Design Lab Experiment No. 2:

*Motion Sensing System Implementation using Raspberry Pi*

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ECE 442 Internet of Things and Cyber Physical Systems

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**Acknowledgment**: I acknowledge all works including figures, codes and writings belong to me and/or persons who are referenced. I understand if any similarity in the code, comments, customized program behavior, report writings and/or figures are found, both the helper (original work) and the requestor (duplicated/modified work) will be called for academic disciplinary action.

Signature: \_\_\_\_Alan Biju Palayil\_\_\_\_\_\_\_\_\_\_

**I. Introduction**

**A. Purpose**

In this lab, we are building a motion sensing system using a Raspberry Pi single-board computer, where the sensing data are transmitted to a server through a client-server communication. Using a UDP connection between the server and Raspberry Pi, encrypt data from the Pi and decrypt the data in the server and have it displayed graphically.

The purpose of this exercise is to introduce different methods of communications between a microcomputer and I/O devices using Raspberry Pi, AES symmetric key encryption, and a client-server UDP connection.

**B. Background**

This experiment is divided into two parts:

1. Implementation of real-time motion sensing device using I2C protocol:

I2C is used to transfer data between master and slave devices. It uses two pins SDA and SCL. With the SCL, clock line to synchronize all data transfer over the bus and SDA, data line used to specify the addresses and transfer data. The Pi acts as the master and accelerometer as slave. The slave responds to the request of the master and the Pi requests the readings of the axes as an input data to be stored and displayed on the Pi.

1. Implementation of real-time motion sensing device using SPI protocol and establishing server-client communication:

The concept of SPI transfers data between master and slave devices. It uses 3-4 wires for the connections. SCK, MOSI, MISO, and SS are used. The Master initiates the communication by SS of slave to low. 1st byte is sent by the master with MSB for writing. In 2nd byte, slave will respond to master by sending the data from register on to master. The Pi will initiate the communication and act as master while the slave accelerometer will send the data to the master.

This data is sent using the server-client communication to the server. The PC acts as the server and Pi acts as the client. Using AES, the data is encrypted and transmitted over the internet. The server decrypts the data using the same key as encryption and uses it.

**II. Lab Procedure and Equipment List**

1. **Equipment**
   * 1 x Raspberry Pi 4 single-board computer
   * 1 x Adafruit ADXL345 triple-axis accelerometer
   * 1 x Desktop (as a data storage server)
   * Wires
2. **Procedure**

\*Refer to Lab Manual for detailed Procedure\*

**III. Results and Analysis**

1. **Results**

A picture containing electronics, circuit

Description automatically generated A picture containing electronics

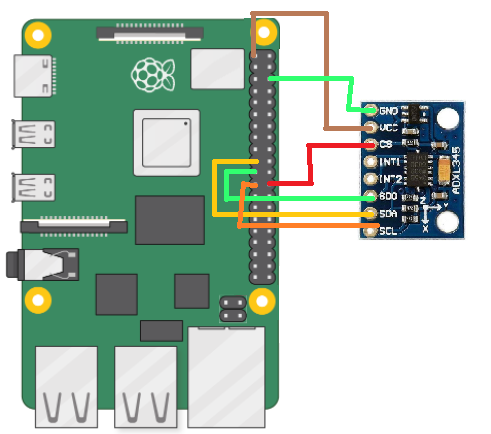
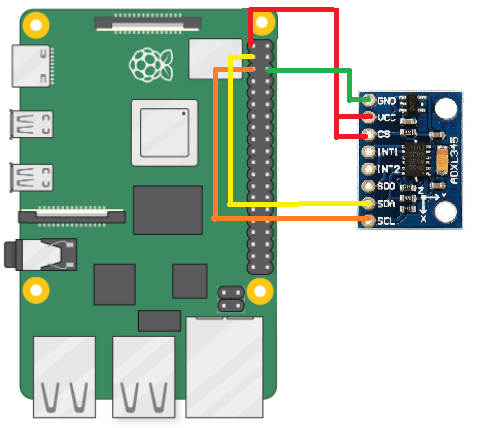
Description automatically generated

*Picture of the wiring for Part A and Part B.*

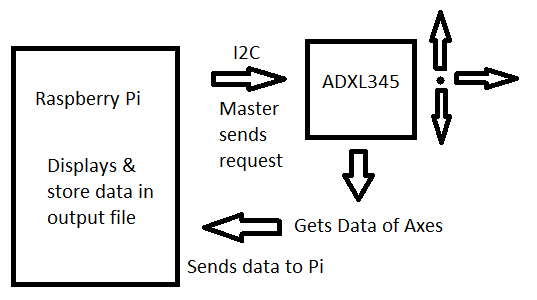
From the experiment, the output received to the server are as expected with no errors found while performing the experiment. The accelerometer was sending the axes data to the Pi and then to the serve. The server received the values in real time and displayed the values in a graph format with some delay.

1. **Answers to Discussion Questions**
   1. Refer to appendix A for the fully commented codes.

*Schematics for Part A and Part B:*



* 1. The Raspberry Pi acts as the master using the I2C connection send the request to slave accelerometer to transmit data. The accelerometer SCL clock line takes care of the synchronization between Pi and accelerometer. The SDA data line sends the data to the Pi. During the request of the master, it sends the coordinates axes data to Pi. The Pi displays it on the screen and stores the values *Flowchart for I2C operation.*



* 1. For an I2C type of connection. The SDA pin of the slave device is used to transmit the data. If more than one slave devices are connected than SDO pin of the other accelerometer acts as the alternate pin for the I2C protocol. The Raspberry Pi chooses the slave devices using these pins that send data to it.

For a SPI type of connection, all other connections can work cohesively between two or more slaves with the Raspberry Pi. The CS is different for different slave sensors and is connected to different pin on the Pi. Thus, making the Pi easily differentiate between two slave devices using which CS pin is connected.

To differentiate between the two connections, the Raspberry Pi can determine it because the pins used for either of the connections are different. SPI uses the Pi’s MISO, MOSI pins while I2C uses SCL and SDA pins. The protocol being different for the two connections, the Pi can identify the slaves whether the slaves are connected to I2C or SPI.

* 1. The register 0x31 is for data format control, to read or write. The 0x2F sends the Interrupt mapping control. Any bits set to 0 in 0x2F sends their respective interrupts from the 0x31 to the INT1 pin, while bits set to 1 in 0x2F sends their respective interrupts from the 0x31 to the INT2 pin.
  2. There is a delay in the data received from the physical accelerometer between the output of the Raspberry Pi and the server side. This is because of two main reasons: first is because the data is received from the accelerometer to the Raspberry Pi unencrypted and the second being that the data is processed to deliver the data in graph format. The data received to the Pi direct and sorted into the file while the data is encrypted before it is sent to the master PC server side. The server side decrypts the data and processes the data to display it into a graph using MatLab. I believe to improve the real-time data on the server side, clean up the existing code a decrease the delay time (sleep function).
  3. There are different sampling rates according to different peripheral for the Pi from 100kHz to 400kHz. Since the maximum sampling rate in theory is 400kHz, the I2C bus bandwidth would be 400000/27=14814 samples per second. To transfer 2 bytes through bus needs at least 27-bits (address + 2 data bytes). For the maximum clock rate is 3.6 MHz when running at 5V. The device requires 18 clocks per data samples, so 3.6 MHz/18=200k samples per second. Sampling Rate for SPI=3.6 MHz/24=150ksps.

To achieve the maximum theoretical sampling rate the complexity of the code needs to take into consideration, check over the timings, look over idle gaps between pollings, and check for unexpected communications or activity on the bus with the accelerometer.

**IV. Conclusion**

The experiment proves that the method mentioned above is good for sending sensor data and dependable too. It can be accessed from the server and then the data can be used for manipulation and controlling other sensors and devices. This serves the purpose of internet of things.

**References**

[1] Experiment 2 Lab Manual

[2] Lecture Note 3 of ECE 442/510

**Appendix**

**Appendix A**

1. *Main.cpp*

/\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

Use example and information in Appendix A in lab instruction manual to finish this file

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*/

#include <stdio.h>

#include <signal.h>

#include <sys/time.h>

#include "i2c-dev.h"

#include "ADXL345.h"

#define I2C\_FILE\_NAME "/dev/i2c-1"

void INThandler (int sig);

int main(int argc, char \*\*argv)

{

int i2c\_fd=open(I2C\_FILE\_NAME, O\_RDWR);

if (i2c\_fd<0)

{

printf("Unable to open i2c control file, err=%d\n",i2c\_fd);

exit(1);

}

printf("Opened i2c control file, id=%d\n",i2c\_fd);

ADXL345 myAcc(i2c\_fd);

int ret=myAcc.init();

if (ret)

{

printf("fialed init ADXL345, ret=%d\n", ret);

exit(1);

}

usleep(100 \* 1000);

signal(SIGINT, INThandler);

short ax, ay, az;

//create file IO

FILE \*fp;

fp = fopen("./output.txt","w+"); //creating an output file to store the data

char TimeString[128];

timeval curTime;

while(1)

{

// get the current time

gettimeofday(&curTime, NULL);

strftime(TimeString,80,"%Y-%m-%d %H:%M:%S",localtime(&curTime.tv\_sec));

printf(TimeString);

printf(": ");

// now, fetch data from sensor

myAcc.readXYZ(ax, ay, az);

//print to screen

printf("Ax : %hi \t Ay : %hi \t Az : %hi \n", ax,ay,az);

printf("----------------------\n");

//print to file

fprintf(fp,TimeString);

fprintf(fp, ": ");

fprintf(fp, "Ax : %hi \t Ay : %hi \t Az : %hi \n", ax,ay,az);

fprintf(fp, "----------------------\n");

if (getchar() == 'q') break;

}

fclose(fp);

return 0;

}

void INThandler(int sig)

{

signal(sig, SIG\_IGN);

exit(0);

}

1. *ADXL345.cpp*

/\*

Basic readout of ADXL345 accelerometer via I2C

Original code taken from the very bottom of this page:

http://www.raspberrypi.org/forums/viewtopic.php?t=55834

Updated by Jan Balewski, August 2014

\*/

#include <assert.h>

#include "ADXL345.h"

//==========================================

//==========================================

bool ADXL345::selectDevice(){

if (ioctl(fd, I2C\_SLAVE, myAddr) < 0) {

fprintf(stderr, "device ADXL345 not present\n");

return false;

}

return true;

}

//==========================================

//==========================================

bool ADXL345::writeToDevice(char \* buf, int len){

if (write(fd, buf, len) != len) {

fprintf(stderr, "Can't write to device ADXL345 buf=%s len=%d\n",buf,len);

return false;

}

return true;

}

//===============

bool ADXL345::readXYZ( short &x , short &y, short &z) {

assert(fd>0); // crash if port was not opened earlier

if(!selectDevice()) return false;

// printf("selectDevice(fd,ADXL345...) passed\n");

char buf[7];

buf[0] = 0x32; // This is the register we wish to read from

if(!writeToDevice(buf,2)) return false;

if (read(fd, buf, 6) != 6) { // Read back data into buf[]

printf("Unable to read from slave for ADXL345\n");

return false;

} else {

x = (buf[1]<<8) | buf[0];

y = (buf[3]<<8) | buf[2];

z = (buf[5]<<8) | buf[4];

}

return true;

}

//==========================================

//==========================================

//==========================================

int ADXL345::init() {

assert(fd>0); // crash if port was not opened earlier

char buf[6]; // Buffer for data being read/ written on the i2c bus

if(!selectDevice()) return -1;

buf[0] = 0x2d; // Commands for performing a ranging

buf[1] = 0x18;

if(!writeToDevice(buf,2)) return -2;

buf[0] = 0x31; // Commands for performing a ranging

buf[1] = 0x0A; //09 4g , A 8g

if(!writeToDevice(buf,2)) return -3;

printf("ADXL345::init() OK\n");

return 0;

}

1. *ADXL345.h*

/\*

Basic readout of ADXL345 accelerometer via I2C bus

Oryginal code taken from the very bottom of this page:

http://www.raspberrypi.org/forums/viewtopic.php?t=55834

Updated by Jan Balewski, August 2014

\*/

#ifndef ADXL345\_HH

#define ADXL345\_HH

#include <stdio.h>

#include <stdlib.h>

#include "i2c-dev.h"

#include <fcntl.h>

#include <string.h>

#include <sys/ioctl.h>

#include <sys/types.h>

#include <sys/stat.h>

#include <unistd.h>

#include <iostream>

class ADXL345 {

public:

ADXL345 (int fdx, unsigned char addx=0x53) { fd=fdx; myAddr=addx;}

int init();

bool readXYZ(short &ax , short &ay, short &az);

private:

bool selectDevice();

bool writeToDevice(char \* buf, int len);

unsigned char myAddr;

int fd;// File descriptor

};

#endif

1. *I2c-dev.h*

/\*

i2c-dev.h - i2c-bus driver, char device interface

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Copyright (C) 1998-99 Frodo Looijaard <frodol@dds.nl>

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along with this program; if not, write to the Free Software

Foundation, Inc., 51 Franklin Street, Fifth Floor, Boston,

MA 02110-1301 USA.

\*/

/\* $Id: i2c-dev.h 5894 2010-12-12 13:22:29Z khali $ \*/

#ifndef LIB\_I2CDEV\_H

#define LIB\_I2CDEV\_H

#include <linux/types.h>

#include <sys/ioctl.h>

//#include <linux/i2c-dev.h>

/\* -- i2c.h -- \*/

/\*

\* I2C Message - used for pure i2c transaction, also from /dev interface

\*/

struct i2c\_msg {

\_\_u16 addr; /\* slave address \*/

unsigned short flags;

#define I2C\_M\_TEN 0x10 /\* we have a ten-bit chip address \*/

#define I2C\_M\_RD 0x01

#define I2C\_M\_NOSTART 0x4000

#define I2C\_M\_REV\_DIR\_ADDR 0x2000

#define I2C\_M\_IGNORE\_NAK 0x1000

#define I2C\_M\_NO\_RD\_ACK 0x0800

short len; /\* msg length \*/

char \*buf; /\* pointer to msg data \*/

};

/\* To determine what functionality is present \*/

#define I2C\_FUNC\_I2C 0x00000001

#define I2C\_FUNC\_10BIT\_ADDR 0x00000002

#define I2C\_FUNC\_PROTOCOL\_MANGLING 0x00000004 /\* I2C\_M\_{REV\_DIR\_ADDR,NOSTART,..} \*/

#define I2C\_FUNC\_SMBUS\_PEC 0x00000008

#define I2C\_FUNC\_SMBUS\_BLOCK\_PROC\_CALL 0x00008000 /\* SMBus 2.0 \*/

#define I2C\_FUNC\_SMBUS\_QUICK 0x00010000

#define I2C\_FUNC\_SMBUS\_READ\_BYTE 0x00020000

#define I2C\_FUNC\_SMBUS\_WRITE\_BYTE 0x00040000

#define I2C\_FUNC\_SMBUS\_READ\_BYTE\_DATA 0x00080000

#define I2C\_FUNC\_SMBUS\_WRITE\_BYTE\_DATA 0x00100000

#define I2C\_FUNC\_SMBUS\_READ\_WORD\_DATA 0x00200000

#define I2C\_FUNC\_SMBUS\_WRITE\_WORD\_DATA 0x00400000

#define I2C\_FUNC\_SMBUS\_PROC\_CALL 0x00800000

#define I2C\_FUNC\_SMBUS\_READ\_BLOCK\_DATA 0x01000000

#define I2C\_FUNC\_SMBUS\_WRITE\_BLOCK\_DATA 0x02000000

#define I2C\_FUNC\_SMBUS\_READ\_I2C\_BLOCK 0x04000000 /\* I2C-like block xfer \*/

#define I2C\_FUNC\_SMBUS\_WRITE\_I2C\_BLOCK 0x08000000 /\* w/ 1-byte reg. addr. \*/

#define I2C\_FUNC\_SMBUS\_BYTE (I2C\_FUNC\_SMBUS\_READ\_BYTE | \

I2C\_FUNC\_SMBUS\_WRITE\_BYTE)

#define I2C\_FUNC\_SMBUS\_BYTE\_DATA (I2C\_FUNC\_SMBUS\_READ\_BYTE\_DATA | \

I2C\_FUNC\_SMBUS\_WRITE\_BYTE\_DATA)

#define I2C\_FUNC\_SMBUS\_WORD\_DATA (I2C\_FUNC\_SMBUS\_READ\_WORD\_DATA | \

I2C\_FUNC\_SMBUS\_WRITE\_WORD\_DATA)

#define I2C\_FUNC\_SMBUS\_BLOCK\_DATA (I2C\_FUNC\_SMBUS\_READ\_BLOCK\_DATA | \

I2C\_FUNC\_SMBUS\_WRITE\_BLOCK\_DATA)

#define I2C\_FUNC\_SMBUS\_I2C\_BLOCK (I2C\_FUNC\_SMBUS\_READ\_I2C\_BLOCK | \

I2C\_FUNC\_SMBUS\_WRITE\_I2C\_BLOCK)

/\* Old name, for compatibility \*/

#define I2C\_FUNC\_SMBUS\_HWPEC\_CALC I2C\_FUNC\_SMBUS\_PEC

/\*

\* Data for SMBus Messages

\*/

#define I2C\_SMBUS\_BLOCK\_MAX 32 /\* As specified in SMBus standard \*/

#define I2C\_SMBUS\_I2C\_BLOCK\_MAX 32 /\* Not specified but we use same structure \*/

union i2c\_smbus\_data {

\_\_u8 byte;

\_\_u16 word;

\_\_u8 block[I2C\_SMBUS\_BLOCK\_MAX + 2]; /\* block[0] is used for length \*/

/\* and one more for PEC \*/

};

/\* smbus\_access read or write markers \*/

#define I2C\_SMBUS\_READ 1

#define I2C\_SMBUS\_WRITE 0

/\* SMBus transaction types (size parameter in the above functions)

Note: these no longer correspond to the (arbitrary) PIIX4 internal codes! \*/

#define I2C\_SMBUS\_QUICK 0

#define I2C\_SMBUS\_BYTE 1

#define I2C\_SMBUS\_BYTE\_DATA 2

#define I2C\_SMBUS\_WORD\_DATA 3

#define I2C\_SMBUS\_PROC\_CALL 4

#define I2C\_SMBUS\_BLOCK\_DATA 5

#define I2C\_SMBUS\_I2C\_BLOCK\_BROKEN 6

#define I2C\_SMBUS\_BLOCK\_PROC\_CALL 7 /\* SMBus 2.0 \*/

#define I2C\_SMBUS\_I2C\_BLOCK\_DATA 8

/\* ----- commands for the ioctl like i2c\_command call:

\* note that additional calls are defined in the algorithm and hw

\* dependent layers - these can be listed here, or see the

\* corresponding header files.

\*/

/\* -> bit-adapter specific ioctls \*/

#define I2C\_RETRIES 0x0701 /\* number of times a device address \*/

/\* should be polled when not \*/

/\* acknowledging \*/

#define I2C\_TIMEOUT 0x0702 /\* set timeout - call with int \*/

/\* this is for i2c-dev.c \*/

#define I2C\_SLAVE 0x0703 /\* Change slave address \*/

/\* Attn.: Slave address is 7 or 10 bits \*/

#define I2C\_SLAVE\_FORCE 0x0706 /\* Change slave address \*/

/\* Attn.: Slave address is 7 or 10 bits \*/

/\* This changes the address, even if it \*/

/\* is already taken! \*/

#define I2C\_TENBIT 0x0704 /\* 0 for 7-bit addrs, != 0 for 10 bits \*/

#define I2C\_FUNCS 0x0705 /\* Get the adapter functionality \*/

#define I2C\_RDWR 0x0707 /\* Combined R/W transfer (one stop only)\*/

#define I2C\_PEC 0x0708 /\* != 0 for SMBus PEC \*/

#define I2C\_SMBUS 0x0720 /\* SMBus-level access \*/

/\* -- i2c.h -- \*/

/\* Note: 10-bit addresses are NOT supported! \*/

/\* This is the structure as used in the I2C\_SMBUS ioctl call \*/

struct i2c\_smbus\_ioctl\_data {

char read\_write;

\_\_u8 command;

int size;

union i2c\_smbus\_data \*data;

};

/\* This is the structure as used in the I2C\_RDWR ioctl call \*/

struct i2c\_rdwr\_ioctl\_data {

struct i2c\_msg \*msgs; /\* pointers to i2c\_msgs \*/

int nmsgs; /\* number of i2c\_msgs \*/

};

static inline \_\_s32 i2c\_smbus\_access(int file, char read\_write, \_\_u8 command,

int size, union i2c\_smbus\_data \*data)

{

struct i2c\_smbus\_ioctl\_data args;

args.read\_write = read\_write;

args.command = command;

args.size = size;

args.data = data;

return ioctl(file,I2C\_SMBUS,&args);

}

static inline \_\_s32 i2c\_smbus\_write\_quick(int file, \_\_u8 value)

{

return i2c\_smbus\_access(file,value,0,I2C\_SMBUS\_QUICK,NULL);

}

static inline \_\_s32 i2c\_smbus\_read\_byte(int file)

{

union i2c\_smbus\_data data;

if (i2c\_smbus\_access(file,I2C\_SMBUS\_READ,0,I2C\_SMBUS\_BYTE,&data))

return -1;

else

return 0x0FF & data.byte;

}

static inline \_\_s32 i2c\_smbus\_write\_byte(int file, \_\_u8 value)

{

return i2c\_smbus\_access(file,I2C\_SMBUS\_WRITE,value,

I2C\_SMBUS\_BYTE,NULL);

}

static inline \_\_s32 i2c\_smbus\_read\_byte\_data(int file, \_\_u8 command)

{

union i2c\_smbus\_data data;

if (i2c\_smbus\_access(file,I2C\_SMBUS\_READ,command,

I2C\_SMBUS\_BYTE\_DATA,&data))

return -1;

else

return 0x0FF & data.byte;

}

static inline \_\_s32 i2c\_smbus\_write\_byte\_data(int file, \_\_u8 command,

\_\_u8 value)

{

union i2c\_smbus\_data data;

data.byte = value;

return i2c\_smbus\_access(file,I2C\_SMBUS\_WRITE,command,

I2C\_SMBUS\_BYTE\_DATA, &data);

}

static inline \_\_s32 i2c\_smbus\_read\_word\_data(int file, \_\_u8 command)

{

union i2c\_smbus\_data data;

if (i2c\_smbus\_access(file,I2C\_SMBUS\_READ,command,

I2C\_SMBUS\_WORD\_DATA,&data))

return -1;

else

return 0x0FFFF & data.word;

}

static inline \_\_s32 i2c\_smbus\_write\_word\_data(int file, \_\_u8 command,

\_\_u16 value)

{

union i2c\_smbus\_data data;

data.word = value;

return i2c\_smbus\_access(file,I2C\_SMBUS\_WRITE,command,

I2C\_SMBUS\_WORD\_DATA, &data);

}

static inline \_\_s32 i2c\_smbus\_process\_call(int file, \_\_u8 command, \_\_u16 value)

{

union i2c\_smbus\_data data;

data.word = value;

if (i2c\_smbus\_access(file,I2C\_SMBUS\_WRITE,command,

I2C\_SMBUS\_PROC\_CALL,&data))

return -1;

else

return 0x0FFFF & data.word;

}

/\* Returns the number of read bytes \*/

static inline \_\_s32 i2c\_smbus\_read\_block\_data(int file, \_\_u8 command,

\_\_u8 \*values)

{

union i2c\_smbus\_data data;

int i;

if (i2c\_smbus\_access(file,I2C\_SMBUS\_READ,command,

I2C\_SMBUS\_BLOCK\_DATA,&data))

return -1;

else {

for (i = 1; i <= data.block[0]; i++)

values[i-1] = data.block[i];

return data.block[0];

}

}

static inline \_\_s32 i2c\_smbus\_write\_block\_data(int file, \_\_u8 command,

\_\_u8 length, const \_\_u8 \*values)

{

union i2c\_smbus\_data data;

int i;

if (length > 32)

length = 32;

for (i = 1; i <= length; i++)

data.block[i] = values[i-1];

data.block[0] = length;

return i2c\_smbus\_access(file,I2C\_SMBUS\_WRITE,command,

I2C\_SMBUS\_BLOCK\_DATA, &data);

}

/\* Returns the number of read bytes \*/

/\* Until kernel 2.6.22, the length is hardcoded to 32 bytes. If you ask for less than 32 bytes, your code will only work with kernels

2.6.23 and later. \*/

static inline \_\_s32 i2c\_smbus\_read\_i2c\_block\_data(int file, \_\_u8 command,

\_\_u8 length, \_\_u8 \*values)

{

union i2c\_smbus\_data data;

int i;

if (length > 32)

length = 32;

data.block[0] = length;

if (i2c\_smbus\_access(file,I2C\_SMBUS\_READ,command,

length == 32 ? I2C\_SMBUS\_I2C\_BLOCK\_BROKEN :

I2C\_SMBUS\_I2C\_BLOCK\_DATA,&data))

return -1;

else {

for (i = 1; i <= data.block[0]; i++)

values[i-1] = data.block[i];

return data.block[0];

}

}

static inline \_\_s32 i2c\_smbus\_write\_i2c\_block\_data(int file, \_\_u8 command,

\_\_u8 length,

const \_\_u8 \*values)

{

union i2c\_smbus\_data data;

int i;

if (length > 32)

length = 32;

for (i = 1; i <= length; i++)

data.block[i] = values[i-1];

data.block[0] = length;

return i2c\_smbus\_access(file,I2C\_SMBUS\_WRITE,command,

I2C\_SMBUS\_I2C\_BLOCK\_BROKEN, &data);

}

/\* Returns the number of read bytes \*/

static inline \_\_s32 i2c\_smbus\_block\_process\_call(int file, \_\_u8 command,

\_\_u8 length, \_\_u8 \*values)

{

union i2c\_smbus\_data data;

int i;

if (length > 32)

length = 32;

for (i = 1; i <= length; i++)

data.block[i] = values[i-1];

data.block[0] = length;

if (i2c\_smbus\_access(file,I2C\_SMBUS\_WRITE,command,

I2C\_SMBUS\_BLOCK\_PROC\_CALL,&data))

return -1;

else {

for (i = 1; i <= data.block[0]; i++)

values[i-1] = data.block[i];

return data.block[0];

}

}

#endif /\* LIB\_I2CDEV\_H \*/

1. *Output.txt*

2022-06-03 04:01:31: Ax : -106 Ay : -220 Az : -71

----------------------

2022-06-03 04:01:45: Ax : -40 Ay : -237 Az : 92

----------------------

2022-06-03 04:01:46: Ax : -38 Ay : -234 Az : 121

----------------------

2022-06-03 04:01:46: Ax : -39 Ay : -243 Az : 114

----------------------

2022-06-03 04:01:47: Ax : -43 Ay : -230 Az : 126

----------------------

2022-06-03 04:01:47: Ax : -38 Ay : -60 Az : 262

----------------------

2022-06-03 04:01:47: Ax : 2 Ay : 30 Az : 254

----------------------

2022-06-03 04:01:48: Ax : 60 Ay : -143 Az : 195

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2022-06-03 04:01:48: Ax : 49 Ay : 1 Az : 276

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2022-06-03 04:01:48: Ax : 35 Ay : 17 Az : 266

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2022-06-03 04:01:48: Ax : 33 Ay : 12 Az : 268

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2022-06-03 04:01:48: Ax : 22 Ay : 9 Az : 255

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2022-06-03 04:01:48: Ax : 22 Ay : 18 Az : 261

----------------------

2022-06-03 04:01:49: Ax : 33 Ay : 36 Az : 273

----------------------

2022-06-03 04:01:49: Ax : 32 Ay : 27 Az : 274

----------------------

2022-06-03 04:01:49: Ax : 30 Ay : 23 Az : 264

----------------------

2022-06-03 04:01:49: Ax : 28 Ay : 32 Az : 268

----------------------

2022-06-03 04:01:49: Ax : 18 Ay : 44 Az : 270

----------------------

2022-06-03 04:01:50: Ax : 24 Ay : 38 Az : 274

----------------------

2022-06-03 04:01:50: Ax : 17 Ay : 1 Az : 263

----------------------

2022-06-03 04:01:50: Ax : 68 Ay : -112 Az : 256

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2022-06-03 04:01:51: Ax : 40 Ay : -104 Az : 268

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2022-06-03 04:01:51: Ax : 7 Ay : -64 Az : 257

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2022-06-03 04:01:52: Ax : -26 Ay : -121 Az : 195

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2022-06-03 04:01:53: Ax : -54 Ay : -271 Az : 71

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**Appendix B**

1. *Encryption.cpp*

#include "encryption.hpp"

int encrypt(const char \* key, const char \* iv, char \* msg, char \* msgCiphered)

{

int key\_length, iv\_length, msg\_length;

key\_length = strlen(key);

iv\_length = strlen(iv);

msg\_length = strlen(msg);

const EVP\_CIPHER \*cipher;

int cipher\_key\_length, cipher\_iv\_length;

cipher = EVP\_aes\_128\_cbc();

cipher\_key\_length = EVP\_CIPHER\_key\_length(cipher);

cipher\_iv\_length = EVP\_CIPHER\_iv\_length(cipher);

if (key\_length != cipher\_key\_length) {

fprintf(stderr, "Error: key length must be %d, %d found\n", cipher\_key\_length, key\_length);

exit(EXIT\_FAILURE);

}

if (iv\_length != cipher\_iv\_length) {

fprintf(stderr, "Error: iv length must be %d, %d found\n", cipher\_iv\_length, iv\_length);

exit(EXIT\_FAILURE);

}

EVP\_CIPHER\_CTX \*ctx = EVP\_CIPHER\_CTX\_new();

int i, cipher\_length, final\_length;

EVP\_CIPHER\_CTX\_init(ctx);

EVP\_EncryptInit\_ex(ctx, cipher, NULL, (unsigned char \*)key, (unsigned char \*)iv);

cipher\_length = msg\_length + EVP\_MAX\_BLOCK\_LENGTH;

EVP\_EncryptUpdate(ctx, (unsigned char \*)msgCiphered, &cipher\_length, (unsigned char \*)msg, msg\_length);

EVP\_EncryptFinal\_ex(ctx, (unsigned char \*)msgCiphered + cipher\_length, &final\_length);

EVP\_CIPHER\_CTX\_free(ctx);

return cipher\_length + final\_length;

}

1. *Encryption.hpp*

#include <stdio.h>

#include <stdlib.h>

#include <string.h>

#include <openssl/evp.h>

int encrypt(const char \* key, const char \* iv, char \* msg, char \* msgCiphered);

1. *Client.cpp*

/\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

Use example and information in Appendix B in Lab instruction manual to finish this file

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*/

#include <iostream>

#include <stdlib.h>

#include <stdio.h>

#include <unistd.h>

#include <string.h>

#include <termios.h>

#include <fcntl.h>

#include <wiringPiSPI.h>

#include <netdb.h>

#include <netinet/in.h>

#include <sys/types.h>

#include <sys/socket.h>

#include "encryption.hpp"

//specify the size of buffer and port for transmit

#define BUFFERSIZE 64

#define PORTNUMBER 6000

//specify key and IV

const char KEY[]= "3874460957140850";

const char IV[]= "9331626268227018";

//specify the address for server

const char hostname[] = "192.168.1.166";

//specify the channel used for SPI

const int spichannel(0);

void initialSPI()

{

wiringPiSPISetupMode(spichannel, 1000000, 3);

usleep(10);

unsigned char buf[2];

buf[0] = 0x2D;

buf[1]=0x18;

wiringPiSPIDataRW(spichannel, (unsigned char \*)&buf, 2);

//std::cout << std::hex << (short)buf[1] << std::end1;

//std::cout << "finished testing" << std::end1;

//configure power

//std::cout << "finished setting up powerctl" << std::end1;

//configure data format (Full\_res, left justify, +-2g)

buf[0]= 0x31;

buf[1]= 0x00;

wiringPiSPIDataRW(spichannel, (unsigned char \*)&buf, 2);

//std::cout << "finished setting up dataformat" << std::end1;

return;

}

void readRawXYZ(short &X, short &Y, short &Z)

{

unsigned char txRxData[2];

unsigned char buf[6];

//read data

for (unsigned short i(0); i<6; i++)

{

txRxData[0] = (unsigned char) ((unsigned short)0xB2 +i);

wiringPiSPIDataRW(spichannel, (unsigned char \*)&txRxData, 2);

buf[i] = txRxData[i];

}

X = (buf[1] << 8) | buf[0];

Y = (buf[3] << 8) | buf[2];

Z = (buf[5] << 8) | buf[4];

return;

}

void readXYZ(float &X, float &Y,float &Z, const short &scale = 2)

{

short x\_raw, y\_raw, z\_raw;

readRawXYZ(x\_raw, y\_raw, z\_raw);

X = (float) x\_raw / 1024 \* scale;

Y = (float) y\_raw / 1024 \* scale;

Z = (float) z\_raw / 1024 \* scale;

return;

}

//return true when keyboard been pressed, false other wise

bool kbhit(void)

{

struct termios oldt, newt;

int ch;

int oldf;

tcgetattr(STDIN\_FILENO, &oldt);

newt = oldt;

newt.c\_lflag &= ~(ICANON | ECHO);

tcsetattr(STDIN\_FILENO, TCSANOW, &newt);

oldf = fcntl(STDIN\_FILENO, F\_GETFL, 0);

fcntl(STDIN\_FILENO, F\_SETFL, oldf | O\_NONBLOCK);

ch = getchar();

tcsetattr(STDIN\_FILENO, TCSANOW, &oldt);

fcntl(STDIN\_FILENO, F\_SETFL, oldf);

if(ch != EOF)

{

ungetc(ch, stdin);

return true;

}

return false;

}

int main()

{

initialSPI();

float x, y, z;

//verify the socket;

int sockfd = socket(AF\_INET, SOCK\_DGRAM, 0);

if(sockfd <0)

{

printf("ERROR opening socket\n");

exit(1);

}

//verify host name/address

struct hostent \*server = gethostbyname(hostname);

if(server == NULL)

{

printf("ERROR, no such host as %s\n",hostname);

exit(1);

}

//Build the server internet address

struct sockaddr\_in serveraddr;

bzero((char \*) &serveraddr, sizeof(serveraddr));

serveraddr.sin\_family = AF\_INET;

bcopy((char \*)server->h\_addr,(char \*)&serveraddr.sin\_addr.s\_addr, server->h\_length);

serveraddr.sin\_port = htons(PORTNUMBER);

char bufRaw[BUFFERSIZE], bufCiphered[BUFFERSIZE \*2];

while(!kbhit())

{

readXYZ(x,y,z);

//format the buffers with output

//float with 2 and 6 digits before and after decimal point

snprintf(bufRaw, BUFFERSIZE, "%2.6f, %2.6f, %2.6f,\n", x,y,z);

printf(bufRaw);

int length = encrypt((const char \*)&KEY, (const char \*)&IV, &bufRaw[0], (char

\*)&bufCiphered);

for(uint i = 0; i< length; i++)

printf("%02x", bufCiphered[i]);

printf("\n");

int sendStatus = sendto(sockfd, bufCiphered, length, 0, (struct sockaddr \*)&serveraddr,

sizeof(serveraddr));

if(sendStatus<0)

{

printf("sent failed with status %d\n", sendStatus);

exit(1);

}

usleep(1000000);

}

return 0;

}

1. *Server.py*

#!/usr/bin/env python

import socket

import sys

import datetime

import matplotlib.pyplot as plot

from matplotlib import animation

from Cryptodome.Cipher import AES

# server network configurations

SERVER\_IP\_ADDRESS = "192.168.1.166" #to be determined

PORT = 6000 #to be determined

time = [0]\*50

for i in range(0,50):

time[i] = i

ax\_points = [float(0)]\*50

ay\_points = [float(0)]\*50

az\_points = [float(0)]\*50

print("starting UDP Server Setup")

sys.stdout.flush()

sock = socket.socket(socket.AF\_INET, socket.SOCK\_DGRAM)

sock.bind( (SERVER\_IP\_ADDRESS, PORT) )

print("waiting for data to receive")

sys.stdout.flush()

KEY = b'3874460957140850'

iv = b'9331626268227018'

fig = plot.figure()

ax = plot.axes(xlim=(0, 50), ylim=(-2, 2))

lineX, lineY, lineZ, = ax.plot([], [], [], [], [], [], lw=2)

def init():

lineX.set\_data([], [])

lineY.set\_data([], [])

lineZ.set\_data([], [])

return lineX, lineY, lineZ,

def updateData(i):

decryption\_suite = AES.new(KEY, AES.MODE\_CBC, IV=iv)

data, addr = sock.recvfrom(64)

print (''.join('{:02x}'.format(x) for x in data))

plain\_text = decryption\_suite.decrypt(data)

data = plain\_text.decode('utf-8')

ax,ay,az,dump = data.split(",")

print("ADXL345 X-Axis: " + ax + "\tY-Axis: " + ay + "\tZ-Axis: " + az + "\t" + datetime.datetime.now().strftime("%Y-%m-%d %H:%M:%S.%f"))

sys.stdout.flush()

del ax\_points[0]

del ay\_points[0]

del az\_points[0]

ax\_points.append(float(ax))

ay\_points.append(float(ay))

az\_points.append(float(az))

lineX.set\_data(time,ax\_points)

lineY.set\_data(time,ay\_points)

lineZ.set\_data(time,az\_points)

return lineX, lineY, lineZ,

anim = animation.FuncAnimation(fig, updateData, init\_func=init,

frames=200, interval=20, blit=True)

plot.show()