TRIBHUVAN UNIVERSITY

INSTITUTE OF ENGINEERING

HIMALAYA COLLEGE OF ENGINEERING

A

Final Year Project Report

on

Brain Controlled Wheelchair

Submitted By

Rajan Gyawali

Ujjwal Raj Nepal

Kushal Timalsina

Bakhat Dhakal

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Abstract

Brain Controlled Wheelchair, an application of **Brain Computer Interface (BCI)** uses NeuroSky Mindwave for signal acquisition from the brain. BCI allows direct communication between a computer and brain bypassing the body's normal neuromuscular pathway. The wheel chair is aimed for the physically impaired people. Brain Controlled Wheelchair directly measures brain activity associated with the user's intent and translates the recorded brain activity into corresponding control signals for certain applications. The signals recorded by the system are processed and classified to recognize the intent of the user.

Independent mobility is core to being able to perform activities of daily living by oneself. Millions of people around the world suffer from mobility impairments and hundreds of thousands of them rely upon powered wheelchairs to get on with their activities of daily living. However, patients are unable to control the powered wheel chairs using a conventional interface. Hence, a non–invasive brain computer interface (BCI) offer a promising solution to this interaction problem.

Keywords: *Brain Computer Interface, non-invasive, disabled, wheelchair*

List of abbreviations

BCI: Brain Computer Interface

BMI: Brain Mind Interface

DNI: Direct Neural Interface

EEG: Electroencephalogram

ERD: Event Related De-synchronization

ERP: Event Related Potential

ERS: Event Related Synchronization

FES: Functional Electrical Simulation

FFT: Fast Fourier Transform

FSM: Finite State Machine

GPIO: General Purpose Input Output

MAIA: Mental Augmentation through Determination of Intended Action

MMI: Mind Machine Interface

RF: Radio Frequency

SoC: System on Chip

SSVEP: Steady State Visual Evoked Potential

VEP: Visual Evoked Potential

1.0 Introduction

1.1 Background

Millions of people around the world suffer from mobility impairments and hundreds of thousands of them rely upon powered wheelchairs to get on with their activities of daily living. However, many patients are not prescribed powered wheelchairs at all, either because they are physically unable to control the chair using a conventional interface, or because they are deemed incapable of driving safely. Consequently, it has been estimated that between 1.4 and 2.1 million wheelchair users might benefit from a smart powered wheelchair, if it were able to provide a degree of additional assistance to the driver.

In our work with brain–actuated wheelchairs, we target a population who are or will become unable to use conventional interfaces, due to severe motor disabilities. Non-invasive BCIs offer a promising new interaction modality that does not rely upon a fully functional peripheral nervous system to mechanically interact with the world and instead uses the brain activity directly.

1.2 Introduction to our project

A brain computer interface (BCI), sometimes called a mind machine interface (MMI), direct neural interface (DNI), or brain machine interface (BMI), is a direct communication pathway between the brain and an external device. BCIs are often directed at assisting, augmenting, or repairing human cognitive or sensory-motor functions. The "**Brain Controlled Wheelchair**" project is designed and developed to implement a modern technology of communication between human and machines which uses brain signals as control signals. It is specially designed for disabled people to help them and uplift their living condition. The desired output of the system is the control of devices using brain signals which is extracted with the help of electrode.

1.2.1 Non Invasive BCIs

Most non-invasive BCI systems use electroencephalogram (EEG) signals i.e., the electrical brain activity recorded from electrodes placed on the scalp. Non-invasive BCIs can be classified into 2 types, namely, **evoked BCI** and **spontaneous BCI**.

An evoked BCI exploits a strong characteristic of the EEG, the so-called evoked potential, which reflects the immediate automatic responses of the brain to some external stimuli.

Spontaneous BCIs are based on the analysis of EEG phenomena associated with various aspects of brain function related to mental tasks carried out by the subject at his/her own will.

1.2.2 Electroencephalography

Electroencephalography (EEG) is the recording of electrical activity along the scalp. EEG measures voltage fluctuations resulting from ionic current flows within the neurons of the brain. EEG is most often used to diagnose epilepsy, which causes obvious abnormalities in EEG readings. It is also used to diagnose sleep disorders, coma, encephalopathy, and brain death. EEG used to be a first-line method of diagnosis for tumors, stroke and other focal brain disorders.

1.3 Objectives

The project "**Brain Controlled Wheelchair**" is aimed to provide easy interfacing to the wheelchair for physically impaired handicapped people. The general objectives of the project are as follows:

- To study different Electroencephalogram (EEG) signals.
- To use Brain Computer Interface as principle control and communication mechanism.
- To control bionic system using brain by physically handicapped people.
- To develop friendly computer application for handicapped and disabled people.

1.4 Scope

The scope of this project is to study and design the brain controlled wheelchair and computer application where message can be selected using the blink of an eye. The computer application acts as a communication protocol between the fully disabled users (user who can only blink their eye) and other people. The project can be divided into two big parts. The first part, interfacing of the active electrode with the system (wheel chair) and computer application (blink talker). The active electrode senses the different signals from the brain, amplifies it and passes it to the USB dongle which is connected to the (controller) Raspberry pi.

The program related to the signal processing is loaded into the controller which determines the user concentration level indicated by different LEDs and the speed of wheel chair is varied with user concentration.

The second part, the “Blink Talker” is the computer application where the people can select messages with the blink of the eye and audio is given as output of the selected message.

2.0 Literature Review

Recently, research and development of BCI have received a great deal of attention because of their ability to bring back to people with devastating neuromuscular disorders and improve the quality of life and self- dependence of these users. It includes various applications such as a cursor on the screen, selecting letters from virtual keyboard, browsing internet and playing games. Based on the techniques used in BCI the literature review is classified as follows:

2.1 P300

The P300 wave is an event Related potential (ERP) component elicited in the process of decision making. It is considered to be an endogenous potential, as its occurrence links not to the physical attributes of a stimulus but to a person's reaction to it. The P300 is thought to reflect processes involved in stimulus evaluation or categorization. It is usually elicited using oddball paradigm, in which low probability target items are mixed with high probability target items. When recorded by electroencephalography, it surfaces as a positive deflection in voltage with latency of roughly 250 to 500 ms [1]. This setup has the advantage of requiring no training from the user and only a few minutes to train the P300 detecting system. This is noteworthy since most of the other BCI techniques require a very long training phase, up to several months in the case of slow cortical potential devices BCI mouse based on P300 waves in EEG signals [2]. The system presents two unique features: it completely dispenses with the problem of detecting P300s (a notoriously difficult task) by logically behaving as an analogue device (as opposed to a binary classifier), and it uses a single trial approach where the mouse performs an action after every trial (once per second). Visual stimuli consisting of 8 arrows randomly intensified are used for direction target selection for wheelchair steering. The classification is based on a Bayesian approach that uses prior statistical knowledge of target and non-target components. Recorded brain activity from several channels is combined with a Bayesian sensor fusion and then events are grouped to an improved event detection. The system has an adaptive performance that adapts to user and P300 pattern quality.

2.2 SSVEP

In neurology, Steady State Visually Evoked Potentials (SSVEP) are signals that are natural responses to visual stimulation at specific frequencies. When the retina is excited by a visual stimulus ranging from 3.5 Hz to 75 Hz [3], the brain generates electrical activity at the same time frequency of the visual stimulus. The technique is used widely, with the electroencephalographic research regarding vision. SSVEP's are useful in research because of the excellent signal to noise ratio and relative immunity to artifacts [4]. SSVEP's also provide means to characterize preferred frequencies of neocortical dynamic process. SSVEP is generated by stationary localized resources and distributed sources that exhibit characteristics of wave phenomena.

2.3. ERD/ERS

Brain activity recorded non-invasively is sufficient to control a mobile robot if advanced robotics is used in combination with asynchronous EEG analysis and machine learning techniques. Until now brain-actuated control has mainly relied on implanted electrodes, since EEG based systems have been considered too slow for controlling rapid and complex sequences of movements. We show that two human subjects successfully moved a robot between several rooms by mental control only, using an EEG based brain machine interface that recognized three mental states.

Several brain controlled wheel chairs have been developed in the course of time. Some of the previous wheelchairs based on BCI have been discussed below:

Tanaka et al.[5] in (2005) come with a discrete approach to the navigation problem: the environment is discretized in squares of 1m and the user is prompted where to move next. They use an EEG BCI based on motor imagery: by imagining left or right limb movements, thus activating the corresponding motor cortex, the user selects where to move next.

A similar principle was used in the sophisticated wheelchair system recently (2009) developed by Minguez et al. [6], where a virtual reconstruction of the surrounding environment (as inferred from laser range scanner data) is displayed with a set of points in the free space that can be selected using a P300 EEG BCI, and these short term goals are reached automatically. As with Tanaka, the system requires a large number of steps to reach a destination, which might exhaust the 25 subject. For instance, Minguez reports that it took 11 minutes and 9 decision steps to realize a 40 meters long path with this system.

In the MAIA (Mental Augmentation through Determination of Intended Action) project [7] (2007) the asynchronous IDIAP BCI has been integrated with the intelligent wheelchair Sharioto[8] of the KU Leuven. With the brain controlled wheelchair from the Ramu et al [9], the user continuously controls the velocity of the wheelchair by imagining left hand, right hand or both feet movements.

2.4 BCI System of Mostafa

In this project a mind controlled ROBOT was built as a prototype. This project used the NeuroSky mindset headset for their operation with gateway between Arduino and Mindwave and the program was run in python environment.

2.5 Blink Talk

The blink talker app created by Bryan Brown was one of the stepping stones in the development of applications related to BCI. He made his knowledge of C# and windows to manufacture a standout application not only the speech impaired but as well as the no with no muscle control below their eyes could have a sniff. With the power of electromyography and an Ultra book this application made the locked in patients to communicate verbally.

The Mindwave communication protocol defined by the NeuroSky is an essential algorithm developed by the NeuroSky developer team which establishes facts on making connection with the Mindwave device.

3.0 System Design

The Brain Controlled Wheelchair consists of both hardware components and software tools. The hardware components and software tools used are listed as below:

3.1 Hardware Components

The hardware components used in the project are as follows.

3.1.1 NeuroSky Mindwave

Figure 3.1: NeuroSky Mindwave

NeuroSky headset is a brain signal capturing device which safely measures brainwave signals and monitors the attention levels of the corresponding people using it. This is a lightweight tool which uses RF to communicate with the remote computer where the signal is analyzed for further manipulation. The NeuroSky headset essentially consists of three major sense analyzing capacity. It consists the eSense meter for attention, mediation and blink detection. The main feature of the headset is the eSense meter. For different types of eSense (i.e. Attention, Mediation), the meter value is reported on a relative eSense scale of 1 to 100. Both the attention, mediation level are measured in a range. By default, output of this Data Value is enabled. It is typically output once a second.

3.1.2 Raspberry Pi (B+)

Figure 3.2: Rapberry Pi B+

The Raspberry Pi is a low cost, credit sized computer that plugs into a computer monitor or TV and uses a standard keyboard and mouse. It is capable little device that enables people of all ages to explore computing and to learn how to program in languages such as Scratch and Python. The model b+ is the revision of the original raspberry pi. It replaced the model B. The GPIO (General Purpose Input Output) header has grown 40 pins. The model b+ has 4 USB ports, better hot plug and overcurrent behavior. This model supports the micro SD which is much nicer push-push version. The audio and video ports are combined together and 3.5mm jack is used. The raspberry pi b+ uses the Broadcom BCM2835 SoC ARM11 700 MHz processor. Raspberry pi here is the peripheral that does the processing task. The signals received with the help of RF are analyzed here.

3.1.3 Optocoupler (4N35)

An optocoupler is a semiconductor device that uses a short optical transmission path to transfer an electrical signal between circuits or elements of a circuit, while keeping them electrically isolated from each other. These components are used in a wide variety of communications, control and monitoring systems that use light to prevent electrical high voltage from affecting a lower power system receiving a signal. In its simplest form, an optocoupler consists of a light-emitting diode (LED), IRED (infrared-emitting diode) or laser diode for signal transmission and a photosensor (or phototransistor) for signal reception. Using an optocoupler, when an electrical current is applied to the LED, infrared light is produced and passes through the material inside the optocoupler. The beam travels across a transparent gap and is picked up by the receiver, which converts the modulated light or IR back into an electrical signal. In the absence of light, the input and output circuits are electrically isolated from each other.

Electronic equipment, as well as signal and power transmission lines, are subject to voltage surges from radio frequency transmissions, lightning strikes and spikes in the power supply. To avoid disruptions, optocoupler offer a safe interface between high-voltage components and low-voltage devices.

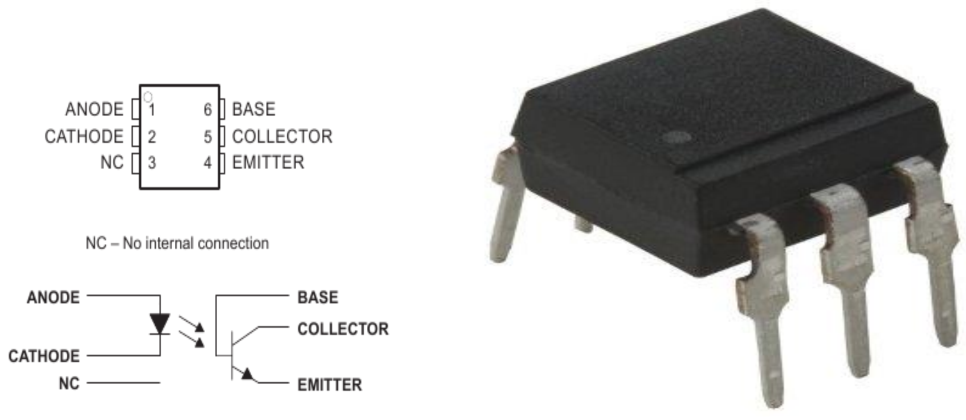

Figure 3.3: Optocoupler

3.1.4 Wheelchair

Wheelchair prototype consists of two wheels driven by two wiper motors. We have used different metal parts to make the wheel chair. The wheelchair is driven by the driver circuit and a power source of 12V DC battery.

The wheelchair is arranged in such a way that the wiper motor is connected to the shaft which is further connected to wheel. When we connect the power supply (12V DC) then the wheel rotate and the movement is achieved. In the ball-bearing mechanism, we have used two bearings in such a way that the tyre rotates in forward direction. Alongside the bearings, a metal plate is adjusted so the wheels and other upper parts are connected by wielding. In this way, we are able to run our wheelchair in forward direction using the EEG signal from Neurosky Mindwave.

3.1.5 IR2110

The IR2110 are high voltage, high speed power MOSFET and IGBT drivers with independent high and low side referenced output channels. Proprietary HVIC and latch immune CMOS technologies enable ruggedized monolithic construction. Logic inputs are compatible with standard CMOS output, down to 3.3V logic. The output drivers feature a high pulse current buffer stage designed for minimum driver cross-conduction. Propagation delays are matched to simplify use in high frequency applications. The floating channel can be used to drive an N-channel power MOSFET or IGBT in the high side configuration which operates up to 500 or 600 volts.

Figure 3.4: Motor Driver IR2110

3.1.6 MOSFETs

Power MOSFETs 3205 from International Rectifier utilize advanced processing techniques to achieve extremely low on-resistance per silicon area. This benefit, combined with the fast switching speed and ruggedized device design that HEXFET power MOSFETs are well known for, provides the designer with an extremely efficient and reliable device for use in a wide variety of applications. The TO-220 package is universally preferred for all commercial industrial applications at power dissipation levels to approximately 50 watts. The low thermal resistance and low package cost of the TO-220 contribute to its wide acceptance throughout the industry. The heat produced by this MOSFET is ejected to the surrounding with the help of heat sink.

Figure 3.5: Power MOSFET

3.1.7 Wiper Motor

These are the DC motors which are used to convert the electrical energy to mechanical energy. These motors are used to drive the wheelchair. The main feature of the wiper motor is the Ohm gear.

Figure 3.6: Wiper Motor

3.2 Software Tools

The software tools, languages and API used in our project are as follows:

- Java
- Python
- Netbeans IDE
- Numpy
- Scipy
- Matplot lib
- Jupyter Notebook
- Spyder
- PuTTy
- VNC Server
- PCB Wizard

3.3 Working of the System

The Mindwave Mobile from NeuroSky which is an an headset that safely measures and transfers the power spectrum (alpha waves, beta waves, etc.) data via RF to wireless communication media like android devices and many more. The human brain radiates different frequencies waves like (Delta, Theta, Alpha, Low Beta, Midrange beta and High beta) based on the work each individual is performing at the current interval of time. The brain signals like attention, meditation are received with the NeuroSky headset and the analog data is presented in digital format and is thrown from RF. The Raspberry pi which has a RF dongol receives the digital data and the data received can be decoded separating it with the characteristics it possesses. Now the data is analyzed by the python script and correspondingly the data is used to control the wheelchair prototype.

The data of attention, meditation and eye blink is used further to make an interactive user friendly interface. Like the working of the wheelchair the blinking of the eyes control the mouse cursor and the corresponding alphabets are selected from an alphabet array.

Wheelchair Algorithm

Step1: Initialize Mind wave electrode

Step2: Turn on Raspberry-pi and receiver dongle

Step3: Raw data is analyzed by python script

Step4: Analyses of attention, mediation data

Step5: If three continuous power value fall in the range of higher alpha wave wheelchair rests.

Step6: If three continuous power value lie in the range of recessive alpha wheelchair moves

Step6: Wiper motor connected in the wheelchair is controlled by the PWM signal.

Blink-Talker Algorithm

Step1: Initialize Mind wave electrode

Step2: Turn on Computer and receiver dongle

Step3: Raw data is analyzed by python script

Step4: Analyses of attention, meditation and eye blink data

Step5: Start of Blink-Talker application

Step6: Keyboard is open in computer and curser moves vertically and horizontally in pattern on screen

Step7: User eye blink is recognized by application and words or alphabet is selected

Step8: Selected text is converted into speech

Flow Chart for Wheel Chair Control

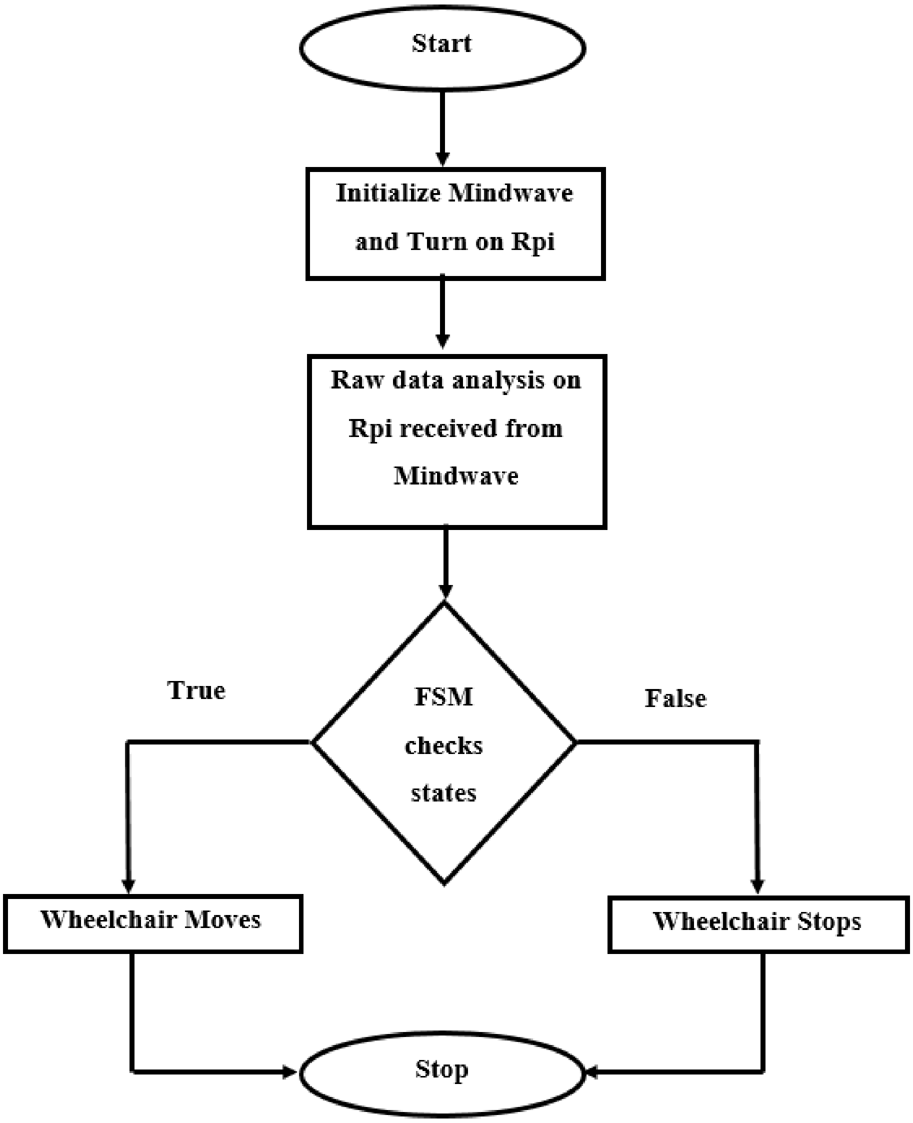

Figure 3.7: Flowchart for WheelChair Control

Flow Chart for Blink Talker Application

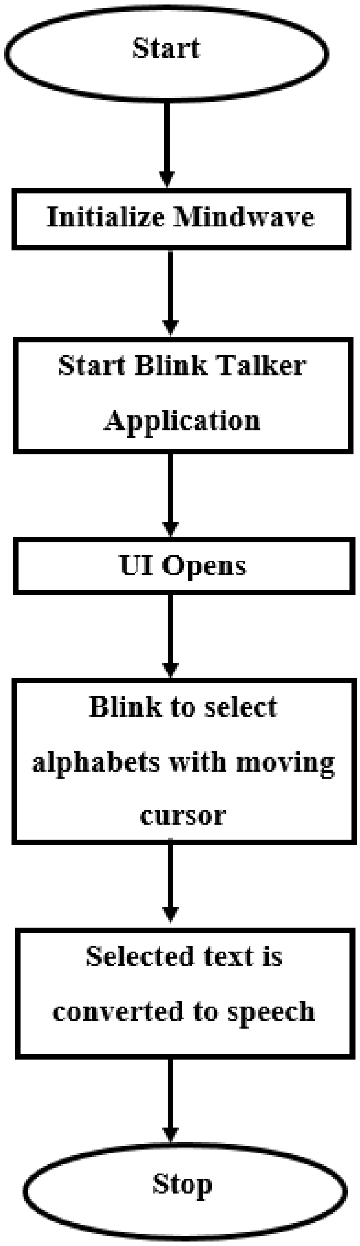

Figure 3.8: Flowchart for Blink Talker Application

4.0 Methodologies

The methodologies of the project is explained after the block diagram below.

4.1 Block Diagram

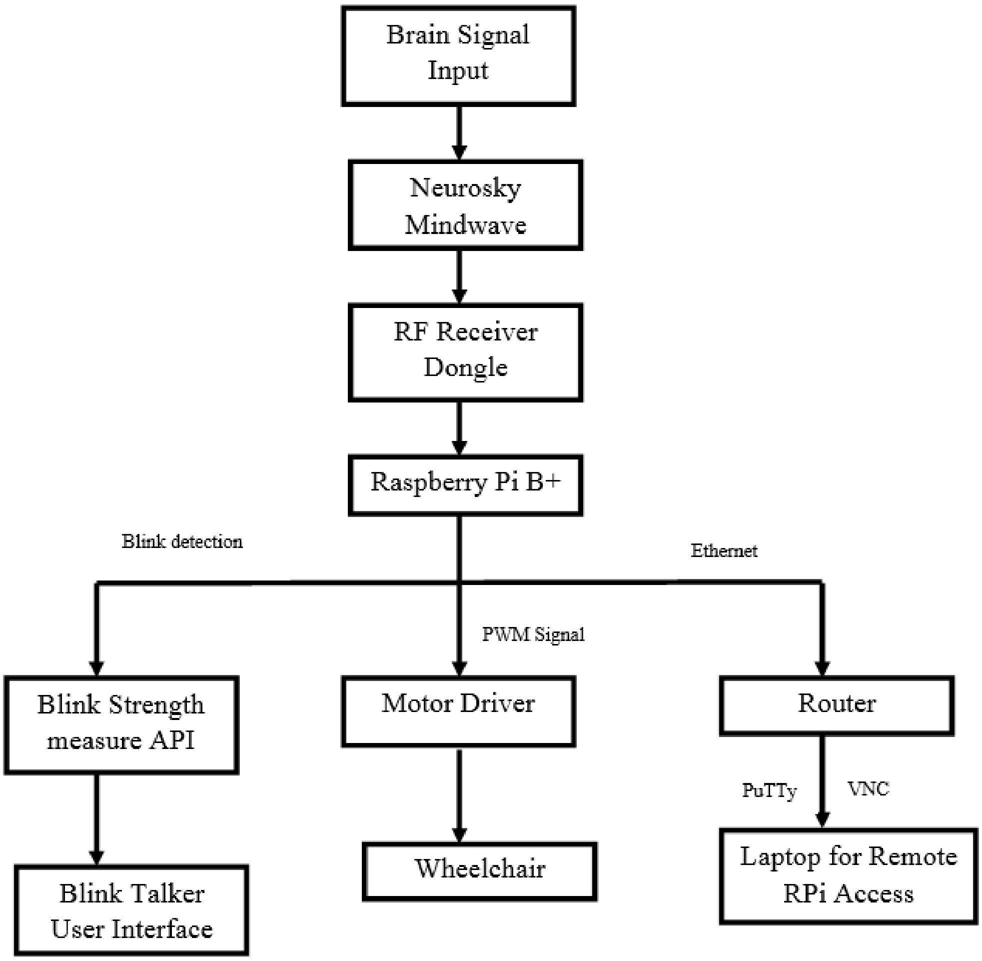

Figure 4.1: Block Diagram of the System

4.2 Explanation of Blocks

4.2.1 EEG Signal Acquisition (NeuroSky Mindwave)

The EEG signal which is the brain wave is sensed by the electrode in the mindwave. The headset has the inbuilt capabilities to sense the brain raw signal and it has an inbuilt API through which we can directly access the data like the attention, mediation and blink strength in digital notation. The thinkgear protocol is the inbuilt protocol through which the mindwave uses the different states of brain to record the signals. In windows OS we can directly call the thinkgear library to directly access the different states value as JSON data.

4.2.2 Signal Processing Unit (Raspberry Pi)

The main block of our project includes the Raspberry pi as the processing engine. We have extracted only the raw signal from the mindwave such that we could go beyond the limits the headset provides by directly giving all the state values.

Algorithm Involved

- Extraction of raw signal from the mindwave
- Write all the raw data to a CSV file
- Split the signal into different time frames
- Plot the FFT of the input signal
- Separate the plot into different frequency band
- Calculate the corresponding energy of the plot
- Plot the live graph of the input signal, its FFT
- Train our mind in such a way that we could be flexible with the data

As mentioned in the algorithm above the operations is carried. After the separation of different energy bands is carried out then comes the application part of controlling the wheelchair and blinker talker application.

a. FFT

DFT plays an important role in many applications of digital signal processing. A major reason for its importance is the existence of efficient algorithms for computing DFT. The fast Fourier transform (FFT) does not represent a transform different than DFT rather they are special algorithms for faster implementation of DFT. FFT requires a comparatively smaller number of operations such as multiplications and additions than the DFT. FFT thus, requires a less computational time than DFT.

A radix-2 decimation-in-time (DIT) FFT is the simplest and most common form of the Cooley–Tukey algorithm, although highly optimized Cooley–Tukey implementations typically use other forms of the algorithm as described below. Radix-2 DIT divides a DFT of size *N* into two interleaved DFTs (hence the name "radix-2") of size *N*/2 with each recursive stage.

The discrete Fourier transform (DFT) is defined by the formula:

$$X_k = \sum_{n=0}^{N-1} x_n e^{-\frac{2\pi i}{N} nk}, \qquad \text{…………...(1)}$$

Where, k is an integer ranging from 0 to N-1.

Radix-2 DIT first computes the DFTs of the even-indexed inputs $(x_{2m} = x_0, x_2, \ldots, x_{N-2})$ and of the odd-indexed inputs $(x_{2m+1} = x_1, x_3, \ldots, x_{N-1})$, and then combines those two results to produce the DFT of the whole sequence. This idea can then be performed recursively to reduce the overall runtime to O (*N* log *N*). This simplified form assumes that *N* is a power of 2; since the number of sample points N can usually be chosen freely by the application, this is often not an important restriction.

The Radix-2 DIT algorithm rearranges the DFT of the function x_n into two parts: a sum over the even-numbered indices $n = 2m$ and a sum over the odd-numbered indices $n = 2m + 1$.

$$X_k = \sum_{m=0}^{N/2-1} x_{2m} e^{-\frac{2\pi i}{N}(2m)k} + \sum_{m=0}^{N/2-1} x_{2m+1} e^{-\frac{2\pi i}{N}(2m+1)k} \qquad \text{………..(2)}$$

One can factor a common multiplier $e^{-\frac{2\pi i}{N}k}$ out of the second sum, as shown in the equation below. It is then clear that the two sums are the DFT of the even-indexed part x_{2m} and the DFT of odd-indexed part x_{2m+1} of the function x_n. Denote the

DFT of the *E*ven-indexed inputs x_{2m} by E_k and the DFT of the *O*dd-indexed inputs x_{2m+1} by O_k and we obtain:

$$X_k = \underbrace{\sum_{m=0}^{N/2-1} x_{2m} e^{-\frac{2\pi i}{N/2} mk}}_{\text{DFT of even-indexed part of } x_m} + e^{-\frac{2\pi i}{N} k} \underbrace{\sum_{m=0}^{N/2-1} x_{2m+1} e^{-\frac{2\pi i}{N/2} mk}}_{\text{DFT of odd-indexed part of } x_m} = E_k + e^{-\frac{2\pi i}{N} k} O_k. \qquad \ldots\ldots\ldots\ldots(3)$$

Thanks to the periodicity of the DFT, we know that

$$E_{k+\frac{N}{2}} = E_k \qquad \ldots\ldots\ldots\ldots(4)$$

And,

$$O_{k+\frac{N}{2}} = O_k. \qquad \ldots\ldots\ldots\ldots(5)$$

Therefore, we can rewrite the above equation as

$$X_k = \begin{cases} E_k + e^{-\frac{2\pi i}{N} k} O_k & \text{for } 0 \le k < N/2 \\ E_{k-N/2} + e^{-\frac{2\pi i}{N} k} O_{k-N/2} & \text{for } N/2 \le k < N. \end{cases} \qquad \ldots\ldots\ldots\ldots(6)$$

FFT is performed to determine the frequency of unknown signal. In the FFT magnitude spectrum, the frequency corresponding to the peak value of the magnitude gives the frequency of the given signal. Here we have used STFT (Short Time Fourier Transform). The time is 1 second.

b. Band Separation

The FFT results are used to compute the signal power in different bands of frequencies. As we know the frequency ranges values for alpha, beta, delta, theta and gamma. We separated the bands of frequency as per the data. ie. (1-4) delta, (4-8) theta, (8-13) alpha, (13-41) beta, (41-100) gamma. We could have analyzed all the ranges but due to randomness of EEG signal we considered alpha waves for our analysis.

c. Power Calculation

The EEG signal is separated into different bands and the corresponding power is calculated. As the FFT result corresponds to the power of the signal, the power is calculated to control the wheelchair. As EEG signal is most random in nature, we could only control the alpha waves and then corresponding power is calculated.

Power = $\frac{X(k)\ \vee^{2}\ \overline{N}}{\sum_{k=0}^{N}}$

The alpha wave power of 4 microwatt is taken as a threshold value for controlling the wheelchair.

d. FSM

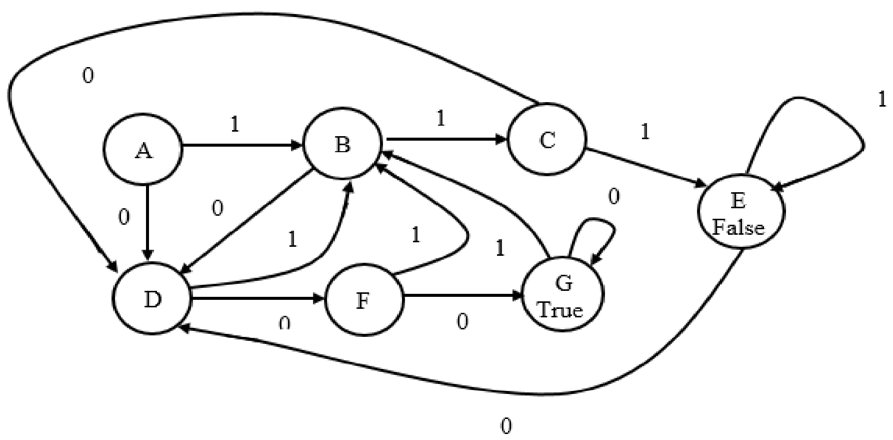

Figure 4.2: FSM design

Finite state machine is used to control the state of wheelchair. The wheelchair either moves forward or stops based on the value of alpha wave we get. As EEG signal is most random in nature, the value obtained each second is not suitable to control the state of the wheelchair. So we use the three similar consecutive values to change the state of wheelchair, ie. to move from the state of moving to the state of rest and vice versa. This is accomplished by the use of Finite State Machine.

Finite State Machine has seven states from A to G. When the machine is reached in state E, the state of the wheelchair is changed to False. This means the wheelchair stops moving. If the FSM reaches to state G, the state of the wheelchair is changed to True. This means the wheelchair starts moving. The overall work procedure is as shown in the diagram.

The input signal '0' or '1' means that if the power of the alpha signal is below 4, we scale that value to 1 and if the power of the alpha signal is greater than or equal to 4, we scale that value to 0. The value 4 is expressed in terms of microwatts.

d. Training the Mind

For training the mindwave we followed the protocol as:

To generate higher alpha waves:

- Relax your body and muscles
- Close your mind and mediate

To generate lower alpha waves:

- Concentrate at a single point
- Continuously blink the eyes

As we know alpha waves are prevalent when the mind meditates. During the event of high mediation alpha waves are dominant with corresponding threshold of above 4 (this result was obtained with continuous training of the brain for our device).

e. Wheelchair Control:

The wheelchair state is controlled by the result of FSM. The wheelchair can either move forward or can be stopped depending upon the state of FSM. The wheelchair is driven by two wiper motors which run only with the PWM signals. So we have used Raspberry Pi to generate the PWM signal with frequency of 50Hz with varying Duty Cycle.

Wheel chair consists of number of metallic parts, four wheels, wiper motors and the driver circuits for controlling the wiper motors. The motors are connected to the rear wheels of the wheelchair. The rear are wheels are fixed through bearings and the shaft of the wheel is connected to wiper motors. The wiper motors are connected to 12V dc power supply through the motor driver circuits. The motor driver circuits get enabled or disabled through the Raspberry Pi. The Raspberry Pi is not directly connected to motor driver circuits, instead they are connected to Raspberry Pi via octocouplers. The octocouplers are connected to prevent the backflow of current to Raspberry Pi. They provide electrical isolation between Raspberry Pi and Motor Drivers.

Figure 4.3: Wheelchair

f. Blinker Talker Interface

Blinker talker interface is the next application of our project. The strength of eye blink is measured and this is used to select the different alphabets in the UI interface built on the same python platform.

Figure 4.4: Blink Talker User Interface

5.0 Cost and Time Analysis

The cost of our project is summarized as shown in the table.

Table 5.1: Cost Summary

S.N.	**Name of components**	**Quantity**	**Total cost (NRs.)**
1	NeuroSky Headset	1	16000
2	Raspberry Pi	1	6000
3	Motor Driver	2	2000
4	Battery	1	1000
5	Wheelchair Components	-	3000
6	Miscellaneous	-	2000
	Total	-	30000

The Gantt chart for the whole project is as shown in this given table. We tried all our best to perform our work as per the schedule and finally came to the result of the project.

Table 5.2: Gantt Chart

SN.	Activities	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
1	Proposal& planning									
2	Material Collection									
3	Mechanical design									
4	Circuit design									
5.	Documentation									
6	Testing & Verification									
7.	Implementation									

6.0 Result Analysis

The Brain Controlled Wheelchair is not simply an application based project. It is a research based project. The project mainly focuses on the signal processing part. Signal processing part is the integral part of the project. The raw signal obtained through the Neurosky Mindwave is processed to extract the feature. From the signal processing part we have extracted feature. Through the extracted feature we have been able to control the wheelchair.

Not only the wheelchair control part our project has other part that is a Blinker Talker simple user interface. For this method we have exploited the Neurosky Mindwave API through which we have detected the blink. Using the blink count the mouse cursor moves left and right confined in the screen.

Though the final result were application oriented, the project scope is huge keeping in mind the data analysis that we have done to generate an algorithm that is hugely sufficient to monitor the brain signals for this particular device. We have made the research aspect of the project clear in the methodologies of the report.

The results can be best summarized in the steps below:

- Raw data extraction through Neurosky Mindwave
- FFT of the extracted raw data
- Separation of different bands of frequencies and calculating their respective powers
- Implementation of Finite State Machine (FSM) for controlling the wheelchair
- Design of simple blinker talker User Interface (UI) which is controlled using the eye blink count.

The detailed results are explained as below:

6.1 Extraction of Raw Data

Raw data extraction is the major part of the work done till now. We have successfully extracted the raw data from the NeuroSky Mindwave headset. NeuroSky headset is itself is a highly equipped and sensitive device. It has an inbuilt ThinkGear chip which is the base for the raw data extraction. The ThinkGear chip contains a ThinkGear algorithm which calculates the EEG values. The data is extracted with python and is analyzed with JAVA.

In the data extraction process the raw data which is 16 bit is transmitted through RF transmitter which is inbuilt in the NeuroSky Mindwave. The data is received with the help of wireless USB dongle connect in the PC. The raw value can lie in between -32768 to +32767. First byte high order bits of 2's complement while the second byte represents the lower order bits. To reconstruct full signal simply shift the first byte by 8 bits and bitwise. In high level languages it can be done as:

Raw = value[0]*256+value[1]

If(Raw>=32768)

Raw = Raw- 65536

Generally the raw value ranges from -2048 to +2047.

6.1.1 Packet Structure (ThinkGear packets)

Asynchronous serial stream of bytes is passed. Serial stream is parsed and interpreted as ThinkGear packets in order to properly extract and interpret the ThinkGear data values. There are basically three parts:

Packet Header, Packet payload, packet checksum. Combining the header and checksum provides data stream synchronization and data integrity check while the format of data payload ensures that new data fields can be added to the packet in the future without breaking. There are different code for different argument types. For example 0x02 signifies poor signal quality, 0x04 signifies attention eSense values etc.

Packet Structure

[SYNC] [SYNC] [PLENGTH] [PAYLOAD...] [CHKSUM]

_________________________ ______________ _____________

^^^^^^^^^(Header)^^^^^^^^ ^^(Payload)^^ ^(Checksum)^

Data row format

([EXCODE]...) [CODE] ([VLENGTH]) [VALUE...]

____________________ ____________ ___________

^^^^(Value Type)^^^^ ^^(length)^^ ^^(value)^^

First the library of Mindwave is created in python keeping in mind all the data structure as well as the parsing mechanism. Although we can use windows environment and can directly access the attention, mediation values. We have tried something new using the Linux platform. The library is loaded first and then the program to calculate the raw values is calculated. The sampling frequency is 512 Hz and similarly we used n point FFT in Python for frequency transformation. The raw data values are extracted and saved in a CSV file which is fed into the FFT code in Python and FFT with graph of the input signal is calculated. Graph shows that the raw data extracted was indeed an EEG signal with frequency around 10Hz.

Sample 1

55 37 56 75 42 10 16 23 22 18 28 54 75 65 29 26 51 57 42 37 65 86 58 27 24 34 45 68 75 74 53 29 48 81 96 89 82 69 70 90 85 86 77 42 17 4 -3 3 24 41 66 77 100 112 98 106 117 106 96 85 70 58 38 36 55 82 73 48 37 58 92 105 96 85 80 76 80 74 72 90 92 65 41 57 60 56 44 49 70 113 135 124 107 104 112 105 97 92 82 70 74 86 91 103 88 66 67 88 116 124 112 114 122 123 108 112 108 104 112 133 131 106 73 70 83 82 68 57 58 60 49 32 39 42 16 -4 -6 -5 -5 -6 -24 -58 -114 -132 -57 27 66 87 86 71 83 99 114 98 72 69 104 148 161 154 134 116 96 67 53 51 61 84 120 123 97 97 100 99 99 117 134 125 105 75 52 59 85 83 69 74 107 125 121 107 87 82 96 104 89 82 88 72 53 59 59 33 -9 -28 -19 1 -8 -20 -49 -85 -90 -56 -24 -25 -20 0 34 38 43 80 102 100 112 115 98 85 85 85 72 50 40 43 44 33 12 13 34 50 56 52 49 44 44 40 44 58 72 67 49 66 71 40 21 32 50 51 49 53 38 34 36 16 7 18 20 12 5 8 17 17 28 53 69 66 59 81 104 107 100 103 112 123 130 128 112 87 73 84 86 83 80 91 105 136

151 109 73 83 117 125 105 87 76 87 107 121 148 153 108 51 41 66 86 106 101 65 44 54 64 58 74 80 56 42 34 10 7 28 34 9 4 25 53 69 58 50 53 55 54 57 55 51 66 90 68 27 19 34 68 97 113 106 83 84 116 123 102 87 102 120 123 122 139 148 128 98 86 85 72 90 105 71 44 48 66 81 76 69 54 68 85 66 55 56 39 12 10 34 40 36 43 66 67 33 -17 -50 -22 55 131 137 118 117 148 204 235 213 177 164 185 242 310 347 358 345 300 268 300 336 322 291 263 265 249 197 157 128 98 76 77 97 114 101 84 84 77 22 -19 -14 0 8 -3 -9 -22 -34 -46 -38 -27 -38 -66 -74 -40 -23 -43 -41 -17 -17 -37 -46 -36 -11 3 9 19 23 17 3 -3 -11 -3 16 18 -12 -29 -8 8 16 33 25 7 9 28 48 44 29 12 33 65 50 33 28 36 44 39 26 16 -4 -22 -14 -6 -5 -4 -22 -43 -61 -58 -40 -18 -57 -101 -69 -24 -29 -57

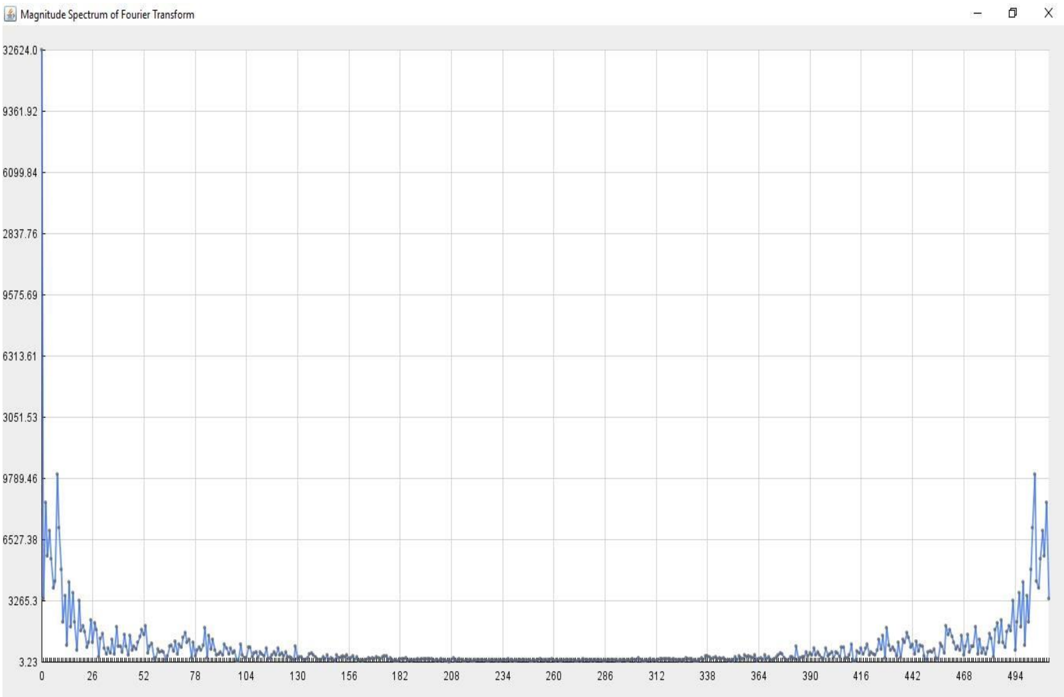

Figure 6.1: FFT of sample signal.

Observing the graph, we can see the frequency of signal at that instant was about 10Hz. This lies in the range of EEG signal. The sample was taken in peaceful environment.

6.2 Alpha Dominant State

The input voltage, corresponding FFT signal and the power of the alpha dominant signal are as follows:

Sample 1

Input Time Signal

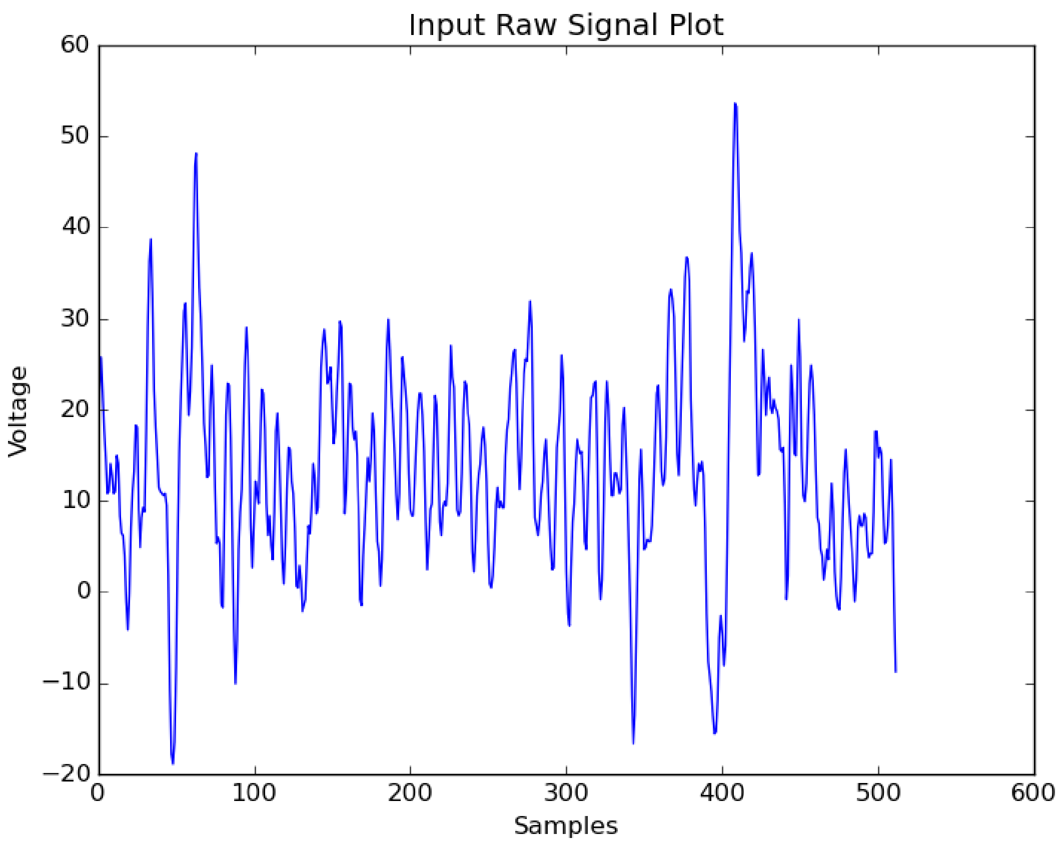

Figure 6.2: Input Time Signal of Alpha Dominant Wave Sample I

FFT of the signal

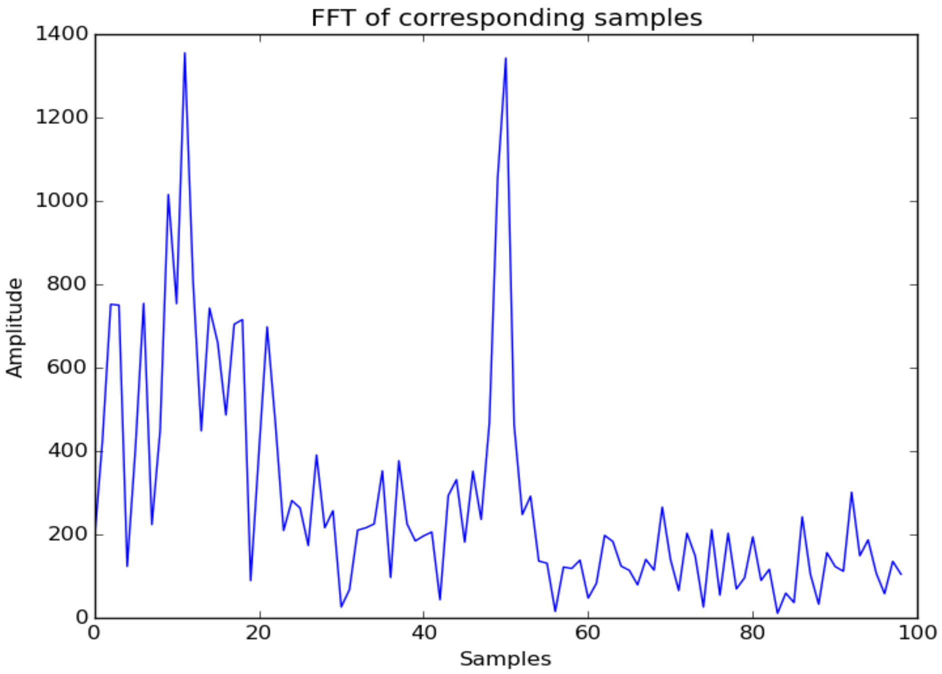

Figure 6.3: FFT of Alpha Dominant Wave Sample I

Power of the signal

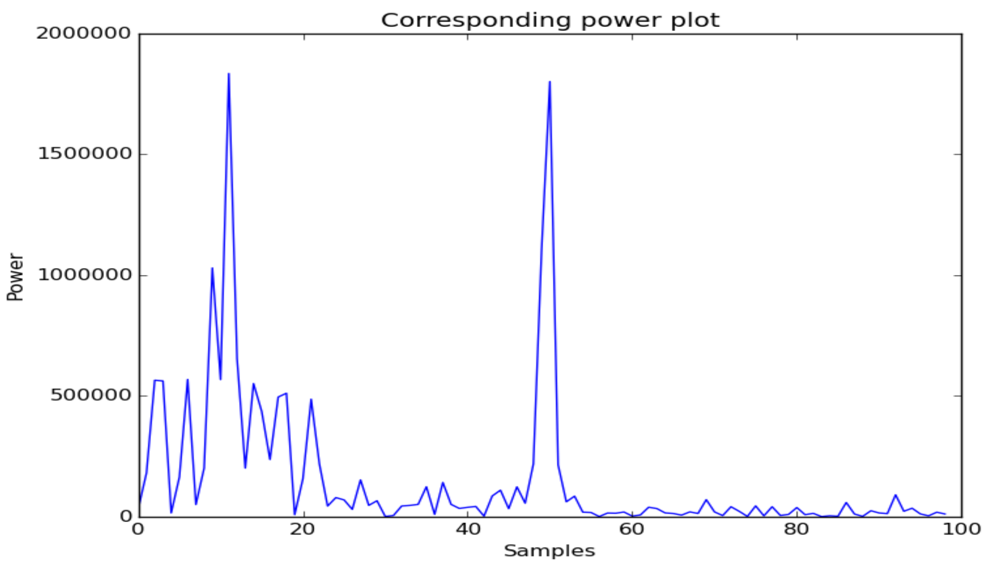

Figure 6.4: Power Plot of Alpha Dominant Wave Sample I

Sample 2

Input Time Signal

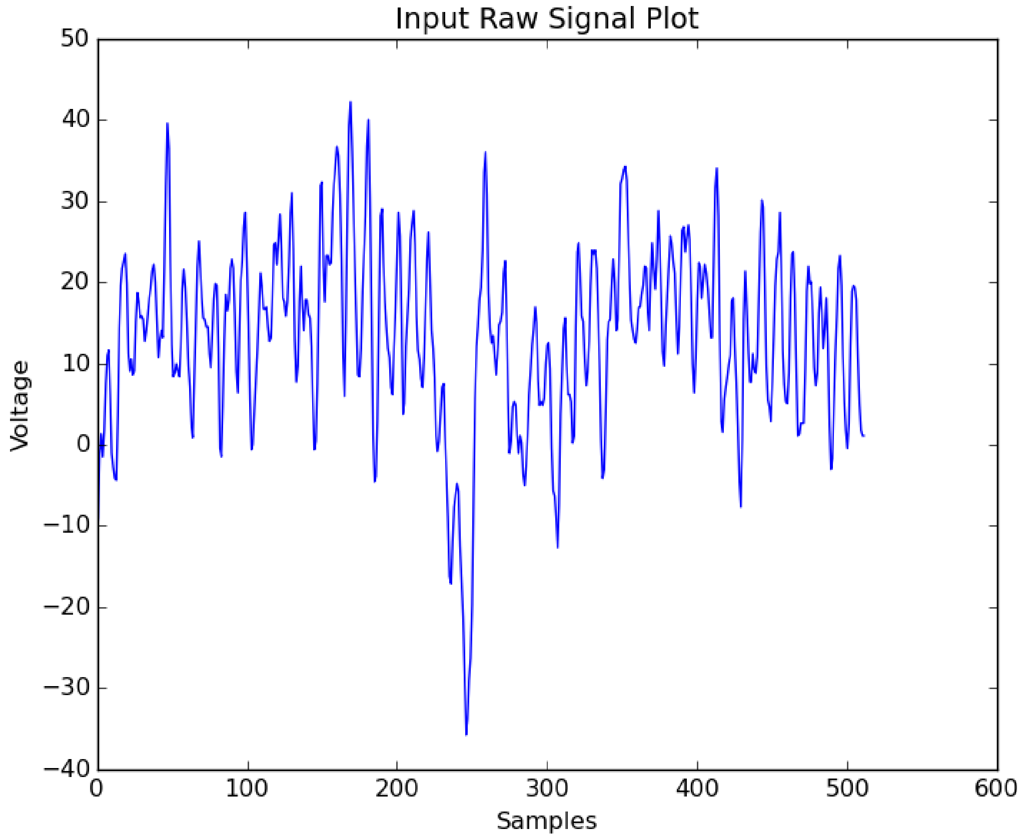

Figure 6.5: Input Time Signal of Alpha Dominant Wave Sample II

FFT of the signal

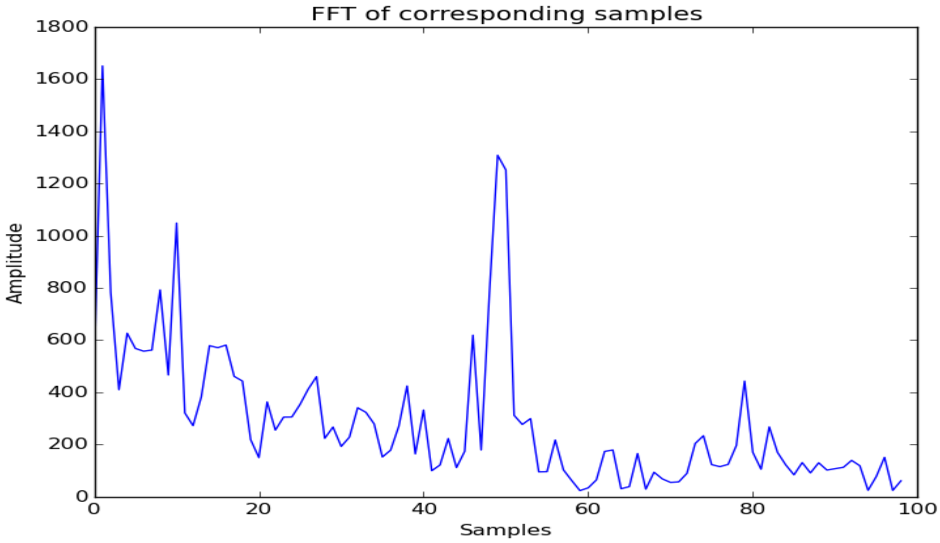

Figure 6.6: FFT of Alpha Dominant Wave Sample II

Power of the signal

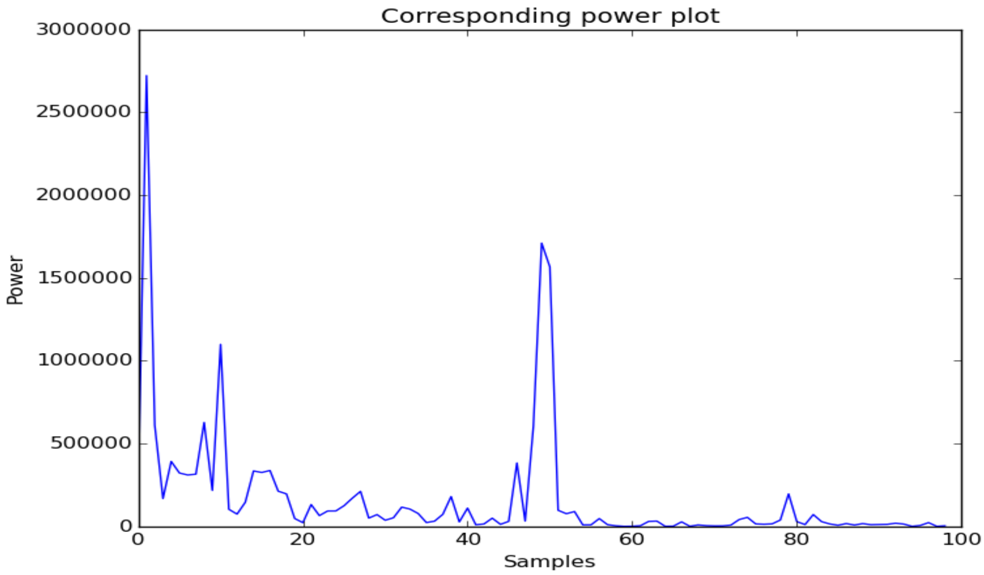

Figure 6.7: Power Plot of Alpha Dominant Wave Sample II

6.3 Alpha Recessive State

The input voltage, corresponding FFT signal and the power of the alpha recessive signal are as follows:

<u>Sample 1</u>

Input time signal

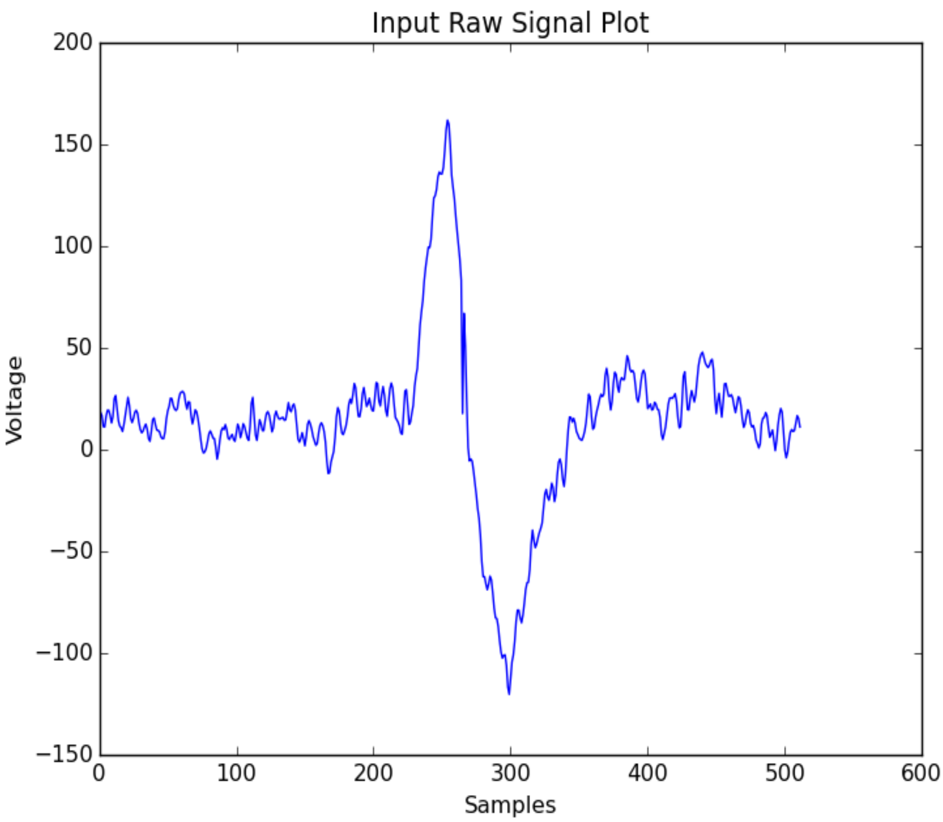

Figure 6.8: Input Time Signal of Alpha Recessive Wave Sample I

FFT of the signal

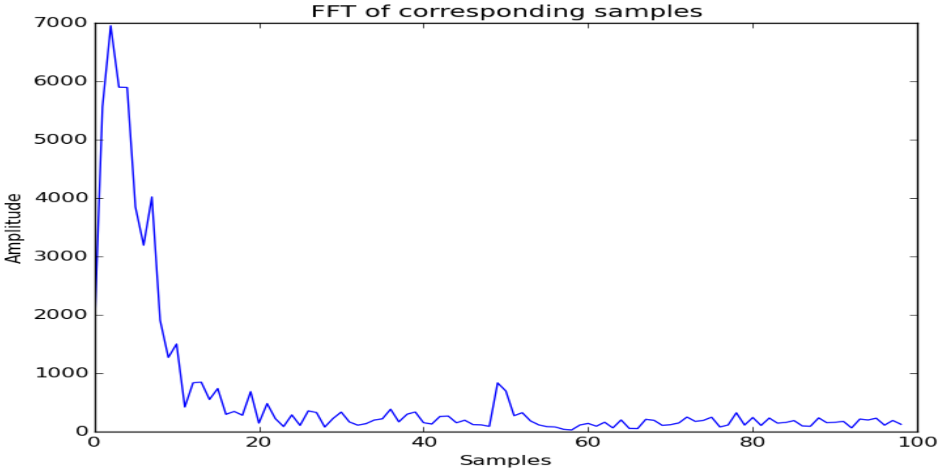

Figure 6.9: FFT of Alpha Recessive Wave Sample I

Power of the signal

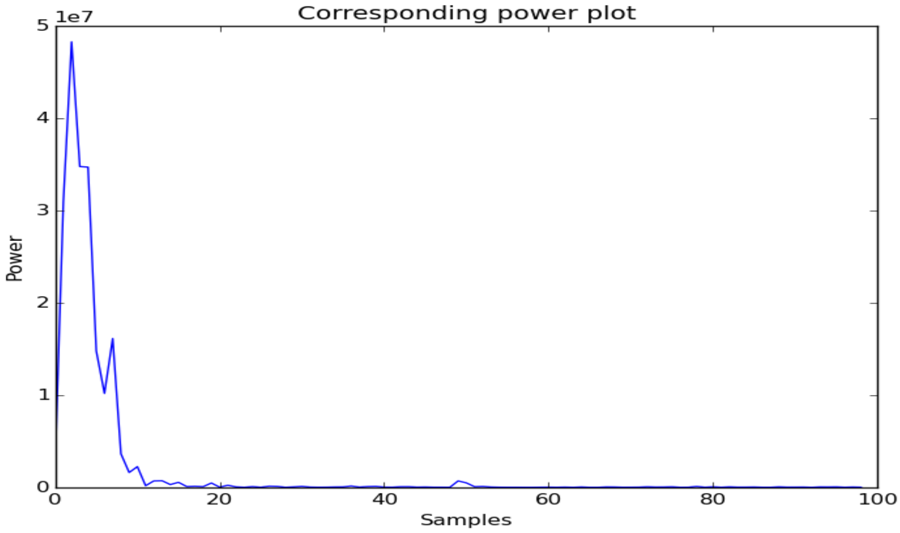

Figure 6.10: Power Plot of Alpha Recessive Wave Sample I

<u>Sample 2</u>

Input time signal

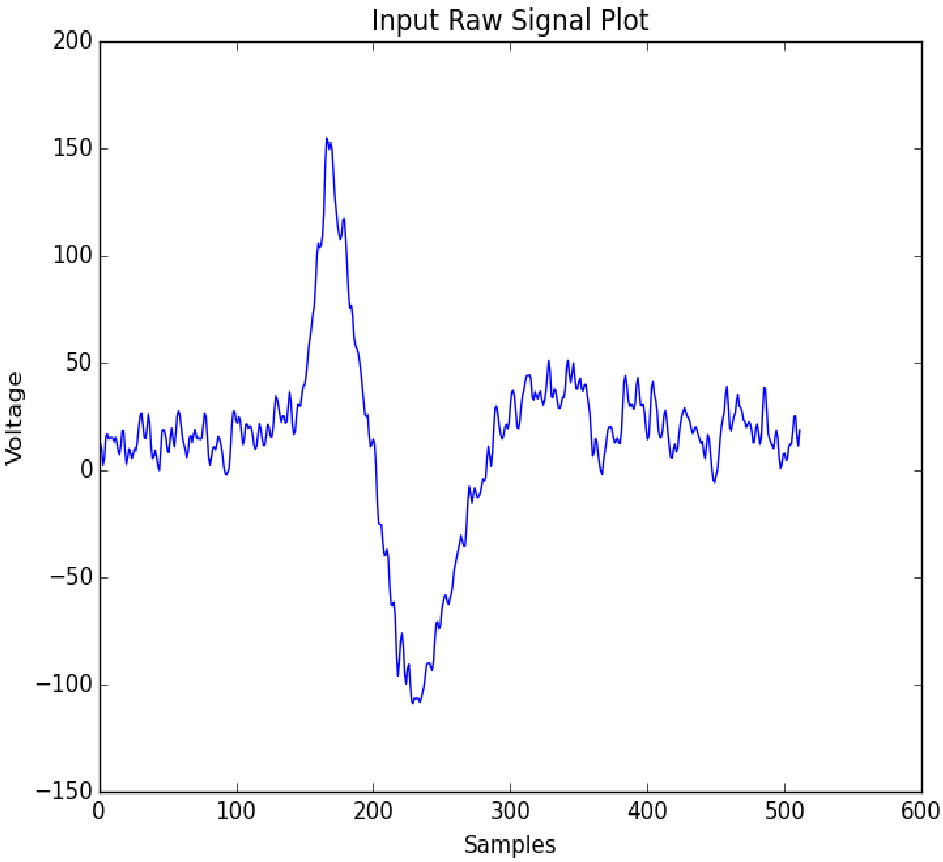

Figure 6.11: Input Time Signal of Alpha Recessive Wave Sample II

FFT of the signal

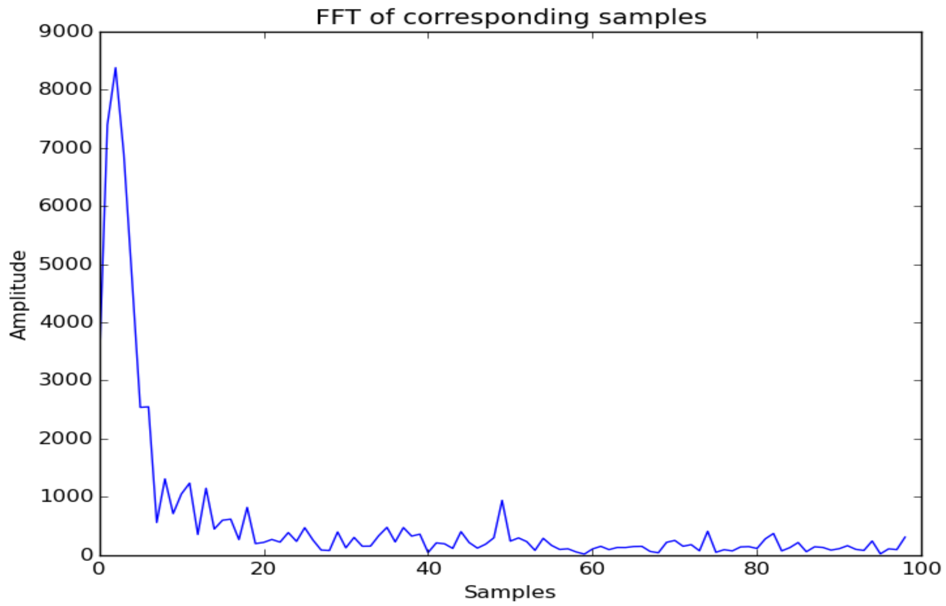

Figure 6.12: FFT of Alpha Recessive Wave Sample II

Power of the signal

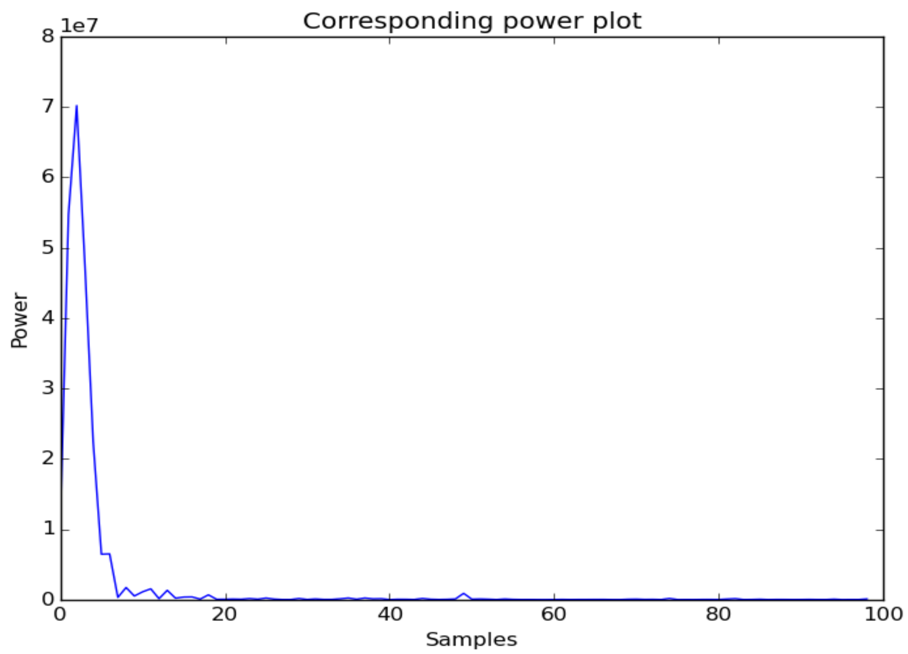

Figure 6.13: Power Plot of Alpha Recessive Wave Sample II

6.4 Finite State Machine Design

FSM is designed to control the wheelchair. The power generated in the alpha band of the signal is used to control the wheelchair. FSM consists of seven states with two states E and G for transition.

6.5 Problems Encountered

A good project comes up with many problems. Getting a grasp of the Mindwave was itself a challenge and more was yet to come. As per our work schedule we initially started our work with the headset. We wanted to work ourselves with JAVA for all purpose and initially developed a Mindwave library in JAVA which could connect to the headset through ThinkGear Connector. The ThinkGear is a built in library through which we could directly access the data from the Mindwave. Due to some reasons the output data which was in JSON format came in some sort of boxes which was unreadable. We tried sorting it with writing all the driver code and all itself but the problem persisted. So as Language hasn't been a problem throughout we thought of an idea to develop the library in python itself as we could directly program the headset with this. Data was extracted which was not much difficult. The major problem was the FFT. Initially we developed a program to calculate 8 point FFT but later realized that 8 point FFT was not good enough, so we started working on for n point FFT. The n –point FFT was little complicated but with hard work comes perfection and finally we became successful to compute the n point FFT in JAVA. However, this was done with ease later on Python. With the work shifted to python from Java the major problem that we faced were first developing an API that the headset could easily accommodate with. With the API built we extracted the signal as per the requirement and the major problem is the live plot of the graph. The problem with the wheelchair was that the chain kept on being loose so we finally came up with the idea of using the wheelchair without using chain. The chain control mechanism was main problem in our project which was replaced by using ball-bearings and replacing the old large tires with new tubeless tires

The Problems encountered can be best summed up in the following points:

- Extracting the raw data from Mindwave initially on windows platform.
- Training the Mind is the most difficult task.
- Chain tight mechanism in wheelchair.

7.0 Limitations, Further Enhancements and Conclusion

7.1 Limitations

As no projects are perfect our project too have limitations. Calling the Mindwave API and using the API results would have been fast and easy process to accomplish but the Final Year project credit would have been on jeopardy. So using our own methods to process the signal was itself a huge task. The limitations of the project can be explained as:

- The movement of wheelchair is confined in only the forward direction.
- Due to various control process the response time is little slow, so the wheelchair takes time to respond to the brain signal.
- Wheelchair supports limited weight around 50 kg due to its hardware impairments.
- The wheelchair can be controlled efficiently only by the person with adequate training and knowledge.
- As the EEG signals are very low frequency signals the effect of noise is adverse in signals, due to which sometimes glitch values appear.

7.2 Further Enhancements

This project can be a milestone in the field of recent research on the BCI. Though the electrode couldn't be made with the available materials but still the processing part has a lot on the stake. The project can be further enhanced in the following ways:

- Moving the wheelchair in different directions can be made by proper extraction of other features from the brain signals.
- Making the supporting components of wheelchair rigid such that it can support heavier loads.

- With limited processing capacity of Raspberry Pi B+ the processing was slow and lagging which can be optimized using high capacity devices like Raspberry Pi.
- Blinker Talker user interface can be integrated in fast processing Raspberry Pi adding a screen through which user can monitor his brain signal activities.
- Furthermore the project will have a huge prospect if this can be built as a web application.

7.3 Conclusion

We finally succeeded on completing the Brain Controlled Wheelchair and Blinker Talker interface. Brain signal processing is the integral part of the project. We successfully extracted the raw data from the Neurosky Mindwave and correspondingly analyzed it. During the analysis portion we calculated FFT to verify the Brain Signals, we separated bands of frequencies and corresponding power of the bands of frequencies.

The main theme of the project was to help the disabled people communicate using the Brain Controlled Wheelchair and Blinker Talker. After the completion of the project we can assure that this project is not limited to a prototype, this can be a final product which can be implemented in the real world scenario with minor modifications. A well trained mind can control the wheelchair as per the specifications mentioned.

The project has been a great learning platform and experience at the end of the engineering education. As already specified we can implement this project in real time which we believe will definitely be handy for the physically impaired people.

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Appendix – I: Snapshots

Figure 1: Wheelchair Construction

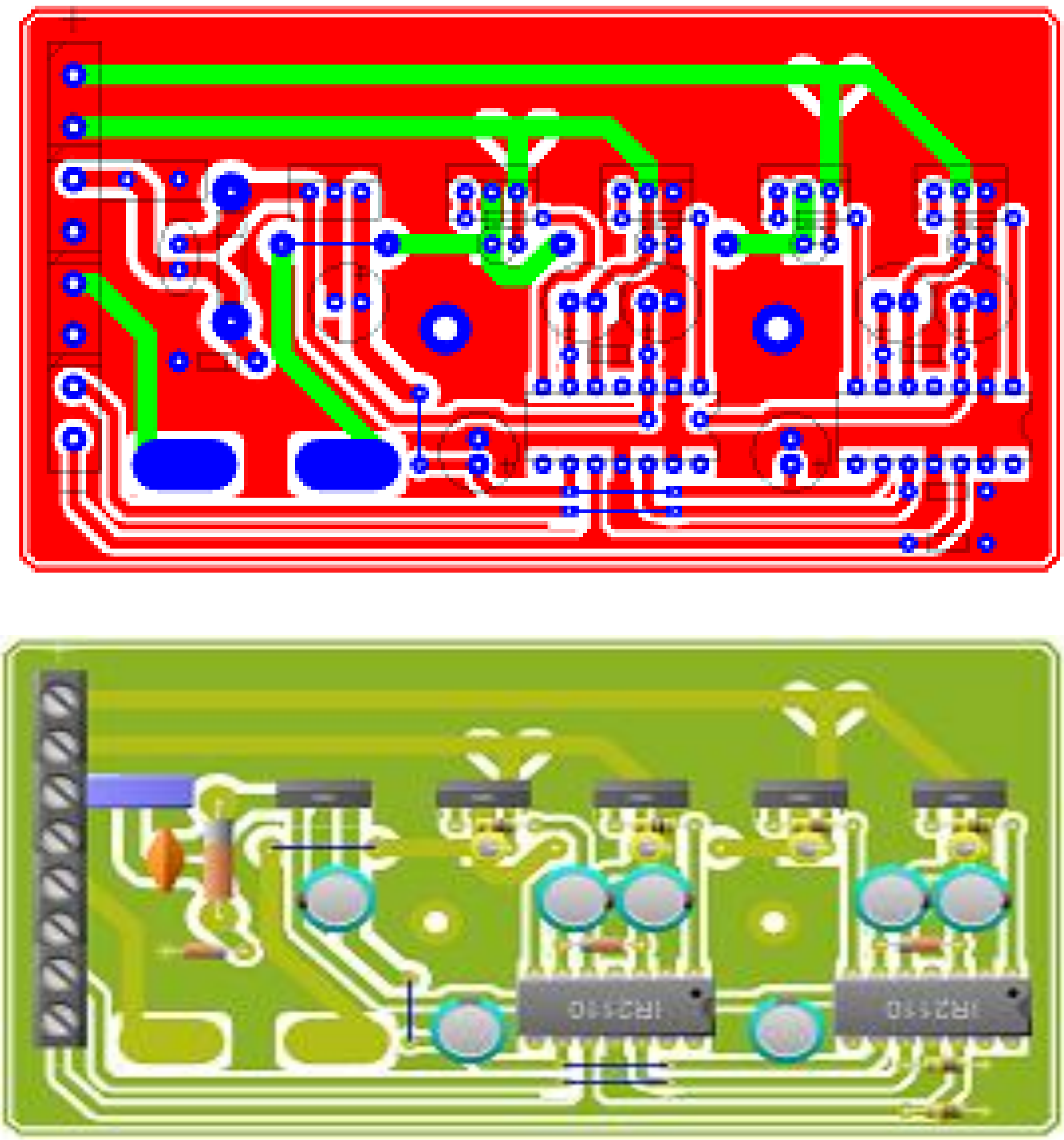
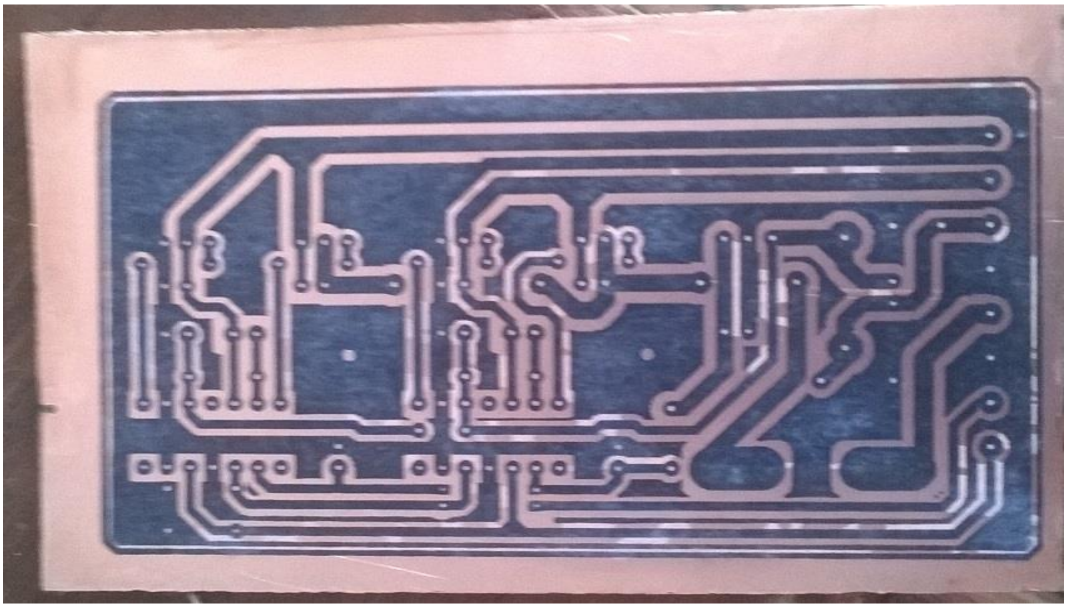


Figure 2: PCB layout in PCB Wizard



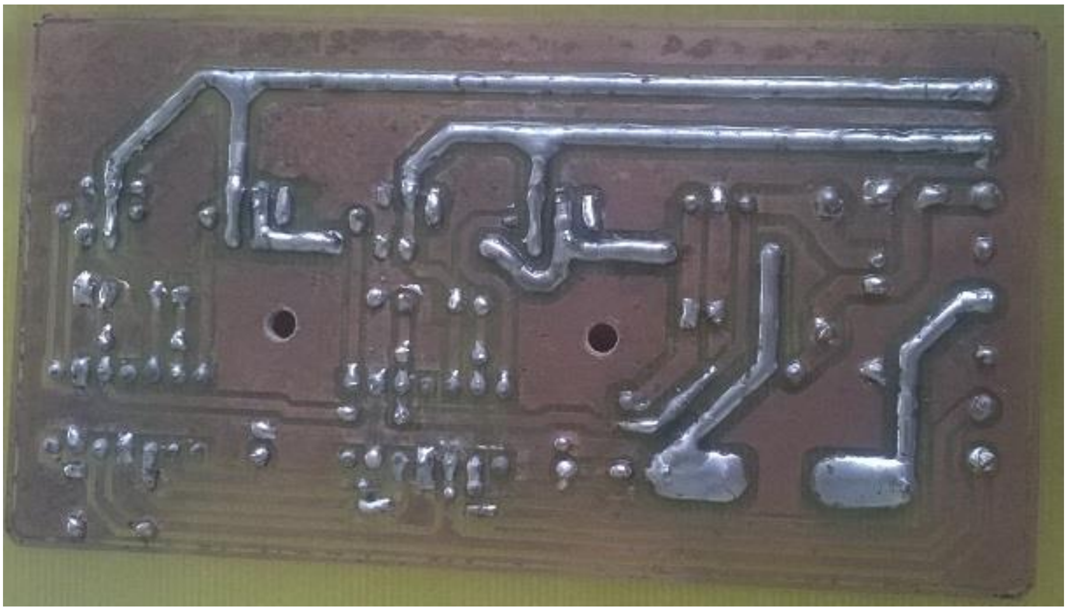


Figure 3: Actual PCB Design

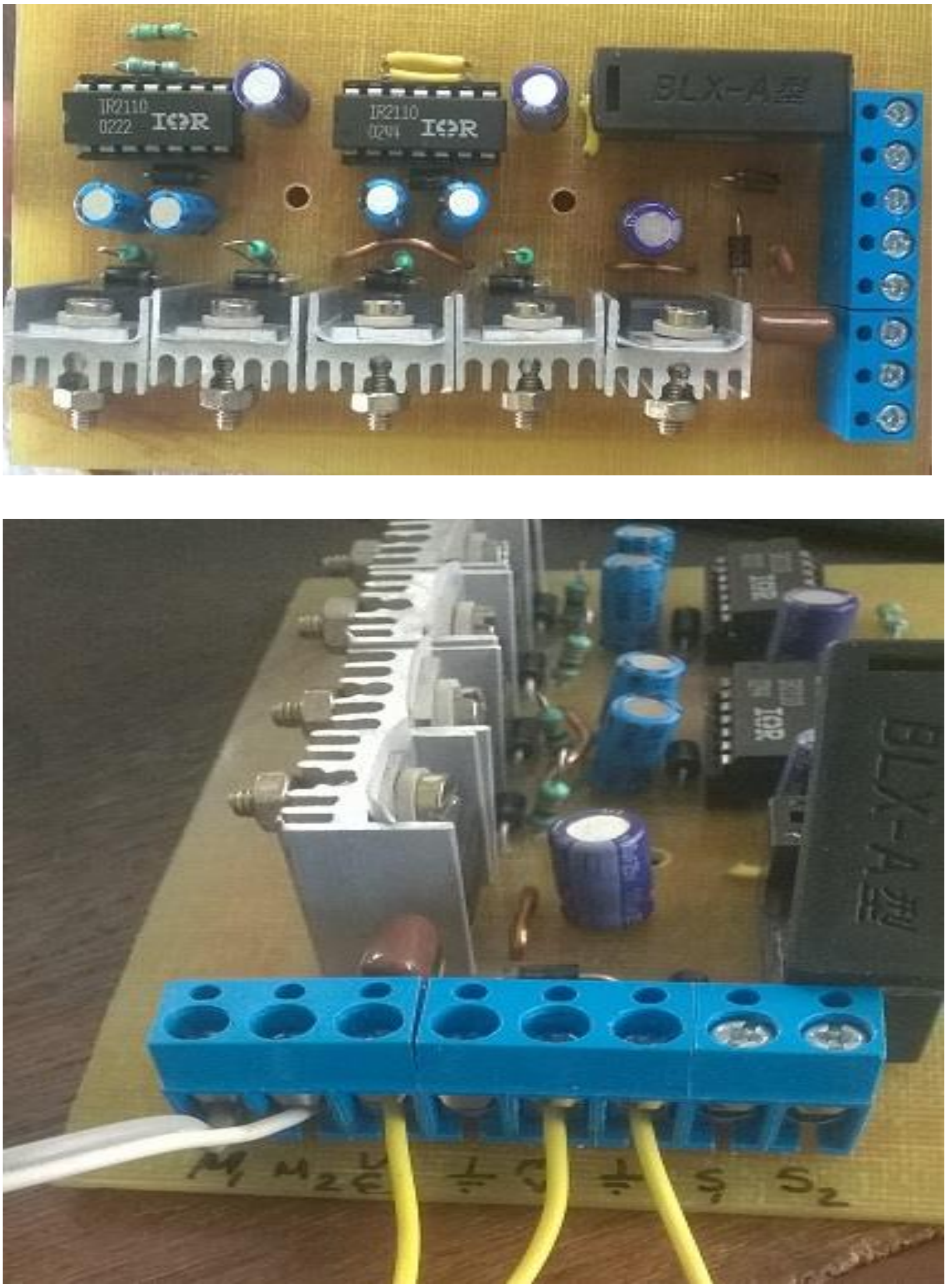


Figure 4: Driver Circuit