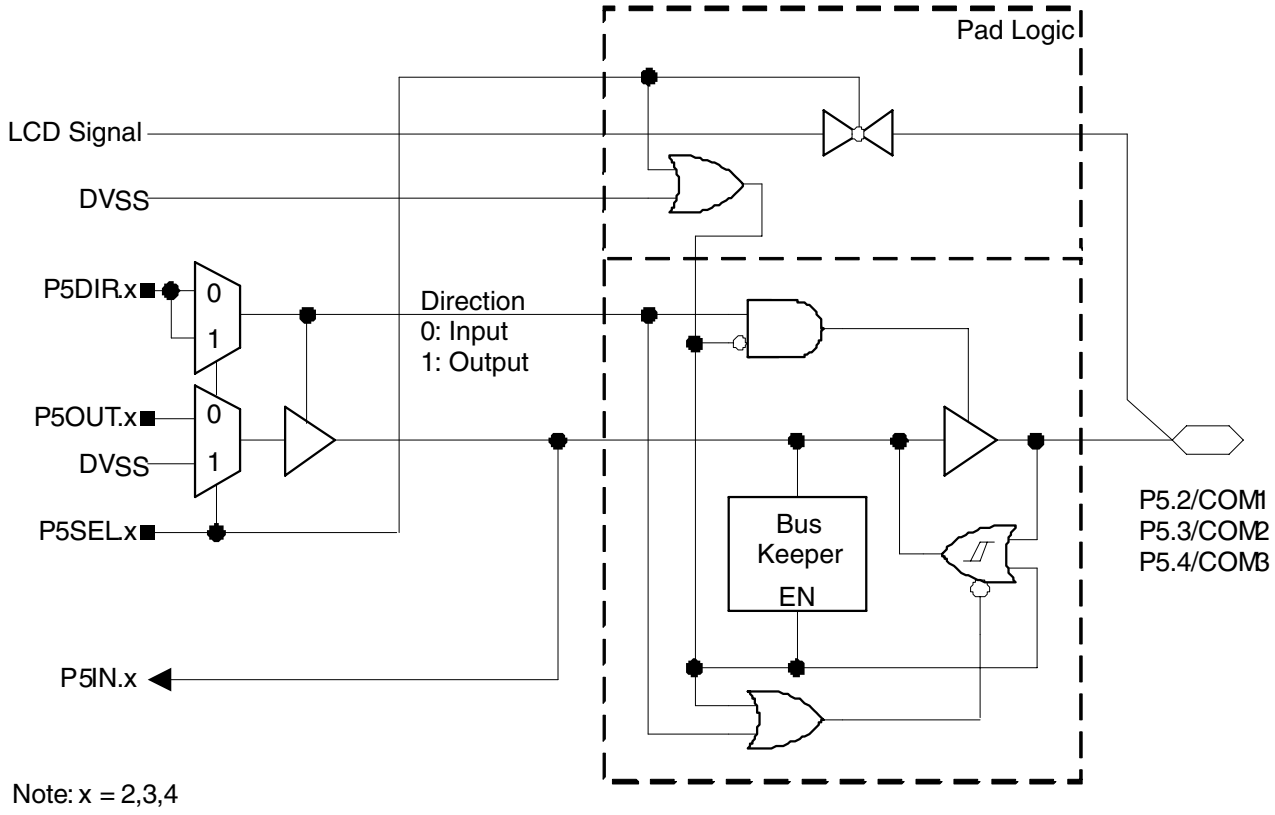
Note: x = 1
y = 0
# = Signal from or to ADC12
(MSP430x461x only)

port P5 (P5.1) pin functions

PIN NAME (P5.X)	X	FUNCTION	CONTROL BITS / SIGNALS			
			P5DIR.x	P5SEL.x	INCHx	LCDS0
P5.1/S0/A12	1	P5.1 (I/O) (see Note 1)	I: 0; O: 1	0	X	0
		A12 (MSP430x461x only, see Notes 1, 2)	X	1	12	0
		S0 enabled (see Note 1)	X	0	X	1
		S0 disabled (see Note 1)	X	1	X	1

NOTES: 1. X: Don't care.
2. Setting the P5SEL.x bit disables the output driver as well as the input Schmitt trigger to prevent parasitic cross currents when applying analog signals.

port P5, P5.2 to P5.4, input/output with Schmitt trigger

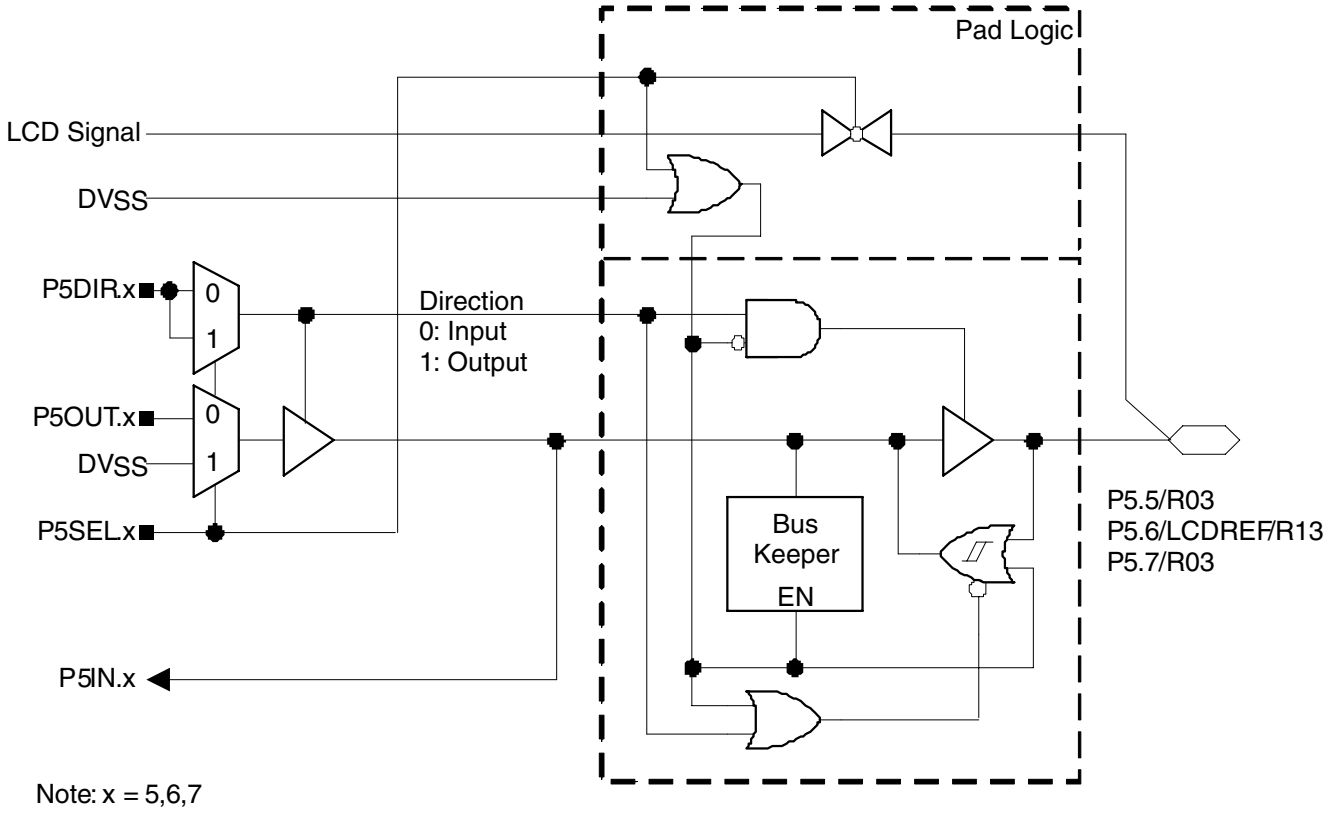


port P5 (P5.2 to P5.4) pin functions

PIN NAME (P5.X)	X	FUNCTION	CONTROL BITS / SIGNALS	
			P5DIR.x	P5SEL.x
P5.2/COM1	2	P5.2 (I/O)	I: 0; O: 1	0
		COM1 (see Note 1)	X	1
P5.3/COM2	3	P5.3 (I/O)	I: 0; O: 1	0
		COM2 (see Note 1)	X	1
P5.4/COM3	4	P5.4 (I/O)	I: 0; O: 1	0
		COM3 (see Note 1)	X	1

NOTE 1: X: Don't care.

port P5, P5.5 to P5.7, input/output with Schmitt trigger

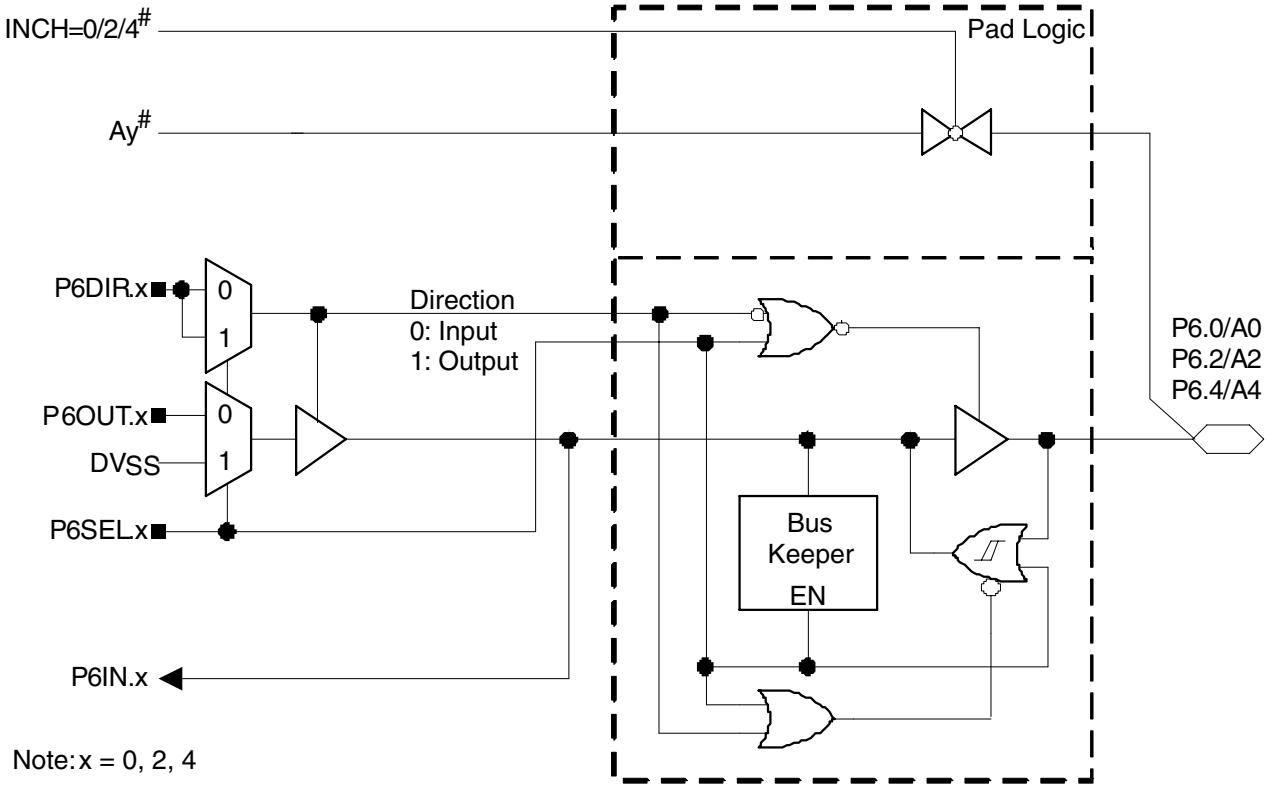


port P5 (P5.5 to P5.7) pin functions

PIN NAME (P5.X)	X	FUNCTION	CONTROL BITS / SIGNALS	
			P5DIR.x	P5SEL.x
P5.5/R03	5	P5.5 (I/O)	I: 0; O: 1	0
		R03 (see Note 1)	X	1
P5.6/LCDREF/R13	6	P5.6 (I/O)	I: 0; O: 1	0
		R13 or LCDREF (see Notes 1, 2)	X	1
P5.7/R03	7	P5.7 (I/O)	I: 0; O: 1	0
		R03 (see Note 1)	X	1

NOTES: 1. X: Don't care.
2. External reference for the LCD_A charge pump is applied when VLCDREFx = 01. Otherwise R13 is selected.

port P6, P6.0, P6.2, and P6.4, input/output with Schmitt trigger



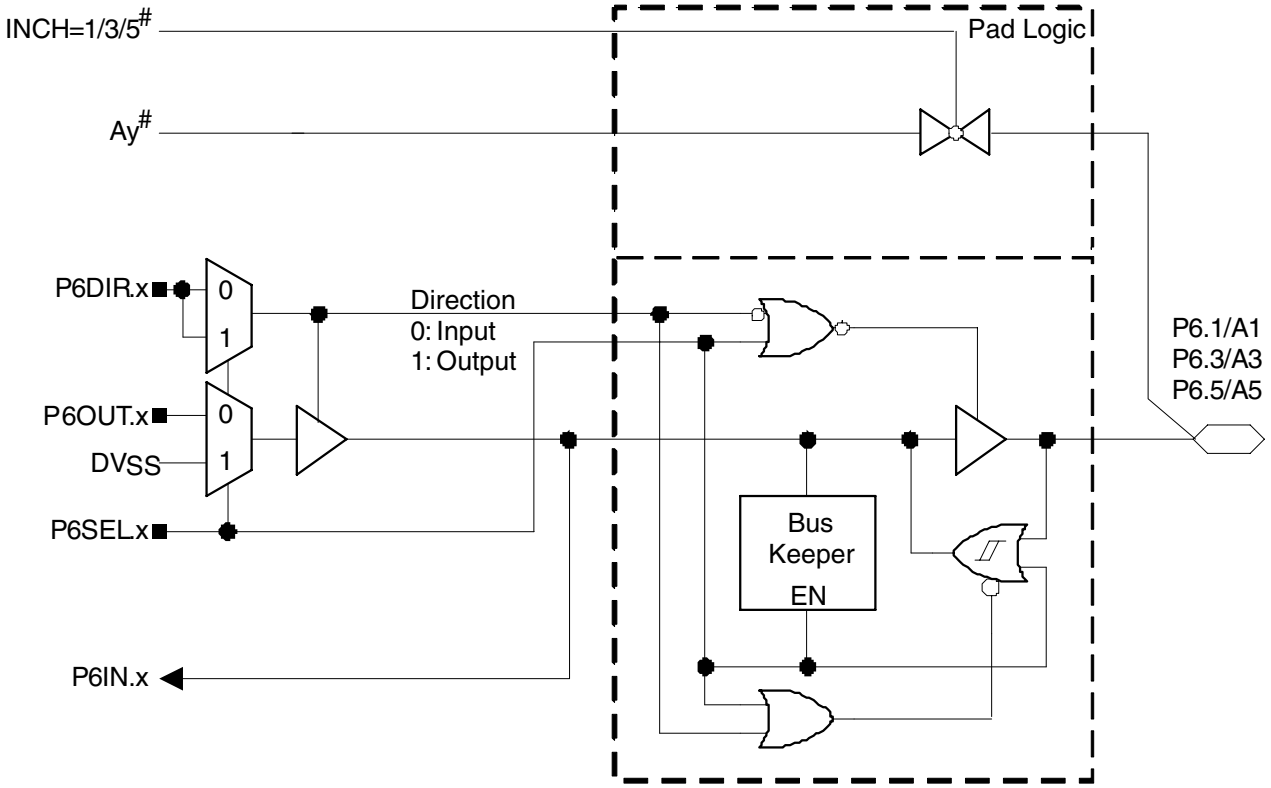
Note: x = 0, 2, 4
y = 0, 1
# = Signal from or to ADC12
(MSP430x461x only)

port P6 (P6.0, P6.2, and P6.4) pin functions

PIN NAME (P6.X)	X	FUNCTION	CONTROL BITS / SIGNALS		
			P6DIR.x	P6SEL.x	INCHx
P6.0/A0	0	P6.0 (I/O) (see Note 1)	I: 0; O: 1	0	X
		A0 (MSP430x461x only, see Notes 1, 3)	X	1	0
P6.2/A2	2	P6.2 (I/O) (see Note 1)	I: 0; O: 1	0	X
		A2 (MSP430x461x only, see Notes 1, 3)	X	1	2
P6.4/A4	4	P6.4 (I/O) (see Note 1)	I: 0; O: 1	0	X
		A4 (MSP430x461x only, see Notes 1, 3)	X	1	4

NOTES: 1. X: Don't care.
2. N/A: Not available or not applicable.
3. Setting the P6SEL.x bit disables the output driver as well as the input Schmitt trigger to prevent parasitic cross currents when applying analog signals.

port P6, P6.1, P6.3, and P6.5 input/output with Schmitt trigger



Note: x = 1, 3, 5

y = 0, 1, 2

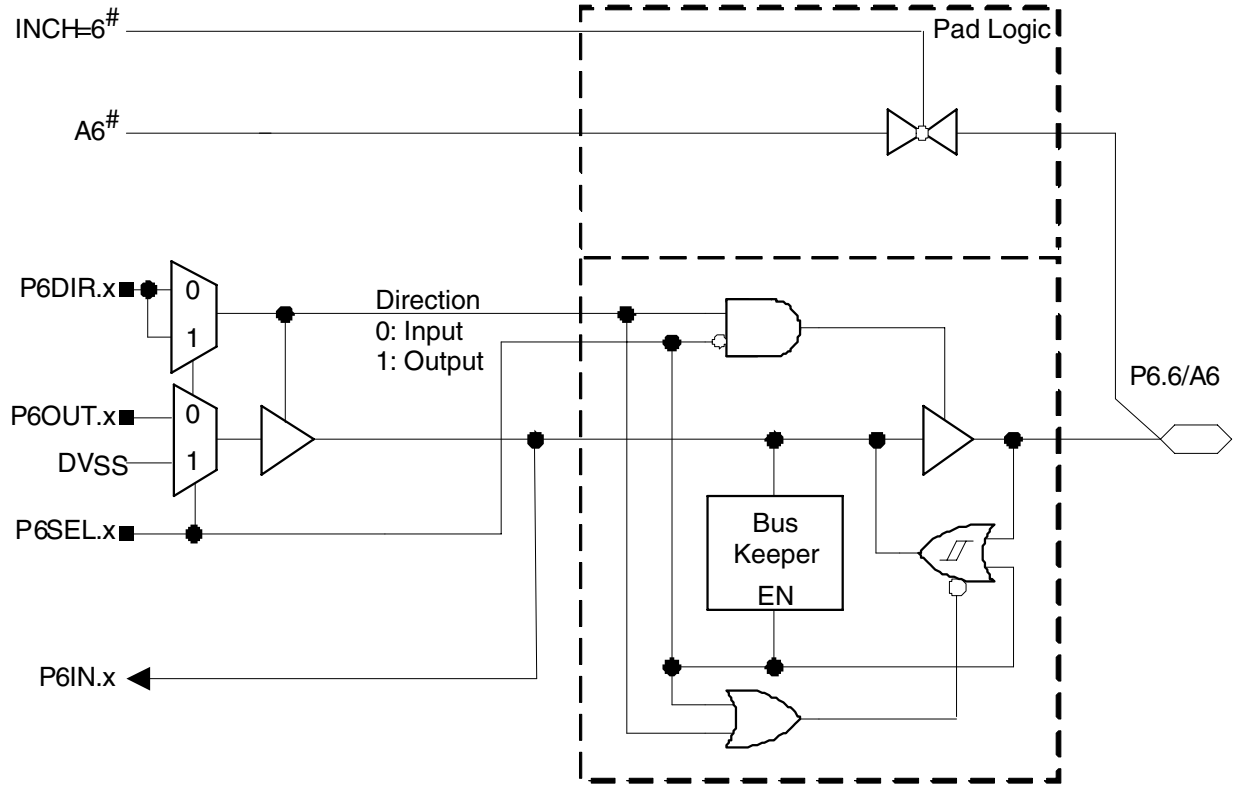
= Signal from or to ADC12 (MSP430x461x only)

port P6 (P6.1, P6.3, and P6.5) pin functions

PIN NAME (P6.X)	X	FUNCTION	CONTROL BITS / SIGNALS		
			P6DIR.x	P6SEL.x	INCHx
P6.1/A1	1	P6.1 (I/O) (see Note 1)	I: 0; O: 1	0	X
		A1 (MSP430x461x only, see Notes 1, 3)	X	1	1
P6.3/A3	3	P6.3 (I/O) (see Note 1)	I: 0; O: 1	0	X
		A3 (MSP430x461x only, see Notes 1, 3)	X	1	3
P6.5/A5	5	P6.5 (I/O) (see Note 1)	I: 0; O: 1	0	X
		A5 (MSP430x461x only, see Notes 1, 3)	X	1	5

NOTES: 1. X: Don't care.
2. N/A: Not available or not applicable.
3. Setting the P6SEL.x bit disables the output driver as well as the input Schmitt trigger to prevent parasitic cross currents when applying analog signals.

port P6, P6.6, input/output with Schmitt trigger



Note: x = 6

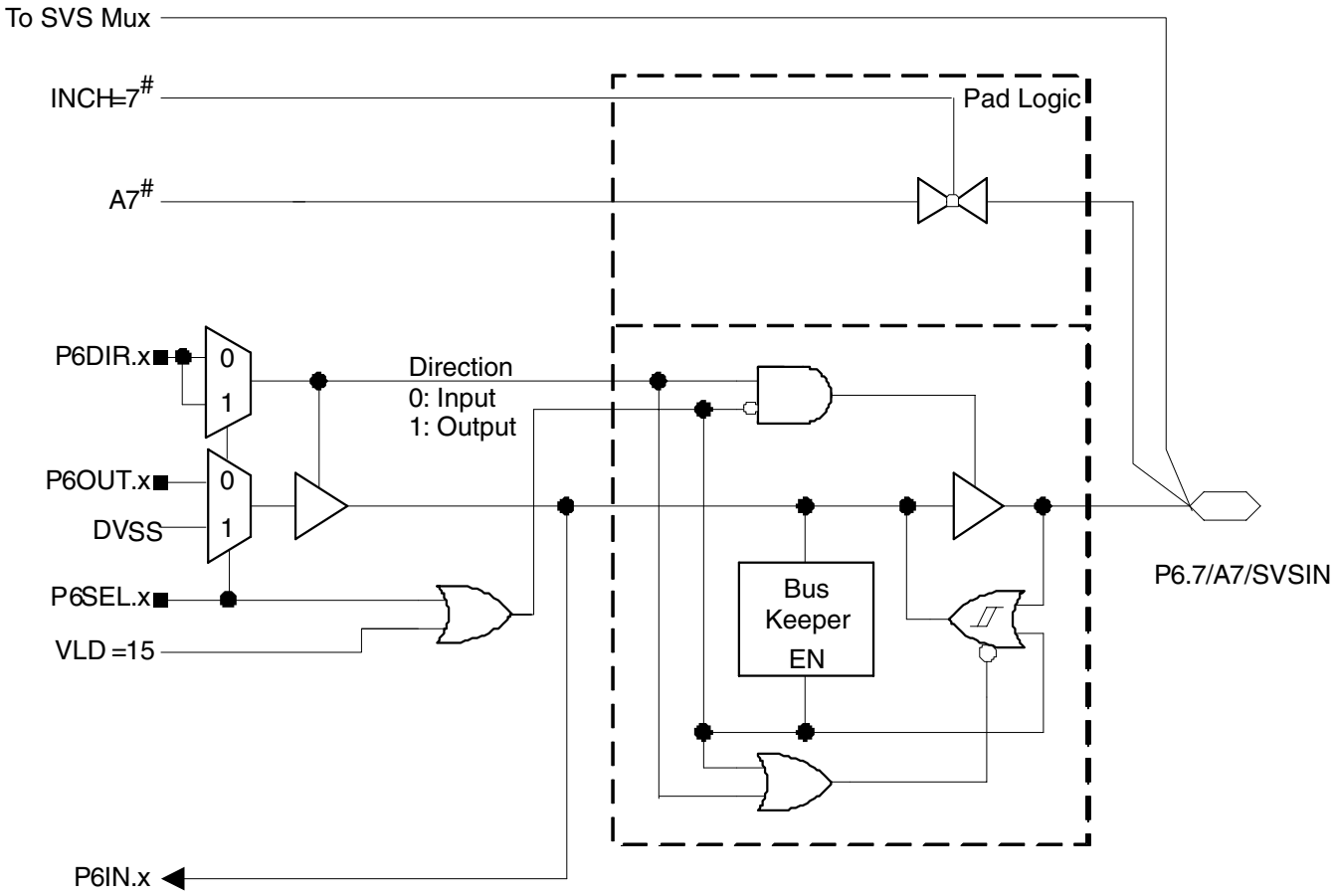
= Signal from or to ADC12
(MSP430x461 only)

port P6 (P6.6) pin functions

PIN NAME (P6.X)	X	FUNCTION	CONTROL BITS / SIGNALS		
			P6DIR.x	P6SEL.x	INCHx
P6.6/A6	6	P6.6 (I/O) (see Note 1)	I: 0; O: 1	0	X
		A6 (MSP430x461x only, see Notes 1, 2)	X	1	6

NOTES: 1. X: Don't care.
2. Setting the P6SEL.x bit disables the output driver as well as the input Schmitt trigger to prevent parasitic cross currents when applying analog signals.

port P6, P6.7, input/output with Schmitt trigger



Note: x = 7

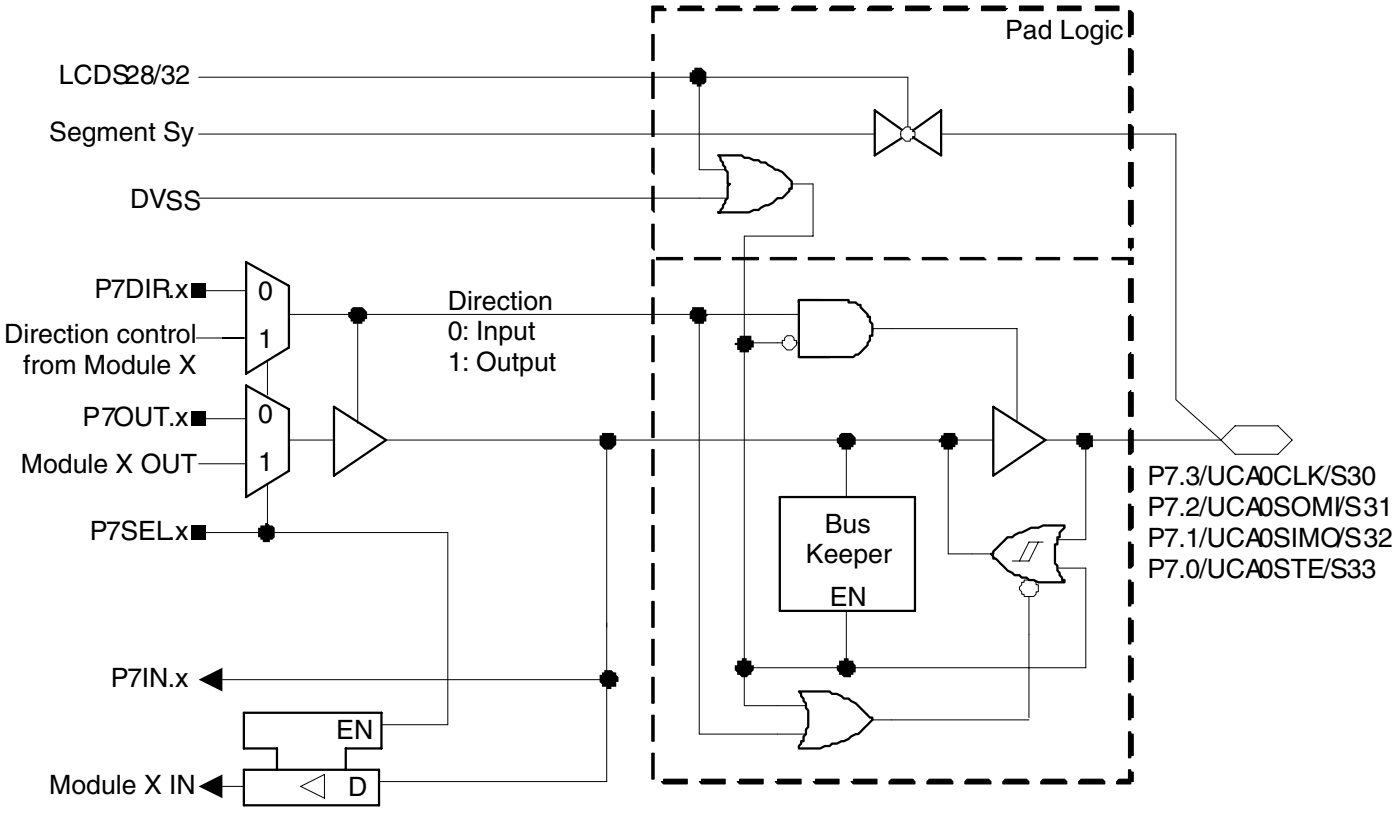
= Signal from or to ADC12
(MSP430x461x only)

port P6 (P6.7) pin functions

PIN NAME (P6.X)	X	FUNCTION	CONTROL BITS / SIGNALS		
			P6DIR.x	P6SEL.x	INCHx
P6.7/A7/SVSIN	7	P6.7 (I/O) (see Note 1)	I: 0; O: 1	0	X
		A7 (MSP430x461x only, see Notes 1, 2)	X	1	7
		SVSIN (see Notes 1,3)	0	1	0

NOTES: 1. X: Don't care.
2. Setting the P6SEL.x bit disables the output driver as well as the input Schmitt trigger to prevent parasitic cross currents when applying analog signals.
3. Setting VLDx = 15 will also cause the external SVSIN to be used. In this case, the P6SEL.x bit is a do not care.

port P7, P7.0 to P7.3, input/output with Schmitt trigger



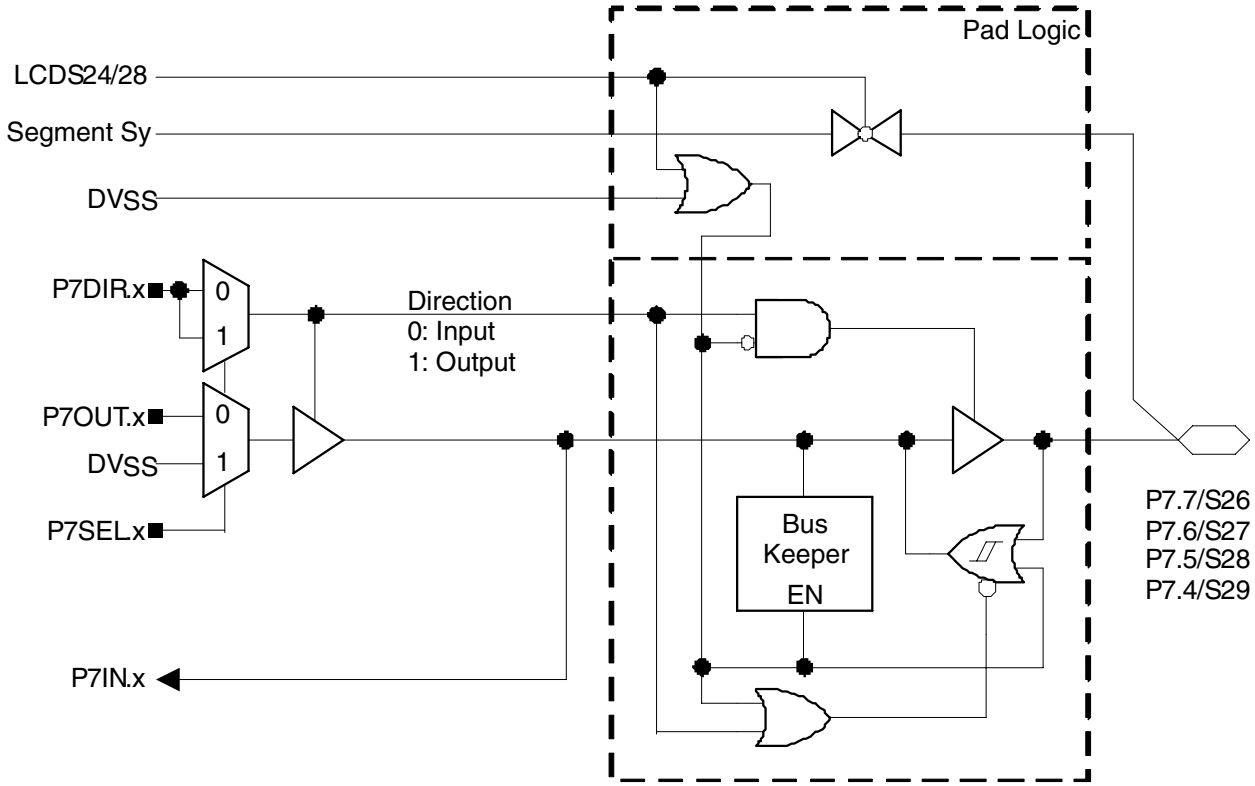
Note: x = 0, 1, 2, 3
y = 30, 31, 32, 33

port P7 (P7.0 to P7.1) pin functions

PIN NAME (P7.X)	X	FUNCTION	CONTROL BITS / SIGNALS		
			P7DIR.x	P7SEL.x	LCDS32
P7.0/UCA0STE/S33	0	P7.0 (I/O)	I: 0; O: 1	0	0
		USCI_A0.UCA0STE (see Notes 1, 2)	X	1	0
		S33 (see Note 1)	X	X	1
P7.1/UCA0SIMO/S32	1	P7.1 (I/O)	I: 0; O: 1	0	0
		USCI_A0.UCA0SIMO (see Notes 1, 2)	X	1	0
		S32 (see Note 1)	X	X	1
P7.2/UCA0SOMI/S31	2	P7.2 (I/O)	I: 0; O: 1	0	0
		USCI_A0.UCA0SOMI (see Notes 1, 3)	X	1	0
		S31 (see Note 1)	X	X	1
P7.3/UCA0CLK/S30	3	P7.3 (I/O)	I: 0; O: 1	0	0
		USCI_A0.UCA0CLK (see Notes 1, 3)	X	1	0
		S30 (see Note 1)	X	X	1

NOTES: 1. X: Don’t care.
2. The pin direction is controlled by the USCI module.
3. The pin direction is controlled by the USCI module.

port P7, P7.4 to P7.7, input/output with Schmitt trigger



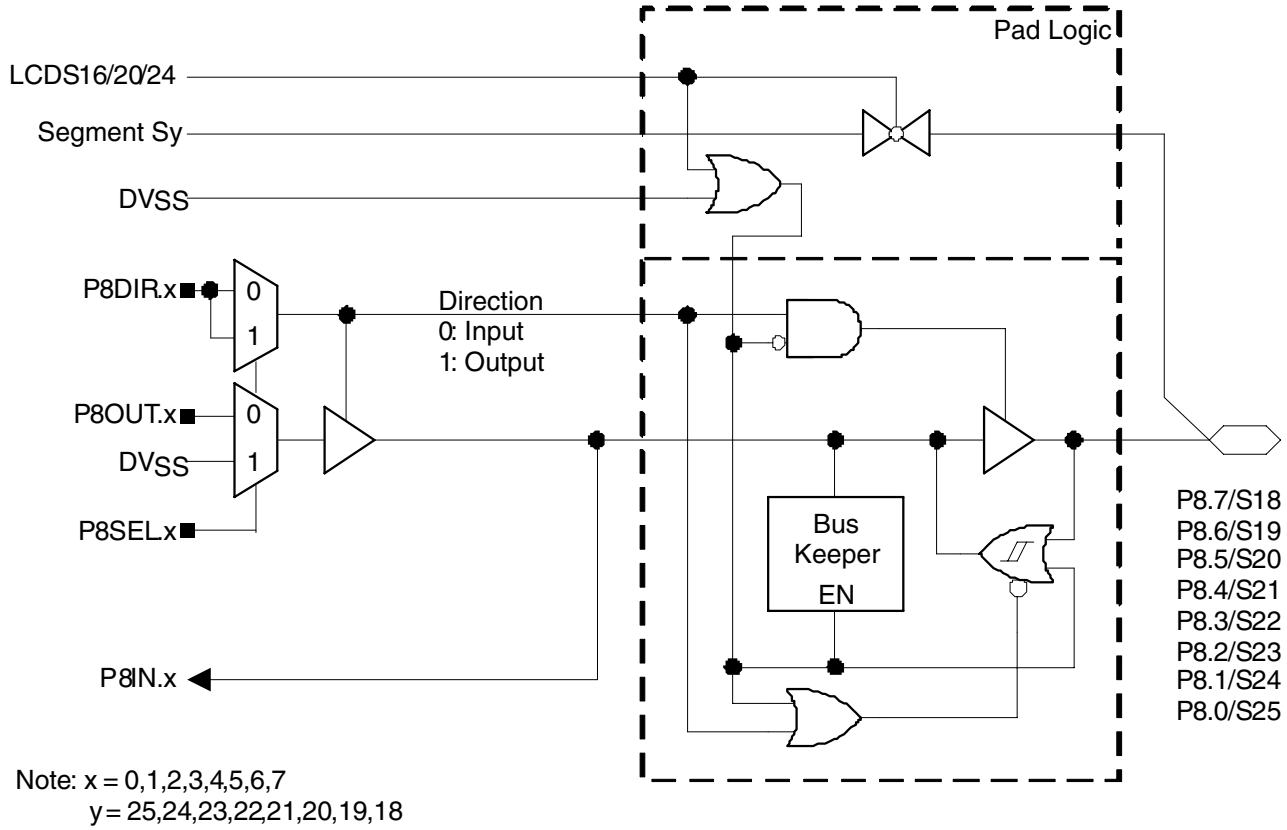
Note: x = 4, 5, 6, 7
y = 26, 27, 28, 29

port P7 (P7.4 to P7.5) pin functions

PIN NAME (P7.X)	X	FUNCTION	CONTROL BITS / SIGNALS		
			P7DIR.x	P7SEL.x	LCDS28
P7.4/S29	4	P7.4 (I/O)	I: 0; O: 1	0	0
		S29 (see Note 1)	X	X	1
P7.5/S28	5	P7.5 (I/O)	I: 0; O: 1	0	0
		S28 (see Note 1)	X	X	1
P7.6/S27	6	P7.6 (I/O)	I: 0; O: 1	0	0
		S27 (see Note 1)	X	X	1
P7.7/S26	7	P7.7 (I/O)	I: 0; O: 1	0	0
		S26 (see Note 1)	X	X	1

NOTE 1: X: Don't care.

port P8, P8.0 to P8.7, input/output with Schmitt trigger



Note: x = 0,1,2,3,4,5,6,7
y = 25,24,23,22,21,20,19,18

port P8 (P8.0 to P8.1) pin functions

PIN NAME (P8.X)	X	FUNCTION	CONTROL BITS / SIGNALS		
			P8DIR.x	P8SEL.x	LCDS16
P8.0/S18	0	P8.0 (I/O)	I: 0; O: 1	0	0
		S18 (see Note 1)	X	X	1
P8.1/S19	0	P8.0 (I/O)	I: 0; O: 1	0	0
		S19 (see Note 1)	X	X	1
P8.2/S20	2	P8.2 (I/O)	I: 0; O: 1	0	0
		S20 (see Note 1)	X	X	1
P8.3/S21	3	P8.3 (I/O)	I: 0; O: 1	0	0
		S21 (see Note 1)	X	X	1
P8.4/S22	4	P8.4 (I/O)	I: 0; O: 1	0	0
		S22 (see Note 1)	X	X	1
P8.5/S23	5	P8.5 (I/O)	I: 0; O: 1	0	0
		S23 (see Note 1)	X	X	1

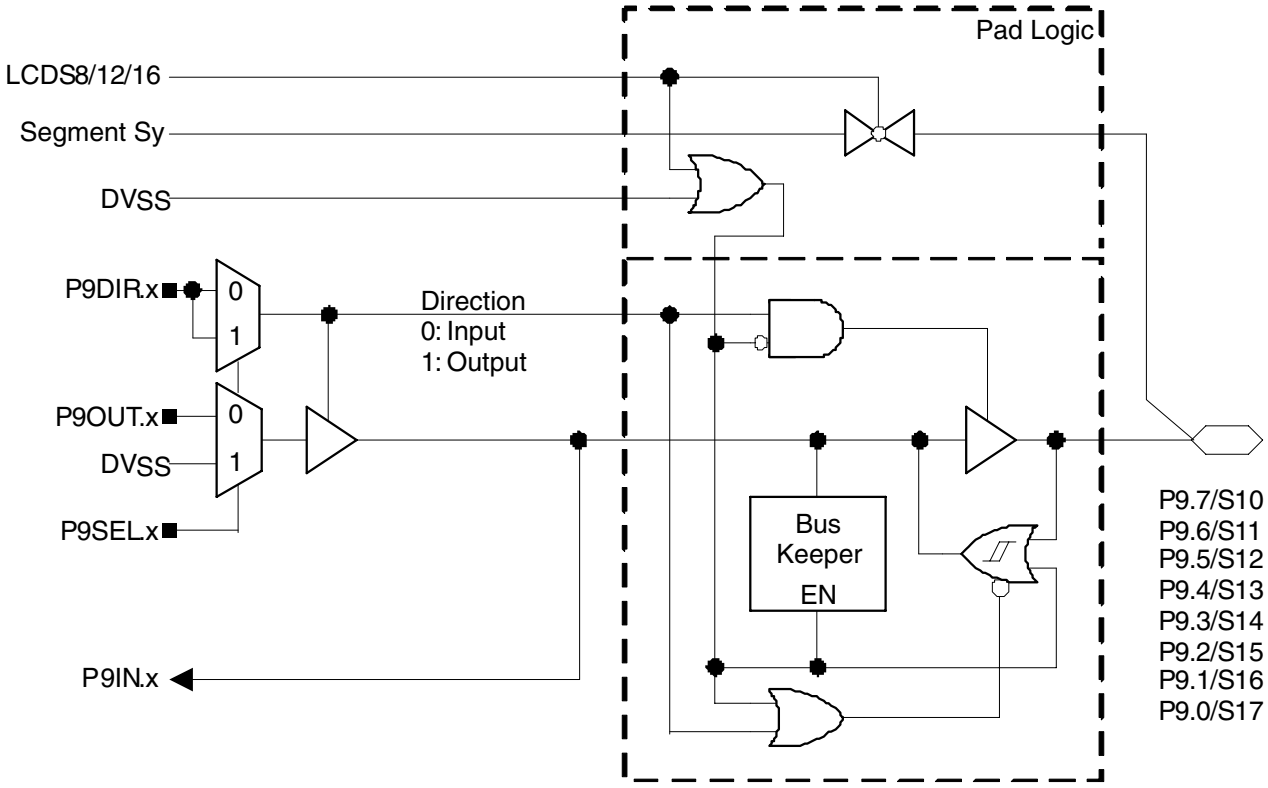
NOTE 1: X: Don't care.

port P8 (P8.6 to P8.7) pin functions

PIN NAME (P8.X)	X	FUNCTION	CONTROL BITS / SIGNALS		
			P8DIR.x	P8SEL.x	LCDS24
P8.6/S24	6	P8.6 (I/O)	I: 0; O: 1	0	0
		S24 (see Note 1)	X	X	1
P8.7/S25	7	P8.7 (I/O)	I: 0; O: 1	0	0
		S25 (see Note 1)	X	X	1

NOTE 1: X: Don't care.

port P9, P9.0 to P9.7, input/output with Schmitt trigger



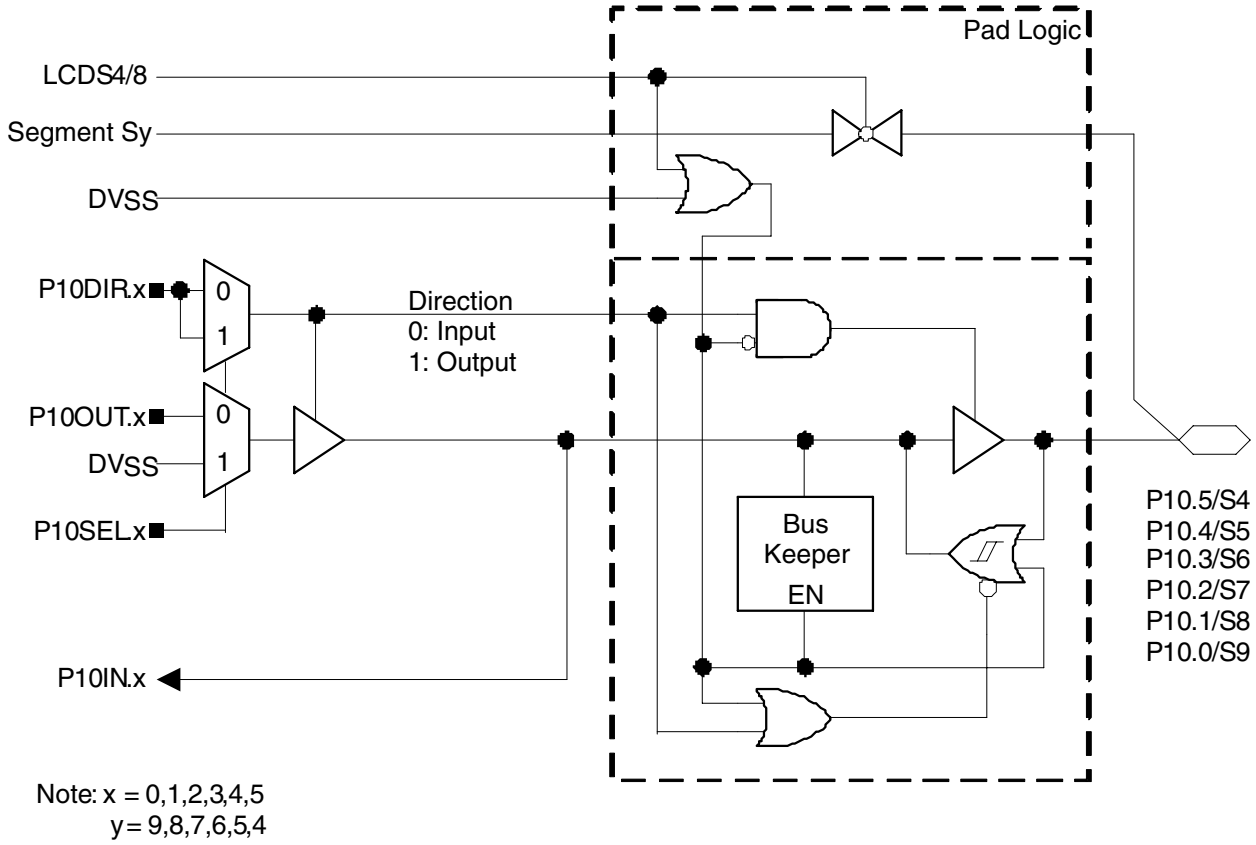
Note: x = 0,1,2,3,4,5,6,7
y = 17,16,15,14,13,12,11,10

port P9 (P9.0 to P9.1) pin functions

PIN NAME (P9.X)	X	FUNCTION	CONTROL BITS / SIGNALS		
			P9DIR.x	P9SEL.x	LCDS16
P9.0/S17	0	P9.0 (I/O)	I: 0; O: 1	0	0
		S17 (see Note 1)	X	X	1
P9.1/S16	1	P9.1 (I/O)	I: 0; O: 1	0	0
		S16 (see Note 1)	X	X	1
P9.2/S20	2	P9.2 (I/O)	I: 0; O: 1	0	0
		S15 (see Note 1)	X	X	1
P9.3/S21	3	P9.3 (I/O)	I: 0; O: 1	0	0
		S14 (see Note 1)	X	X	1
P9.4/S22	4	P9.4 (I/O)	I: 0; O: 1	0	0
		S13 (see Note 1)	X	X	1
P9.5/S23	5	P9.5 (I/O)	I: 0; O: 1	0	0
		S12 (see Note 1)	X	X	1
P9.6/S24	6	P9.6 (I/O)	I: 0; O: 1	0	0
		S11 (see Note 1)	X	X	1
P9.7/S25	7	P9.7 (I/O)	I: 0; O: 1	0	0
		S10 (see Note 1)	X	X	1

NOTE 1: X: Don’t care.

port P10, P10.0 to P10.5, input/output with Schmitt trigger

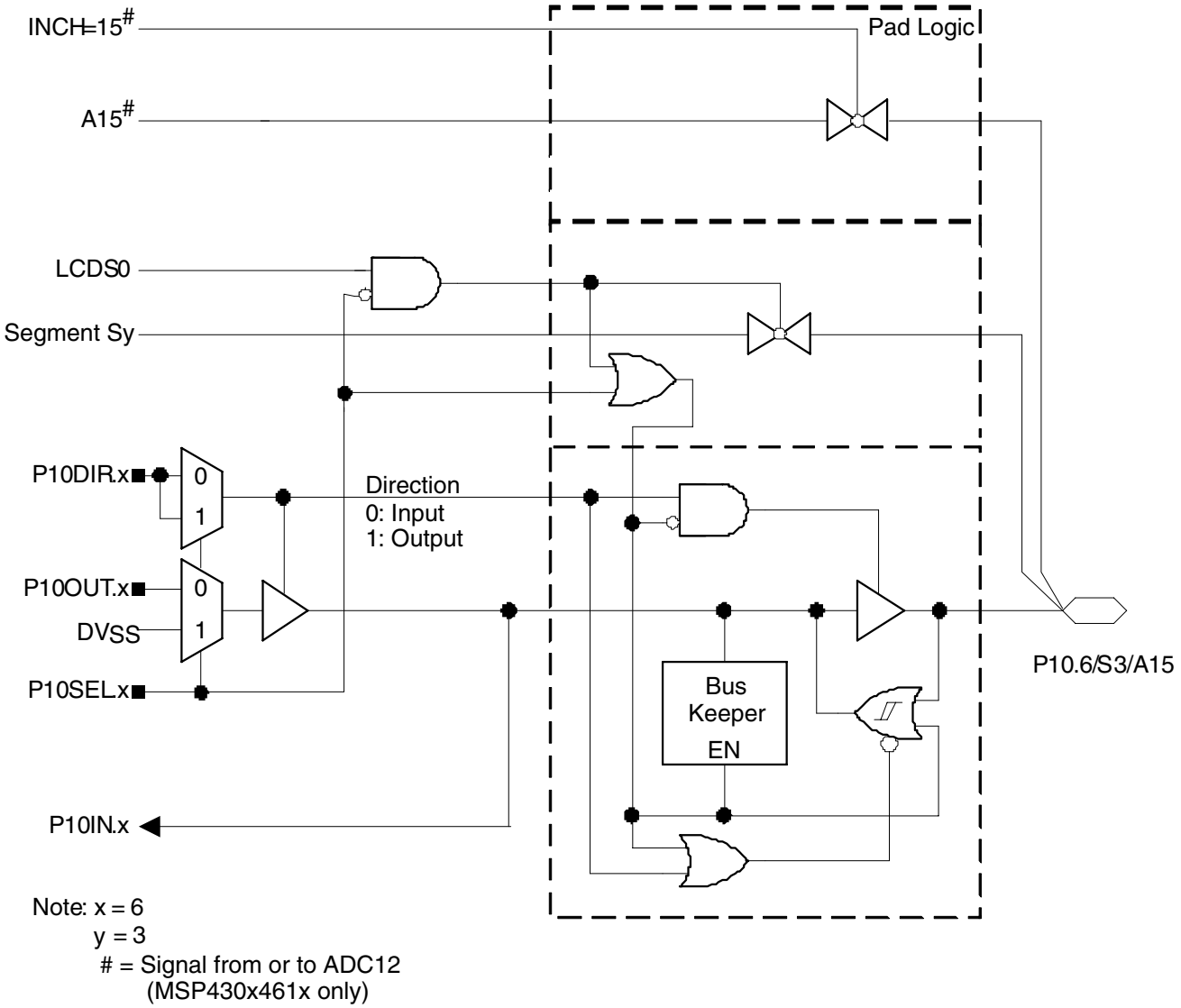


port P10 (P10.0 to P10.1) pin functions

PIN NAME (P10.X)	X	FUNCTION	CONTROL BITS / SIGNALS		
			P10DIR.x	P10SEL.x	LCDS8
P10.0/S8	0	P10.0 (I/O)	I: 0; O: 1	0	0
		S8 (see Note 1)	X	X	1
P10.1/S7	1	P10.1 (I/O)	I: 0; O: 1	0	0
		S7 (see Note 1)	X	X	1
P10.2/S7	2	P10.2 (I/O)	I: 0; O: 1	0	0
		S7 (see Note 1)	X	X	1
P10.3/S6	3	P10.3 (I/O)	I: 0; O: 1	0	0
		S6 (see Note 1)	X	X	1
P10.4/S5	4	P10.4 (I/O)	I: 0; O: 1	0	0
		S5 (see Note 1)	X	X	1
P10.5/S4	5	P10.5 (I/O)	I: 0; O: 1	0	0
		S4 (see Note 1)	X	X	1

NOTE 1: X: Don't care.

port P10, P10.6, input/output with Schmitt trigger

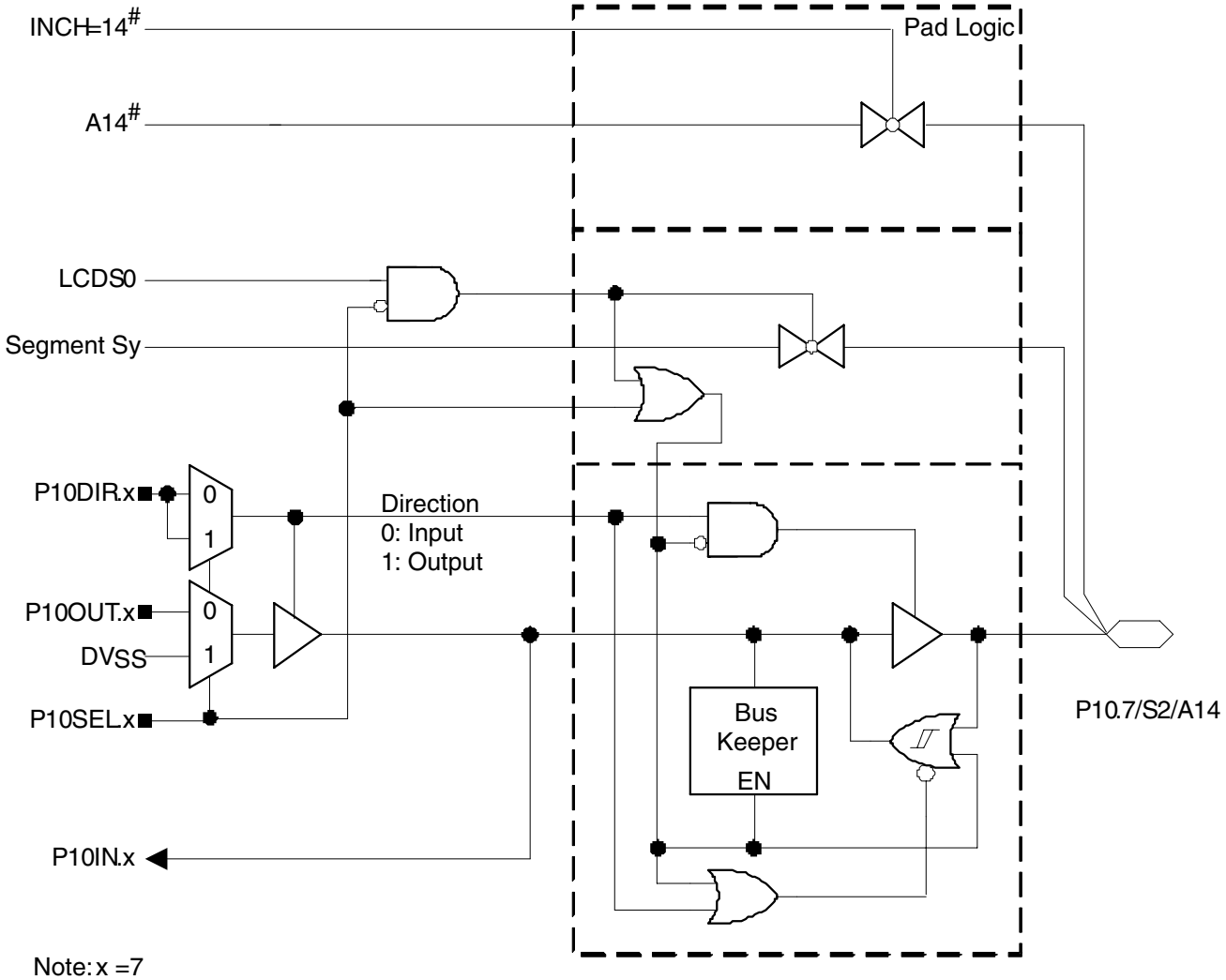


port P10 (P10.6) pin functions

PIN NAME (P10.X)	X	FUNCTION	CONTROL BITS / SIGNALS			
			P10DIR.x	P10SEL.x	INCHx	LCDS0
P10.6/S3/A15	6	P5.0 (I/O) (see Note 1)	I: 0; O: 1	0	X	0
		A15 (MSP430x461x only, see Notes 1, 3)	X	1	15	0
		S3 enabled (see Note 1)	X	0	X	1
		S3 disabled (see Note 1)	X	1	X	1

NOTES: 1. X: Don't care.
2. N/A: Not available or not applicable.
3. Setting the P10SEL.x bit disables the output driver as well as the input Schmitt trigger to prevent parasitic cross currents when applying analog signals.

port P10, P10.7, input/output with Schmitt trigger



Note: x =7

y = 2

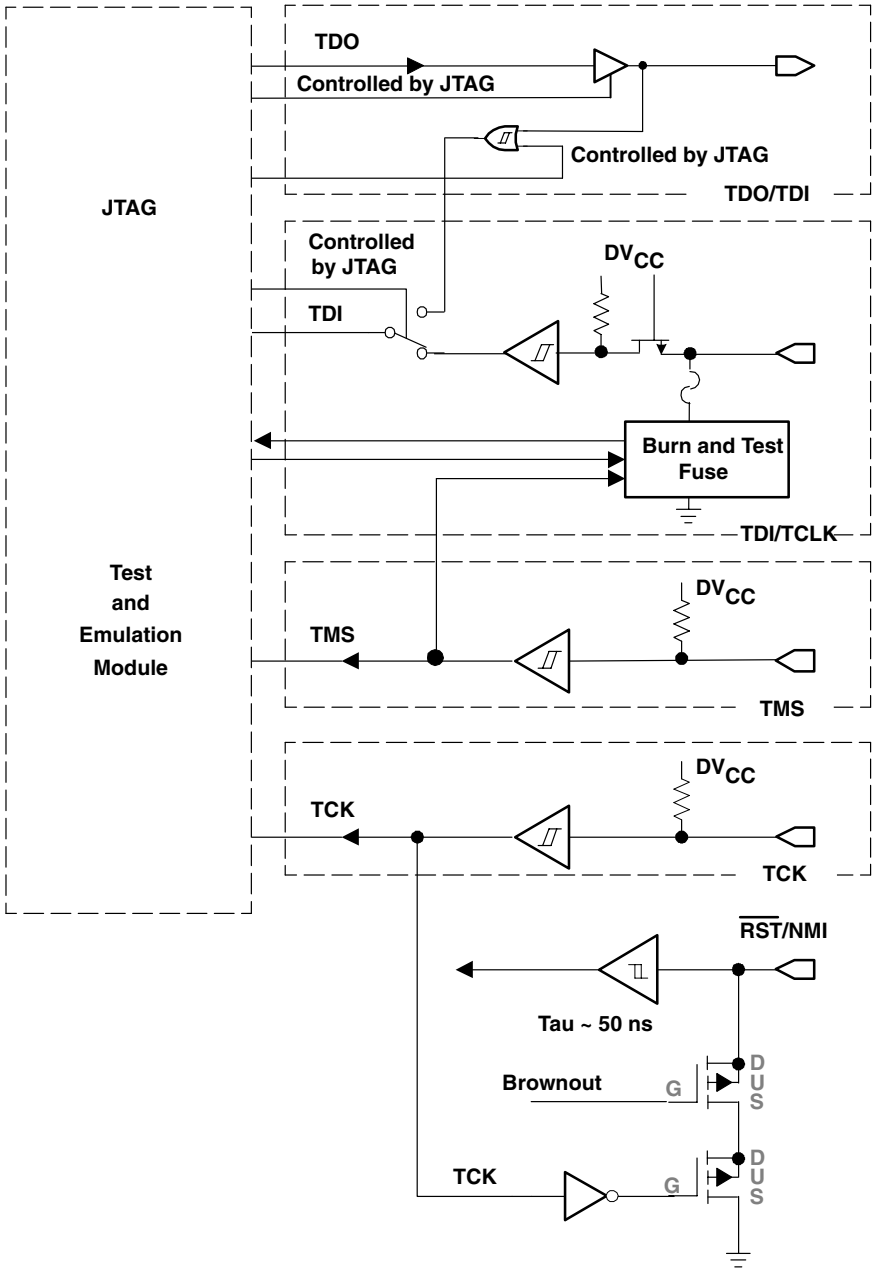
= Signal from or to ADC12 (MSP430x461x only)

port P10 (P10.7) pin functions

PIN NAME (P10.X)	X	FUNCTION	CONTROL BITS / SIGNALS			
			P10DIR.x	P10SEL.x	INCHx	LCDS0
P10.7/S2/A14	7	P10.7 (I/O) (see Note 1)	I: 0; O: 1	0	X	0
		A14 (MSP430x461x only, see Notes 1, 3)	X	1	14	0
		S2 enabled (see Note 1)	X	0	X	1
		S2 disabled (see Note 1)	X	1	X	1

NOTES: 1. X: Don't care.
2. N/A: Not available or not applicable.
3. Setting the P10SEL.x bit disables the output driver as well as the input Schmitt trigger to prevent parasitic cross currents when applying analog signals.

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



JTAG fuse check mode

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

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

The fuse check current only flows when the fuse check mode is active and the TMS pin is in a low state (see Figure 26). 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.

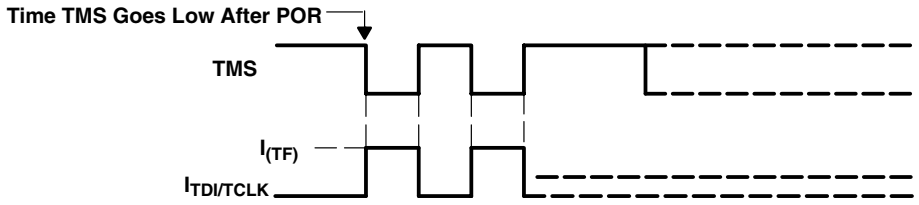


Figure 26. Fuse Check Mode Current

Data Sheet Revision History

Literature Number	Summary
SLAS675	Production Data data sheet release

NOTE: Page and figure numbers refer to the respective document revision.

Corrections to MSP430F461x, MSP430F461x1 Data Sheet (SLAS675)

Document Being Updated: *MSP430F461x, MSP430F461x1 Mixed Signal Microcontroller*

Literature Number Being Updated: SLAS675

Page	Change or Add
68	The table includes *LCDS36* in the "CONTROL BITS / SIGNALS" column. This is correct for P4.2/STE1/S39, P4.3/SIMO/S38, P4.4/SOMI/S37, and P4.5/SOMI/S36. For P4.6/UCA0TXD/S35 and P4.7/UCA0RXD/S34, the correct control bit is **LCDS32**.
78	The table includes *LCDS32* in the "CONTROL BITS / SIGNALS" column. This is correct for P7.0/UCA0STE/S33 and P7.1/UCA0SIMO/S32. For P7.2/UCA0SOMI/S31 and P7.3/UCA0CLK/S30, the correct control bit is **LCDS28**.
79	The table includes *LCDS28* in the "CONTROL BITS / SIGNALS" column. This is correct for P7.4/S29 and P7.5/S28. For P7.6/S27 and P7.7/S26, the correct control bit is **LCDS24**.
81	The "port P8 (P8.0 to P8.1) pin functions" table includes *LCDS16* in the "CONTROL BITS / SIGNALS" column. This is correct for P8.0/S18 and P8.1/S19. For P8.2/S20, P8.3/S21, P8.4/S22, and P8.5/S23, the correct control bit is **LCDS20**.
83	In the "PIN NAME (P9.X)" column, the segment signal names on P9.2 through P9.7 are incorrect–they should be: **P9.2/S15** **P9.3/S14** **P9.4/S13** **P9.5/S12** **P9.6/S11** **P9.7/S10** The table includes *LCDS16* in the "CONTROL BITS / SIGNALS" column. This is correct for P9.0/S17 and P9.1/S16. For P9.2/S15, P9.3/S14, P9.4/S13, and P9.5/S12, the correct control bit is **LCDS12**. For P9.6/S11 and P9.7/S10, the correct control bit is **LCDS8**.
84	In the "PIN NAME (P10.X)" and "FUNCTION" columns, the segment signal names on P10.0 and P10.1 are incorrect–they should be changed to: **P10.0/S9** **P10.1/S8** The table includes *LCDS8* in the "CONTROL BITS / SIGNALS" column. This is correct for P10.0/S9 and P10.1/S8. For P10.2/S7, P10.3/S6, P10.4/S5, and P10.5/S4, the correct control bit is **LCDS4**.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
MSP430F46161IPZ	ACTIVE	LQFP	PZ	100	90	RoHS & Green	NIPDAU	Level-3-260C-168 HR	-40 to 85	M430F46161	Samples
MSP430F46161IPZR	ACTIVE	LQFP	PZ	100	1000	RoHS & Green	NIPDAU	Level-3-260C-168 HR	-40 to 85	M430F46161	Samples
MSP430F4616IPZ	ACTIVE	LQFP	PZ	100	90	RoHS & Green	NIPDAU	Level-3-260C-168 HR	-40 to 85	M430F4616	Samples
MSP430F4616IPZR	ACTIVE	LQFP	PZ	100	1000	RoHS & Green	NIPDAU	Level-3-260C-168 HR	-40 to 85	M430F4616	Samples
MSP430F46171IPZ	ACTIVE	LQFP	PZ	100	90	RoHS & Green	NIPDAU	Level-3-260C-168 HR	-40 to 85	M430F46171	Samples
MSP430F46171IPZR	ACTIVE	LQFP	PZ	100	1000	RoHS & Green	NIPDAU	Level-3-260C-168 HR	-40 to 85	M430F46171	Samples
MSP430F4617IPZ	ACTIVE	LQFP	PZ	100	90	RoHS & Green	NIPDAU	Level-3-260C-168 HR	-40 to 85	M430F4617	Samples
MSP430F4617IPZR	ACTIVE	LQFP	PZ	100	1000	RoHS & Green	NIPDAU	Level-3-260C-168 HR	-40 to 85	M430F4617	Samples
MSP430F46181IPZ	ACTIVE	LQFP	PZ	100	90	RoHS & Green	NIPDAU	Level-3-260C-168 HR	-40 to 85	M430F46181	Samples
MSP430F46181IPZR	ACTIVE	LQFP	PZ	100	1000	RoHS & Green	NIPDAU	Level-3-260C-168 HR	-40 to 85	M430F46181	Samples
MSP430F4618IPZ	ACTIVE	LQFP	PZ	100	90	RoHS & Green	NIPDAU	Level-3-260C-168 HR	-40 to 85	M430F4618	Samples
MSP430F4618IPZR	ACTIVE	LQFP	PZ	100	1000	RoHS & Green	NIPDAU	Level-3-260C-168 HR	-40 to 85	M430F4618	Samples
MSP430F46191IPZ	ACTIVE	LQFP	PZ	100	90	RoHS & Green	NIPDAU	Level-3-260C-168 HR	-40 to 85	M430F46191	Samples
MSP430F46191IPZR	ACTIVE	LQFP	PZ	100	1000	RoHS & Green	NIPDAU	Level-3-260C-168 HR	-40 to 85	M430F46191	Samples
MSP430F4619IPZ	ACTIVE	LQFP	PZ	100	90	RoHS & Green	NIPDAU	Level-3-260C-168 HR	-40 to 85	M430F4619	Samples
MSP430F4619IPZR	ACTIVE	LQFP	PZ	100	1000	RoHS & Green	NIPDAU	Level-3-260C-168 HR	-40 to 85	M430F4619	Samples

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) RoHS: TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

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

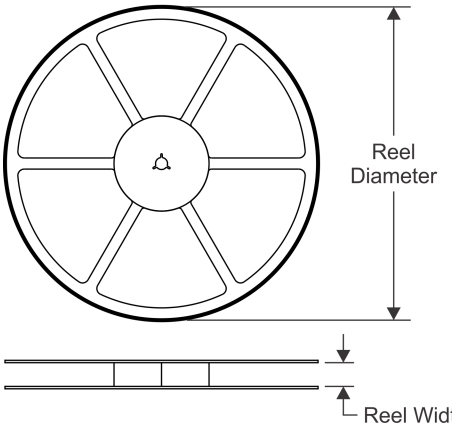
(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

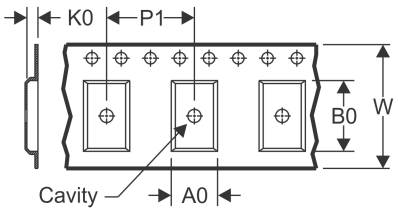
(6) Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

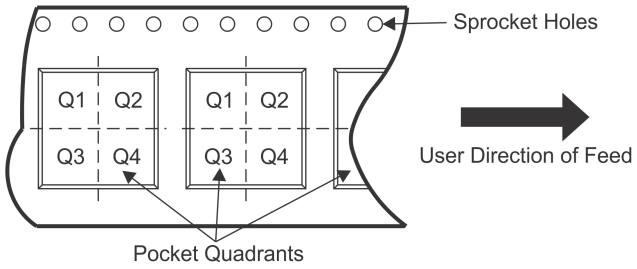


TAPE DIMENSIONS



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

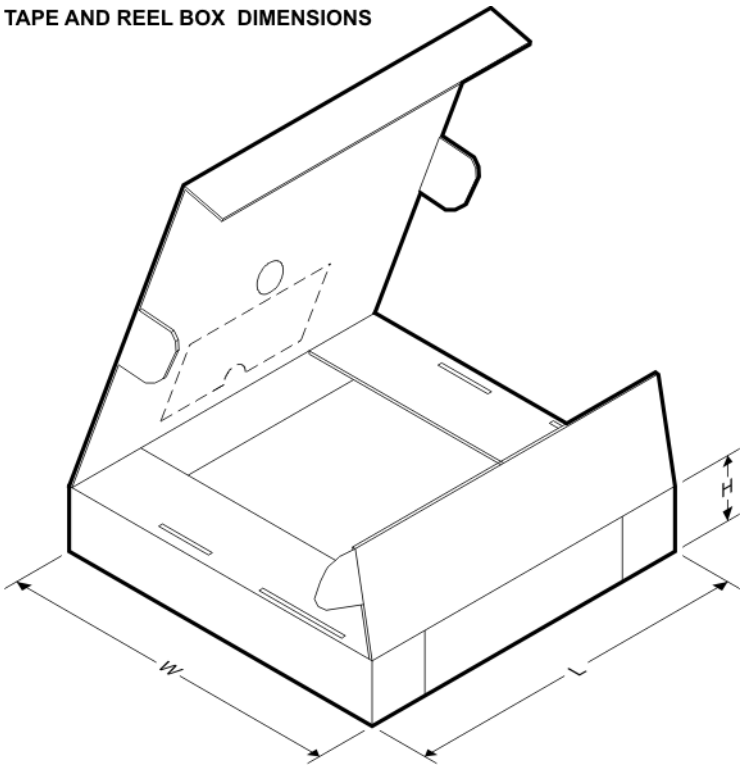
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
MSP430F46161IPZR	LQFP	PZ	100	1000	330.0	24.4	17.0	17.0	2.1	20.0	24.0	Q2
MSP430F4616IPZR	LQFP	PZ	100	1000	330.0	24.4	17.0	17.0	2.1	20.0	24.0	Q2
MSP430F46171IPZR	LQFP	PZ	100	1000	330.0	24.4	17.0	17.0	2.1	20.0	24.0	Q2
MSP430F4617IPZR	LQFP	PZ	100	1000	330.0	24.4	17.0	17.0	2.1	20.0	24.0	Q2
MSP430F46181IPZR	LQFP	PZ	100	1000	330.0	24.4	17.0	17.0	2.1	20.0	24.0	Q2
MSP430F4618IPZR	LQFP	PZ	100	1000	330.0	24.4	17.0	17.0	2.1	20.0	24.0	Q2
MSP430F46191IPZR	LQFP	PZ	100	1000	330.0	24.4	17.0	17.0	2.1	20.0	24.0	Q2
MSP430F4619IPZR	LQFP	PZ	100	1000	330.0	24.4	17.0	17.0	2.1	20.0	24.0	Q2

TAPE AND REEL BOX DIMENSIONS

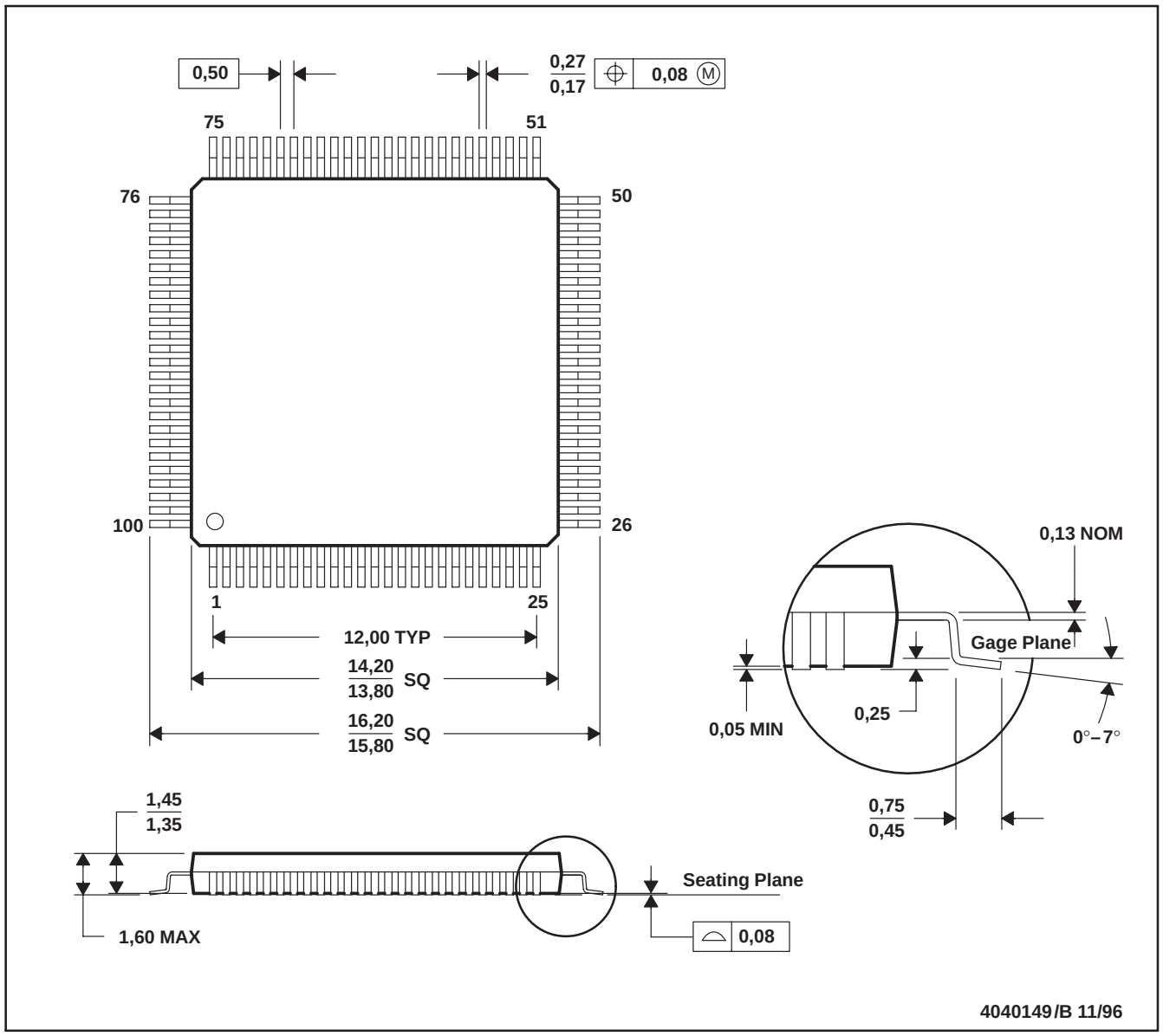


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
MSP430F46161IPZR	LQFP	PZ	100	1000	367.0	367.0	45.0
MSP430F4616IPZR	LQFP	PZ	100	1000	367.0	367.0	45.0
MSP430F46171IPZR	LQFP	PZ	100	1000	367.0	367.0	45.0
MSP430F4617IPZR	LQFP	PZ	100	1000	367.0	367.0	45.0
MSP430F46181IPZR	LQFP	PZ	100	1000	367.0	367.0	45.0
MSP430F4618IPZR	LQFP	PZ	100	1000	367.0	367.0	45.0
MSP430F46191IPZR	LQFP	PZ	100	1000	367.0	367.0	45.0
MSP430F4619IPZR	LQFP	PZ	100	1000	367.0	367.0	45.0

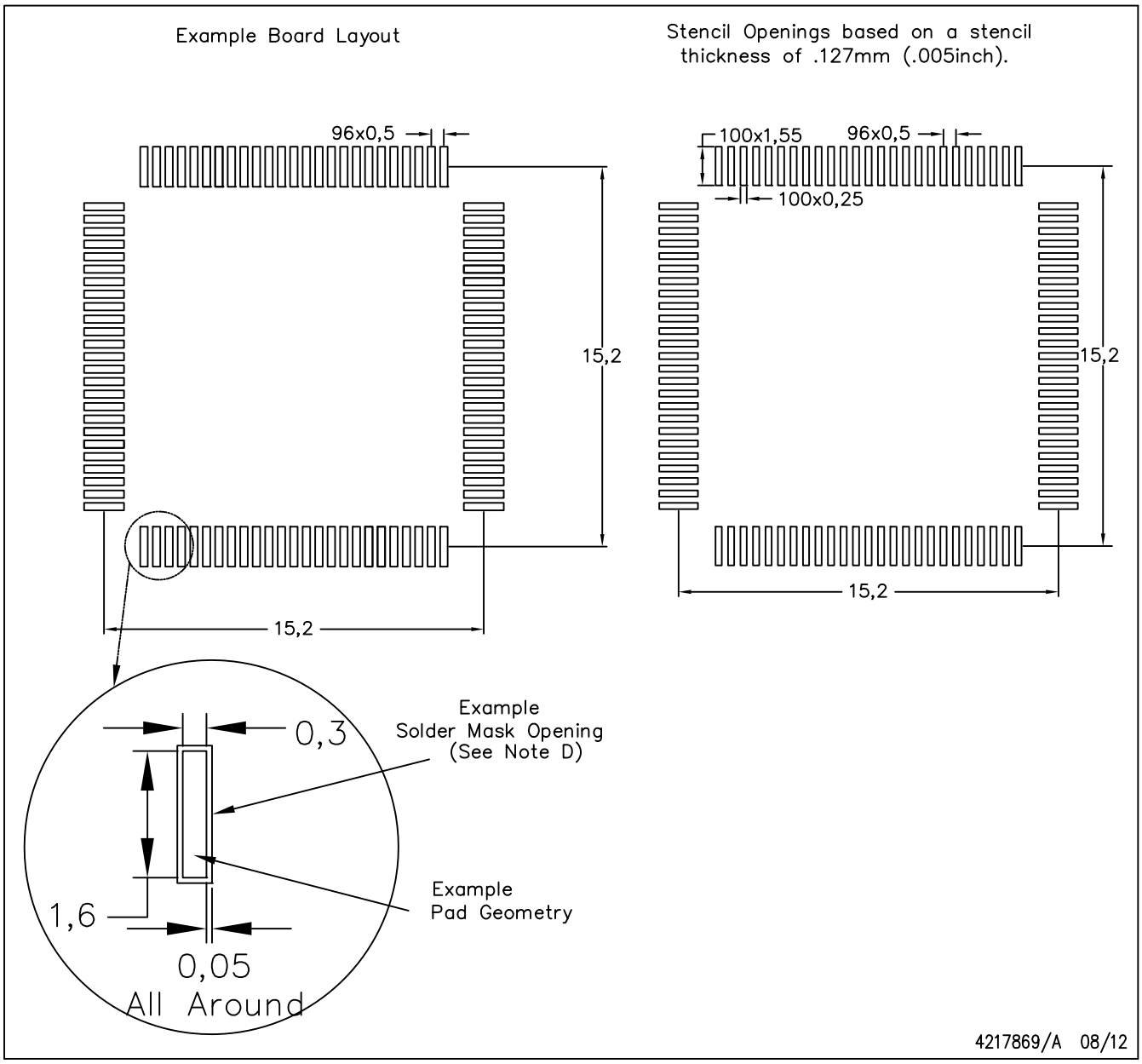
MTQF013A – OCTOBER 1994 – REVISED DECEMBER 1996

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



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

PZ (S–PQFP–G100) PLASTIC QUAD FLAT PACK



NOTES:

A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. 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. Example stencil design based on a 50% volumetric metal load solder paste. Refer to IPC–7525 for other stencil recommendations.
D. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

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