# Faculty of Electronic and Computer Technology and Engineering

**EEG-BASED DROWSINESS ALERT SYSTEM WITH IOT**



**NUR MUNIRAH BINTI DIN**

**Bachelor of Electronics Engineering Technology (Industrial Electronics) with Honours**

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**EEG-BASED DROWSINESS ALERT SYSTEM WITH IOT**

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**A project report submitted
in partial fulfillment of the requirements for the degree of
Bachelor of Electronics Engineering Technology (Industrial Electronics) with
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**Faculty of Electronic and Computer Technology and Engineering**

**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

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# DEDICATION

*Inscription for my beloved parents, my kind-hearted supervisor, and Mariam Melaka' sisters. To my lovely Mr. Din Bin Sulong, Mrs.Noraini Binti Nawi: "Even though you are far from me, the support and prayers you always send to me will not be able to repay until the Day of Judgment."*

# ABSTRACT

Driver drowsiness and fatigue are significant issues that can lead to accidents on the road. Drowsy driving weaken a driver's ability to focus, make quick decisions, and react to potential hazards. In extreme cases, drowsy drivers may experience microsleeps, which the driver is essentially unconscious, and if it occurs while driving, it can result in serious accidents. Electroencephalogram (EEG) are commonly employed to measure neural activity, serving as a widely utilized physiological indicator for detecting driver drowsiness. This paper presents  the solution to detect drowsiness at the early stage using EEG signal and an alert system to trigger the driver by an audible alarm, status display on LCD, and a light indicator. The input is acquired using the MindLink Neuro Sensor, a wireless, wearable dry EEG headset that is connected to the microcontroller via bluetooth. The data will be send and stored on Internet of Thing (IoT) which is via Thingspeak platform, which includes features like collecting data in real-time, processing data, creating visual representations, and using various applications and plugins.  In this project, analyzing the power spectral density of the driver's EEG and assessing the duration of theta wave persistence enables the identification of whether the driver is entering a drowsy state or not. Furthermore, using decreasing in attention and increasing in meditation is also the reason for a driver in a drowsy state.

# *ABSTRAK*

Keletihan dan kelesuan pemandu merupakan isu penting yang boleh menyebabkan kemalangan di jalan raya. Pemanduan dalam keadaan mengantuk melemahkan keupayaan pemandu untuk memberi tumpuan, membuat keputusan cepat, dan bertindak balas terhadap bahaya yang mungkin timbul. Dalam kes-kes ekstrem, pemandu yang mengantuk mungkin mengalami mikrotidur, di mana pemandu secara praktiknya tidak sedar, dan jika ia berlaku semasa memandu, ia boleh menyebabkan kemalangan serius. Elektroensefalogram (EEG) biasanya digunakan untuk mengukur aktiviti neural, berperanan sebagai penunjuk fisiologi yang banyak digunakan untuk mengesan keletihan pemandu. Kertas ini menyajikan penyelesaian untuk mengesan keletihan pada peringkat awal menggunakan isyarat EEG dan sistem amaran untuk memberi isyarat kepada pemandu melalui alarm yang kedengaran, paparan status pada LCD, dan penunjuk cahaya. Masukan diperolehi menggunakan MindLink Neuro Sensor, headset EEG tanpa wayar yang dipakai dan kering yang dihubungkan ke mikropengawal melalui Bluetooth. Data akan dihantar dan disimpan pada platform Internet of Things (IoT) melalui Thingspeak, yang mempunyai ciri-ciri seperti mengumpul data secara langsung, memproses data, mencipta representasi visual, dan menggunakan pelbagai aplikasi dan plugin. Dalam projek ini, menganalisis ketumpatan spektrum kuasa EEG pemandu dan menilai tempoh ketekalan gelombang theta membolehkan pengenalan sama ada pemandu sedang memasuki keadaan mengantuk atau tidak. Selanjutnya, pengurangan perhatian dan peningkatan dalam meditasi juga merupakan sebab pemandu dalam keadaan mengantuk.

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For all the experience and struggle of the past years, for times of success reminded of the happiness and for the time of failure reminded my own weakness, Thanks to my entire beloved one through the concern.

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# CHAPTER 1

# INTRODUCTION

## 1.1 Background

The act of operating a motor vehicle while sleepy or exhausted is known as "drowsy driving" or "fatigue." A driver's ability to concentrate is frequently compromised by fatigue. When a driver is work hard to stay awake while operating a vehicle, they are not fully focused on the road ahead, other vehicles, or other obstructions. In 2021, there were 684 fatalities related to sleep-deprived drivers, accounting for 1.6% of all fatalities. Compared to 632 in 2020, this is an increase of 8.2% (NHTSA). One method for addressing sleepiness concerns is the electroencephalogram (EEG), which is the electrical activity of the human brain. It is an accurate way to gauge drowsiness because EEG begin to change in earlier stages of tiredness, they are significant for early drowsiness detection. Literally, the brainwaves are consisted of five wave which is delta, theta, alpha, beta and gamma. Delta is the lowest frequencies which is in a range of 0.1Hz to 3.5 Hz. Its occur when deep sleep and some abnormal process. The dominant is rhythm in infants up to one year. It is the highest in amplitude and lower in frequency. For theta wave, with a frequency range of 4 to 7Hz, is a pattern associated with both drowsiness and the initial phases of sleep. It is most noticeable in the frontal-central regions of the head and gradually shifts towards the rear, taking the place of the alpha rhythm during the early stages of drowsiness. While alpha wave is in the range between 18Hz to 12Hz. In this project, Nodemcu ESP8266 is used as a microcontroller, hc-05 bluetooth module is to connect between EEG sensor and microcontroller, and an IoT platform that allows data from the EEG sensor to be sent to the cloud and save it to analyze the pattern.

## 1.2 Addressing Global Warming through Project

Through a number of indirect channels, this research, which uses EEG technology to identify and treat sleepy driving, helps to mitigate global warming. Traffic accidents are significantly influenced by sleepy driving. Through efficient detection and mitigation of driver fatigue, the research seeks to lower the number of collisions. Reduced traffic congestion and vehicle idling are the results of fewer accidents, which eventually reduce total carbon emissions from the transportation sector. Improved road safety promotes larger efforts to build sustainable and ecologically aware societies in addition to saving lives.

## 1.3 Problem Statement

Driver drowsiness and fatigue pose significant threats to road safety, leading to an increased risk of accidents. The challenge arises from the lack of effective to detect early signs of drowsiness in drivers, such as the onset of the brainwave pattern that associated with drowsiness and the initial stages of sleep. Conventional methods often fail to intervene at the crucial early stages, allowing drowsy driving to persist, leading to impaired focus, delayed reactions, and, in extreme cases, microsleeps. The absence of a reliable alert system will increase the risks associated with drowsy driving, contributing to a higher incidence of accidents and fatalities on the road. This project seeks to address this problem by utilising EEG signals for early drowsiness detection and implementing a comprehensive alert system. The integration of the MindLink Neuro Sensor with a microcontroller and the utilization of IoT for real-time data processing and visualization are crucial steps in overcoming the existing challenges. The problem statement emphasizes the need for a proactive solution that enhances road safety by interfering at the earliest indications of driver drowsiness, ultimately reducing the occurrence of accidents and fatalities related to this critical issue.

## 1.4 Project Objective

The objective of this project is to develop an effective system for early detection of driver drowsiness and fatigue using Electroencephalogram (EEG) signals. The project aims to address the significant safety concerns associated with drowsy driving by implementing a proactive alert system. The specific objectives are as follows:

a) To analyze EEG signals to detect early signs of driver drowsiness.

b) To implement an alert system that can trigger a drowsy driver from fallen asleep.

c) To transmit a brainwave data to the cloud.

## 1.5 Scope of Project

The scope of this project is:

a) The target user is for a driver that driving a car or other vehicles, in a fatigue condition and drowsy state.

b) This project use EEG Sensor, a wireless, wearable dry EEG headset, with a NodeMcu as a microcontroller and a bluetooth module technology to facilitate communication and data transfer.

c) The alert system use is to notify the driver when drowsiness is a buzzer, LCD display and a light indicator to display status and warn the driver to rest.

d) The brainwave data will store in a cloud platform.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

The human brain controls physical processes such as heartbeat, movement, and speech, as well as thought, memory, and emotional perception [1]. Hans Berger conducted a series of studies in 1929 to demonstrate the electrical activity of the human brain [2]. Berger discovered that voltage changes resulting from the brain's electrical activity could be recorded and monitored by attaching electrodes to the scalp and amplifying the signal; thus, he created (and recorded) the first electroencephalogram (EEG) [2].

## 2.2 Electroencephalography (EEG)

An electroencephalography (EEG) sensor is an electronic device that detects the electrical impulses generated by the brain. It typically records the changing electrical signals produced by densely packed groups of neurons near the surface of the brain over a period of time. Electroencephalography (EEG) is a non-invasive medical imaging technology that utilizes metal electrodes and a conductive fluid to measure the electrical activity on the surface of the scalp [3]. These sensors function by measuring the minor fluctuations in electrical current between the skin and the electrode, amplifying the current, and applying various filtering techniques, such as bandpass filtering [4]. The analysis of EEG signals, which serve as electrical representations of brain physiology, can be utilized to explore brain function and overall health. Therefore, through the examination of data extracted from EEG signals, various brain diseases, abnormalities, and injuries can be detected [5].

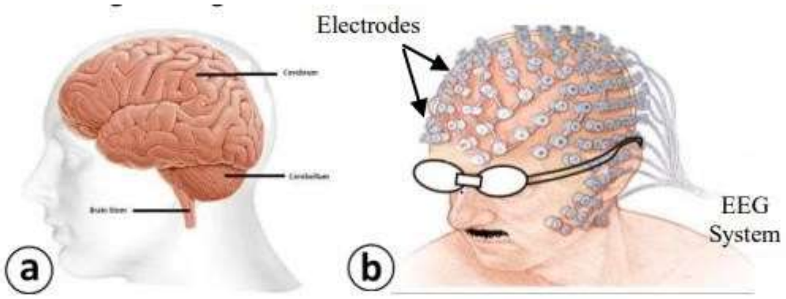


**Figure 2.2: Human brain and EEG acquisition [4].**

### 2.2.1 Brain Computer Interface

To operate external devices, connect with others, assist in rehabilitation, or restore functions, brain-computer interfaces continuously acquire and evaluate brain signals. Brain-computer interfaces consist of three components [1]. Non-invasive, minimally invasive, and intrusive. For achieving the most accurate signal quality, invasive techniques of brain-computer interfaces are employed. These specialized electrodes are utilized specifically for addressing issues related to the cortex. These systems find application in individuals with paralysis or in restoring vision by connecting the brain to external cameras. While these brain-computer interface (BCI) systems provide superior signal quality, they are susceptible to the formation of scar tissue. This scar tissue can lead to a weakened signal, which may ultimately be lost [1].



Partially Invasive Brain Computer Interfaces are inserted into the skull, positioned outside the brain. Electrocorticography (ECoG) employs similar technology to noninvasive electroencephalography, but with electrodes placed inside a thin plastic pad situated above the cortex and beneath the dura mater. These devices offer a robust signal, although it is not as potent as that provided by invasive BCIs [1]. Non-invasive brain-computer interfaces employ electrodes placed on the skull's surface to detect variations in EEG conditions. Despite the fact that the signal being produced has the smallest values, noninvasive BCI is the safest and most straightforward approach to capturing EEG [1].

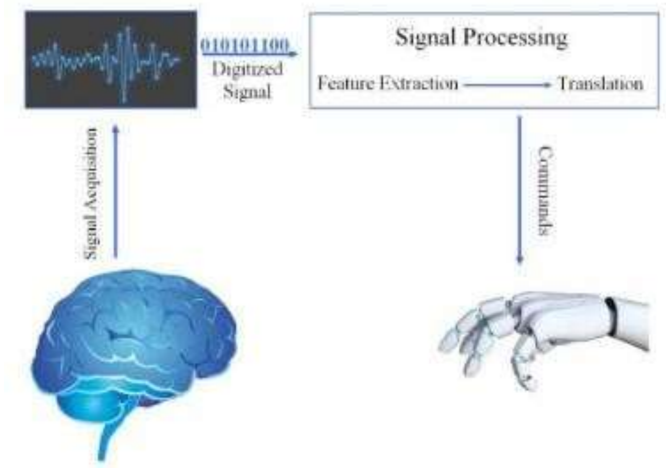


**Figure 2.2.1.1: Basic flow diagram of BCI system [1].**


**Figure 2.2.1.2: Designs of noninvasive EEG equipment utilizing BCI technology include EEGSmart, Nihon Kohden, and Cognixion, which serve as examples in the commercial market. [5].**

### 2.2.2 Brainwave Frequencies

The brain tissue system consisted of billions of brain cells called neurons. Each neuron transmits fluctuating electric waves called brain waves [6]. Brainwaves can be broadly classified into five categories based on their oscillation frequencies which is gamma, beta, alpha, theta, and delta waves [7]. A dominant wave will depend on the activities of the brain. The frequency of EEG signals is a critical factor for evaluating abnormalities in clinical EEGs and studying cognitive behaviors in cognitive research.

**Table 2.2.2.1: The five fundamental brain waves characteristic [3].**

| Frequency band | Frequency | Brain states |
|---|---|---|
| Gamma (γ) | >35 Hz | Concentration |
| Beta (β) | 12–35 Hz | Anxiety dominant, active, external attention, relaxed |
| Alpha (α) | 8–12 Hz | Very relaxed, passive attention |
| Theta (θ) | 4–8 Hz | Deeply relaxed, inward focused |
| Delta (δ) | 0.5–4 Hz | Sleep |

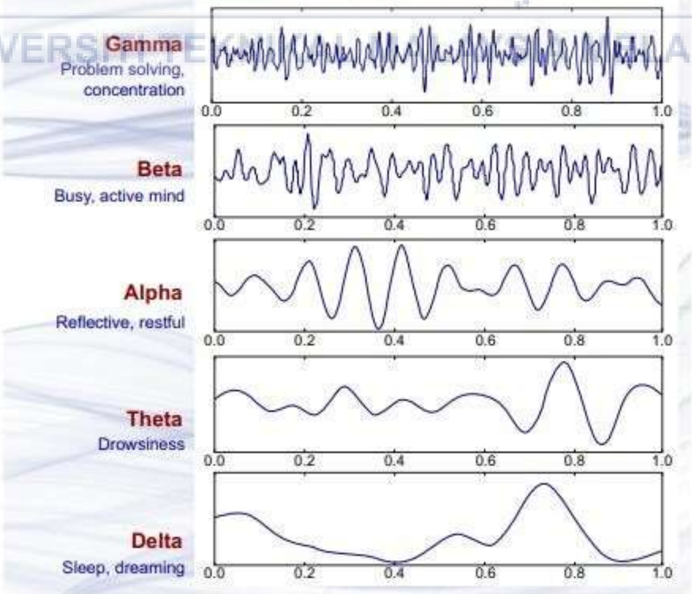


**Figure 2.2.2.2: Samples of brain waves with prevailing frequencies [3].**

### 2.3 Application of EEG

Although EEG technology has been there for the better part of the last century, the general public has just recently been able to use it. A few decades ago, the only people who could set up and analyze recordings using electrode caps with 64 channels or more in a highly controlled laboratory setting were neuroscientific researchers and clinicians. These uniformly spaced, high-density electrodes on the human scalp were important in enabling scientists to identify before unidentified brain processes related to movement, thought, and emotional processing. Recent developments in processing and computer hardware have enabled scientists all over the world to learn a great deal more about the intricate workings of the human brain. As a result, deeper understanding of numerous [4].

#### 2.3.1 Stroke Rehabilitation Monitoring

Ischemic heart disease is classified by the World Health Organization (WHO) as the second most common cause of death, surpassed only by stroke. This condition arises when a blood artery in the brain ruptures or when the blood supply to the brain is obstructed. Stroke can result in impaired motor abilities, such as paralysis in the hands or legs. Reestablishing motor function necessitates specialized care, such as rehabilitation, which aids the patient in resuming regular daily activities. However, the recovery process is frequently inconsistent and insufficient [8].

The active participation of clinicians is essential in overseeing the progress of stroke patients during the rehabilitation process. Because all monitoring procedures involve visual inspection, the problem is that clinicians have difficulty accurately and precisely assessing the rehabilitation progress of these patients. The physician's primary tool for assessing the effectiveness of rehabilitation is visual observation. However, visual observation has several limitations, including subjectivity and the impossibility of detailed and accurate assessment because the physician is unable to detect minute variations in such things as movement speed, reaction time, or amplitude of the brain signal when a command is given. EEG can be used to solve such problems. The application of BCI (Brain-Computer Interaction), an EEG technique, has been widely employed in the exploration of human mobility and the brain. Various applications of brain-computer interfaces (BCIs) have the potential to enhance the rehabilitation process [8].

### 2.3.2 Alzheimer's Disease Diagnosis

Alzheimer's disease (AD), a neurological condition, is estimated to be responsible for over 46 million dementia cases globally, constituting nearly 70% of all dementia cases. While there is currently no cure for AD, a comprehensive assessment of disease progression and early diagnosis can significantly improve the quality of life for individuals with AD and their caregivers. Presently, AD is diagnosed through standardized mental status exams, occasionally accompanied by costly imaging studies and invasive laboratory procedures, leading to a time-consuming and expensive process. However, electroencephalography (EEG) has emerged as a noninvasive alternative method for investigating AD over the past decade, providing competition to pricier neuroimaging devices like MRI and PET [9].



### 2.3.3 Sleep Monitoring

Human health depends on sleep, and both the quantity and quality of sleep are influenced by lifestyle and human health. The well-being of the body and mind, as well as the economy, depend on how well people sleep in our modern, always-on culture. Consequently, one of the key focal points in sleep medicine pertains to the sleep quality, which is frequently investigated through the analysis of sleep patterns within a sleep clinic. Nevertheless, the current expense associated with clinical sleep monitoring is considerable [10].

To address the issue of time-consuming sleep stage classification performed by clinicians, researchers have introduced automated sleep classification systems. These systems utilize comprehensive polysomnography recordings, including electroencephalogram (EEG), electrooculogram (EOG), and chin electromyogram (EMG), or more recently, single- channel EEG recordings [10].

### 2.3.4 Sweat Rate on Skin

In recent years, commercial applications for pedometers and heart rate monitors have been realize. These functions can now be effectively implemented in a smart watch for hundreds of dollars. Compared to step counting or heart rate monitoring, biopotential, such as electroencephalograms (EEG) or electrocardiograms (ECG), can analyze more health- related data. The EEG signal, which is the biopotential generated by brain activity, is widely used to assess people's mood. While the EEG signal has been employed for medical diagnosis for an extended period, there are still certain challenges associated with monitoring through wearable devices [11].

Sweating is another physical phenomenon that occurs constantly on the body in addition to EEG signals. Sweat glands on the skin secrete sweat, which primarily serves to control body temperature. Sweat holds a significant amount of valuable information regarding the human body, such as indications of environmental well-being, the level of water loss from the body, and the intensity of physical activity [11].

### 2.4 Study Related to Project

#### 2.4.1 Measure Drowsiness

A. *Behavioral Measures*

There are several ways to detect drowsiness based on behavioral measure. As an illustration, a system utilizes the front camera of the driver's smartphone positioned on the car's windshield, consistently employing the camera to assess the driver's conduct, specifically whether their eyes are open or closed [12]. The Viola-Jones algorithm, formulated by Paula Viola and Michael Jones in 2001, is a real-time object-recognition framework capable of swiftly and precisely detecting features in images. While effective in rapidly and accurately identifying objects, particularly human faces, this algorithm encounters a challenge with slow processing during the training data phase despite its quick detection capability [13].

B. *Physicological Measures*

Many researchers measure the drowsiness based on physicological measure. The driver's unusual condition, indicated by measuring physiological signals such as EOG, ECG, and EMG, is examined by utilizing their correlations. The fluctuation in heart rate directly conveys information about the user's physiological condition, proving particularly valuable for gathering detailed insights into the cycle of drowsiness [14]. EOG signals can be captured in a way that is not invasive or intrusive. The driver monitoring system, which relies on cameras, observes eye movements to construct a multiple regression model. This model can forecast the driver's reaction time, which is the duration it takes for recognition and response to requests in automated driving [15]. Nevertheless, these measures identify the drowsy state of the driver only once they surpass a particular attentiveness threshold, unlike the automated analysis of physiological signals [16]. In this paper will propose a project to detect drowsiness and alert the driver from unconcious.

### 2.4.2 Drowsiness Brainwave

The initial signs of drowsiness are marked by a rise in theta wave activity [17]. Fatigue leads to a reduction in physiological arousal, decelerated sensorimotor functions, and compromised information processing, slowing down workers' capability to respond efficiently in emergency or unconventional situations [18]. So that, analyzing the four types of brainwaves identified through EEG can reveal these alterations. Delta waves are more prevalent when sleeping. An increase in theta waves suggests the early onset of drowsiness. Alpha waves signify a calm state while awake, diminishing with concentration, stimulation, or visual focus, indicating worker fatigue leading to potential sleepiness. Beta waves intensify when alert and diminish during drowsiness [17]. Drowsiness resulting from both insufficient sleep (theta waves) and a lack of mental relaxation (alpha waves) accompanied by heightened brain activity (beta waves) leads to tension, stress, and diminished concentration [17].

### 2.4.3 Alert System for Driver

A driver alert system is a safety feature designed to track a driver's actions and provide a warning when they become distracted or drowsy for a prolonged period, risking a loss of awareness of the road ahead. These devices are meant to identify the obvious indicators of a drowsy or alcoholic driver and either issue a warning or initiate corrective action. While the methods of detection and correction used by each system differ they all work towards the same overall goal.

**Figure 2.4.3: A Drowsy Alert System.**

### 2.4.4 Wearable EEG



Electroencephalography (EEG) electrodes can be categorized into two types: dry and wet. Wet electrodes utilize gel or saline liquid to enhance conductivity, but they tend to dry out over time. In contrast, dry electrodes do not require the use of gel or saline liquid. The choice of electrode type in EEG has an impact on the Power Spectral Density (PSD) of brain signals [19].

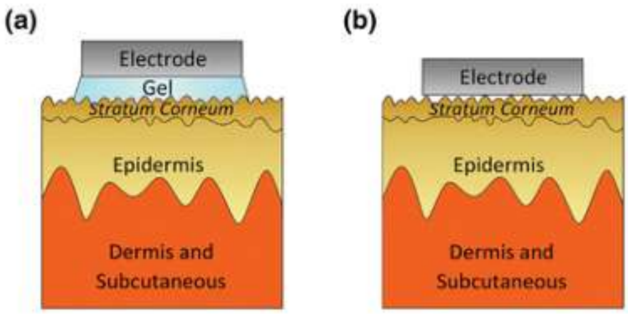


**Figure 2.4.4: (a) Wet and (b) Dry electrode**

Wet electrode systems entail the application of a conductive gel or saline liquid to establish conductivity between the scalp. The wet electrode, commonly known as the disposable Ag/AgCl wet electrode, is often chosen for electrophysiological signal detection. It is favored for its affordability, effective skin fitting, and good conductivity. In contrast, dry electrodes are directly applied to the skin without the need for gel or saline liquid, making them easy to attach without requiring trained technicians. Additionally, dry electrode function more like polarizable electrodes, featuring a large contact capacitance. This configuration introduces air as a dielectric layer between the electrode and the skin surface, significantly increasing the total impedance [19].

### 2.4.5 NodeMCU

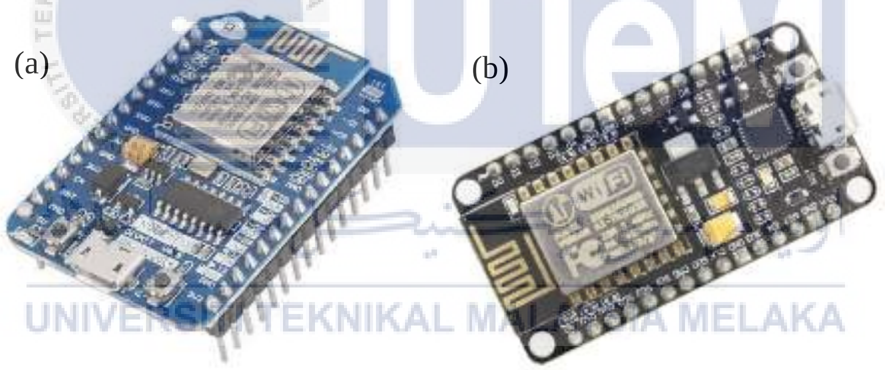


**Figure 2.4.5: (a) NodeMCU Development Board/kit v0.9 (Version1), (b) NodeMCU Development Board/kit v1.0 (Version2)**

NodeMCU is an open-source firmware based on LUA, designed for the ESP8266 wifi chip. It is specifically developed to harness the capabilities of the ESP8266 chip and is packaged with the NodeMCU Development board/kit. Given NodeMCU's open-source nature, its hardware design is accessible for editing, modification, and building. The NodeMCU Development Kit/board is equipped with the ESP8266 wifi-enabled chip. Developed by Espressif Systems, the ESP8266 is an economical Wi-Fi chip that operates with the TCP/IP protocol. Further details about the ESP8266 can be found in the ESP8266 WiFi Module documentation.

### 2.4.6 Bluetooth Module


**Figure 2.4.6: Bluetooth Module HC-05 and HC-06**

The HC-05 is a Bluetooth module of class 2, intended for transparent wireless serial communication. It comes pre-configured as a slave Bluetooth device. Once paired with a master Bluetooth device like a PC, smartphone, or tablet, its operation seamlessly integrates with the user, requiring no specific user code for the Bluetooth module in the microcontroller program[20].

On the other hand, the HC-06 is a class 2 slave Bluetooth module designed for transparent wireless serial communication. It exclusively functions as a slave device, unlike the HC-05, which can operate as both a Master and Slave. This distinction means that while the HC-05 can initiate a connection with another device, the HC-06 can only accept connections from other devices. Once paired with a master Bluetooth device, such as a PC, smartphone, or tablet, the HC-06 operates transparently to the user[20].

## 2.5 Previous Related Research Work

### 2.5.1 Arduino based Real Time Drowsiness and Fatigue Detection for Bikers using Helmet [16].

This research focuses on enhancing the safety of motorcycle riders through the development of a specialized system. The proposed solution incorporates EEG sensors integrated into the helmet to identify the rider's drowsy condition. A Brain-wave sensor captures the biomedical signals from the rider's brain in real-time, offering continuous monitoring for signs of drowsiness and fatigue. By integrating a miniaturized sensor into the helmet, this system serves as a crucial component in providing a mind-machine interface (MMI) to effectively address challenges such as drowsiness and fatigue. Upon detecting the rider in a drowsy state, the system issues a warning through an alarm and initiates a gradual slowdown and eventual stop of the motor [16].

In the event that the driver's brain signals fall within the frequency range of 4-8Hz, indicating a drowsy state, an alarm will be activated. If the driver persists in this state, specifically if the alarm sounds continuously three times, the motor will gradually decelerate and eventually come to a complete stop [16].

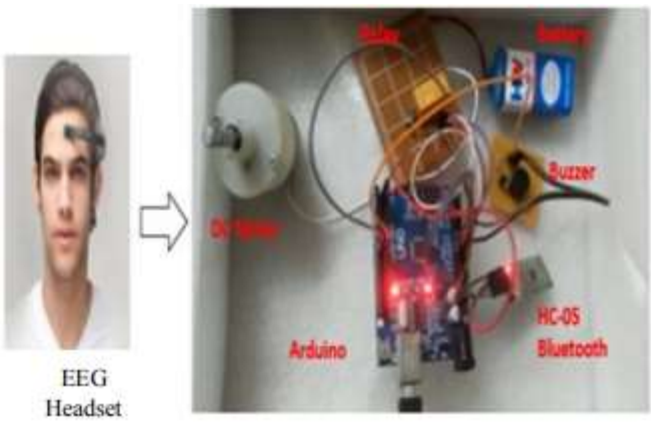


**Figure 2.5.1: Proposed System [16].**

**Table 2.5.1: Signal Observation [16]**

| S. No | Frequency of the Signals (Hertz) | Arduino Readings (microvolts) | Alarm Ring | LED | state |
|---|---|---|---|---|---|
| 1 | 1.4 | 16 | No | Yellow | Sleep |
| 2 | 2.7 | 24 | No | Yellow | Sleep |
| 3 | 3.7 | 29 | No | Yellow | Sleep |
| 4 | 8.3 | 76 | No | Blue | Normal |
| 5 | 8.4 | 79 | No | Blue | Normal |
| 6 | 9.3 | 97 | No | Blue | Normal |
| 7 | 13.5 | 112 | No | Green | Active |
| 8 | 5.2 | 43 | Yes | Red | Drowse |
| 9 | 4.9 | 39 | Yes | Red | Drowse |
| 10 | 5.7 | 46 | Yes | Red | Drowse |

A threshold value is employed to differentiate the biker's state. Through training with logistic regression to predict this threshold, the analysis reveals that raw data falling below 49 and above 32 correlates with the frequency range between 4-8 Hz [16].

### 2.5.2 Morpheus Alert [21]

The paper introduces a smartphone app utilizing an affordable EEG brain-computer interface. Named Morpheus Alert, the application monitors the ratio index of brain waves (Alpha + Theta) / Beta, along with the user's attention level, to identify drowsiness and mitigate microsleeps. The study involves two scenarios for recording EEG data and analyzing variations in the ratio index and attention levels between normal and drowsy states [21]. This app assesses the ratio index of brain waves (Alpha + Theta) / Beta and the user's attention level to detect and prevent drowsiness-induced microsleeps. The research includes two scenarios to capture EEG data and examine differences in the ratio index and attention levels under normal and drowsy conditions [21].


**Figure 2.5.2.1: Workflow [21]**

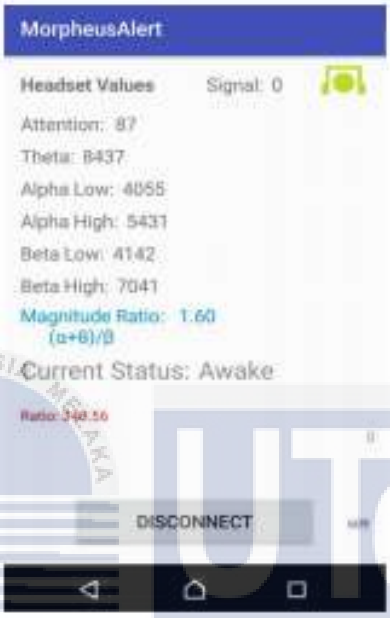


**Figure 2.5.2.2: Morpheus Alert [21]**

In the test sessions, the application demonstrated a 73% accuracy in effectively identifying drowsiness. The employed method, which involves monitoring attention levels and the magnitude values of brain waves (alpha, beta, and theta), yielded favorable outcomes. Specifically, reduced attention levels coupled with elevated magnitude values of alpha and theta waves were found to be correlated with the occurrence of drowsiness [21].

### 2.5.3 Early driver drowsiness detection using electroencephalography signals [22].

This research investigates driver behavior by analyzing brainwave patterns to identify signs of drowsiness. The study utilized EEG headsets interfaced with Open BCI software to collect brain signals from participants. To validate the data, the Karolinska Sleepiness Scale (KSS) was employed as a subjective measure. Signal processing, implemented through MATLAB, focused on extracting the alpha frequency band from power spectral density estimation using the periodogram method. A decision tree was employed to classify the extracted features, resulting in high accuracy ranging from 77.1% to 97.20% for each subject. Drowsiness was successfully identified based on the observed increase in alpha power [22].



**Figure 2.5.3: Ultracortex Mark IV EEG headset [22]**

The findings align with the alpha background, indicating that the initiation of alpha power is linked to closed eyes and a state of relaxation, whereas the reduction of alpha power is attributed to open eyes [22].

### 2.5.4 Drowsy Driver Detection System [23].

This technology utilizes various sensors and components to observe the driver's actions and issue warnings in case of indications of drowsiness. It incorporates an eye sensor, an MQ3 alcohol sensor, and a GPS module to identify signs of drowsy driving, such as alcohol consumption and eye blinking. The information collected by these sensors is analyzed, and alerts are transmitted to the driver or relevant authorities if it is determined that the driver is fatigued. Operating on Node MCU, an alcohol sensor, an eye blink sensor, GPS, and GSM, this system holds the potential to significantly decrease accidents arising from driver fatigue, contributing to enhanced road safety for all [24].

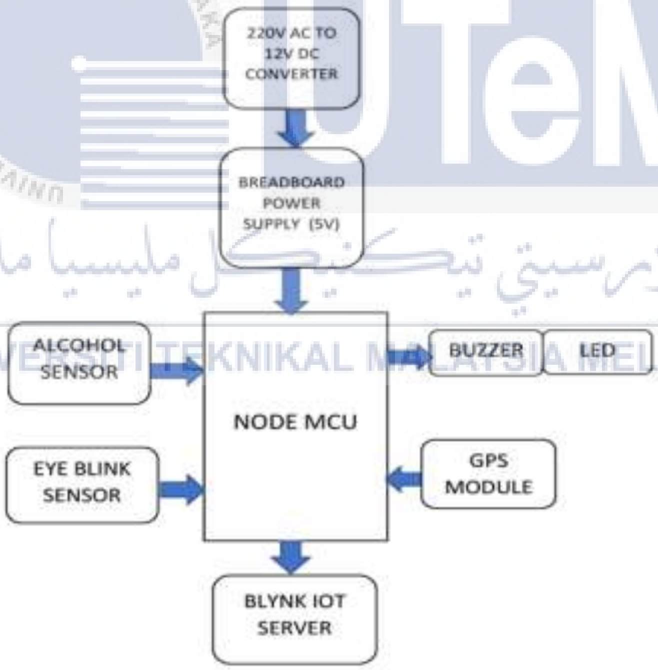




**Figure 2.5.4: Block Diagram [24]**

### 2.5.5 IoT-Based Smart Alert System for Drowsy Driver Detection [25].

The paper under consideration discusses a drowsy driver alert system created through a specific approach. This method involves the analysis of Video Stream Processing (VSP) using the eye blink concept, utilizing the Eye Aspect Ratio (EAR) and Euclidean distance of the eye. Additionally, a Face Landmark algorithm is employed for accurate eye detection. Upon identification of driver fatigue, the IoT module sends a warning message, including collision impact details and location information. This alert is communicated through a voice output facilitated by the Raspberry Pi monitoring system [25].

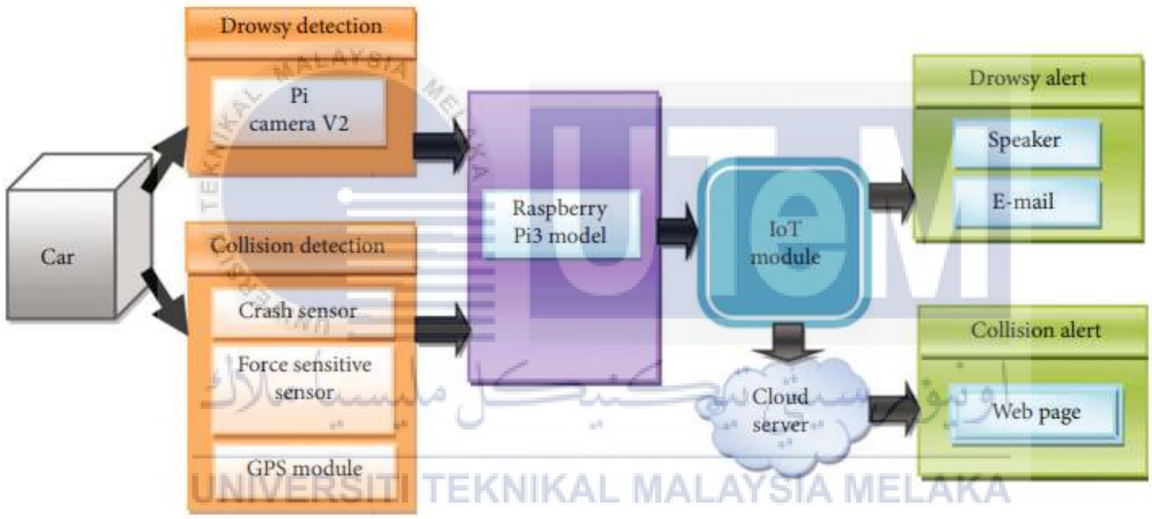


**Figure 2.5.5: The proposed system**

This system has achieved effective drowsy detection through the utilization of the facial landmark method. Additionally, it incorporates an alternative interface to detect collisions resulting from drowsiness or an unconscious state while driving [25].

### 2.5.6 Drowsiness Detection and Alert System Using Wearable Dry Electroencephalography for Safe Driving [26]

This paper introduces a system for detecting and alerting drowsiness levels in drivers by employing a MindLink Neuro Sensor, a wireless EEG headset, connected to a microcontroller. The system utilizes an audible alarm, LCD status display, and a light indicator to notify the driver. The research explores brain wave activities associated with drowsiness, focusing on alpha, beta, and theta waves triggered during activities like yawning. However, the experiment primarily relies on the MindLink EEG headset, emphasizing changes in the alpha wave as the key indicator of drowsiness [26].




**Figure 2.5.6: illustrates the contrast between the alpha wave patterns during wakefulness and drowsiness states [26].**

The graph experiences more frequent fluctuations, characterized by increased peaks and higher peaks compared to the awake state. Once the software is trained to identify these patterns, the system can effectively activate an alarm when it detects the onset of a drowsy state [26].

## 2.6 Previous Researcher Works Comparison

| No | Author | Year | Title | Method |
|---|---|---|---|---|
| 1 | Paul, I Joe Louis | 2020 | Arduino based Real Time Drowsiness and Fatigue Detection for Bikers using Helmet | • EEG-based MMI (Mind Machine interface)<br>• Microcontroller: Arduino Uno<br>• LED indicator states of driver<br>• Motor control |
| 2 | Martinez-Maradiaga, Daniel Meixner, Gerrit | 2017 | Morpheus Alert | • NeuroSky MindWave Mobile EEG headset<br>• Android application |
| 3 | Yaacob, Sazali Muhamad'arif, Nur Iman Zahra Krishnan, Pranesh Rasyadan, Amir Yaakop, Muhyi | 2020 | Early driver drowsiness detection using electroencephalography signals | • EEG Headset<br>• Approach the Karolinska Sleepiness Scale (KSS).<br>• MATLAB – processing brainwave pattern |

| | | | | |
|---|---|---|---|---|
| | Mohamed, Firdaus | | | |
| 4 | Dr. Jyoti Rothe | 2023 | Drowsy Driver Detection System | • Microcontroller: NodeMCU<br>• Alcohol sensor, an eye blink sensor<br>• GPS, and GSM |
| 5 | Biswal, Anil Kumar Singh, Debabrata Pattanayak, Binod Kumar Samanta, Debabrata Yang, Ming Hour | 2021 | IoT-Based Smart Alert System for Drowsy Driver Detection | • Video Stream Processing (VSP) is analyzed by eye blink<br>• Concept through an Eye Aspect Ratio (EAR) and Euclidean distance of the eye.<br>• Raspberry Pi monitoring system. |

| | | | | |
|---|---|---|---|---|
| 6 | Abd Gani, Shamsul Fakhar Ahmad, Muhammad Amir Aziz, Khairul Azha A. Kadmin, Ahmad Fauzan Hamzah, Rostam Affendi Hamid, Mohd Saad | 2022 | Drowsiness Detection and Alert System Using Wearable Dry Electroencephalography for Safe Driving | • Minlink EEG Neuro Sensor, wearable dry EEG headset,<br>• Activate an audible alarm, display the status on an LCD, and illuminate a light indicator to notify the driver. |

## 2.7 Summary

For all this project employ various technologies such as EEG, video stream processing, and sensor-based approaches to detect drowsiness in drivers, aiming to enhance road safety through timely alerts and interventions. The choice of hardware and sensors varies across the systems, reflecting diverse approaches to address this critical issue.

Summarizing the approaches and components utilized by previous researchers, it suggests that the EEG-based Drowsiness Alert System with IoT is likely to integrate a variety of features. The chosen methods for the project will be Mindlink Neurosky sensor, NodeMCU microcontroller and IoT will be used as the processing unit for the project.

# CHAPTER 3

# METHODOLOGY

## 3.1 Introduction

This chapter focuses on the implementation strategies aimed at accomplishing the project's objectives. It documents all the activities carried out throughout the project's execution. A flow chart is utilized in this section to provide a clear depiction of the project's completion process. Each step in the flow chart is thoroughly explained in detail. Additionally, appropriate equipment is carefully selected to ensure compatibility with the project requirements.

## 3.2 Sustainable Development

Drowsy driving is identified as a significant factor leading to accidents. Detecting and mitigating drowsiness contributes to road safety, aligning with the sustainable development goal of ensuring the well-being of individuals and communities. The use of EEG technology and IoT reflects an application of resource-efficient and innovative technologies. This resonates with sustainable development goals related to responsible consumption and the promotion of sustainable practices. The focus on early detection using EEG signals addresses the root cause of accidents. Preventing accidents contributes to sustainable development goals related to creating safe and resilient infrastructure.



## 3.3 Methodology

The aim of this project is to develop an effective system for early-stage drowsiness detection employing EEG signals and an alert system. The system activates an audible alarm, displays the driver's status on an LCD, and uses a light indicator to alert the driver. The MindLink

Neuro Sensor, a wireless and wearable dry EEG headset, captures the input and connects to the microcontroller via Bluetooth. Subsequently, the acquired data is transmitted and stored on the Internet of Things (IoT) through the ThingSpeak platform.

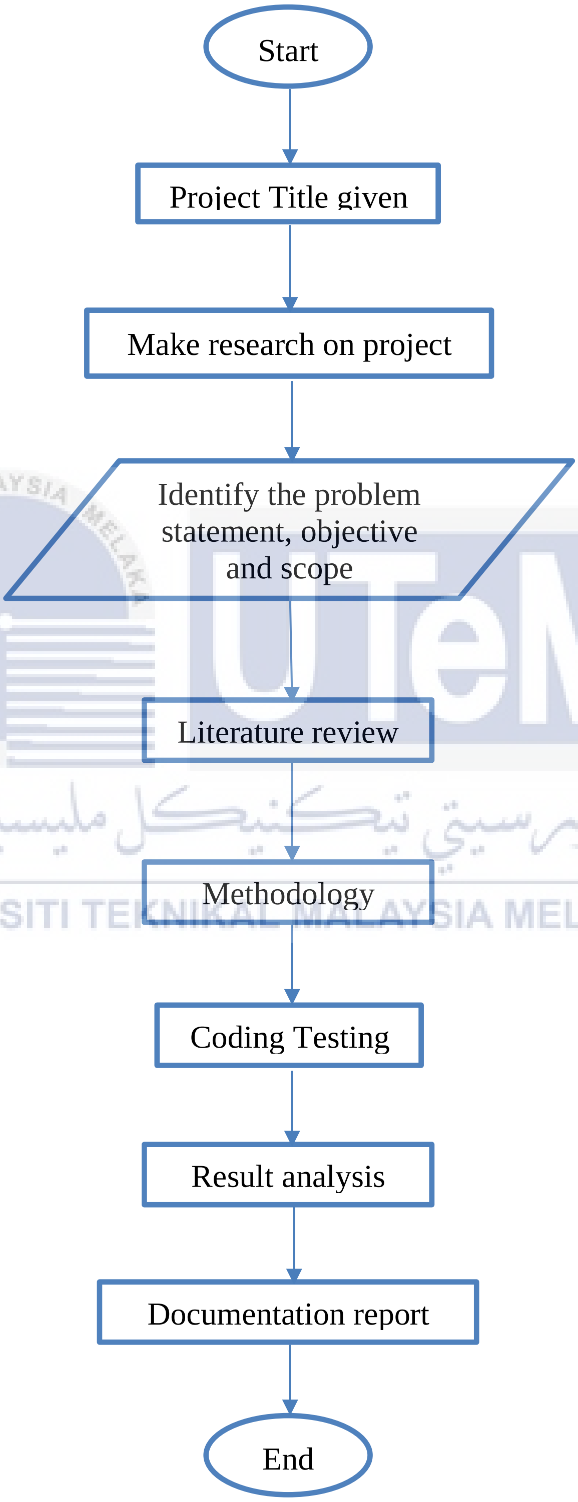




**Figure 3.3.1: Project Development Flowchart**

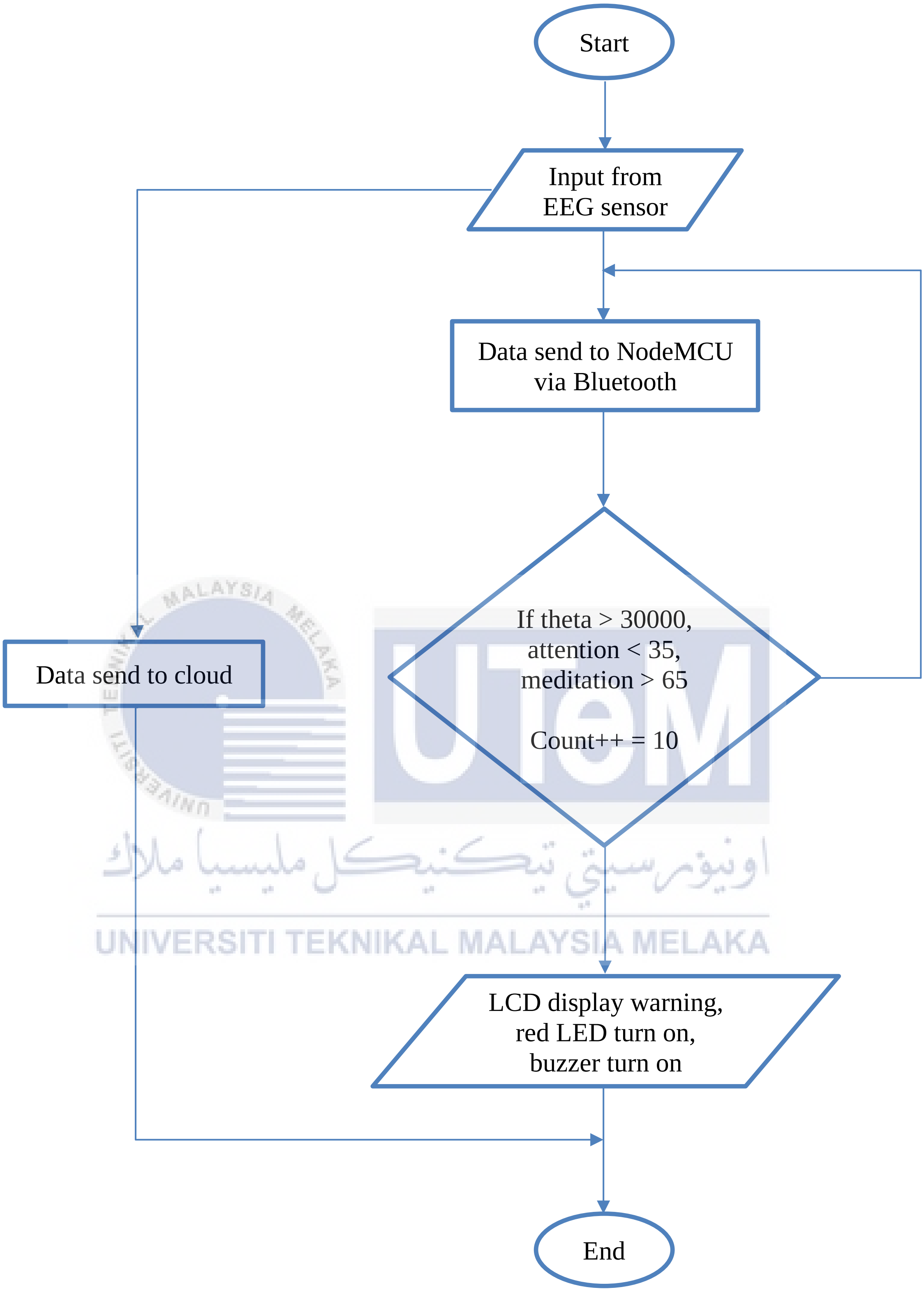


**Figure 3.3.2: Proposed Project System Flowchart**

## 3.4 Proposed Block Diagram and Circuit Diagram

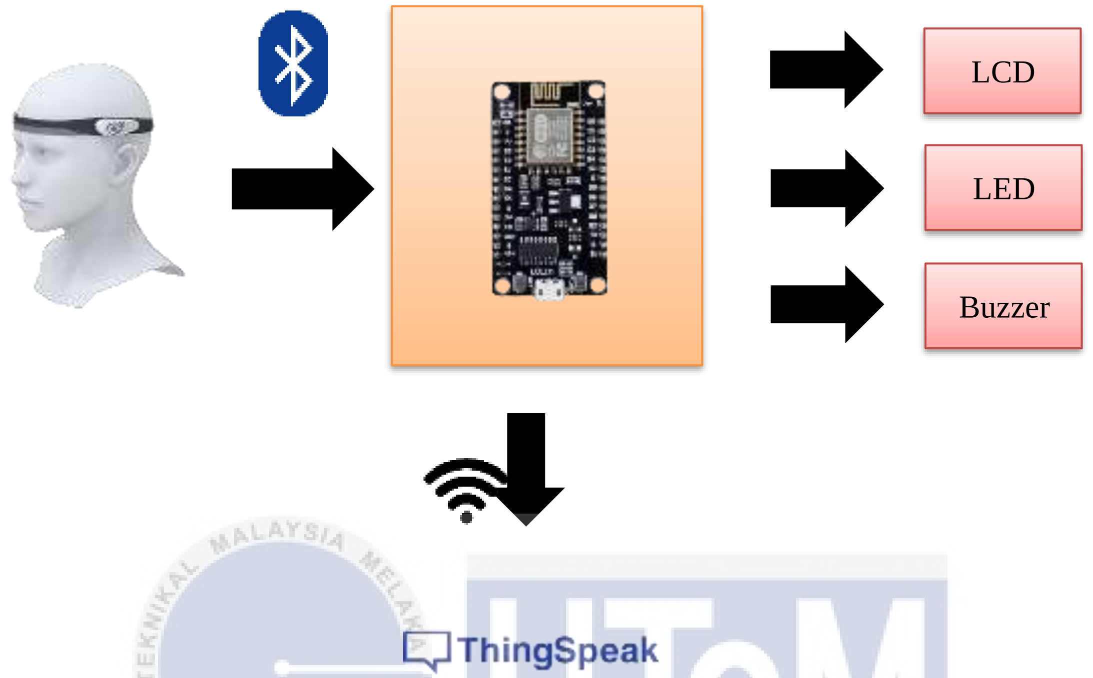


**Figure 3.4.1: shows the proposed block diagram of EEG-Based Drowsiness Alert System with IoT.**

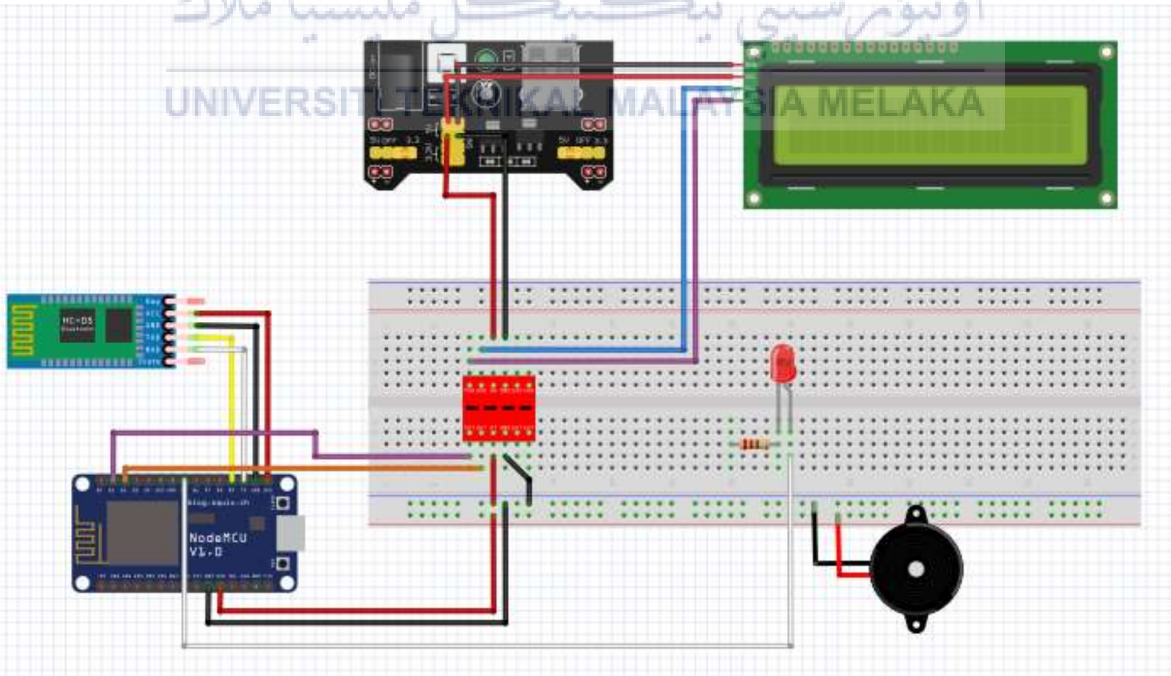


**Figure 3.4.2: Project Circuit Diagram**

### 3.5 Software Development

In this project, software development plays a crucial role in various stages and components of the system. The software development in this project is Arduino IDE and cloud, ThingSpeak.

#### 3.5.1 Arduino IDE

The Arduino IDE (Integrated Development Environment) is a software application that provides a platform for programming and developing applications for Arduino microcontrollers. It is a user-friendly development environment that simplifies the process of writing, compiling, and uploading code to Arduino boards.

#### 3.5.2 ThingSpeak Internet of Things

ThingSpeak is an Internet of Things (IoT) platform developed by MathWorks. It provides a cloud-based infrastructure for collecting, storing, visualizing, and analyzing data from connected devices or sensors. ThingSpeak is designed to enable IoT applications and facilitate the integration of data from various sources. The platform offers MATLAB integration, allowing users to perform advanced analytics and data processing on the collected IoT data. MATLAB code can be written and executed directly within ThingSpeak to perform calculations, statistical analysis, machine learning, and more.


**Figure 3.5.2: Thinkspeak interface**

## 3.6 Hardware

### 3.6.1 EEG Sensor MindLink

**Figure 3.6.1: EEG Brainwave Mindlink Neuro Sensor** [27]**.**

Electroencephalography (EEG) sensor is one of the sensors that measure the electricity that generated by synchronized activity of thousand neurons. Other than that, all the activity has been detected on that sensor with provided an excellent time resolution. Brain has many areas that give a different result when measure using an EEG Sensor at someone. In this project EEG Sensor function is to measure of brain electrical activity, especially to detect early state of drowsy for a driver. The Mindlink Smart Headset Brainwave Sensor Head Band is a cost-effective and easily transportable device that serves as a Brain- Computer Interface Headset. It establishes a wireless link between the human brain and various devices like smartphones and tablets. Unlike conventional medical brainwave sensing devices that necessitate multiple wet electrodes, the Mindlink headset only requires a single dry, metal sensor placed on the user's forehead. Remarkably, it can reliably detect brainwave activity [27].

### 3.6.2 NodeMCU ESP8266

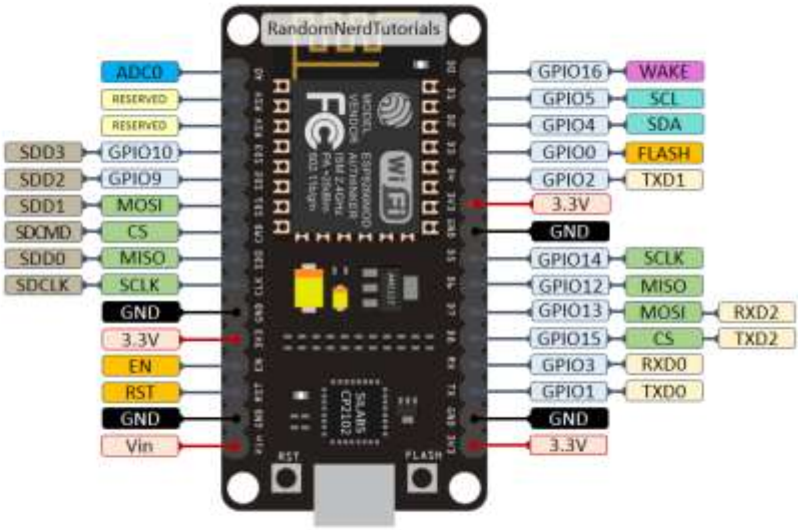


**Figure 3.6.2: Interface of NodeMCU ESP8266 pinout**

The NodeMCU is a cost-effective System-on-a-Chip (SoC) designed for open-source software and hardware development. It is centered around the ESP8266, a chip from Espressif Systems. The ESP8266 integrates essential computer components such as CPU, RAM, WiFi connectivity, and an up-to-date operating system with an SDK. This combination makes NodeMCU a versatile and ideal option for various Internet of Things (IoT) projects.

There are four power pins on the NodeMCU, which include the VIN pin and three 3.3V pins. The VIN pin serves to directly power the NodeMCU/ESP8266 and its associated peripherals. The power supplied to VIN undergoes regulation through the onboard regulator on the NodeMCU module. Additionally, it is possible to provide a regulated 5V input to the VIN pin. The three 3.3V pins function as outputs from the onboard voltage regulator and can be utilized to supply power to external components.

The NodeMCU ESP8266 features 17 GPIO pins that can be programmatically assigned to various functions like I2C, I2S, UART, PWM, IR Remote Control, LED Light, and Button operations. Each digitally-enabled GPIO is customizable, allowing configuration for internal pull-up or pull-down, or setting to high impedance. When designated as an input, these pins can be further configured for edge-trigger or level-trigger settings, enabling the generation of CPU interrupts. In this project, it is use to program a coding which contain Bluetooth from sensor, Wi-fi to send to the cloud, and display output to LCD, buzzer and LED.

### 3.6.3 Bluetooth Module HC-05

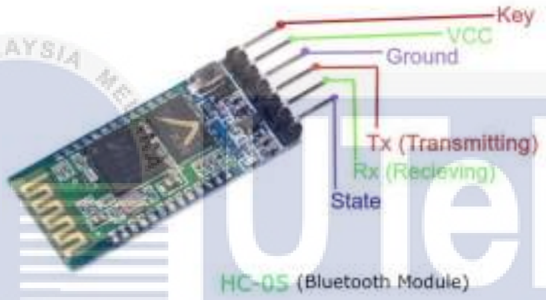


**Figure 3.6.2: Bluetooth Module HC-05[30]**



This component is like an Arduino, but it has a Bluetooth mode that can be connected to the device for collect the result. An alternative to wired connectors in electronics is the utilization of HC-05 for serial communication. This wireless communication method is commonly employed for exchanging files between small devices, such as mobile phones, through a short-range connection. The operation of HC-05 occurs within the 2.45GHz frequency range. There are two ways to use the HC-05 Bluetooth Module: in command mode and in data mode. In this project, this component will transmit signal data from sensor to the display serial monitor.

### 3.6.4 Breadboard Power Supply Module

**Figure 3.6.4: MB102 Breadboard Power Supply Module** [28]

The 3.3V/5V output MB102 Breadboard power supply module is an easy to use, most useful breadboard component that can be added with any breadboard related projects where 5V, 3.3V or both power requirements are required. Its ease of use allows users to connect any DC power supply unit that has 6.5-12 VDC power output from a barrel jack. The board has two independent channels of power output for breadboards. These power channels can be independently configured for 3.3V, 0V, and 5V operations. The module also offers a push switch to turn OFF and ON the entire power supply module. An additional feature is a USB input with two 5V, two 3.3V, and 4 GND pinout for additional power pin requirements. The power LED will notify the user of input power availability status [28].

### 3.6.5 Logic Level Converter

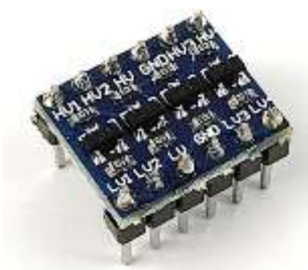

**Figure 3.6.5: Logic Level Converter 4-Ch Bi-Directional Module**[29]

The Logic Level Converter 4-Ch Bi-Directional Module facilitates the connection of 3.3V and 5V logic circuits. Primarily employed for linking 3.3V and 5V logic signals, it's versatile enough to accommodate various logic voltages, including 1.8V and 2.8V in newer devices. This module is also suitable for handling unique voltage requirements. With 4 bi-directional channels, it proves beneficial for bidirectional data buses like I2C, where data transmission occurs in both directions. Additionally, it can adapt to unidirectional signals such as TTL serial communications and standard logic signals. The design of the circuit cleverly integrates N-Channel MOSFET transistors and pull-up resistors to efficiently manage voltage translation [29].

### 3.6.6 LCD Display



**Figure 3.6.6: I2C interface 16x2 LCD display module**[30]

This is I2C interface 16x2 LCD display module, a high-quality 2-line 16-character LCD module with on-board contrast control adjustment, backlight and I2C communication interface. For Arduino beginners, no more cumbersome and complex LCD driver circuit connection. The real significance advantages of this I2C Serial LCD module will simplify the circuit connection, save some I/O pins on Arduino board, simplified firmware development with widely available Arduino library [30]. In this project, it is use to display a warning message for drowsy driver.

### 3.6.7 Buzzer

**Figure 3.6.7: Piezo Buzzer**

Producing a minimum sound level of 90dB, this buzzer emits a slow pulse tone, making it well-suited for applications requiring a warning signal. With a rated voltage of 12VDC, it operates within a range of 3 to 28VDC. Connected through 140mm leads, it doesn't necessitate external circuitry for sound production, as it comes equipped with its own internal circuit and only requires a DC voltage [31]. In this project, it is use to trigger a drowsy driver from fall asleep.

### 3.6.8 LED

**Figure 3.6.8: Red LED indicator**

An LED, or Light Emitting Diode, is a semiconductor device that produces light when an electric current flows through it. LEDs find common applications in lighting, such as indicators, displays, and general illumination. Renowned for their energy efficiency, extended lifespan, and compact design, LEDs are available in various colors. Their versatility and energy-saving characteristics have led to widespread use in electronic devices, lighting fixtures, automotive lighting, and various other applications. In this project, it use to be an indicator of drowsy state for driver.

**CHAPTER 4**

# RESULTS AND DISCUSSIONS

This chapter provides a detailed explanation of the data analysis and experimental findings conducted throughout the project. It encompasses a thorough discussion and conclusion on all data obtained during the analysis. Subsequently, the accumulated data will be visually represented through graphs and presented in tabular form within this chapter.

## 4.1 Hardware Result

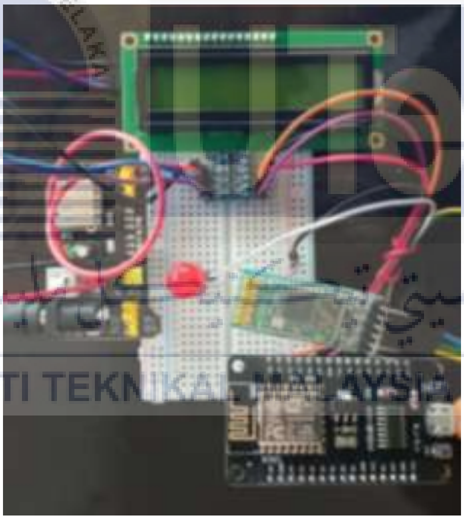

**Figure 4.1.1: Project Circuit Wiring**


**Figure 4.1.2: Project prototype**

The user is now able to put on the headset, ensuring proper placement of the metal nodes directly on the forehead for obtaining precise sensor data, as shown in Figure 4.1.3.



**Figure 4.1.3: Mindlink EEG Headset by ensure the metall nodes is direct contact with the forehead.**


**Figure 4.1.3: Mindlink EEG Raw Data was send**

The output value sequence in serial monitor is for attention, meditation, delta, theta, low alpha, quality, attention calculate and blink. For this project will only focus on value theta, attention and meditation.


**Figure 4.1.4: LCD display warning, LED turn on and buzzer is on**

**Table 4.1: Result after 10 times reach the value needed to detect drowsy**

| Theta | Attention | Meditation | LCD display | Buzzer, LED |
|---|---|---|---|---|
| 36290 | 13 | 51 | No alert | OFF |
| 22687 | 50 | 69 | No alert | OFF |
| 40986 | 64 | 64 | No alert | OFF |
| 60708 | 1 | 66 | Alert | ON |

## 4.2 Analysis for Brainwave pattern

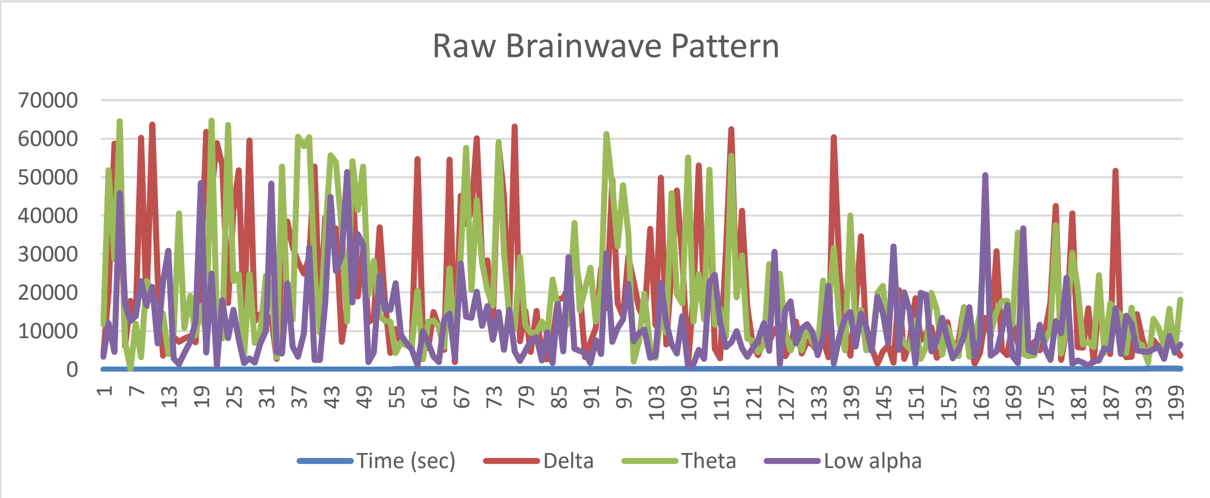


**Figure 4.2: Signal Waves changing with time**

In this project, an analysis has been conducted on a subject who was directed to perform specific activities. The individual was instructed to engage in activities such as reading, opening their eyes and relaxing, yawning and relaxing, as well as closing their eyes and remaining calm. The purpose of these activities was to analyze movement patterns in three types of brain waves: delta, theta, and alpha waves. Additionally, focus and meditation were also considered in this analysis. The assessment aims to identify levels of alertness and fatigue for vehicle drivers.

### 4.2.1 Delta Wave Analysis

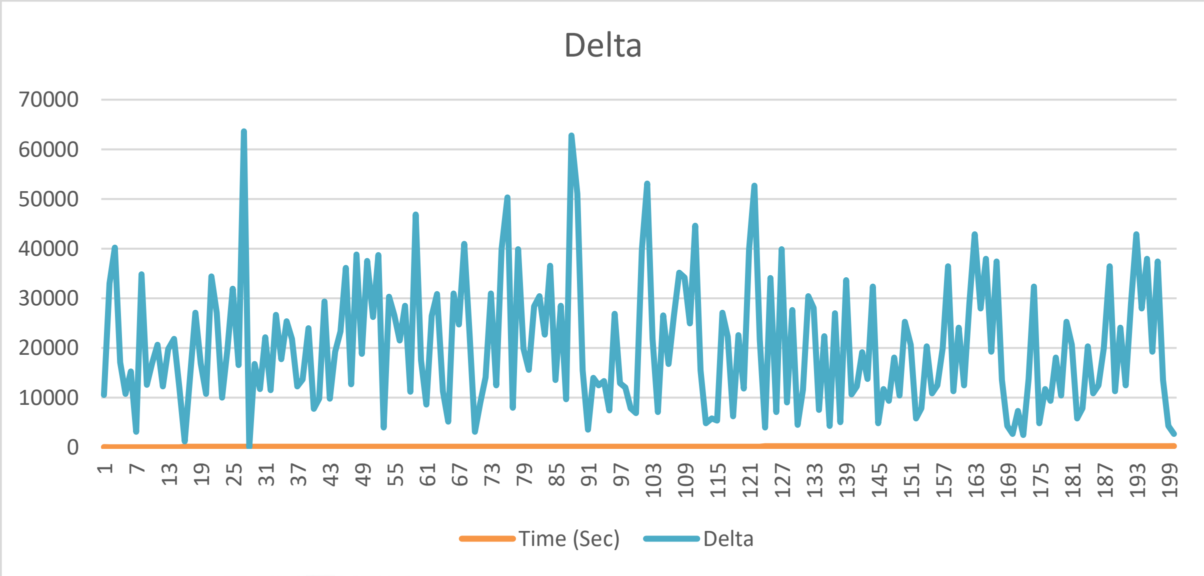


**Figure 4.2.1.1: Delta Wave during reading**

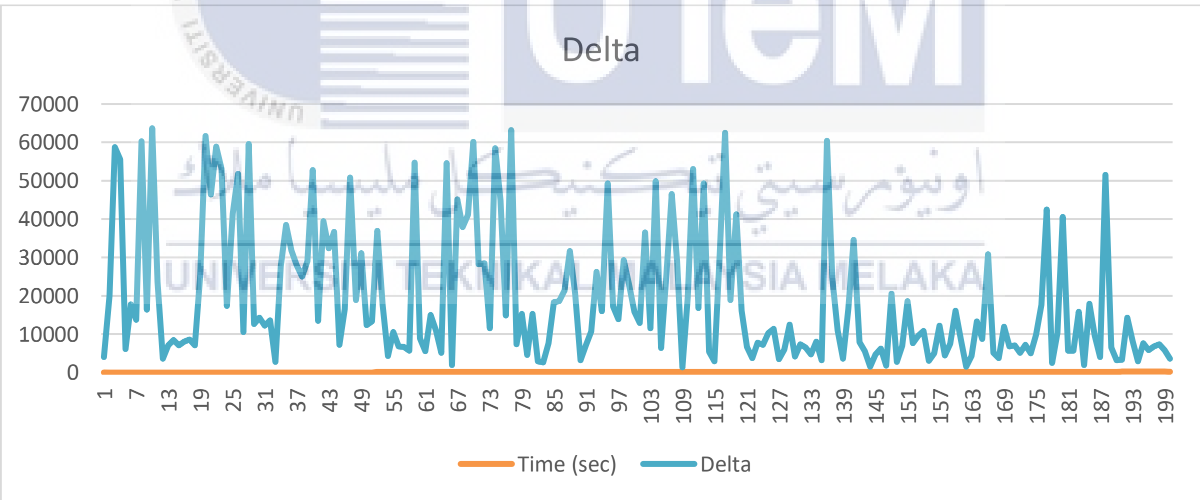


**Figure 4.2.1.2: Delta Wave during relax and open eyes**

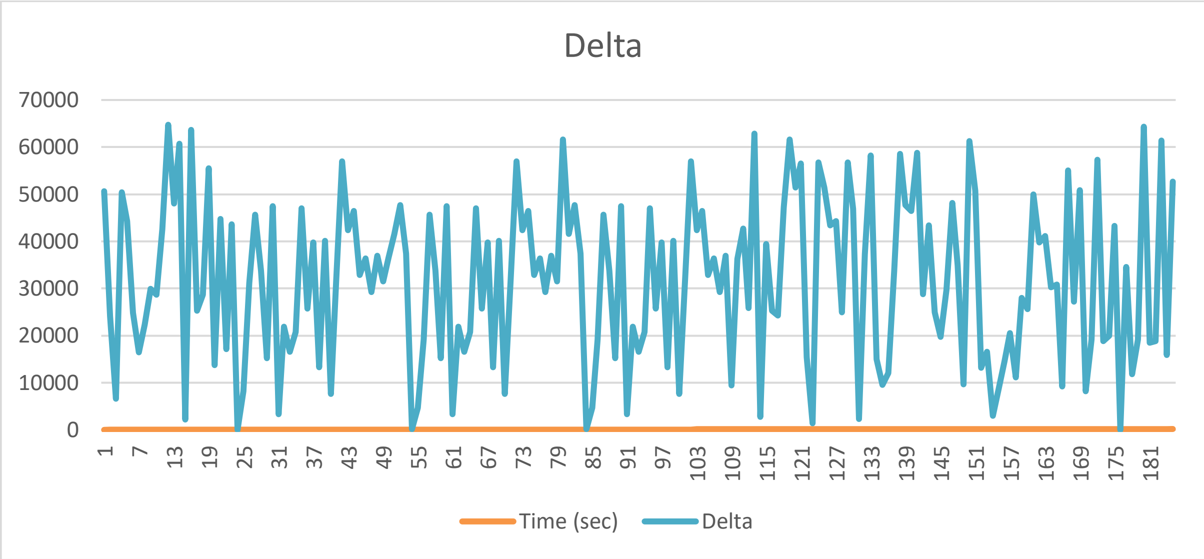


**Figure 4.2.1.3: Delta Wave during relax and yawn**

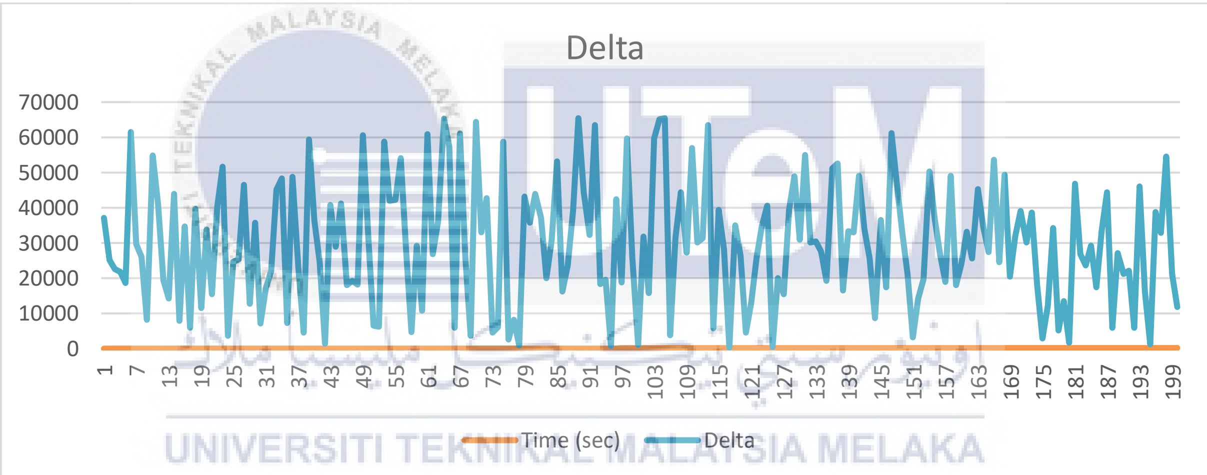


**Figure 4.2.1.4: Delta Wave during relax and close eyes**

Delta waves are present during deep sleep and certain abnormal processes, characterized by their slowest and highest amplitude. Peak performers typically reduce Delta wave activity when aiming for intense focus and optimal performance. In contrast, individuals with **a**ttention deficit disorder often experience an increase in Delta activity when attempting to concentrate, contrary to the usual pattern. From the analysis above, delta wave is slower during reading activity and become active during relax and close eyes.

### 4.2.2 Theta Wave Analysis

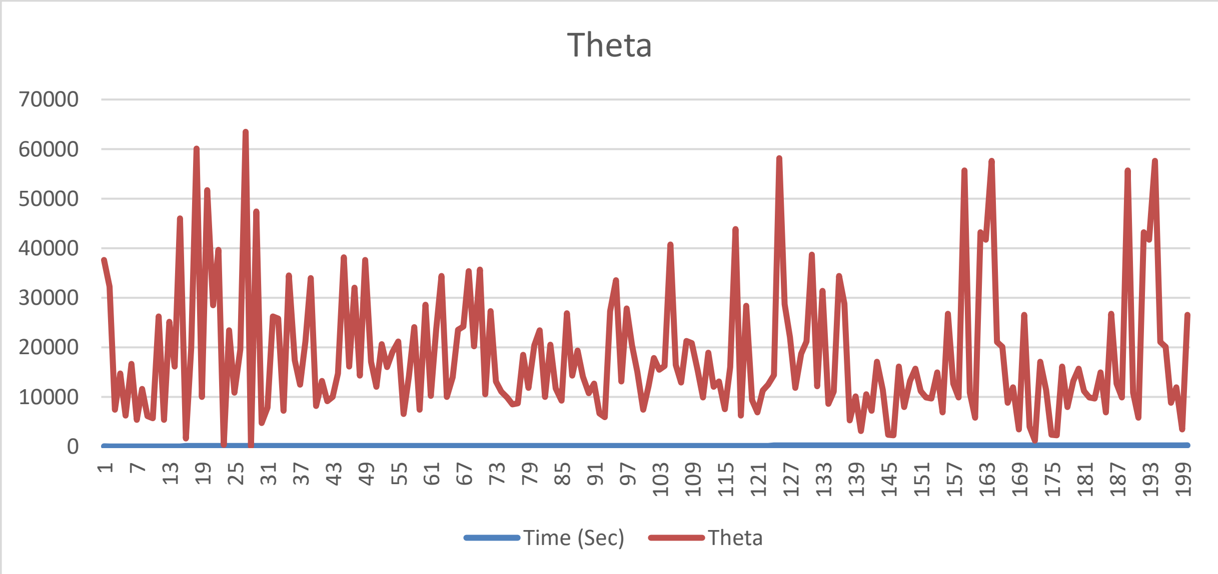


**Figure 4.2.2.1: Theta Wave during reading**

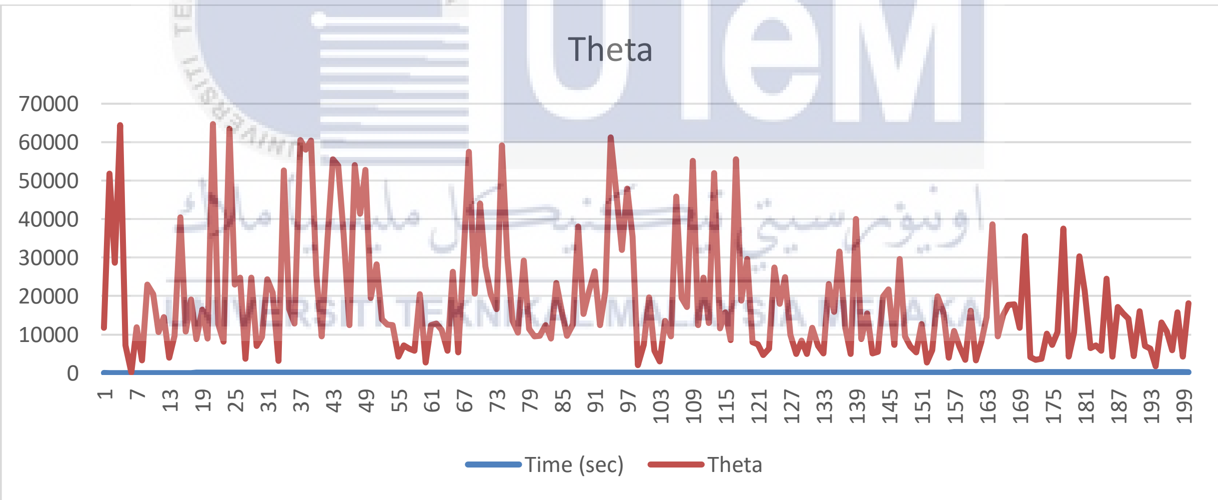


**Figure 4.2.2.2: Theta Wave during relax and open eyes**

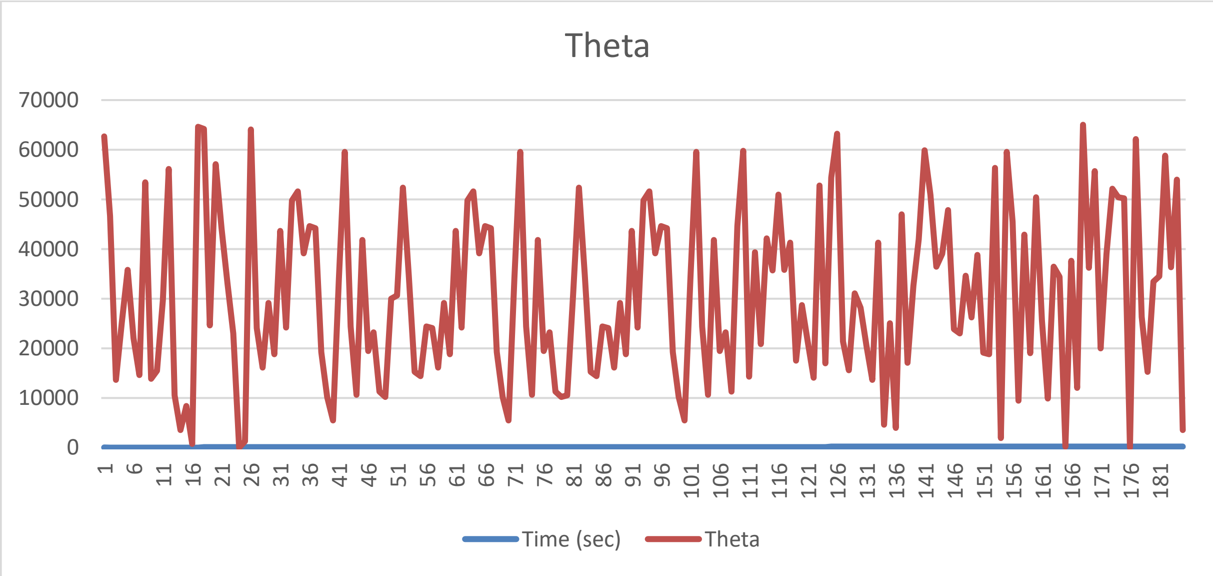


**Figure 4.2.2.3: Theta Wave during relax and yawn**

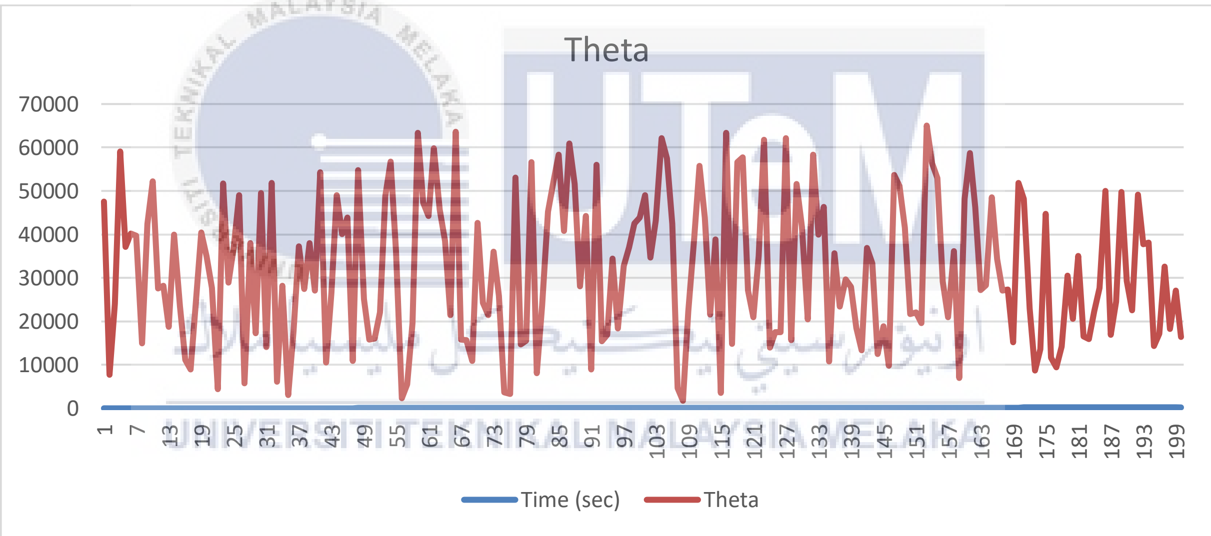




**Figure 4.2.2.4: Theta Wave during relax and close eyes**

Theta activity is categorized as a form of "slow" brain activity. Theta waves become prominent during internal focus, meditation, prayer, and spiritual awareness. This state reflects the transitional phase between wakefulness and sleep and is linked to the subconscious mind. The states of subjective feelings include intuition, creativity, recall, fantasy, imagery, creativity, dreaminess, changing thoughts, and drowsiness. From the graph analysis, theta active during relax and yawn. The average value for theta during relaxed and yawn is 30676.81.

### 4.2.3 Low Alpha Wave Analysis

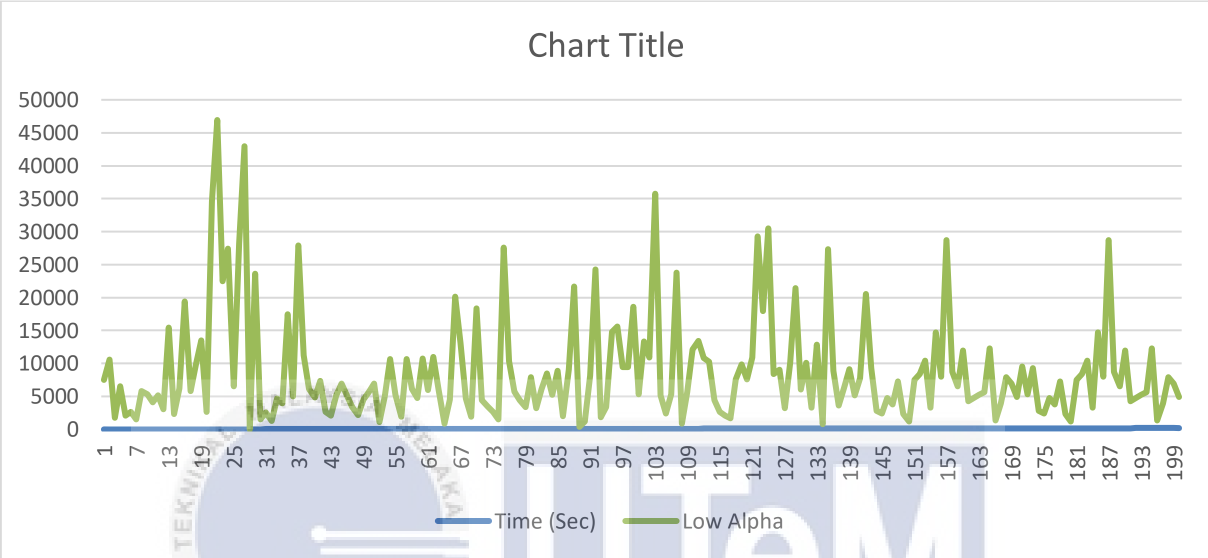


**Figure 4.2.3.1: Low Alpha Wave during reading**

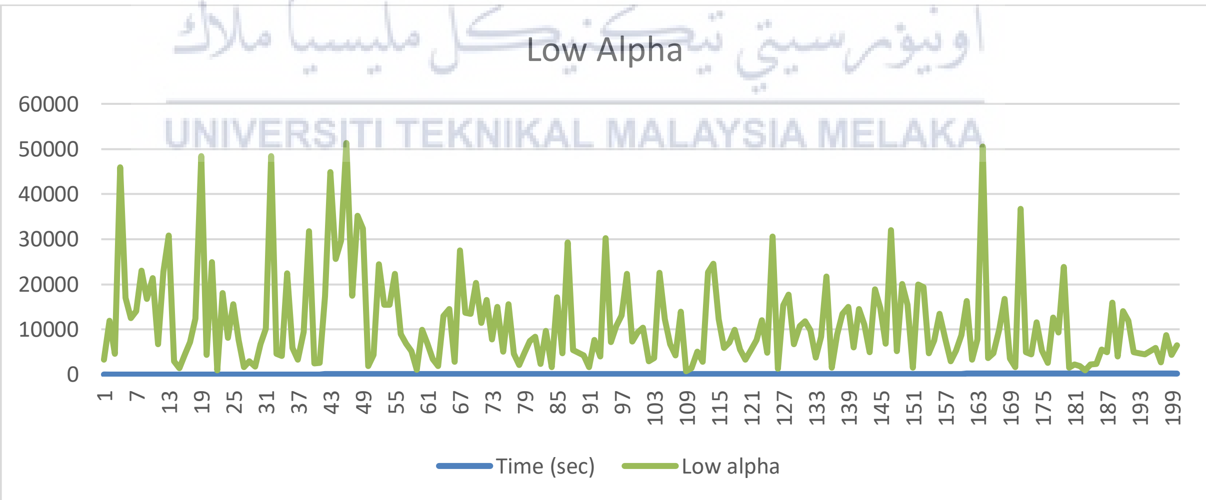


**Figure 4.2.3.2: Low Alpha Wave during relax and open eyes**

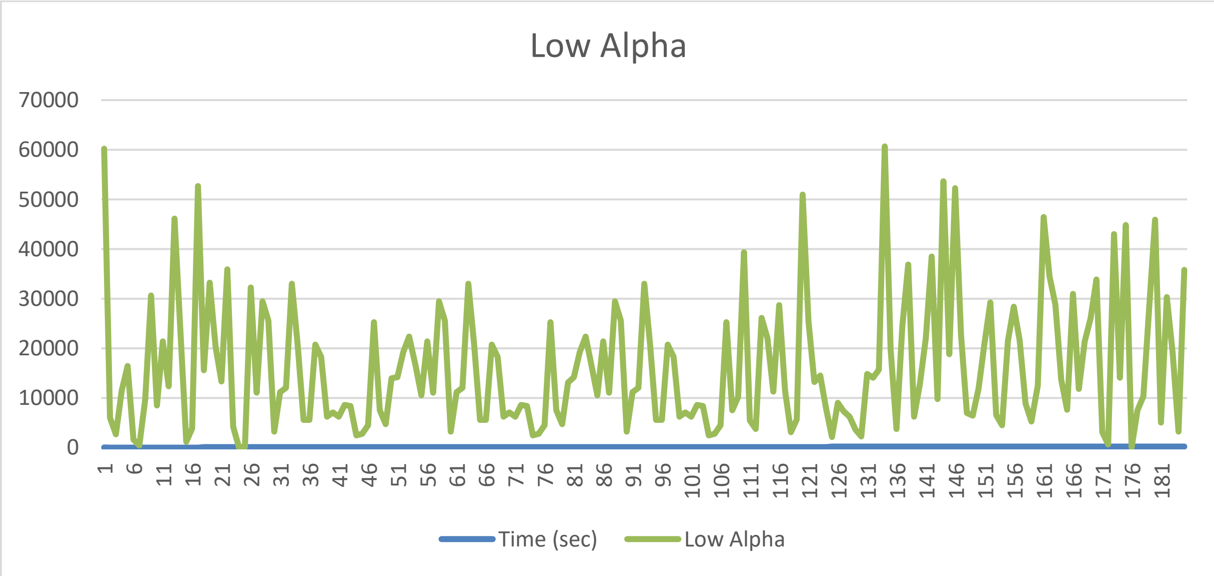


**Figure 4.2.3.3: Low Alpha during relax and yawn**

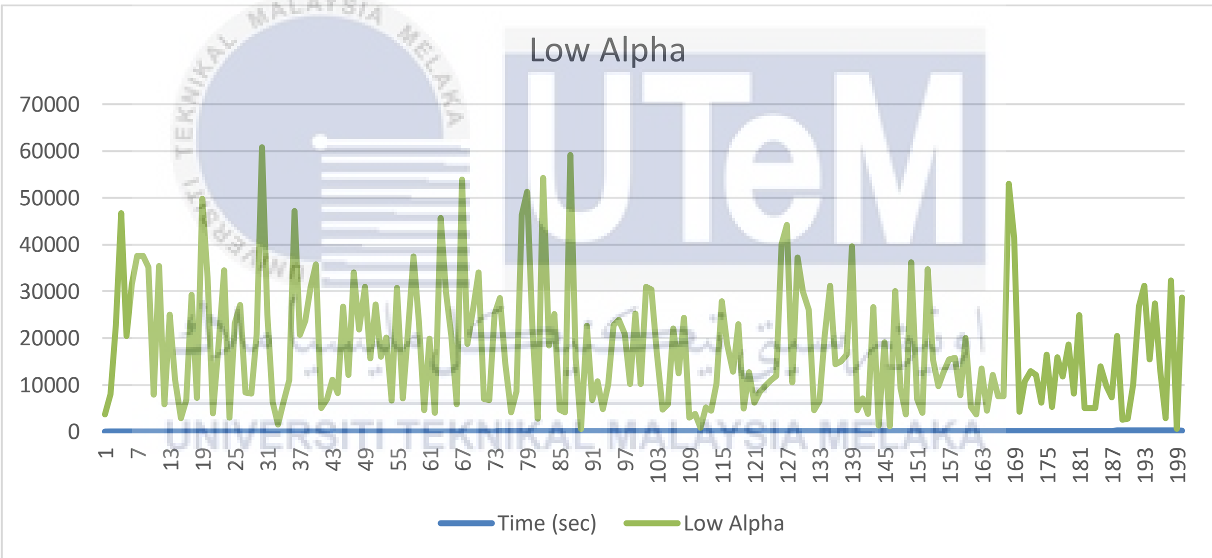


**Figure 4.2.3.4: Low Alpha during relax and close eyes**

Alpha waves occur when experience in a state of calm and relaxation, like during meditation or a serene stroll in nature. They contribute to a feeling of inner peace and are thought to boost creativity and concentration. The subjective states of feeling include being at ease, not agitated, in a state of alert tranquility, and consciously aware, without drowsiness. From the graph analysis above, alpha is the lowest during relaxed and open eyes.

### 4.2.4 Analysis for Attention

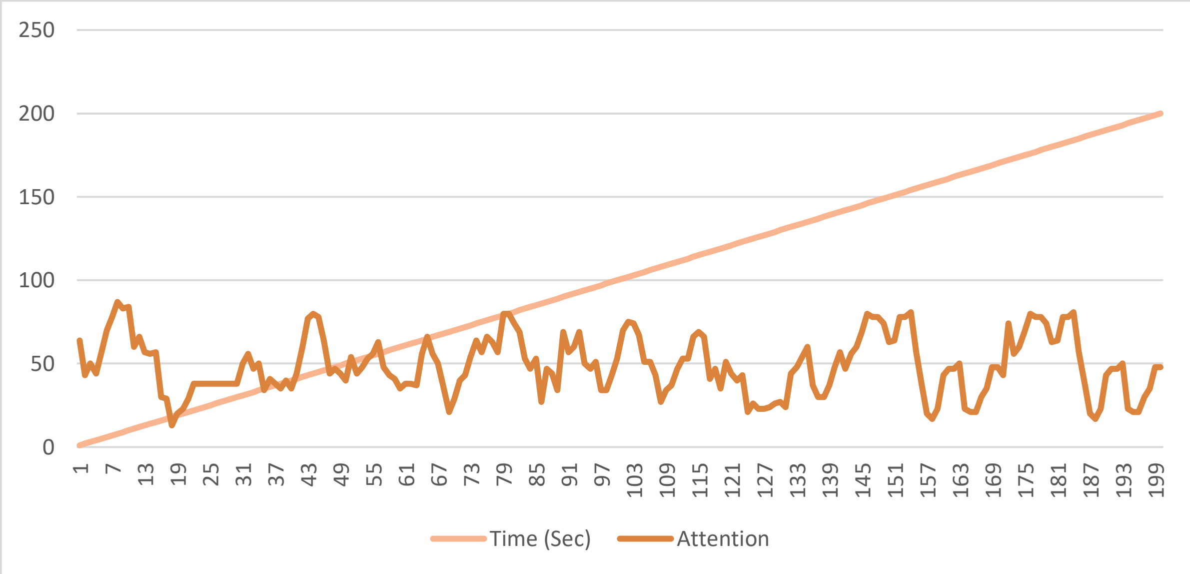


**Figure 4.2.4.1: Attention during reading**

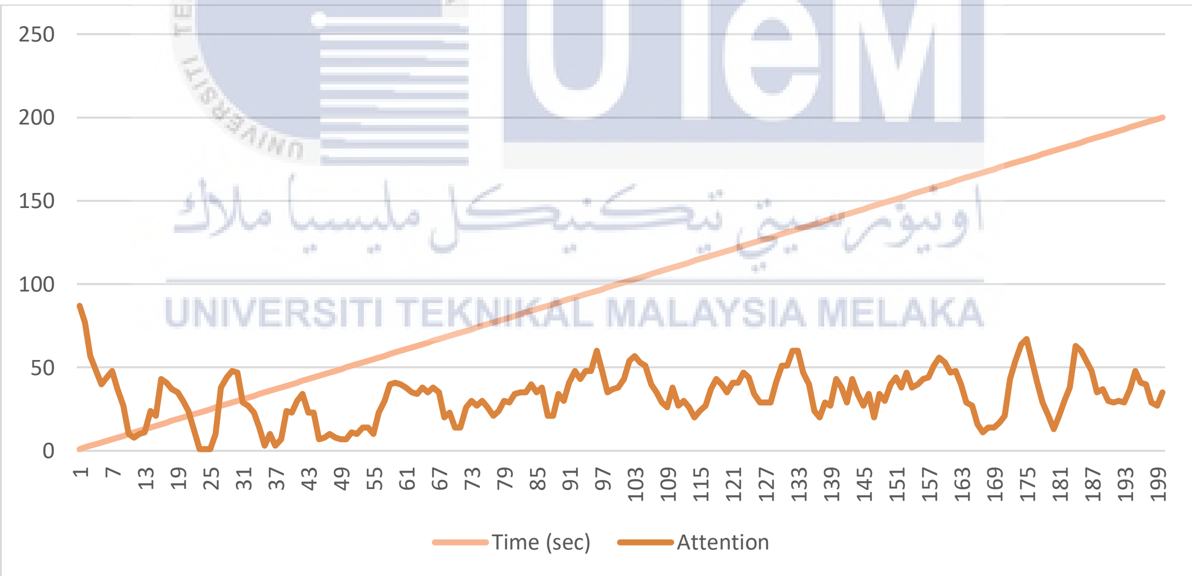




**Figure 4.2.4.2: Attention during relax and open eyes**

From the analysis, the value of attention during relaxed and open eyes is lower than the value during reading. Most of the value is below 50. The average value of attention is 33.94. In this project, the value of attention used to detect drowsy driver is when it reached below 35.

### 4.2.5 Analysis for Medication

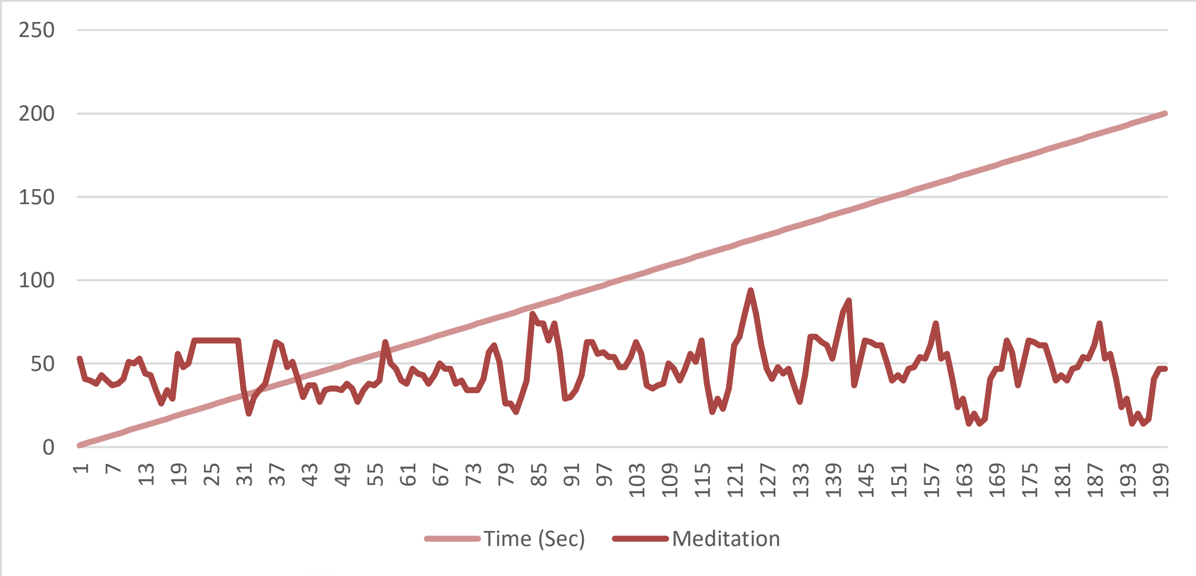


**Figure 4.2.5.1: Meditation during reading**

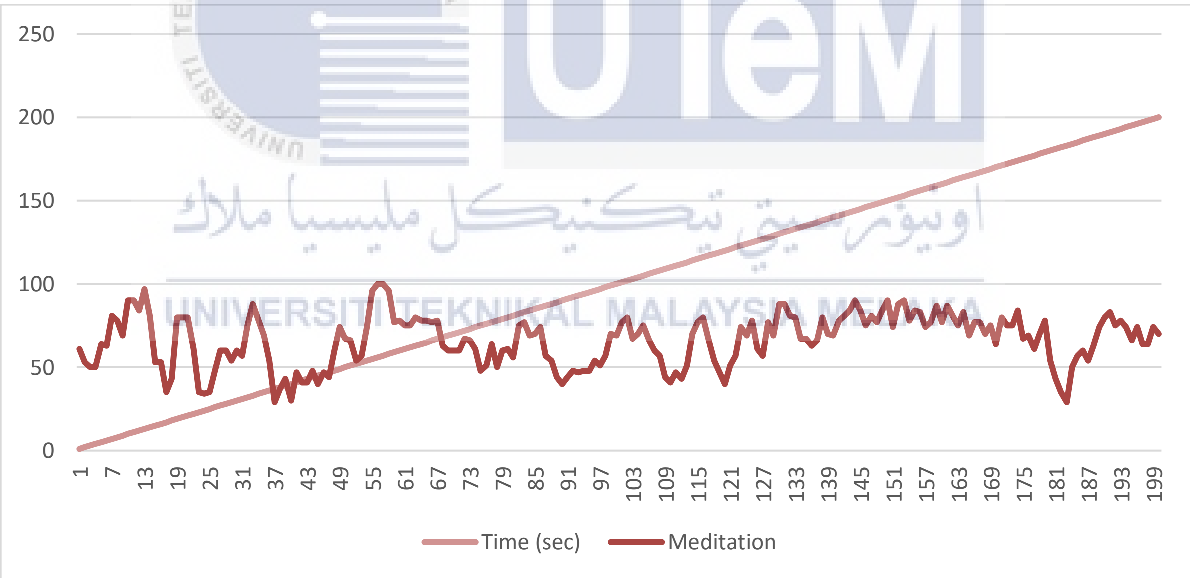


**Figure 4.2.5.2: Meditation during relax and open eyes**

From the analysis, value of meditation during relaxed and opened eyes is higher than the value during reading. It is reached 100 which is the maximum value of meditation. The average value of meditation during relaxed and open eyes is 66. In this project, the meditation value used to detect a drowsy driver is when the value is reach above 65.

### 4.2.6 Analysis Data on ThingSpeak

Thingspeak is an IoT platform that can store data and analyze it in real-time. Below is a graph analysis for theta, attention, and meditation during a person in sleep. The time taken for a person being experimented is 25 minutes. The time for data to reach Thingspeak is not synchronized with what is displayed in the serial monitor. This is due to the fact that Free ThingSpeak user accounts are subject to a 15-second rate limit, whereas paid options, such as commercial accounts is 1-second rate limit.

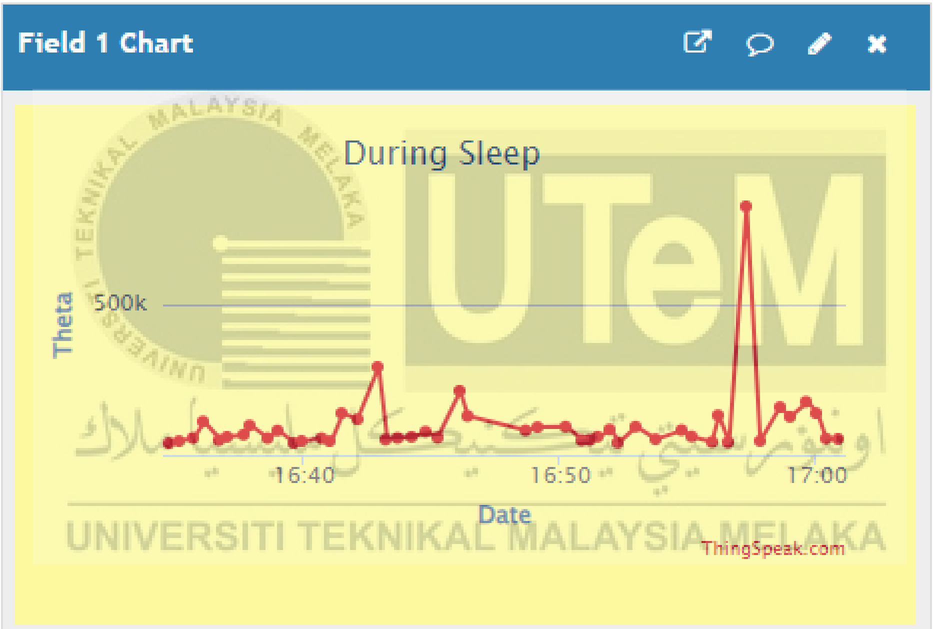


**Figure 4.2.6.1: Theta graph during person in sleep**

From the graph above, the theta values on Thingspeak are significantly higher compared to the theta values on the serial monitor. Ideally, theta values should be below 65000. Based on the analysis, the graph displayed on Thingspeak cannot be considered for analyzing an individual's drowsiness level.

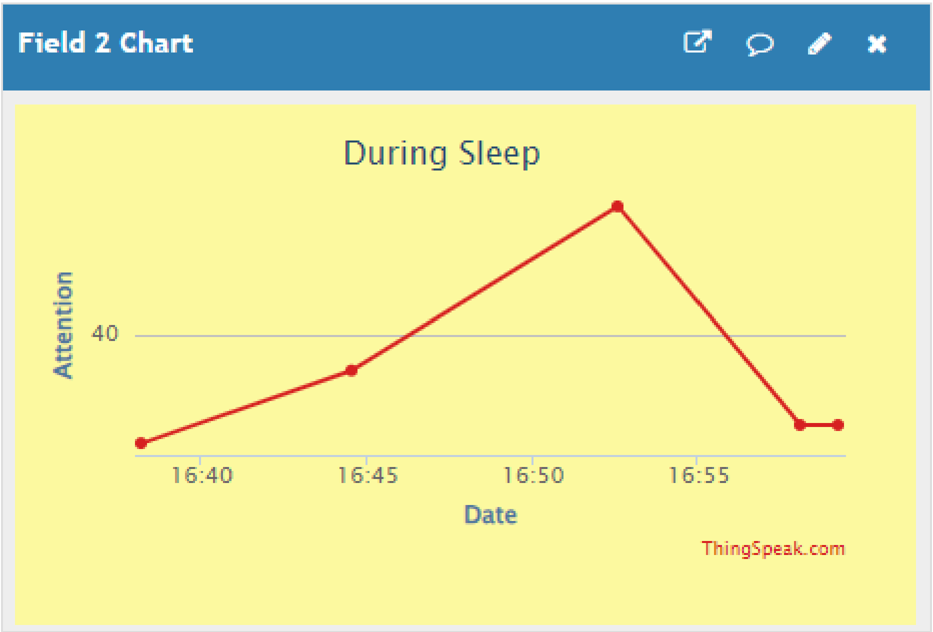


**Figure 4.2.6.2: Attention graph during a person in sleep**

Based on the graph above, the lowest attention value displayed on Thingspeak is approximately 10. From the attention analysis on Thingspeak, it can be considered for analyzing an individual's drowsiness level.



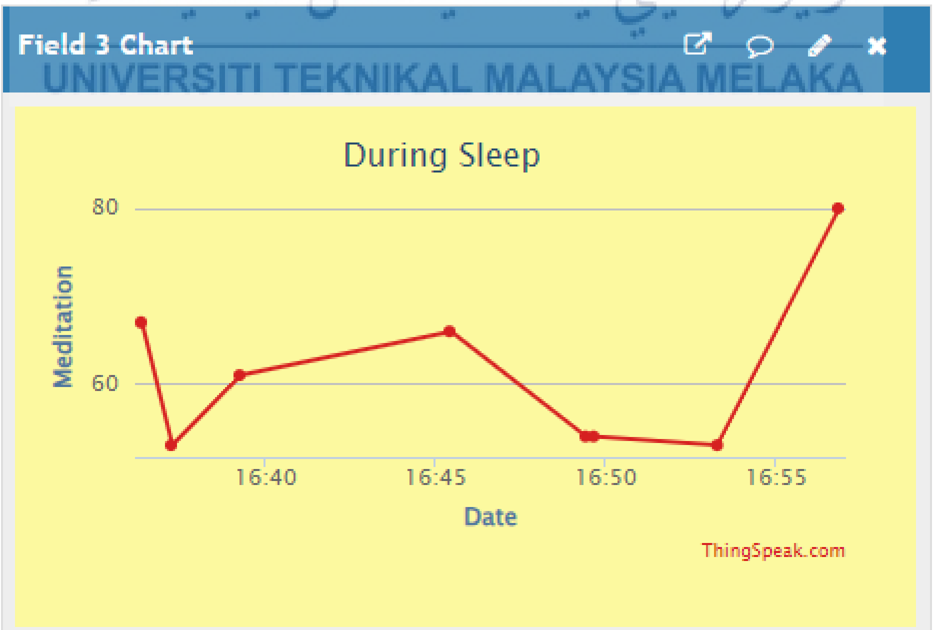


**Figure 4.2.6.3: Meditation graph during a person in sleep**

Based on the graph above, the highest meditation value displayed on Thingspeak is 80. From the meditation analysis on Thingspeak, it can be considered for analyzing an individual's drowsiness level.

# CHAPTER 5

# CONCLUSION AND RECOMMENDATIONS

In conclusion, the project successfully fulfills its objectives by analyzing EEG signal for early detection of driver drowsiness, implementing an alert system based on theta, attention and meditation values, and transmitting brainwave data to the cloud-based storage. The outcomes underscore the potential for real-time monitoring and detection of drowsiness in drivers, contributing to enhanced road safety.

The analysis of EEG signals, particularly theta waves, offers valuable insights into the initial indications of driver drowsiness. Additionally, delta waves exhibit slower activity during reading and become more active during relaxation and closed eyes. In this project, theta value to detect drowsy driver have been selected which is above 30000.



For the implementation of an alert system targeting drowsy drivers, attention values below 34 are employed to identify a drowsy state. The average attention value during relaxation and open eyes is 33.94. Furthermore, meditation values exceeding 65 are considered indicative of drowsiness, with an average value of 66 observed during relaxation and open eyes.

In the context of transmitting brainwave data to the cloud, Thingspeak, an IoT platform, is harnessed for both storage and real-time analysis of brainwave data. However, a synchronization issue between Thingspeak and the serial monitor is identified, attributed to rate limits.

**Recommendation**

For future work and improvements in the project, consider the following:

1. Advanced Signal Processing Techniques - Explore advanced signal processing techniques beyond basic filtering. Techniques such as wavelet analysis or machine learning algorithms can enhance the accuracy of drowsiness detection.
2. Real-time Data Analysis - Implement real-time data analysis capabilities to enable immediate responses to changes in driver alertness. This could involve optimizing algorithms or employing edge computing to process data onboard.
3. Machine Learning Integration - Integrate machine learning algorithms for predictive analysis based on historical data. This can enhance the system's ability to adapt and provide more personalized alerts to drivers.
4. User-Friendly Interface - Improve the user interface for easy configuration and monitoring. A user-friendly dashboard or mobile app can enhance the accessibility of the system.
5. Validation Studies - Conduct extensive validation studies with a diverse group of drivers to ensure the system's effectiveness across various demographics, driving conditions, and cultural factors.
6. User Feedback Integration - Establish a mechanism for collecting and analyzing user feedback. This can help identify areas for improvement and address any user-specific issues or preferences

By incorporating these suggestions, the project can evolve into a more sophisticated and user-friendly system for real-time drowsiness detection, contributing to enhanced road safety.

**Potential for Commercialization**

The project's commercial potential lies in creating an advanced system for real-time monitoring of driver alertness and detecting drowsiness. Possible avenues for commercialization include integrating the system with existing automotive safety features, developing standalone devices for vehicles, and collaborating with car manufacturers or automotive safety companies. Offering the technology as part of fleet management solutions could reduce the risk of accidents and enhance overall road safety for companies with large vehicle fleets.

Transforming the technology into wearable devices, such as smart headbands or caps for drivers, may attract interest from individuals and organizations focused on personal safety and well-being. Exploring partnerships with logistics and transportation companies to integrate the system into their operations can ensure the safety of drivers engaged in long-haul journeys. Collaborating with insurance companies to integrate the system as a safety feature might lead to reduced insurance premiums for individuals or companies implementing the technology. Exploring partnerships with smart city initiatives for the integration of the technology into smart infrastructure allows for a comprehensive approach to road safety.

Providing the technology as a service for research institutions or companies involved in studying and improving driver behavior and safety can be a valuable avenue for commercialization. Developing customized solutions for specialized vehicles, such as public transportation or emergency services, where driver alertness is crucial, is another potential market.

Partnering with companies in the health and wellness industry to promote the technology as a tool for general well-being and stress management can open new avenues for commercialization. Exploring international expansion opportunities, considering variations in road safety regulations and cultural acceptance, can broaden the project's reach.

To ensure successful commercialization, it is vital to conduct thorough market research, identify target industries, establish strategic partnerships, and ensure compliance with safety and privacy regulations. Continuous improvement and updates based on user feedback and technological advancements will be essential for long-term success.

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# APPENDICES

This is the coding for the overall system. Coding is upload to the NodeMCU ESP8266 as a microcontroller

```
#include <ESP8266WiFi.h>
#include <WiFiClient.h>
#include <ThingSpeak.h>
#include <LiquidCrystal_I2C.h>
LiquidCrystal_I2C lcd (0x27, 16, 2);
const int piezoPin = D6;
const int ledPin = D5;
int count = 0;

const char* ssid = "Moon"; //Your Network SSID
const char* password = "79911210"; //Your Network Password


WiFiClient client;

unsigned long myChannelNumber = 2401838; //Your Channel Number (Without
Brackets)
const char * myWriteAPIKey = "R7YBEZI5H3OGESAO"; //Your Write API Key
const int Field_number1 = 1;
const int Field_number2 = 2;
const int Field_number3 = 3;

// checksum variables
byte payloadChecksum = 0;
byte CalculatedChecksum;
byte checksum = 0;              //data type byte stores an 8-bit unsigned
number, from 0 to 255
int payloadLength = 0;
byte payloadData[64] = {0};
//byte poorQuality = 0;
byte attention = 0;
byte meditation = 0;
//byte quality_C = 0; //ni tambah Sept 2021
//byte kira_attention = 0; //kira berapa kali attention
//byte blinks = 0; //kira berapa kali blinks

// system variables
long lastReceivedPacket = 0;
boolean bigPacket = false;
boolean brainwave = false;
```

```
void setup()
{
Serial.begin(57600);
// Connect to WiFi network
WiFi.begin(ssid, password);
ThingSpeak.begin(client);

Serial.begin(57600);       // Bluetooth
pinMode(ledPin, OUTPUT);
pinMode(piezoPin, OUTPUT);
lcd.init();
lcd.backlight();
lcd.clear();
delay(500);
int count = 0;
}

byte ReadOneByte() {
   int ByteRead;
  // Wait until there is data
  while(!Serial.available());
  //Get the number of bytes (characters) available for reading from the
serial port.
  //This is data that's already arrived and stored in the serial receive
buffer (which holds 64 bytes)
  ByteRead = Serial.read();

  return ByteRead; // read incoming serial data
  }

unsigned int delta_wave = 0;
unsigned int theta_wave = 0;
unsigned int low_alpha_wave = 0;
unsigned int high_alpha_wave = 0;
unsigned int low_beta_wave = 0;
unsigned int high_beta_wave = 0;
unsigned int low_gamma_wave = 0;
unsigned int mid_gamma_wave = 0;

void read_waves(int i) {
  delta_wave = read_3byte_int(i);
  i+=3;
  theta_wave = read_3byte_int(i);
  i+=3;
  low_alpha_wave = read_3byte_int(i);
  i+=3;
  high_alpha_wave = read_3byte_int(i);
  i+=3;
```

```
  low_beta_wave = read_3byte_int(i);
  i+=3;
  high_beta_wave = read_3byte_int(i);
  i+=3;
  low_gamma_wave = read_3byte_int(i);
  i+=3;
  mid_gamma_wave = read_3byte_int(i);
}

int read_3byte_int(int i) {
  return ((payloadData[i] << 16) + (payloadData[i+1] << 8) + 
payloadData[i+2]);
}

void loop()
{
if(ReadOneByte() == 0xAA) {
if(ReadOneByte() == 0xAA) {
payloadLength = ReadOneByte();
if(payloadLength > 169) //Payload length can not be greater than 169
return;
payloadChecksum = 0;
      for(int i = 0; i < payloadLength; i++) {      //loop until payload 
length is complete
        payloadData[i] = ReadOneByte();             //Read payload
        payloadChecksum += payloadData[i];
      }
      checksum = ReadOneByte();                     //Read checksum byte 
from stream
      payloadChecksum = 255 - payloadChecksum;      //Take ones compliment 
of generated checksum
      if(checksum == payloadChecksum) {
        //poorQuality = 200;
        attention = 0;
        meditation = 0;
 }
     brainwave = false;
     for(int i = 0; i < payloadLength; i++) { // Parse the payload
          switch (payloadData[i]) {
          //case 02:
            //i++;
            //poorQuality = payloadData[i];
            //bigPacket = true;
            //break;
          case 04:
            i++;
            attention = payloadData[i];
            break;
```

```
          case 05:
            i++;
            meditation = payloadData[i];
            break;
          case 0x80:
            i = i + 3;
            break;
          case 0x83:                          // ASIC EEG POWER INT
            i++;
            brainwave = true;
            byte vlen = payloadData[i];
           // Serial.print(vlen, DEC);
          ///  Serial.println();
            read_waves(i+1);
            i += vlen; // i = i + vlen
            break;
          }                                  // switch
        }                                    // for loop

        //if(bigPacket) {
          //if(poorQuality == 0){
          //}
          //else{                              // do nothing
           //}
         //}

        //quality_C = (100-(poorQuality/2)); //kalau kurang dari 100 user
blinks mata

            if(brainwave && attention > 0 && attention < 100) {
            Serial.print(attention, DEC);
        Serial.print("  ");
           Serial.print(meditation, DEC);
        Serial.print("  ");
            //Serial.print(delta_wave, DEC);
        //Serial.print(",");
            Serial.print(theta_wave, DEC);
        Serial.print("  \n");
           // Serial.print(low_alpha_wave, DEC);
        //Serial.print(",");
           // Serial.print(quality_C, DEC);
        //Serial.print(",");
          //  Serial.print(kira_attention, DEC);
        //Serial.print(",");
          //  Serial.print(blinks, DEC);
        //Serial.println();

        if(theta_wave > 30000 && attention < 35 && meditation > 65)
```

```
        {
          count = count+1;
          if(count == 5)
          {
            digitalWrite(ledPin,HIGH);
            lcd.setCursor(5,0);
            lcd.print("Alert!!!");
            lcd.setCursor(3,1);
            lcd.print("Please rest");
            for(int i = 1; i<=10; i++)
            {
              lcd.display();
              tone(piezoPin, 1000);
              digitalWrite(ledPin, HIGH);
              delay(1000);
              lcd.noDisplay();
              noTone(piezoPin);
              digitalWrite(ledPin, LOW);
              delay(1000);
            }
            count = 0;
          }
        ThingSpeak.writeField(myChannelNumber, Field_number1, (long)
theta_wave, myWriteAPIKey); //Update in ThingSpeak
        ThingSpeak.writeField(myChannelNumber, Field_number2, attention,
myWriteAPIKey); //Update in ThingSpeak
        ThingSpeak.writeField(myChannelNumber, Field_number3, meditation,
myWriteAPIKey); //Update in ThingSpeak
        delay(500);

        }
}
}
}
}
```