Wearable sensors for personalized health

By

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16377

Dissertation submitted in partial fulfilment of

the requirement for the Bachelor of Engineering (Hons)

(Electrical and Electronic Engineering)

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CERTIFICATION OF APPROVAL

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A project of dissertation report submitted to Electrical and Electronic Engineering

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Approved by,

____

(Dr. Ho Tatt Wei)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

JANUARY 2016

CERTIFICATION OF ORIGINALITY

This is to clarify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgement, and that original work contained herein have not been undertaken or done by unspecified sources or persons.

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Muhammad Zulhilmi bin Noslan

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ABSTRACT

From World Health Expectancy website stated that Malaysia is at 19th world ranking, whereby peoples are dead because of chronic diseases. Critically thinking that all of this occurs because of citizens are not fully aware of their health and there is no approaching method to monitor their health since in the beginning stage.

In this era of modernization, a thousand of research have been done in medical field to create and innovate the existing technologies in order to improve people's life by producing the easiest way to monitor health rate that can be applied to patients easily and systematically. This is the most highlighted part to make sure our society can get benefit from the new discovered technologies by the scientists through effective research by professional instructors. Nowadays, there a few of product in the market such as Fitbit that promote fitness monitoring device which is 'wearable' that we can bring it and use it everywhere for many purposes likes jogging, walking and even working. So that people can easily monitor their healthiness such as heart rate, temperature, and oxygen rate in one device which currently only can be done in the hospital.

All of this done by engineers in order to ensure our communities can increase the quality of life systematically parallel with the era of globalization. On the other hand, this technology can be applied also for hospitalized purpose which can increase the patient’s outcomes via personalized healthcare.

ACKNOWLEDGEMENT

I am nothing without them. At first, I would like to give highest credit to my beloved supervisor Dr. Ho Tatt Wei and Dr. Tang Tong Boon as my Co-supervisor for their continuous support to me from the beginning until the submission of this report. I'm so glad have an opportunity works with them because they were very helpful when I'm facing problem working on this project. Furthermore, with their professional skills made me gain a lot of knowledge through this course not only in engineering knowledge but also for my future life. Besides, I would like to express my earnest thank you to my lab technician, Mdm. Azirawati for her time in guiding me on how to work on the new equipment that have been suggested by my supervisor and also giving a motivation to be strong and stay focused for this project. Last but not list, a lovely thank you I would like to give to my classmate for their unlimited caring and support all the time until I have successfully completed this course.

CHAPTER 1

INTRODUCTION

1.1.Background

Wearable sensor is a leading technology nowadays in providing the latest version of personalized health. [1] Due to this innovation, many brands such as Fitbit, promoting the latest technologies, by providing wearable sensor devices with various of health monitoring purposes.

Basically, those product is focusing more on body fitness and it consists of one or two sensors in a device. Hence, for future intention, the idea of using a microcontroller in controlling the several wearable sensors and sending the data to the server via Wi-Fi or Bluetooth is such an innovative thinking that is also suitable for hospitalized purposes. This can be done by implementing embedded system into the microcontroller to do interrupt or interface with the sensor in order to get the data from it. Basic theory of this concept is to detect the important parameter in human body such as oxygen, heart rate, temperature and humidity and represent it into a data that can be read.

Bluetooth is an example of the wireless communication that has been used widely in many wearable applications to stream data from host to other devices. By using this method, data can be streamed by the microcontroller from the sensor via Bluetooth in order to save and transfer it to the server.

1.2.Problem statement

Based on the previous research, there are certain consideration need to take care of, such as basic theory for the sensors and the microcontroller, the configuration of all components and the most importantly is the compatibility between all the components in order to come out with complete prototype that suited with the objective and specification of this project.

First, a research has to be done in selecting the parameters that need to be monitored in this project. This is the first concern of this project on what the important parameter that the sensor can sense so it can give response about the health rate of the user from the beginning stage of the decease.

Second, all data that microcontroller had streamed from the sensor should can be monitored by server continuously. The problem occurs for example, when the doctor can only can detect their patient’s condition if they are going to the hospital and when that happen the decease might go to the worst case.

1.3.Objective and scope of study

The scope of this study is to design a wearable sensor to supervise human personalized health by using latest technology to ensure the product will be beneficial for society and also can be used for hospitalized purposes. The device basically will be able to detect and integrate important parameters in the human body that usually be used in hospital for chronic care. Besides, this study is concerned about improving the people's life whereby designing a device that called 'wearable', so user still able to monitor their health even when they are moving from one place to other places.

The fundamental objective of this study is to:

- Implement a suitable sensor with microcontroller for hospitalized and chronic care market.

CHAPTER 2

LITERATURE REVIEW

2.1. Wearable design concept

Previously, many factors have been discussed to come out with a proper wearable design concept to get the desired output product. In terms of functionality, the products are providing important wearable specification to make it easy to use and bring it anywhere. Besides, nowadays wearable system is using the battery which is rechargeable as a power supply such as lithium-ion battery that can reduce power consumption. [2]

Furthermore, weight and size for this system has been fabricated to be small and light just suited for the user to bring it anywhere without facing any trouble. The smartphone is one of the example device that can perform as a wearable system right now for monitoring user's fitness. For example, the indication such as led flashlight at the phone is used to detect human pulse rate either is normal or not, then it will display the data on the screen.

Figure 1: Sensors portable healthcare[3]

In the other dimension Fitbit is another example for wearable system that have been introduced to the public which successfully giving new colour in the society's life. [4] Based on fitness concept, this gadget is able to detect distance travelled, pulse rate, calories burned, and heart rate by putting the gadget on the wrist. In addition, user can simply see their performance and all the data in the smartphone with auto-sync. For other sources, Nike fuelband, Nike sportband and iPhone moves apps also have the same features which to detect human motion and record the distance through the accelerometer.

Figure 2: Fitbit Flex design[5]

2.2. Sensors

2.2.1. Oxygen (spO2)

Oxygen sensor or pulse oximeter is used to monitor the Saturation of Peripheral Oxygen (spO2) in a human's blood to ensure quantity of oxygen gas is enough to be delivered all over the body. Haemoglobin is the molecules in red blood cell that carry oxygen in the human body, whereby:

$$SpO2 = \frac{HbO2}{Hb+HbO2}[6]$$

HbO2 = oxyhaemoglobin

Hb = haemoglobin

During this stage, pulse oximeter will detect spO2 by using two basic indicator which is LED infrared light and light detector. Due to oxyhaemoglobin's behaviour, it's easily can absorb the light that emitting to it, so this phenomenon can be taken as a principle method in order to get the spO2 reading by using this theory:

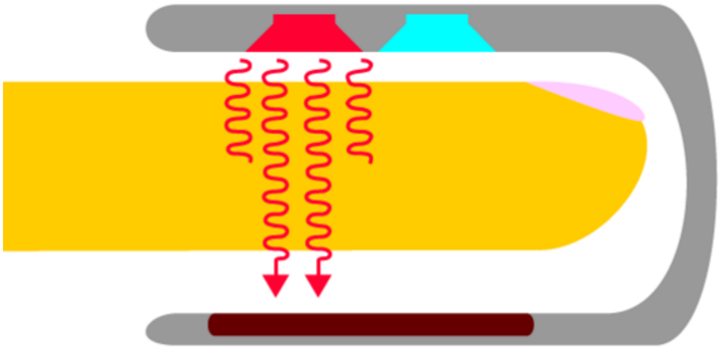

Figure 3: Basic principle of pulse oximeters[7]

When a hand is placed into pulse oximeter, it will emit the LED infrared light through the hand and received by the light detector at the bottom, which is functioning to collect how much light successfully passed through the hand while the remaining of the lights will be absorb by HbO2, so a hypothesis can be made whereby the lesser the light is detected by the light detector, the more spO2 in the blood.

In other cases, oxyhaemoglobin also absorbing the light with different wavelength base on certain condition such as:

1. Concentration of light
2. Length, distance of light path

One of the pulse oximeter that are available in the market for now is Nellcor spO2 Oximax DS-100A sensor which consists of reusable spO2 bandage sensor and DB-9 pin cable connector.

2.2.2. Heart rate

By using the same concept with the previous sensor, the heart rate will be calculated on how much the oxyhaemoglobin can absorb the infrared light per time. At the same time, de-oxyhaemoglobin will absorb the red light with different wavelength:

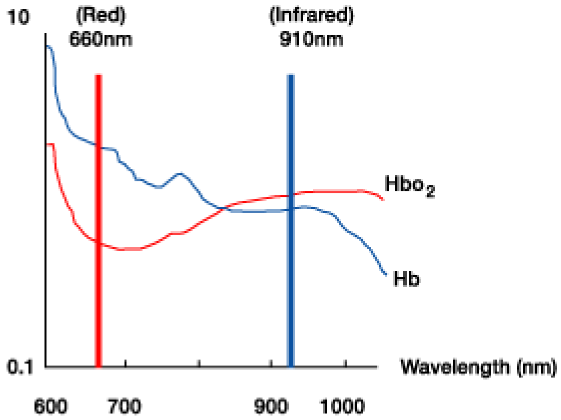

Figure 4: Infrared light and red light wavelength[8]

The figure above clearly explained the wavelength range between infrared light and red light. At 60nm, de-oxyhaemoglobin absorbed most of the red light while oxyhaemoglobin absorbed most of the infrared light at 910nm. Pulse Sensor is a well-designed heart rate sensor for microcontroller such as the Arduino. With 3 wired cable for analog output, 5V and ground made the sensor is easy to configure and implement to the microcontroller to get the result.

2.2.3. Body temperature

Temperature sensitive resistors are used as an analogue sensor to determine the body temperature. As the voltage drop at the resistor, means the higher the temperature will be recorded. By this concept, the voltage output of the resistor is directly proportional to the degree Celsius. LM35 is a sensor chip that ability to read the temperature value in Fahrenheit or Celsius from the output voltage by using this principle:

SensorOutput(mVolts)=ADCreadings X (500/1024)

Temp.(deg celcius)= (SensorOutput – 500)/(10)[9]

SHT1X sensor is a product by Sensirion that providing full-calibrated chip temperature and humidity sensor with low power consumption. Besides, the chip is fabricated with unique sensor element that guarantee the stability of the operation and produce digital output.

2.2.4. Humidity rate

Humidity in the medical field is defined as the total moistures or water loss in the skin whereby it is calculated by the density gradient of water evaporation with two sensors which are humidity and temperature sensor. Transepidermal water loss (TEWL) sensor is used this combination of these sensors to prove this theory:

$$\frac{dm}{dt} = -D.A.\frac{dp}{dx}[10]$$

A = surface (m^2)

m = water transported (g)

t = time (h)

D = diffusion constant (=0.0877 g/m(hmmHg))

p = vapour pressure of the atmosphere (mm Hg)

x = distance from skin surface to point measurement (m)

Expended moisture from skin fill in this sensor and the remaining will condense.

This will cause growing of a film of water and from this stage, TEWL value is taken. [11] SHT1X temperature and humidity sensor are also providing operational to sense human humidity (it comes together with temperature sensor) with the same configuration but different purposes.

CHAPTER 3

METHODOLOGY

3.1. Overview

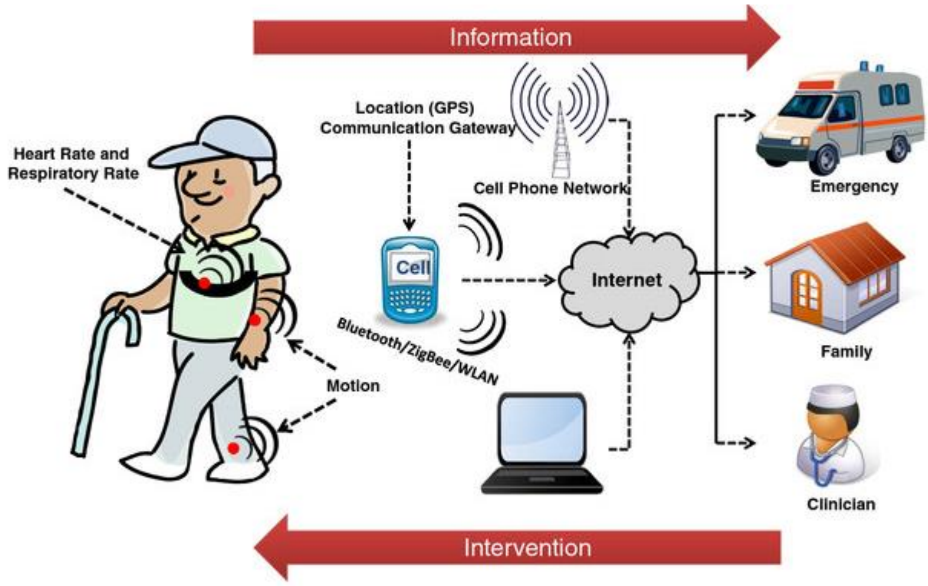

Figure 5: Wearable sensors system application[12]

Roughly, this project is about creating a wearable sensors which contain multi-sensors such as oxygen, heart rate, body temperature and humidity that will be used for hospitalized and chronic care market purposes by using method of detecting all parameters on the user's skin. A microcontroller will be used to stream and save all data from the sensor via Bluetooth to be sent to the server (family, clinician) through the internet for 24 hours monitoring and analysis purposes.

Shimmer is a wearable sensors product kit that come with complete set of user manual, sensors, multi-charger and other accessories that well suited for wearable applications. The type of sensor available in this kit are:

- Wide range accelerometer
- Temperature
- Humidity
- Heart rate
- Muscle contraction

This product has been tested and satisfied by worldwide as a user friendly product which contain a software for specific sensor, low power consumption and can give the desired output with systematic ways. In this project, Shimmer will be used as a sensor platform to sense all the parameters needed and transfer to the microcontroller via Bluetooth communication.

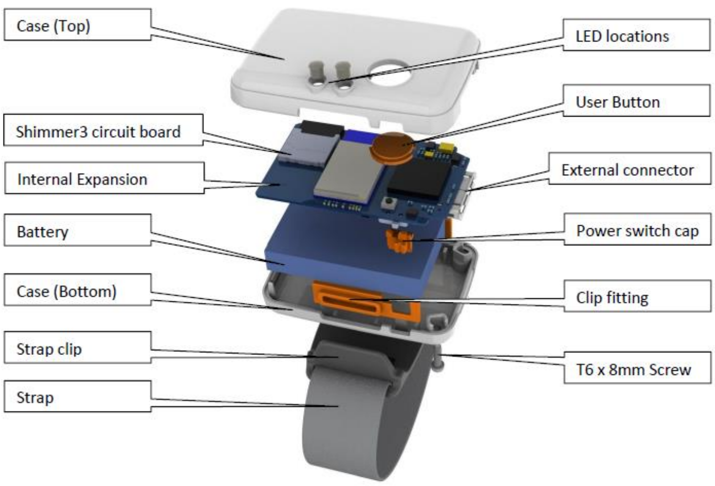

Figure 5: Shimmer Design concept[13]

The figure above shows the shimmer design concept that consists of external battery, external connector, circuit board and strap as an accessory. By using a sensor's probe, the shimmer will detect the desired parameter and sending the data to the microcontroller. This is the details of specification for shimmer's microcontroller and sensors:

Wide Range Accel.	**STMicro LSM303DLHC**
Range	±2g/4g/6g/8g
Sensitivity	1000LBS/g
Numeric Resolution	16 bit
Typical Operating Current	1.10uA
RMS Noise	27.5 x 10^-3 m/s^2
Gyro	**Invensense MPU 9150**
Range	±250/500/100 dps
Sensitivity	131 LSB
Numeric Resolution	16 bit
Typical Operating Current	3.5mA
RMS Noise	0.0481 dps
Pressure Sensor	**Bosch BP 180**
Range	300-1100 hPa
Numeric Resolution	16 bit
Typical Operating Current	1uA
RMS Noise	0.4m

Table 1: Specification of Shimmer sensors[14]

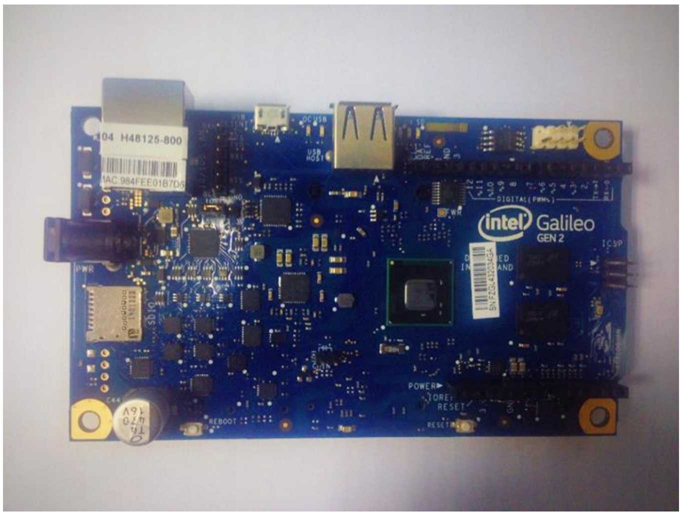

Figure 6: Intel Galileo Gen 2 Board

Figure 6 shows the Intel Galileo Gen2 microcontroller board that will be used in this project to collect all data from the shimmer to send to the server and it come with WiFi/Bluetooth communication card. There are several reasons this board is selected to be implemented in this project, the first point is Intel Galileo board is using latest technologies which can be run in the latest version of windows. Besides, the design concept of this board is created and ideal for ‘wearable’ applications. Furthermore, Intel Galileo has higher performance in term of RAM and processor rather than the other microcontroller.

Model	Intel Quark SoC X1000
Speed	40MHz
Instruction Set	32 bit
SRAM	512kB
USB	2.0 Storage Device
EEPROM	8kB
SD Card	Up 32GB
Firmware	8 MB Nor Flash

Table 2: Specification of Intel Galileo Gen 2 Board

3.2. Design flow concept

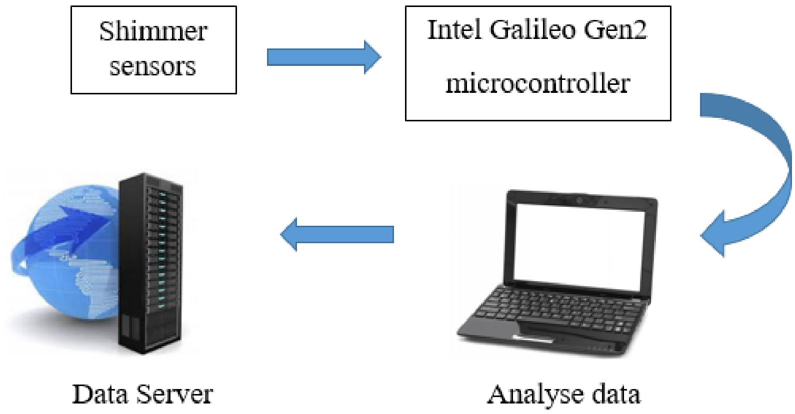

Figure 7 : Flow diagram of overall system concept

Figure above shows roughly the flow of design concept on how the sensors work until the all the data has been transferred to the server. At the first stage, Shimmer's sensor will detect the desired parameter on the human body, then microcontroller will get all the data from the sensor via Bluetooth and interpret it to proper form. After that, the data will transfer to PC to analyse and monitoring purposes. For advance step, finally the data will send to the server for further action.

Key Milestones	
First stage	**Second stage**
▪ Getting data from the sensor ▪ Create embedded system in order for microcontroller to read all data from the sensor	▪ Analyse the result through PC ▪ Send the data to server

Table 3: Key Milestones for the project

Main Task	First Semester/Week													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
• Literature review														
• Identify hardware and purchasing														
• Extended proposal														
• Hardware testing														
• Programming through Intel Galileo														
• Proposal defence														
• Prototype experimental testing														
• Interim report														
• Data collection														

Table 4: Gantt chart for FYP 1

Main Task	Second Semester/Week													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
• Data collection														
• Data processing and Prototype improvement														
• Progress report														
• Project dissertation and presentation														

Table 5: Gantt chart for FYP 2

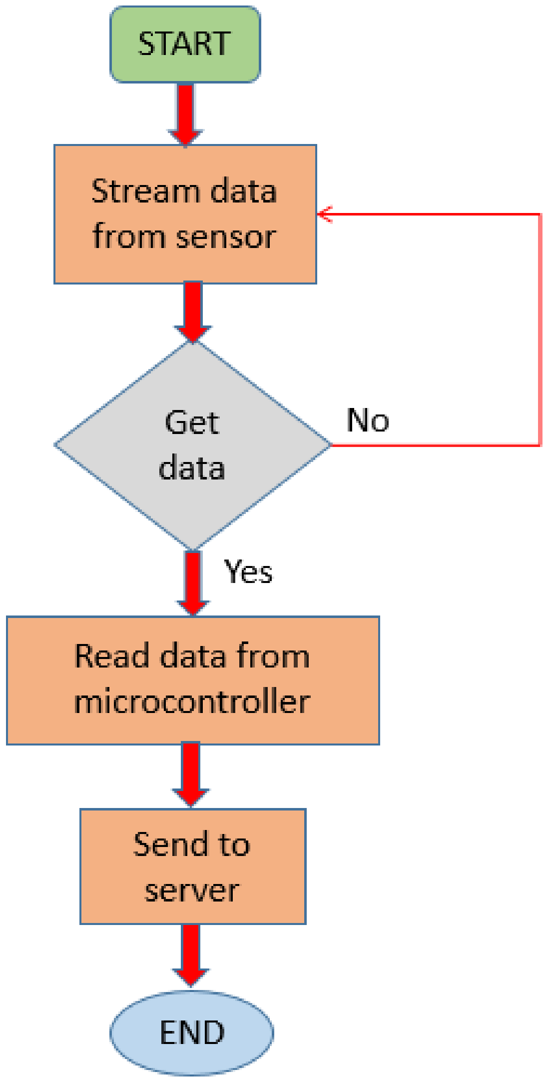

Figure 8: Flow chart of embedded system for this project

‘

3.3. Hardware Setup

Based on previous discussion, the main component of this project are Intel Galileo Gen2 Board and Shimmer kits. The Intel Galileo of the second generation board is designed to specialize in wearable applications and one of the best microcontroller for students and professional developers. For the starting up, Galileo board is connected to 12V power supply.

This board consists of two types of USB which is 2.0 USB Host and 2.0 USB Client (micro USB). In order to transfer the programming to Galileo board manually, the USB Client port will be used and USB Host for external use. For the second part of the setup is to insert the Bluetooth card to Galileo Board. For this project, external HC05 Bluetooth module is used to stream data from shimmer.

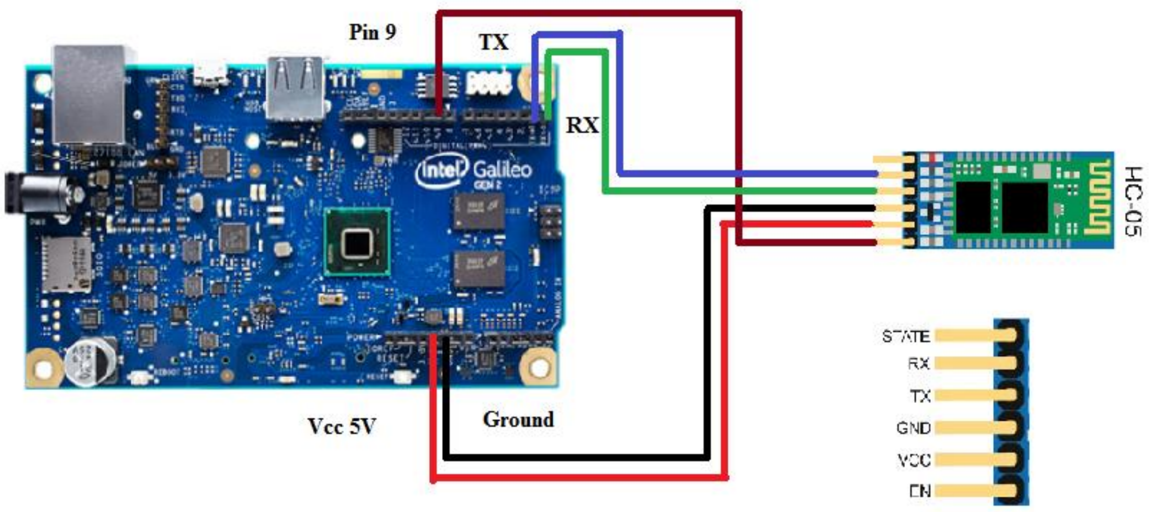

Figure 9: Intel Galileo Gen 2 Board and HC05 Bluetooth Module Connection

The figure above shows one of the models for a Bluetooth module that's compatible with the microcontroller and how to connect the module to the board. This Bluetooth module consists of five basic pin which is Vcc to Vcc 5V, ground to ground, KEY to output pin 9, Tx to Rx and Rx to Tx. The reason for the switched pin connection between Tx and Rx is because the HC05 must be claimed as a master which is the device that send the command.

Next stage is to set up shimmer sensor kits to the user’s body. Before that, shimmer consists of four main sensor devices which is:

Shimmer GSR

Galvanic Skin Response is a difference in electrical resistance of the skin caused by such as emotion. This sensor can detect heart rate, body humidity.

Shimmer EMG

Electromyogram is to measure the electrical of muscle contractions and nerve conduction in the human body.

Shimmer ECG

Electrocardiogram is to measure the electrical potential based on the cardio activity as changed in magnitude of voltage against time.

Shimmer Bridge Amplifier

This sensor can detect various of resistance in human body that can read measurement of pressure, stress and body temperature.

Inside the shimmer sensor itself, there has an external battery 3.7V for wearable application. To transfer the programming from PC to shimmer, a device called shimmer dock is used by connecting the USB cable to PC.

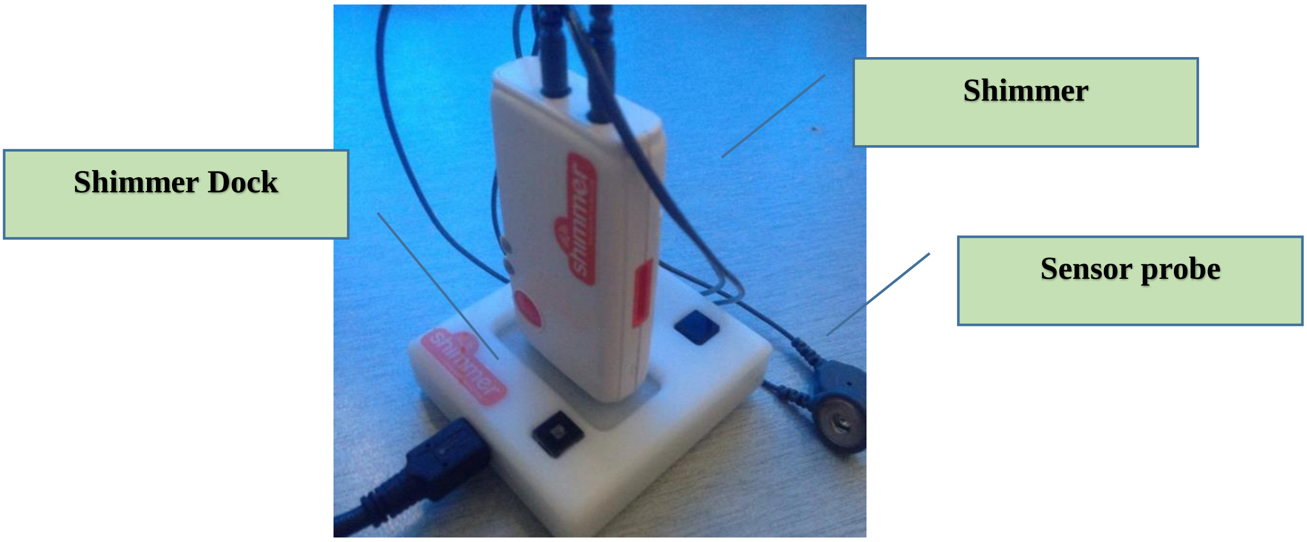

Figure 10: Placing the shimmer at shimmer dock

The figure above shows how to place shimmer sensor at shimmer dock in order to transfer programme from PC. After getting the programme, the required parameter is detected from the shimmer sensor by placing the sensor probe at a human body. For various application sensor probe will be placed at different part of human body for example to detect the heart rate by using Shimmer GSR for, the sensor probe will be placed on the finger to get a better result and for Shimmer EXG and ECG on the chest.

3.4. Software Setup

Shimmer has come with several open software for the specific purpose for developers, so that they can either use default programme or edit the programme by using LabVIEW, MathLab or C# to their own needs. Shimmer is using an open source of firmware called BtStream for general purpose to stream data via Bluetooth and it is compatible with other software applications.

Before that, shimmer’s driver has to be installed on the PC to make shimmer work properly. Then, to stream and receive data, the firmware has to be configured in order to call the right command in BtStream while the communication between PC and Shimmer can be done via Bluetooth serial communication. Shimmer Bootloader is a software that used to load and compile Btstream into shimmer by selecting shimmer’s port location in PC and click ‘program’.

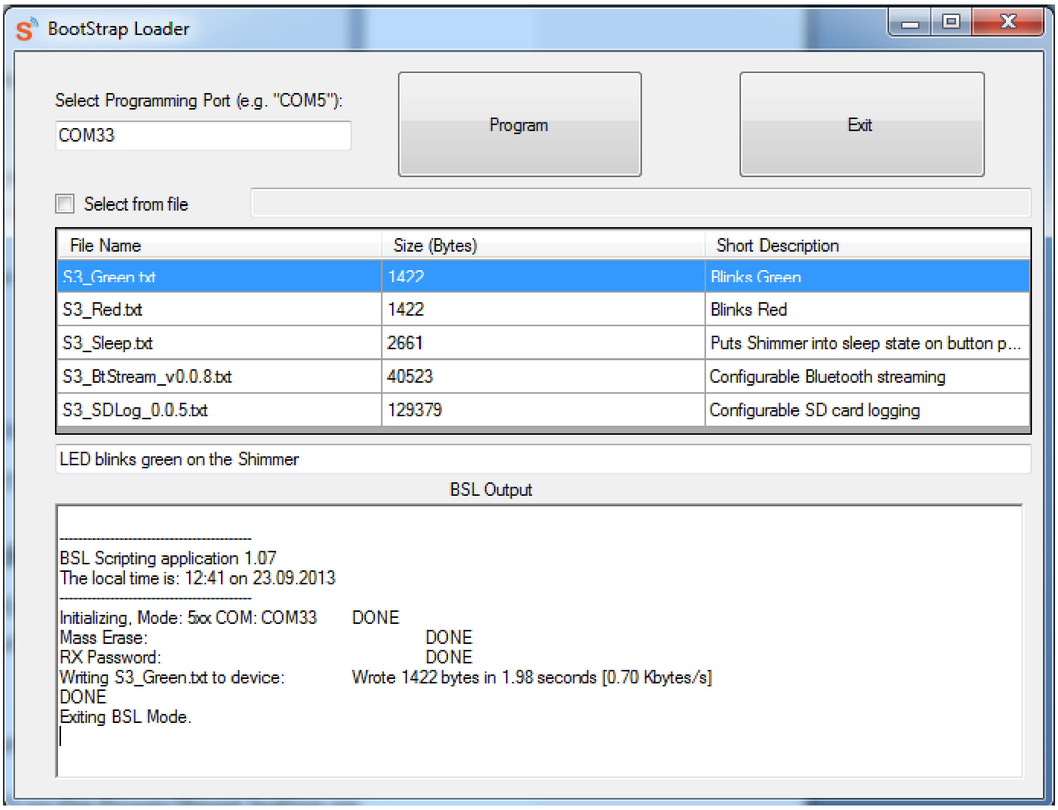

Figure 11: Shimmer Bootloader software application

When the firmware is successfully compiled, next step is to run the program and display the required data through Shimmer Connect. This application allow the user display and save all data received from shimmer streaming over Bluetooth by selecting the sampling rate, parameter, enable/disable sensor and power monitoring. When shimmer start streaming, the responding graph will display on the screen and it can be saved to a file and also converted to a table.

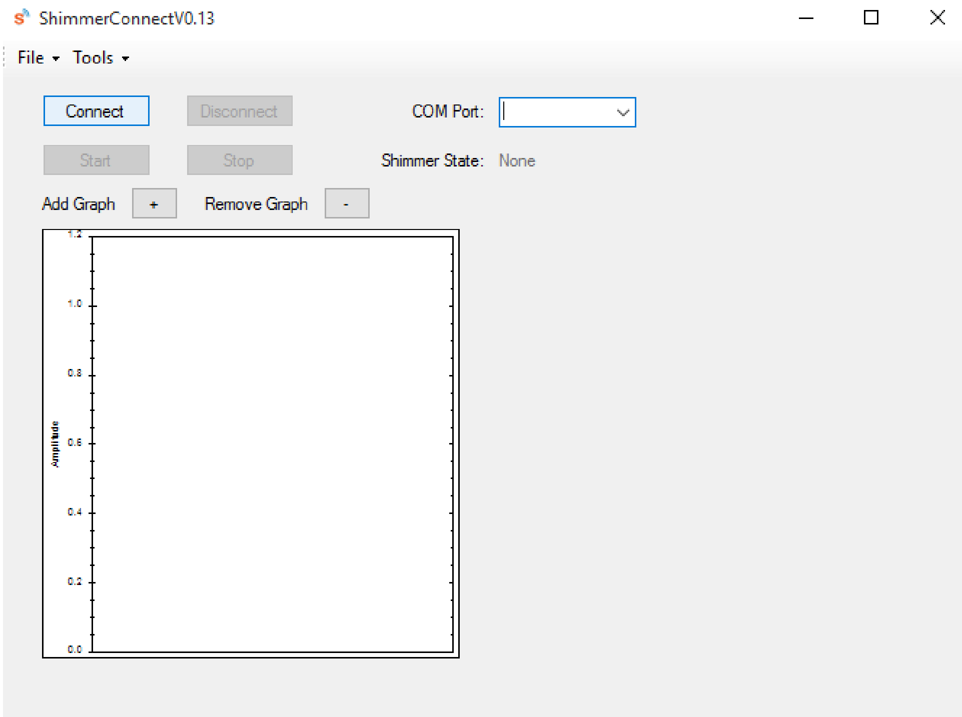

Figure 12: Shimmer Connect software application

For the microcontroller, Linux is used as the operating system instead of Windows since that Bluetooth for Galileo can run only in Linux. In other words, the rest of the works will execute in Linux before all saved data being transferred to the server.

3.5. Hardware-Software interface

When shimmer and PC are communicating via Bluetooth, packets of bytes are sent in both directions that consists of command, the first bytes sent is for identifier which to ask the user what type of interrupt need to perform. For serial communication or interrupt, normally shimmer will use Hexadecimal language and all the command can be found in BtStream's manual. By using Inter-Integrated Circuit (I2C), the analog data from the sensor were sent at clock rate of 1MHz and sampling rate of 51.2Hz.

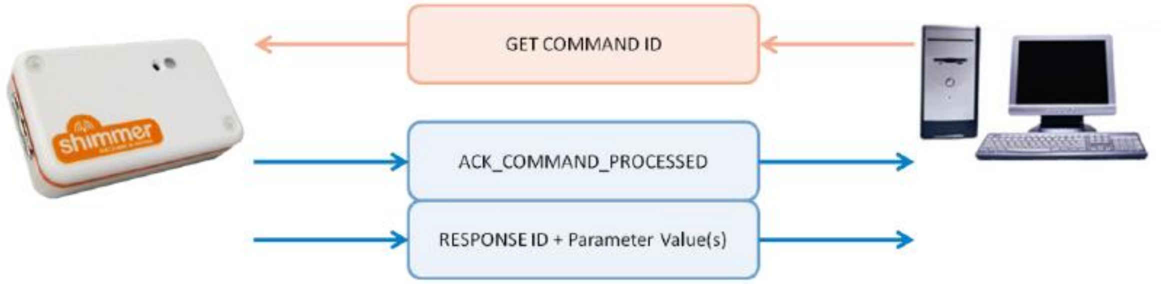

Figure 13: Packets sent for acknowledgement command

The command start with GET command to identify the first byte, for example GET_SAMPLING_COMMAND in hex. is 0X03. Shimmer will send the data back to host after received this command in two bytes, the first byte is for the command and second byte is for the command's value.

Shimmer GSR

To use GSR, the range for resistance value must be determined first:

Setting	Full Scale Range
0	10kOhm-56kOhm
1	56kOhm—220kOhm
2	220kOhm-680kOhm
3	680kOhm-4.7MOhm
4	Auto-range

Table 6: Setting value for GSR range

For easiest way, select the auto-range in order to auto-set the range based on the current reading. Theoretically, there is the formula to calculate the skin resistance by getting the inverse of skin conductance:

Resistance (Ω) = $\frac{1e6}{conductance(S)}$[15]

While range of current is based on two most significant Bits of shimmer output and the twelve least significant Bits give the ADC value.

1100 0000 0000 0000

Range **`ADC Value**

<u>Shimmer EMG/ECG</u>

EMG system is consists of amplifier, filter and analog-digital converter that will convert the analog input to digital by 24-Bit value for each sample. EMG will be connected to five electrodes consists of positive and negative terminal for two channels and one electrode for neutral. Every ADC output from EMG has 24-Bit digital format with relationship of:

EMG signal in mVolts = $\frac{((ADC\ output - ADC\ offset).ADC\ sensitivity)}{Gain}$[16]

Where

ADC sensitivity = $\frac{Vref}{ADC\ max} = \frac{2420mVolts}{2^{23}-1}$[16]

While the gain for this sensor is from a sine wave signal that generated from the electrodes with approximate 2 mV peak-to-peak with frequency 0.05Hz to 159Hz.

<u>Shimmer Bridge Amplifier</u>

To obtain the output load from the sensor, the voltage is measured in mVolts and ADC is measured from zero-load reading and desired reading.

After that convert the ADV(different) to Voltage(different) using ratio of:

3000mV/4095bits=Vdiff(mV)/ADCdiff(bits)[17]

4095 is the resolution of the shimmer 12bits ADC

Then the voltage must be divided by gain to compute load-cell output:

LCout(mV/V) = Vdiff(mV) / (2.8*gain)[17]

Load = LCout/Rout [17]

For the resistance value, it depends on voltage whereby:

Rs = $\frac{(200*10^3)Vo}{(10.1)Pv-Vo}$[17]

Pv=3V and Vo is measured in Volts.

3.5.1. Bluetooth interface

For the first step in this part, the interfacing between galileo and shimmer will be configured by using HC05. To stream the data from the sensor, HC05 have to be a master and the shimmer have to a slave. As per advised, the baud rate for the HC05 normally is 9600, current between10mA to 40mA and frequency of 2Hz. To pair the HC05 with shimmer, a program is used and in the Arduino IDE software to configure the serial port connection between galileo and HC05. In the program, HC05 will open the serial port and keep reading the incoming command from the user. At the same time, the serial monitor in the Arduino software should display all the command that have been sent to the HC05.

This interface using concept of 9600 8N1, which is 9600 baud rate, 8 data bits, no parity and 1 stop bit. For 9600 bps, the data will be transferred maximum of 8 bits then it will stop, and start again transferring if there any bit left.[18]

1	0	0	0	1	0	1	0	1	1	0	0	1
START	b0	b1	b2	b3	b4	b5	b6	b7	STOP	b0	b1	b2

Table 7: 9600 8N1 example

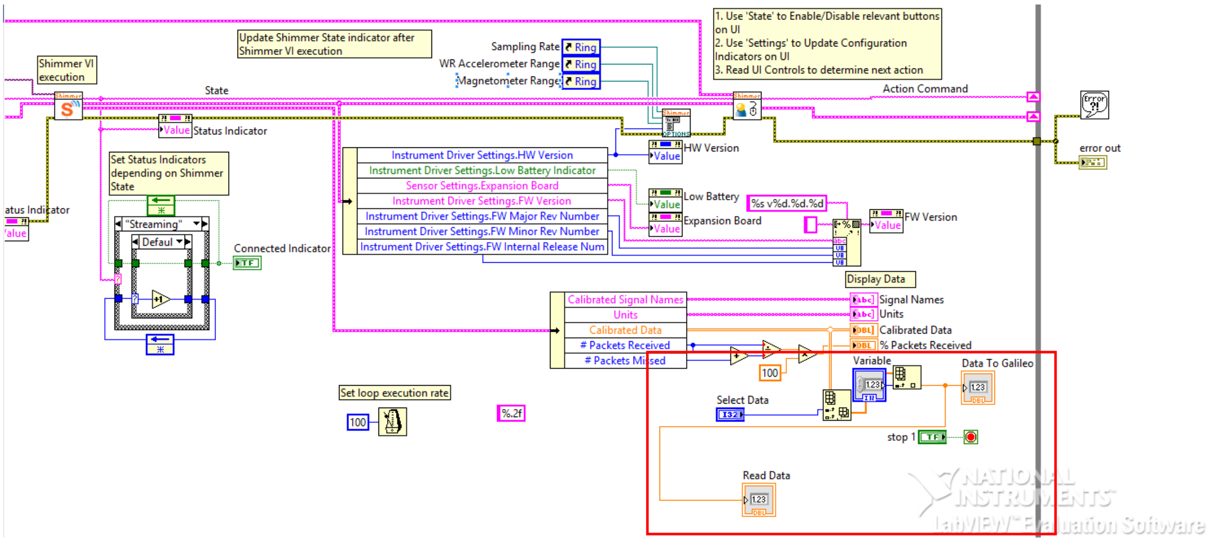

Figure 14: Block Diagram In LabView Software

Figure above shows the block diagram that has been made by shimmer for shimmer GSR sensor in LabView software. The block diagram inside the red box is the added block diagram to include the communication between galileo and shimmer. The received packets from the shimmer will be connected to the automatic switch to select the respective data in order to be read and display by the galileo as well. For the timestamp, shimmer will update each data for every 100ms while galileo is unable to grab that data because it’s too fast. In order for the galileo to grab every data that shimmer sent, delay is added on galileo’s port for 2 seconds, so that the galileo is able to process the previous data before it can grab new data from shimmer.

CHAPTER 4

RESULT AND DISCUSSION

4.1. Interface Testing

To make sure the communication between shimmer and microcontroller is working properly via Bluetooth, the interface has been tested by using RealTerm to configure the correct command to stream shimmer's data via Bluetooth. RealTerm is a serial communication software that perform operation such as controlling, debugging and capturing binary or other difficult stream data and it support Bluetooth communication. This software also allow only one command can be sent at one time, and the value can be displayed in various languages such as decimal and hexadecimal.

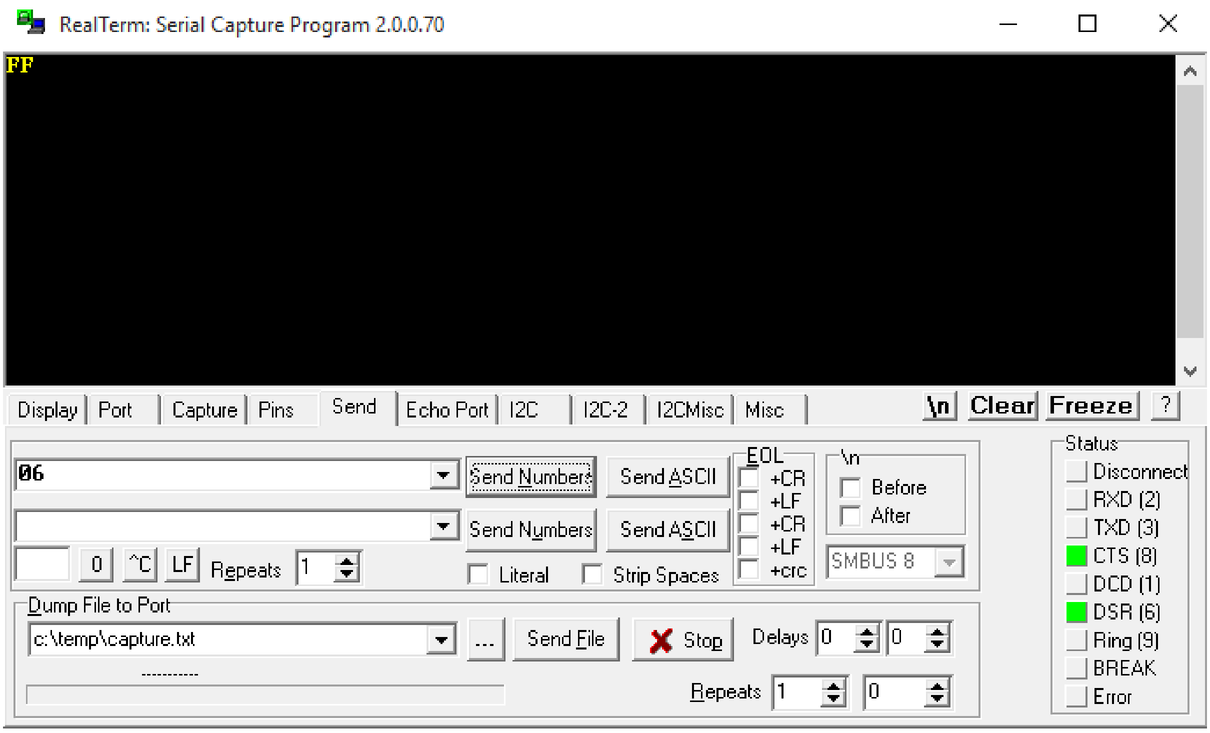

Figure 15: Interfacing between RealTerm and Shimmer

Figure 16:Normal LED

Figure 17: Toggled LED

Figure 15 shows an example of command that valid for shimmer sensor and the data received by RealTerm via Bluetooth communication. Based on shimmer.h command file:

Command	Hexadecimal
#define TOGGLE_LED_COMMAND	0x06

Shimmer is using hexadecimal language, when user want to send command for toggle the LED, they must send 06 number in order for shimmer to interpret the command and give a feedback. For the result, figure 16(a) and (b) show the feedback before and after the LED get toggled.

4.2. Measured Data

With Bluetooth communication, data can be displayed in serial monitor at certain times with specific parameter. The graph also has been converted into a table to analyse it and then makes the comparison of the output with different condition to ensure all the output are desired data. All data for this part are collected from the shimmer's software itself in order to have the theoretical value and to be compared with the experimental value for the next part.

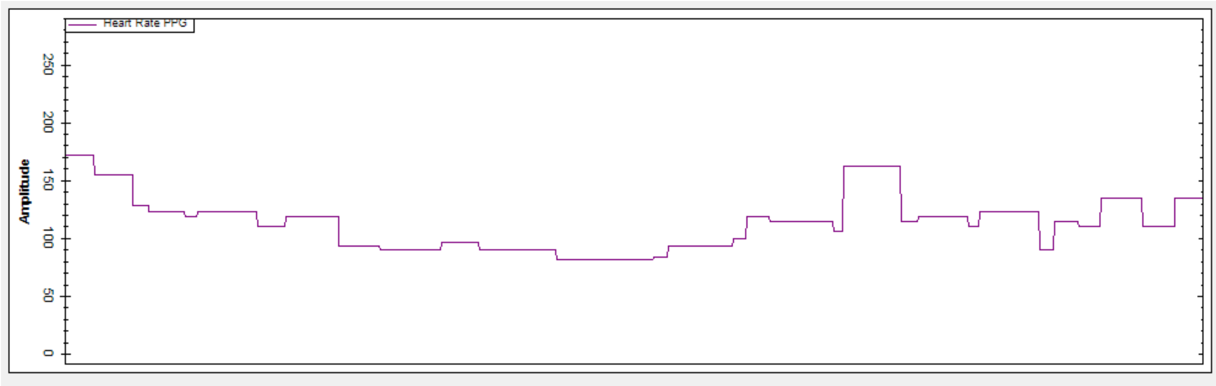

Figure 18: Heart Rate 1 Graph

	A	B	C	D	E	F	G	H
1	Shimmer	Shimmer	Shimmer	Shimmer	Shimmer	Shimmer	Shimmer	
2	Timestam	Timestam	Internal A	Internal A	GSR	GSR	Heart Rate PPG	
3	RAW	CAL	RAW	CAL	RAW	CAL		
4	no units	mSecs	no units	mVolts*	no units	kOhms*	Beats/min	
5	8320	506234.4	2078	1522.344	2026	20.54143	114	
6	8960	506253.9	2053	1504.029	1923	22.25031	114	
7	9600	506273.4	1818	1331.868	1862	23.40336	114	
8	10240	506293	1852	1356.777	1936	22.01911	114	
9	10880	506312.5	1776	1301.099	2030	20.48035	114	
10	11520	506332	1982	1452.015	2028	20.51084	114	
11	12160	506351.6	2023	1482.051	2138	18.95817	114	
12	12800	506371.1	2033	1489.377	2185	18.36419	96	
13	13440	506390.6	1901	1392.674	2145	18.86728	96	
14	14080	506410.2	2024	1482.784	2170	18.54968	96	
15	14720	506429.7	2113	1547.985	2130	19.06312	96	
16	15360	506449.2	2040	1494.505	2203	18.14645	96	
17	16000	506468.8	1945	1424.908	1976	21.33693	96	
18	16640	506488.3	1894	1387.546	2084	19.68988	96	
19	17280	506507.8	1872	1371.429	2045	20.25448	96	
20	17920	506527.3	2055	1505.495	1934	22.05436	96	
21	18560	506546.9	1827	1338.462	1895	22.76515	96	

Table 8 : Heart Rate 1 Table

Figure and table above shows the graph and reading for heart rate monitoring at certain times. This data was taken by user during his normal condition. For the output, the graph looks quite stable within the range of 96 to 170 bpm (beats per minute).

Theoretically, when people are in normal condition for example reading or watching television, the heart will beat consistently because during this condition, human will inhale and exhale consistently, so heart will pump the blood slowly to all over body time by time. In addition, the heart rate for sleeping people within 60 to 100 bpm, means the data collected which is 96 to 114 bpm is a normal reading and accepted.

In table 8, column A and B represent the timestamp in milliseconds, C is a row data collected for the heart rate while D is the same data in millivolts, E is a GSR raw data collected based on column C, F is the resistance value contents in the human body and G is the converted heart rate data. As shown above, for example in raw 5, the data that collected during 20.54kohm resistance with voltage of 1522.34 mV is the highest reading for the heart rate while in raw 12, the data that collected during 18.36kohm resistance with voltage of 1489.38 mV is the lowest reading for the respective time.

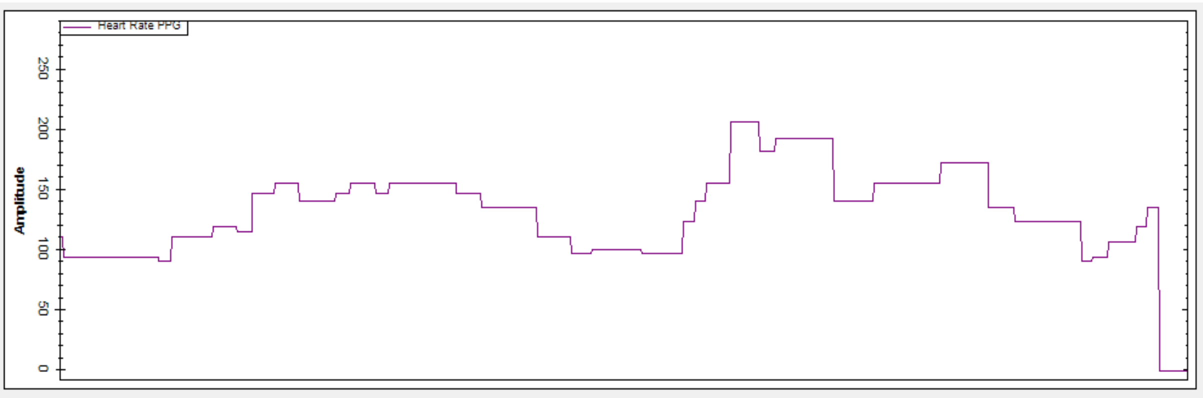

Figure 19:Heart Rate 2 Graph

	A	B	C	D	E	F	G	H
1	Shimmer	Shimmer	Shimmer	Shimmer	Shimmer	Shimmer	Shimmer	
2	Timestam	Timestam	Internal A	Internal A	GSR	GSR	Heart Rate PPG	
3	RAW	CAL	RAW	CAL	RAW	CAL		
4	no units	mSecs	no units	mVolts*	no units	kOhms*	Beats/min	
5	22272	502660.2	1974	1446.154	2006	20.8524	134	
6	22912	502679.7	1963	1438.095	1978	21.30393	134	
7	23552	502699.2	1897	1389.744	2081	19.73219	134	
8	24192	502718.8	1866	1367.033	2029	20.49558	134	
9	24832	502738.3	2005	1468.864	2095	19.53629	134	
10	25472	502757.8	1922	1408.059	1876	23.12829	134	
11	26112	502777.3	1910	1399.267	2088	19.63375	134	
12	26752	502796.9	1880	1377.289	2059	20.04812	134	
13	27392	502816.4	1820	1333.333	1894	22.78397	134	
14	28032	502835.9	1929	1413.187	1850	23.64441	134	
15	28672	502855.5	1842	1349.451	1907	22.54161	154	
16	29312	502875	1975	1446.886	1980	21.27103	154	
17	29952	502894.5	1900	1391.941	2077	19.78889	154	
18	30592	502914.1	1859	1361.905	2013	20.7425	154	
19	31232	502933.6	1959	1435.165	1968	21.46996	154	
20	31872	502953.1	1868	1368.498	2005	20.8682	154	

Table 9:Heart Rate 2 Table

Figure and table above shows the second graph and reading for heart rate monitoring at certain times. This data was taken by user when he starts to jump. For the output, the graph looks unstable within the range of 96 to 190 bpm (beats per minute).

Theoretically, when people are not in normal condition for example, when they are exercising or walking, the heart will beat inconsistently because during this condition, human will inhale and exhale faster than the normal one and sometime the time for inhaling and exhaling is not the same. In addition, the maximum heart rate for human normally is below 210bpm, means the data collected which is 96 to 190bpm is an accepted reading.

In table 9, for example in raw 15, the data that collected during 20.85kohm resistance with voltage of 1446.15 mV is the lowest reading for the heart rate while in raw 12, the data that collected during 22.54kohm resistance with voltage of 1349.45mV is the highest reading for the respective time. Noted that the data displayed in the table is randomly picked within the range in the graph just to show the relationship between the voltage, resistance and the heart rate.

4.3. Real Data

4.3.1. Shimmer GSR

For this part, all data are collected experimentally by using LabView. From this software, data will be streamed by Bluetooth from the galileo to the shimmer and display the output in LabView and LCD as well. Since shimmer is compatible with LabView with a complete block diagram for its sensor, the block diagram for the communication part between the shimmer and galileo is only added at the point of the data is collected.

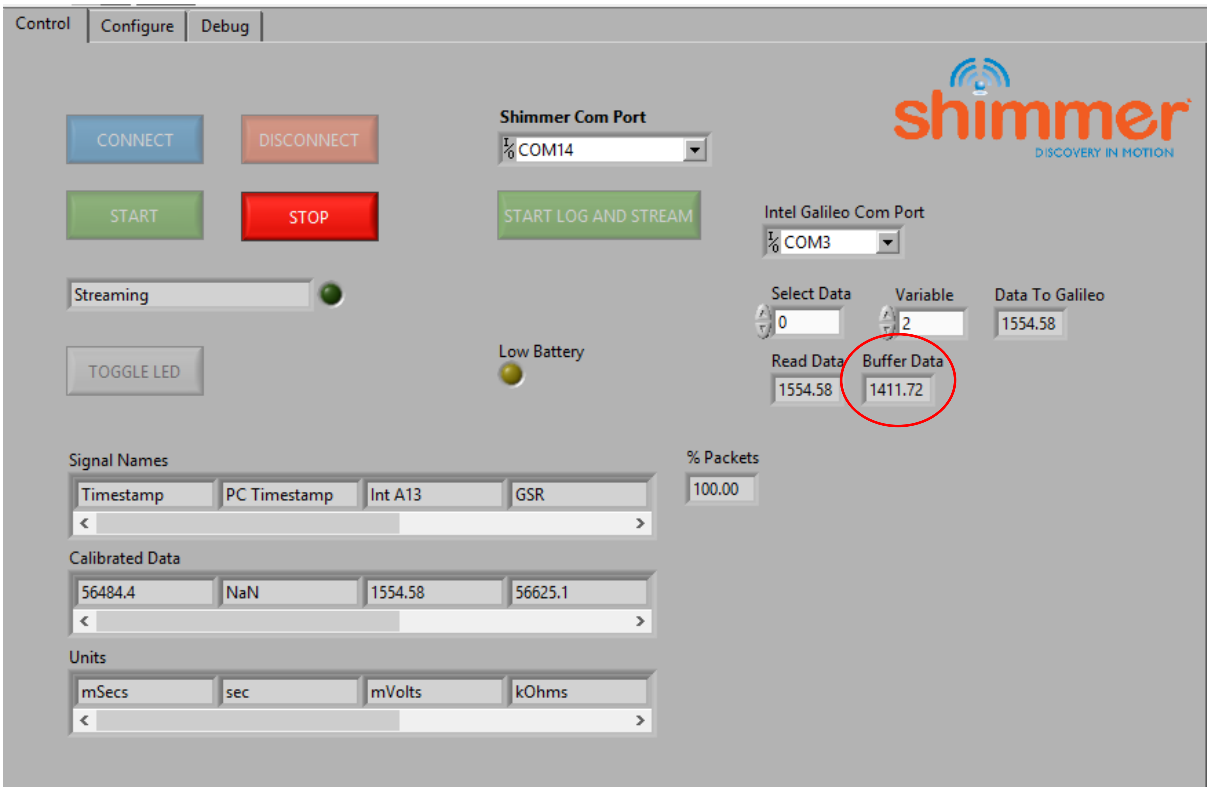

Figure 20 : Streamed data for Heart Rate in rest condition

Figure above shows the display of streamed data from the galileo to shimmer using LabView software. Read data is the data from shimmer and buffer data is the data that galileo grab from the shimmer. During rest condition at certain time, read data from shimmer is displayed as 1554.58 mV while the buffer data to the galileo is 1411.72 mV.

Since the time for the shimmer to update its data is 100ms per data while the time take for the galileo to grab data from shimmer is about 3s to 5s, galileo will randomly grab the data from shimmer within that time as a buffer data, that’s why the value between read data and buffer data is different. But the galileo correctly read the data from the shimmer because the read data for the shimmer and galileo are the same which is 1554.58 mV.

For this part of analysis, Int13 output port in unit of mV is represents the heart rate in bpm, which is the more value of mV, the higher the value of heart rate. Theoretically, output voltage from Int13 is represents the ADC value from the sensor itself. Sometimes the data from shimmer is not stable because the output voltage is influenced by the resistivity and quantity of oxygen in the human body.

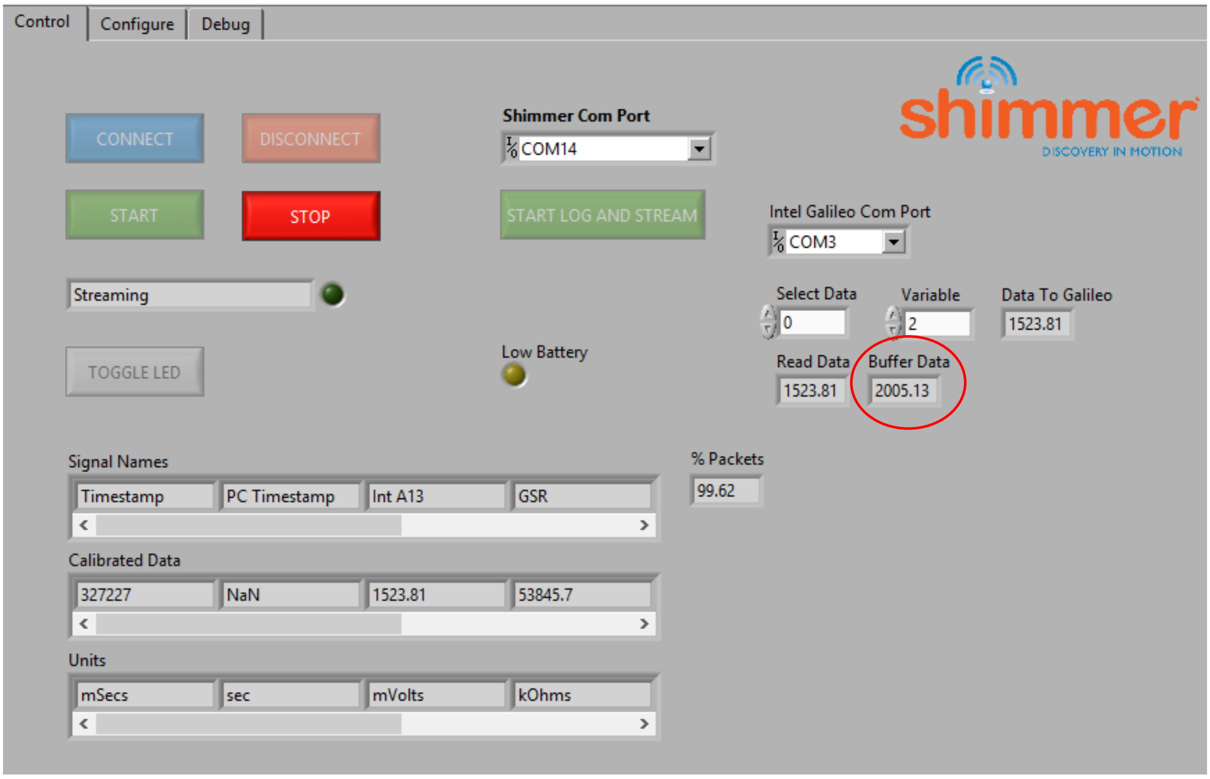

Figure 21: Streamed data for Heart Rate in active condition

Next step is to make a comparison between the output data in rest condition and active condition. In previous part, the buffer data is 1411.72 mV but as shown in figure 21, the buffer data is increasing to 2005.13 mV. This proved that the shimmer gets high of ADC value for heart rate at this condition rather than previous one. In other words, during active condition human will exhale and inhale in short time makes heart to pump blood faster, this will make heart rate getting higher. For the result, it will give higher ADC value and voltage.

In simple words, the results from the measured data and real data is reliable and effective due to the theory of heart rate is measured.

4.3.2. Shimmer Bridge Rectifier

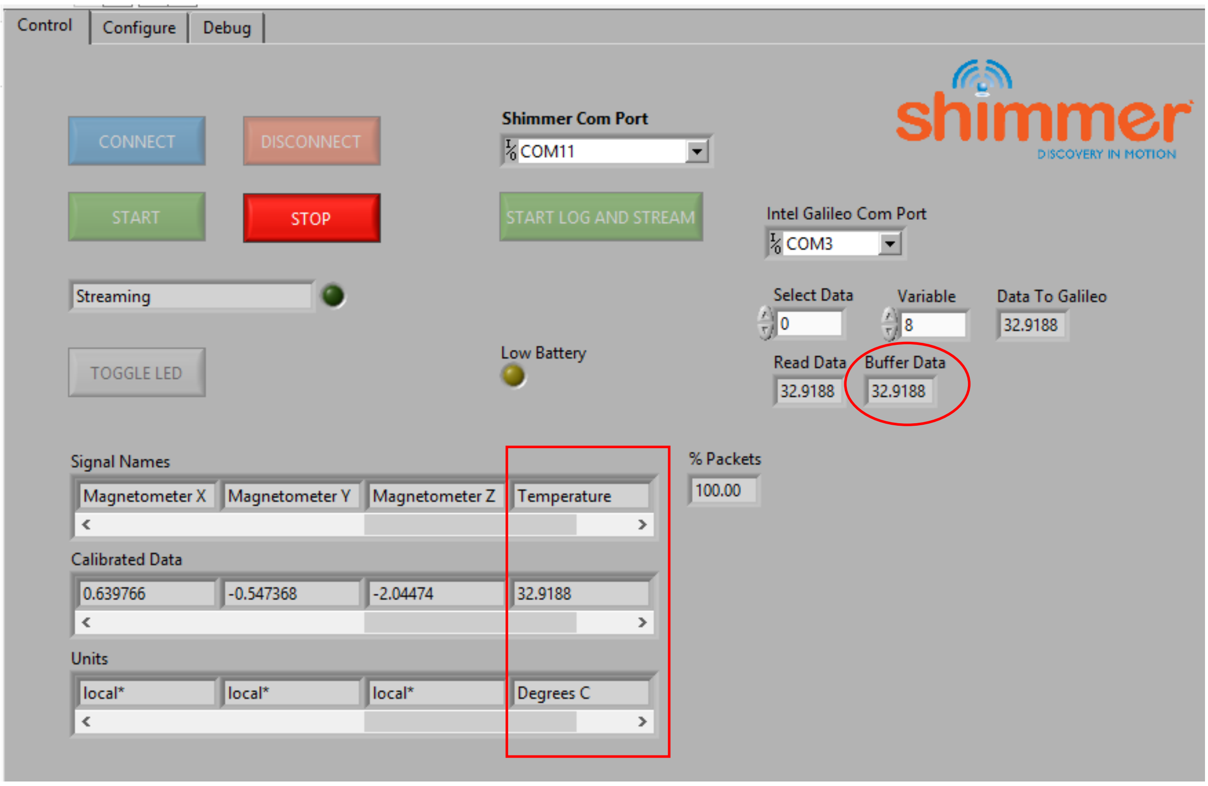

Figure 22: Body Temperature

This data is get from shimmer Bridge Rectifier sensor that shows clearly the body temperature in degree Celsius with com port 11 and sent to the galileo in port 3. The read data from shimmer is 32.9188°C, since temperature is a slow process reaction and made shimmer took some times to update the data makes the data that galileo grabbed which is buffer data is same with read data. Theoretically, the normal body temperature for human is about 37°C which is higher than the experimental value. The value is actually depending on the body resistivity during the data is collected, so the lower the resistance value, the higher the temperature value.

Temperature (°C)	Resistance (kΩ)
-18	16.8
10	9.3
26	4.5
37	1.5
80	0.55

Table 10 : Relationship Between Temperature and resistivity

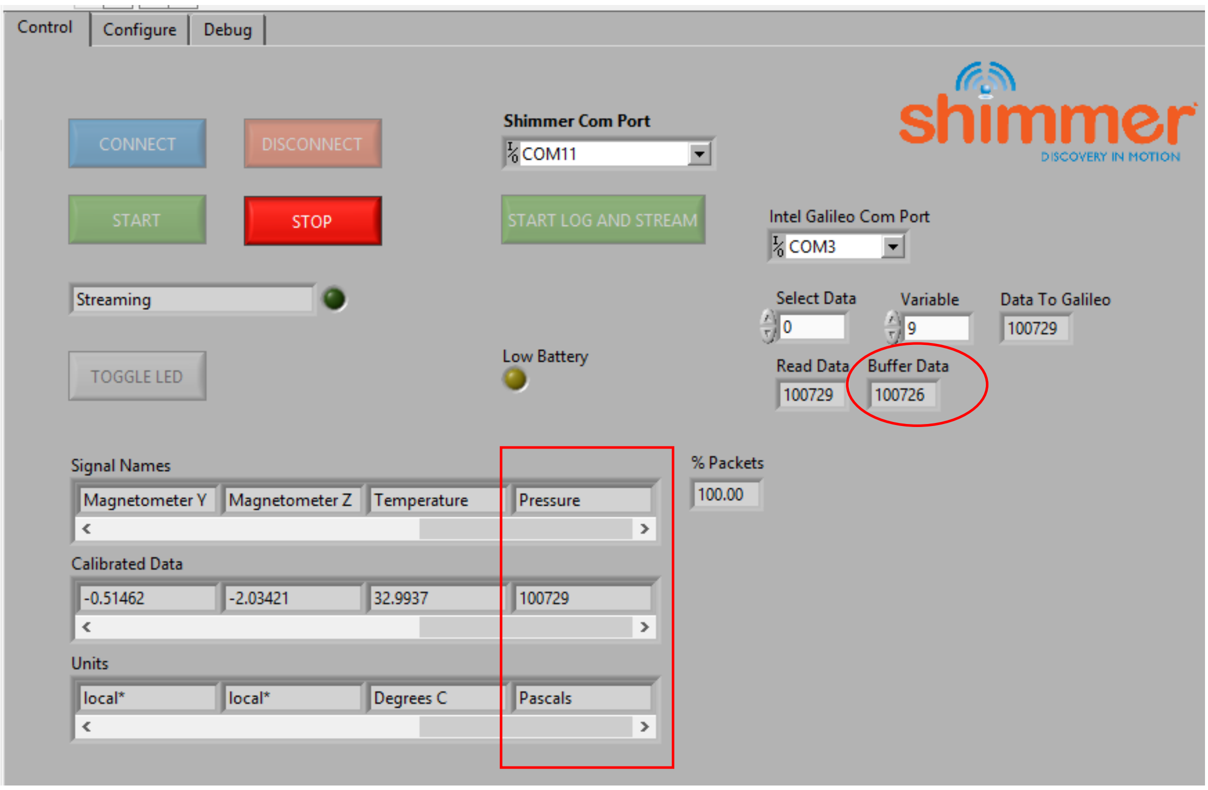

Figure 23: Body Pressure

Figure above shows the body pressure for user by using same sensor as before with unit of Pascal. The data streamed from shimmer is 100729 Pascal but buffered data is 100726. The value is not same because of the delay during grabbing the data makes galileo to grab the random data during that time but the data shimmer and galileo has received is still same and correct.

4.3.3. Shimmer ECG/EMG

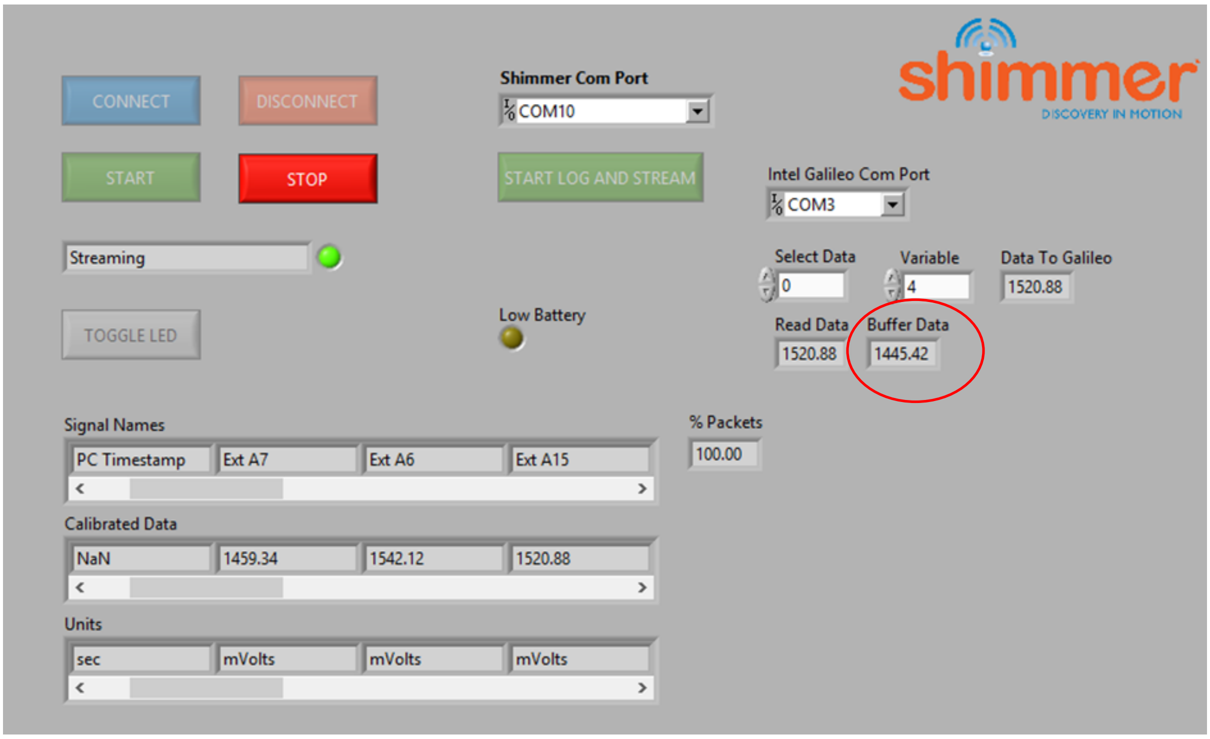

Figure 24 : Streamed data during rest condition

Figure above shows the streamed data from Shimmer ECG/EMG during rest condition with com port 10 for shimmer and port 3 for galileo. In this part, displayed data for galileo is 1445.42mVolts which means in this condition the muscle is not doing any work or does not contract and makes the electricity value in the muscle is lesser.

During this condition, the electrode inside muscle is far away each other makes the electricity moves slower in the body. When this situation happened, the nerve conduction velocity becomes slower and lowering the output voltage.

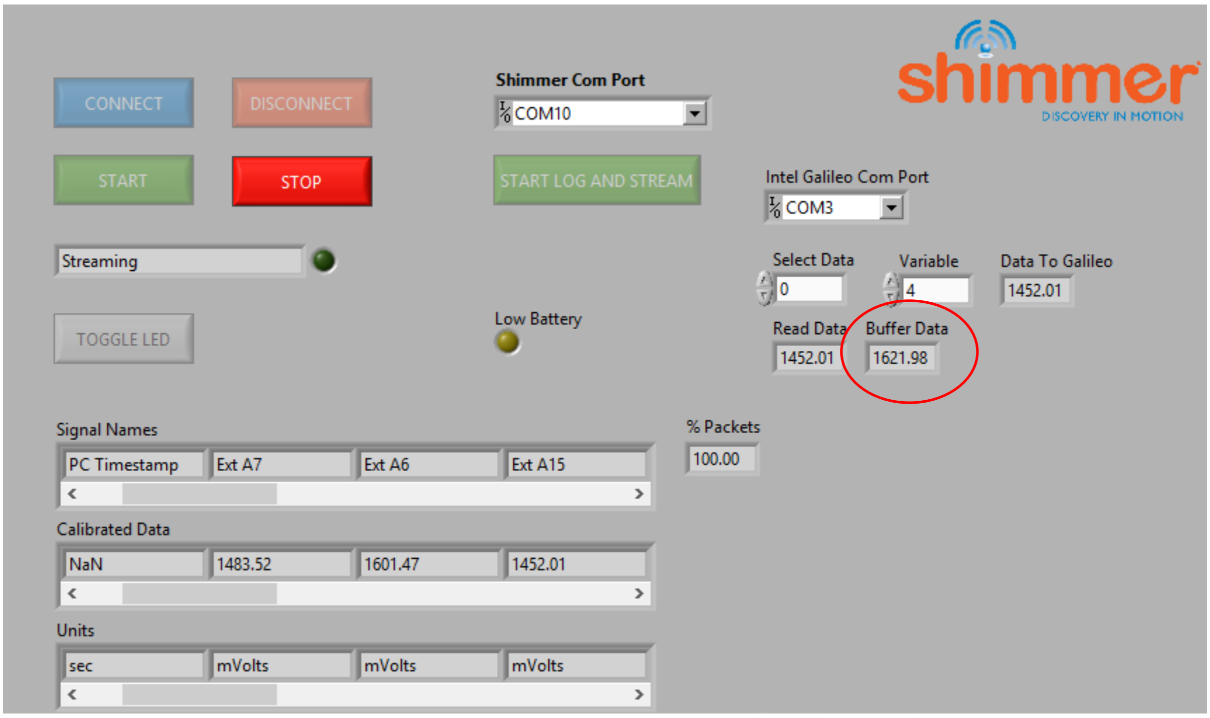

Figure 25: Streamed data during active condition

Figure above shows the streamed data from Shimmer ECG/EMG during active condition. In this part, displayed data for galileo is 1621.98mVolts which means in this condition the muscle is doing works and contracting each other, makes the electricity value in the muscle becomes higher. During this condition, the electrode inside muscle is located besides each other and makes the electricity moves faster in the body.

When this situation happened, the nerve conduction velocity becomes faster and make the output voltage higher. When it comes to situation where the tissue in the muscle get damaged, the output voltage become much higher than normal reading. This situation also can be traced by the sensor in effective ways to ensure that our body stay healthy.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

The previous research regarding wearable sensors has been done in many ways, but it is focusing more on fitness purposes and basic health care of the person instead of for choric diseases and hospitalized purposes. In conclusion, this project is focusing on designing several sensors for wearable application that are able to be controlled and interpreted by microcontroller in order for data to be send to server. Based on case study, a deeply research has been done for selecting the best sensor that can match with the specification needed in this project. The purpose of using microcontroller in this project is because it can operate like a ‘small’ computer on a single integrated circuit that contents several important functions and are able to control the shimmer systematically. The most important part for this project is the type of interfacing that will be used in order the enable the communication between shimmer and microcontroller via Bluetooth. I2C communication bus will be used in this project since that it only required normal speed for data transferring and support multi master configuration so no need to select the slave.

5.2. Recommendations

For Future purposes, the experiment should be conducted by using shimmer ECG/EMG and bridge rectifier to see more various result from various parameters in human body. This is important to make sure the method used in order to get this project done is strongly proven correctly and precisely. Besides that, the real data can be displayed in term of graph instead of one to one data to make the analysis process is done easily and systematically. Graph is the best way to see the changes data during the experiment for the rest and active condition for the real data, by this method we can observe the stability of buffer data from the read data for both condition precisely.

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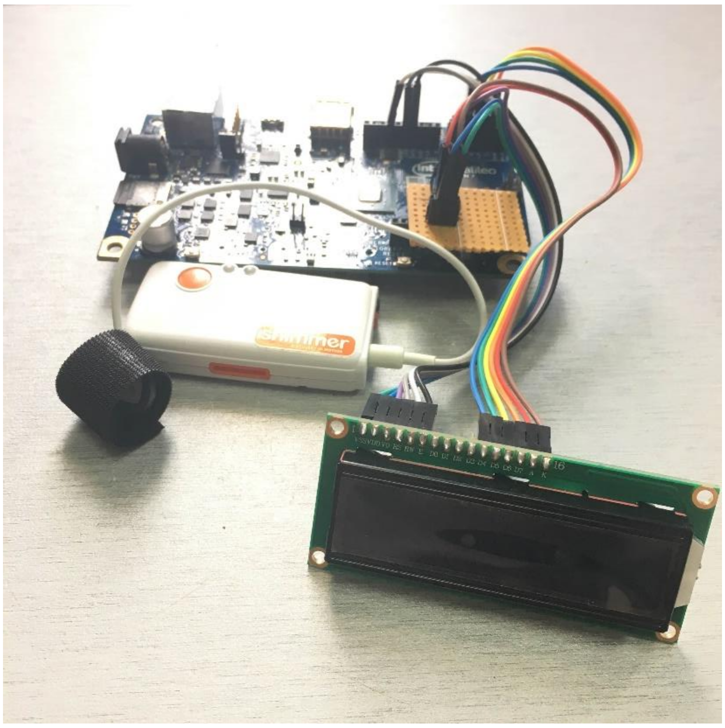
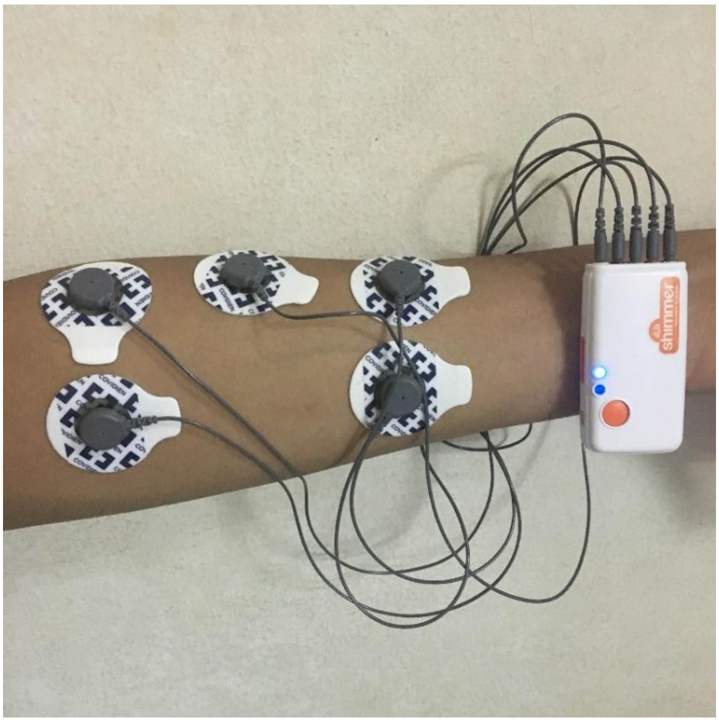
APPENDICES



APPENDIX I: Wearable Sensor's Application



APPENDIX II : Shimmer ECG/EMG's application

APPENDIX III : Shimmer GSR's application

APPENDIX IV : Shimmer Bridge Rectifier's application