

SPI and I2C communication with CMA3000-D01 using MSP430 ultra low-power microcontroller

1 INTRODUCTION

The objective of this document is to show how to set up SPI/I2C communication between VTI Technologies CMA3000-D01 digital acceleration sensor component and a Texas Instruments MSP430 microcontroller. In the code examples:

- The MSP430 MCU is configured
- CMA3000-D01 measurement mode is activated
- An interrupt is used to read acceleration output data registers when new data is available

Please refer to document "CMA3000-D0X Product Family Specification 8281000" for further information on CMA3000-D01 register addressing and SPI/I2C communication. For MSP430 related information please see Texas Instruments web pages (<http://www.ti.com>).

2 DEVELOPMENT HARDWARE

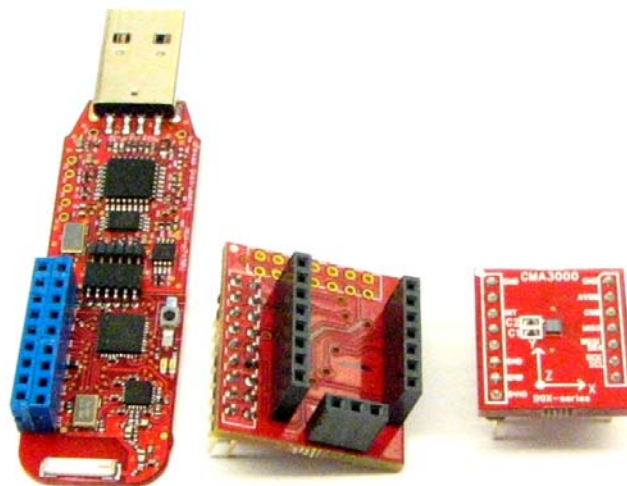


Figure 1. From left to right, eZ430-RF2500, adapter PCB VTI29631 and CMA3000-D01 chip carrier

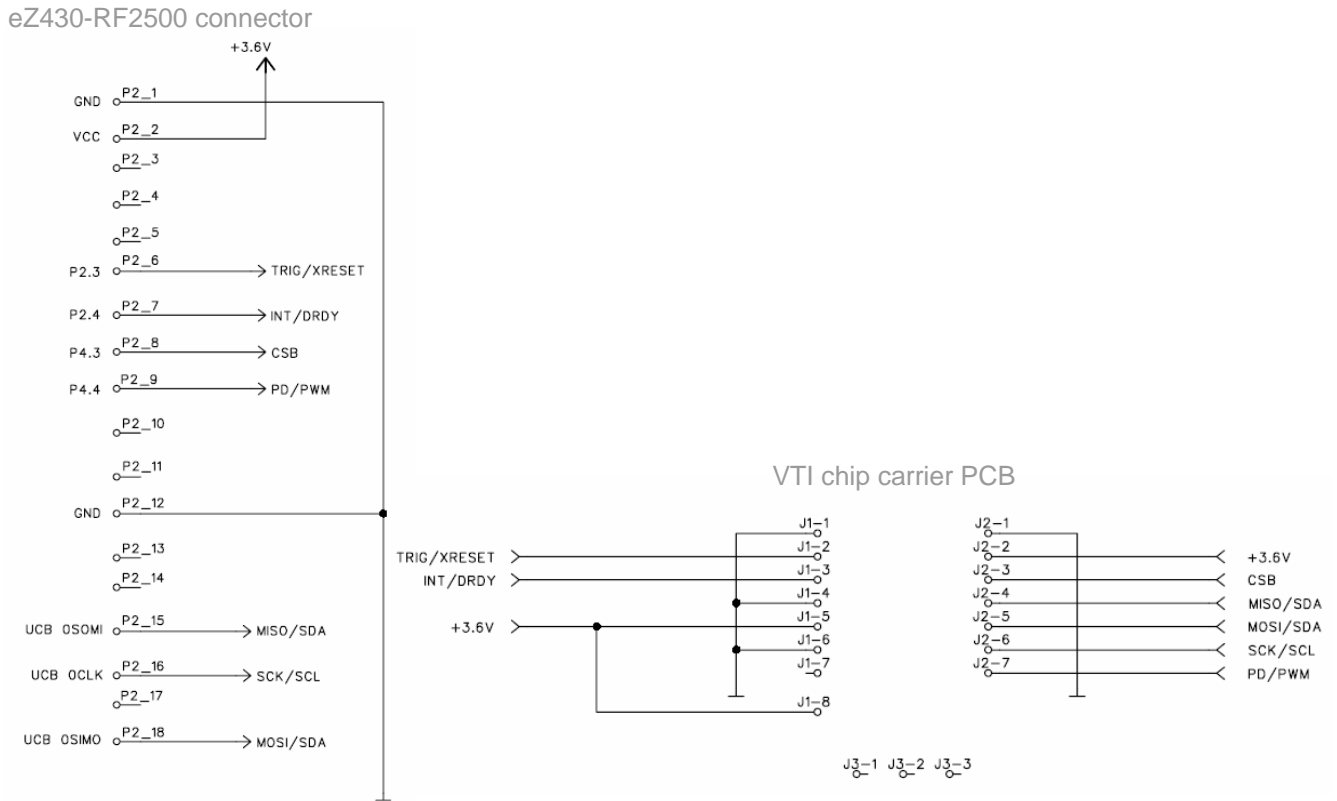


Figure 2. Adapter PCB VTI29631 circuit diagram

3 C-CODE

The example code is written for Texas Instruments eZ430-RF2500 Development Tool (MSP430F2274) using IAR Embedded Workbench KickStart for MSP430 V4 IDE. To interface CMA3000-D01 to the eZ430-RF2500 an adapter PCB VTI29631 is used (available through Hy-Line's web shop (<http://www.hy-line.de/vti-msp430>)).

The C-language software examples for SPI and I2C buses on the next pages shows an easy way to implement communication with the CMA3000-D01. Universal Serial Communication Interface peripheral inside the MSP430F2274 is used for communication.

The codes set up an interrupt to wake up the MCU from low power mode thru CMA3000-D01 INT-pin when new data from the sensor is available. When no data is available (no interrupt) the MCU is kept in low power mode 4 (LPM4) to achieve lower current consumption. Clocks are set up so that the MCU clock frequency is 16 MHz, SPI clock is 250 kHz and I2C clock 100 kHz. These are not ideal for typical applications, but allow us to demonstrate how to set up clock domains while simultaneously emphasizing that when using SPI bus there must be at least 11 SCK clock periods between SPI frames.

3.1 SPI Interface Example

Code flowchart:

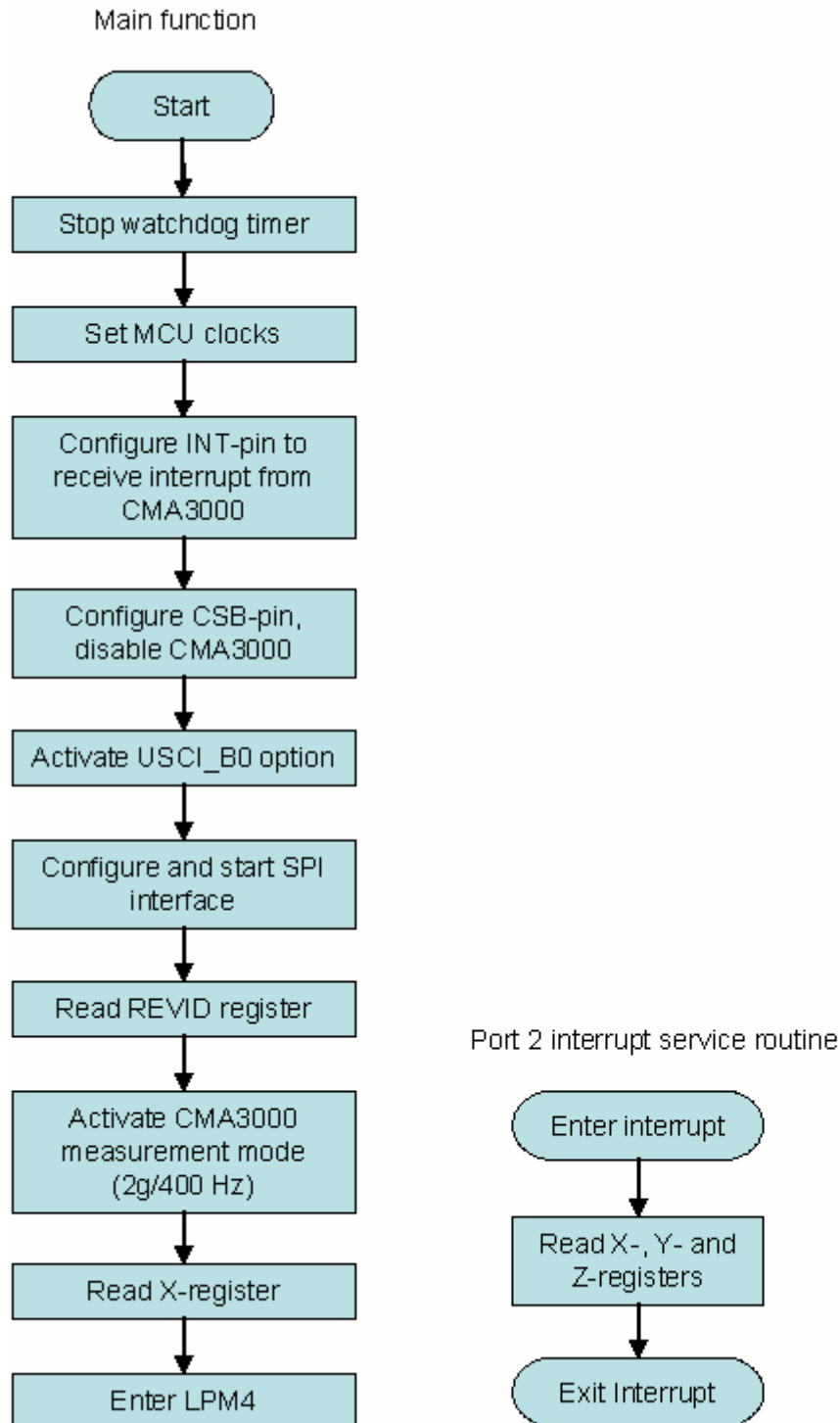


Figure 3. SPI Example Code Flowchart

C-Code Example, SPI Interface

```

//*****
//  MSP430F2274 Demo - USCI_B0, SPI Interface to CMA3000 Acceleration Sensor
//
//  Uses Texas Instruments eZ430-RF2500 Development Tool with VTI Adapter PCB
//  VTI29631A0. Wireless connection not used.
//
//*****

// CONSTANTS
#define XTAL 16000000L
#define TICKSPERMS (XTAL / 1000 / 5 - 1)
#define TICKSPERUS (TICKSPERMS / 1000)

// LIBRARIES
#include "msp430x22x4.h"

// PORT DEFINITIONS
#define PORT_INT_IN      P2IN
#define PORT_INT_OUT     P2OUT
#define PORT_INT_DIR     P2DIR
#define PORT_INT_IE      P2IE
#define PORT_INT_IES     P2IES
#define PORT_INT_IFG     P2IFG
#define PORT_INT_VECTOR  PORT2_VECTOR

#define PORT_CSB_OUT     P4OUT
#define PORT_CSB_DIR     P4DIR
#define PORT_SPI_DIR     P3DIR
#define PORT_SPI_SEL     P3SEL

// REGISTER AND FLAG DEFINITIONS
#define TX_BUFFER        UCB0TXBUF
#define RX_BUFFER        UCB0RXBUF
#define IRQ_REG          IFG2
#define RX_IFG           UCB0RXIFG
#define SPI_CTL0         UCB0CTL0
#define SPI_CTL1         UCB0CTL1
#define SPI_BR0          UCB0BR0
#define SPI_BR1          UCB0BR1

// CMA3000 Registers
#define WHO_AM_I         0x00
#define REVID            0x01
#define CTRL             0x02
#define STATUS          0x03
#define RSTR            0x04
#define INT_STATUS       0x05
#define DOUTX           0x06
#define DOUTY           0x07
#define DOUTZ           0x08
#define MDTHR           0x09
#define MDFFTMR         0x0A
#define FFTHR           0x0B
#define I2C_ADDR        0x0C
    
```

```

// Control Register setup
#define G_RANGE_2      0x80 // 2g range
#define INT_LEVEL_LOW  0x40 // INT active high
#define MDET_NO_EXIT   0x20 // Remain in motion detection mode
#define I2C_DIS        0x10 // I2C disabled
#define MODE_PD        0x00 // Power Down
#define MODE_100       0x02 // Measurement mode 100 Hz ODR
#define MODE_400       0x04 // Measurement mode 400 Hz ODR
#define MODE_40        0x06 // Measurement mode 40 Hz ODR
#define MODE_MD_10     0x08 // Motion detection mode 10 Hz ODR
#define MODE_FF_100    0x0A // Free fall detection mode 100 Hz ODR
#define MODE_FF_400    0x0C // Free fall detection mode 400 Hz ODR
#define INT_DIS        0x01 // Interrupts enabled

// PIN DEFINITIONS
#define PIN_INT        BIT4
#define PIN_CSB        BIT3
#define PIN_MOSI       BIT1
#define PIN_MISO        BIT2
#define PIN_SCK        BIT3

// FUNCTION PROTOTYPES
unsigned char ReadRegister(unsigned char Address);
unsigned char WriteRegister(unsigned char Address, unsigned char Data);
void wait_ms(unsigned short ms);
void wait_us(unsigned short us);

unsigned char Data;
unsigned char RevID;
unsigned char Xdata;
unsigned char Ydata;
unsigned char Zdata;

void main(void)
{
    WDTCTL = WDTPW + WDTHOLD; // Stop watchdog timer

    BCSCTL1 = CALBC1_16MHZ; // Set DCO to calibrated 16MHz
    DCOCTL = CALDCO_16MHZ;
    BCSCTL2 |= DIVS_3; // SMCLK to 2 MHz

    PORT_INT_DIR &= ~PIN_INT;
    PORT_INT_IE |= PIN_INT; // INT pin interrupt enabled
    PORT_INT_IES = 0x00; // Generate interrupt on Lo to Hi edge
    PORT_INT_IFG &= ~PIN_INT; // Clear interrupt flag

    PORT_CSB_DIR |= PIN_CSB;
    PORT_CSB_OUT |= PIN_CSB; // Unselect acceleration sensor

    PORT_SPI_SEL |= PIN_MOSI | PIN_MISO | PIN_SCK; // P3.3,2,1 USCI_B0 option select
    PORT_SPI_DIR |= BIT0; // P3.0 output direction

    // Initialize SPI interface to acceleration sensor
    SPI_CTL0 |= UCSYNC | UCMST | UCMSB | UCCKPH; // SPI master, 8 data bits, MSB first,
    // clock idle low, data output on falling edge

```

```

SPI_CTL1 |= UCSSEL1;           // SMCLK as clock source
SPI_BR0  = 0x08;             // Low byte of division factor for baud rate (250 kHz)
SPI_BR1  = 0x00;             // High byte of division factor for baud rate
SPI_CTL1 &= ~UCSWRST;       // Start SPI hardware

ReVID = ReadRegister(REVID);   // Read REVID register
wait_us(44);                  // 11 * tsck
Data = WriteRegister(CTRL, G_RANGE_2 | I2C_DIS | MODE_400); // Activate measurement mode: 2g/400Hz
wait_us(44);

Xdata = ReadRegister(DOUTX);   // Dummy read to generate first INT pin Lo to Hi
                                // transition in all situations, also while debugging

__bis_SR_register(LPM4_bits + GIE); // Enter LPM4 w/interrupt
}

// Port 2 interrupt service routine, INT pin
#pragma vector=PORT_INT_VECTOR
__interrupt void Port_INT_ISR(void)
{
    if (PORT_INT_IN & PIN_INT)
    {
        Xdata = ReadRegister(DOUTX); // Read DOUTX register
        wait_us(44);                // 11 * tsck
        Ydata = ReadRegister(DOUTY); // Read DOUTY register
        wait_us(44);
        Zdata = ReadRegister(DOUTZ); // Read DOUTZ register
        PORT_INT_IFG &= ~PIN_INT;   // Clear interrupt flag
    }
}

// Read a byte from the acceleration sensor
unsigned char ReadRegister(unsigned char Address)
{
    unsigned char Result;

    Address <<= 2;                 // Address to be shifted left by 2 and RW bit to be reset

    PORT_CSB_OUT &= ~PIN_CSB;     // Select acceleration sensor

    Result = RX_BUFFER;           // Read RX buffer just to clear interrupt flag

    TX_BUFFER = Address;         // Write address to TX buffer

    while (!(IRQ_REG & RX_IFG)); // Wait until new data was written into RX buffer
    Result = RX_BUFFER;          // Read RX buffer just to clear interrupt flag

    TX_BUFFER = 0;               // Write dummy data to TX buffer

    while (!(IRQ_REG & RX_IFG)); // Wait until new data was written into RX buffer
    Result = RX_BUFFER;          // Read RX buffer

    PORT_CSB_OUT |= PIN_CSB;     // Deselect acceleration sensor

    // Return new data from RX buffer
    return Result;
}

```

```

// Write a byte to the acceleration sensor
unsigned char WriteRegister(unsigned char Address, unsigned char Data)
{
    unsigned char Result;

    Address <<= 2;           // Address to be shifted left by 2
    Address |= 2;           // RW bit to be set

    PORT_CSB_OUT &= ~PIN_CSB; // Select acceleration sensor

    Result = RX_BUFFER;     // Read RX buffer just to clear interrupt flag

    TX_BUFFER = Address;   // Write address to TX buffer

    while (!(IRQ_REG & RX_IFG)); // Wait until new data was written into RX buffer
    Result = RX_BUFFER;     // Read RX buffer just to clear interrupt flag

    TX_BUFFER = Data;      // Write data to TX buffer

    while (!(IRQ_REG & RX_IFG)); // Wait until new data was written into RX buffer
    Result = RX_BUFFER;     // Read RX buffer

    PORT_CSB_OUT |= PIN_CSB; // Deselect acceleration sensor

    return Result;
}

// wait ms
void wait_ms(unsigned short ms)
{
    unsigned short a, b;

    for (a = ms; a > 0; a--) // outer loop takes 5 ck per round
        for (b = TICKSPERMS; b > 0; b--) // inner loop takes 5 ck per round
            asm("nop");
}

// wait us
void wait_us(unsigned short us)
{
    unsigned short a;

    us *= TICKSPERUS;
    for (a = us; a > 0; a--) // loop takes 5 ck per round
        asm("nop");
}

```

3.2 I2C Interface Example

VTI adapter PCB VTI29631 does not support I2C use with CMA3000-D01 so to enable I2C communication with the eZ430-RF2500 the PCB needs to be modified as follows:

- Cut MISO/SDA trace close to J2
- Cut SCK/SCL trace close to J2
- Wire J2-4 to ground
- Wire P2-15 to J2-6
- Add 10 kOhm pull-up resistors from MOSI/SDA and J2-6 to +3.6V

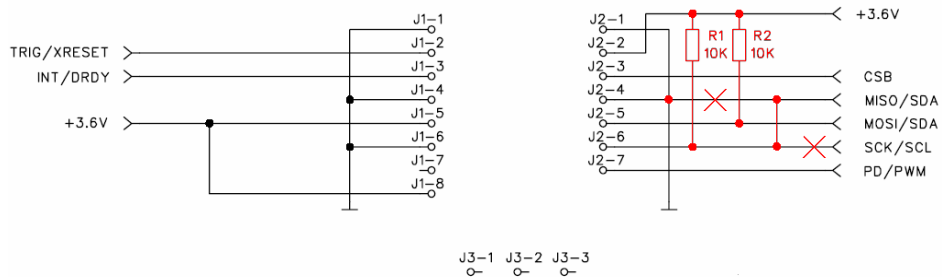


Figure 4. PCB VTI29631 modification for I2C use

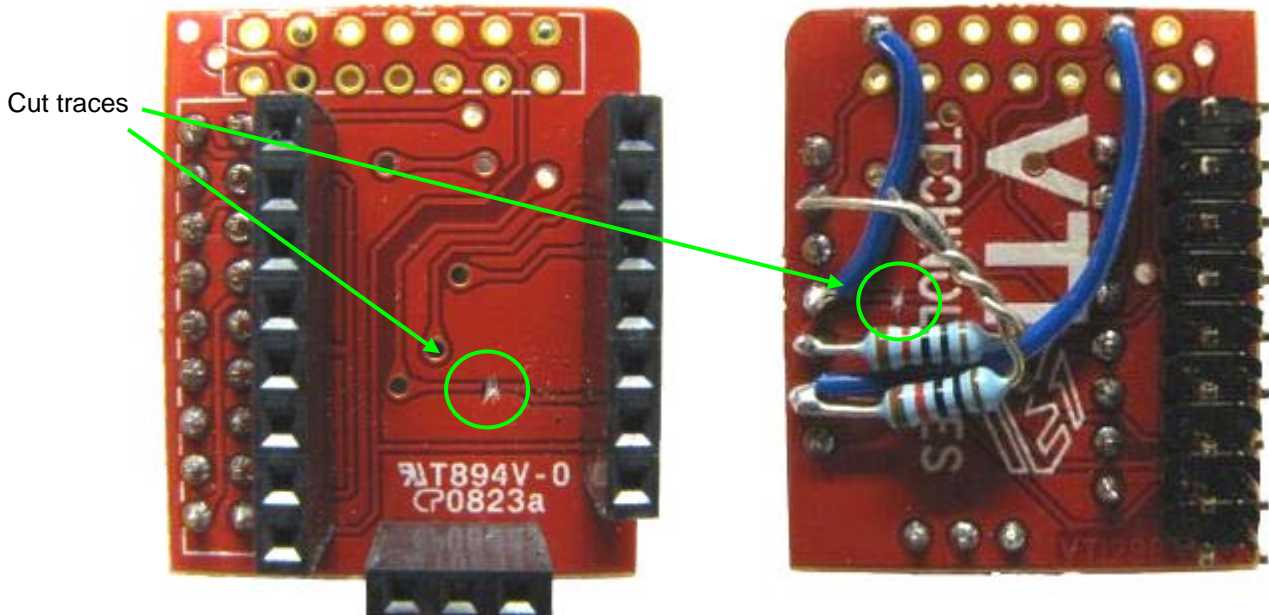


Figure 5. Modified VTI29631 PCB

Code flowchart:

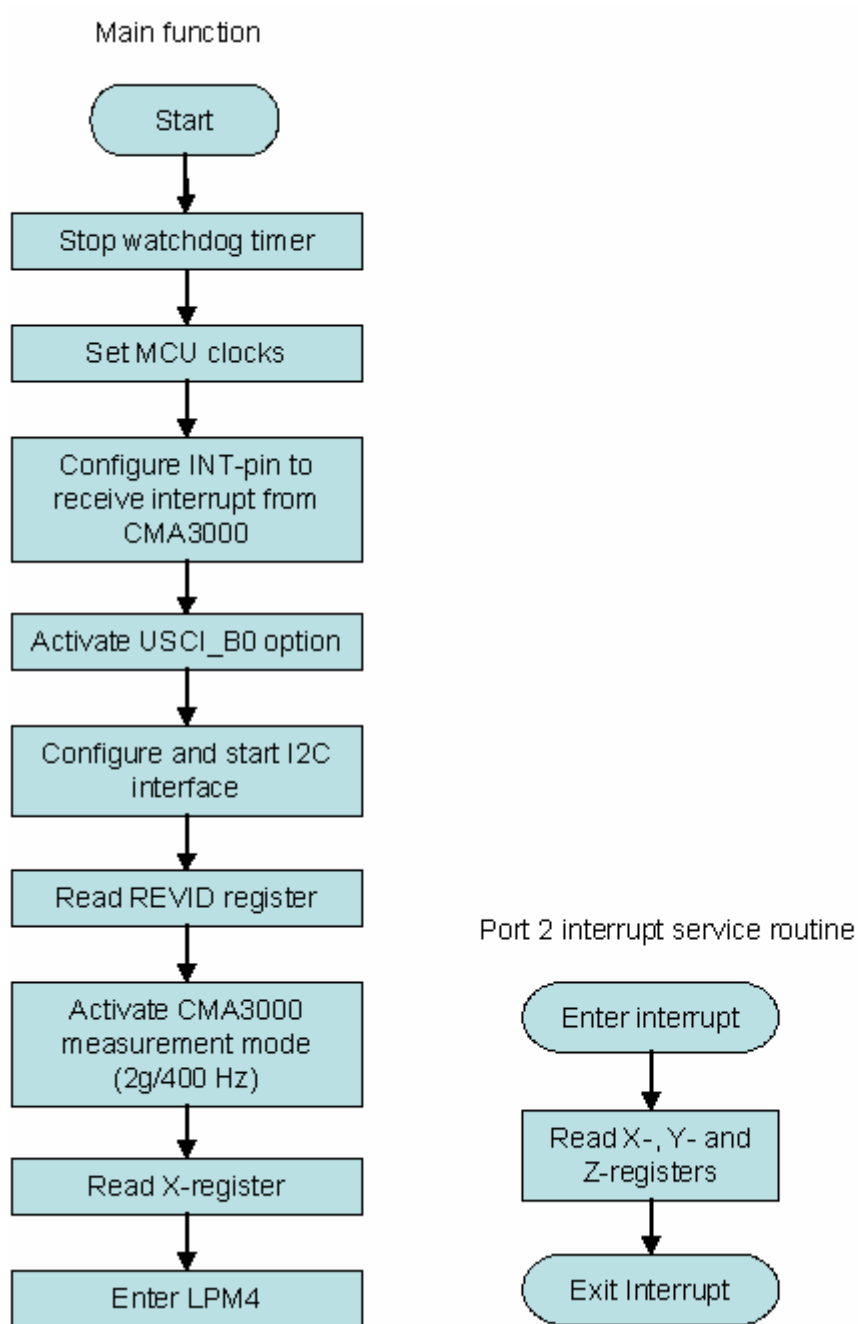


Figure 6. I2C Example Code Flowchart

C-Code Example, I2C Interface

```

//*****
//  MSP430F2274 Demo - USCI_B0, I2C Interface to CMA3000 Acceleration Sensor
//
//  Uses Texas Instruments eZ430-RF2500 Development Tool with VTI Adapter PCB
//  VTI29631A0. Wireless connection not used. Adapter PCB VTI29631 needs to be
//  modified for I2C to work.
//
//*****

// LIBRARIES
#include "msp430x22x4.h"

// PORT DEFINITIONS
#define PORT_INT_IN      P2IN
#define PORT_INT_DIR    P2DIR
#define PORT_INT_IE     P2IE
#define PORT_INT_IES    P2IES
#define PORT_INT_IFG    P2IFG
#define PORT_INT_VECTOR PORT2_VECTOR

#define PORT_I2C_DIR    P3DIR
#define PORT_I2C_SEL    P3SEL
#define PORT_I2C_OUT    P3OUT

// REGISTER AND FLAG DEFINITIONS
#define TX_BUFFER       UCB0TXBUF
#define RX_BUFFER       UCB0RXBUF
#define IRQ_REG         IFG2
#define RX_IFG          UCB0RXIFG
#define TX_IFG          UCB0TXIFG

// CMA3000 Registers
#define WHO_AM_I        0x00
#define REVID            0x01
#define CTRL             0x02
#define STATUS          0x03
#define RSTR             0x04
#define INT_STATUS      0x05
#define DOUTX           0x06
#define DOUTY           0x07
#define DOUTZ           0x08
#define MDTHR           0x09
#define MDFFTMR         0x0A
#define FFTHR           0x0B
#define I2C_ADDR        0x0C

// Control Register setup
#define G_RANGE_2       0x80 // 2g range
#define INT_LEVEL_LOW  0x40 // INT active high
#define MDET_NO_EXIT    0x20 // Remain in motion detection mode
#define I2C_DIS         0x10 // I2C disabled
#define MODE_PD         0x00 // Power Down
#define MODE_100        0x02 // Measurement mode 100 Hz ODR
#define MODE_400        0x04 // Measurement mode 400 Hz ODR
#define MODE_40         0x06 // Measurement mode 40 Hz ODR
#define MODE_MD_10     0x08 // Motion detection mode 10 Hz ODR
#define MODE_FF_100    0x0A // Free fall detection mode 100 Hz ODR
#define MODE_FF_400    0x0C // Free fall detection mode 400 Hz ODR
#define INT_DIS         0x01 // Interrupts enabled

```

```

// PIN DEFINITIONS
#define PIN_INT          BIT4
#define PIN_CSB          BIT3
#define PIN_MOSI         BIT1
#define PIN_MISO         BIT2
#define PIN_SCK          BIT3

// FUNCTION PROTOTYPES
unsigned char ReadRegister(unsigned char Address);
unsigned char WriteRegister(unsigned char Address, unsigned char Data);

unsigned char Data;
unsigned char RevID;
unsigned char Xdata;
unsigned char Ydata;
unsigned char Zdata;

void main(void)
{
    WDTCTL = WDTPW + WDTHOLD;                // Stop watchdog timer

    BCSCTL1 = CALBC1_16MHZ;                  // Set DCO to calibrated 16MHz
    DCOCTL = CALDCO_16MHZ;
    BCSCTL2 |= DIVS_3;                       // SMCLK to 2 MHz

    PORT_INT_DIR &= ~PIN_INT;
    PORT_INT_IE |= PIN_INT;                 // INT pin interrupt enabled
    PORT_INT_IES = 0x00;                    // Generate interrupt on Lo to Hi edge
    PORT_INT_IFG &= ~PIN_INT;              // Clear interrupt flag

    // Initialize I2C interface to acceleration sensor
    PORT_I2C_DIR |= BIT0;                   // Set port 3 pin 0 as output and set high.
    PORT_I2C_OUT |= BIT0;

    UCBOCTL1 |= UCSWRST;                    // Put state machine in reset
    UCBOCTL1 |= UCSSEL_2;                   // SMCLK as clock source
    PORT_I2C_SEL |= BIT2 | BIT1;           // Set port 3 pins 1 and 2 for I2C peripheral
    UCBOCTL0 |= UCMST + UCSYNC + UCMODE_3; // I2C mode, master, synchronous
    UCBOBR0 = 20;                           // 2MHz/20 = 100kHz
    UCBOBR1 = 0;
    UCBOI2CSA = 0x1C;                        // Slave Address is 1Ch
    UCBOCTL1 &= ~UCSWRST;                   // Start I2C state machine

    RevID = ReadRegister(REVID);             // Read REVID register
    Data = WriteRegister(CTRL, G_RANGE_2 | MODE_400); // Activate measurement mode: 2g/400Hz

    Xdata = ReadRegister(DOUTX);            // Dummy read to generate first INT pin Lo to Hi transition
                                           // in all situations, also while debugging

    __bis_SR_register(LPM4_bits + GIE);     // Enter LPM4 w/interrupt
}

```

```

// Port 2 interrupt service routine, INT pin
#pragma vector=PORT_INT_VECTOR
__interrupt void Port_INT_ISR(void)
{
    if (PORT_INT_IN & PIN_INT)
    {
        Xdata = ReadRegister(DOUTX);           // Read DOUTX register
        wait_us(110);                          // 11 * tsc1
        Ydata = ReadRegister(DOUTY);           // Read DOUTY register
        wait_us(110);
        Zdata = ReadRegister(DOUTZ);           // Read DOUTZ register
        PORT_INT_IFG &= ~PIN_INT;              // Clear interrupt flag
    }
}

// Read a byte from the acceleration sensor
unsigned char ReadRegister(unsigned char Address)
{
    unsigned char Result;

    // Read data from I2C slave device at the DeviceAddress specified.

    UCBOCTL1 |= UCTR + UCTXSTT;                // I2C TX, start condition

    while (!(IRQ_REG & TX_IFG));                // Wait for slave address transmit to complete

    TX_BUFFER = Address;                       // Load TX buffer with register address

    while (!(IRQ_REG & TX_IFG));                // Wait for transmit to complete

    IRQ_REG &= ~TX_IFG;                        // Clear USCI_B0 TX int flag

    // Send restart with transmit/receive bit NOT set
    UCBOCTL1 &= ~UCTR;                         // Toggle transmitter bit
    UCBOCTL1 |= UCTXSTT;                       // I2C start condition

    while(UCBOCTL1 & UCTXSTT);                 // Wait for start to complete
    UCBOCTL1 |= UCTXSTP;                       // I2C stop condition

    while (!(IRQ_REG & RX_IFG));                // Wait for receive buffer to fill

    Result = RX_BUFFER;                        // Fill receive data buffer with received byte

    while (UCBOCTL1 & UCTXSTP);                // Wait for stop condition to complete

    IRQ_REG &= ~RX_IFG;                        // Clear USCI_B0 RX int flag

    // Return new data from RX buffer
    return Result;
}

```

```
// Write a byte to the acceleration sensor
unsigned char WriteRegister(unsigned char Address, unsigned char Data)
{
    // Write data to I2C slave device at the DeviceAddress specified.

    UCBOCTL1 |= UCTR + UCTXSTT;           // I2C TX, start condition

    while (!(IRQ_REG & TX_IFG));          // Wait for slave address transmit to complete

    TX_BUFFER = Address;                  // Load TX buffer with register address

    while (!(IRQ_REG & TX_IFG));          // Wait for transmit to complete

    TX_BUFFER = Data;                     // Load TX buffer with data byte

    while (!(IRQ_REG & TX_IFG));          // Wait for transmit to complete
    UCBOCTL1 |= UCTXSTP;                  // I2C stop condition

    while (UCBOCTL1 & UCTXSTP);           // Wait for stop condition to complete

    IRQ_REG &= ~TX_IFG;                   // Clear USCI_B0 TX int flag

    return 0;
}
```

4 RESULT WAVEFORMS

There is no display on the development hardware so a logic analyzer was used to verify the results.

Figure 7 (SPI) and Figure 9 (I2C) show how the register reading is triggered from the CMA3000-D01 INT-pin. After the interrupt has activated, the output registers are read out in sequence, while making sure that in the case of SPI bus the communication frame spacing will be at least 11 SCK cycles.

In Figure 8 (SPI) and Figure 10 (I2C) it can be seen how the interrupt takes place immediately after CMA3000-D01 has new data available for reading. It also shows how the INT pin is automatically cleared by reading the acceleration output data.

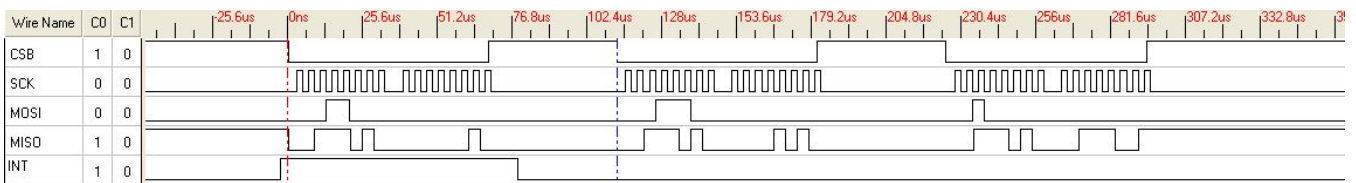


Figure 7. SPI waveforms when reading DOUTX- DOUTY- and DOUTZ-registers

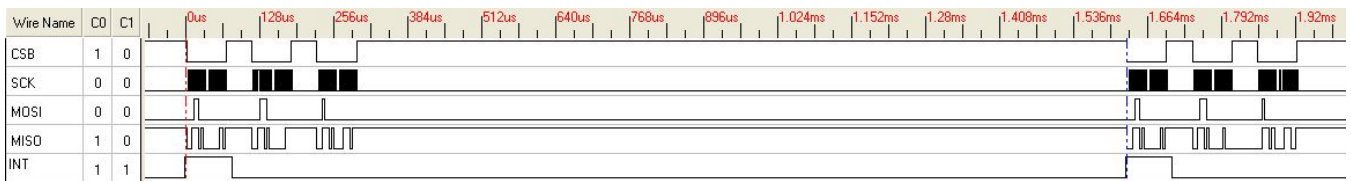


Figure 8. Register reading is triggered by CMA3000-D01's INT signal, SPI bus

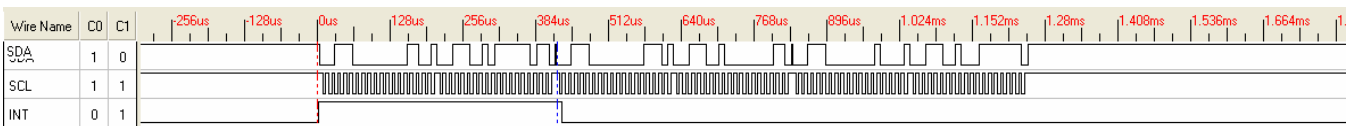


Figure 9. I2C waveforms when reading DOUTX- DOUTY- and DOUTZ-registers

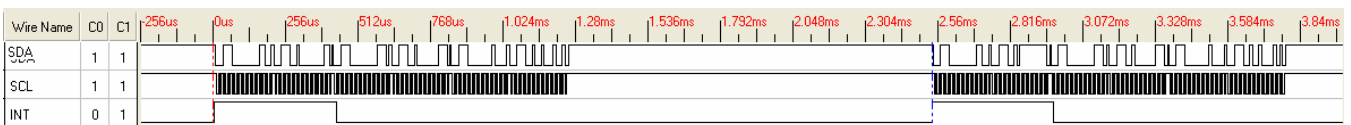


Figure 10. Register reading is triggered by CMA3000-D01's INT signal, I2C bus