LOW COST WIRELESS SURFACE EMG ACQUISITION SYSTEM

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A report submitted in partial fulfillment of the requirements for the degree of Bachelor in Electrical Engineering (Control, Instrumentation and Automation) with Honours

Faculty of Electrical Engineering
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2015

I declare that this report entitle “Low Cost Wireless Surface EMG Acquisition System” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Author :NUR AMALINA BINTI AHMAD SHOBANI

Date :

Dedicated, in thankful appreciation for support, encouragement and Understandings to my beloved mother and father,

Khalijah bt Suid,

Ahmad Shobani b Haji Ibrahim

and those people who have guided and inspired me throughout my journey of education.

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ABSTRACT

A low-cost wireless surface EMG acquisition system has been designed for general purpose human-machine interaction. The system includes disposable surface EMG sensors, wireless communication using Bluetooth modules and signal analysis unit. Surface EMG acquisition system has been developed for the measurement of electrical activity of muscles and validates the design prototype of lowest wireless acquisition system. Generally, Bluetooth has an advantage which is almost ubiquitous technology and universally compatible and a wide variety of devices employ it. In this study, the system uses three channels of electrodes that sense muscles activity potential in microvolt and was wireless to transferred to the device with limitation 1kb per seconds. The low cost wireless was design using Bluetooth module. Its EMG signal is friendly and also reliable for users with high flexibility in being significant proposition in modern biomedical engineering surrounding. All through the process, the signal was acquisited from muscle activity. Besides that, the implementation of designing the command to configure the signal obtains to be transmitted to the computer's software using MATLAB and software of ARDUINO.

.

ABSTRAK

Satu rangkaian tanpa wayar direka untuk mengambil data Electromyography (EMG) dan bertujuan sebagai alat interaksi antara manusia degan mesin (manusia-mesin). Sistem ini menggunakan alat pengesan EMG serta modul Bluetooth tanpa wayar dan isyarat analysis sebagai perantaraan untuk menunjukkan graf EMG tersebut. Dalam tajuk ini membincangkan kaedah untuk meghasilkan prototaip tanpa wayar kos rendah serta mengambil ukuran arus elektrik yang dihasikan pada pergerakkan otot. Bluetooth mempunyai kelebihan teknologi yang bersifat universal dan mendapat perhatian daripada peranti-peranti lain. Dalam projek ini, sistem ini menggunakan tiga sensor (*disposable electrode)* mikrovolt dan rangkaian komunikasi tanpa wayar menggunakan Bluetooth. Sistem ini merupakan salah satu cara yang digunakan dalam bidang kejuruteraan serta mempunyai fleksibilti pengguna yang tinggi disebabkan sistem ini adalah mesra pengguna. Secara kesuluruhan, sistem ini di bina untuk mengambil data EMG di dalam otot dan menghantar isyarat ke komputer mengunakan kaedah tanpa wayar dan di klasifikasikan menggunakan perisian didalam komputer iaitu MATLAB serta ARDUINO.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	ACKNOWLEDGEMENT	**iv**
	ABSTRACT	**v**
	ABSTRAK	**vi**
	TABLE OF CONTENTS	**vii**
	LIST OF FIGURE	**x**
	LIST OF TABLE	**xi**
	LIST OF APPENDICES	**xii**
1	**INTRODUCTION**	**1**
	1.1 Background	1
	1.2 Problem Statement	2
	1.3 Objective	2
	1.4 Scope of Project	3
	1.5 Thesis Overview	3
2	**LITERATURE REVIEW**	**4**
	2.1 Introduction	4
	2.2 Principle of Electromyography	4
	2.3 Anatomy and physiology of the muscle contraction `	5
	2.4 Type of muscles in the hand	7
	2.5 Generation of EMG	7
	2.6 Advantages and disadvantages of EMG signal	7
	2.6.1 Advantages of EMG signal	7
	2.6.1 Disadvantage of EMG signal	7
	2.7 Bluetooth Wireless Communication	8
	2.8 Advantages of Bluetooth Communication	9
	2.9 Architecture Overview of Bluetooth Communication	9
	2.10 Related work done is EMG based low cost wireless surface EMG acquisition system	11
	2.10.1 Surface Electromyography (EMG)	11
	2.10.2 Low-cost wireless	12

		2.10.3 Hand movement	13
3	**METHODOLOGY**		**14**
	3.1	Introduction	14
	3.2	Block Diagram	14
	3.3	Flowchart	15
	3.4	The implementation of ARDUINO interface with shield EKG by using real-time data	17
		3.4.1 Placement of EMG electrode and the technique of signal acquisition	18
		3.4.2 Disposable Electrode	19
		3.4.3 Shield	20
		3.4.4 ARDUINO UNO	22
	3.5	Develop Low Cost Wireless using ARDUINO UNO and Bluetooth	23
		3.5.1 Placement of EMG electrode and the technique of signal acquisition	23
		3.5.2 ARDUINO UNO	24
		3.5.3 Bluetooth modules	24
		3.5.4 Bluetooth Module HC-05	25
	3.6	Chapter Summary	27
	3.7	Key Milestone	28
	3.8	Gantt chart	29
4	**RESULT AND DISCUSSION**		**30**
	4.1	Introduction	30
	4.2	Design different gesture	30
	4.3	The processed of EMG Signals	31
	4.4	Data Surface EMG during off-line time with filter	32
	4.5	Chapter Summary	

5	**CONCLUSION AND RECOMMENDATION**		**40**
	5.1	Introduction	40
	5.2	Conclusion	40
	5.3	Recommendation	41
	REFERENCES		**42**
	APPENDIX		**44**

LIST OF FIGURE

FIGURE	TITLE	PAGE
2.1	Different body muscles and structures	5
2.2	Generation of EMG	8
2.3	Structures of Bluetooth network	10
2.4	Bluetooth scatternet diagram	10
3.1	Block diagram of wireless surface EMG acquisition system	14
3.2	Flow Chart of Project	16
3.3	Block diagram process of EMG signal	17
3.4	Block diagram of EMG based control system	17
3.5	Muscles and their Architecture	18
3.6	Disposable electrodes with a single 3.5mm plug connector	19
3.7	Alcohol Pad	20
3.8	Top layout of the shield	21
3.9	Bottom layout of the shield	21
3.10	Main parts of the shield board	22
3.11	ARDUINO UNO front	22
3.12	ARDUINO UNO back	22
3.13	USB cable	23
3.14	Connection between ARDUINO UNO and Bluetooth HC-05	24
3.15	Symbols of Bluetooth	25
4.1	Five different gesture of wrist join	30
4.2	Structure Process Low Cost Wireless Surface EMG acquisitions System	31
4.3	Low Cost Wireless Surface EMG acquisition System Hardware	32
4.4	Maximum amplitude for each muscle	38
4.5	Maximum amplitude for each muscle	38
4.6	Maximum amplitude for each muscle	38

LIST OF TABLE

TABLE	TITLE	PAGE
3.1	Requirements and Description needed for volunteers	15
3.2	Gain and frequency used	21
3.3	Example of command Test in serial connection	25
3.4	Example of command Reset in serial connection	26
3.5	Example of command Restore default status in serial	26
3.6	Example of command module Bluetooth address in	26
	Serial connection	26
4.1	Forearm Muscles and Functionality	33
4.2	Signal from gesture Ulnaris Wrist Flexion (UWF)	34
4.3	Signal from gesture Ulnaris Wrist Extension (UWE)	35
4.4	Signal from gesture Wrist Extension	36

LIST OF APPENDICES

APPENDICES TITLE	PAGE
Appendix A: Bluetooth HC-05	44
Appendix B: Package size information	45
Appendix C: The circuit connect the module to 5V serial port of MCU	46

CHAPTER 1

INTRODUCTION

1.1 Background

This study is focusing on developing a low-cost wireless system recording for general purpose human-machine interactive control and prosthetic system. The system includes a disposable surface EMG sensor, wireless communication module, and signal analysis unit.

Surface EMG is the comprehensive reflection of biological signal on the skin surface during muscle contraction which contains abundant and accurate motion information.

Generally, Bluetooth is one of an open standard for wireless that using for Personal Computer [PC] to be connected with supporters. In wireless communication, most commonly devices that enable to send and receive communicate are Bluetooth and Wi-Fi. In this project, Bluetooth module was choosing because it are low cost, robustness and have low power. For example, innovative solution which is users can perform include printing or faxing capabilities, laptop or computer making or receiving call from a mobile phone, with many more application available.

The proposed low-cost wireless acquisition system is composed by main three parts. The parts are surface EMG sensor, Bluetooth acquisition module and signal analysis module. Surface EMG sensors amplify the analog signals and filter the surface EMG signal. The wireless acquisition module sends the control instruction from the PC client and transmits the surface EMG signals from sensors to the PC client (desktop). The analysis modules send the control instruction to set the parameters of data acquisition module as well as receive, analyse and display surface EMG signals on the screen.

1.2 Problem Statement

The purpose of this study is to develop a low cost wireless as hardware and record the data surface EMG acquisition system. This low cost wireless must be robust wireless communication capable to recorded, transmit and transfer data surface electromyography (sEMG) to personal computer [PC] client. This study also provides the student with experience in the development process from the conceptual to the implementation. The idea to develop this project occurs to:

1. The development surface EMG acquisition system and a low-cost wireless which are trustworthy, comfortable for users and for a minimum cost.
2. Produce general purpose human-machine especially for athletes.
3. Intensive research work on prostheses innovative using for arm surface EMG.

1.3 Objective

The goal of this project is to develop a low cost wireless surface EMG acquisition system. The main objectives to ensure the successful of the project are as follow:

i. To develop a low-cost wireless acquisition system for different gesture of surface EMG signals.
ii. To validate the design prototype of low cost wireless acquisition system accurately.

1.4 Scope of the Project

This project, the overall focus on develops a low-cost wireless system and surface EMG acquisition system. In order to verify the practicability of this project, it was designed a prototype with ARDUINO Uno to test the filter circuit, and acquisition performance. Experimental test will be carried out in three (3) subject average age twenty

one (21), average height on hundred and sixty cm (160), and average weight around sixty kg (60). The limitation range of the Bluetooth connection is between 5-20 meters.

1.5 Thesis Overview

This thesis the design a low cost wireless surface EMG acquisition system. Generally, all the process is done in this project is describing by each chapter. The overview of all chapters can be simplified as follow:

Chapter 2 presents the study that related to previous project. From the study of previous paper improvement to make sure the project completed. This is important in order to make sure this project is satisfied.

Chapter 3 discusses the methodology of the development low cost wireless system and applied data surface EMG in ARDUINO UNO to display at MATLAB (PC). In this chapter, it consists of open block diagram and flow charts which are explained about the process of develop this project. It also discusses briefly how it work properly and designed.

Chapter 4 is discussing and displaying all the result obtained and the limitation of this project. All discussions are concentrated on the result and the overall performance of the wireless communication and real time data EMG signal

.

Chapter 5 in overall is discussing the conclusion and summary of the development of low cost wireless surface EMG acquisition system. In this chapter also conclude the overall project implementation and its future recommendation.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, the theory involved in the design of a low-cost wireless surface EMG acquisition system has been studied. Other than that, the design has been clearly started with the research work that has been done by previous analysis of this low-cost wireless surface EMG acquisition system. In the past, many strategies and methods have been implemented in solving this surface EMG and how to construct a wireless system.

2.2 Principle of electromyography

Electromyography (EMG) investigates the capacity of muscle trough dissection of the electrical indicators exuded throughout husky compressions. Electromyography is rating the electrical activity that is connected with the enactment of the muscle which happens automatically due to the muscle comprehension. At the depolarization limit, the movement possibilities of the engine nerve will dreive the muscle fibre to contract. The happening will cause the production of the electromagnetic field. The depolarization that moves between the films of the muscle is known as the muscle activity potential. The engine unit activity is the spatial and transient summation of the singular muscle movement possibilities for all the filaments of the solitary engine unit. Subsequently, the EMG indicator is the arithmetical summation of the engine unit movement possibilities inside the pick-up zone of the node being utilized [1].

2.3 Anatomy and physiology of the muscle contraction

In human body, muscles are the most delicate tissue that lies under most creatures' skin. Biological term, muscle consists of protein, fibre of mission that slide past each one in turn. Handle a constriction that changes both the length and the state of the cell. Essentially, muscles are fundamentally obliged to keep up and derive carriage, momentum and also developing inward organs. As an example, the restriction of heart and also the evolution of livelihood through digestive framework by means of peristalsis. Muscle tissues are inferred from the mesodermal layer of embryonic germ cells in a methodology known as myogenesis. There are three sorts of muscle, skeletal or striated, cardiovascular, and smooth. Muscle movement might be thought-out, being either voluntary or automatic. Heart and smooth muscles contract automatically, while the skeletal muscles contract upon summons. Muscles are transcendentally fuelled by the oxidation of fats and carbs, however anaerobic concoction responses are additionally utilized, especially by quick twitch strands [2]. These compound responses produce adenosine triphosphate (ATP) atoms which are utilized to power the development of the myosin heads [2].

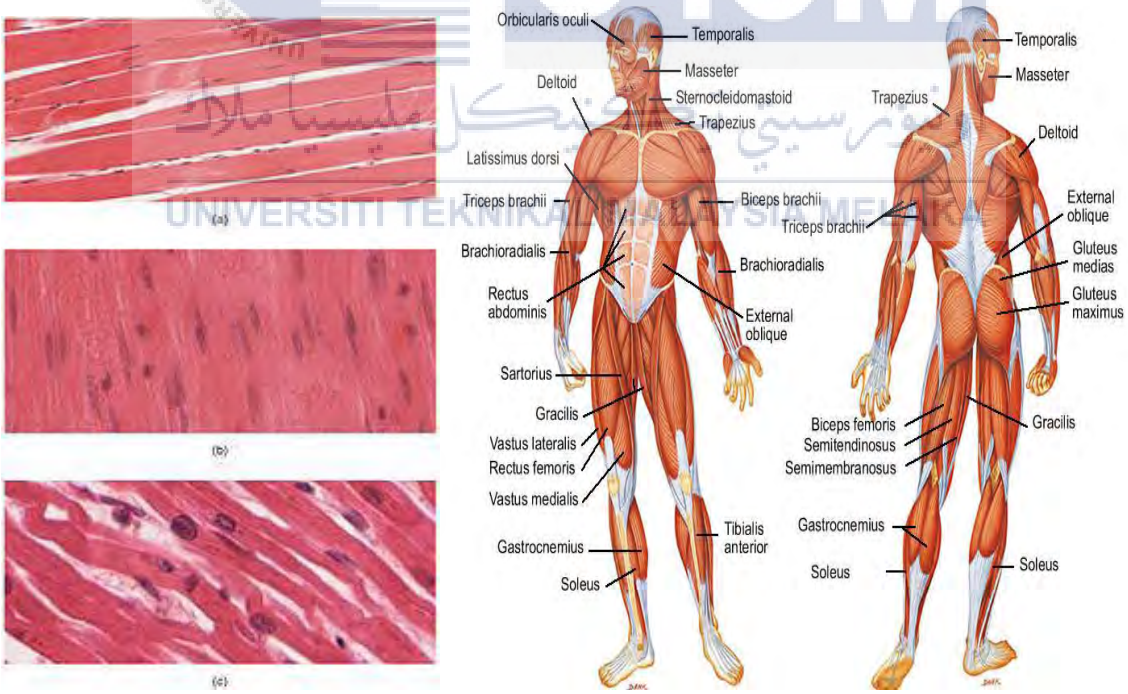


Figure 2.1: Different body muscles and structures [2]

The important contrasts part has three sorts of muscle (skeletal, heart and smooth) which each have noteworthy contrasts. So, that every one of the three utilizes the development of acting against myosin to make constriction. In skeletal muscle, compression is invigorated by electrical driving forces transmitted by the nerves, the motoneurons (engine nerves) especially. Cardiovascular and smooth muscle constrictions are empowered by inner pacemaker cells which customarily contract, and proliferate withdrawals to other muscle cells they the neurotransmitter acetylcholine.

2.4 Type of muscles in the hand

As known, human's hand are the most unpredictable as well as complicatedly structure which are allow to move depends on the brain's development. Biological term, in human body there are 60 different muscles that will work as one to complete the tasks. Flexion and broadening of the hand phalanges of fingers are proficient by extraneous muscles of the hand (of those of the lower arm). Exact finger developments that require the coordination of snatching and adduction with the flexion and expansion are practically the assignment of the little inalienable muscles (those inside) of the hand. The natural muscles of the hand are further separated into the thenar (concerning palm on the thumb side) and hypothenar (concerning palm besides the little finger), and the halfway gatherings. The extensions between the hand and the lower arm is the wrist (or carpus), a gathering of eight little bones fitted together in a cobblestone system and bound set up by solid ligaments. The posterior forearm muscle are basically the muscle that control the movement of the fingers. These muscles works along the tendons at the wrist to help both the wrist and the hand to express movement. Alternately, they join to tendons that stretch out along each one finger are installed in long sheaths on the palm side of the hand. When, the lower arm contracts it pulls on the tendons and the sheath to twist the finger. There are a circle inside the wrist permits the 180 switch on the top to the bottom of the hand is called pronation and supination. For every single fingers of human's hand carries on correspondingly to each other and has comparative musculature. While the thumb is also remarkable itself. The thumb is greatly vital to the hand's adaptability on the grounds that it restricts alternate fingers, which implies we can squeeze a little question between the thumb and finger to lift it up.

2.5 Generation of EMG

The EMG is produced when an engine neuron movement potential the spinal line lands at an engine and plate. Its landing causes an arrival of Ach (Acetylcholine) at the synaptic separated (1) with causes a depolarization (Action Potential). This activity potential electrically voyages descending from the surface in a transverse tubule (2). This thusly causes an arrival of Ca++ (3), bringing about cross-extension trying (4) and the sarcomere of the muscle to get (5). An electromyography (EMG) is an estimation of the electrical movement in muscles as a side effect of constriction. An EMG is the summation of movement possibilities from the muscle filaments under the anodes set on the skin [3]. If there more muscles that fire, it will be more amazing the measure of movement possibilities recorded and the more stupendous the EMG perusing.

2.6 Advantages and disadvantages of EMG signal

EMG has both advantages and disadvantages

2.6.1 Advantages of EMG signal:

i. EMG is cheaper in comparison to another technique.
ii. EMG can gives a lot of data which are both scalar and continuous.
iii. EMG also identify for more muscular activity than visual measurement.

2.6.2 Disadvantages of EMG signal:

i. EMG is very noisy
ii. Natural expression may alter.
iii. Surface EMG has channel crosstalk

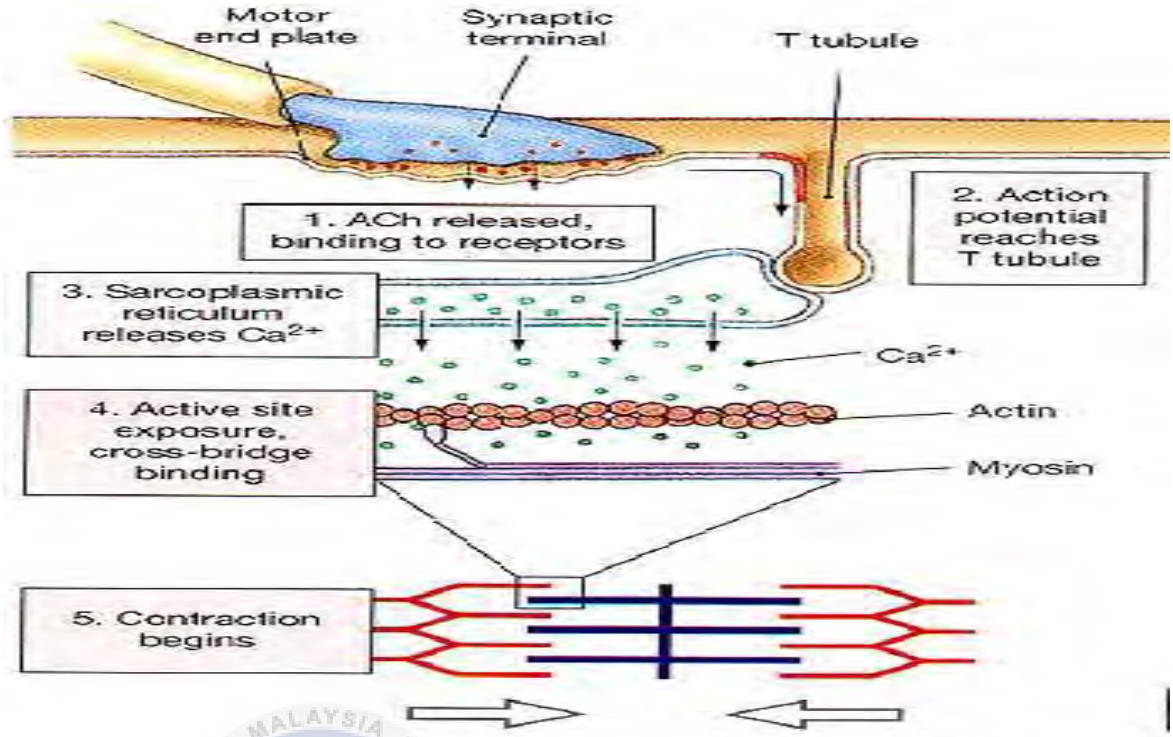


Figure 2.2 Generation of EMG [3]

2.7 Bluetooth Wireless Communications

Bluetooth is one of an open standard method for data wireless communication. Mostly Bluetooth are connected with supporters from the PC and the cell phone industries. Generally, Bluetooth is primary market data and voice transfer between communication devices and theirs connected units. Bluetooth use a method short radio links to take over cable between computer and their connected units. Bluetooth using a similar way with IrDA protocol that using radio frequency (RF) 2.5 GHz industrial, utilizing and medical (ISM) band. Application Bluetooth includes PC peripheral networking, hiding computing and the data synchronizing. Bluetooth is designed to be low cost, however it has a limited connection distance and the transmission speed. Bluetooth can only support 780 kb/s that can used for 721 kb/s unidirectional data transfer (57.6 kb/s return back direction) or it can up until 432 kb/s symmetric data transfer.

2.8 Advantages of Bluetooth communication

Bluetooth have several advantages. Advantages of Bluetooth technology are

i. Bluetooth is using to transfer information between two or more devices such as IrDA and HomeRF,
ii. Suite to low-bandwidth like transferring data.
iii. Ability to simultaneous handles both data and transmission.
iv. Bluetooth have capability to support one asynchronous data channels and voice channels.

2.9 Architecture Overview of Bluetooth Communication

Based on the Figure 2.3, it illustrated Bluetooth specification link to control hardware and link manager portions by using integrated as one chip or a radio module and base-band module, implements the RF, baseband. This hardware did not just control reception and radio transmission, but it also need the digital signal processing for the baseband protocol. The function includes establishing connection, support asynchronous (data) and synchronous (voice) link, the connection error and the authentication. This link manager firmware produce with baseband CPU performs low-level device discovery, link setup, authentication, and link configuration. Link manager are provides two devices communication which is utilizes the services of the underlying link controller (baseband) and provide a host controller interface (HCI) as a standard interface to software.

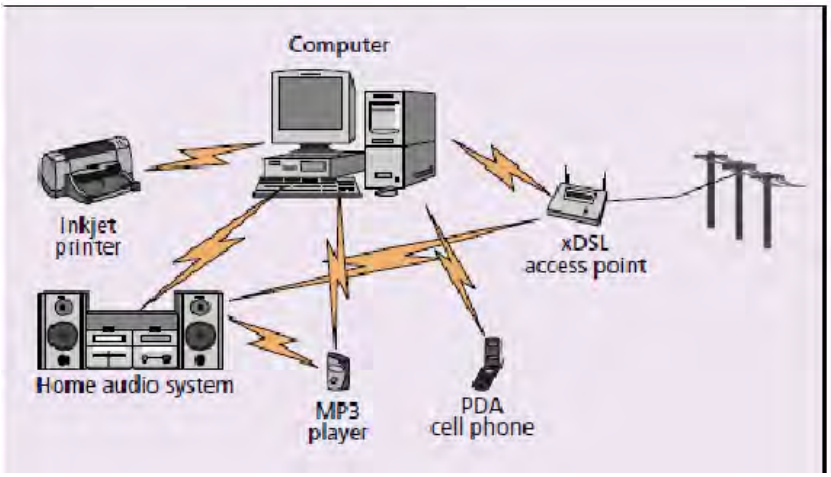


Figure 2.3: Structures of Bluetooth network

From the Figure 2.3 shows the structure of Bluetooth network for the configuration of Bluetooth system through towards numerous applications. This hardware control inkjet printer, home audio system, MP3 player, PDA cell phone and xDSL access point.

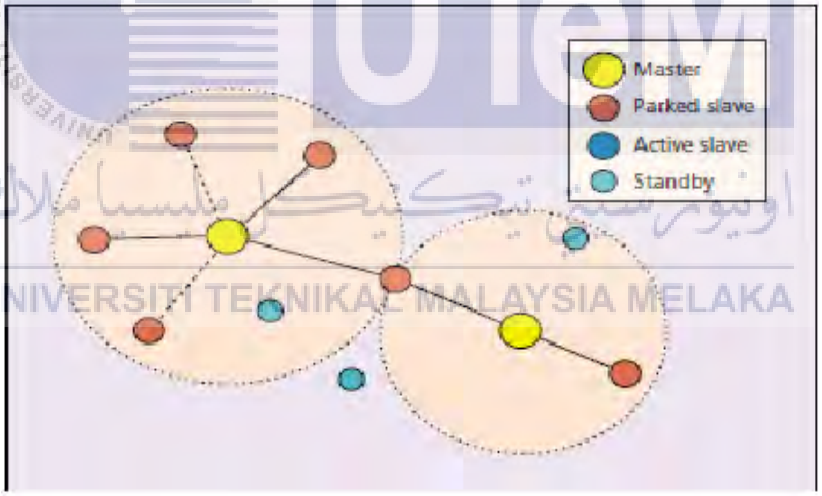


Figure 2.4: Bluetooth scatternet diagram

From the legend in the Figure 2.4 above, the Bluetooth scatternet diagram can be explained groups of two eight devices that called piconets. The colours of yellows is a single master devices, red for parked slave device, blue for active slave devices and light blue for standby. Generally, the was connected between piconets and scatternet.

2.10 Related works done is EMG based low-cost wireless surface EMG acquisition system

2.10.1 Surface Electromyography (sEMG)

Surface EMG uses when a muscle contracts, electrical activity is generated within the muscle which may be measured using electrodes placed on the surface of the skin. This electrical signal is usually the order of up to 3,000 micro volts and is referred to as electromyography or EMG. First EMG is about a Wireless sEMG recording system and application to muscle fatigue detection, 2012 [4]. Surface electromyography (sEMG) is an important measurement for monitoring exercise and fitness. Because if it high sampling frequency requirement, wireless transmission of sEMG data is a challenge. In this article a wireless sEMG measurement system with a sampling frequency of 2 KHz is developed based upon an MSP 430 microcontroller and Bluetooth transmission. Muscle fatigue detection is an important application of sEMG. Seconds, this article title is about Low Cost Surface Electromyography Signal Amplifier Based on Arduino Microcontroller, 2014 [5]. In the study, the sampling capacity of the Arduino microcontroller Atmel Atmega328 with an A / D converter with 10-bit resolution and its reconstructing capability of a signal of surface electromyography are analysed. This paper also show, how to design the Arduino and gain the data EMG. The development a low cost EMG signal acquisition system using surface EMG electrode are present their main of further analysis process[6]. Electromyogram or EMG signal is a very small signal; it requires a system to enhance for display purpose or for further analysis process. This paper presents the development of low cost physiotherapy EMG signal acquisition system with two channel input. In the acquisition system, both input signals are amplified by a differential amplifier and undergo signal pre-processing to obtain the linear envelope of the EMG signal. Obtained EMG signal is then digitized and sent to the computer to be plotted. Then, an Integrated Surface EMG Data Acquisition System for Sports Medicine Applications by Vinod, A.P.; Chai Yee DA [7]. This paper presents the design and implementation of a PC-based integrated surface electromyogram (sEMG) data acquisition system for the measurement of electrical activity of muscles, efficiency of electrical activity, explosion power (response velocity), and fatigue degree. These parameters are most imperative to physical assessment in sports medicine. The system's hardware consists of four (4) basic units which are detection units, signal conditioning unit, signal processing unit and multi-channel analog to digital

converter unit. The graphical user interface displays the EMG signal waveform and extracted parameters.

2.10.2 Low-Cost wireless

Low- cost wireless will be built in order to minimize the cost. One of the examples of low-cost wireless is built a low-cost wireless sensor system and its application in dental retainer written by Brandl, M.; Grabner, J.; Kellner, K.; Seifert, F.; Nicolics, J.; Grabner, S.; Grabner, G [8]. In this paper, they have shown a wireless interrogable sensor device based on an ultra-low-power microcontroller for data collection and radio frequency identification (RFID) interface of data transmission is presented ultra-low-power and low-cost wireless temperature data logger system is presented with its application in observing dental retainer use. The seconds, the paper research about a low-cost wireless system for measuring energy efficiency in industry [9]. The relevant data is collected from by multiple nodes, provided with sensors and located at the key points in the factory. After that, the system has been implemented and tested in a meat processing company. By this way, companies can know their energy efficiency and take appropriate actions to improve efficiency. The third papers are research about Electrocardiogram (ECG) Monitoring System using Bluetooth technology [10]. In this thesis there using Bluetooth wireless as a prototype for wireless ECG monitoring system and able to read ECG signal from the patient, also send a signal via using Bluetooth link and after that display the ECG waveform at the personal PC [11]. Bluetooth that using at the project can permit the ECG monitoring system. The system consists three part which is the ECG sensors, signal processing circuit also PC and display interface. The electrical signal can detect from patients body after Bluetooth are enable to monitor ECG system circuit and the sensor detect the ECG. In this project, they use between Bluetooth module connection and USB dongle connected to assembly language and can processed digital signals through layers of wireless networking application.

2.10.3 Hand Movement

In this classification method of hand movements using multi-channel electrode written by Nagata, K.; Adno, K.; Yamada, M.; Magatani, ., K [12], they described a classification method of hand movements using 96 channels matrix-type (16x6) of multi-channel surface electrode. There are many systems that use the EMG as a control system. That system has 96 channels electrode to solve some of those conventional problems. Only attached the electrode, they can obtain the correct EMG this way means provide a simple and easy way. They study how to develop of the EMG pattern recognition method using multi-channel electrode. Seconds' paper has written by Hassan M.A ET all present about Classification of the Imagination of the Left and Right Hand Movements Using EEG [13]. This paper shows how brain computer detect imagination of the left and right movement that can be used to control a wheelchair accordingly. Fortunately, any form of movement make by the imagination of left and right hand will cause some brain activity. That circumstance will allow the electrical signal to be detected by the electroencephalogram electrodes. Hence, plenty of researches have been done in order to fulfil the desirable of the hand movement.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter provides discussion of the methodology used in conducting this study of Low Cost Wireless Surface EMG Acquisition System. Its begin with brief explanation of project study, where general methodology used in conducting this project is discussed. The process discusses design low cost wireless both in hardware and the software using ARDUINO and Bluetooth. The description, circuit operations and the modes of operation circuit are presented.

3.2 Block diagram

Figure 3.1: Block diagram of wireless surface EMG acquisition system

The block diagram in Figure 3.1 is about the system structure. The proposed low-cost wireless acquisition system is composed of three parts, that is surface EMG sensors, Bluetooth acquisition model and signal analysis module. Surface EMG sensors amplify the analog signals and filter the surface EMG signals. The wireless acquisition module receives the control instruction from the PC client and transmits the surface EMG signals from sensor to the PC client. The EMG signals will be via Bluetooth acquisition module

transmitted which will be gathered in the analysis module for validation step resulting signal display on PC client.

3.3 Flow Chart of the Methodology

The coding of Bluetooth connection is designed using Arduino UNO and validates the data using MATLAB to show the graph of EMG signal. The graph will show to prove the effectiveness of the Bluetooth that function as a wireless. The flow chart of the project is shown in Figure 3.2.

Firstly, the objective, problem statement and scope of study are identified as a guideline for this project. Moving on, with collecting data on the journal, article, report, mini project and some of them have been explain in Literature Review. Then, second step begin with how to build a low cost wireless.

First, there are a few volunteers needed for some tests. These volunteers need to follow the stated guidelines in table 3.1 which are:

Table 3.1: Requirements and Description needed for volunteers

Requirements	Descriptions
Age	21 to 24 years old
Height	More than 160cm
Weight	More or less than 60kg

The EMG signal are taken by placing electrodes at the selected muscles which are the extensor carpi ulnaris muscle, flexor carpi ulnaris muscle and extensor carpi radialislongus muscle. The data taken are raw and eventually get filtered in MATLAB, and eventually the real time EMG data get transferred to a Bluetooth (wireless). Hence, the Bluetooth will send the signal into a personal computer (PC) in order to show the signal on the screen.

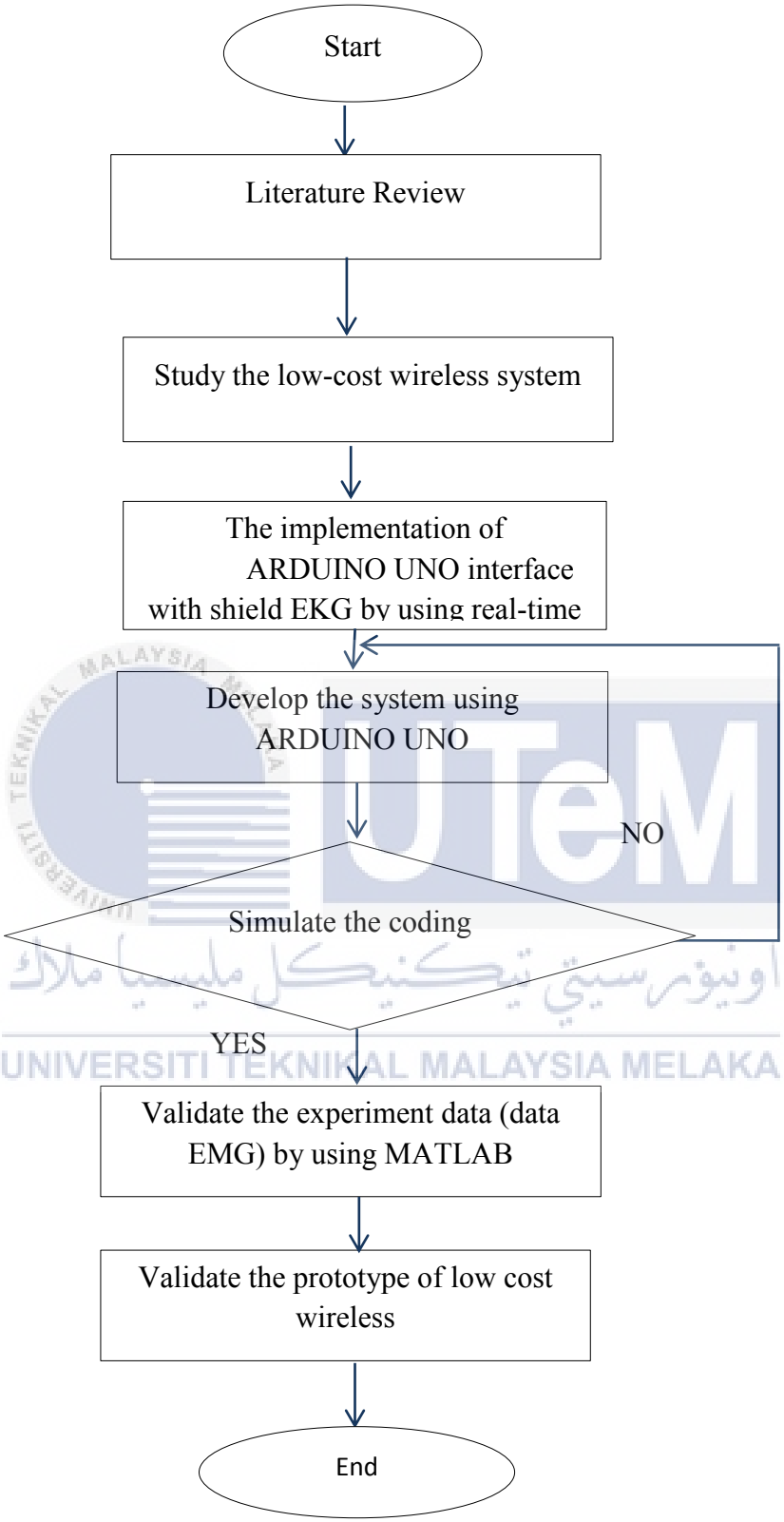


Figure 3.2: Flow chart of the project

3.4 The implementation of ARDUINO interface with shield EKG by using real-time data

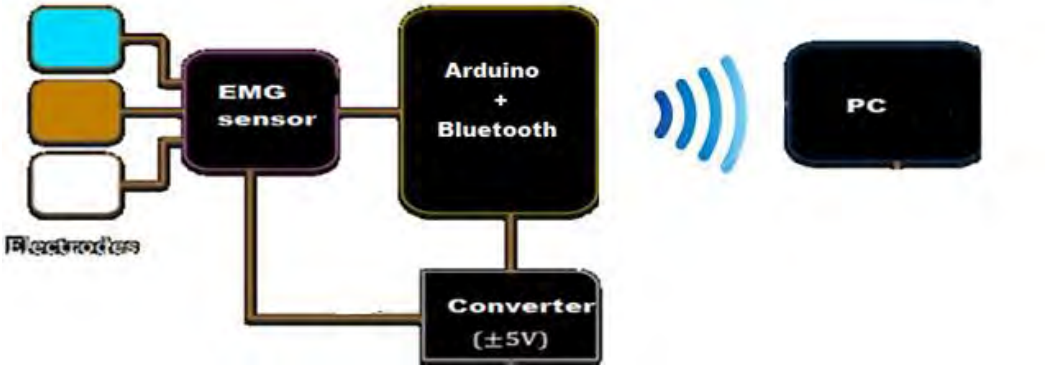


Figure 3.3: Block diagram process of EMG signal

Figure 3.3 show block diagram process of EMG signal. EMG signals are detect and measure from surface EMG electrode that provides a non-invasive. The electrodes form a chemical equilibrium between the detecting surface and skin of the body through electrolytic conduction that current can flow into electrode. Application of disposable electrode EMG is to detect current flow muscle activity and control the devise extensions to achieve prosthesis for physically disabled and amputated population. After that, real time data will send the signal into personal computer (PC) in order to show the signal on the screen.

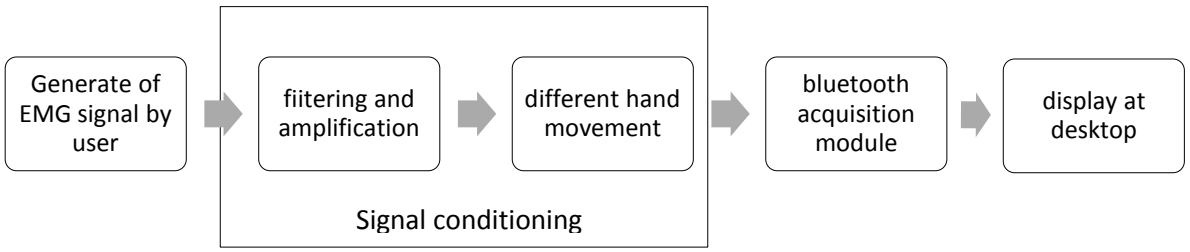


Figure 3.4: Block diagram of EMG based control system

Figure 3.4 shows the block diagram of EMG based control system, first signal will be generated by user according through placing the electrode. After that, filter the signal conditioning by using MATLAB. The data will send through Bluetooth acquisition module and will display the signal at Personal Computer [PC].

3.4.1 Placement of EMG electrode and the technique of signal acquisition

EMG electrodes more difficult compared surface EMG that easy to relate. This is because it is extensively used in robotic mechanisms to get the prosthesis. Usually surface EMG widely use in rehabilitation prosthesis as it will does not course any kind of discomfort to the subject or people. In order to get the best sEMG, the important thing is find the suitable muscles that EMG signal can be extracted. But not only that, skin preparation one of the important part to know as well. Two type of electrode have been used in muscle signal (invasive electrode and non-invasive electrode). When the EmG signal are required from electrode directly from the skin, the signal was composite all muscle fiber occur in the muscles underlying skin.

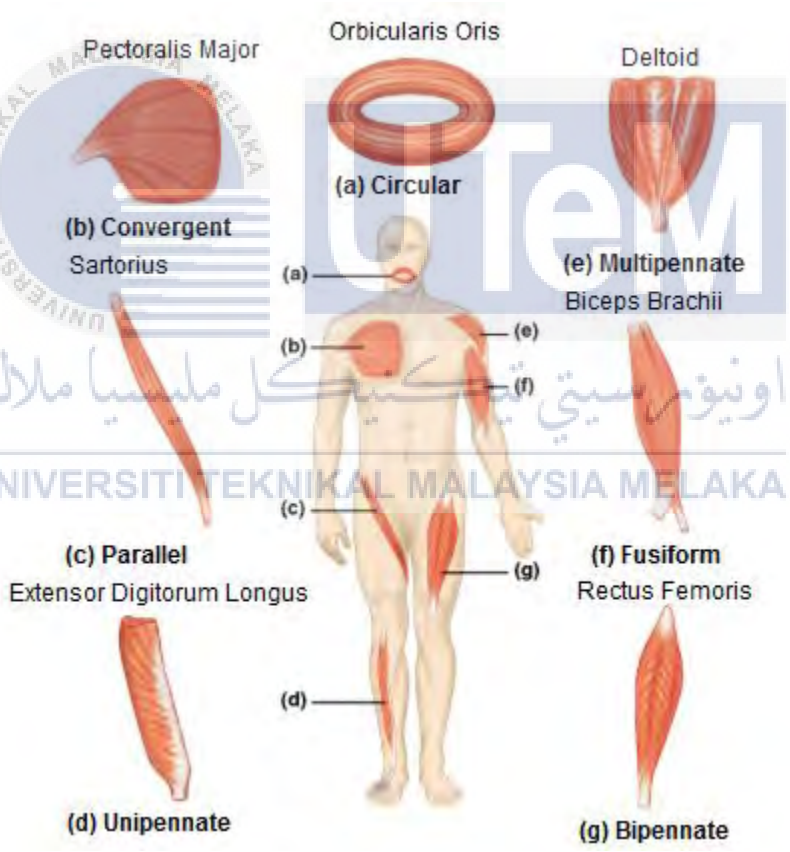


Figure 3.5: Muscles and their Architecture

3.4.2 Disposable Electrode

The electrode sensor used in this study besides muscle at the hand is the disposable electrodes. The sensors consist of three electrode connected with one 3.5mm plug

connector, and each electrodes usually consists of a sensing element (snap) in contact with an electrolyte (gel). The function of electrolyte is to minimize the gap between electrodes and skins, and also to reduce resistance.

Once the electrode placed on the surface of the skin, the skin becomes an integral part of the circuitry, and the noise level in the signal can be high if there is a slightest air gap between skins and electrodes. Figure 3.6 below shows the three disposable electrodes connected in a single 3.5mm plug connecter and these electrodes connected to the shield board in order to obtain the signal.

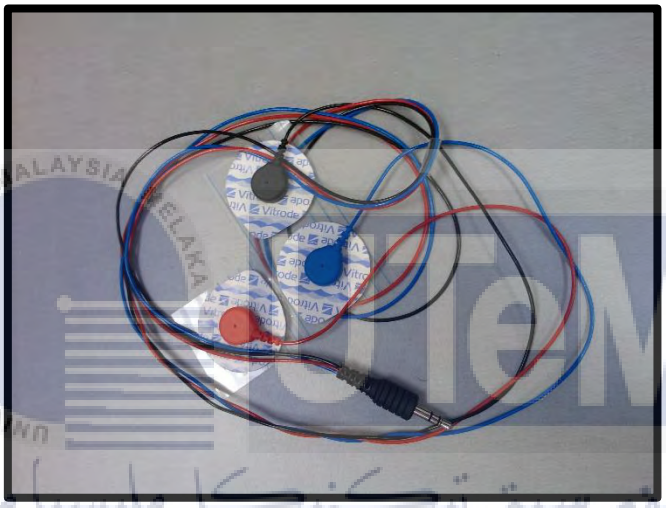


Figure 3.6: Disposable electrodes with a single 3.5mm plug connector

Meanwhile, a dry skin contributes to a good pad adhesion and trace quality and any hair should be minimized and removed before applying the electrodes. Alcohol pad applied on the area of the skin, in order to clean it, where electrodes should be placed and wait for the alcohol to dry.

Figure 3.7: Alcohol pad

3.4.3 Shield

SHIELD-EKG-EMG is an extension module for Olimex's ARDUINO board where it was attached on top of the ARDUINO board, while SHIELD-EKG-EMG-PA wire clips will connect between the boards and electrodes. This shield allows ARDUINO Mega to pick up EOG signals, monitor and recognize the eye movement by analyzing the muscle activity.

The disposable electrodes connect with this shield, and it is powered by the host board which in this study will be the ARDUINO Mega 2560. The power for SHIELD-EKG-EMG is between 3.3V or 5V, and the power LED will be lighted up when the shield is powered up. Figure 3.8 and Figure 3.9 below shows the top layout and bottom layout of the SHIELD-EKG-EMG respectively

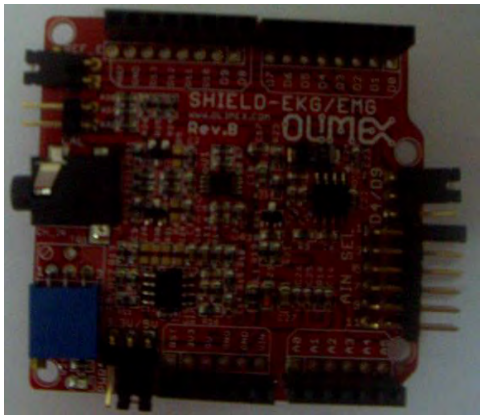


Figure 3.8: Top layout of the shield

Figure 3.9: Bottom layout of the shield

The board build with instrumentation amplifier, two high-pass filters, 3rd order "Besselworth" filter, high frequency rejection (HF) and also provides high voltage protection. To amplify the CRP, the instrumentation amplifier is used; and to pass high frequency signal and remove noise, high pass filter is used.

Besselworth filter is a combination of Butterworth and Bessel filter and it is good enough to prevent aliasing artifacts. Table 3.2 below shows the gain and frequency used for amplifier and filters.

Table 3.2: Gain and frequency used

Part	**Description**
Instrumentation amplifier	Gain, G=10
High-pass filter	Cut-off frequency, f_c=0.16Hz
3rd order "Besselworth" filter	Cut-off frequency, f_c=40Hz Gain, G=3.56

Hence, the main parts of the shield have to be determined before making any connection in order to prevent any damage on the shield and Figure 3.10 below shows the main parts of the SHIELD-EKG-EMG board.

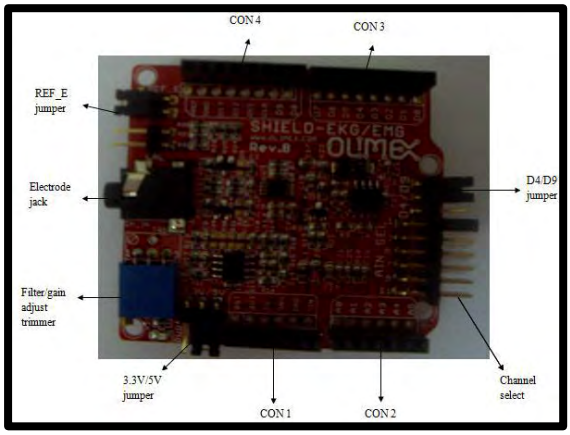


Figure 3.10: Main parts of the shield board

3.4.4 ARDUINO UNO

ARDUINO UNO is an interface between MATLAB Simulink and the SHIELD-EKG-EMG board, and it transfers the signals obtained from the shield board to MATLAB Simulink in order to process the signal and extract the features based from the signal.

Figure 3.11: ARDUINO UNO front

Figure 3.12: ARDUINO UNO back

In order to turn on the ARDUINO, a connection needed by using a USB cable and connect it to a computer. Also, an AC-to-DC adapter can also power on the ARDUINO by plugging a 2.1mm center-positive plug available on the board's power jack, or battery by embedding the Gnd and Vin pin headers of the POWER connector to get it started. Also, this type of ARDUINO is compatible with most shields because it is an upgrade version of ARDUINO Mega.

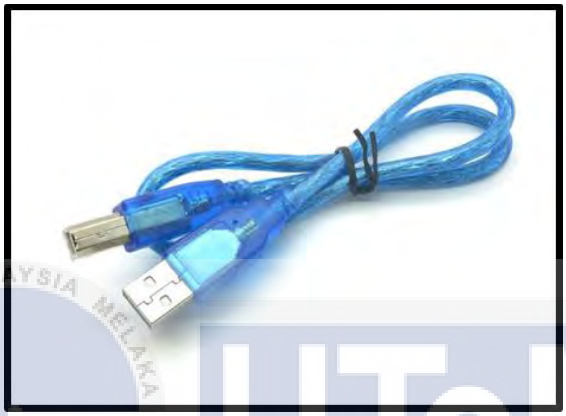


Figure 3.13: USB cable

The range for the usage of an external supply used on the ARDUINO board is between 6 to 20 volts, but if the supply below 5V, the 5V pin may supply less than 5V and causing the board unstable. While if the usage more than 12V, voltage regulator may overheat and damage the board. So, the recommended range is between 7 to 12 volts. Each pin can give and take a maximum of 40mA with an internal pull-up resistor of 20 to 50kΩ.

3.5 Develop Low Cost Wireless using ARDUINO UNO and Bluetooth

3.5.1 Wireless acquisition module via Bluetooth protocol

The wireless module contains ARDUINO UNO, an ARM controller and Bluetooth communication module. The AD converter and the ARM controller are optically isolated to reduce the crosstalk from digital signal to analog signal. The ARM controller saves the

raw EMG data info the SD card, and transmits the recorded signals to the HC-05 Bluetooth module through the USRT serial communication protocol, via which realizing the interaction with the PC client. Bluetooth communication modules achieve data transmission through low-power radio communication technology, whose maximum transfer rate is 1 MB/s.

3.5.2 ARDUINO UNO

ARDUINO Bluetooth serial connection usually can be useful in many application like controlling servos, motors, and writing to LCDs. ARDUINO read the sensor then pass the value via serial Bluetooth to PC processing. It can receive transceiver around 30 feet but it really depends on many other variables. In figure 3.14 shows the connection between ARDUINO UNO and Bluetooth module HC-05.

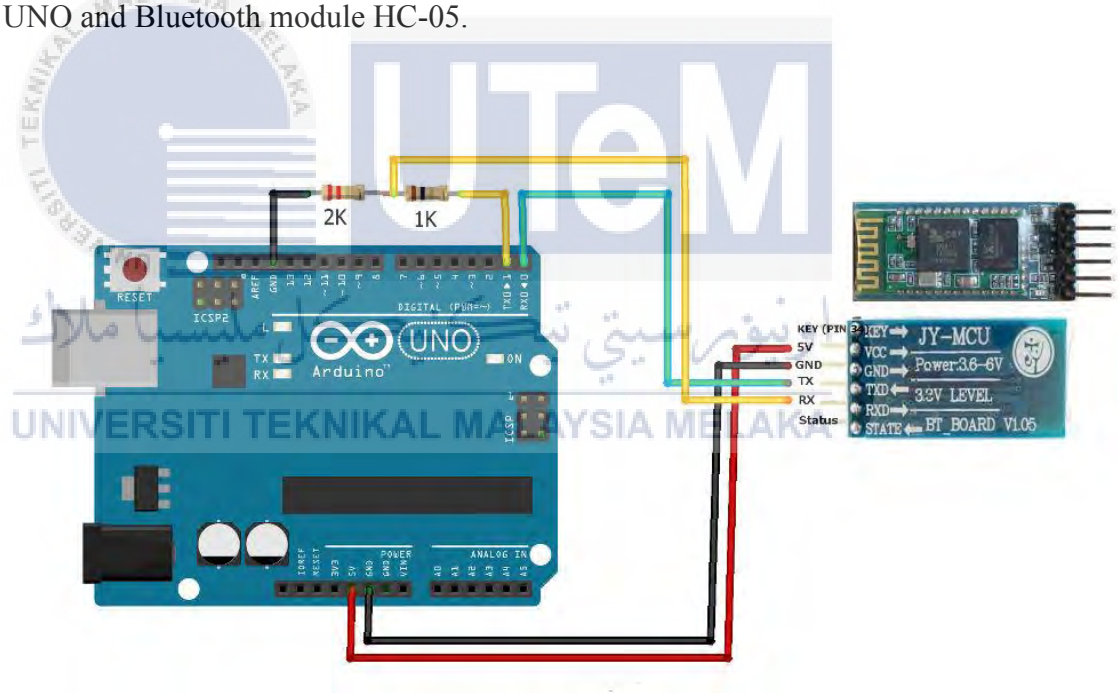


Figure 3.14: Connection between ARDUINO UNO and Bluetooth HC-05

3.5.3 Bluetooth module

Bluetooth is one of the solutions to get rid cables and use short-range, wireless, and inexpensive and universally adopter devices to facilitate on-demand connectivity among devices. Bluetooth is one of wireless technology standard that using short radio link. Its

providing wireless communication along with small size, minimal power consumption and the lowest prices. Its design to be s]a simplest and to became a standard in wireless connectivity. The advantages of Bluetooth is does not can link to computers, but also can link with PDAs, headphones, headsets, printers and other technology with each other. Bluetooth also provides easy pairing between devices and consume less power but trade-off is made in terms of security and data exchanges speeds. But the range maximum operating is around 10m while Wi-Fi is around 100m. Figure 3.15 below show symbol of Bluetooth.

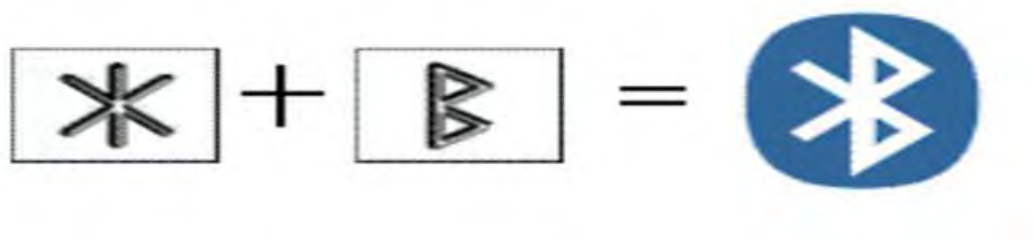


Figure 3.15: Symbols of Bluetooth

3.5.4 Bluetooth modules HC-05

HC-05 is Bluetooth serial communication module that has two modes. For the first mode is order-response work mode and second mode is automatic connection work mode. If the modules is at the automatic connection work mode, it will be follow the set lastly to transmit the data automatically. But, when the modules is at order-response work mode, user can send the AT command to the modules to set control parameters and sent control order. Table 3.3 until table 3.6 show the examples detailed description of command HC-05

i. Test

Table 3.3: Example of Command Test in Serial Connection

Command	Response	Parameters
AT	OK	None

ii. Reset

Table3. 4: Example of Command Reset in Serial Connection

Command	Response	Parameters
AT+RESET	OK	None

iii. Restore default status

Table 3.5: Example of Command Restore Default Status in Serial connection

Command	Response	Parameters
AT+ORGL	OK	None

iv. Get module Bluetooth address

Table 3.6: Example of Command Module Bluetooth Address in serial Connection

Command	Response	Parameters
AT+ADDR?	+ADDR :<Param> OK	Param: Bluettoth address

Example:

Module Bluetooth address: 12: 34: 56: ab: cd: ef

at+addr?\r\n

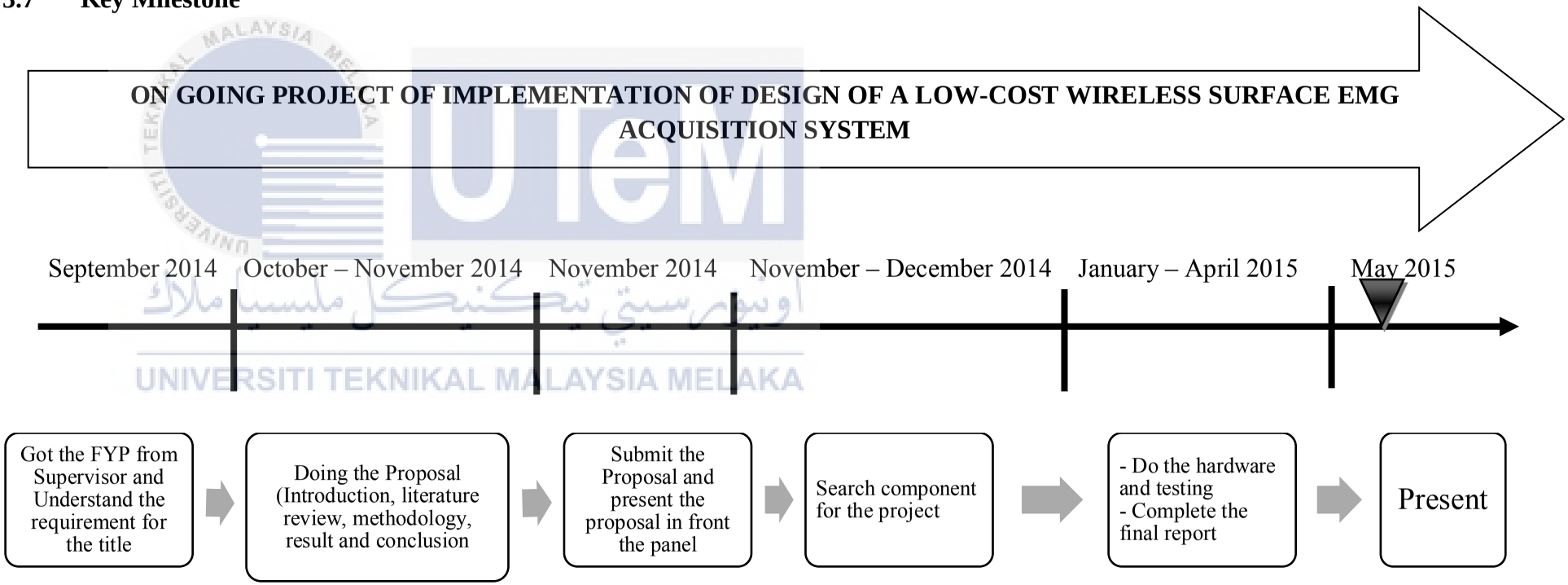
+ADDR:1234:56:abcdef

OK

3.6 Chapter Summary

In this chapter, the required low cost wireless system based on gain the data EMG using wireless Bluetooth module was obtained. In this chapter, the important thing using in build the low cost wireless has been presented. The data signal EMG also presented at the desktop by using MATLAB.

3.7 Key Milestone



Indicate position of work

3.8 Gantt Chart FYP 1and FYP 2

Project Task	Final Year Project 1					Final Year Project 2				
	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Mei	Jun
Discussion with supervisor related to FYP title										
Search Journal and Literature Review about low-cost wireless and surface EMG acquisition system										
Understand the theory and operation of previous work										
Project Proposal - Introduction & Literature Review										
Project Proposal – Methodology, Preliminary Result & Conclusion										
Extracting EMG Signal Data using ARDUINO and EKG/EMG Shield										
Hardware implementation										
Hardware testing										
Analysis & Discussion										
Report Writing										

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

This chapter provides result and discussion of the design of Low Cost Wireless surface EMG acquisition system in conducting this project from beginning until it is complete. It begins with brief explanation of project overview, where starting project is located until project run is discussed. The process of each step that involved is described and discuss thoroughly in this chapter. This chapter is very important to ensure the objective project is successful.

4.2 Design of different gesture

There are four different gesture for this experiment, which are Equilibrium State (ES), Ulnaris Wrist Extension (UWE), Ulnaris Wrist Flexion (UWF), and Wrist Extension (WE). Different gestures are shown in Figure 4.1. Data acquisition of three subject have done for this experiment. Based on previous work, the value of threshold beginning was set at 90 mV and the ending is 30mV.

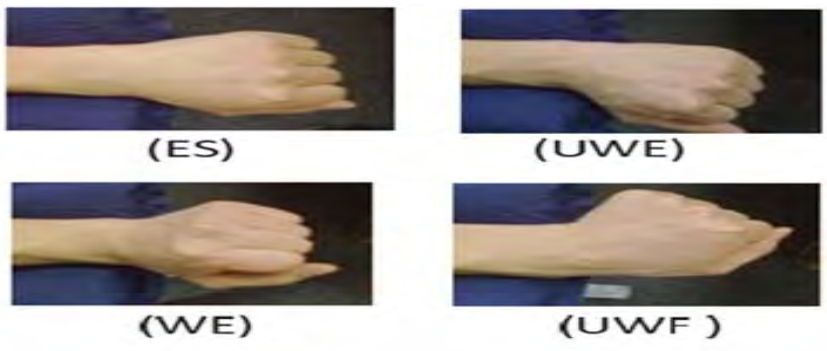


Figure 4.1: Four Different Gesture of Wrist Join

4.3 The processed of EMG Signals

The Figure 4.2 and 4.3 shows the structures process and the hardware device of Low Cost Wireless EMG Acquisition System. First, the EMG signal taken by placing electrode that selected muscles and use the alcohol pad to remove dead cell. The electrode disposable connected with muscle sensor through electrode cable. After that, the signal will send via Bluetooth module into personal computer [PC] in order to show the signal on the screen. Experimental procedure will be show as follows:

i. The subjects have to sits on a chair and in a relax mood. After that, their hands have to be applied with an alcohol pad in order to get rid of any dusts and dead skin. And as soon as the skins dry, the real time data will be taken by using disposable electrodes and muscle sensor (shield EKG)

ii. Meanwhile, for the Bluetooth connection, the hardware has been made by using ARDUINO UNO as can be seen on the Figure 4.3 below

iii. The EMG analysis data taken will be plotted and the data showed by using MATLAB.

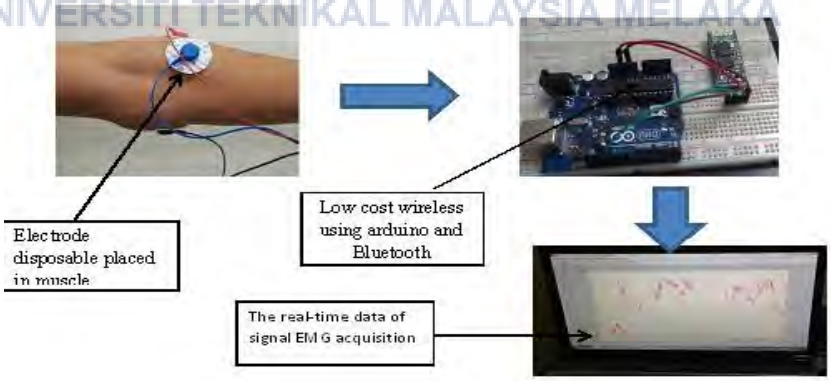


Table 4.2: Structure Process Low Cost Wireless Surface EMG acquisition System

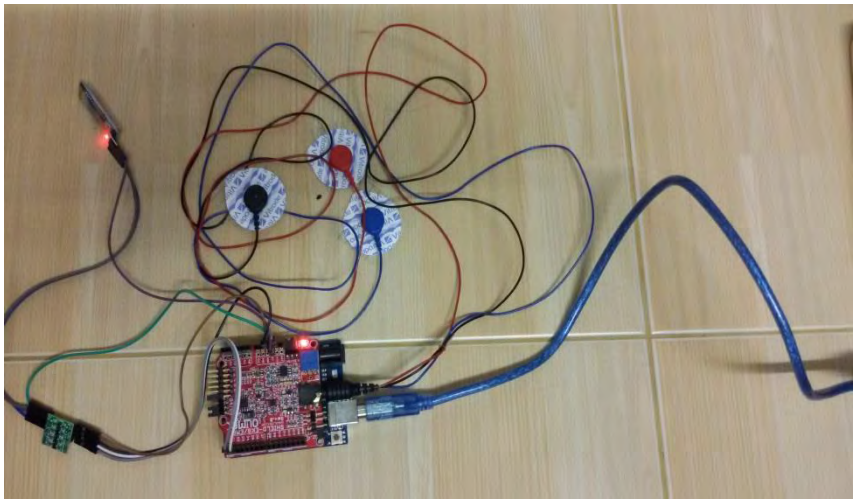


Table 4.3: Low Cost Wireless Surface EMG acquisition System Hardware

4.4 Data Surface EMG during Off-line time with filter

Table 4.3 shows the listed locations of the electrode in different muscles. The subject was sits on the chair with forearm in the rest position and facing palm down. The arm and wrist are fixed in the same level. The surface EMG signal in this experiment was recorded.

Table 4.1: Forearm muscles and Functionality

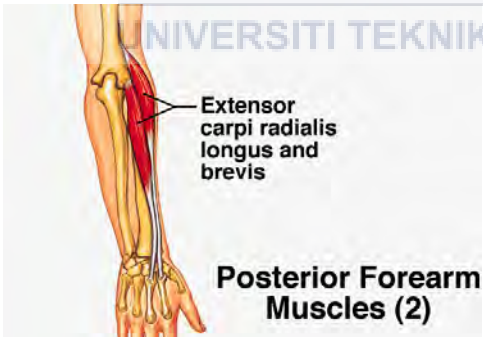
Muscle	Function
Extensor carpi ulnaris 	Extend
Flexor carpi ulnaris 	Flex and retract
Extensor carpi radialislongus 	Extend and outreach

Table 4.2: Signal from gesture Ulnaris Wrist Flexion (UWF)

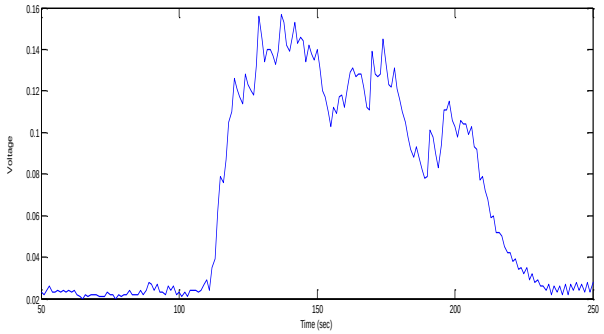
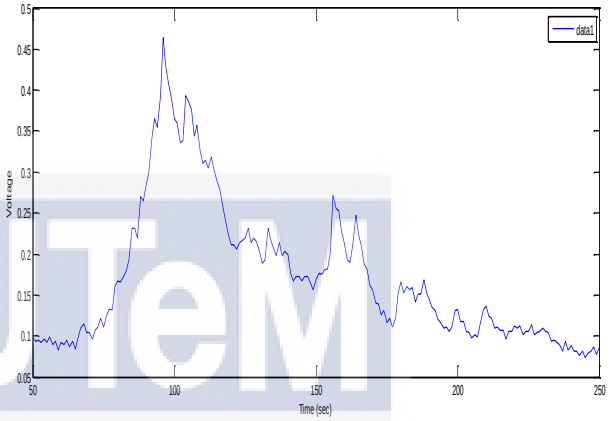
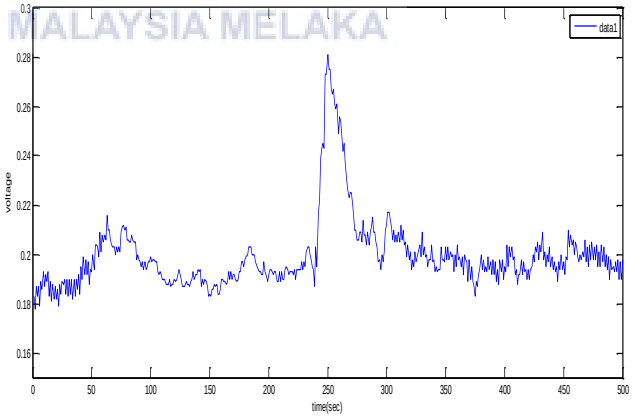
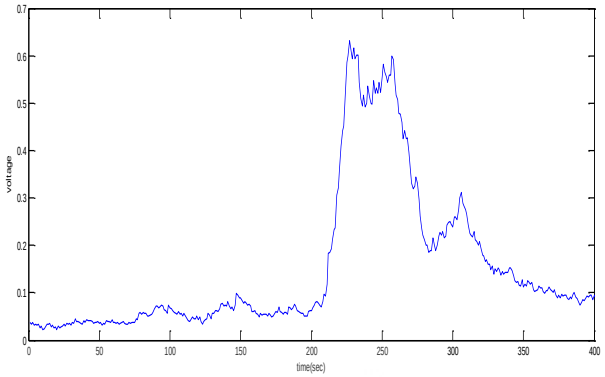
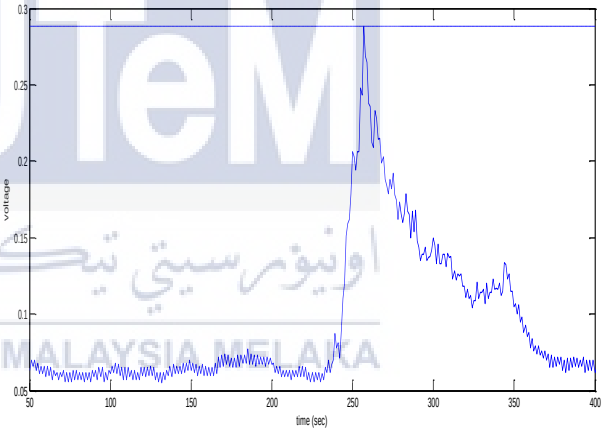
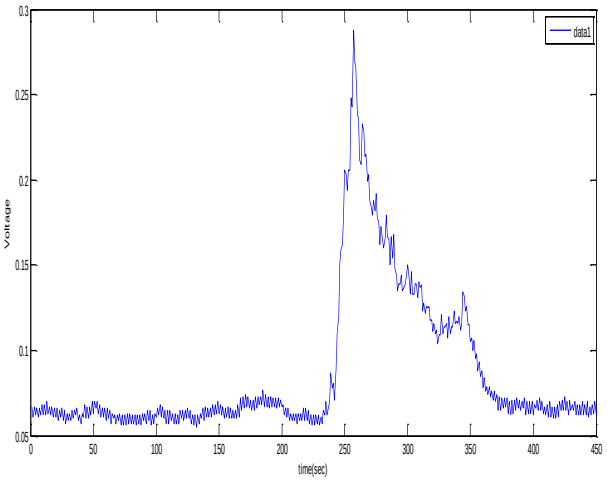
Subject	Muscle Action	Signal of EMG
1  (UWF)	Extensor carpi ulnaris	
2  (UWF)	Flexor carpi ulnaris	
3  (UWF)	Ulnaris Wrist Flexion (UWF)	

Table 4.2 above shows the signal obtained from three subjects for the gesture of Ulnaris Wrist Flexion (UWF). The hand used in taking the signals are different for both man and woman subject, which are for left hand for man and right hand for woman. Based on the table above, subject one and two is woman shows that when they flex their hand to

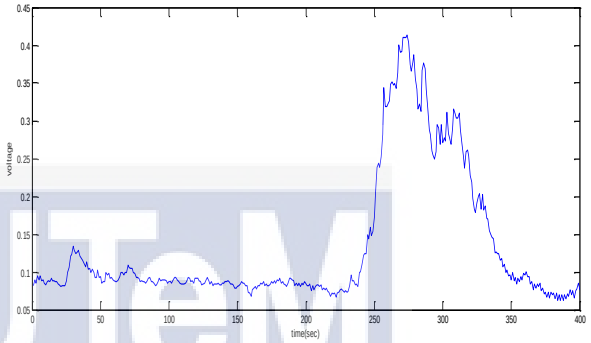
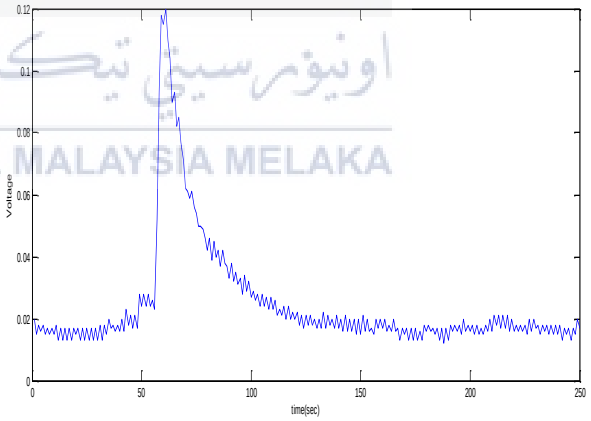
the left, the peak signals amplitude rose. Meanwhile for subject two, the peak amplitude rose higher because the energy used are more than subject one and two.

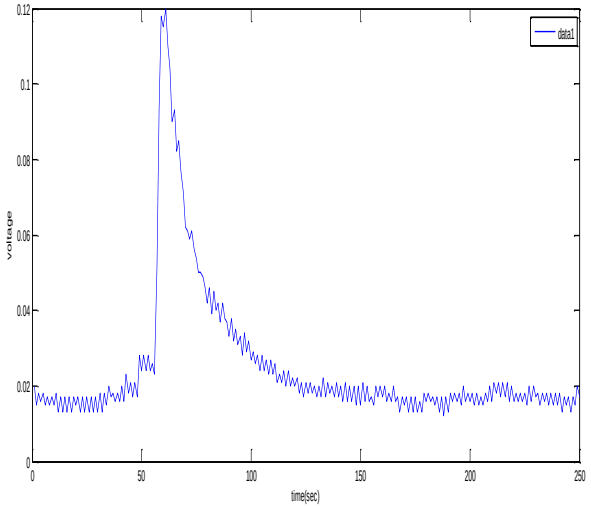
Table 4.3: Signal from gesture Ulnaris Wrist Extension (UWE)

Subject	Muscle Action	Signal of EMG
1 	Extensor carpi ulnaris	
2 	Flexor carpi ulnaris	
3 	Ulnaris Wrist Flexion (UWF)	

While Table 4.3 above shows the signal obtained from three subjects for the gesture of Ulnaris Wrist Extension (UWE). Same as Table 4.2, subject one and three are both woman shows the peak amplitude of the signal when they move their hands to the right but for subject two, when he move his hand, the voltage peak is higher from subject one and two because he used more energy in flexing his hand.

Table 4.4: Signal from gesture Wrist Extension

Subject	Muscle Action	Signal of EMG
1  (WE)	Extensor carpi ulnaris	
2  (WE)	Flexor carpi ulnaris	

3  (WE)	Ulnaris Wrist Flexion (UWF)	

Hence, Table 4.4 show the signal obtained from 3 subjects for the gesture Wrist Extension. For Table 4.4 is when the subject flexes the hand upwards.

Tables 4.4 shows that when subject one and three flex and squeeze their hand, the peak amplitude of the signal rose but when subject two did the same action, the peak rose higher because the male subject used more energy in flexing and squeeze their hands. Figure 4.4 until 4.5 below shows the maximum amplitude for each of the signal plotted.

- Extensor Carpi Ulnaris

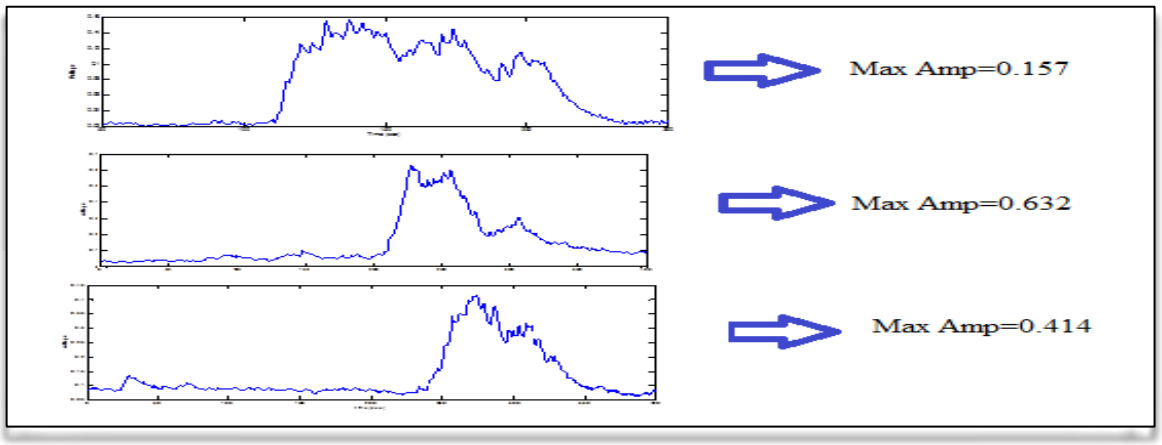


Figure 4.4: Maximum amplitude for each muscle

- Flexor Carpi Ulnaris

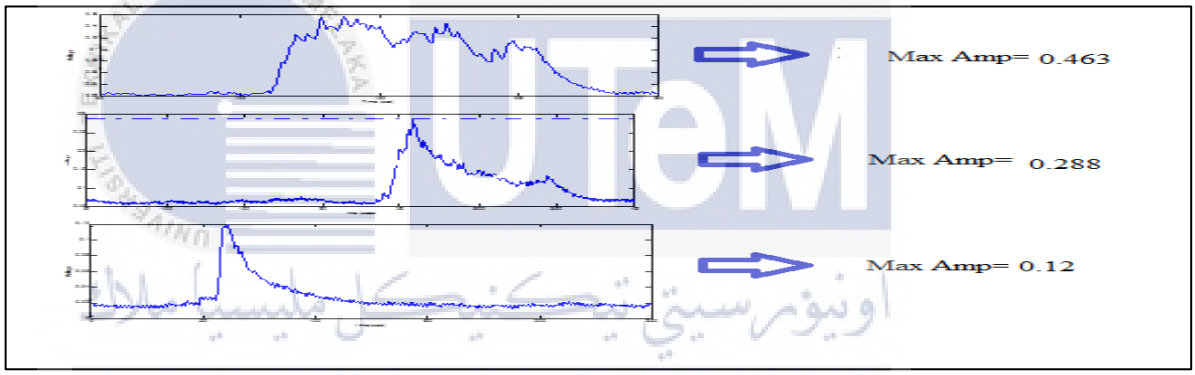


Figure 4.5: Maximum amplitude for each muscle

- Ulnaris Wrist Flexion

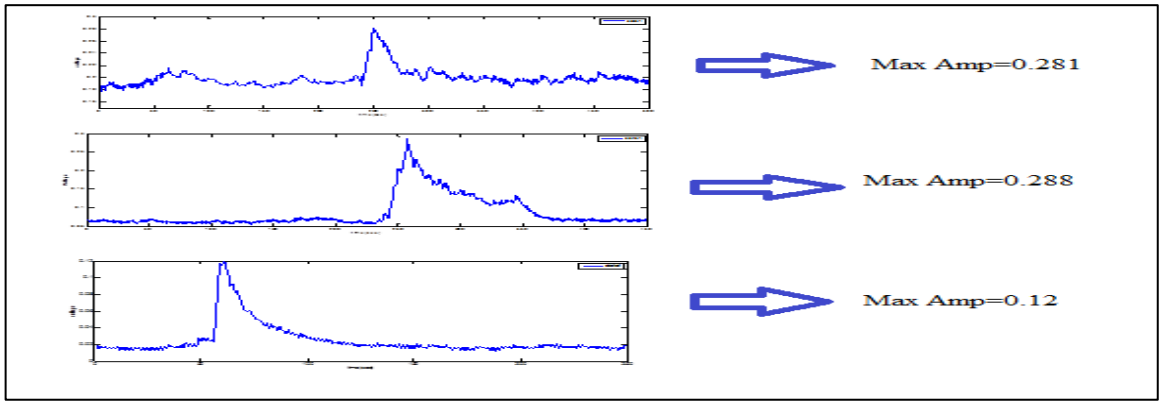


Figure 4.6: Maximum amplitude for each muscle

4.5 Chapter Summary

The experiment result demonstrates the effectiveness of the low cost wireless system, which is has the capability to record the surface EMG signal. The distance range between 15 meters are using to recorded EMG signal. Other than that, Bluetooth has proven to be one of the wireless modules that serves as a low cost wireless technology. The amplitudes of surface EMG signal including of extensor carpi ulnaris, flexor carpi ulnaris, extensor carpi radialis longus and flexor carpy radialis corporate jointly too recognize different gesture. But the accuracy also heavily depends on the performance of the subject and the variation sensitivity also occur the flexibility of the skin.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Introduction

This chapter discuss about conclusion and recommendation. This chapter includes project summary, project finding and further recommendation to improve the project.

5.2 Conclusion

As a conclusion, this low-cost multi-channel surface EMG system could perform EMG recording, storage, and analysis through Bluetooth with a resolution of micro-volt. The motion classification module using high performance microprocessor to decode the surface EMG feature and predict the motion behaviour for potential multifunctional prosthesis control application. ARDUINO is an open-source electronics prototype platform, design to make the process using electronic in multidisciplinary project more accessible. After that, the design like technologies such as Bluetooth and wireless software enable large range of application scenarios. The conclusion from Chapter 1 to chapter 5 is summarized as below:

i. Bluetooth wireless one of the low cost wireless acquisition for general purpose human machine-interaction.
ii. The signal EMG data acquisition system has provided a human-machine interaction for useful in our daily life.
iii. Surface EMG signal provide more natural and convenient for general purpose human-machine interactive control and prosthetic system.

Thorough in this system shows the effectiveness of Bluetooth's function as a wireless module compared with others. Other than that, this study also wants to show if Bluetooth modules can give the cheapest wireless module system to the users. Moreover, it is also to introduce this Bluetooth module as one of the low cost wireless system in the bio-medical field in order to send the data straight to the personal computer (PC) for analysis.

5.3 Recommendation and Improvement

After the build of low cost wireless making conclusion and some suggestion are made so that measurement method and analysis can be done to improve the field of design a low cost wireless surface EMG acquisition system in future. The recommendation as a follow

i. Research more about EMG signal with better integration of the system for the better development of acquisition system
ii. Using specific software or coding for the display of EMG signal in real time more accurately.

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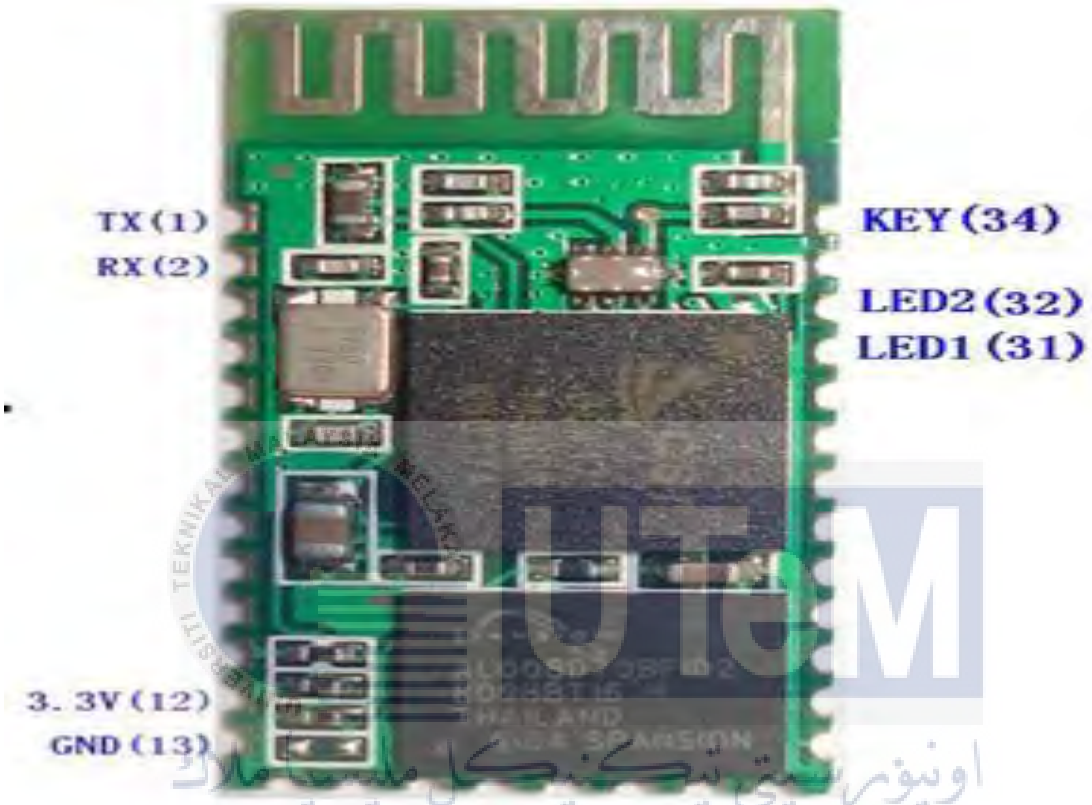
APPENDIXS

Appendix A: Bluetooth HC-05



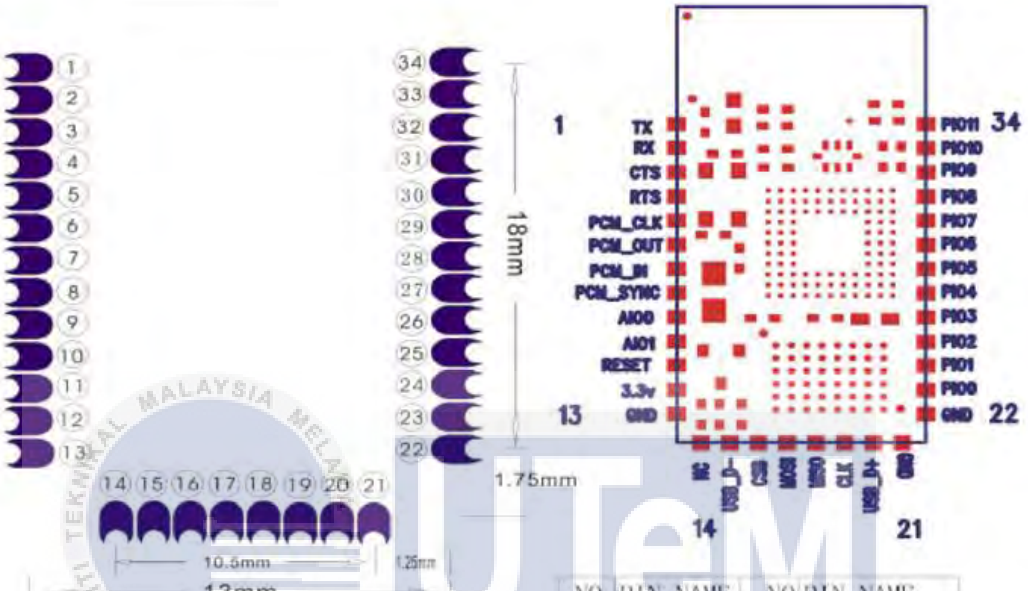
Appendix B: Package size information

LINVOR BLUE T

www.linvor.com

LV-BC-2.0

单位： mm



PCB Layout 请参考实物

NO	PIN NAME	NO	PIN NAME
1	TX	20	USB D+
2	RX	21	GND
3	CTS	22	GND
4	RTS	23	PIO0
5	PCM CLK	24	PIO1
6	PCM OUT	25	PIO2
7	PCM IN	26	PIO3
8	PCM SYNC	27	PIO4
9	AIO0	28	PIO5
10	AIO1	29	PIO6
11	RESET	30	PIO7
12	3.3V	31	PIO8
13	GND	32	PIO9
14	NC	33	PIO10
15	USB D-	34	PIO11
16	CSB		
17	MOSI		
18	MISO		
19	CLK		

Appendix C: The circuit connect the module to 5V serial port of MCU