

**DEVELOPMENT OF A MYOELECTRIC DETECTION CIRCUIT
WITH IOT APPLICATIONS FOR USER MOTION INTENTIONS**

LEE LEONG JIN



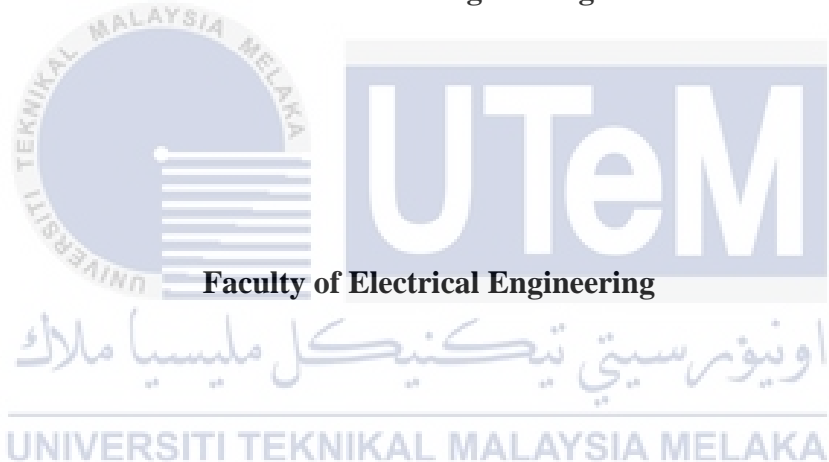
**BACHELOR OF MECHATRONICS ENGINEERING WITH
HONOURS
UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

2020

**DEVELOPMENT OF A MYOELECTRIC DETECTION CIRCUIT WITH IOT
APPLICATIONS FOR USER MOTION INTENTIONS**

LEE LEONG JIN

**A report submitted
in partial fulfillment of the requirements for the degree of
Bachelor of Mechatronics Engineering with Honours**



UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2020

DECLARATION

I declare that this thesis entitled “DEVELOPMENT OF A MYOELECTRIC DETECTION CIRCUIT WITH IOT APPLICATIONS FOR USER MOTION INTENTIONS is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature

:



Name

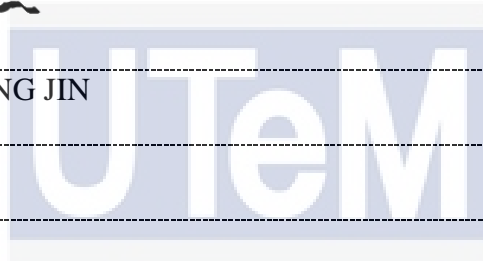
:

LEE LEONG JIN

Date

:

22/1/2021



اونيورسيتي تيكنيكل مليسيا ملاك

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

APPROVAL

I hereby declare that I have checked this report entitled “Development of a myoelectric detection circuit with IoT applications for user motion intentions” and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Mechatronics Engineering with Honours

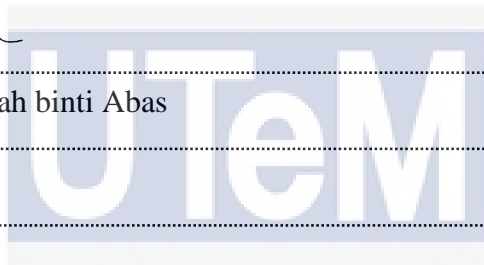
Signature :

Supervisor Name :

Dr. Norafizah binti Abas

Date :

22/1/2021



اونيورسيتي تيكنيكل مليسيا ملاك

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DEDICATIONS

To my beloved supervisor, panels, coursemates, friends, and family members. Thank you for all the advise, encouragement and support throughout this journey and in the preparation phase of this report.



ACKNOWLEDGEMENTS

Firstly, I would like to express my gratitude towards my supervisor, Dr. Norafizah binti Abas who is always there and ask me not to be worried. The action from my supervisor is heartwarming and this encourages me to keep moving forward to tackle the obstacles that I had face by looking at another alternative. There is always a solution to every problem and the road to the solution is guided by supervisor. I appreciate every effort and guidance from her as well as her patience and without that I could not achieve in completing my Final Year Project.

Secondly, I would like to express my sincere appreciation to both my FYP panels, Dr. Saifulza and Dr. Anuar for their given advices and suggestions on my project during the seminar. The advice and suggestions given had been adapted into the project and improvements are made.

Lastly, thank you to all my beloved friends and family members for always helping me and encourage me when I had doubt with myself. I am truly grateful for having u all in my life. Thank You!



ABSTRACT

In this research, the development of myoelectric muscle sensor with IoT technology for continuous prediction of user motion intention is explored. The myoelectric sensor is designed to measure the EMG signals extracted from the forearm muscles due to the hand movement/grasping at different wrist angle, that is then combined with mechanical sensor modalities (accelerometer and hand dynamometer) for continuous movement predictions to ensure simultaneous movements can be realized. The circuit is designed using simulation software and constructed before analyzed by conducting several set of data collection. After the proof of concept is completed, the sensor is interfaced with IoT technology so that the data can be wirelessly acquired and stored in the cloud where it can be retrieved for rehabilitation assessment. The proposed research contributes towards the enhancement of control strategies to ensure simultaneous movements with proportional articulation that includes user motion intention can be realised to control the exoskeleton hand. It is towards the aim to provide better human-machine interaction for the hand impairment survivors in regaining their hand strength and functionality, and improve their quality of life.

اونيورسيتي تيكنيكل مليسيا ملاك

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

ABSTRAK

Dalam penyelidikan ini, pengembangan sensor otot myoelectric dengan teknologi IoT untuk ramalan berterusan niat gerakan pengguna diterokai. Sensor myoelectric direka untuk mengukur isyarat EMG yang diekstrak dari otot-otot lengan bawah yang disebabkan pergerakan tangan / mencengkam pada sudut pergelangan tangan yang berbeza, yang kemudian digabungkan dengan modaliti sensor mekanikal (accelerometer dan dynamometer tangan) untuk ramalan pergerakan berterusan untuk memastikan pergerakan serentak dapat dicapai. Litar ini dirancang menggunakan perisian simulasi dan dibina sebelum dianalisis dengan melakukan beberapa set pengumpulan data. Setelah pembuktian konsep selesai, sensor dihubungkan dengan teknologi IoT sehingga data dapat diperoleh dan disimpan di awan tanpa wayar di mana ia dapat diambil untuk penilaian pemulihan. Penyelidikan yang dicadangkan menyumbang ke arah peningkatan strategi kawalan untuk memastikan pergerakan serentak dengan artikulasi berkadar yang merangkumi niat gerakan pengguna dapat direalisasikan untuk mengendalikan tangan exoskeleton. Ini bertujuan untuk memberikan interaksi manusia-mesin yang lebih baik untuk mangsa cacat tangan dalam memulihkan kekuatan dan fungsi tangan mereka, dan seterusnya meningkatkan kualiti hidup mereka.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

TABLE OF CONTENTS

	PAGE
DECLARATION	
APPROVAL	
DEDICATIONS	
ACKNOWLEDGEMENTS	1
ABSTRACT	2
ABSTRAK	3
TABLE OF CONTENTS	4
LIST OF TABLES	7
LIST OF FIGURES	8
LIST OF SYMBOLS AND ABBREVIATIONS	11
LIST OF APPENDICES	12
CHAPTER 1 INTRODUCTION	13
1.1 Project Background	13
1.2 Motivation	14
1.3 Problem Statement	15
1.4 Objective	16
1.5 Project Scope	16
CHAPTER 2 LITERATURE REVIEW	17
2.1 Introduction	17
2.2 EMG Signal	17
2.2.1 Anatomical and physiology background	18
2.2.2 EMG Measurement Technique	19
2.2.2.1 Non-invasive Measurement Technique	19
2.2.2.2 Invasive Measurement Technique	21
2.3 Myoelectric Detection Circuit	22
2.3.1 EMG signal acquisition circuitry and configurations	28
2.4 Noises in EMG Signal	30
2.4.1 Inherent noise in electronics equipment	31
2.4.2 Ambient noise	31
2.4.3 Motion artifact	31
2.4.4 Inherent instability of signal	32
2.4.5 Electrocardiographic (ECG) artifact	32
2.4.6 Cross talk	32
2.4.7 Electrode contact	33
2.4.8 Transducer noise	33

2.4.9	Baseline shifts	33
2.5	Handgrip Force and Wrist Angle Measurement System	33
2.6	Internet of Things (IoT)	34
2.6.1	IoT architecture	35
2.7	Summary	37
CHAPTER 3		38
METHODOLOGY		
3.1	Introduction	38
3.2	Flowchart of Research Methodology	39
3.3	Design of myoelectric circuit in simulation	41
3.3.1	Power Supply	42
3.3.2	Bypass capacitor	43
3.3.3	Instrument amplifier	44
3.3.4	Driven Right Leg (DRL) circuit	46
3.3.5	High pass filter	46
3.3.6	Low pass filter	47
3.3.7	Two way rectifier	49
3.3.8	Smoother	49
3.3.9	Inverting amplifier	50
3.3.10	Optocoupler Circuit	51
3.4	Hardware Development of the Myoelectric Circuit Design	52
3.4.1	Circuit construction	53
3.4.2	Circuit testing	53
3.4.3	Proof of concept	54
3.5	Hardware Development of Handgrip Force and Wrist Angle Measurement Systems	55
3.6	Design and Hardware Development of IoT architecture	56
3.7	Integration of Overall System	57
3.8	Data Collection and Overall System Performance Analysis	58
3.8.1	Muscle Selection and Electrode Placement	58
3.8.2	Experimental set-up and Procedure for Continuous Motion Intention Detection	61
3.8.3	Establishment of relationship between EMG signal, hand grip force and various wrist position	61
3.8.4	Analysis of the overall system performance	62
3.9	Summary	63
CHAPTER 4		64
RESULTS AND DISCUSSIONS		
4.1	Simulation Results and Analysis of the Myoelectric Circuit Design	64
4.2	Results and Analysis of the Hardware Development	66
4.2.1	Myoelectric detection circuit	66
4.2.2	Handgrip force and wrist angle measurement	69
4.2.3	IoT Architecture	71
4.3	Results and Analysis of the Overall System Integration	74
CHAPTER 5		77
CONCLUSION AND RECOMMENDATIONS		
5.1	Conclusion	77
5.2	Future Works	77
REFERENCES		78



LIST OF TABLES

Table 2.1: Design of myoelectric detection circuit based on past studies and latest research paper	23
Table 3.1: Characteristic of AD620 [50]	44
Table 3.2: Bill of Materials (BOM)	52
Table 4.1: Mean Absolute Error (MAE) computed for the overall system	75



LIST OF FIGURES

Figure 1.1: Cause of deaths from 2009-2019 in Malaysia [2]	14
Figure 1.2: Cases Registered for Domiciliary Health Care Services, 2017 in Malaysia [3]	14
Figure 1.3: Distribution for Rehabilitation Services [5]	15
Figure 2.1: Characteristic of EMG signals [6]	18
Figure 2.2: Functional motor units which consists of motor units [10]	19
Figure 2.3: Gelled EMG electrode [14]	20
Figure 2.4: Dry EMG electrode [14]	21
Figure 2.5: Needle electrode [14]	21
Figure 2.6: Fine wire electrode [14]	22
Figure 2.7: Ideal position of the electrode [14]	29
Figure 2.8: Monopolar signal acquisition technique [14]	29
Figure 2.9: Bipolar signal acquisition technique [14]	30
Figure 2.10: Hand dynanometer by Vernier [39]	34
Figure 2.11: DIY hand dynanometer [38]	34
Figure 2.12: Layers in proposed modular IoT architecture [41]	36
Figure 2.13: Information flow with inputs and outputs at each layer [41]	36
Figure 3.1: Overall System Architecture	38
Figure 3.2: Basic block diagram for measuring system model	41
Figure 3.3: Block diagram for EMG conditioning	41
Figure 3.4: Connection of power supply in breadboard [48]	42
Figure 3.5: Connection of power supply in Multisim	42
Figure 3.6: Placement of bypass capacitor for AD620	43

Figure 3.7: Placement of bypass capacitor for OPA2604	43
Figure 3.8: Connection of AD620 [51]	44
Figure 3.9: Design of schematic diagram for AD620 circuit	45
Figure 3.10: Design of schematic diagram for DRL circuit	46
Figure 3.11: Design of schematic diagram for high pass filter	47
Figure 3.12: Online calculator for high pass filter design [53]	47
Figure 3.13: Design of schematic diagram for low pass filter	48
Figure 3.14: Online calculator for low pass filter design [54]	48
Figure 3.15: Design of schematic diagram for two way rectifier	49
Figure 3.16: Design of schematic diagram for smoother	50
Figure 3.17: Design of schematic diagram for inverting amplifier	50
Figure 3.18: Design of schematic diagram for optocoupler circuit	51
Figure 3.19: EMG amplification circuit prototype [24]	53
Figure 3.20: Experimental set up to validate the constructed myoelectric circuit	
[30] اونیورسیتی تکنیکل ملیسیا	54
Figure 3.21: Linear enveloped EMG signal from FDS at various hand grasping	
[58]	54
Figure 3.22: The wrist range of motion studied in this project (45 degree	
flexion and 0 degree at neutral).	56
Figure 3.23: Proposed IoT Architecture	57
Figure 3.24: The experimental set-up for data collection	58
Figure 3.25: EMG average power at different hand grip strengths for the FPL,	
FDS, FCR and FCU [24]	59
Figure 3.26: Location of the flexor digitorum superficialis and digit	
interphalangeal joints [24]	59

Figure 3.27: Placement of the palm to determine the location of FDS muscle [24]	60
Figure 3.28: AgCl Electrode placement on the FDS [24]	60
Figure 3.29: Experiment set up [58]	61
Figure 3.30: Expected results for enveloped EMG for wrist angles fixed at 60°, 90° and 120° at various hand grip force [24]	62
Figure 4.1: Schematic diagram designed for myoelectric circuit	64
Figure 4.2: Simulation results of each components	65
Figure 4.3: Constructed Myoelectric Detection Circuit	67
Figure 4.4: Output from differential amplifier	67
Figure 4.5: Output from two-way rectifier	68
Figure 4.6: Construction of myoelectric detection circuit on PCB	69
Figure 4.7: Handgrip Force Measurement	70
Figure 4.8: Wrist Angle Measurement	70
Figure 4.9: Data flow in Node-RED	71
Figure 4.10: IoT dashboard using Node-RED	72
Figure 4.11: IoT dashboard using ThingsBoard software	73
Figure 4.12: Data tracking by using ThingsBoard software	73
Figure 4.13: The experimental results collected for the overall system	74

LIST OF SYMBOLS AND ABBREVIATIONS

ADC	-	Analog-to-Digital Converter
API	-	Application Programming Interface
BLE	-	Bluetooth Low Energy
BOM	-	Bill of Materials
CE	-	Coordinator Enable
CH	-	Channel
CMRR	-	Common Mode Rejection Ratio
CNS	-	Central Nervous System
COM	-	Component Object Model
DAQ	-	Data Acquisition
DC	-	Direct Current
DRL	-	Driven Right Leg
DSP	-	Digital Signal Processing
ECG	-	Electrocardiography
EHW	-	Evolvable Hardware Chip
EMG	-	Electromyography
EOG	-	Electrooculography
FCR	-	Flexor Carpi Radialis
FCU	-	Flexor Carpi Ulnaris
FDS	-	Flexor Digitorum Superficialis
FPL	-	Flexor Pollicis Longus
GND	-	Ground
ID	-	Pan ID
IoT	-	Internet of Things
LPF	-	Low Pass Filter
LPT	-	Line Print Terminal
MCU	-	Microcontroller unit
MUAPs	-	Motor Unit Action Potentials
NI	-	National Instruments
PC	-	Personal computer
PCB	-	Printed Circuit Board
PLI	-	Power Line Interference
RMS	-	Root Mean Square
SEMG	-	Surface Electromyography
TTL	-	Transistor-transistor Logic
USB	-	Universal Serial Bus
Vcc	-	Common Collector Voltage

LIST OF APPENDICES

APPENDIX A

85



CHAPTER 1

INTRODUCTION

1.1 Project Background

In the 21st century, health systems are confronted with new challenges such as global aging population, increase number of people with chronic condition and people living with disabilities are now more than ever before. Rehabilitation is required as the country grows and health systems expand, to ensure that people get the best possible result after an accident or illness. It means getting out of the hospital sooner with less risk of complications and less need for ongoing support. However, people do not have access to the rehabilitation services they need in many parts of the world, insufficient numbers of trained rehabilitation practitioners, inadequate facilities and obstacles to access such high out-of-pocket expenses are challenges that need to be addressed [1].

According to the latest Institute for Health Metrics and Evaluation data published in 2020, stroke is the top 3 leading causes of death in Malaysia from 2009 to 2019 as shown in Figure 1.1 [2]. Although stroke is the top 3 leading causes of death in Malaysia but there are a lot of people who survived stroke as shown in Figure 1.2 where it is the most (62%) cases registered for domiciliary health care services [3]. People who survived stroke need to undergo rehabilitation to regain their speech, cognitive, motor, or sensory skills. Rehabilitation program for stroke often involve the training of strength, mobility, and range-of-motion exercises which are monitor by utilising the electromyography (EMG) signals. The EMG signals will record the electrical potential generated during muscle contraction. The EMG signals becomes continuously denser and the maximal peaks in the signal will have a higher amplitude when more force is used [4]. Thus, the properties of EMG signals are useful for doctors to keep track and evaluate the process in stroke rehabilitation of patient to ensure a fast and efficient recovery.

What causes the most deaths?

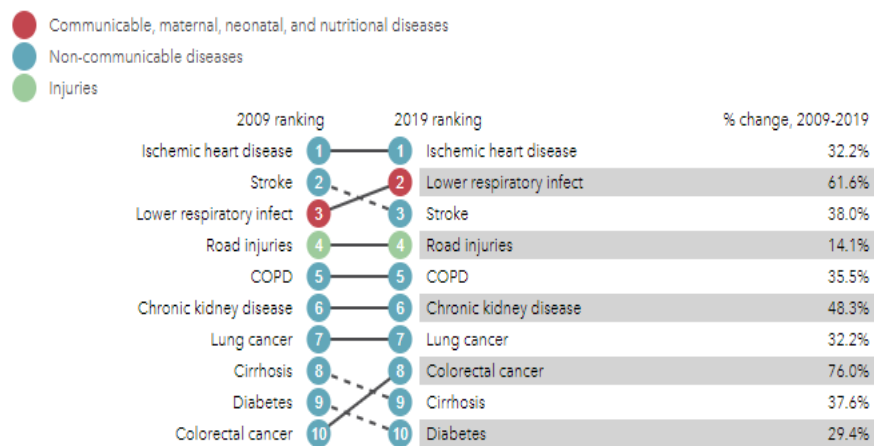


Figure 1.1: Cause of deaths from 2009-2019 in Malaysia [2]

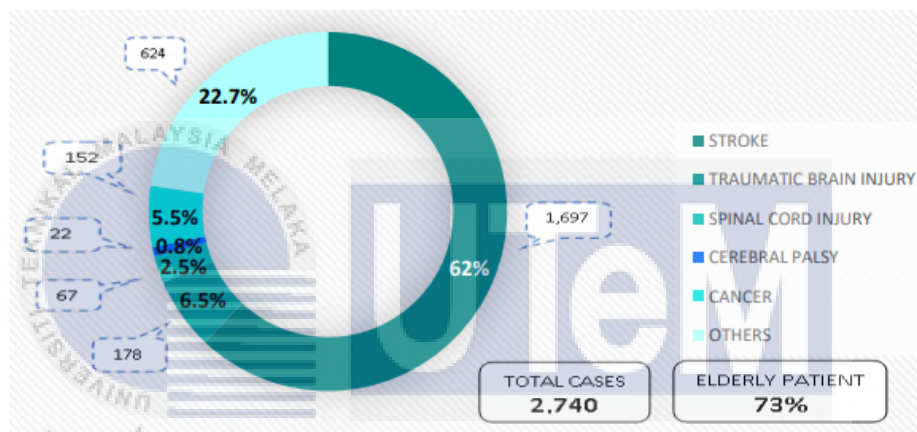


Figure 1.2: Cases Registered for Domiciliary Health Care Services, 2017 in Malaysia [3]

1.2 Motivation

According to a survey performed in 2018, it is observed that the rehabilitation services provided within the state of Selangor and Federal Territories of Kuala Lumpur is distributed unevenly especially for the population of urban poor and people in the rural areas as shown in Figure 1.3 [5]. The costs for development, construction, and manpower would be high to set up new healthcare facilities. An alternative solution should be considered such as the use of a home-based virtual rehabilitation programme. Thus, to visualize this conception, the idea of designing a myoelectric circuit for user motion intention with IoT application is inspired. This development would be able to help doctor to monitor the patient recovery progress from a distant. Besides, the developed circuit can also be utilised as a control signal for prosthetic

devices such as prosthetic hands, arms, and lower limbs to achieve human-machine interaction.

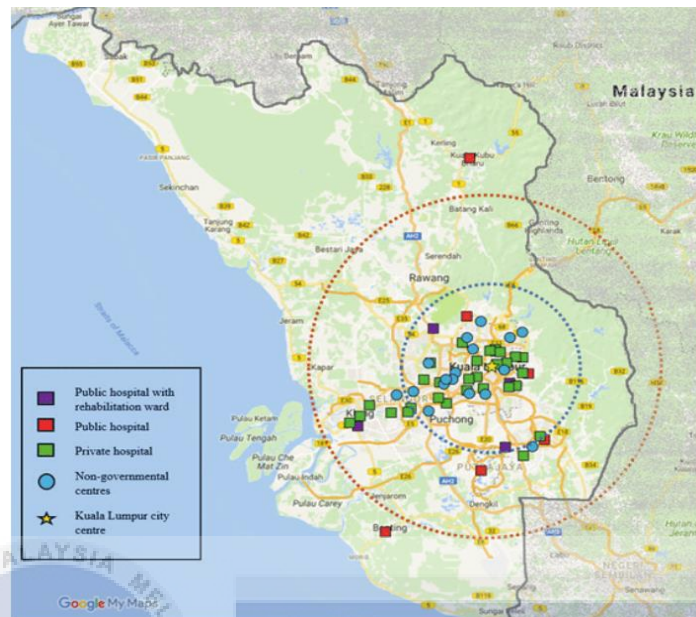


Figure 1.3: Distribution for Rehabilitation Services [5]

1.3 Problem Statement

With the advancement of technologies and breakthroughs in healthcare today, the number of people who survived stroke had risen drastically over the year. This scenario had led to the increase in demand for rehabilitation or assistive devices. In a way to help the patient to recover efficiently, user motion intention needs to be considered to robustly control the assistive devices to be compatible for different people at different level of recovery progress. The user motion intention is observed by the outcome of EMG signals. However, raw EMG signals which is nonlinear and associated with noise is not suitable to be used to study its relationship with user motion intention. Thus, the raw EMG signals requires amplification, filtration, and rectification so that the signal generated is linear enveloped before it can be readily used as control input to control the assistive devices.

At present, there are various of technique in processing the EMG signals. Despite the fact that there are a lot of commercially available EMG detecting circuit in the market but each and every of it had their own design specification and most of the devices does not include IoT application as a part of it. In addition, by adapting IoT into the EMG circuit will ease the process for data collection and enable physician

to monitor and track the recovery of a patient from a distance which results in a better treatment and experience with lower expenses as it eliminates the cost for travel, hospital room and exorbitant doctor fees. Besides, during the wide spread of COVID-19 currently, the adaptation of IoT will also lower the risk of one getting affected. Therefore, to ensure seamless interaction between human-machine interaction by including motion intentions and IoT as part of research, the best method of design and gap analysis between research paper need to be contemplated by recognizing the strength and limitation of each so that the circuit designed could respond accordingly and correctly whenever the muscle contracted.

1.4 Objective

The objectives of this project are as follows:

- i. To design a myoelectric circuit for detection of user motion intention with IoT application.
- ii. To establish relationship between forearm EMG signal with different handgrip force and wrist position using the designed circuit.
- iii. To analyse the designed circuit in terms of accuracy and rms error.

1.5 Project Scope

The scopes of this project are as follows:

- i. All subjects are normally limbed in this experiment with no previous or present muscular injuries or diseases.
- ii. The electrode used in this experiment is subjected to surface electrode only which would not cause harm to subject.
- iii. The designed circuit is validated using the data collected by previous researcher using the EMG device by Vernier where the established relationship are compared and analysed.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Throughout recent years, scientist have been utilizing EMG for diagnosis of various of neuromuscular diseases. There are a lot of method in acquiring the EMG signals as for this project will be focus primarily on the development of a myoelectric detection circuit with IoT applications for user motion intentions. In this chapter, the theories of EMG are explained and reviews of previous design approaches as well as associated issues is conducted. Based on the boon and bane discussed from the reviewed paper, an appropriate approach is selected to provide comprehensible design consideration and implementations. In addition, recent development and recommendations from each paper is also taken into account. By comparison study, a better understanding of EMG signal and its analysis procedure is produced which will help in designing a more powerful, flexible, and efficient myoelectric detection circuit.

2.2 EMG Signal

Electromyographic (EMG) signal are electrical potentials generated due to voluntary muscle contraction and is sometimes referred as myoelectric activity. This signal is normally a function of time and is describable in terms of its amplitude, frequency, and phase. The EMG signal is complicated as it is controlled by the nervous system and is dependent on the anatomical and physiological properties of muscles as shown in Figure 2.1 [6]. The amplitude of this signal usually ranges from 50 μ V to 20-30 mV. As the amplitude of the raw EMG signal is too small, thus the EMG signal need to be processed before it can be used as a control input for the controller by amplification, filtration, rectification, smothering and etc. Thus, research have been carried out for developing better algorithms, upgrading existing methodologies, improving detection techniques to reduce noise, and to acquire accurate EMG signals [7]. The processed EMG signal can be then used to analyse or use to study the relationship of EMG signal properties with different muscle group. The amplitude of this biopotentials is proportional to the intensity of the contraction. EMGs are detected in a frequency range

between 20-450 Hz [6]. EMGs can be also utilize for clinical/biomedical applications, Evolvable Hardware Chip (EHW) development, and modern human-machine interaction [7]. According to the International Society of Electrophysiological Kinesiology [8], the minimum specifications for EMG signals are as below:

- Input Impedance: $>10^{10}\Omega$ en DC y $>10^8\Omega$ a 100 Hz
- Amplification gain: $200-100.000 \pm 10\%$ on discrete
- Gain nonlinearity: $\leq \pm 2.5\%$
- Gain stability: Variation should be 5%/year
- CMRR: $>90\text{dB}$

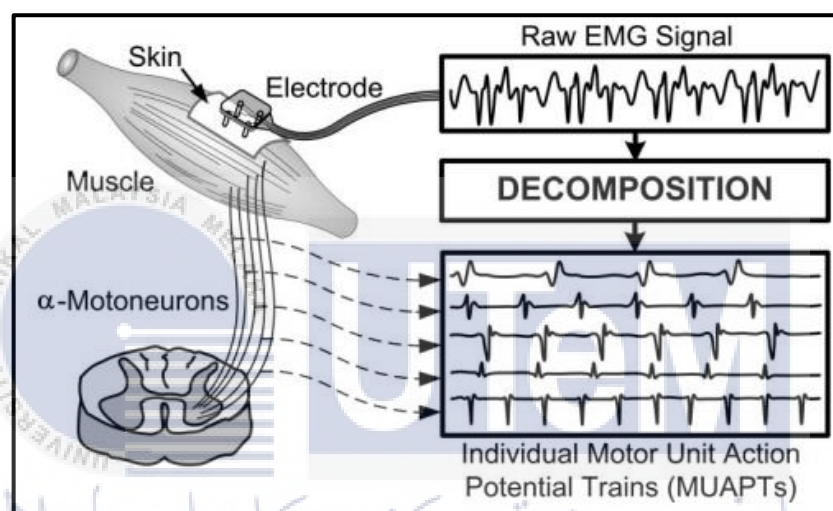


Figure 2.1: Characteristic of EMG signals [6]

2.2.1 Anatomical and physiology background

The central nervous system (CNS) is made up of the brain and the spinal cord. It controls most bodily functions which includes awareness, movements, sensation, thoughts, speech, and memory. The function of the spinal cord is to send signals (messages) back and forth between the brain and peripheral nerves [9]. The biological signal from the brain is transmitted to the muscle fibers through neurons in the spinal cord resulting in the muscle's movement/contraction when a person intends to move as shown in Figure 2.2 [10]. Neurons have a similar function to wires in an electronic circuit since both neurons and wires serve as the medium to transport signals [11]. Contraction of these activated fibers generates a voltage known as Motor Unit Action Potential (MUAP). The shapes and firing rates of Motor Unit Action Potentials (MUAPs) in EMG signals provide an important source of information for the diagnosis

of neuromuscular disorders [7]. The EMG signal is a summation of MUAPs. The amplitude of MUAPs is related to the muscle contraction [12]. The stronger the muscle contraction and the higher the number of activated muscles, the higher the recorded voltage amplitude will be [13].

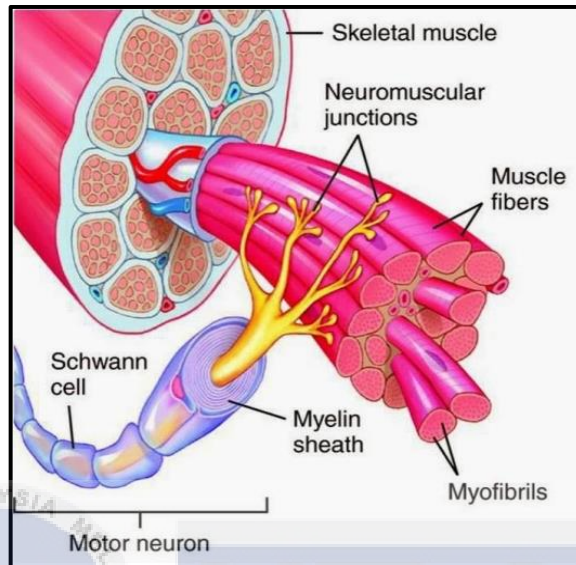


Figure 2.2: Functional motor units which consists of motor units [10]

2.2.2 EMG Measurement Technique

The EMG electrode is used inside a human body's muscle to detect muscle response and bioelectrical activity. There are two main types of measurement technique which are the non-invasive method that involved the use of surface (or skin electrode) and the invasive method that involved the use of inserted electrode. Surface electrode includes gelled and dry EMG electrode which can be either passive or active while inserted electrode includes needle and fine wire electrode [14]. The pros and cons of these electrode will be discussed and explained.

2.2.2.1 Non-invasive Measurement Technique

Surface electrode is often used in the study of muscle activity as it provides the only non-invasive index of the level of muscle activation present [15]. Besides, surface electrodes are better than needle electrodes for recording a compound muscle action potential as they register the total contributions from all discharging motor units [16]. Surface electrodes are applied to the skin of subject and may be in the form of electrolyte gel which purpose is to improve connection, or in the dry form which does