EEL 4742C: Embedded Systems

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11/18/2019
EEL4742-0011
Lab 9 Inter-Integrate Circuit (12C) Communication

Introduction

In this lab we will be implementing inter-integrated circuit communication (I2C) using the Educational booster pack with the MSP430. In the first part of this experiment we will read the device ID and the manufacturers ID each second and displayed to the terminal using UART. In the second part, the booster pack contains a light sensor that will be read from every second and displayed on the terminal.

Part 9.1: I2C Transmission

I2C works by using two busses, one for data SDA, and one for a clock SCL. Using this two-bus system we can sync the clock of the MSP and the booster pack, in doing so, we can read or write data to or from the booster pack.
The I2C transmission can read two bytes at time. The master (MSP430) will first send a start signal. Then the master sends the address of the device and whether we are meant to read or write with the device to that device. Once the master has received an acknowledge, the master can start sending or receiving data with the device as we mention before, 2 bytes at a time.

- If we are receiving data, the master device will send a NACK signal as well as a stop to signal.
- If we are sending data, the device will acknowledge it has received the data, but will immediately stop, no NACK

We can interact with multiple internal registers of the device that will give us data or allow us to send data between the device and the master.

In the code we were given the I2C initialize function and the I2c read functions. We need to implement the UART write, and 32Khz clock that way we can write our value directly to the terminal.
Using the i2c_read_word function we will send the device location address (0x44) and the address of the value for the manufacturer's ID (0x7E) and device ID (0x7F).

The code prints to the terminal the manufacturer's ID and device ID every second.

What is the address of the Manufacturer ID register? What value does this register return?

0x7E
This value returns the value store on the device pointed to by address. It will return the manufacturer ID

What does this value mean?

It is a pointer to where the value is being store on the device.

What is the address of the Device ID register? What value does this register return?

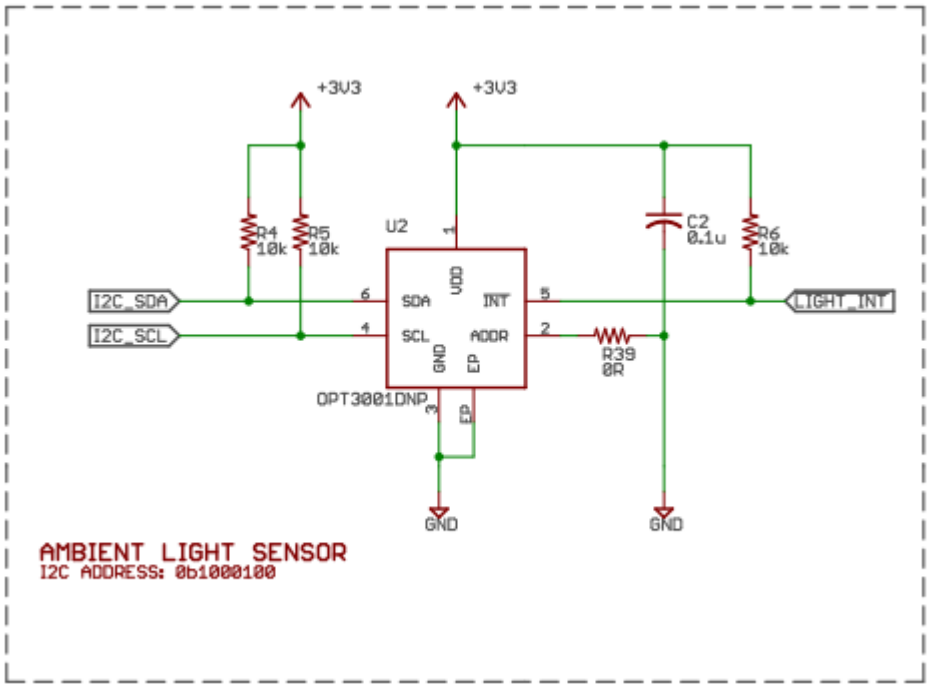
0x7F
This value returns the value store on the device pointed to by address. It will return the device ID

What is the light sensor's I2C address?

0x00 for configuration
0x01 for the results

What is the value of the pull-up resistors on the I2C wires? Include a screenshot of the schematics highlighting the I2C address and the pull-up resistors.

The resistors are set to pull-up to high are set to 10k ohms




```
//Christopher Badolato
//11/12/2019
//Lab 9.1
//EEL 4742 0011
//I2c intro

#include <msp430.h>
#include <stdio.h>

#define FLAGS UCA1IFG // Contains the transmit & receive flags
#define RXFLAG UCRXIFG // Receive flag
```

```
#define TXFLAG UCTXIFG // Transmit flag
#define TXBUFFER UCA1TXBUF // Transmit buffer
#define RXBUFFER UCA1RXBUF // Receive buffer
#define redLED BIT0 // Red LED at P1.0
#define greenLED BIT7 // Green LED at P9.7

// Configure eUSCI in I2C master mode
void Initialize_I2C(void) {
        // Enter reset state before the configuration starts...
    UCB1CTLW0 |= UCSWRST;
        // Divert pins to I2C functionality
    P4SEL1 |= (BIT1|BIT0);
    P4SEL0 &= ~(BIT1|BIT0);
        // Keep all the default values except the fields below...
        // (UCMode 3:I2C) (Master Mode) (UCSSEL 1:ACLK, 2,3:SMCLK)
    UCB1CTLW0 |= UCMODE_3 | UCMST | UCSSEL_3;
        // Clock divider = 8 (SMCLK @ 1.048 MHz / 8 = 131 KHz)
    UCB1BRW = 8;
        // Exit the reset mode
    UCB1CTLW0 &= ~UCSWRST;
}

//////////////////////////////////////////////////////////////////
// Read a word (2 bytes) from I2C (address, register)
int i2c_read_word(unsigned char i2c_address, unsigned char i2c_reg,unsigned int *
data) {
    unsigned char byte1, byte2;
    // Initialize the bytes to make sure data is received every time
    byte1 = 111;
    byte2 = 111;

    //********** Write Frame #1 **************************
    UCB1I2CSA = i2c_address; // Set I2C address

    UCB1IFG &= ~UCTXIFG0;
    UCB1CTLW0 |= UCTR; // Master writes (R/W bit = Write)
    UCB1CTLW0 |= UCTXSTT; // Initiate the Start Signal

    while ((UCB1IFG & UCTXIFG0) ==0) {}
    UCB1TXBUF = i2c_reg; // Byte = register address

    while((UCB1CTLW0 & UCTXSTT)!=0) {}
    if(( UCB1IFG & UCNACKIFG )!=0)
        return -1;
    UCB1CTLW0 &= ~UCTR; // Master reads (R/W bit = Read)
    UCB1CTLW0 |= UCTXSTT; // Initiate a repeated Start Signal

    //*************************************************
    //********** Read Frame #1 **************************
    while ( (UCB1IFG & UCRXIFG0) == 0) {}
    byte1 = UCB1RXBUF;
    //*************************************************
    //********** Read Frame #2 **************************
    while((UCB1CTLW0 & UCTXSTT)!=0) {}
    UCB1CTLW0 |= UCTXSTP; // Setup the Stop Signal
```

```
    while ( (UCB1IFG & UCRXIFG0) == 0) {}
    byte2 = UCB1RXBUF;

    while ( (UCB1CTLW0 & UCTXSTP) != 0) {}
    //*************************************************
    // Merge the two received bytes
    *data = ( (byte1 << 8) | (byte2 & 0xFF) );
    return 0;
}

void config_ACLK_to_32KHz_crystal() {
        // By default, ACLK runs on LFMODCLK at 5MHz/128 = 39 KHz
        // Reroute pins to LFXIN/LFXOUT functionality
    PJSEL1 &= ~BIT4;
    PJSEL0 |= BIT4;

        // Wait until the oscillator fault flags remain cleared
    CSCTL0 = CSKEY; // Unlock CS registers
    do {
        CSCTL5 &= ~LFXTOFFG; // Local fault flag
        SFRIFG1 &= ~OFIFG; // Global fault flag
    } while((CSCTL5 & LFXTOFFG) != 0);

    CSCTL0_H = 0; // Lock CS registers
    return;
}

// Configure UART to the popular configuration
// 9600 baud, 8-bit data, LSB first, no parity bits, 1 stop bit
// no flow control
// Initial clock: SMCLK @ 1.048 MHz with oversampling
void Initialize_UART2(void){
        // Divert pins to UART functionality
    P3SEL1 &= ~(BIT4|BIT5);
    P3SEL0 |= (BIT4|BIT5);
        // Use ACLK clock; leave other settings default
    UCA1CTLW0 |= UCSSEL_1;
        // Configure the clock dividers and modulators
    UCA1BRW = 6;
    UCA1MCTLW = UCBRS1 | UCBRS2 | UCBRS3 | UCBRS5 | UCBRS6 | UCBRS7;
        // Exit the reset state (so transmission/reception can begin)
    UCA1CTLW0 &= ~UCSWRST;
}

void uart_write_char(unsigned char ch){
            // Wait for any ongoing transmission to complete
        while ((FLAGS & TXFLAG) == 0 ) {}
            // Write the byte to the transmit buffer
      TXBUFFER = ch;
}

    // The function returns the byte; if none received, returns NULL
unsigned char uart_read_char(void){
    unsigned char temp;
```

```
            // Return NULL if no byte received
    if( (FLAGS & RXFLAG) == 0)
        return NULL;
            // Otherwise, copy the received byte (clears the flag) and return it
    temp = RXBUFFER;
    return temp;
}

uart_write_uint16(unsigned int currentValue){
    int number;

    if(currentValue >= 10000){
        number = currentValue/10000;
        uart_write_char('0'+ number);
    }
    if(currentValue >= 1000){
        number = (currentValue/1000) % 10;
        uart_write_char('0'+ number);
    }
    if(currentValue >= 100){
        number = (currentValue/100) % 10;
        uart_write_char('0'+ number);
    }
    if(currentValue >= 10){
        number = (currentValue/10) % 10;
        uart_write_char('0'+ number);
    }
    number = currentValue % 10;
    uart_write_char('0' + number);
}

int main(void){
    unsigned int manualID;
    unsigned int devID;
    unsigned int value;

    WDTCTL = WDTPW | WDTHOLD;   // stop watchdog timer
    PM5CTL0 &= ~LOCKLPM5; // Enable the GPIO pins


        //32khz clock
    config_ACLK_to_32KHz_crystal();
        //configure uart
    Initialize_UART2();

    Initialize_I2C();

    i2c_read_word(0x44, 0x7E, &manualID);
    i2c_read_word(0x44, 0x7F, &devID);
        //ACLK, div 1, upmode

    TA0CTL = TASSEL_1 | ID_0 | MC_1 | TACLR;
    TA0CCR0 = (65536 - 1);

    for(;;){
```

```
        for(value = 0; value <= 65535; value++){
                //write the current integer
            uart_write_uint16(value);

            uart_write_char(' ');

            uart_write_uint16(manualID);

            uart_write_char(' ');

            uart_write_uint16(devID);

            uart_write_char('\n');
                //return
            uart_write_char('\r');
            while((TA0CTL & TAIFG) == 0){}
            TA0CTL &= ~TAIFG;
        }
    }
}
```

Part 9.2: Reading Measurements from the Light Sensor

In this part of the lab we will be using the code from the previous part to print right to the terminal using data from the booster pack. We will be accessing the sensor this time with the i2c_write_word to configure the setting of the sensor to ensure we are receiving the data we actually want. Then we will read the data from the booster pack with this configuration set.

First we must send our i2c configuration with the i2c_write_word() function to address 0x01. In this case I created a mask variable and store the values (in binary) onto the mask.
Using the code below I shifted on the values we intend to send to the configuration register R1,r2,r3 represent the value of our exponent in our case we set the exponent to 1.28 which means, for every 1 value we receiving it will actually represent 1.28 in lux.

```
    unsigned int mask = 0, r0 , r1, r2, CT = 0, M1, M0, ME, r3;

    r0 = 1<<12;
    r1 = 1<<13;
    r2 = 1<<14;
    r3 = 0 << 15;
    CT << 11;
    M1 = 1<<10;
    M0 = BIT9;
    ME = BIT2;

    mask |= (r0|r1|r2|CT|M1|M0|ME);
```

Once we have this mask set, we can send it to the configuration register on the booster pack to let us know which value to send back. The code below will send our mask to the configuration register

```
    i2c_write_word(0x44, 0x01, mask);
```

What is the address of the configuration register on the sensor?

0x01

What configuration value (hex) did you write to the sensor? Show how this value is formatted into bit fields.

0111 0110 0000 0100
0x7604

Does the data make sense based on what you expected?

Yes, we must multiply the mantissa value sent back by 1.28 to print to correct lux value to the terminal.

```
//Christopher Badolato
//11/12/2019
//Lab 9.2
//EEL 4742 0011
//I2c intro

#include <msp430.h>
#include <stdio.h>

#define FLAGS UCA1IFG // Contains the transmit & receive flags
#define RXFLAG UCRXIFG // Receive flag
#define TXFLAG UCTXIFG // Transmit flag
#define TXBUFFER UCA1TXBUF // Transmit buffer
#define RXBUFFER UCA1RXBUF // Receive buffer
#define redLED BIT0 // Red LED at P1.0
#define greenLED BIT7 // Green LED at P9.7

// Configure eUSCI in I2C master mode
void Initialize_I2C(void) {
        // Enter reset state before the configuration starts...
    UCB1CTLW0 |= UCSWRST;
        // Divert pins to I2C functionality
    P4SEL1 |= (BIT1|BIT0);
    P4SEL0 &= ~(BIT1|BIT0);
        // Keep all the default values except the fields below...
        // (UCMode 3:I2C) (Master Mode) (UCSSEL 1:ACLK, 2,3:SMCLK)
    UCB1CTLW0 |= UCMODE_3 | UCMST | UCSSEL_3;
        // Clock divider = 8 (SMCLK @ 1.048 MHz / 8 = 131 KHz)
    UCB1BRW = 8;
        // Exit the reset mode
    UCB1CTLW0 &= ~UCSWRST;
}

//////////////////////////////////////////////////////////////////
// Write a word (2 bytes) to I2C (address, register)
int i2c_write_word(unsigned char i2c_address, unsigned char i2c_reg,unsigned int
data) {
```

```
    unsigned char byte1, byte2;
    byte1 = (data >> 8) & 0xFF; // MSByte
    byte2 = data & 0xFF; // LSByte
    UCB1I2CSA = i2c_address; // Set I2C address
    UCB1CTLW0 |= UCTR; // Master writes (R/W bit = Write)
    UCB1CTLW0 |= UCTXSTT; // Initiate the Start Signal
    while ((UCB1IFG & UCTXIFG0) ==0) {}
    UCB1TXBUF = i2c_reg; // Byte = register address
    while((UCB1CTLW0 & UCTXSTT)!=0) {}
    //********** Write Byte #1 **************************
    UCB1TXBUF = byte1;
    while ( (UCB1IFG & UCTXIFG0) == 0) {}
    //********** Write Byte #2 **************************
    UCB1TXBUF = byte2;
    while ( (UCB1IFG & UCTXIFG0) == 0) {}
    UCB1CTLW0 |= UCTXSTP;
    while ( (UCB1CTLW0 & UCTXSTP) != 0) {}
    return 0;
}


//////////////////////////////////////////////////////////////////
// Read a word (2 bytes) from I2C (address, register)
int i2c_read_word(unsigned char i2c_address, unsigned char i2c_reg,unsigned int *
data) {
    unsigned char byte1, byte2;
    // Initialize the bytes to make sure data is received every time
    byte1 = 111;
    byte2 = 111;

    //********** Write Frame #1 **************************
    UCB1I2CSA = i2c_address; // Set I2C address

    UCB1IFG &= ~UCTXIFG0;
    UCB1CTLW0 |= UCTR; // Master writes (R/W bit = Write)
    UCB1CTLW0 |= UCTXSTT; // Initiate the Start Signal

    while ((UCB1IFG & UCTXIFG0) ==0) {}
    UCB1TXBUF = i2c_reg; // Byte = register address

    while((UCB1CTLW0 & UCTXSTT)!=0) {}
    if(( UCB1IFG & UCNACKIFG )!=0)
        return -1;
    UCB1CTLW0 &= ~UCTR; // Master reads (R/W bit = Read)
    UCB1CTLW0 |= UCTXSTT; // Initiate a repeated Start Signal

    //**************************************************
    //********** Read Frame #1 **************************
    while ( (UCB1IFG & UCRXIFG0) == 0) {}
    byte1 = UCB1RXBUF;
    //**************************************************
    //********** Read Frame #2 **************************
    while((UCB1CTLW0 & UCTXSTT)!=0) {}
    UCB1CTLW0 |= UCTXSTP; // Setup the Stop Signal
```

```
    while ( (UCB1IFG & UCRXIFG0) == 0) {}
    byte2 = UCB1RXBUF;

    while ( (UCB1CTLW0 & UCTXSTP) != 0) {}
    //*************************************************
    // Merge the two received bytes
    *data = ( (byte1 << 8) | (byte2 & 0xFF) );
    return 0;
}

void config_ACLK_to_32KHz_crystal() {
        // By default, ACLK runs on LFMODCLK at 5MHz/128 = 39 KHz
        // Reroute pins to LFXIN/LFXOUT functionality
    PJSEL1 &= ~BIT4;
    PJSEL0 |= BIT4;

        // Wait until the oscillator fault flags remain cleared
    CSCTL0 = CSKEY; // Unlock CS registers
    do {
        CSCTL5 &= ~LFXTOFFG; // Local fault flag
        SFRIFG1 &= ~OFIFG; // Global fault flag
    } while((CSCTL5 & LFXTOFFG) != 0);

    CSCTL0_H = 0; // Lock CS registers
    return;
}

// Configure UART to the popular configuration
// 9600 baud, 8-bit data, LSB first, no parity bits, 1 stop bit
// no flow control
// Initial clock: SMCLK @ 1.048 MHz with oversampling
void Initialize_UART2(void){
        // Divert pins to UART functionality
    P3SEL1 &= ~(BIT4|BIT5);
    P3SEL0 |= (BIT4|BIT5);
        // Use ACLK clock; leave other settings default
    UCA1CTLW0 |= UCSSEL_1;
        // Configure the clock dividers and modulators
    UCA1BRW = 6;
    UCA1MCTLW = UCBRS1 | UCBRS2 | UCBRS3 | UCBRS5 | UCBRS6 | UCBRS7;
        // Exit the reset state (so transmission/reception can begin)
    UCA1CTLW0 &= ~UCSWRST;
}

void uart_write_char(unsigned char ch){
            // Wait for any ongoing transmission to complete
        while ((FLAGS & TXFLAG) == 0 ) {}
            // Write the byte to the transmit buffer
      TXBUFFER = ch;
}

    // The function returns the byte; if none received, returns NULL
unsigned char uart_read_char(void){
    unsigned char temp;
            // Return NULL if no byte received
```

```
    if( (FLAGS & RXFLAG) == 0)
        return NULL;
            // Otherwise, copy the received byte (clears the flag) and return it
    temp = RXBUFFER;
    return temp;
}

uart_write_uint16(unsigned int currentValue){
    int number;

    if(currentValue >= 10000){
        number = currentValue/10000;
        uart_write_char('0'+ number);
    }
    if(currentValue >= 1000){
        number = (currentValue/1000) % 10;
        uart_write_char('0'+ number);
    }
    if(currentValue >= 100){
        number = (currentValue/100) % 10;
        uart_write_char('0'+ number);
    }
    if(currentValue >= 10){
        number = (currentValue/10) % 10;
        uart_write_char('0'+ number);
    }
    number = currentValue % 10;
    uart_write_char('0' + number);
}

int main(void){
    unsigned int result;
    unsigned int exponent, mantissa;
    unsigned int mask = 0, r0 , r1, r2, CT = 0, M1, M0, ME, r3;

    r0 = 1<<12;
    r1 = 1<<13;
    r2 = 1<<14;
    r3 = 0 << 15;
    CT << 11;
    M1 = 1<<10;
    M0 = BIT9;
    ME = BIT2;

    mask |= (r0|r1|r2|CT|M1|M0|ME);

    unsigned int value;

    WDTCTL = WDTPW | WDTHOLD;    // stop watchdog timer
    PM5CTL0 &= ~LOCKLPM5; // Enable the GPIO pins


        //32khz clock
    config_ACLK_to_32KHz_crystal();
        //configure uart
```

```
    Initialize_UART2();

    Initialize_I2C();

    i2c_write_word(0x44, 0x01, mask);


    TA0CTL = TASSEL_1 | ID_0 | MC_1 | TACLR;
    TA0CCR0 = (65536 - 1);

    for(;;){
        for(value = 0; value <= 65535; value++){
                //write the current integer
            i2c_read_word(0x44, 0x00, &result);

            mantissa = (1.28 * result);

            uart_write_uint16(value);


            uart_write_char(' ');

            uart_write_uint16(mantissa);

            uart_write_char('\n');
                //return
            uart_write_char('\r');

            while((TA0CTL & TAIFG) == 0){}
            TA0CTL &= ~TAIFG;
        }
    }
}
```

Student Q&A

1. The light sensor has an address pin that allows customizing the I2C address. How many addresses are possible? What are they and how are they configured? Look in the sensor's data sheet.

Four I2C address are possible by connecting the ADDR pin to one of four pins: GND CDD, CDA, or SCL
They are locations where our signals are sent or received.
Each register has an 8-bit address and has a size of 16-bits.

2. According to the light sensor's data sheet, what should be the value of the pull-up resistors on the I2C wires? Did the Booster Pack use the same values?

10k ohms Yes the booster pack used the same values.

Conclusion

In this experiment we have implement Inter-Integrated Circuit (12C) Communication using the MSP430 and the booster pack light sensor. First, we pulled the manufacturers ID and device ID from the booster pack and displayed them on the terminal every second. Then, using similar code, we used the booster pack to sense the light in the room by configuring the I2C to read the values from the sensor register. Then reading the values from the register we printed them to the terminal.