Lab 7 Report

EEL4742C - 00446

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Contents

Introduction

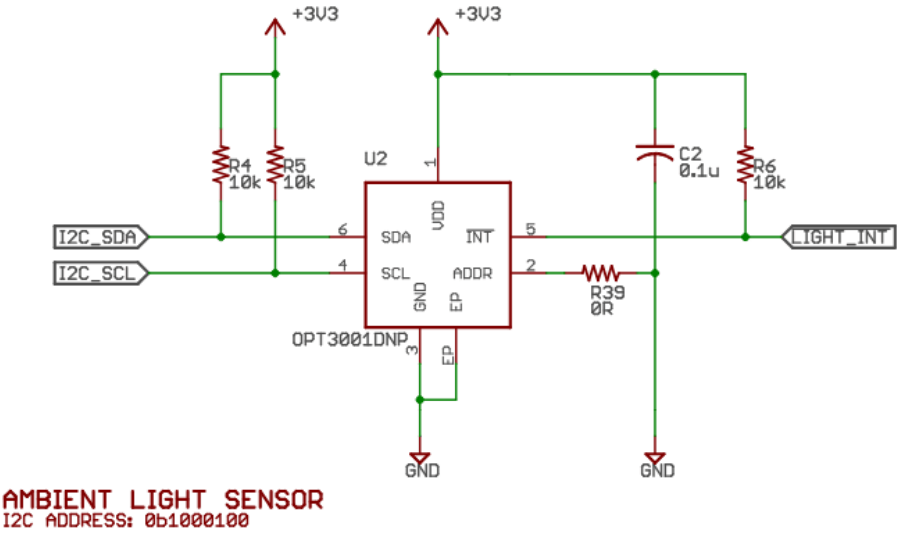
In this lab, we learned how to use the I2C module on the MSP430 as well as what I2C is generally, via programming the I2C link that connects the board to the booster pack that we put on it.

7.1 I2C Transmission

Now, in this section we are told to answer some questions!! YIPPEEEE!!!! So let's get into it, shall we? The sensor can specifically have the following 4 address, via editing the ADDR pin on the light sensor. They are:

- 0x44: GND (Ground)
- 0x45: VDD (Voltage)
- 0x46: SDA (Serial Data)
- 0x47: SCL (Serial Clock)

Now, since the default address (first address) of the light sensor is 0x44, it also means that ADDR is 0x44 and therefore is connected to the ground. Now, for the I2C lines, they are using a pull-up resistor of $10k\Omega$ (screenshot of the schematic being right below this very paragraph). And, when using the code below, we see a manufacturer ID of TI, and a device ID of 0x3001.



```c
#include <msp430fr6989.h>
#include <stdint.h>
#include <string.h>

// UART Channels are P3.4 and P3.5 for transmit and recieve respectively
#define transmit BIT4
#define recieve BIT5

// WE LOVE DEFINES
#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

// Global variables for states of runway1 and 2
volatile int red_state = 0; // runway 1 state
volatile int green_state = 0; // runway 2 state
volatile int blink_state = 0;

// Functions provided by the lab
void initialize_i2c(void)
{
  // Configure the MCU in Master mode
  // Configure pins to I2C functionality
  // (UCB1SDA same as P4.0) (UCB1SCL same as P4.1)
  // (P4SEL1=11, P4SEL0=00) (P4DIR=xx)
  P4SEL1 |= (BIT1|BIT0);
  P4SEL0 &= ~(BIT1|BIT0);
  // Enter reset state and set all fields in this register to zero
  UCB1CTLW0 = UCSWRST;
  // Fields that should be nonzero are changed below
  // (Master Mode: UCMST) (I2C mode: UCMODE_3) (Synchronous mode: UCSYNC)
  // (UCSSEL 1:ACLK, 2,3:SMCLK)
  UCB1CTLW0 |= UCMST | UCMODE_3 | UCSYNC | UCSSEL_3;
  // Clock frequency: SMCLK/8 = 1 MHz/8 = 125 KHz
  UCB1BRW = 8;
  // Chip Data Sheet p. 53 (Should be 400 KHz max)
  // Exit the reset mode at the end of the configuration
  UCB1CTLW0 &= ~UCSWRST;
}

int i2c_read_word(unsigned char i2c_address, unsigned char i2c_reg, unsigned int * data)
{
  unsigned char byte1=0, byte2=0; // Intialize to ensure successful reading
  UCB1I2CSA = i2c_address; // Set address
  UCB1IFG &= ~UCTXIFG0;
  // Transmit a byte (the internal register address)
  UCB1CTLW0 |= UCTR;
  UCB1CTLW0 |= UCTXSTT;
  while((UCB1IFG & UCTXIFG0)==0) {} // Wait for flag to raise
  UCB1TXBUF = i2c_reg; // Write in the TX buffer
  while((UCB1IFG & UCTXIFG0)==0) {} // Buffer copied to shift
```

```
    register; Tx in progress; set Stop bit
  // Repeated Start
  UCB1CTLW0 &= ~UCTR;
  UCB1CTLW0 |= UCTXSTT;
  // Read the first byte
  while((UCB1IFG & UCRXIFG0)==0) {} // Wait for flag to raise
  byte1 = UCB1RXBUF;
  // Assert the Stop signal bit before receiving the last byte
  UCB1CTLW0 |= UCTXSTP;
  // Read the second byte
  while((UCB1IFG & UCRXIFG0)==0) {} // Wait for flag to raise
  byte2 = UCB1RXBUF;
  while((UCB1CTLW0 & UCTXSTP)!=0) {}
  while((UCB1STATW & UCBBUSY)!=0) {}
  *data = (byte1 << 8) | (byte2 & (unsigned int)0x00FF);
  return 0;
}

int i2c_write_word(unsigned char i2c_address, unsigned char i2c_reg
    , unsigned int data)
{
  unsigned char byte1, byte2;

  UCB1I2CSA = i2c_address;              // Set I2C address

  byte1 = (data >> 8) & 0xFF;           // MSByte
  byte2 = data & 0xFF;                  // LSByte

  UCB1IFG &= ~UCTXIFG0;

  // Write 3 bytes
  UCB1CTLW0 |= (UCTR | UCTXSTT);

  while( (UCB1IFG & UCTXIFG0) == 0) {}
  UCB1TXBUF = i2c_reg;

  while( (UCB1IFG & UCTXIFG0) == 0) {}
  UCB1TXBUF = byte1;

  while( (UCB1IFG & UCTXIFG0) == 0) {}
  UCB1TXBUF = byte2;

  while( (UCB1IFG & UCTXIFG0) == 0) {}

  UCB1CTLW0 |= UCTXSTP;
  while( (UCB1CTLW0 & UCTXSTP) != 0 ) {}
  while((UCB1STATW & UCBUSY)!=0) {}

  return 0;
}

// Reverses a given string
void strrev(char *str)
{
  unsigned int i = 0;
  unsigned int j = strlen(str) - 1;
  char temp;
```

```
  while (i < j)
  {
    temp = str[i];
    str[i] = str[j];
    str[j] = temp;
    i++;
    j--;
  }
}

// Converts an unsigned 16-bit integer to a null-terminated string (base 10).
void custom_itoa(uint16_t number, char *buffer)
{
  unsigned int i = 0;

  // Handle the special case of 0
  if (number == 0)
  {
    buffer[i++] = '0';
    buffer[i] = '\0';
    return;
  }

  // Process individual digits
  while (number > 0)
  {
    int remainder = number % 10;
    buffer[i++] = remainder + '0'; // Convert digit to its ASCII character
    number = number / 10;
  }

  buffer[i] = '\0'; // Null-terminate the string

  // The digits are in reverse order, so we need to reverse the string
  strrev(buffer);
}

// Configures ACLK to 32 KHz crystal
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);
```

```
163
164   CSCTL0_H = 0; // Lock CS registers
165   return;
166 }
167
168 void initialize_uart(void)
169 {
170   // Configuring the pins to use backchannel uart
171   P3SEL1 &= ~(transmit | recieve);
172   P3SEL0 |= (transmit | recieve);
173
174   // Setting the clock to SMCLK
175   UCA1CTLW0 |= UCSSEL_2;
176
177   // Setting the dividers and enabling oversampling
178   UCA1BRW = 6;
179   // setting the modulators and such
180   UCA1MCTLW = UCBRF3 | UCBRS5 | UCOS16;
181
182   // Exiting the reset state
183   UCA1CTLW0 &= ~UCSWRST;
184 }
185
186 void uart_write_char(volatile unsigned char ch)
187 {
188   while (!(FLAGS & TXFLAG))
189   {
190     // Wait for transmission that is ongoing to complete
191   }
192
193   TXBUFFER = ch;
194   return;
195 }
196
197 unsigned char uart_read_char(void)
198 {
199   if (!(FLAGS & RXFLAG))
200   {
201     return 0; // no byte was recieved
202   }
203
204   // Return the buffer
205   volatile unsigned char return_char = RXBUFFER;
206   return return_char;
207 }
208
209 void uart_write_string(char *string)
210 {
211   unsigned int i; // counter
212   for (i = 0; i < strlen(string); i++)
213   {
214     uart_write_char(string[i]);
215   }
216   return;
217 }
218
219 void uart_write_uint16 (uint16_t number)
```

```
{
  // Converting the number via snprintf
  char buffer[6]; // 5 characters is the max amount of characters
    for 65,536
  custom_itoa(number, buffer);
  uart_write_string(buffer);
  return;
}

void uint16_to_4hex(unsigned int given_uint, char output[5])
{
  static const char hex[] = "0123456789ABCDEF"; // All possible
    hexes
  output[0] = hex[(given_uint >> 12) & 0xF];
  output[1] = hex[(given_uint >> 8) & 0xF];
  output[2] = hex[(given_uint >> 4) & 0xF];
  output[3] = hex[(given_uint >> 12) & 0xF];
  output[4] = hex[(given_uint) & 0xF];
  return;
}

int main(void)
{
  // Enabling the leds and other stuff
  WDTCTL   = WDTPW | WDTHOLD; // Stop WDT
  PM5CTL0 &= ~LOCKLPM5;       // Enable GPIO pins

  // doing what the function says
  initialize_uart();

  // yup, whatever it says
  initialize_i2c();

  // Actual logic for selection
  for (;;)
  {
    unsigned int manufacturerID = 0;
    unsigned int deviceID       = 0;

    i2c_read_word(0x44, 0x7E, &manufacturerID);
    i2c_read_word(0x44, 0x7F, &deviceID);

    // Converting the ids to ascii
    char man_ascii[3];
    man_ascii[0] = (char)((manufacturerID >> 8) & 0xFF); // High
    byte
    man_ascii[1] = (char)(manufacturerID & 0xFF); // Low byte
    man_ascii[2] = '\0';

    // transmitting the data
    uart_write_string("Manufacturer ID: ");
    uart_write_string(man_ascii);
    uart_write_char('\n');

    // Converting the device id.
    char dev_ascii[5];
    uint16_to_4hex(deviceID, dev_ascii);
```

```
274     uart_write_string("Device ID: ");
275     uart_write_string(dev_ascii);
276     uart_write_char('\n');
277 
278     __delay_cycles(1000000); // delay of 1 million cycles
279   }
280 }
```

7.2 Reading Measurements from the Light Sensor

Now, for this part of the lab, we are told to answer MORE questions (crazy, I know). THEREFORE, to make you're life easier, I'm going to... guess what... ANSWER THEM!!!!!! The address of the config register on the sensor is 0x01. And the value that I used, in HEX (because that's how you want it) was 0x7614 or into the bit fields to be 0111 0110 0000 0100. And, thankfully, the sensor readings seem very sensible (get it, sensor.... sensible??? I'm not the only one laughing, right???), as well as consistent.

```
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#include <stdint.h>
#include <string.h>

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#define transmit BIT4
#define recieve BIT5

// WE LOVE DEFINES
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#define TXFLAG UCTXIFG // Transmit flag
#define TXBUFFER UCA1TXBUF // Transmit buffer
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// Global variables for states of runway1 and 2
volatile int red_state = 0; // runway 1 state
volatile int green_state = 0; // runway 2 state
volatile int blink_state = 0;

// Functions provided by the lab
void initialize_i2c(void)
{
  // Configure the MCU in Master mode
  // Configure pins to I2C functionality
  // (UCB1SDA same as P4.0) (UCB1SCL same as P4.1)
  // (P4SEL1=11, P4SEL0=00) (P4DIR=xx)
  P4SEL1 |= (BIT1|BIT0);
  P4SEL0 &= ~(BIT1|BIT0);
  // Enter reset state and set all fields in this register to zero
  UCB1CTLW0 = UCSWRST;
  // Fields that should be nonzero are changed below
  // (Master Mode: UCMST) (I2C mode: UCMODE_3) (Synchronous mode: UCSYNC)
  // (UCSSEL 1:ACLK, 2,3:SMCLK)
  UCB1CTLW0 |= UCMST | UCMODE_3 | UCSYNC | UCSSEL_3;
  // Clock frequency: SMCLK/8 = 1 MHz/8 = 125 KHz
  UCB1BRW = 8;
  // Chip Data Sheet p. 53 (Should be 400 KHz max)
  // Exit the reset mode at the end of the configuration
  UCB1CTLW0 &= ~UCSWRST;
}

int i2c_read_word(unsigned char i2c_address, unsigned char i2c_reg, unsigned int * data)
```

```
{
  unsigned char byte1=0, byte2=0; // Intialize to ensure successful
     reading
  UCB1I2CSA = i2c_address; // Set address
  UCB1IFG &= ~UCTXIFG0;
  // Transmit a byte (the internal register address)
  UCB1CTLW0 |= UCTR;
  UCB1CTLW0 |= UCTXSTT;
  while((UCB1IFG & UCTXIFG0)==0) {} // Wait for flag to raise
  UCB1TXBUF = i2c_reg; // Write in the TX buffer
  while((UCB1IFG & UCTXIFG0)==0) {} // Buffer copied to shift
    register; Tx in progress; set Stop bit
  // Repeated Start
  UCB1CTLW0 &= ~UCTR;
  UCB1CTLW0 |= UCTXSTT;
  // Read the first byte
  while((UCB1IFG & UCRXIFG0)==0) {} // Wait for flag to raise
  byte1 = UCB1RXBUF;
  // Assert the Stop signal bit before receiving the last byte
  UCB1CTLW0 |= UCTXSTP;
  // Read the second byte
  while((UCB1IFG & UCRXIFG0)==0) {} // Wait for flag to raise
  byte2 = UCB1RXBUF;
  while((UCB1CTLW0 & UCTXSTP)!=0) {}
  while((UCB1STATW & UCBBUSY)!=0) {}
  *data = (byte1 << 8) | (byte2 & (unsigned int)0x00FF);
  return 0;
}

int i2c_write_word(unsigned char i2c_address, unsigned char i2c_reg
    , unsigned int data)
{
  unsigned char byte1, byte2;

  UCB1I2CSA = i2c_address;             // Set I2C address

  byte1 = (data >> 8) & 0xFF;          // MSByte
  byte2 = data & 0xFF;                 // LSByte

  UCB1IFG &= ~UCTXIFG0;

  // Write 3 bytes
  UCB1CTLW0 |= (UCTR | UCTXSTT);

  while( (UCB1IFG & UCTXIFG0) == 0) {}
  UCB1TXBUF = i2c_reg;

  while( (UCB1IFG & UCTXIFG0) == 0) {}
  UCB1TXBUF = byte1;

  while( (UCB1IFG & UCTXIFG0) == 0) {}
  UCB1TXBUF = byte2;

  while( (UCB1IFG & UCTXIFG0) == 0) {}

  UCB1CTLW0 |= UCTXSTP;
  while( (UCB1CTLW0 & UCTXSTP) != 0 ) {}
```

```
98    while((UCB1STATW & UCBUSY)!=0) {}
99
100   return 0;
101 }
102
103 // Reverses a given string
104 void strrev(char *str)
105 {
106   unsigned int i = 0;
107   unsigned int j = strlen(str) - 1;
108   char temp;
109   while (i < j)
110   {
111     temp = str[i];
112     str[i] = str[j];
113     str[j] = temp;
114     i++;
115     j--;
116   }
117 }
118
119 // Converts an unsigned 16-bit integer to a null-terminated string
      (base 10).
120 void custom_itoa(uint16_t number, char *buffer)
121 {
122   unsigned int i = 0;
123
124   // Handle the special case of 0
125   if (number == 0)
126   {
127     buffer[i++] = '0';
128     buffer[i] = '\0';
129     return;
130   }
131
132   // Process individual digits
133   while (number > 0)
134   {
135     int remainder = number % 10;
136     buffer[i++] = remainder + '0'; // Convert digit to its ASCII
        character
137     number = number / 10;
138   }
139
140   buffer[i] = '\0'; // Null-terminate the string
141
142   // The digits are in reverse order, so we need to reverse the
        string
143   strrev(buffer);
144 }
145
146 // Configures ACLK to 32 KHz crystal
147 void config_ACLK_to_32KHz_crystal()
148 {
149   // By default, ACLK runs on LFMODCLK at 5MHz/128 = 39 KHz
150
151   // 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;
}

void initialize_uart(void)
{
  // Configuring the pins to use backchannel uart
  P3SEL1 &= ~(transmit | recieve);
  P3SEL0 |= (transmit | recieve);

  // Setting the clock to SMCLK
  UCA1CTLW0 |= UCSSEL_2;

  // Setting the dividers and enabling oversampling
  UCA1BRW = 6;
  // setting the modulators and such
  UCA1MCTLW = UCBRF3 | UCBRS5 | UCOS16;

  // Exiting the reset state
  UCA1CTLW0 &= ~UCSWRST;
}

void uart_write_char(volatile unsigned char ch)
{
  while (!(FLAGS & TXFLAG))
  {
    // Wait for transmission that is ongoing to complete
  }

  TXBUFFER = ch;
  return;
}

unsigned char uart_read_char(void)
{
  if (!(FLAGS & RXFLAG))
  {
    return 0; // no byte was recieved
  }

  // Return the buffer
  volatile unsigned char return_char = RXBUFFER;
  return return_char;
}

```

```
209 void uart_write_string(char *string)
210 {
211   unsigned int i; // counter
212   for (i = 0; i < strlen(string); i++)
213   {
214     uart_write_char(string[i]);
215   }
216   return;
217 }
218
219 void uart_write_uint16 (uint16_t number)
220 {
221   // Converting the number via snprintf
222   char buffer[6]; // 5 characters is the max amount of characters
        for 65,536
223   custom_itoa(number, buffer);
224   uart_write_string(buffer);
225   return;
226 }
227
228 void uint16_to_4hex(unsigned int given_uint, char output[5])
229 {
230   static const char hex[] = "0123456789ABCDEF"; // All possible
        hexes
231   output[0] = hex[(given_uint >> 12) & 0xF];
232   output[1] = hex[(given_uint >> 8) & 0xF];
233   output[2] = hex[(given_uint >> 4) & 0xF];
234   output[3] = hex[(given_uint >> 12) & 0xF];
235   output[4] = hex[(given_uint) & 0xF];
236   return;
237 }
238
239 int main(void)
240 {
241   // Enabling the leds and other stuff
242   WDTCTL   = WDTPW | WDTHOLD; // Stop WDT
243   PM5CTL0 &= ~LOCKLPM5;       // Enable GPIO pins
244
245   // doing what the function says
246   initialize_uart();
247
248   // yup, whatever it says
249   initialize_i2c();
250
251   // Actual logic for selection
252   for (;;)
253   {
254     unsigned int light = 0;
255
256     // Writing the configuration to the light sensor
257     /*
258     *  The configuration register is:
259     *  RN [15:12] (R/W)- b1100 is reset
260     *  CT [11] (R/W)- b1 is reset
261     *  M[ 10:9] (R/W) - b00 is reset
262     *  OVF [8] (R) - b0 is reset
263     *  CRF [7] (R) - b0 is reset
```

```
264       *  FH [6] (R) - b0 is reset
265       *  FL [5] (R) - b0 is reset
266       *  L [4] (R/W) - b1 is reset
267       *  POL [3] (R/W) - b0 is reset
268       *  ME [2] (R/W) - b0 is reset
269       *  FC [1:0] (R/W) - b00 is reset
270       *
271       *  R/W is Read/Write
272       *  R is Read
273       */
274       i2c_write_word(0x44, 0x01, 0x7614);
275       // Reading the value of the light sensor
276       i2c_read_word(0x44, 0x00, &light);
277
278       // Converting the gathered reading to the proper value
279       int correctedLight = light * 1.28;
280
281       // writing to the serial console what the light sensor found
282       uart_write_string("Lux: ");
283       uart_write_uint16(correctedLight);
284       uart_write_char('\n');
285
286       __delay_cycles(1000000); // delay of 1 million cycles
287     }
288   }
```

Student Q&A

1

Given: *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.*
The light sensor has 4 addresses that are possible. They are:

- 0x44: GND (Ground)
- 0x45: VDD (Voltage)
- 0x46: SDA (Serial Data)
- 0x47: SCL (Serial Clock)

2

Given: *According to the light sensor's data sheet, what should be the value of the pull-up resistors on the I2C wires? Did the BoosterPack use the same values?*
The value of the pull-up resistor is $10k\Omega$ in the BoosterPack, and is, as well, the same value that is recommended by the light sensor's data sheet.

3

Given: *What I2C clock frequency do each of the eUSCI module and the sensor support?*
The MSP430 supports only standard and fast mode, or 100KHz and 400KHz, only. However, the light sensor supports all 3 modes of I2C, being standard, fast, and high-speed, or 100KHz, 400KHz, and 2.6MHz.