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# AUTONOMOUS WHEELCHAIR (MOBILE ROBOT) VIA EOG SIGNAL RECOGNITION

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"I hereby declare that I have read through this report entitle "Autonomous Wheelchair (Mobile Robot) Via EOG Signal Recognition" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Control, Instrumentation and Automation)"



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Supervisor's Name : ………………………………………….

Date : ………………………………………….

**AUTONOMOUS WHEELCHAIR (MOBILE ROBOT) VIA EOG SIGNAL RECOGNITION**

**WONG CHUI YEE**

**A report submitted in partial fulfilment of requirements for the degree of Bachelor in Electrical Engineering (Control, Instrumentation And Automation) with Honors**



**Faculty of Electrical Engineering**

**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**2014**

I declare that this report "Autonomous Wheelchair (Mobile Robot) Via EOG Signal Recognition" is the result of my own research except as cite in the reference. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ……………………………………………..

Name : ……………………………………………...

Date : ……………………………………………..

To my beloved mother and father

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## ABSTRACT

The purpose of this study is to use electrooculography (EOG) signal as an alternative controlled technique for wheelchair direction control. The main result for this project is the corneal-retinal potential obtained from the electrodes. Corneal-retinal potential (CRP) is the result of hyperpolarization and depolarization existing between retina and cornea. The amplitude of CRP for this project was collected from 5 volunteers. The CRP was obtained from the electrodes and the signal was then transferred to the Matlab. Three electrodes were attached on skin near eyes region to obtain EOG signal. In Matlab, signal analysis was carried out to attain some information about the signals such as maximum and minimum value of the amplitude of the corneal-retinal potential (CRP). Threshold level is determined based on the features of the signal. Threshold level is used to determine the direction of the wheelchair prototype. The overall of this study is to implement the threshold level set using the CRP collected onto the wheelchair prototype. At the end of this project, a comprehensive report about analysis and discussion made based on the results obtained from experiment is produced.

**ABSTRAK**

Tujuan kajian ini adalah menggunakan *electrooculography* (EOG) sebagai teknik alternatif untuk mengawal pergerakan kerusi roda. Dapatan kajian utama untuk projek ini adalah potensi kornea-retina yang diperolehi dari elektrod. Potensi kornea-retina (CRP) adalah hasil daripada hyperpolarization dan depolarization antara retina dan kornea. Amplitud CRP untuk projek ini telah diambil dari 5 peserta. CRP itu telah diperoleh dari elektrod pakai buang dan isyarat itu kemudian dipindahkan ke perisian Matlab. Tiga elektrod akan ditampal di muka untuk mendapatkan EOG signal. Dalam Matlab, analisis isyarat telah dijalankan untuk mencapai beberapa maklumat mengenai isyarat seperti nilai maksimum dan minimum ampiltud potensi kornea-retina (CRP). *"Threshold level"* ditentukan berdasarkan ciri-ciri isyarat. *"Threshold level"* digunakan untuk menentukan hala tuju prototaip kerusi roda. Keseluruhan kajian ini ialah untuk menentukan *"threshold level"* CRP yang akan digunakan bagi mengawal prototaip kerusi roda. Pada akhir projek ini, satu laporan komprehensif tentang analisis dan perbincangan dibuat berdasarkan keputusan yang diperolehi daripada eksperimen yang telah dijalankan.

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| | |
|---|---|
| JKM | Social Welfare Department |
| PWD | People With Disabilities |
| EPW | Electrical Powered Wheelchair |
| EEG | Electroencephalography |
| EMG | Electromyography |
| ECG | Electrocardiography |
| EOG | Electrooculography |
| CRP | Corneal-retinal Potential |
| Mm | milimetre |
| mV | milivolt |
| dB | decibel |
| Hz | Hertz |
| PA system | Public Address System |
| IC | Integrated Circuit |
| BCI | Brain Computer Interface |
| ERD/ERS | Desynchronization-synchronization |
| PSD | Power Spectral Density |
| HHT | Hilbert Huang Transform |
| FFT | Fast Fourier Transform |
| ANN | Artificial Neural Network |
| RMS | Root Mean Square |
| AC | Alternating Current |
| DC | Direct Current |
| USB | Universal Serial Bus |
| PWM | Pulse Width Modulation |

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# CHAPTER 1

# INTRODUCTION

## 1.1 Overview

The Person with Disabilities Act (2008, art. 2) defines people with disabilities are person who have long term physical, mental, intellectual or sensory impairments which prevent them from participating the social activities effectively.

Wheelchair is an important communication tool for those who are handicapped and suffered from diseases such as paralysis, Parkinson's disease and Lou Gehrig's disease. With the wheelchair, patients are able to move around and interact with other people. Wheelchairs help people with moving disabilities to help them in sustainable into environment. There are many types of techniques have been applied to the wheelchair in order to ease the patients. The most commonly used technique is controlling the wheelchair by using joysticks or tactile screen. However this technique (using joystick or tactile) cannot satisfy the demands of elderly or patients who have restricted limb movement [1].



Controlling wheelchair by using joysticks requires excellent control from the user [2]. Some users especially those users who suffer from Parkinson's disease or Lou Gehrig's disease face difficulty in controlling wheelchair by using joystick. Patients who suffer from these diseases have difficulty in controlling their limb movement. They have little or no control to their muscle. These patients unable to control their limb motion and hence cannot control the wheelchair by using traditional method which is joystick or tactile screen. Good motor functionality of hand muscle is needed to handle the surrounding region when controlling the wheelchair using joysticks.

## 1.2 Project Motivation

Patients who suffer from paralysis, Parkinson's disease and Lou Gehrig's disease make them facing difficulties in mobility issues. According to Social Welfare Department (JKM) statistics in August 2010, showed that there are 313685 people with disabilities (PWD) are registered. According to Malaysian Parkinson's Disease Association, it is approximated that about 15000 to 20000 patients suffer from Parkinson's disease in Malaysia. All these patients rely on wheelchair to enable them to interact with environment [1].

The number of people with disabilities (PWD) has an increasing trend in Malaysia, demands for wheelchairs is also increasing. The common type controlled wheelchair is electrical powered wheelchair (EPW). This electrical powered wheelchair (EPW) is controlled by using a joystick. Joystick is the common instrument in controlling electrical powered wheelchair (EPW). User can move to the targeted location by controlling the joystick as shown in Figure 1.1. However, controlling technique using joystick as shown in Figure 1.2 is not convenient for other disabled people such as those who suffer from paralysis, Parkinson's disease and Lou Gehrig's disease. They have difficulties in controlling the joystick because they do not have good motor functionality of hand muscle.



Figure 1.1: Joystick controller [21]

Figure 1.2: Electrical powered wheelchair using joystick controller

Existing hands-free controlled wheelchairs in the market are costly which encourage the development of an alternative method to substitute currently hands-free controlled wheelchairs that are available in the market. EOG signal recognition technique can be developed in a low cost method. Implementation of EOG signal recognition in navigating the wheelchair can help to reduce the cost of the wheelchair and thus it is affordable by many disabled people.

## 1.3 Hypotheses

Hypothesis is used to determine reason on method selection. Two hypotheses have been made for this project. The first hypothesis for this project is majority of people who suffer muscular and neurological disorders still have the ability to move their eyes. The second hypothesis is shifting of gaze will result a potential and negative potential voltage respectively. Based on these two hypotheses, electrooculography (EOG) signal recognition is proposed.

## 1.4 Problem Statements

Wheelchair is the common tool for disabled people. The conventional wheelchair (hands-rim controlled wheelchair) and electrical powered wheelchair (EPW) which is controlled by a joystick are not suitable for all types of disabilities for example people who suffer Parkinson's disease because they do not able to control their hand coordination well thus cannot control the wheelchair using joystick. People with muscular and neurological disorder still have the ability to move their eyes. Therefore, EOG signal recognition technique is developed to help those disabled people with Parkinson's disease.

When eyes are moving, they will generate a potential difference, known as corneal-retinal potential (CRP). The polarity for this voltage potential obtained is different for different directions. The polarity is positive for right and upward eyes movement while the polarity is negative for left and downward eyes movement.

To navigate the wheelchair using EOG signal, the threshold level of the corneal-retinal potential (CRP) has to be determined accurately. Threshold level is determined through the features of EOG signal obtained. Threshold level can be the maximum, minimum, mean or root mean square (RMS) values of the signal obtained. It has to be very critical in selecting the threshold level. If the selected threshold level is too high, it is very hard to achieve, meanwhile if the selected threshold level is too low, then it will be very sensitive. Any eyes movement will lead to changing in motor direction. Thus, threshold level has to be determined precisely and accurately.

## 1.5 Objectives

Following are the objectives for this project:

1.) To classify features of electrooculography (EOG) signal.
2.) To develop a controlled wheelchair prototype using electrooculography (EOG) technique.

In order to achieve the first objectives, experiments have to be conducted to obtain EOG signal and analysis has be done to classify the features of EOG signal. A motor based with PIC microcontroller is used to develop a wheelchair prototype. The features extracted from EOG signal is used to control the wheelchair prototype.

## 1.6 Scope

This project is basically focussing on develop a hands-free controlled wheelchair prototype which is suitable for patients with severe motor disabilities using electrooculography (EOG). Dimension for the wheelchair prototype is 200mm×110mm×120mm (length × width × height). This project proposes the used of wheelchair for those who are paralyse but having the ability for eyes coordination. Movement of eyes produces EOG signal which is then read by EOG kit (Shield EKG-EMG board). These EOG signals are used to control the directions of the wheelchair which are left, right, forward and reverse direction. For those who are motor disabilities that do not have ability for eye coordination will not be covered in this project. Matlab Simulink is the software used to obtain and process the EOG signal. PIC microcontroller is used to program the direction control for wheelchair prototype. Besides, factors such as light intensity colour in surrounding environment and personal conditions for example tiredness, sleepiness and stressed condition will not be included in the consideration in EOG method. The experiment will be carried out in indoor. Place such as laboratory and lecture room to avoid disturbance to the signal. The experiment should be conducted in a silent situation. For volunteers who take part in the testing cannot be colour blindness and night blindness and their age is in the range from 20 to 24 years old.

## 1.7 Report Outline

The report starts with understanding the motivation of the project, determines the objectives of carrying out this project and then followed by defining the scope of the project. Literature part consists of reading some journals about this topic to gain a rough idea on the method to carry out the experiment. By reading journals, it provides many related information about the project and acts as a guideline to conduct the experiments. The next step is to propose a suitable method to conduct the experiment after reading the journals. The methodology part describes the procedures to obtain results. Results obtained are tabulated. Discussions are made based on the results obtained. In conclusion, it concludes all the results and discussions. Hence it is the part to determine whether the objectives are achieved or not. Suggestions for future work are also included in this report.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Basic Topologies

In this section, simple concept about electrooculography (EOG) will be introduced such as the EOG background, types of EOG signal, and basic components used in obtaining EOG signal will be explained.

### 2.1.1 Electrooculography (EOG) Background

Electrooculography is a bio-signal which is produced by eye-movements. It is a test to measure the electrical response of the light-sensitive cells (rods and cones) and motor nerve components of the eyes [3]. It is the simplest and the weakest bio-signal that can be obtained from human body. The signal pattern is not quite complex [4]. EOG is the most effective test for the study of the functioning of the vestibular system [5].

EOG is the electrical signal obtained by the potential difference between the cornea and retina of the eyes. It is produced inside the eyeball by the metabolically active retinal epithelium [6]. Electrooculography (EOG) observes the eye-movements [7]. The movements of the eyes can be considered as steady-electrical dipoles which are anterior pole and posterior pole. Anterior pole is cornea which is positive pole while posterior pole is retina which is negative pole [8]. The larger amount of electrically active nerve present in the retina compared to the cornea. This difference leads to the potential difference between cornea and retina which is known as corneal-retinal potential (CRP) [9]. As eyeballs rotate, CRP is produced.

Corneal-retinal potential (CRP) is a result from depolarization and hyperpolarisation existing between the retina and cornea [7].

EOG potential is the resting potential of the retina. The potential is varied proportionally to the displacement of the eyeballs inside the conductive environment of the skull [6]. Depolarization and hyperpolarisation of between retina and corneal produce potential difference across the eyes, which is known as corneal-retinal potential (CRP). In dark condition, photoreceptors are depolarized and continuously active and releasing glutamate to bipolar and horizontal cells. When light arrives, photoreceptors hyperpolarise and amount of glutamate released decreases. Photoreceptors contain light-absorbing pigment molecules. On-centre bipolar cells and off-centre bipolar cells have their own glutamate receptors [17].

### i.) Hyperpolarisation

Hyperpolarisation is a process that occurs in the presence of light. When light is present, photons will strike a pigment molecules which causes photoreceptors to hyperpolarise. The photoreceptors receive a photon of light, sodium gates in the membranes of the cell close and neurones become hyperpolarize. When photoreceptors are hyperpolarised, they will release less inhibitory neurotransmitters (glutamate) which then cause the bipolar cell to depolarize. In the presence of light, number of calcium ion channels open is low and thus the rate of neurotransmitter being released is decreased. As bipolar cells are depolarizing, action potential is generated and this in turn causes the ganglion cells to depolarize and generate action potential. Figure 2.1 shows the hyperpolarisation process [20].

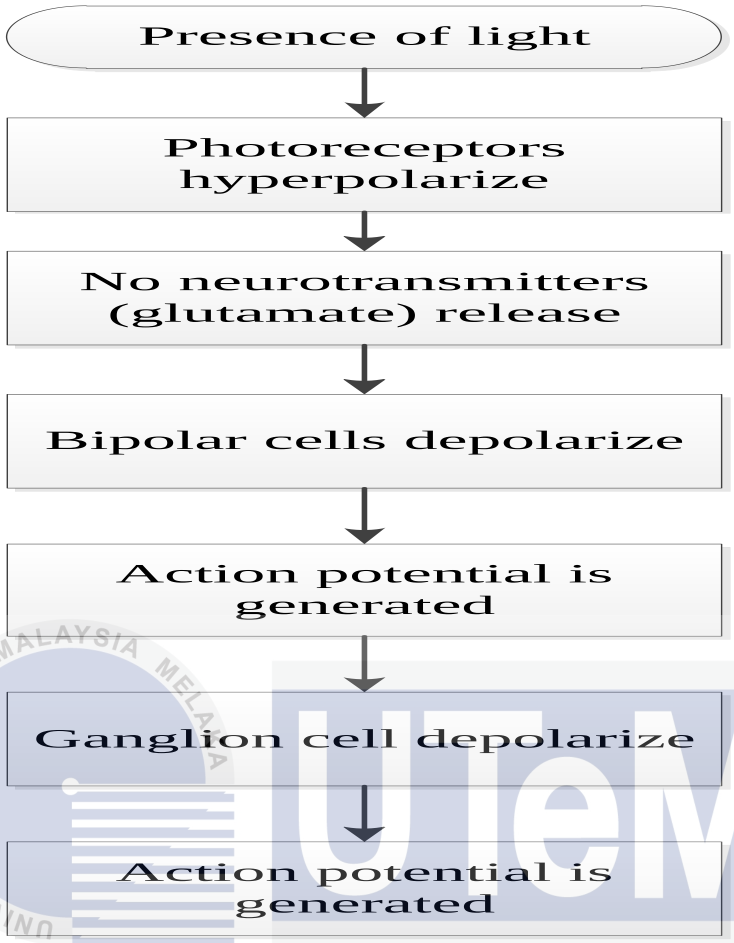


Figure 2.1 Hyperpolarisation process



**ii.) Depolarisation**

Depolarisation is a process that takes place in the absence of light. In the dark condition, photoreceptors do not receive photon. Under this condition, photoreceptors are depolarized. Depolarization of photoreceptors release inhibitory neurotransmitters (glutamate) which then prevent the bipolar cells from depolarizing. This is because in the dark, numbers of sodium ion channels opened at the synaptic terminal increase which leads to increase in higher neurotransmitters released. Therefore, ganglion cells do not depolarize and hence no action potential is generated. Figure 2.2 shows the process of depolarization [20].

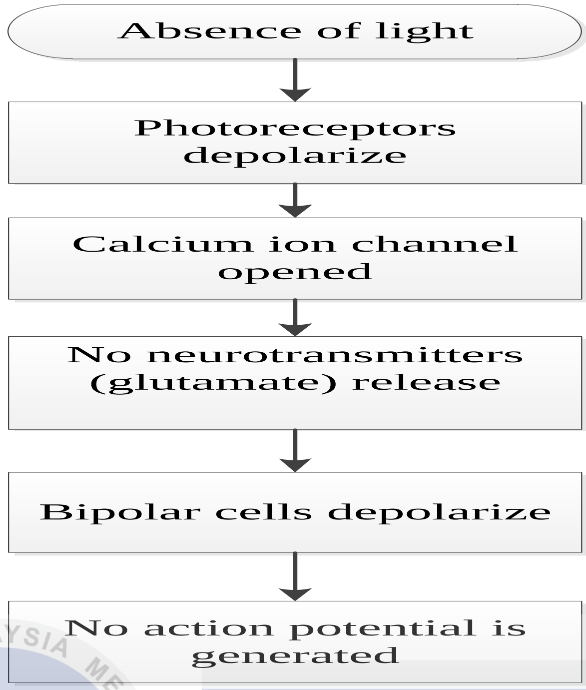


Figure 2.2 Depolarisation process

### 2.1.2 Types of EOG Signal

There are four basic types of eye movements. Following are the explanation for the different types of eye movements.



#### i.) Saccadic Eye Movements

Saccadic eye movement is a rapid change of eye direction form one fix point to another. Saccadic eye movements are inconsistent. It can be acquired through a subject's head that is in still and relaxation mode while reading a book. As the subject is reading across the text, eyes will make larger voluntary movements which are known as saccades. Saccadic movement occurs due to eyes cannot respond to the changes in the position of the target. When the target moves suddenly, there is a delay occur before the eyes begin to move to the new target.

**ii.) Smooth Pursuit Movements**

Smooth pursuit movements are slower tracking movement of the eyes. This movement is under voluntary control which is not same as saccadic. Saccadic movement can be voluntary and also involuntary. Subject can determine whether or not to follow the moving target.

**iii.) Vergence Movements**

Vergence movements are disconjugate where the two eyes do not move in the same direction. This movement involves convergence or divergence of the lines of sight of each eye to see an object that is nearer or further. This means that the subject is slowly focusing on the target or distracting by the object near by the target.

**iv.) Vestibulo-ocular Movements**

Vestibulo-ocular movements occur to maintain the image in eyes while head position is changing. Vestibular system senses the momentary changes in head position and creates rapid corrective eye movements [22].



### 2.1.3 Electrooculography (EOG) Signal Detection

The potential difference produced is very small which is in the range of 0.05mV to 3.5mV and this potential difference is linearly proportional to eye displacement [11]. To control a wheelchair using EOG signal, the analogue form of EOG signal has to be converted into a more suitable signal for controlling purpose [2].

To acquire EOG signal, electrodes are placed near the eyes. 5 electrodes are needed to obtain the electrical signal where two electrodes are placed on the outer side of the eyes, two electrodes are placed on the up and down portion of the eyes and another electrode is placed on the forehead as shown in Figure 2.3. Table 2.1 shows the function of each electrode.

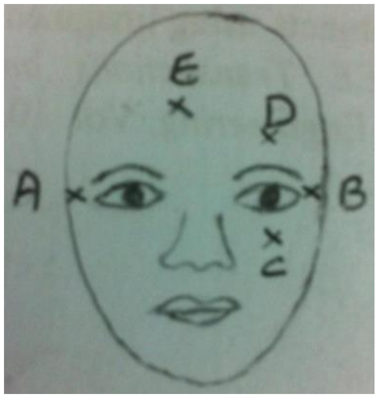


Figure 2.3: Electrodes placement

Table 2.1: Function of each electrode

| Position of electrode | Function |
|---|---|
| A, B | Detect horizontal movement |
| C,D | Detect vertical movement |
| E | Reference (Ground) |



### 2.1.4 Basic Components of the System

The basic components that are used in obtaining the signal are EOG amplifier, filter and control system. Amplifier is used to amplify the amplitude of the signal. The original amplitude of the signal is very small and it is hard to control the motor direction. Hence, the amplitude of the signal needs to be amplified. Filter is used to eliminate or reduce the unwanted noise that presents in the signal. Control system is used perform feedback operation to ensure that the accuracy of direction of the wheelchair.

**i.) EOG Amplifier**

EOG amplifier is used to amplify the acquired signal. The potential difference acquired from the eye movements is very small ranges from 0.0mV to 3.5mV. This small potential difference cannot be used to process the microcontroller operations [12]. Thus, an amplifier is needed to amplify the magnitude of the voltage. The common amplifier used is instrumentation amplifier. Its function is to amplify the differential signal obtained from the electrodes [12]. There are two stages of instrumentation amplifier in the circuit. The first stage is an instrumentation amplifier with common mode rejection of 120dB and gain of 100. The second stage is an instrumentation amplifier with gain of 100 [4].

**ii.) Filter**

Like other bio-signal, EOG signal will also be interfered by environmental disturbances. Hence, filtering process is required to eliminate the disturbances from the system. The filters consist of high pass filter and low pass filter in order to remove high frequency and low frequency noise signal. For high pass filter, the frequency is set at 0.5Hz or 1.0 Hz. High pass filter is used to pass the signal which is higher than the threshold level and reduce wandering baseline. For low pass filter, the frequency is set at 40Hz. It is used to pass the signal which is lower than the threshold level and reduce 60Hz power line noise [12]. Power line noise is an electromagnetic interference [4]. Although low pass filter is set at 40Hz, the power line interference is still present in the system. Thus, a notch filter is applied to eliminate the power line interference. A notch filter is a band stop filter with narrow stop band. A narrow stop band will have high Q factor. Notch filters are commonly used in Public Address (PA) system and in instrument amplifier such as acoustic guitar to reduce feedback.

**iii.) Control System**

Control system is the central part of an IC system. Control system is used to perform transduction and feedback operation [3]. The control system is used to control the direction of the wheelchair. Output from the wheelchair is then feedback to the control system to improve the performance of the wheelchair. Control system is an interface between wheelchair and EOG signal. This control system is used to determine the validity of the command. The received analogue (EOG) signal is digitized to control the wheelchair. Based on the digitization of the signal, threshold level for a system is set. The threshold level determines direction of the wheelchair.

Control system has to distinguish the command given by the user. By measuring time duration between successive pulses enables the control system to remove pulses due to interference such as eye blinking and involuntary eye movements.

### 2.1.5 Noise Removal

To reduce the effects, shifting resting potential (mean value) has to be minimized [2]. In order to minimize the shifting resting potential, high pass filter with cut-off frequency at 0.05Hz is applied. Besides, amplifier with programmable gain ranges from 500, 1000, 2000 and 5000 can also help to reduce the effect of shifting resting potential [11].



## 2.2 Related Previous Work

This section is to compare the methods that have been done in previous research by other people. In comparing the methods, determine the advantages and limitations of each method. At the end of this section, a summary will be written which relates to the most suitable method that is going to be used for this project.

### 2.2.1 Developed Methods

There are many other technologies have been developed in improving the wheelchair in order to help the disabled people. These can help to help the severely disabled people who are unable to move their body to control the wheelchair easily without using joysticks. These techniques of controlling wheelchair include eectroocuolography (EEG) or thought controller, voice recognition and head pose and gaze direction, electromyography (EMG), and electrooculography (EOG). Thought controller and voice controller would be discussed in the following sections.

#### i.) Thought Controlled (EEG) Wheelchair

Brain Computer Interface (BCI) gives another option to substitute joystick controlled wheelchair. It navigates the wheelchair by using a thought controller. Desynchronization-synchronization (ERD/ERS) is one of the spontaneous mental signal which focuses on the motor imagery area by imagining hand, feet and tongue movement [13]. Controlling using thought controller is a flexible control technique [14].

Advantages of EEG based system are having better resolution and portable of the system [13]. Besides, EEG based control system does not require motor skills in order navigating the wheelchair. It is suitable for those with limited limb movement as it does not require motor skills [14]. The disadvantages for controlling using EEG based system are EEG signal is very sensitive to noise which means that other bio potentials produced in the body such as EOG and EMG will have effect on the EEG signal [13]. One of the main disadvantages of controlling wheelchair using EEG signal is that the user needs to have a good neck and head movement. Table 2.2 summarises the advantages and disadvantages of the EEG controlled wheelchair.

Table 2.2: Comparison of advantages and disadvantages of EEG signal

| **Advantages** | **Disadvantages** |
|---|---|
| • EEG signal having better resolution.<br>• Do not require motor skills | • EEG signal is very sensitive to noise.<br>• Users need to have a good neck and head movement.<br>• EEG signal is seldom deterministic |

To extract EEG signal, power spectral density (PSD) and Hilbert Huang transform (HHT) are used. Power spectral density (PSD) is performed by squaring the Fast Fourier Transform (FFT) of each one second segment signal to convert the time based into EEG frequency band. While in Hilbert Huang Transform (HHT), it is a time-frequency analysis algorithm and is suitable for analyzing non-linear and non-stationary data. [13] Artificial neural network (ANN) is a classification method. It classifies the non-linear signal and it is widely used for classification in biomedical application. [13,14] To use artificial neural network (ANN), the feature data value needs to be scaled to the range within zero and one [13]. Table 2.3 shows the comparison of methodology used for EEG signal wheelchair control.

As shown in Table 2.3, the similarity between these two methods is that band pass filter. However the range of frequency used is different. If the range is higher, it can receive a wider range of signal frequency. The usage of digital signal processing is able to enhance quality of raw signal. Sampling rate is the sampling time of the system. The higher the sampling rate, the smaller the sampling time and this shows that more data will be obtained at higher sampling rate.



Table 2.3: Comparison of methodology used for EEG signal wheelchair control

| | | |
|---|---|---|
| **Journal Title** | Toward Fewer EEG Channels and Better Feature Extractor of Non-Motor Imagery Tasks Classification for a Wheelchair Thought Controller | Adaptive EEG Thought Pattern Classifier for Advanced Wheelchair Control |
| **Year** | 2012 | 2007 |
| **Author(s)** | Rifai Chai, Sai Ho Ling, Gregory P.Hunter and Hung T.Nguyen | D.A. Craig and H.T. Nguyen |
| **Methodology** | • The sampling rate was 256 Hz<br>• Digital signal processing was used to enhance quality of the raw signal. | • The sampling rate was 1024Hz.<br>• Volunteers were required to perform 4 different mental |

| | | |
|---|---|---|
| | • Bandwidth of a band pass filter was in the range of 0.1 Hz to 40Hz.<br>• Notch filter was used and with bandwidth of 50 Hz.<br>• With fewer electrodes used in two EEG channels present more portability setting-up. | tasks.<br>• Band pass filter used was in the range of 0.1 Hz to 100Hz.<br>• Two seconds of data was removed from the beginning and the end of the sample in order to remove transitional effects. |

**ii.) Voice Controlled Wheelchair**

For voice controlled wheelchair, voice commands are used to navigate or drive the wheelchair. Voice command is a better information method with high efficiency and low load for users [15]. Voice command has been implemented into other fields such as Interface Agent for Process Plant [15, 16].

To control wheelchair using voice command, the commands used were to be determined first [15]. The commands were used to show the desired pathway. This command was combined with the surrounding environment through the solar sensor to identify a safety track [16]. Table 2.4 shows the advantages and disadvantages using voice controlled while Table 2.5 shows the comparison methodology for voice controlled wheelchair.



Table 2.4: Advantages and disadvantages of voice controlled wheelchair

| **Advantages** | **Disadvantages** |
|---|---|
| • Reduced the physical operating on wheelchair. [16]<br>• User can maintain a proper positioning. [16]<br>• Can be used by many wheelchair users as voice control system requires clear and reliable voice commands. [16] | • Voice input system may fail to recognize user's voice. [16]<br>• Information is transmitted by voice in a limited rate. [15]<br>• Time delay occurred as to process pronunciation and recognition. [15]<br>• New command will be ignored before completion of the first command. [15] |

As shown in Table 2.5, common modes used in voice controlled method are momentary mode and latched mode. These two modes are used to give command in order to drive a wheelchair. Commander is used to determine the commands set in navigating the wheelchair. Before applying voice controlled method, experiment using simulator was done to check whether the commands used would be sufficient to navigate a wheelchair.

Table 2.5: Comparison of methodology used in voice controlled wheelchair

| | | |
|---|---|---|
| **Journal title** | Voice Control of a Powered Wheelchair | Guidance of a Wheelchair by Voice |
| **Year** | 2002 | 2000 |
| **Author (s)** | Richard C.Simpson and Simon P.Levine | Kayoko Komiya, Kiyoshi Morita, Kouu Kagekawa and Kenji Kurosu |
| **Methodology** | • Momentary mode and latched mode were used to give command.<br>• Speech Commander, a continuous-speech voice recognition system was required to determine the commands set<br>• The experiments were categorized into 2 conditions which were condition with navigation assistance active (condition WNA) and condition without navigation assistance (condition NNA) | • The commands in navigating the wheelchair were set.<br>• Preliminary test was done by using Micro-robot KHEPERA<br>• Momentary mode and latched mode were used to test with the wheelchair<br>• Experiment using simulator was done to check whether the commands used would be sufficient to navigate a wheelchair. |

### 2.2.2 Problems Faced When Using EOG Controlled Wheelchair

Based on the previous work done by some researchers [1-2], [7], [10], [18-19], electrooculography (EOG) measures the electrical potential difference during the eye movement which is known as corneal-retinal potential (CRP). This potential difference acts as an input signal in controlling the wheelchair. Electrooculography (EOG) technique is suitable because those who suffer muscular and neurological disorders still retain the ability to move eyes. They still have the ability to control their eye movements even though they have severe disabilities. Electrooculography (EOG) provides a more natural mode in controlling the wheelchair.

EOG signal ranges from 0.5mV to 3.5mV and varies with frequency range of about 100Hz [10]. EOG signal is linearly proportional to eye movements (gaze angle) in the region between +30° and -30° [18]. EOG signal depends on the input from the eyes [19]. Using manual method, user is required to look up to move forward, look down to move backward, look right to turn right and look left to turn left. Hence, while determining direction of wheelchair, user is not allowed to look around surrounding direction [7]. This indicates that user has to pay fully concentration while driving the wheelchair [1].

The bio-signals such as EMG, ECG, EEG and EOG produced in human body are seldom deterministic. Magnitude for the potential difference varies with time even under controlled environment [10]. This shows that even the same patient is used under same controlled environment will acquire different EOG signal. EOG signal depends on many external and internal factors [2]. For instances, interference of other bio-signals like EEG, EMG and ECG, eyeball rotation and eyelid movement.



## 2.3 Summary of Review

Electrooculography (EOG) is a practicable method to be implemented in controlling the wheelchair. EOG technique can be applied to any disabled people as long as they retain the ability of eyes movements.

Table 2.6 shows the limitations of voice controlled wheelchair, EEG signal controlled wheelchair and EOG signal controlled wheelchair. Voice controlled, EEG signal controlled and EOG signal controlled methods are examples of hands-free controlled wheelchair methods. Hands-free controlled method means that the wheelchair can be controlled without using hand. Wheelchair user can navigate the wheelchair without using hands to control the direction of wheelchair. According to Table 2.6, limitations for EOG signal controlled wheelchair are less than the other two methods which are voice controlled wheelchair and EEG signal controlled wheelchair. Hence, the proposed hands-free controlled wheelchair method is using EOG signal controlled.

Table 2.6: Limitations of voice controlled wheelchair, EEG signal wheelchair control and EOG signal controlled wheelchair

| **Type of control** | **Limitations** |
|---|---|
| Voice controlled | • Cannot be navigated well in noisy environment<br>• Limited voice command<br>• Not practicable for crowded environment and irregular pathway |
| EEG signal controlled | • Weak signal strength<br>• Complicated signal<br>• Difficulty for electrode placement<br>• Wrong recognition |
| EOG signal controlled | • User needs to pay full attention while driving the wheelchair<br>• Signal is seldom deterministic |

Processes in obtaining EOG signal are same as the previous researchers [2], [4-6], had done. To obtain the EOG signal, electrodes are attached to the skin near the eyes region. However in this study, horizontal signals and vertical signals will be obtained separately instead of obtaining horizontal and vertical signals at the same time. This means that only 3 electrodes instead of 5 electrodes will be attached to skin near eyes region at one time to obtain either horizontal signals or vertical signals.

The processes of obtaining EOG signal include amplifying and also filtering the signal. Purpose of amplifying the signal is to amplify the signal obtained in order to be used for controlling purpose for the motor. A shield board with built in amplification and filtering processes is used instead of developing own amplifier and filter circuit as previous researchers had done. By using built in amplification and filtering processes will help to minimise the noise presents in the signal.

**CHAPTER 3**

**METHODOLOGY**

## 3.1 Experimental Equipments Lists

The following section will explain the functions for each equipment that is going to be used in conducting the experiment such as the electrode sensor, Olimex shield board and Arduino Mega 2560.

### 3.1.1 Disposable Electrodes

The electrode sensor used is disposable electrodes as shown in Figure 3.1. This electrode sensor consists of three electrodes in a channel for left, right and ground. This electrodes sensor has equipped with gel like substance. The gel-like substance is used to minimize the gap between skin and also electrodes and to reduce resistance between skin and electrodes. If there is air gap between skin and electrodes, higher level of noise will exist in the signal. These electrodes are connected to the shield board to obtain the signal.

Figure 3.1: Disposable electrodes

### 3.1.2 Shield

Shield used is Shield-EKG-EMG board. The shield board is used to connect the disposable electrodes. It is powered by the host board where the shield is mounted on such as Arduino like board. The power for the shield board is either 3.3V or 5V. Once the shield board is powered up, the power LED on the board will be lighted up. Top layout and bottom layout of the shield board are shown in Figure 3.2 and Figure 3.3 respectively. Appendix A shows the physical dimension of the board.


Figure 3.2: Top layout of the shield board


Figure 3.3: Bottom layout of the shield board

The shield board consists of instrumentation amplifier, two high-pass filters and 3$^{rd}$ order “Besselworth” filter. It also contains high frequency (HF) rejection and provides high voltage protection. The instrumentation amplifier is used to amplify the corneal-retinal potential (CRP); high pass filter is used to remove noise and pass high frequency signal. It reduces the amplitude of signal with frequencies lower than the cut-off frequency. Besselworth filter is a combination of Butterworth and Bessel filter. The filter is good enough to prevent aliasing artifacts. Table 3.1 shows the gain and frequency used for the amplifier and filters. Appendix B shows the full schematic circuit diagram.

Table 3.1: 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<br>Gain, G=3.56 |

Before do any connection, the main parts of the shield board have to be determined to prevent any damage to the shield board. Figure 3.4 shows the main parts on the shield board.

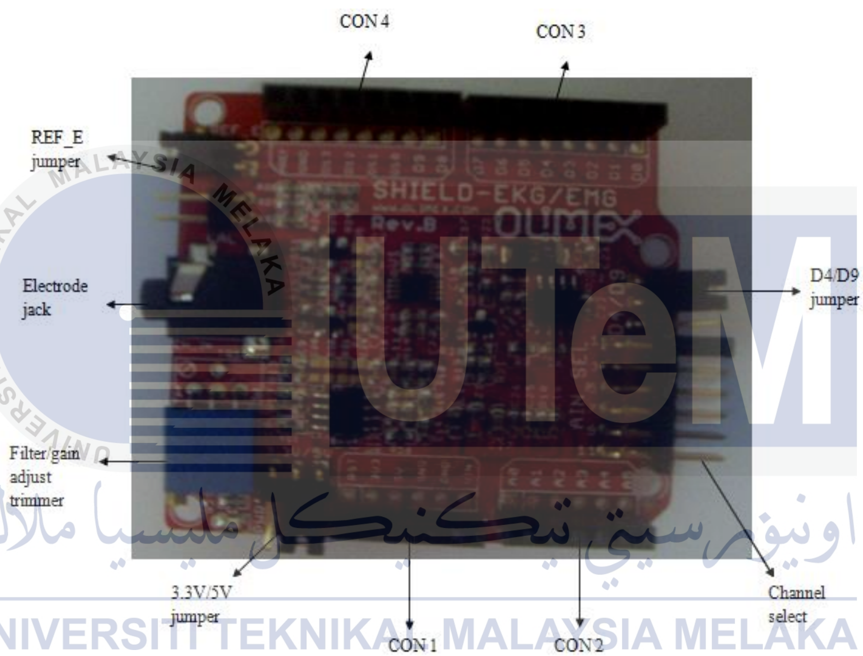




Figure 3.4: Main parts on the board

### 3.1.3 Arduino Mega 2560

Arduino Mega 2560 is the interface between Matlab Simulink and the shield board. It transfers the signal obtained from the shield board to Matlab Simulink in order to process the signal and extract the features from the signal.

Power supply for Arduino Mega 2560 as shown in Appendix C and Appendix D is obtained from USB connection or external power supply. AC-to-DC adapter or battery is the example of external power supply for Arduino Mega. Range of the external power supply for Arduino Mega 2560 is between 6V to 20V.

The board consists of 54 digital input or output pins with inclusive 14 pins which can be used as PWM output, 16 analogue input pins, 4 hardware serial ports, 16MHz crystal oscillator, ICSP header, USB connection, reset button and a power jack. Function of the pins is shown in Appendix F. To start programming using Arduino Mega 2560, the board is either connected to a computer by using a USB cable or an external power supply. Appendix E shows the summary of the technical specifications for Arduino Mega 2560.

## 3.2 Experimental Approach

This section explains about the steps in conducting the experiments. Besides that, reliability test and validity test will also be explained in this section. Reliability test and validity test are used to test the accuracy of the signal obtained and the threshold level set.

### 3.2.1 Electrodes Placement

To obtain the CRP, disposable electrodes are attached to the skin nearby eyes. Muscles that the electrodes attached to are known as extraocular muscle. Extraocular muscle is made up of six muscles which are superior rectus, inferior rectus, lateral rectus, medial rectus, inferior oblique and superior oblique as shown in Figure 3.5. Figure 3.6 (a) shows the electrodes placement in order to obtain horizontal signal; Figure 3.6 (b) shows the electrodes placement in order to obtain vertical signal; while Figure 3.6 (c) shows the grounding at non-muscles area. The grounding should avoid muscles area because contraction of muscles will contribute artifact to the signal obtained. All these muscles are responsible in controlling the eyes movements are shown in Table 3.2. Steps to carry out the experiment will be described in the following section.

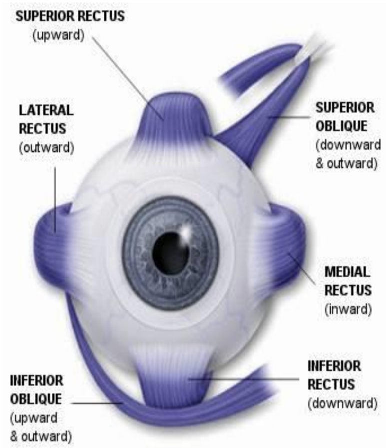


Figure 3.5: Eyes muscles

Figure 3.6 (a): Electrodes placement in experiment (for horizontal signal)

Figure 3.6 (b): Electrodes placement in experiment (for vertical signal)

Figure 3.6 (c): Grounding at non-muscle area



Table 3.2: Function of the muscles

| **Name of muscle** | **Function** |
|---|---|
| Superior rectus | Control upward movement |
| Inferior rectus | Control downward movement |
| Lateral rectus | Control outward movement |
| Medial rectus | Control inward movement |
| Superior oblique | Control downward and outward movement |
| Inferior oblique | Control upward and outward movement |

### 3.2.2 Experimental Steps

The experiments will involve 5 volunteers. Following table shows the requirements set for the volunteers before they take part in the experiment.

Table 3.3: Requirements for volunteer

| Requirement | Description |
|---|---|
| Age (years) | 20-24 |
| Eyesight | Can be shortsighted or longsighted but cannot have other deficiencies such as colour blindness or night blindness. |
| Environment | Indoor condition with fluorescent light intensity |

The test will be carried out in indoor condition. The volunteer will look at the centre point first for 2 seconds, then look to the left at the targeted object and maintain at that eyes position for 4 seconds to obtain the left signal as shown in Figure 3.7. The method is the same for obtaining right. The volunteer will have to look at the centre point first for 2 seconds, then look to the right at the targeted object and maintain at that eyes position for 4 seconds as shown in Figure 3.8. This process will be carried for 6 seconds for one direction and volunteer is required to maintain the sitting posture during the whole experimental process. These processes are the same in obtaining vertical signal which are upward and downward signals as shown in Figure 3.9 and Figure 3.10. Only eyes movement is involved. Besides, during the testing process, the volunteers have to pay full attention to avoid eyes blinking. Blinking is an unconscious eye movement. However, when a person is paying full attention, number of eyes blinking will be decreased.



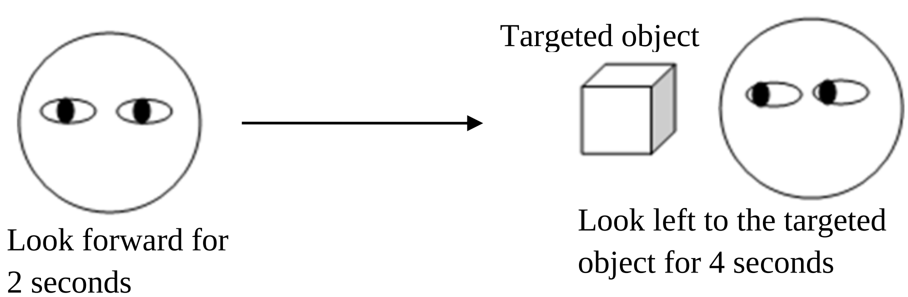


Figure 3.7: Obtaining left signal

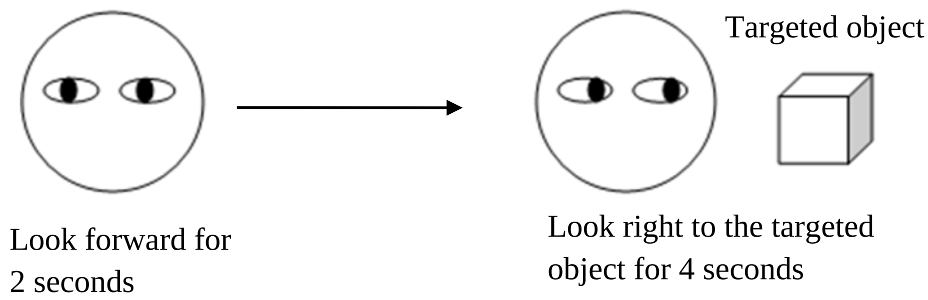


Figure 3.8 Obtaining right signal

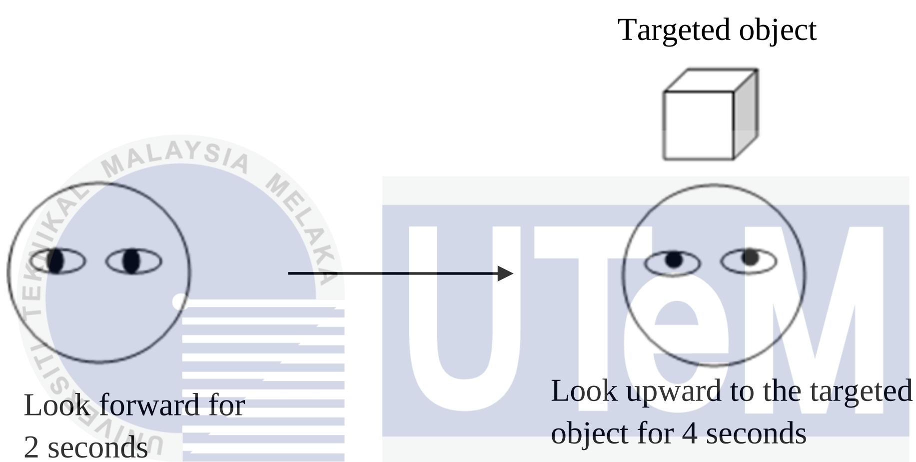


Figure 3.9: Obtaining upward signal



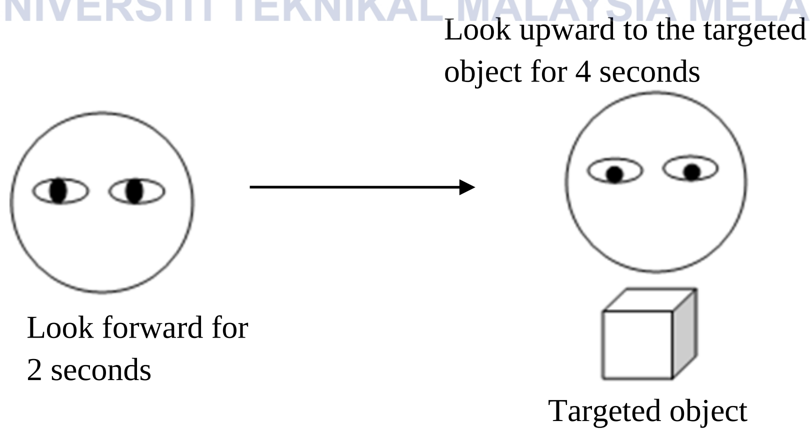


Figure 3.10: Obtaining downward signal

### 3.2.3 Reliability Tests

There are 2 methods to test the reliability of the data obtained. The first method is to repeat the process of obtaining left and right signal for 5 times. This step is to show the repeatability of the data obtained that is the data obtained is about the same if the experiment is conducted for 5 times. The second method is looking to the left and right direction in a given interval of time. This means that the volunteer will have to look to the left direction first and then look to the right direction or vice versa in a given time. The methods mentioned will be conducted as well for upward and downward directions.

**Method 1: Repeat 5 times for the process in obtaining left and right directions**

After obtaining the first set of data for one volunteer, the process (look at the centre point then to the left direction and look at the centre point then look to the right direction) will be repeated for another 4 times to obtain left and right signal on the same volunteer. This method is to make sure that the amplitude when the eyes are moving either to the left and right direction is at about the same amplitude in 5 times. Place to conduct the experiment might be changed in order to obtain a more accurate results. If disturbances do not exist, the amplitude of the corneal-retinal potential (CRP) obtained will be the same. Besides, by applying this method, features during eyes movement can be easily obtained. This step is the same for obtaining upward and downward directions.



**Method 2: Having a combination of signal at one time**

Combination of signal means that in the given interval of time, the volunteer will have to look to left and right direction at the targeted object to obtain the left and right signal in a same plot. Time taken for carrying out for this method will be longer, which is 8 seconds.
Steps to be carried out for this method are as followed:

1.) Volunteer will look at the centre point for 2 seconds.
2.) After 2 seconds, volunteer will look to the left direction at the targeted object and maintain at that eyes position for 4 seconds.
3.) After that, the volunteer will look at the centre point again for 2 seconds.

4.) Steps 1 to steps 3 will be repeated for 5 times.

A graph is plotted to compare the amplitude of the signal obtained in Method 1. Step 1 to Step 4 will be repeated with different directions in order to obtain vertical signal. If the amplitude of signals obtained is not same, the experiment will be conducted in another day in order to let the volunteers to have enough of rest. If the personal condition of the volunteer is good, then the place for conducting the experiment will be shifted in order to obtain a better result.

### 3.2.4 Validity Test

After obtaining data sets for left and right direction, determine the threshold level for turning left and right direction. Threshold level is the minimum value to trigger the motor to turn into left or right direction.

To verify the threshold level set, 5 different volunteers will be involved in this validity test whereby the volunteer will be required to look forward, look to the left direction and look to the right direction in order to move the wheelchair prototype. This process is to verify the accuracy of the threshold level set. Different people will have different corneal-retinal potential (CRP). This means that the threshold level will be varied for different people. The threshold level set is based on the amplitude of corneal-retinal potential (CRP) obtained. This amplitude of corneal-retinal potential (CRP) is taken from the experiments conducted for each different volunteer. Therefore if all of the 5 volunteers involved able to make the wheelchair prototype move according to eyes movement based on their own threshold level set, the threshold level set is correct. Threshold level set depends on the user.



By conducting validity and reliability tests, the data obtained can be confirmed and proven. These two tests are used to show the accuracy and repeatability of the data extracted from the signal. Accuracy and repeatability are the characteristics to test the functionality of the wheelchair prototype.

### 3.3 Flowchart

Figure 3.11 (a) shows the flow chart in obtaining the signal. If there is signal detected by the disposable electrodes, it will proceed to the next step, which is signal processing. In signal processing, the features of the signal are extracted. These features are used to set the threshold level in navigating the wheelchair prototype. As shown in Figure 3.11 (b), wheelchair will only change its direction once the threshold level is reached. The wheelchair prototype will navigate according to the threshold level set.

The flow of this project consists of 4 subroutines that are subroutine A, subroutine B, subroutine C and subroutine D. These 4 subroutines are to navigate wheelchair prototype either to left direction, move forward, turn right or reverse respectively. The changing of direction of wheelchair prototype is determined by the threshold level set in each subroutine.

Indicator "P" represents the standby mode. This means that if no EOG signal is detected, the process is in standby mode and wheelchair prototype remains static.

Table 3.4: Indicator for the flowchart

| **Indicator** | **Function** |
|---|---|
| A | Subroutine A |
| B | Subroutine B |
| C | Subroutine C |
| D | Subroutine D |
| P | Standby mode |

**i.) Flow chart for signal detection**

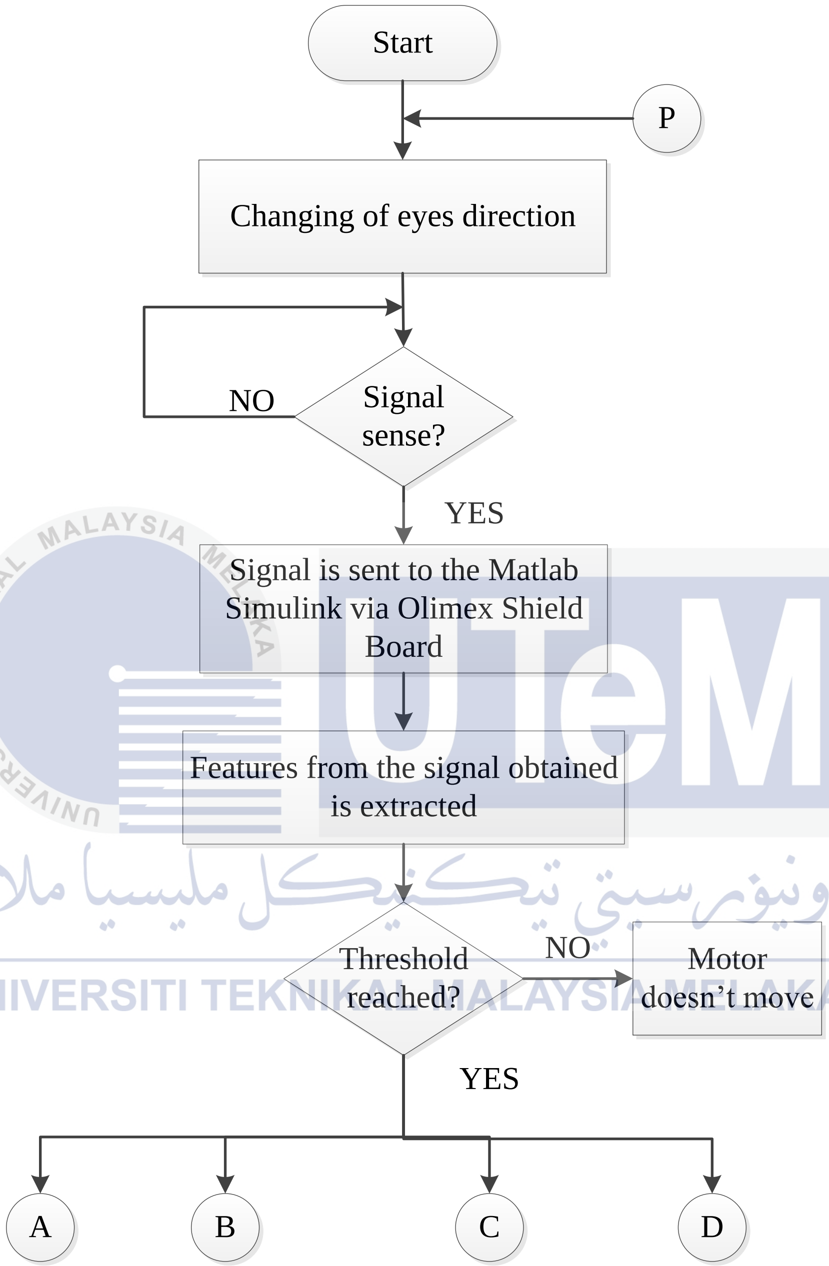


Figure 3.11 (a): Flow chart for signal detection

**ii.) Flow chart for controlling direction of wheelchair prototype**

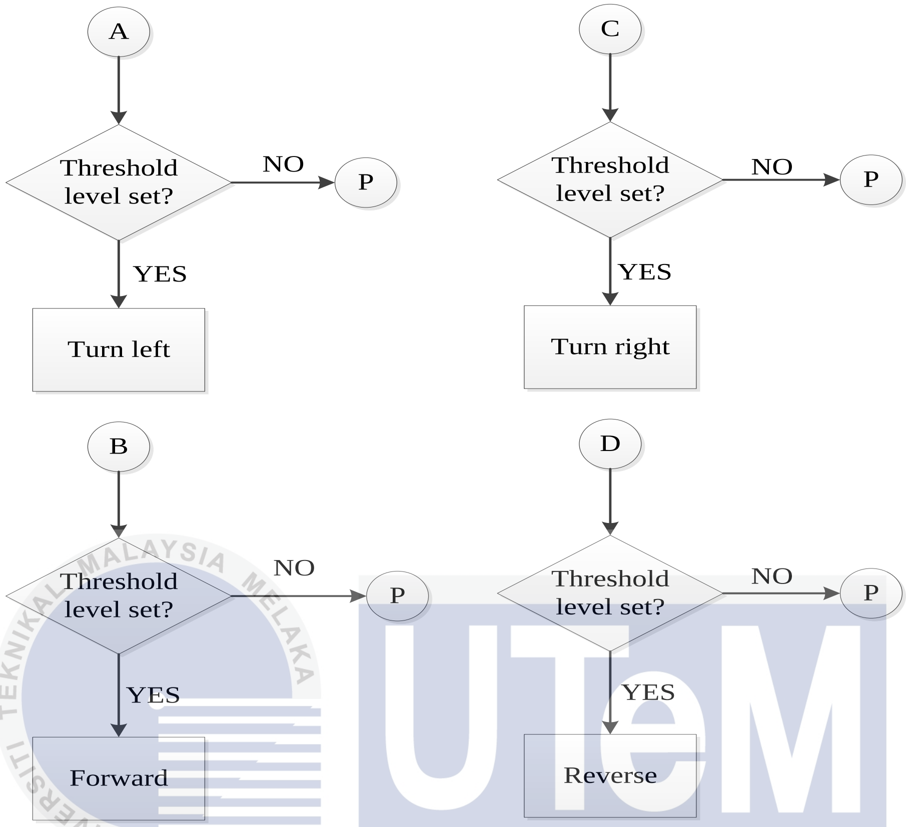


Figure 3.11 (b): Flow chart for directing wheelchair prototype

**iii.) Summary of the Process**



Figure 3.12 summarizes the process from obtaining the signal to navigating the direction of wheelchair prototype. It starts with the detecting the signal using disposable electrodes. The disposable electrodes are connected to the Arduino Mega and Olimex EKG-EMG shield to obtain EOG signal. Matlab Simulink is used to process and extract the features of the signal obtained. After processing the signal, the threshold level of the signal is determined. The features used in determining the threshold level are the maximum and minimum points. These maximum and minimum points are taken at the time when eyes movement is detected. Once the threshold level is achieved, the wheelchair prototype will be navigated to the direction accordingly. PIC microcontroller is used to program the direction of wheelchair prototype. Input signal to the PIC microcontroller is used to control the motors of wheelchair prototype.

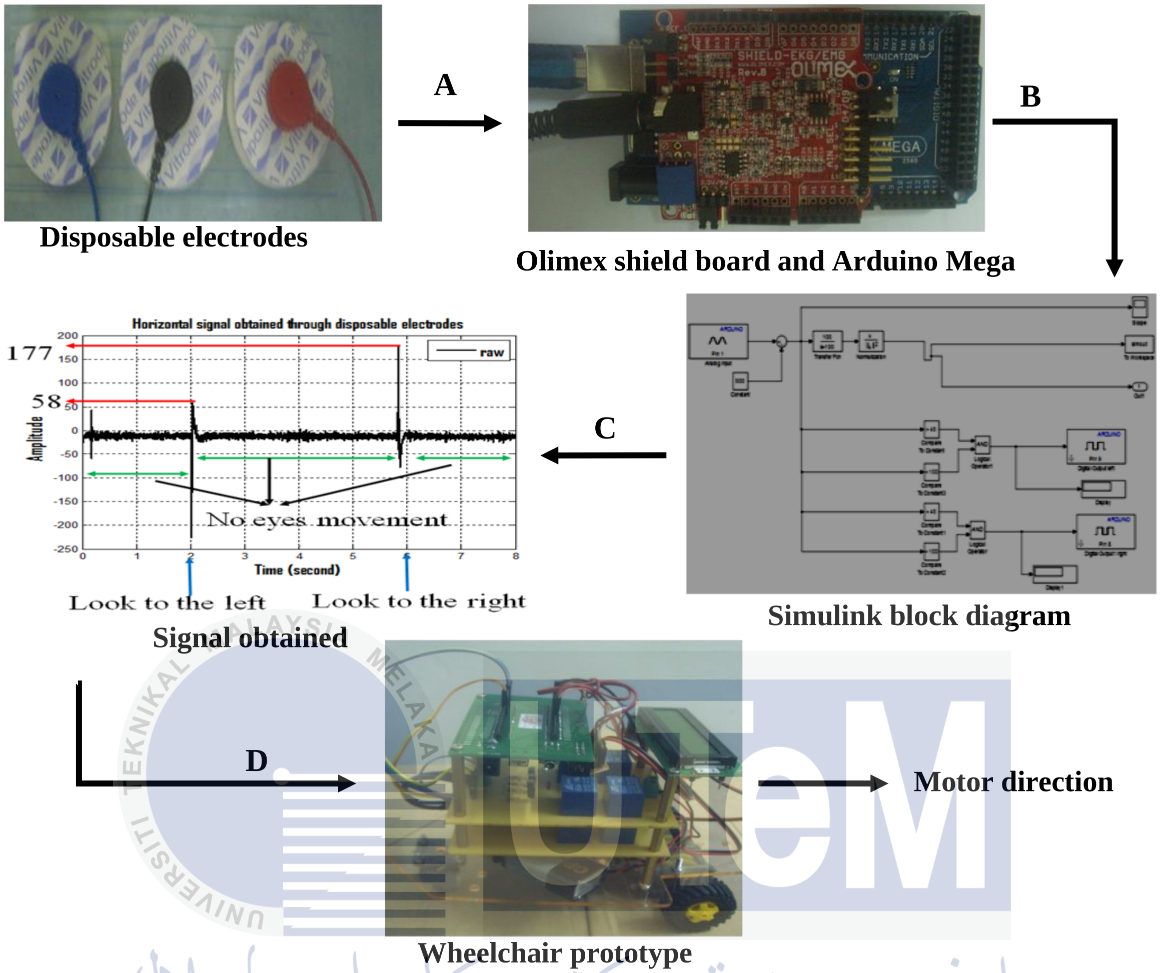


Figure 3.12 Summary of the process



Table 3.5 shows the processes mentioned in the Figure 3.12. These processes are the major processes in determining the threshold level set that control the direction of wheelchair prototype, which are left, right, forward and reverse. The threshold level has to be achieved in order to make any movement in wheelchair prototype.

Table 3.5: Processes in determining threshold level

| **Process** | **Function** |
|---|---|
| A | Signal detection |
| B | Signal obtained is directed to Matlab Simulink |
| C | Signal processing and features extraction |
| D | Threshold level determination |

# CHAPTER 4

# RESULTS AND DISCUSSIONS

The following tables and figures are the result obtained for one volunteer. Figure 4.1 to Figure 4.4 show the data obtained after signal analysis using Matlab. The sampling time for the experiment was set at 0.001s which means the frequency set was 1000Hz. At every 0.001s, there will be signal taken and recorded.

## 4.1 Results Obtained for Separately Signal

This section explains about the signal obtained for left, right, upward and downward directions. Results obtained are tabulated in the forms of figures and tables which are able to give a better understanding about the processes or experiments that have been conducted.



### 4.1.1 Right Signal

Figure 4.1 shows the right signal obtained. As can be seen from the Figure 4.1, when there is no movement of eyes, the signal obtained is considered as constant. Noise is presence in the signal but the noise is small as compared to the right signal. The peak is occurred at the time where eyes started to change direction which is looking to the right direction. The peak indicates that there is eyes movement. If eyes direction is maintained at the right position, the signal will drop to the level which is same as no eyes movement.

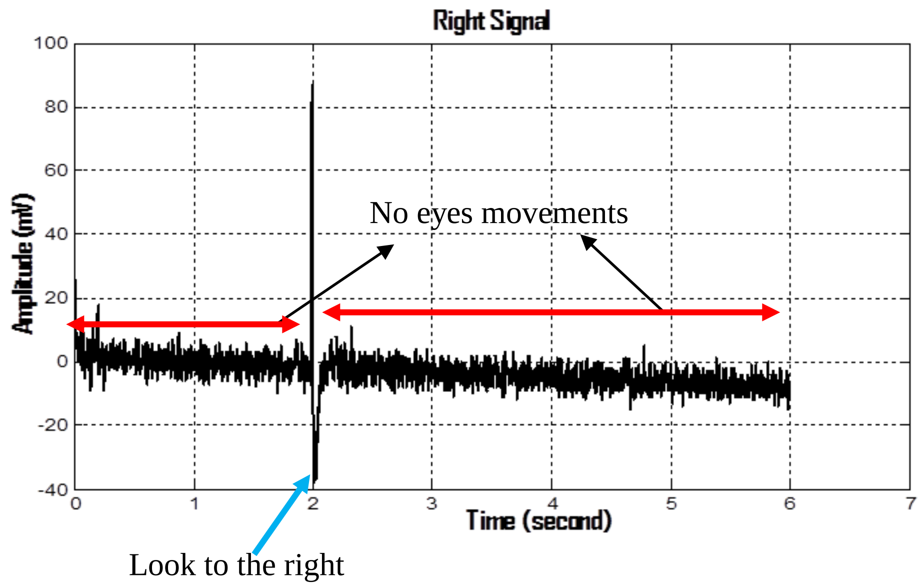


Figure 4.1: Waveform obtained for right signal

Table 4.1 shows the features such as maximum, minimum, mean, median and standard deviation values obtained from the right signal as shown in Figure 4.1. These features will be used in determining the threshold level for right direction.

Table 4.1: Features extracted from right signal

| **Features obtained** | **Amplitude (mV)** |
|---|---|
| Minimum | -38 |
| Maximum | 87 |
| Mean | -3.177 |
| Median | -3 |
| Standard deviation | 5.622 |

### 4.1.2 Left Signal

Figure 4.2 shows the left signal obtained. There is a peak at 2 second which indicates that there is eyes movement at that time. The noise presents in the signal is smaller compared to the peak amplitude.

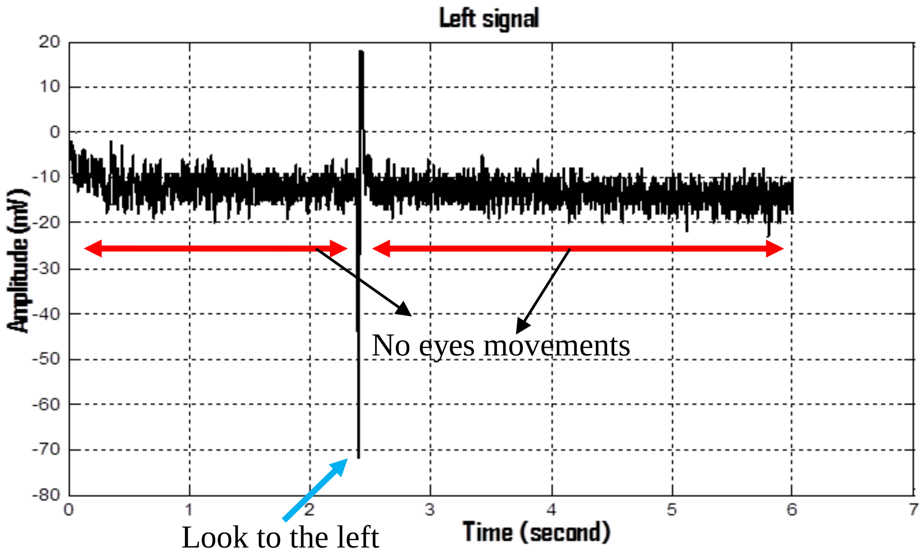


Figure 4.2: Waveform obtained for left signal

Table 4.2 shows the features extracted from the left signal. From the signal extracted, the information that can be known is maximum, minimum, mean, median and standard deviation of the signal. These values are then used to set the threshold level for left direction.

Table 4.2: Features extracted from left signal

| **Features obtained** | **Amplitude (mV)** |
|---|---|
| Minimum | -72 |
| Maximum | 18 |
| Mean | -12.66 |
| Median | -13 |
| Standard deviation | 3.821 |



### 4.1.3 Upward Signal

Figure 4.3 shows the waveform for upward signal. The total time taken in obtaining this signal is 6 seconds. The volunteer was asked to look upward at the 2nd second and maintained at that position for another 4 seconds to obtain the waveform as shown in Figure 4.3. The peak is occurred only when there is eyes movement. When eyes are changing direction, peak is then occurred. The signal is remained approximately as a straight line when no eyes movement is involved. The overshoot at the starting of the signal, which is circled in green colour in Figure 4.3, shows the offset of the signal. This offset is due to the power supply of from the shield board.

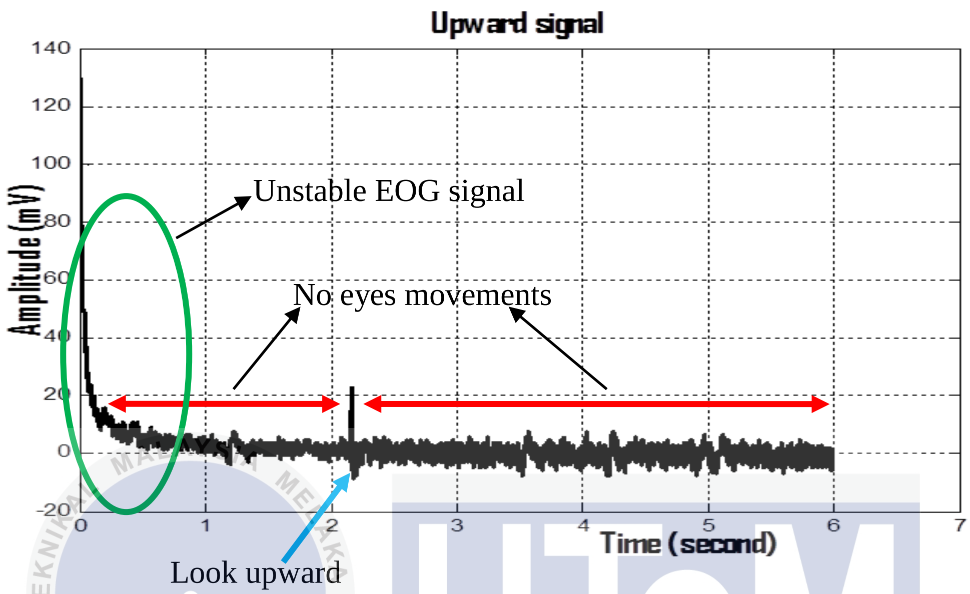


Figure 4.3: Waveform obtained for upward signal

Table 4.3 shows the features extracted from the waveform as shown in Figure 4.3. The maximum amplitude is 23mV (ignore the overshoot occurred in the starting of the signal) while the minimum value is -9mV. The maximum and minimum values are taken at the time where eyes are changing direction. Standard deviation is obtained by considering all the data taken during the experiment.

Table 4.3: Features extracted from upward signal

| **Features obtained** | **Amplitude (mV)** |
|---|---|
| Minimum | -9 |
| Maximum | 23 |
| Mean | 2.04 |
| Median | 1 |
| Standard deviation | 7.605 |

### 4.1.4 Downward Signal

Figure 4.4 shows the waveform obtained for downward signal. The signal is the same as the previous signal obtained. This means that the signal is approximately a straight line or constant when there is no eyes movement; peak when there is eyes movement involved. The difference is that the amplitude or the corneal-retinal potential (CRP) obtained. As mentioned in section 4.1.2, the overshoot as circled in green colour is due to the spike of power supply from the shield board.

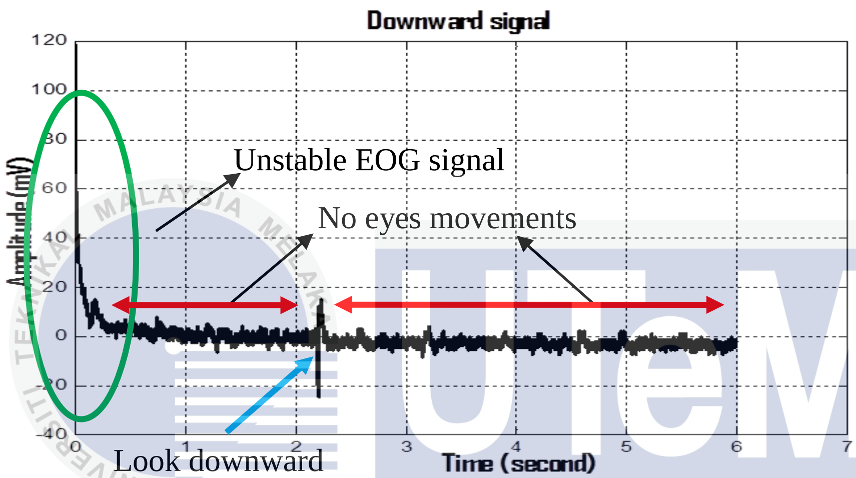


Figure 4.4: Waveform obtained for downward signal



Table 4.4 shows the information that can be obtained from the waveform as shown in Figure 4.4. The minimum and maximum values are obtained at the time when eyes are changing direction, from looking at centre to looking downward. By changing direction is to show the difference of corneal-retinal potential (CRP) for static eyes condition and eyes moving condition. The maximum corneal-retinal potential (CRP) obtained when eyes are looking downward is 15mV while the minimum corneal-retinal potential (CRP) is -25mV.

Table 4.4: Features extracted from downward signal

| **Features obtained** | **Amplitude (mV)** |
|---|---|
| Minimum | -25 |
| Maximum | 15 |
| Mean | -0.8267 |
| Median | -2 |
| Standard deviation | 6.56 |

## 4.2 Result Obtained For Combination Signals

Figure 4.5 to Figure 4.6 show the combination signals for horizontal and vertical signal. These signals are used to check the repeatability of the signals obtained as mentioned in methodology.

### 4.2.1 Horizontal Signal

Figure 4.5 shows the combination of horizontal signal. To obtain this signal, the experiment is conducted for 8 seconds. At the $2^{nd}$ second, the volunteer was told to look at the right direction and maintained at that direction for 4 seconds. After that, the volunteer was required to look to the left direction to back to the centre point again for 2 seconds. When eyes maintain at one position or no eyes movement, the signal obtained will be the same and peak only occurs at the moment where eyes are changing direction.

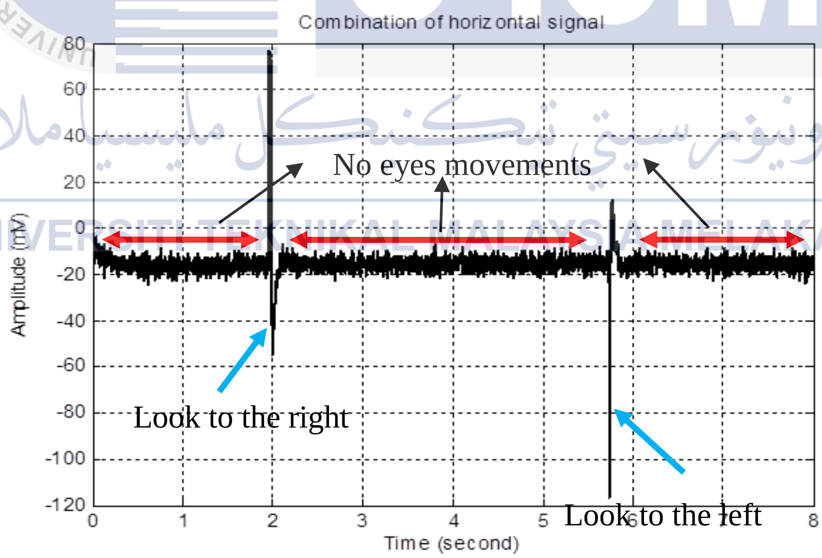


Figure 4.5: Waveform obtained for combination of horizontal signals

As can be seen from Table 4.5, the amplitude of left and right signal is about the same as shown in Table 4.1 and Table 4.2. Although there are some differences between the amplitude obtained, however the similarities between these two signals. When looking to the right direction, the maximum amplitude is higher as compared to the maximum amplitude of the left signal. The minimum amplitude of the left signal is higher than the minimum amplitude of the right signal. The amplitude of the right signal is more positive than the amplitude of the left signal; the amplitude of the left signal is more negative than the amplitude of the right signal.

Table 4.5: Features obtained for combination of horizontal signals

| **Direction** | **Features obtained** | **Amplitude (mV)** |
|---|---|---|
| Looking to the right | Minimum | -54 |
| | Maximum | 77 |
| Looking to the left | Minimum | -117 |
| | Maximum | 11 |

### 4.2.2 Vertical Signal

Figure 4.6 shows the combination of vertical signal. From the peaks, they show that there are eyes movements at 2$^{nd}$ second and 6$^{th}$ second. The straight line indicates that eyes are not moving or maintained at one position. When no eyes movements are involved, the signal is settle down and oscillates at the original value. Peaks indicate that eyes are changing direction.



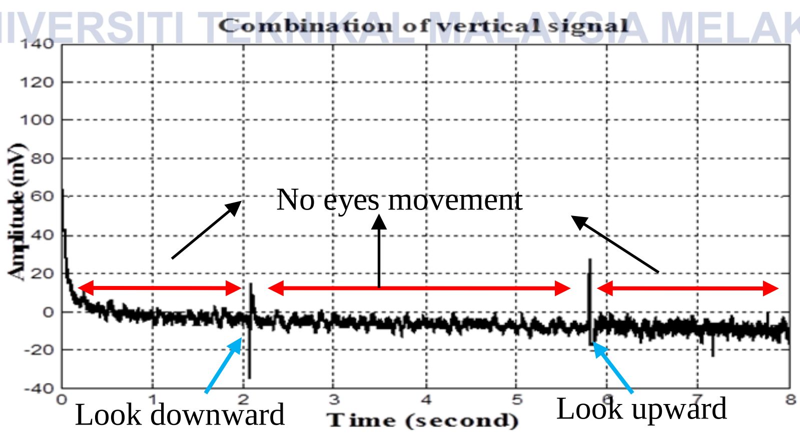


Figure 4.6: Waveform obtained for combination of vertical signals

Features stated in Table 4.6 are extracted from the combination of vertical signal as shown in Figure 4.6. From this table, it shows that the maximum and minimum readings for upward and downward are about the same as in Table 4.3 and Table 4.4 even if both actions, which are looking upward and downward, are carried out consecutively. The readings are almost the same compared with the readings that are taken in action looking upward and downward separately.

Table 4.6: Features obtained for combination of vertical signals

| **Direction** | **Features obtained** | **Amplitude (mV)** |
|---|---|---|
| Look upward | Minimum | -10 |
| | Maximum | 24 |
| Look downward | Minimum | -35 |
| | Maximum | 15 |

## 4.3 Process in Determining Threshold Level

This section explains about steps in determining the threshold level for left and right direction. Threshold level is responsible in controlling the direction of the wheelchair prototype. Once the threshold level is achieved, the wheelchair prototype will navigate accordingly to the threshold level set.



### 4.3.1 Threshold Level for Horizontal Direction (Left or Right)

Table 4.7 and Table 4.8 show the readings of features extracted from right and left signal respectively for one volunteer after the experiment had been conducted for 5 times. From these two tables, values that are highlighted in yellow colour will be used in determining the threshold level for left and right direction. The maximum value for looking to the right direction is more positive than looking to the left direction. From the value obtained for maximum amplitude, when the eyes look to right direction, its amplitude is over 50mV for 5 times consecutively; when eyes look to the left direction, its amplitude is greater than -50mV for 5 times consecutively. Hence the threshold level now can be set. Table 4.9 shows the threshold level set for allowing the motor to change left and right direction. The motor will change direction according to the signal detected (X). The positive threshold level is used in controlling right direction while the negative threshold level is used in controlling left direction.

Table 4.7: Features extracted from right signal after 5 times of experimental testing

| **Features obtained** | **Amplitude (mV)** | | | | |
|---|---|---|---|---|---|
| | **Trial 1** | **Trial 2** | **Trial 3** | **Trial 4** | **Trial 5** |
| Minimum | -32 | -34 | -23 | -34 | -20 |
| Maximum | 80 | 72 | 93 | 123 | 96 |

Table 4.8**:** Features extracted from left signal after 5 times of experimental testing

| **Features obtained** | **Amplitude (mV)** | | | | |
|---|---|---|---|---|---|
| | **Trial 1** | **Trial 2** | **Trial 3** | **Trial 4** | **Trial 5** |
| Minimum | -83 | -92 | -81 | -84 | -61 |
| Maximum | 20 | 22 | 14 | 21 | 24 |

Table 4.9: Threshold level set for turning left and right directions

| **Signal detected (X) (mV)** | **Direction** |
|---|---|
| X> 40 AND X>50 | Turn right |
| X< -40 AND X< -50 | Turn left |



### 4.3.2 Threshold Level for Vertical Direction (Forward or Reverse)

Following shows the method in determining the threshold level for vertical direction. The threshold level is obtained after the experiment has been conducted for 5 times consecutively. The major values used in determining the threshold level are the maximum and minimum corneal-retinal potential (CRP). This is because the maximum and minimum values are extracted from positive region and negative region of the signal obtained respectively.

Table 4.10 and Table 4.11 show the maximum and minimum corneal-retinal potential for upward and downward direction. As can been clearly seen from these two tables are the corneal-retinal potential for upward signal is more positive than downward signal, which means that the maximum corneal-retinal potential (CRP) for upward signal is higher than downward signal. From this trend, the threshold level set for moving forward and backward as shown in Table 4.12 can be determined. Yellow highlighted values are the values required in determining the threshold level.

As shown in Table 4.10 and Table 4.11**,** range of the maximum values for upward signal is between 24 to 29mV while for downward signal is between 10 to 20mV. Hence, the threshold level set for moving forward is when the signal detected is greater than 18mV and 21mV (positive portion) as shown in Table 4.12. The range of minimum value for upward signal is between -6 to -10mV while for downward signal is between -24 to -39mV. Therefore the threshold level set for moving backward is when the signal detected is less than -15 and -20mV (negative portion) as shown in Table 4.12.

Table 4.10: Features extracted from upward signal after 5 times of experimental testing

| **Features obtained** | **Amplitude (mV)** | | | | |
|---|---|---|---|---|---|
| | **Trial 1** | **Trial 2** | **Trial 3** | **Trial 4** | **Trial 5** |
| Minimum | -6 | -9 | -9 | -10 | -7 |
| Maximum | 29 | 27 | 23 | 27 | 24 |

Table 4.11: Features extracted from downward signal after 5 times of experimental testing

| **Features obtained** | **Amplitude (mV)** | | | | |
|---|---|---|---|---|---|
| | **Trial 1** | **Trial 2** | **Trial 3** | **Trial 4** | **Trial 5** |
| Minimum | -32 | -25 | -31 | -24 | -39 |
| Maximum | 20 | 15 | 13 | 14 | 10 |

Table 4.12: Threshold level set for moving forward and backward

| **Signal detected (X) (mV)** | **Direction** |
|---|---|
| X> 18 AND X>21 | Move forward |
| X<-15 AND X< -20 | Move backward |

## 4.4 Blinking Effect

Figure 4.7 shows the effect of blinking to the signal. The spikes which circled by the red circle shown in the figure are the result of blinking. The spike at the second seconds is excluded. At the second seconds, the volunteer was asked to look downward. Therefore the spike at the second seconds indicates the time when the volunteer was looking downward. Blinking of eyes will cause a spike on the signal obtained. The spikes are due to the blinking of eyes. When there are no eyes movements involved, the signal oscillates at about the origin. Hence, during the process of obtaining the signal, volunteer will have to concentrate to avoid blinking.

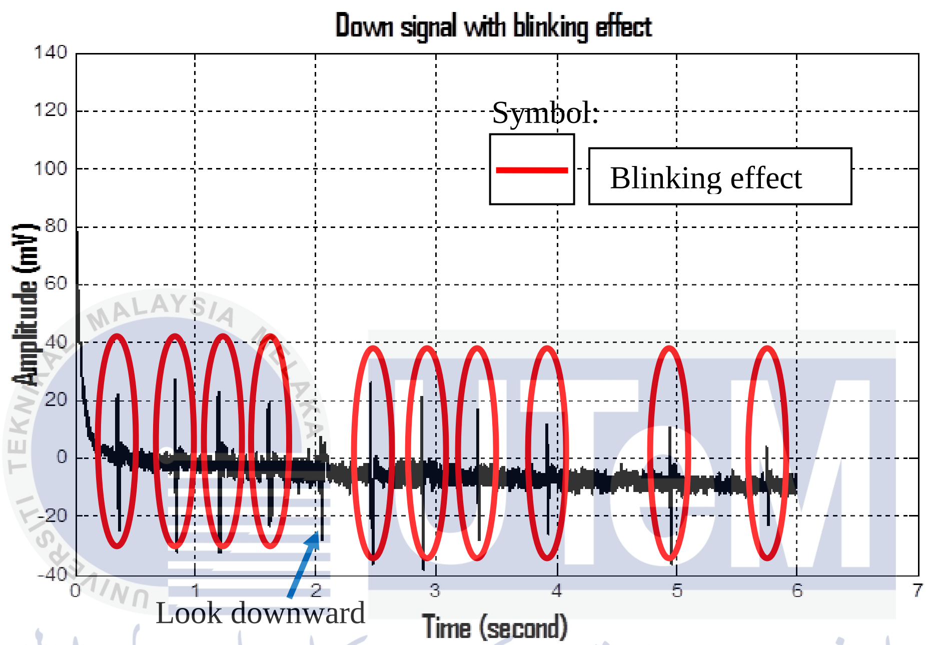


Figure 4.7: Blinking effect to EOG signal



## 4.5 Effect of Low Pass Filter

Low pass filter is added to the circuit in order to filter the noise. It allows low frequency to pass through and attenuate high frequency. The black coloured line in Figure 4.8 indicates the original EOG waveform without the presence of low pass filter while blue coloured line indicates EOG waveform with the presence of low pass filter. As can be seen from Figure 4.8, the signal has been improved. Some noise has been eliminated from the signal and hence the signal to noise ratio is enhanced. In zoom in portion, amplitude for low pass filter is lower than the amplitude without low pass filter. This shows that some portion has been eliminated as noised thus caused the amplitude to be decreased. The cut-off frequency is 50Hz whereby when low pass filter is applied, frequency that is lower than 50Hz can pass through and frequency that is higher than 50Hz will be attenuated.

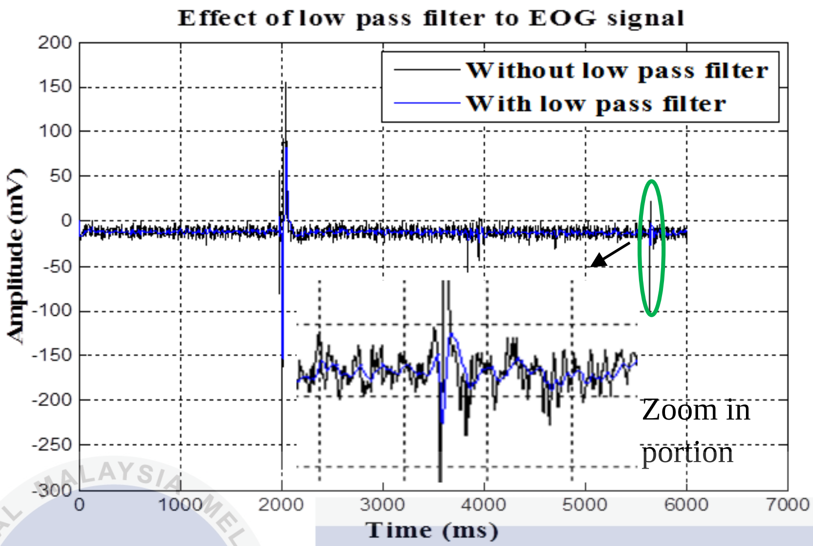


Figure 4.8: Effect of low pass filter of EOG signal

## 4.6 Results Obtained for 5 Volunteers

Table 4.13 shows the results obtained for five volunteers. The experiment has been conducted for five times on five volunteers. As can be seen from the table, the corneal-retinal potential is different for all the five volunteers. All of them have their own corneal-retinal potential (CRP). The purpose of conducting the experiment for five times is used to show the reliability of the result. After the experiment has been conducted for five times, a series of data have been obtained and tabulated. There is a small deviation of the corneal-retinal potential (CRP) obtained during the whole experiment. The deviation of values is considered as small. The deviation of values is due to the tiredness of eyes in the experiment. Eyes muscles become tension and therefore cause the deviation of the potential difference.

All five volunteers have their own corneal-retinal potential (CRP). Each person has different corneal-retinal potential. This may due to the muscle contraction is different for each person. The strength of the muscle contraction can affect the amplitude produced. There are also other factors which may contribute to the difference of corneal-retinal potential (CRP) for each person such as noise generated between the electrodes' contacts and the skin, metabolic rate of the tissues and also visual stimulation [23].

Although corneal-retinal potential obtained for all the five volunteers are different, there are still having similarity between the results obtained. The similarity is that the trend of the signal obtained. Looking to the left is more negative as compared to looking to the right. The amplitude in negative portion is larger for looking to the left than looking to the right direction. The amplitude in positive region for looking upward is greater than looking downward. Hence, this shows that looking to right and upward have greater positive values while looking to left and downward have greater negative values. The threshold level setting for right and upward is positive meanwhile for left and downward is negative. The main consideration in determining the threshold level is the minimum value that is used to trigger the changing of direction for wheelchair prototype.

Table 4.13: Results of the four directions obtained for 5 volunteers.

| **Volunteer** | **Trial** | **Amplitude (mV)** | **Direction** | | | |
|---|---|---|---|---|---|---|
| | | | **Left** | **Right** | **Upward** | **Downward** |
| 1 | First | Max | 20 | 80 | 29 | 20 |
| | | Min | -83 | -32 | -6 | -32 |
| | Second | Max | 22 | 72 | 27 | 15 |
| | | Min | -92 | -34 | -9 | -25 |
| | Third | Max | 14 | 93 | 23 | 13 |
| | | Min | -81 | -23 | -9 | -31 |
| | Fourth | Max | 21 | 123 | 27 | 14 |
| | | Min | -84 | -34 | -10 | -24 |
| | Fifth | Max | 24 | 96 | 24 | 10 |
| | | Min | -61 | -20 | -7 | -39 |
| 2 | First | Max | 13 | 25 | 15 | 5 |
| | | Min | -34 | -15 | -12 | -28 |
| | Second | Max | 14 | 23 | 13 | 3 |
| | | Min | -29 | -12 | -17 | -32 |
| | Third | Max | 16 | 23 | 14 | 2 |
| | | Min | -27 | -15 | -14 | -25 |
| | Fourth | Max | 14 | 24 | 12 | 5 |
| | | Min | -30 | -14 | -15 | -27 |
| | Fifth | Max | 15 | 26 | 15 | 4 |
| | | Min | -32 | -17 | -17 | -30 |
| 3 | First | Max | 14 | 45 | 43 | 11 |
| | | Min | -44 | -16 | -36 | -74 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Second | Max | 15 | 41 | 39 | 11 |
| | | Min | -40 | -20 | -45 | -64 |
| | Third | Max | 16 | 39 | 37 | 12 |
| | | Min | -48 | -20 | -47 | -60 |
| | Fourth | Max | 19 | 38 | 40 | 10 |
| | | Min | -55 | -20 | -39 | -72 |
| | Fifth | Max | 15 | 40 | 42 | 11 |
| | | Min | -50 | -18 | -43 | -68 |
| 4 | First | Max | 4 | 20 | 16 | 8 |
| | | Min | -32 | -5 | -5 | -30 |
| | Second | Max | 4 | 19 | 18 | 2 |
| | | Min | -38 | -7 | -6 | -30 |
| | Third | Max | 9 | 16 | 16 | 5 |
| | | Min | -30 | -6 | -10 | -36 |
| | Fourth | Max | 5 | 18 | 15 | 4 |
| | | Min | -36 | -7 | -8 | -32 |
| | Fifth | Max | 7 | 19 | 14 | 7 |
| | | Min | -34 | -6 | -8 | -31 |
| 5 | First | Max | 7 | 25 | 30 | 5 |
| | | Min | -31 | -12 | -12 | -46 |
| | Second | Max | 8 | 22 | 28 | 8 |
| | | Min | -26 | -13 | -14 | -49 |
| | Third | Max | 9 | 26 | 27 | 7 |
| | | Min | -25 | -17 | -16 | -51 |
| | Fourth | Max | 8 | 26 | 31 | 9 |
| | | Min | -28 | -15 | -14 | -47 |
| | Fifth | Max | 9 | 23 | 30 | 8 |
| | | Min | -30 | -16 | -17 | -46 |



After the readings for five experiments have been tabulated, the threshold level for four directions is then set as shown in Table 4.14. To set the threshold, the first step is to obtain the signal. From the signal obtained, select the features. The features that are used for this project are the maximum and minimum point taken at the time where eyes movement is detected. Thus, the range of the threshold level is determined.

As shown in Figure 4.9, the left and right signals are consists of negative and positive region; the right signal has higher positive region, while left signal has higher negative region. Therefore, the polarity set for right signal is positive and polarity for left signal is negative. The green and orange dotted lines show the common amplitude for left and right signal at negative and positive regions respectively. Thus, threshold level set for turning right is in positive region and must be greater than the orange dotted line. Threshold level set for turning left is in negative region and must be smaller than the green dotted line. The steps are the same for obtaining vertical threshold level. These processes are similar to obtain the threshold level for each volunteer. Hence, Table 4.14 can be obtained. There are two values set to control one direction for safety purpose. These two values used must within the range set as Figure 4.9. Thus, different volunteers will have their own range of threshold level.

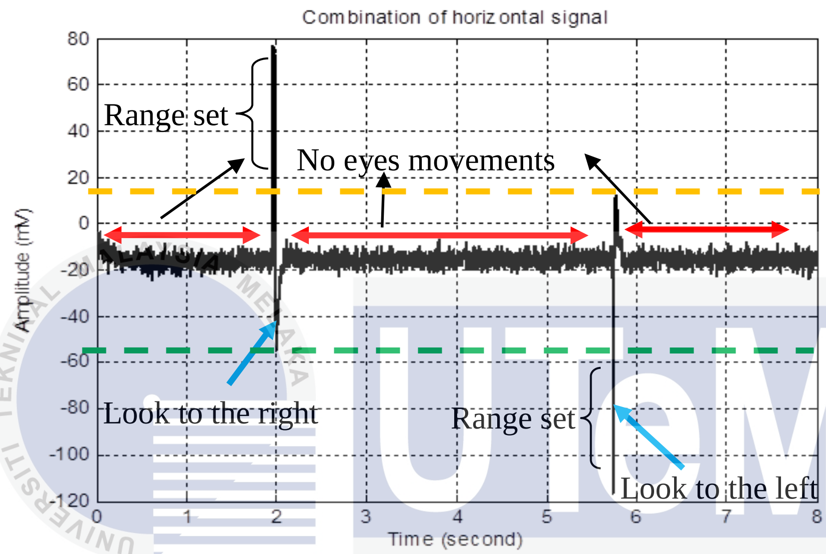


Figure 4.9: Threshold level determination



From Table 4.14, it shows that the threshold level that causes changes in direction of wheelchair prototype is different. Each volunteer has their own minimum level in order to make changes in direction for wheelchair prototype.  The threshold level set might be same in controlling left, right, forward and reverse as indicated by green shaded region. For volunteer 3, threshold level set in controlling right direction also is the threshold level set in navigating the wheelchair prototype to move forward. Conflict will not occur in making decision for wheelchair prototype direction although the threshold level is the same in controlling different directions such as threshold level set for right and forward is the same as shown by volunteer 3 or threshold level set for left and reverse are equal as shown by volunteer 4 and volunteer 5. This is because horizontal and vertical movement of wheelchair prototype direction is controlled by two different channels.

Table 4.14: Threshold level set for 4 directions for 5 volunteers

| **Threshold level** / **Volunteer** | **Signal Detected, X (mV)** | | | |
|---|---|---|---|---|
| | **Left** | **Right** | **Forward** | **Reverse** |
| **Volunteer 1** | X< -40 AND X< -50 | X>40 AND X>50 | X>18 AND X>21 | X< -15 AND X< -20 |
| **Volunteer 2** | X< -20 AND X< -25 | X>15 AND X>20 | X>5 AND X>10 | X< -18 AND X< -23 |
| **Volunteer 3** | X< -35 AND X< -40 | X>30 AND X>35 | X>30 AND X>35 | X< -50 AND X< -60 |
| **Volunteer 4** | X< -20 AND X< -25 | X>10 AND X>15 | X>5 AND X>10 | X< -20 AND X< -25 |
| **Volunteer 5** | X< -20 AND X< -25 | X>10 AND X>15 | X>5 AND X>10 | X< -20 AND X< -25 |

## 4.7 Simulink Block Diagram

Figure 4.10 shows the Simulink block diagram that is used to obtain signal and process signal extraction. The constant block diagram that is selected in blue colour is used to allow the signal to start at origin. The signal will oscillate near the origin at resting or no eyes movements are involved. There is a change in amplitude when there are eyes movements or eyes are changing direction.

In Arduino Input block, the selected input pin is used to obtain the data from the sensor. This input pin must be same as the pin number chosen in the Olimex shield board.



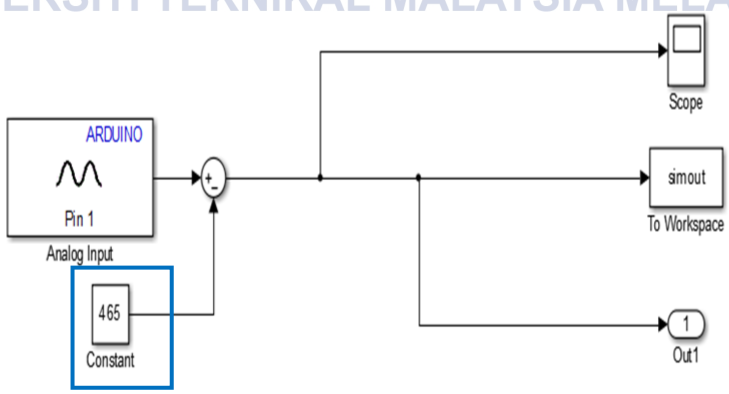


Figure 4.10: Simulink block diagram in obtaining signal

Logic gates as selected in black colour shown in Figure 4.11 and Figure 4.12 are used to compare with the signal detected and the threshold level set. Threshold setting is the two inputs enter logic gate for each direction. “AND” gate is used in controlling the direction of wheelchair prototype because the wheelchair prototype will only change its direction if both inputs are true. If one of the inputs does not achieve the threshold level set, the output from the logic gate is “0”. Therefore, the wheelchair prototype will not move. As can be seen from Table 4.15, the output is “1” when both the inputs are “1”. Other than this condition, the output from “AND” gate is “0”. When the output from “AND” gate is “0”, the wheelchair prototype will remain static. “OR” gate is not suitable in controlling the direction of wheelchair prototype. If “OR gate is used, either one of the input has achieved the threshold level of each direction, it will trigger the moving of wheelchair prototype.

Constant block diagrams as selected in red colour in Figure 4.11 and Figure 4.12 are used to set the threshold level. Output from the logic gates determines the direction of the motor. The data type from the logic gates is Boolean type which means only “HIGH, 1” or “LOW, 0”. This indicates that if the output from the logic gates is “HIGH”, then the motor will move otherwise it will stop. Wheelchair prototype will move according to the output from the logic gates.



Table 4.15: Truth table for “AND” gate

| **Input** | | **Output** |
|---|---|---|
| **X1** | **X2** | |
| 0 | 0 | 0 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

The outputs selected in green colour as shown in Figure 4.11 and Figure 4.12 are the controlled signal for PIC microcontroller. They act as the input for PIC microcontroller and controlling the direction of wheelchair prototype. They are the output from logic gate and then transferred to PIC microcontroller in order to navigate the direction of wheelchair prototype. The controlled signal is in binary form that is either “1” as high or “0” as low.

The block diagram as shown in Figure 4.11 and Figure 4.12 are used for all the 5 volunteers. The different is the value set for the threshold setting block (selected in red colour). This is because different threshold level is set for different user.

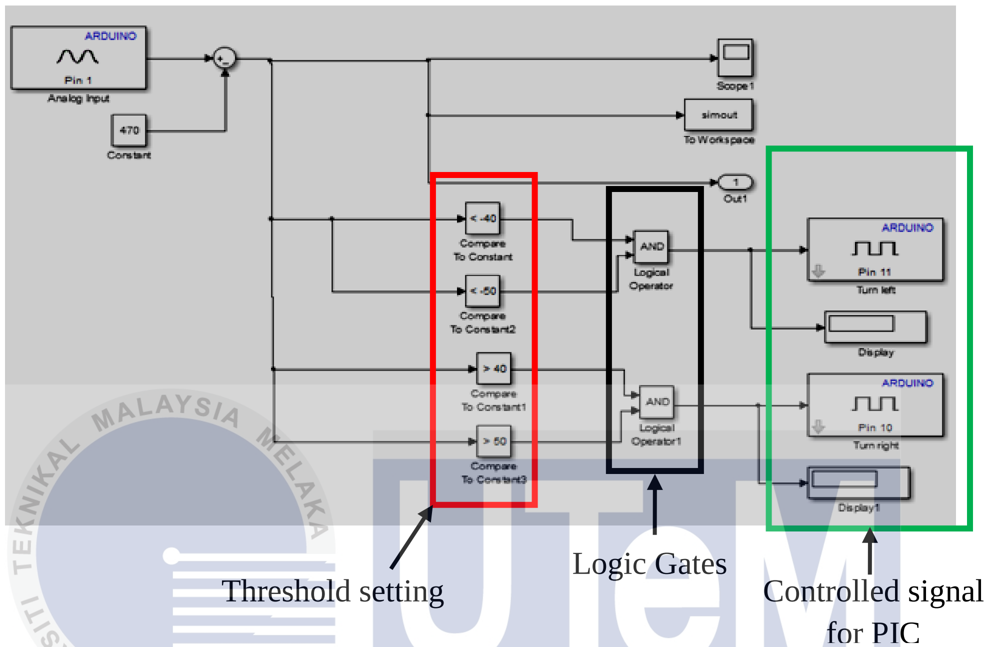


Figure 4.11: Simulink block diagram for controlling horizontal direction

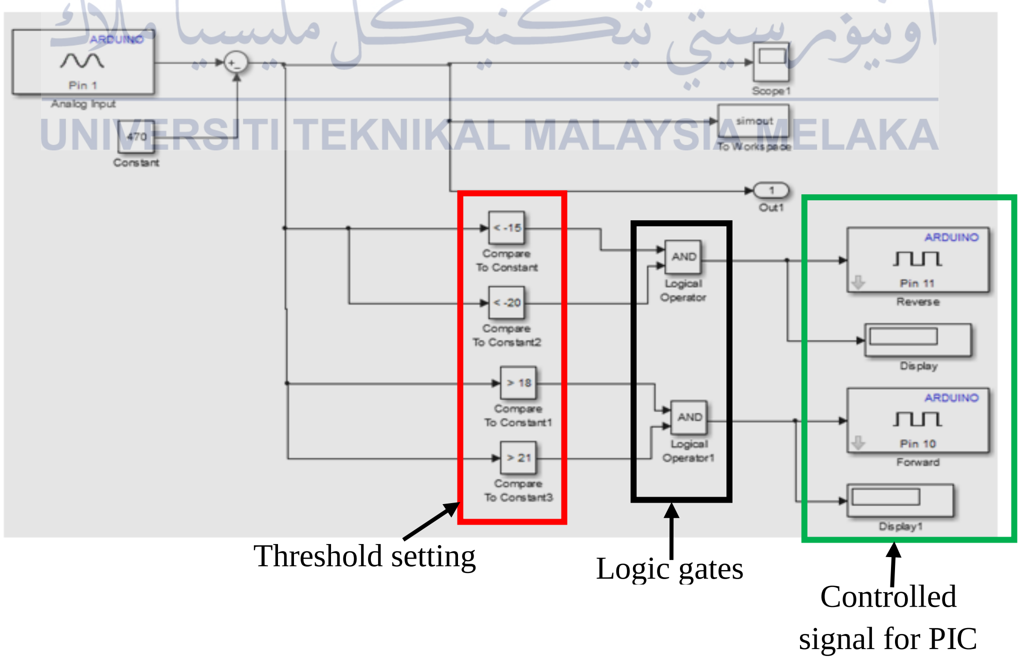


Figure 4.12: Simulink block diagram for controlling vertical direction

## 4.8 Connection between Arduino Mega and PIC Microcontroller

Figure 4.13 shows the complete connection in obtaining the signal and transferring it to microcontroller to navigate the wheelchair prototype. The wire is shielded with aluminium foil as shown in Figure 4.14 is to minimize the noise that will be introduced into the EKG-EMG shield board. Noise is the disturbance that will affect the signal easily. EOG signal is very sensitive to the surrounding environment. Any small disturbance will bring changes to the signal obtained. The sensor obtained the signal and transferred it the Arduino Mega.

The signal is then undergoes processing to produce the controlled signal. Output from the Arduino Mega is being transferred to the input of the microcontroller. The controlled signal is the output from Arduino Mega which also acts as the input for microcontroller. The controlled signal is the signal which directs the direction of the wheelchair prototype.

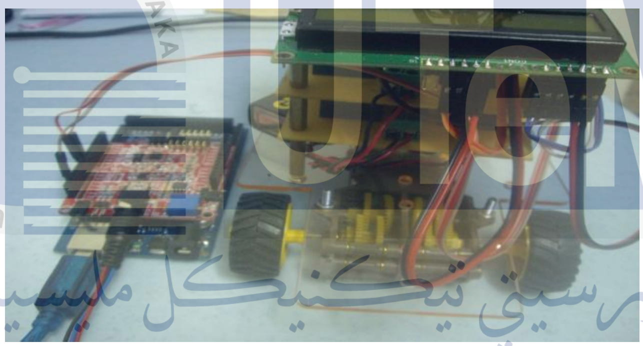

Figure 4.13: Connection between Arduino Mega and PIC microcontroller



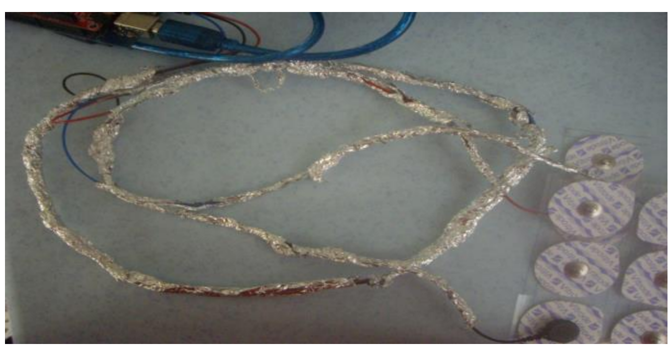

Figure 4.14: Wire shielded with aluminium foil

Microcontroller shown in Figure 4.15 is used to control the direction of the motor driver. Output from Arduino Mega will be fed into microcontroller as the input. The output from Arduino Mega, which is “0” (LOW) or “1” (HIGH) is being transferred to microcontroller to determine the direction of the motor driver. Programming in microcontroller can be used to receive the control signal and control the direction of the motor. Output from the microcontroller controls the moving of the wheels which then causes change in the direction of the wheelchair prototype.

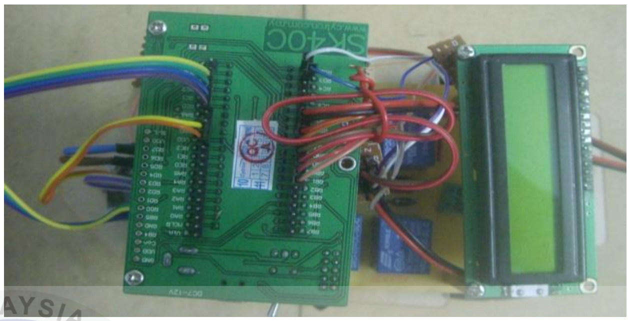

Figure 4.15: PIC microcontroller with LCD display

## 4.9 Wheelchair Prototype

Figure 4.16 shows the prototype of the wheelchair. The wheelchair prototype is now equipped with Arduino Mega, Olimex EKG-EMG shield board, PIC microcontroller, LCD display, motor driver and robot base. Motor drivers, LCD display and PIC microcontroller are stacked on the robot base. 9V battery is used as the power supply for the motor drivers. External power supply of 12V is required as a power supply for PIC microcontroller. This can help to minimize the noise introduced into the EOG signal obtained. If the external power supply is not connected to the PIC microcontroller, this means that the only power supply is coming from laptop. The power supply will be shared between Arduino Mega and PIC microcontroller. Since the power supply is shared, therefore there will be noise introduced to the signal acquired through the jumpers and the output result will be affected. Once the motor driver is triggered by the controlled signal, the wheelchair prototype will be directed to the desired direction which is left, right, forward or reverse. LCD display is used to show the status of the wheelchair prototype.

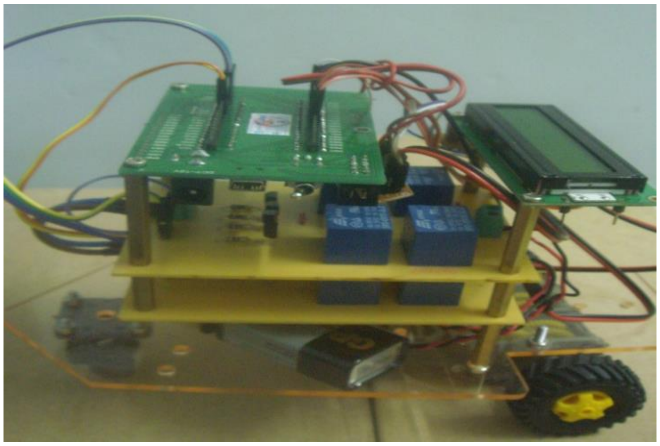

Figure 4.16: Wheelchair prototype

### 4.10 Summary for Results and Discussions

After the experiment has been conducted for five times, the results are recorded and tabulated. Five volunteers are required to accomplish the experiment. Before the experiment is conducted, the skin of the volunteer is wiped with wet tissue and alcohol swipe to reduce the resistance between skin and the electrodes. This also can help to increase the contact of skin with the electrodes.

Volunteers are required to carry out the experiment for five times in order to check the reliability. Although the five readings are not maintained the same throughout the five times of experiment, yet the derivation from each value is small. All the five readings for each direction are in about the same range.

From the results obtained, each person will have their own corneal-retinal potential (CRP) as shown in Table 4.13. Therefore the threshold level set depends on the amplitude obtained for each person, which is shown in Table 4.14. The similarity between the readings taken from five volunteers is the polarity of corneal-retinal potential obtained. When looking to right direction, it is more positive as compared to left direction. Potential for right direction has a more positive value than potential for left direction. When looking upward, the potential is more positive as compared to looking downward. Potential for upward is more positive than downward. It can be clearly seen that polarity for potential looking to right and upward is more positive than potential looking to left and downward as shown in Table 4.16.

Table 4.16: Potential polarity for four directions

| Direction \ Polarity | Positive (+) | Negative (-) |
|---|---|---|
| Left | | |
| Right | | |
| Upward | | |
| Downward | | |

Signal obtained can be affected by surrounding environment such as light intensity and noise level. Surrounding environment is important in conducting the experiment. Electromagnetic wave and magnetic field in the laboratory can be considered as disturbances. Once they are introduced into the signal, they will be amplified with EOG signal. Hence the result obtained will be having lot of noise as compared to the waveform obtained at hostel or lecture room. Besides, blinking can cause spikes into the signal obtained. If the amplitude for eyes blinking is not high enough to achieve the threshold level set, it will not affect the direction of the wheelchair prototype. However in order to reduce the probability occurrence that the spike of blinking achieves threshold level set, user has to reduce the frequency of blinking.

As can be seen from Table 4.13, corneal-retinal potential (CRP) is different for each person. This may due to the muscle contraction is different for each person. The strength of the muscle contraction can affect the amplitude produced. There are also other factors which may contribute to the difference of corneal-retinal potential (CRP) for each person such as noise generated between the electrodes' contacts and the skin, metabolic rate of the tissues and also visual stimulation [23]. The noise generated between the electrodes contact and skin can be minimised by applying electrolytic gel to reduce the resistance between the electrodes and the skin.

Results obtained in Table 4.13 are classified into two categories that are horizontal signal and vertical signal. Data plotted in Figure 4.17 and 4.18 are based on Table 4.13. As shown in Figure 4.17, the polarity for the EOG signal obtained for left eyes movement is more negative as compared to the EOG signal obtained for right eyes movement. While for Figure 4.18, the EOG signal for downward eyes movement is more negative as compared to upward eyes movement. Figure 4.17 and Figure 4.18 show the reliability of the results obtained. There is not much deviation between the data obtained for each volunteer after the experiments had been conducted for five times.

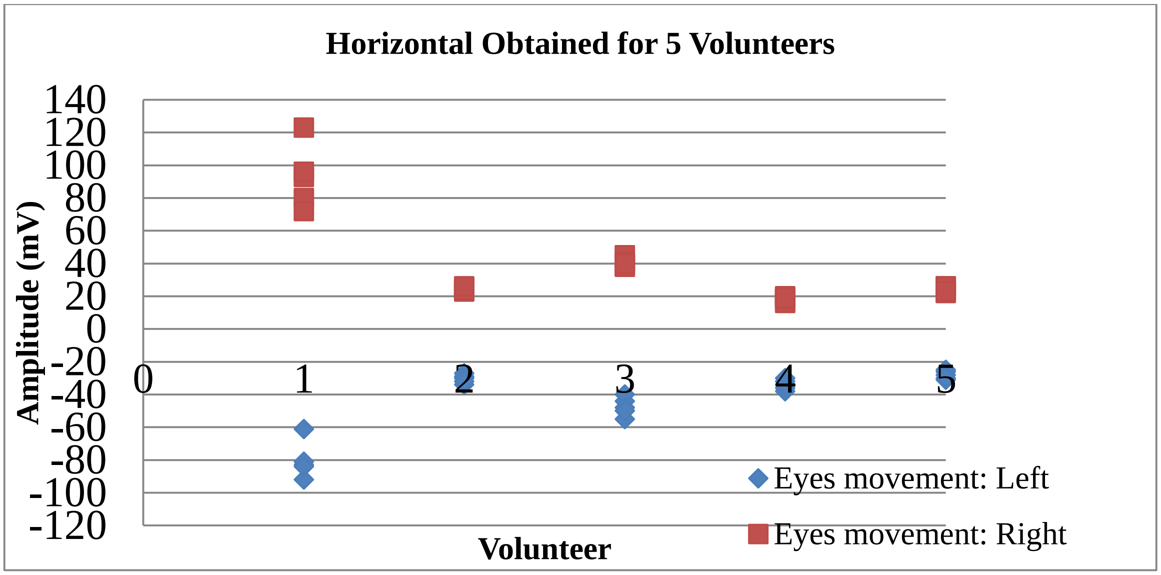


Figure 4.17: Horizontal signal obtained for 5 volunteers

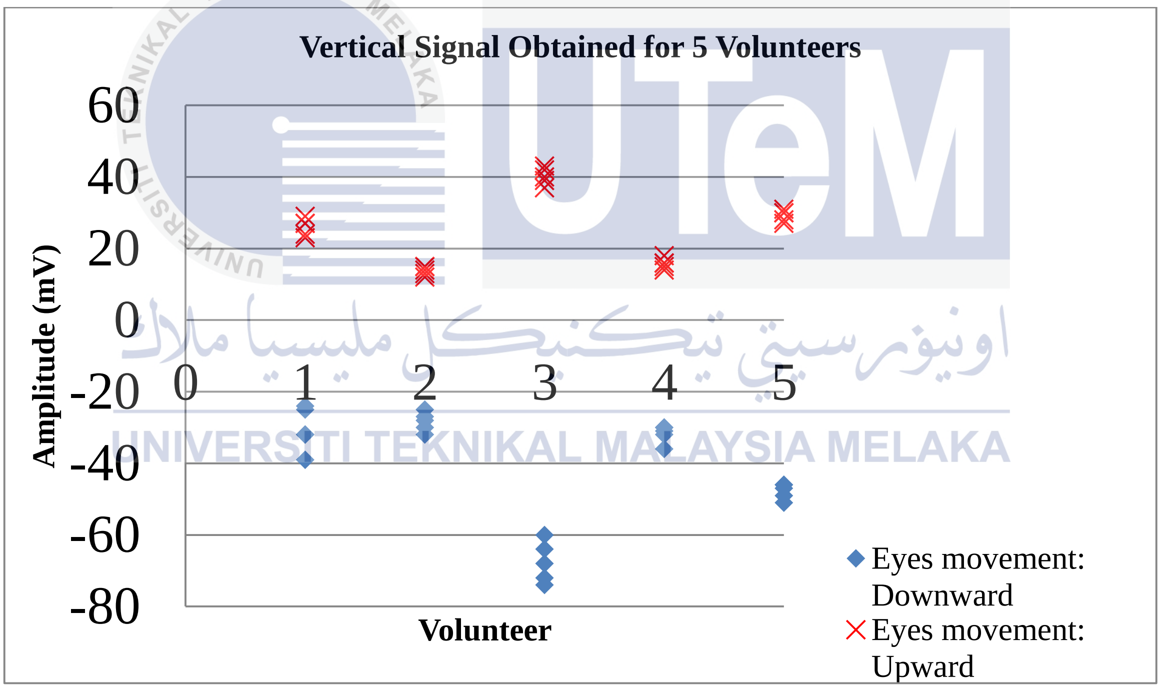




Figure 4.18: Vertical signal obtained for 5 volunteers

Threshold setting is then adjusted to navigate direction of wheelchair prototype. Direction of wheelchair prototype that is turning left, right, moving forward or reverse is based on the threshold level set. Different user will have different threshold level to make wheelchair prototype change direction. Wheelchair prototype will change direction according to the signal obtained. It will only move once the threshold level is achieved.

# CHAPTER 5

# CONCLUSIONS AND RECOMMENDATIONS

## 5.1 Conclusions

EOG signal is a bio-potential produced by eye movement. The method using electrooculography (EOG) signal to be implemented in a wheelchair can be considered as a great move in developing an alternative method to control the wheelchair.

From the EOG signal obtained, there will be a peak at the moment eyes are changing direction. When eyes are in static or no movement involved, the signal will become a straight line. If eyes are looking to left or right direction and maintained at that position, the signal obtained is also a constant which can be considered as no eyes movement involved. Threshold level is the minimum amplitude that should be achieved in order to move the wheelchair prototype. If the threshold level is not achieved, the motor will be in static condition or in other word, the motor will not moved. The motor will only changed direction if the threshold level has been achieved. The motor will change direction according to the signal detected.

## 5.2 Recommendations

It is recommended that implementing EOG signal in the wheelchair can be widely used as it eases the movement for disabled people and allow the disabled people to live more independently. For safety purpose, bumper sensor should be installed in the wheelchair prototype. This bumper sensor is used to detect the obstacles located near the wheelchair prototype.

### 5.3 Future Work

The threshold level is different for different people. In order to meet the need for different user, it is recommended that fine tuning process can be installed. A rheostat is required to adjust the optimum threshold level for each user. This allows the user to set his or her threshold level. The threshold level set depends on user.

Artificial neural network is recommended to be used in this research. Artificial neural network consists of a set of interconnected neurons which combined to output a signal to solve a certain problem based on the input signals it received. For artificial neural network, it can consist of multiple inputs and outputs. These multiple inputs have their own performance characteristics. The output of the system depends on the activation function that is applied on each neuron. The inputs are eyes movement. Artificial neural network is able to differentiate eyes movement through the training and hence give the correct output response. A learning rule is used to adapt the synaptic weights to solve the task. For example Cohen's neural network is useful in the detection of eyes blinking. The training set of the Cohen's neural network is composed of a series of EOG grahoelements of certain length and certain window overlap. Generalization may be possible by finding logical connections among data obtained from different volunteers and thus helps in detecting eyes blinking.

EOG signal is very sensitive. Any changes in the environment will introduce artifacts to the EOG signal. Although the wire has been shielded with aluminium foil, the surrounding noise still can affect the signal obtained. Conducive environment is needed to carry out the experiment. Therefore, it is recommended that filter has to be installed to eliminate the noise. Better filtering process is required or using wireless device to eliminate the noise in order to make sure that functionality of the wheelchair prototype.

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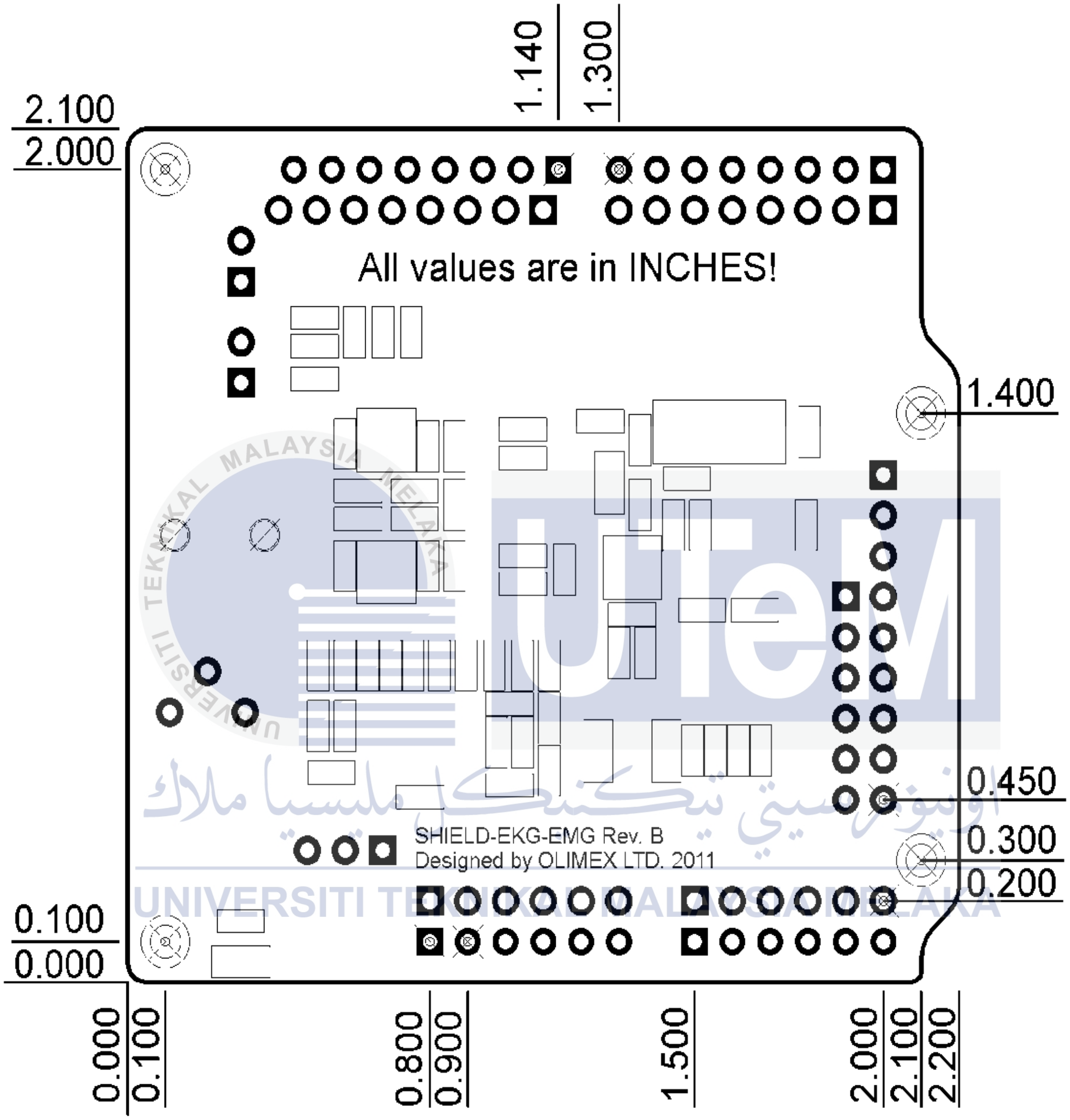
# APPENDICES

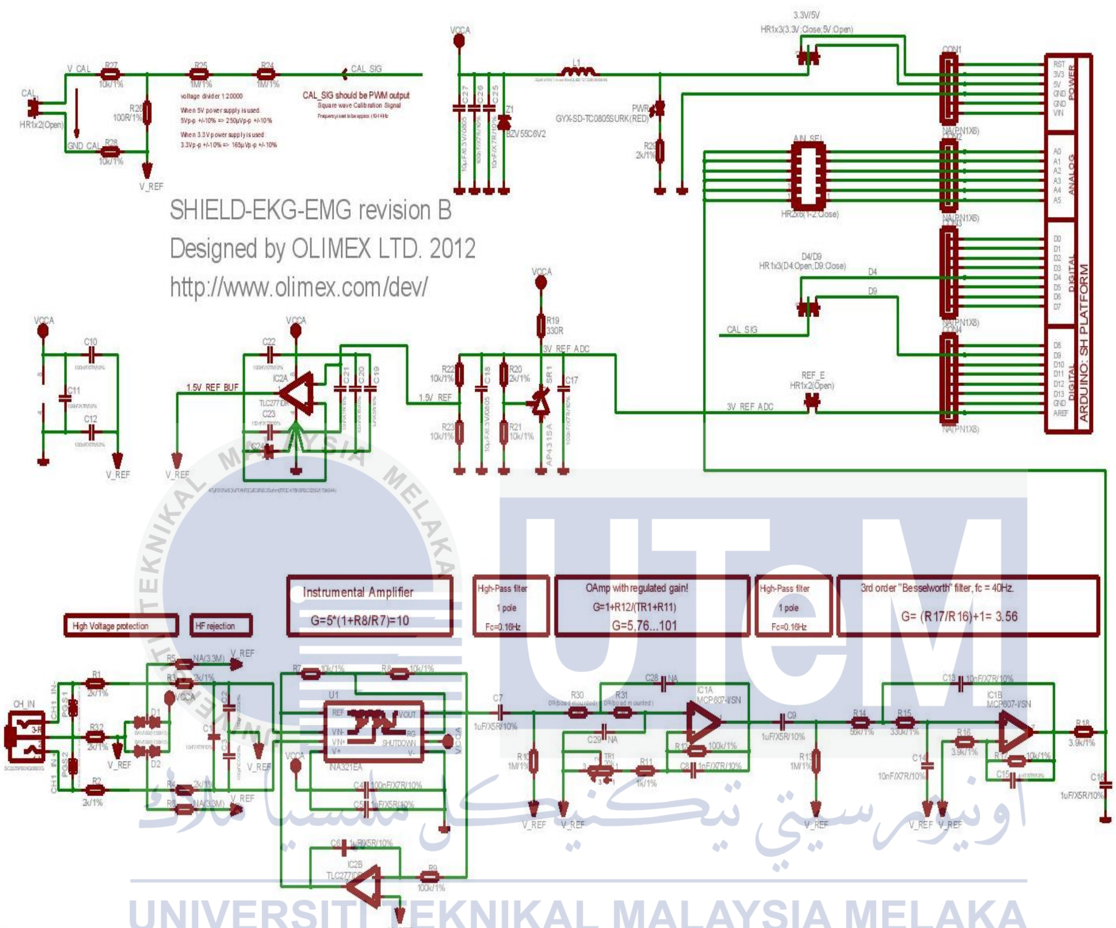
**APPENDIX A**






Appendix A Physical dimension of the shield board

# APPENDIX B



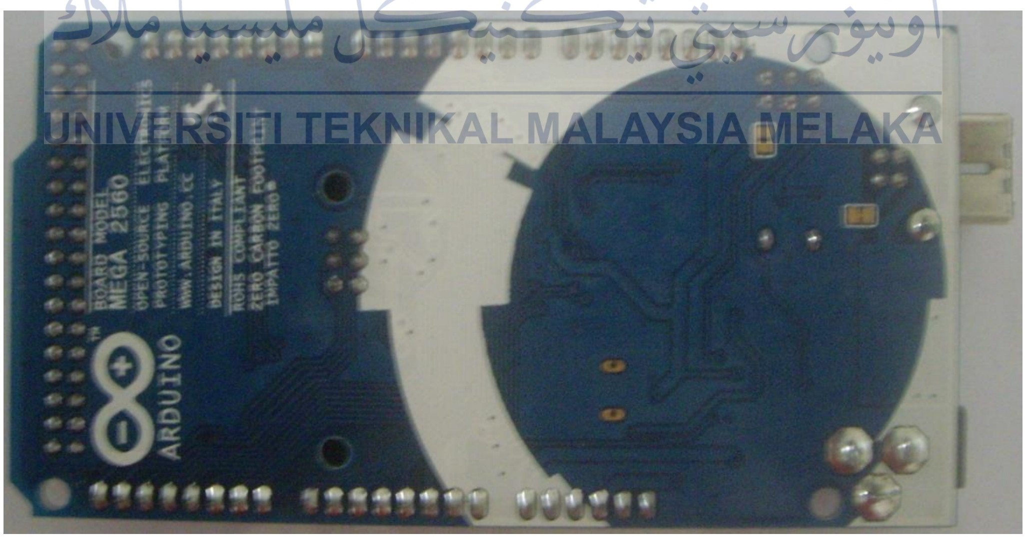



Appendix B Schematic diagram of Shield-EKG-EMG board

**APPENDIX C**


Appendix C Top layout of Arduino Mega 2560

**APPENDIX D**




Appendix D Bottom layout of Arduino Mega 2560

**APPENDIX E**

| **Part** | **Description** |
|---|---|
| Type of microcontroller | AT Mega 1280 |
| Operating voltage | 5V |
| Input Voltage (Recommended) | 7V-12V |
| `Input Voltage (Limits) | 6V-20V |
| Digital I/O Pins | 54 (of which 14 pins are PWM outputs) |
| Number of analogue input pins | 16 |
| DC current per I/O pin | 40mA |
| DC current for 3.3V pin | 50mA |
| Flash memory | 128KB of which 4KB used by bootloader |
| SRAM | 8KB |
| EEPROM | 4KB |
| Clock speed | 16MHz |

Appendix E Technical specifications for Arduino Mega 2560

# APPENDIX F

| Part | Functions |
|---|---|
| **Power Pins** | |
| VIN | Input voltage to the Arduino Mega 2560 when it is using an external power supply |
| 5V | Regulated power supply<br>As a power to the board |
| 3V3 | 3.3V which is generated by FTDI chip |
| GND | Ground pin |
| Memory | To store code |
| **Input and Output pins** | |
| TX/RX | To receive and transmit TTL data |
| External Interrupt | To trigger an interrupt |
| PWM | Provide 8-bit PWM output |
| SPI | Support SPI communication |
| LED | Built in LED |
| $I^2C$ | Support $I^2C$ (TWI) communication |
| AREF | Reference voltage for the analogue input |
| Reset | To reset the microcontroller when it is LOW |
| Communication | To enable communication between a computer, another Arduino or another microcontroller |

Appendix F Function of each part on Arduino Mega 2560

# Appendix G

Engineering For Society

certificate of Bronze Prize

is presented to

WAN MOHD BUKHARI BIN WAN DAUD; WONG CHUI YEE; MUSA BIN YUSUP LADA; FOO JIA EN

for commending an excellent and creative effort to invent

Autonomous Wheelchair (Mobile Robot) Powered Via EOG Signal Recognition

exhibited at the

INTERNATIONAL ENGINEERING INVENTION & INNOVATION EXHIBITION (i-ENVEX) 2014

held on

APRIL 11TH – 13TH, 2014
UNIVERSITI MALAYSIA PERLIS

Brig. Jen. Datuk Prof. Dr. Kamarudin Hussin
Vice Chancellor
Universiti Malaysia Perlis (UniMAP)

Academician Tan Sri Emeritus
Prof. Dr. Augustine S H Ong



Appendix G Certificate of Bronze price for I-ENVEX 2014

# Appendix H


Appendix H Certificate of Bronze price for UTeMEX 2013

**Appendix I**

# Autonomous Wheelchair (Mobile Robot) Powered Via EOG Signal Recognition

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***Abstract*– The approach of the wheelchair control by using electrooculography (EOG) signal recognition is proposed in this paper. This method allows users to control their wheelchair by using eyes movement. The main objective of this project is to identify the hyperpolarization and depolarization existing between retina and cornea that produce the corneal-retinal potential (CPR). The amplitude of CRP is collected from 5 participants while the results in form of signal are transferred to the Matlab environment for analyzed. The signal analysis was carried out to attain some information about the signals such as maximum and minimum value. Threshold level is determined based on the features of the signal and it has been used to determine the direction of the wheelchair. The implementation of the threshold level set using the CRP collected onto the wheelchair prototype is successfully achieved.**

**Keywords:** ***power mobile robot, electrooculography, signal recognition***

## I. Introduction

According to Malaysia Social Welfare Department (JKM) statistics in August 2010, there were 313,685 people with disabilities (PWD) are registered. According to Malaysian Parkinson's Disease Association, it is approximated that about 15,000 to 20,000 patients suffer from Parkinson's disease in Malaysia. All these patients rely on wheelchair to enable them to interact with environment.

The number of people with disabilities (PWD) has an increasing trend in Malaysia, demands for wheelchairs is also increasing. The common type controlled wheelchair is electrical powered wheelchair (EPW). This electrical powered wheelchair (EPW) is controlled by using a joystick. Joystick is the common instrument in controlling electrical powered wheelchair (EPW). User can move to the targeted location by controlling the joystick.

Wheelchair is an important communication tool for those who are handicapped and suffered from disease such as paralysis, Parkinson's disease and Lou Gehrig's disease. Technique in controlling wheelchair such as using joystick or tactile cannot satisfy the demands of elderly or patients who have restricted limb movement [1].

Controlling wheelchair by using joystick requires excellent control from the user [2]. Some users especially those users who suffer from Parkinson's disease or Lou Gehrig's disease face difficulty in controlling wheelchair by using joystick. Patients who suffer from these diseases have difficulty in controlling their limb movement. They have little or no control to their muscle. These patients unable to control their limb motion and hence cannot control the wheelchair by using traditional method which is joystick or tactile screen. Good motor functionality of hand muscle is needed to handle the surrounding region when controlling the wheelchair using joysticks.

## II. Electrooculography (EOG)

Electrooculography is a bio-signal which is produced by eye-movements. EOG is used to detect the signal potentials from eyes movement characteristics [3]. It is a test to measure the electrical response of the light-sensitive cells (rods and cones) and motor nerve components of the eyes [4]. It is the simplest and the weakest bio-signal that can be obtained from human body. The signal pattern is not quite complex [5]. EOG is the most effective test for the study of the functioning of the vestibular system [6].

EOG is the electrical signal obtained by the potential difference between the cornea and retina of the eyes. It is produced inside the eyeball by the metabolically active retinal epithelium [7]. Electrooculography (EOG) observes the eye-movements [8]. The movements of the eyes can be considered as steady-electrical dipoles which are anterior pole and posterior pole. Anterior pole is cornea which is positive pole while posterior pole is retina which is negative pole [9]. The larger amount of electrically active nerve present in the retina compared to the cornea. This difference leads to the potential difference between cornea and retina which is known as corneal-retinal potential (CRP) [10]. As eyeballs rotate, CRP is produced. Corneal-retinal potential (CRP) is a result from depolarization and hyperpolarisation existing between the retina and cornea [8].

EOG potential is the resting potential of the retina. The potential is varied proportionally to the displacement of the eyeballs inside the conductive environment of the skull [7]. Depolarization and hyperpolarisation occur between retina and corneal which then produce potential difference across the eyes. In dark condition, photoreceptors are depolarized and continuously active and



Appendix I Paper Publication: The 2nd Power and Energy Conversion Symposium (PECS 2014)