Shri Vile Parle Kelavani Mandal's
DWARKADAS J. SANGHVI COLLEGE OF ENGINEERING
(Autonomous College Affiliated to the University of Mumbai)

EMG Controlled Wheelchair

Submitted in partial fulfillment of the requirement
of the degree of

Bachelor of Technology in
Electronics Engineering

By

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Under the guidance of

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University of Mumbai

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CERTIFICATE

This is to certify that the project entitled, **"EMG Controlled Wheelchair"** is a bonafide work of **"Neel Karia" (60001190033), "Rohit Joshi" (60001190045)** and **"Yash Khanolkar" (60001190060)** submitted in the partial fulfillment of the requirement for the award of the Bachelor of Technology in Electronics Engineering.

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DECLARATION

We declare that this written submission represents our ideas in our own words and where others ideas or words have been included, we have adequately cited and referenced the original sources. We also declare that, we have adhered to all the principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in our submission. We understand that any violation of the above will be a cause for disciplinary action by the Institute and can also evoke penal action from the sources, which have thus not been properly cited or from whom proper permission has not been taken, when needed.

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APPROVAL SHEET

Project entitled, **"EMG Controlled Wheelchair"**, submitted by **Neel Karia (60001190033), Rohit Joshi (60001190045)** and **Yash Khanolkar(60001190060)** is approved for the award of the Bachelor of Technology in Electronics Engineering

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Abstract

For people suffering from physical disabilities, conventional wheelchairs can prove to be tedious due to their manual operation and the requirement of an additional caretaker. To address precisely this problem, our team has dwelved into the relatively less explored concept of Electromyography and has developed an **'EMG Controlled Wheelchair'**. The Electromyographic (EMG) signal is a biomedical signal that measures electrical currents generated in muscles during its contractions representing neuromuscular activities.

We have used the EMG Muscle sensor V3.0 module for acquisition of EMG signals and further conditioning has been done by implementing a buffer, amplification, Schmitt trigger and zero crossing detector apparatus. The signal thus derived is then fed into the ESP32 microcontroller which commands the drivers to control the motors with the help of PWM pulses.

Our programming logic has been kept quite simple with only provisions for left, right and forward motion being present. The wheelchair we are using is fully customized with a low center of gravity to avoid toppling. Also, the batteries and motors have been chosen after accurate torque and battery life calculations.

We have added safety features like the emergency stop button in case of any irregularities with the wheelchair or the patient. Ultrasonic sensor has been implemented for the process of obstacle detection and preventive action. Other aspects like IOT and control efficiency are some of the other parameters under the limitless scope provided by our project.

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List of Abbreviations

EMG	Electromyography
EEG	Electroencephalogram
EMG_L	EMG detected on left hand
EMG_R	EMG detected on right hand
SEMG	Surface EMG
FCR	Flexor carpi radiallis
ECR	Extensor carpi radiallis
ADC	Analog to Digital Converter
PWM	Pulse Width Modulation
GPIO	General purpose Input / Output
EXOR	Exclusive - OR
CMRR	Common Mode Rejection Ratio
PCB	Printed Circuit Board
SAC	Signal Acquisition Circuit
DSO	Digital Signal Oscilloscope
SOC	System on chip
2S	Two in series

List of Symbols

Symbol	**Denotes**
DC	Direct Current
Na	Sodium
K	Potassium
fs	Static frictional force
m	Mass
N	Normal force
g	Acceleration due to gravity
a	Acceleration of the body
μ	Static Coefficient of friction
P	Power
ω	Angular frequency
τ	Torque

CHAPTER - 1
INTRODUCTION

1.1 Background

Traditionally, it was quite complicated for a person with constricted mobility to travel independently as the wheelchairs which were available were either needed to be handled manually or an additional caretaker was required to push the wheelchair which added to the financial costs of the person concerned. Some other improvements in such a wheelchair were made over time with the advancement of technology. This included controlling the wheelchair with the help of joystick. Though, this can still be an option, people having minimal arm of leg activity may not be physically able to operate even a joystick due to the need for performing basic muscle or joint movement. To solve such basic problems, a unique product known as '**EMG Controlled Wheelchair'** came into existence.

An automated wheelchair became an increasing necessity for the differently-abled. Although, Electromyography (EMG) has it's roots as early as the 17^{th} century, the fact that muscle contractions can be recorded with the help of electrical activity was not discovered till 1849. **Electromyography is a technique that measures a particular muscle's response / movement and converts it into electrical pulses to perform a particular function.**

In the early 20^{th} century this concept was too erratic and inaccurate to drive any tasks with the help of muscle movements due to lack of ways to detect muscle movements. All of this changed in the 1980s when electrodes were introduced for this specific purpose and technology developed to a point where powerful filters and instrumentation amplifiers were developed which would be used in the future to build the EMG Signal Control Wheelchair.

1.1 About the project

Our project mainly focuses on capitalizing on whatever restricted muscle movement is possible and using that motion as a means to move the wheelchair. This topic was chosen as our project after significant planning and research to ensure that it's incorporation can be done on a practical basis. EMG controlled wheelchair provides an alternative to joystick controlled wheelchair and is technologically simple to use.

We have made use of powerful and precise DC motors and an efficient electronic system and batteries. We can customize our wheelchair according to the user's requirements. A fool-proof code has been written with basic logic and certain emergency features have also been included in the event of some mishap. We are also open to trying to accommodate any additional features related to the specific requirement of the patient.

1.2 Aim and Scope of the project

1.2.1 Aim

- This project aims to alleviate the problems of movement for physically challenged people.
- We also aim make use of EMG Signals to reduce the effort needed to operate the wheelchair.
- Because many of the wheelchair users may be elderly, we plan to keep it simple and minimize the use of technological equipment as much as possible.
- We look forward to highlight the benefits of Electromyography and its broad future scope.

1.2.2 Scope

- From this report, you will be able to understand the background of Electromyography and the need for this wheelchair.
- We have included some information from the research paper which we referred which acted as our source of references.
- The logic which we applied is thoroughly explained along which each building block of the signal acquisition system and other connections.
- The software simulation and the practical hardware results obtained are included for easy understanding of our implementation.
- Finally, the future scope of the project and the knowledge we obtained while working on the project is mentioned for laying the foundation for future work in this area.

1.3 Differences with respect to modern technology

The present day technology assisted wheelchairs are more inclined towards being incorporated with EEG signal control capabilities. EEG is a technique which is used to measure electrical activity of the brain by placing electrodes on top of the head (or scalp) in contrast with EMG, which mainly tracks electrical impulses due to muscle activities. EEG may seem more accurate than EMG, but Electromyographic signals are much less complex to understand and interpret and the end cost of the product is relatively less. EEG on the other hand, requires most sophisticated technology and quite precise op-amps due to the feeble nature of such signals.

1.4 Features of the wheelchair

- The wheelchair is implemented with electrodes and muscle sensors which sense the twitching of the muscles.
- The wheelchair will be in a permanent state of braking unless explicitly initiated by the user.
- Our wheelchair has an innovative wheel design wherein the front wheel is connected to two secondary small wheels which drives the front wheel.
- These small wheels are connected directly to motor shaft. This apparatus reduces motor torque and prevents the wheelchair for toppling
- The wheelchair has been incorporated with an emergency stop or switching functionality so that any accomplice or the user himself can press the switch in case of any malfunctions.
- The batteries used to power the wheelchair have a long-lasting life and are rechargeable. Hence, the wheelchair can be used as much as required.

CHAPTER - 2
REVIEW OF LITERATURE

2.1 General Research - EMG signal physiology

- EMG signal is generated by the electrical activity of the muscle fibres which are active during contraction.
- Skeletal muscles are made up by motor units which are basically the atomic unit of a muscle.
- The fibres of the motor unit work in synchronization with one another.
- The output derived from muscle movement is basically the culmination of repeated contraction and relaxation of several motor units.
- Level of contraction of muscles can be controlled by two methods – **spatial recruitment and temporal recruitment.**
- Spatial recruitment refers to the increase in signal strength with increase in the number of motor units.
- Temporal recruitment refers to the increase in frequency of action by each motor unit to increase the strength of muscle contraction.

2.1 Surface EMG Electrode positioning

- To obtain a clear surface EMG signal recording, we must ensure that the position of surface electrodes is relatively far from the tendons and bones.
- In this subtopic, we investigate the location where electrodes can be present to be able to gather high-quality information about EMG signals based on two wrist movements – extension and flexion [3].
- Based on the above research, we find that the most optimized electrode position is situated on the forearm.
- Surface EMG (SEMG) can be used to detect muscle activities and diagnose nerve compression or injury.
- In this research, two healthy young men without any kind of neural injuries were taken as subjects to check electrode positions over **flexor carpi radialis (FCR)** and **extensor carpi radiallis (ECR)** for flexion and relaxation of the wrists [3].

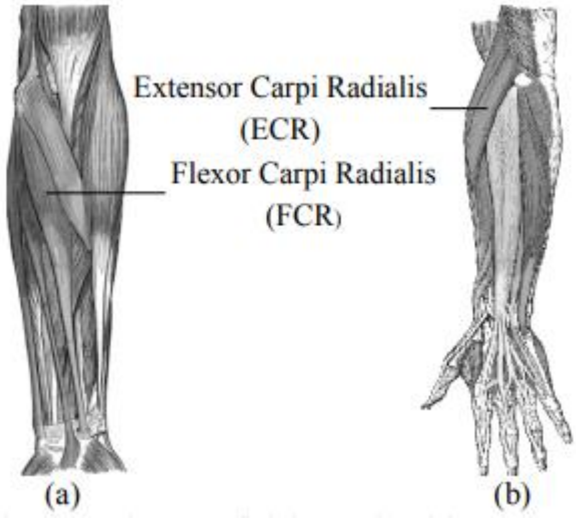


Fig 2.1: Location of FCR and ECR muscle on the forearm

- Many such subjects were taken and various positions were tested with respect to ECR and FCR keeping the bony elbow part as the ground terminal [3].
- The distance between wrist and electrodes measured for each subject was found to be dependent to the length of the forearm of the subject.
- Hence, the distance between the two non-ground terminals was measured to provide an estimate about the strength of the muscle signal received.
- SEMG signals of FCR and ECR muscles were sampled at 4 KHz in a single differential mode [3].
- The derived signal was filtered with a Butterworth band pass filter with a cut-off frequency of about 50Hz -500Hz [3].
- According to the results, there was significant difference between ideal electrode position depending on the method of analysis – quantitative and qualitative [3].
- The observed norm for getting highly accurate EMG signals is to fix the wrist flexion position at 90% of the forearm length aver FCR and 90% of the forearm length through ECR [3].

2.2 EMG Signal processing analysis

- Precision instrumentation amplifiers are required to amplify EMG signal due to the small range of the signal received [4].
- This requires careful selection of gain value to avoid any kind of information signal

loss in the later stages of signal processing.

- The most vital step in signal processing is the removal of disturbances due to noise.
- Full wave rectifier helps in rectifying the signal to make it suitable for microprocessor processing.
- An additional final stage signal amplification is necessary to raise the signal value to the standard operating voltage range of the microprocessor [4].
- Lastly, an ADC is used to convert analog signal into digital to be able to perform various tasks through the microprocessor [4].

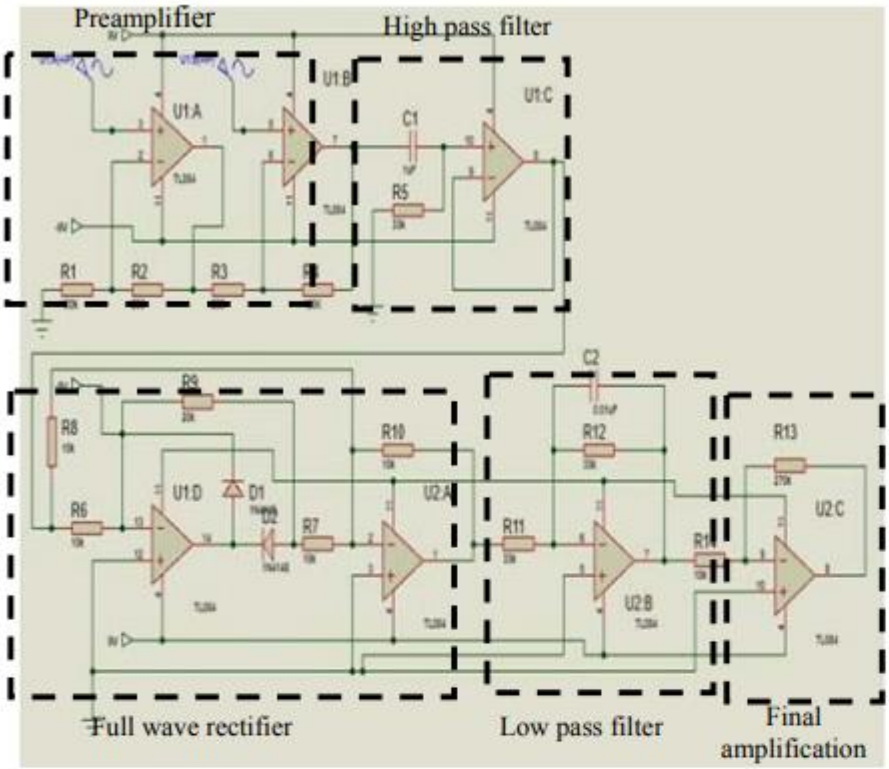


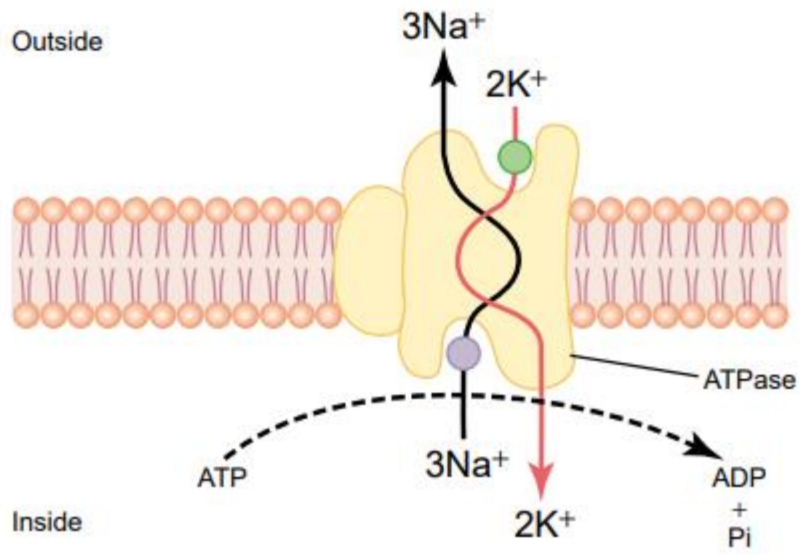
Fig 2.2: The stages of EMG signal acquisition circuit

- **Pre – Amplifier:** Input value for both amplifiers is set a particular value for a specific frequency. Due to the feeble nature of the input value, a high gain value is required to get sufficient signal strength at the output.
- **High Pass Filter:** High pass filters are used to eliminate DC offset in the system [4]. The frequency value is set in such a way that even when offset voltage is added to ensure the functioning of high pass filter, the overall offset voltage remains 0 [4].

- **Rectification:** A full-wave precision rectifier is used for EMG signal rectification. This is because this rectifier provides accuracy in measurement of small signal and the rectification from positive to negative cycle is achieved without affecting the signal information [4].
- **Low-pass filter and final amplification:** After the rectification process, low-pass filter and final amplification is required to enhance the information of the signal. Low-pass filter is also useful to smoothen any signal fluctuations [4]**.**

2.3 Sodium – Potassium Pump

- A large concentration of a substance may be required inside the cell of a human body even though only small ion concentration is present outside the cell in case of potassium (K^+) ions [2].
- Contrastingly, low concentration in the fluid inside the cell and high concentration in the fluid outside is required in the case of sodium (Na^+) ions [2].
- This process takes place in the form of active transport, which pertains to the travel of ions against the flow of electric or pressure gradient.
- Sodium – Potassium (Na – K) pump is a transport process which is used to pump potassium ions from outside to inside of a cell while performing the reverse process in the case of sodium ions [2].
- This is done to maintain the potential difference between sodium and potassium ion concentration and have negative electrical cell voltage [2].
- Na – K pump is used for controlling the cell volume.
- Due to higher permeability of sodium ions in relation to cell membrane, 3 sodium ions exit the cell while 2 potassium ions enter it [2].
- Hence, a negative electrical potential is created across the cell membrane which depicts the electrogenic tendency of the Na –K pump [2].
- This electrical potential plays a pivotal role in nerve and muscle fibres used for signal transmission and is the logic behind the signals recorded for operating EMG signal controlled wheelchair [2].



2.3: Pictorial depiction of mechanism of Sodium – Potassium pump

CHAPTER - 3

SYSTEM MODEL / ARCHITECTURE

3.1 Explanation of the code

```
#define BLYNK_TEMPLATE_ID "TMPLTzUwc1KR"
#define BLYNK_TEMPLATE_NAME "EMG Wheelchair"
#define BLYNK_AUTH_TOKEN "yM1LFR7bOkuEKAqaOxAUdXNhFyGIEeq-"
char auth[] = "yM1LFR7bOkuEKAqaOxAUdXNhFyGIEeq-";

#include <WiFi.h>
#include <WiFiClient.h>
#include <BlynkSimpleEsp32.h>
WiFiClient  client;

// Motor Control variables-DO NOT CHANGE
const unsigned int Motor_PWM_Freq = 30000;
const unsigned int MRight_PWM_Channel = 0;
const unsigned int MLeft_PWM_Channel = 1;
const unsigned int Motor_PWM_Resolution = 8; // 0 to 255 for 8 bits
unsigned int Motor_PWM_DutyCycle = 150;
const int del = 1000; //to calculate the difference of the delay between the left and right emg
unsigned long previousMillis = 0;
unsigned long currentMillis = 0;
bool EMG_L = 0;
bool EMG_R = 0;
```

All the motor control variables like Channels and Resolution are listed in the above section of code along with the delays and the time loop. We have taken PWM frequency as 30000 and different channels for each motor. The resolution and duty cycle of the PWM are also set to a particular value. Lastly, the status of signal received from the left or right hand is initially kept 0 and this is a Boolean variable, meaning it will fluctuate between 0 and 1 based on the signal.

```
//Pins-CAN CHANGE ONLY THIS
uint8_t MLeft_PIN = 32; // PWMA Pin Motor
```

```
uint8_t MRight_PIN = 33; // PWMB Pin Motor
const int EMG_Left = 5;//EMG input
const int EMG_Right = 18;//EMG input
```

In the above section of the code, the pin numbers of ESP32 are assigned to EMG input and PWM going to the motors. These parameters can be changed provided you change the same pins of the ESP32 on the hardware.

```
//Wifi settings
const char* ssid = "";   // your network SSID (name)
const char* pass = "";   // your network password

//Ultrasonic settings
#define echo 3
#define trig 2
long tym;
int dist;
```

We have set the variables and pins of the ultrasonic sensor in the above portion of the code. Here echo pin is found at pin 3 while trigger is given by pin 2.

```
void Motor_Control_Setup()
{
  ledcSetup(MLeft_PWM_Channel, Motor_PWM_Freq, Motor_PWM_Resolution);
  ledcSetup(MRight_PWM_Channel, Motor_PWM_Freq, Motor_PWM_Resolution);
  ledcAttachPin(MLeft_PIN, MLeft_PWM_Channel); ////GPIO32 //LED1_Pin// PWM_A
// Motor Control ClockWise // Attach the LED PWM Channel to the GPIO Pin
  ledcAttachPin(MRight_PIN, MRight_PWM_Channel); ////GPIO35 //LED2_Pin//
PWM_B // Motor Control ClockWise // Attach the LED PWM Channel to the GPIO Pin
  int flag = 0;//flag is odd it will move forward and if flag is even it will stop
}
```

In void Motor_Control_Setup, we are setting up motor control variables and attaching the

PWM channel to the GPIO pin. This is generally not tinkered with during the duration of the program unless we wish to make changes to the channel or any motor control variables.

```
//------------------------------------------------------Forward-----------------------------------------------

void Movement()
{
  Serial.println("Inside movement");
  if (flag % 2 == 1) {
    ledcWrite(MRight_PWM_Channel, 50);
    ledcWrite(MLeft_PWM_Channel, 50);
    Blynk.virtualWrite(V0, 50);
    Blynk.virtualWrite(V1, 50);
  }
  else {
    NoMovement();
  }
}
```

In the void movement function, flag variable is defined to decide movement. Here if this variable is 1 then movement occurs and a PWM value is fed to both channels of motors for forward movement. I flag variable is 0,then there is no movement.

```
//--------------------------------------------------------Right----------------------------------------------

void RightMovement()
{
  Serial.println("Inside right");
  ledcWrite(MRight_PWM_Channel, 0);
  ledcWrite(MLeft_PWM_Channel, 50);
  Blynk.virtualWrite(V0, 0);
  Blynk.virtualWrite(V1, 50);
  delay(500);
```

```
}

//----------------------------------------------------Left----------------------------------------------

void LeftMovement()
{
  Serial.println("Inside left");
  ledcWrite(MRight_PWM_Channel, 50);
  ledcWrite(MLeft_PWM_Channel, 0);
  Blynk.virtualWrite(V0, 50);
  Blynk.virtualWrite(V1, 0);
  delay(500);
}

//---------------------------------------------------No Motion------------------------------------------

void NoMovement()
{
  Serial.println("Inside none");
  ledcWrite(MRight_PWM_Channel, 0);
  ledcWrite(MLeft_PWM_Channel, 0);
  Blynk.virtualWrite(V0, 0);
  Blynk.virtualWrite(V1, 0);
}
```

Similar to the void movement function, we check the left motion, right motion and no motion and accordingly give PWM values to the concerned channels.

```
//---------------------------------------------------Check Distance--------------------------------------

int checkdist() {
  digitalWrite(trig, LOW); // Clears the trig Pin condition
  delay(10);
```

```
  digitalWrite(trig, HIGH); //activates the trig Pin
  delay(10);
  digitalWrite(trig, LOW); //deactivates the trig Pin
  tym = pulseIn(echo, HIGH); // Calculating the distance
  dist = (tym * 0.034) / 2; // Speed of sound wave divided by 2
  return dist;
}
```

The above section of the code is basically for the ultrasonic sensor to check the distance of the obstacle from the wheelchair. We release alternate high and low ultrasound waves from the trigger pin for 10ms each through digitalWrite and the echo pin is inputted with the time duration of the pulse to return to the sensor. Hence, distance is found with the help of simple distance = velocity*time where time is divided by 2 to negate the return duration.

```
//---------------------------------------------------------Setup-------------------------------------------

void setup() {
  WiFi.mode(WIFI_STA);
  Blynk.begin(auth, ssid, pass);
  Serial.begin(115200);
  pinMode(trig, OUTPUT);
  pinMode(echo, INPUT);
  // initialize digital pin LED_BUILTIN as an output.
  pinMode(MLeft_PIN, OUTPUT);
  pinMode(MRight_PIN, OUTPUT);
  Motor_Control_Setup();
}
```

The void setup function assigns the baud rate and defines the pins of the ESP32 as either input or input according to the function of its connected component.

```
//----------------------------------------------------------Loop------------------------------------------
```

```
void loop()
{
  Blynk.run();
  int i = 0;
  if (WiFi.status() != WL_CONNECTED) {
    Serial.print("Attempting to connect");
    while (WiFi.status() != WL_CONNECTED) {
      WiFi.begin(ssid, pass);
      delay(5000);
    }
    Serial.println("\nConnected.");
  }
  while (i <= 5) { //get accurate inputs
    bool prevEMG_L = digitalRead(EMG_Left);
    bool prevEMG_R = digitalRead(EMG_Right);
    delay(100);
    EMG_L = digitalRead(EMG_Left);
    EMG_R = digitalRead(EMG_Right);
    if (EMG_L != prevEMG_L || EMG_R != prevEMG_R) {
      prevEMG_L = EMG_L;
      prevEMG_R = EMG_R;
    }
    else {
      break;
    }
    i++;
  }
  //for proper input delays, find the optimal delay
  //Test with dummy values--- EMG_L =0; EMG_R =0;

  bool res = EMG_L ^ EMG_R;

  //put ultrasonic here
```

```
 while
 if (res == 1) {
    if (EMG_L == 1) {
      Serial.println("Left");
      if (checkdist() >= 1.5) {
        LeftMovement();
      }
    }
    else {
      Serial.println("Right");
      if (checkdist() >= 1.5) {
        RightMovement();
      }
    }
  }

  else {
    flagp = flag;
    if (EMG_R == 1 && EMG_L == 1) {
      flag++;
    }
    if (flagp != flag) {
      Serial.println("Movement");
      Movement();
    }
    else {
      Serial.println("No reading");
      NoMovement();
    }
  }
}
}
```

We apply EXOR logic inside the loop function where we signal received through the EMG module and whether the EXOR of the signal received from both hands is 1 or not. If the signal is 1 then we check which hand was twitching and accordingly move in that direction. If the EXOR value is 0 then we check whether both hands were twitching which indicates forward movement else there is no motion desired. But here even if EXOR is 1, we check whether the wheelchair is close to an obstacle. If it is within 1.5m, then the wheelchair should still not move. A flag is introduced if EXOR is 0 and both EMG_L and EMG_R is 1. If this flag is changed only then movement should occur else no reading should be considered.

3.2 Torque Calculations

3.2.1 Torque exerted on flat surface

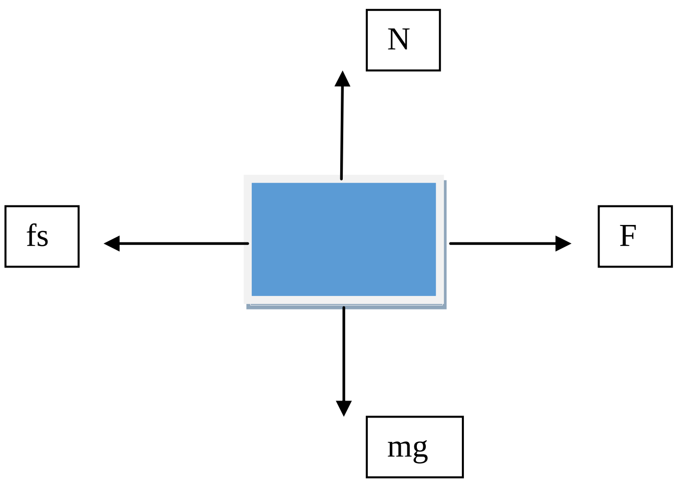


Fig 3.1: Forces exerted by a body on a flat surface

In Fig 3.1, N = normal force (in Newton (N))

Fs = static frictional force (in Newton (N))

m = mass (in Kilograms (kg))

g = acceleration due to gravity (in m/s^2)

μ = static coefficient of friction

From Fig 3.1, it is clear that,

$N = mg$ eq (i)

$fs = \mu N$ eq (ii)

Putting eq (i) in eq (ii), we get,

$fs = \mu(mg)$

Here, we take $\mu = 0.008$ as the ground surface is assumed to be smooth.

m = Mass of wheelchair + Maximum mass of user

We are assuming the weight of wheelchair as 20 kg and the maximum weight of user allowed as 100 kg.

Hence, m = 20 + 100 = 120 kg

The value of g is always 9.8 m/s^2.

$fs = (0.008)(120)(9.8) = (0.008)(1176)$

fs = 9.408 N

We assume Velocity (V) = 5kmph = 1.389 m/s

Acceleration of the wheelchair (a) = (v – u)/t where we assume that the velocity is reached from 0 to 5 in 2 seconds.

$a = (1.389 - 0)/2 = 0.7\ m/s^2$

$F = ma = (120)(0.7)$

F = 84 N

Let radius of the wheel (r) be 0.3 m

Torque (τ) = F.r = (84)(0.3)

τ = 25.2 Nm for both motors

τ = 25.2/2 =12.6 Nm

Hence the torque required is 12.6 Nm for single motor on a flat surface.

Angular frequency (ω) = v/r = 1.389/0.3 = 4.63 rad

$P = \tau.\omega = (12.6)(4.63) = 58.34$ W

P = 58.34 W

Hence the power required is 58.34 W for single motor on a flat surface.

3.2.2 Torque exerted on an inclined surface

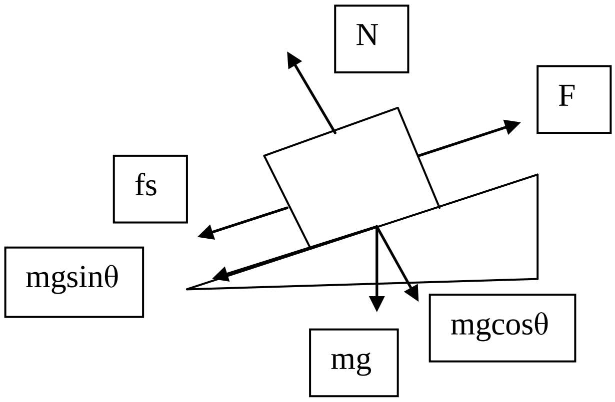


Fig 3.2: Forces exerted by a body on an inclined surface

In fig 3.2, θ is the angle between the horizontal line and the incline of the plane.

All the other parameter values are same as in the first case.

From fig 3.2 we infer that,

$F > fs + mg\sin\theta$ eq (i)

$N = mg\cos\theta$ eq (ii)

$fs = \mu N$ eq (iii)

Putting eq (ii) in eq (iii) we get,

$fs = \mu(mg\cos\theta) = \mu mg\cos\theta$

$\mathbf{fs = \mu mg\cos\theta}$

Putting value of fs in eq (i) we get,

$F > \mu mg\cos\theta + mg\sin\theta$

$F > (0.008)(120)(9.8)\cos(7.4^0) + (120)(9.8)\sin(7.4^0)$

$F > 151.46 + 9.329$

F > 160.789 N

We are considering the value of F = 165N.

Torque (τ) = F.r = (165)(0.3)

τ = 49.5 Nm for both motors

τ = 49.5/2 = 24.75 Nm

Hence the torque required is 24.75 Nm for single motor on an inclined surface.

Angular frequency (ω) = v/r = 1.389/0.3 = 4.63 rad

P = τ.ω = (24.75)(4.63) = 114.59 W

P = 114.59 W

Hence the power required is 114.59 W for single motor on an inclined surface.

Because inclined surface consume more torque and power for vehicular motion, the power and torque value of these surfaces are examined while searching for the optimum motor to drive the wheelchair.

3.3 Signal Acquisition Circuit simulation Model

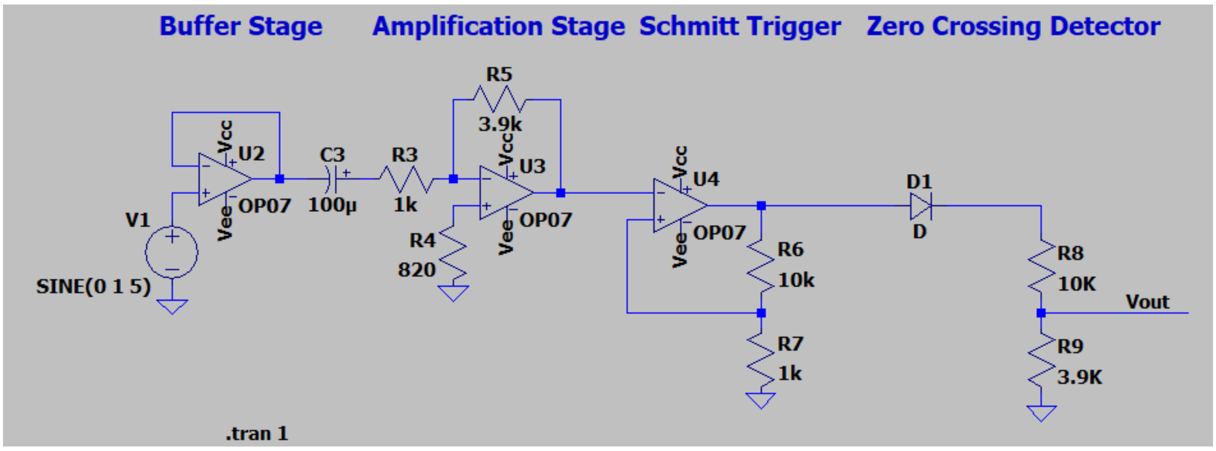


Fig 3.3: Signal Acquisition circuit simulation model on LTSpice

To simulate the signal acquisition circuitry, we have made use of the LTSpice software. LTSpice is a very popular schematic capture tool which can be used as a high-performance SPICE simulation program app and as a waveform viewer with enhancements and models for the easy simulation for analog circuits. We have used version XVII of the software.

We deliberated a lot on what operational amplifier we should use in our circuit and after comparing the parameters of some common operational amplifiers from their datasheets, we find that op-amp OP07 is best suited for biomedical application, as is the case with this wheelchair. This is due to the fact that, as can be observed from table 3.1, op07 has low input offset voltage along with a high CMRR. This means that signal can be measured more accurately and with less noise and low power dissipation. Having a lower slew rate does not matter in our application as we are not dealing with time critical information.

Parameter	**μA 741C [9]**	**TL 084C [10]**	**OP 07C [8]**
Open Loop voltage gain Av	200V/mV	200V/mV	**400V/mV**
Input Resistance Ri	2 MΩ	**1 GΩ**	33 MΩ
Output Resistance Ro	75Ω	-	60 Ω
Input offset voltage Vio	1 – 6mV	3 – 15mV	**60μV**
Common Mode Rejection Ratio CMRR	70 dB	86 dB	**120dB**
Input bias current IiB	80nA	**30pA**	1.8nA
Unity Gain Bandwidth	1MHz	**3MHz**	0.6MHz
Slew Rate	0.5V/μs	**13V/μs**	0.3V/μs
Power Dissipation PDmax	85mW	680mW	**80mW**

Table 3.1: Comparing values for different parameters of operational amplifiers

There are four main stages in our signal acquisition circuit as shown in fig 3.3. These are explained in detail below:

Stage 1: Buffer Stage

Buffer is basically a circuit with High input impedance and Low output impedance along with unity gain. The buffer output stage mirrors the input stage. It is generally used to isolate input from the output. Hence, it is useful in the case of noise interference. We have given the input signal to the non-inverting pin of the op-amp and its output is fed back to the inverting terminal to provide gain value of 1.

Stage 2: Amplification Stage

Here we have taken the inverting configuration of the op-amp where the input comes from the output of the first stage through the capacitor and into the inverting terminal of the op-amp whereas the non-inverting terminal is grounded. Here, we can set a particular gain to get a signal with higher amplitude because the signal perceived by stage 1 may be weak.

Stage 3: Schmitt Trigger

Schmitt trigger basically transforms the signal based on whether the signal value is above a particular threshold or not. In our case, we have set a value of 250 mV. If a gain of 4 is given in the previous stage then this value can go up to 1 V. This helps to segregate the intended signals from the false inputs. It is a resistor divider circuit on the output terminal of the op-amp, the result of which is fed back into the non-inverting op-amp terminal.

Stage 4: Zero Crossing detector

Zero crossing detector is one of the simplest circuits in electronics where the output is low when the input crosses from positive to negative but low when input crosses from negative to positive. The diode is added before the circuit just to clip of the negative part of the signal. The signal hence got as the output of this stage in the final output of the signal acquisition circuitry.

3.4 System Connection

- The electric potential which is derived from the difference between two electrodes connected to the muscles is converted to an analog signal using the signal acquisition circuit.
- This analog signal is fed to the ESP32 microcontroller which converts the analog signal into PWM pulses. The duty cycle of the PWM pulses can be changed from the code for speed modulation.
- The PWM signal is supplied to the motor driver which moves the motor at a particular speed and direction.
- Now, as the shaft to which the motor connected rotates, the small wheel connected to the shaft rotates, which in turn moves the larger wheel to which the smaller wheel is connected, in the opposite direction, facilitating motion of the wheelchair.
- ESP32 is also connected with the ultrasonic sensor, which is programmed to detect obstacle within a particular range and accordingly stop the wheelchair.
- Lastly, switches are connected to the batteries and the motors so that, during emergencies, the supply to the batteries can be cut off and the motors cease to run.

3.5 PCB Design in Kicad

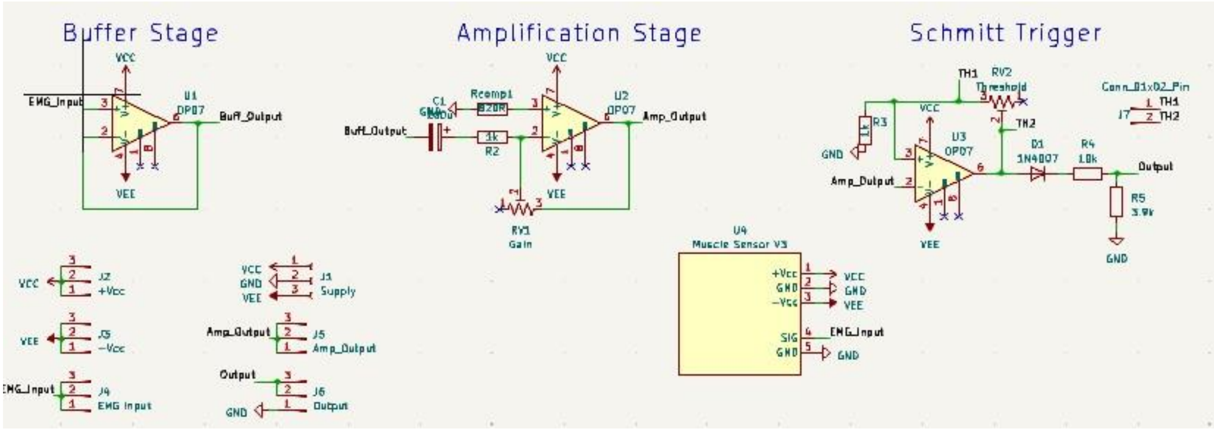


Fig 3.4: The design of the signal acquisition circuit on Kicad

We have designed the circuitry shown in figure 3.4 on Kicad software to list all the components required for the signal acquisition circuit (SAC) on a printed circuit board (PCB). This decision is important to prevent noise interferences from disturbing the accuracy of the system. We perform annotations and electrical rules check to verify the correctness of the system. Then, component footprints are selected where we have chosen dip (Dual –inline package) for the operational amplifiers but smd (surface mounted) resistors which gives improved reliability and performance.

After we have selected the footprints of each component (usually the lowest carbon footprint is preferred), the components are placed in the available printed circuit board area in such a way that the routing of wires in the board culminates in low number of vias and each connection is completed properly. Then, the whole board is given a ground plane and any mistakes in routing and placing the components are searched for. Finally, the PCB layout can be provided for fabrication either to professional manufacturers or the whole fabrication process can be completed by us manually.

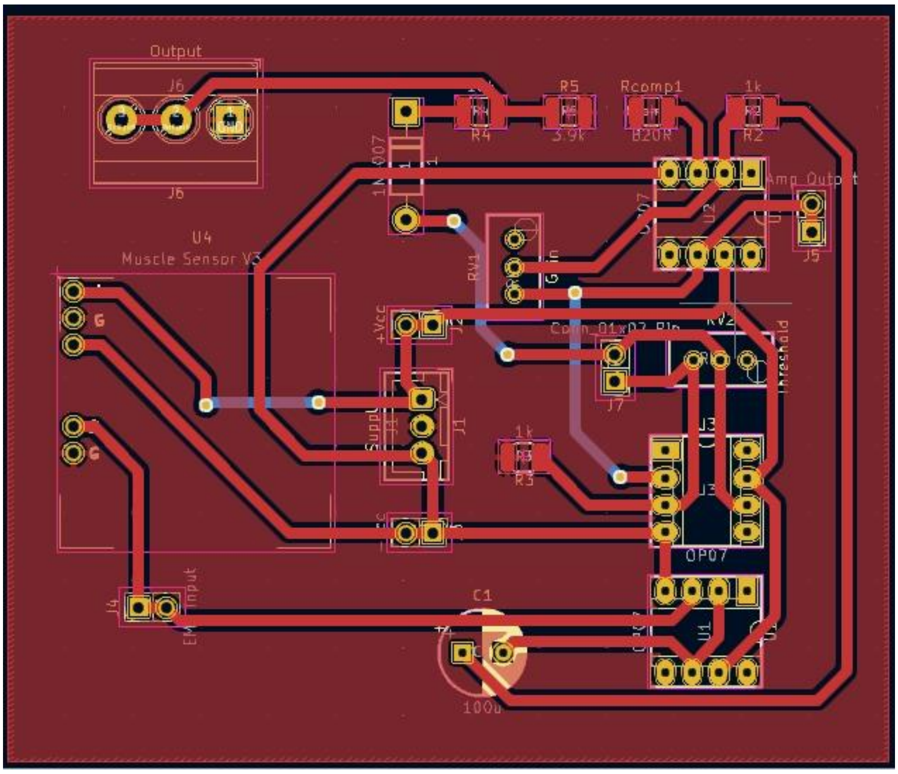


Fig 3.5: Routing of wires in our SAC PCB

CHAPTER - 4

SYSTEM IMPLEMENTATION

4.1 Method

- Literature Survey was performed regarding Electromyography and to ascertain our approach regarding control electronics.
- Simulation was implemented to check the workability of different modules. The Successful simulation of our model was confirmed and favorable output was achieved.
- Torque and current calculations were carried out to estimate the specifications of the motor and other circuit components required. Project material was bought according to this calculation at the lowest cost possible.
- All these modules were integrated to check the circuit physically on the breadboard. The workability of the individual modules was tested with the help of a DSO (Digital Signal Oscilloscope).
- This was replicated on the general purpose board and tested successfully. The soldered components were checked for continuity and any unintended shorting was eradicated.
- Simultaneously, a logical code and custom made wheelchair were being developed. The wheelchair was fabricated out of wood and made out of scratch to be able to freely accommodate additional features.
- The motors and drivers were first connected to dummy motors. After confirming that both are working properly, we tested them with the electronics and then incorporated the apparatus into the wheelchair.
- The EMG Controlled wheelchair was checked with all its components for its workability. It perfectly works as intended according to the code fed in ESP 32 microcontroller for a particular time period and PWM.
- After confirming that the basic prototype of the wheelchair was running perfectly, we added additional safety features to the circuit such as emergency stop button to stop the motor externally and ultrasonic sensor for collision detection and immediate action against the same.

4.2 Building Blocks

4.2.1 EMG Muscle sensor V3.0 module

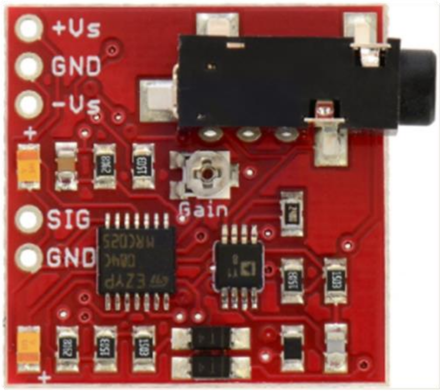


Fig 4.1: EMG Muscle sensor V3.0 module

- The module senses the muscle twitches of the person and converts the voltage potential into an analog signal at its output.
- Positive and negative reference voltage along with two power supplies is required.
- The sensor has a maximum operating voltage of ±18 V but it is not recommended to reach that value to minimize the risk of an electric shock [5].
- A supply of ± 3.5V - ± 5V is sufficient to extract good performance from the muscle sensor [5].
- The module contains filters and instrumentation amplifiers in it in order to purify the signal sensed and provide an almost disturbance-free signal.
- From fig 4.1, +Vs and –Vs are the voltage supply pins which we are going to give +12V and -12V respectively.
- There are two ground pins provided which can be used individually or shorted together.
- The signal pin is from where we receive the analog signal with respect to the potential sensed by the module.
- This module can easily be integrated into a breadboard for general use. [5]
- Lastly, there is a small screw like structure mounted on the sensor which controls the gain of the signal. This can be varied according to the requirement of the user.

4.2.2 ESP 32 Development board

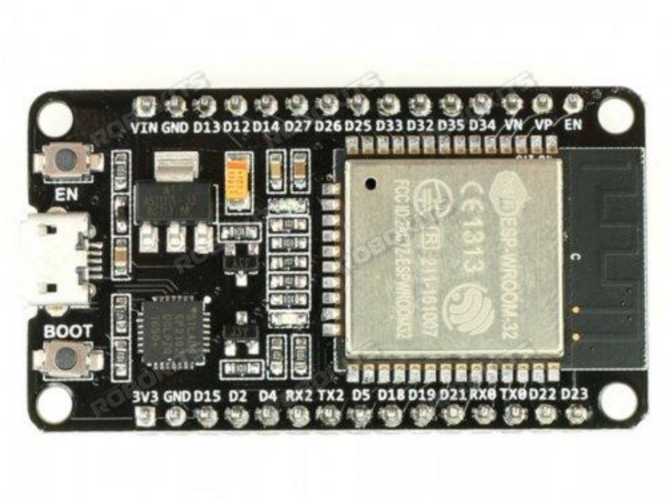


Fig 4.2: ESP 32 Development board

- ESP32 is a low-cost, low-powered system on chip (SOC) integrated microcontroller with WIFI and bluetooth capabilities [6].
- It has a single or dual-core 32 bit processor with a range of clock frequencies [6].
- More importantly, it has PWM compatibility which is very important for our application where we need to convert the analog signal from signal acquisition circuit into a PWM signal to be able to drive the wheelchair [6].
- This microcontroller can be called as the brain of our implementation because every change in the wheelchair direction or speed is conveyed by the ESP32 to the motor.
- We are using pin 19 and pin 33 for supplying PWM pulses to the motor and pin 18 and pin 35 to receive the input from the signal acquisition circuit.
- Ground is always required and voltage supply pin of the ESP32 is provided voltage either through a power bank or a laptop port.
- ESP 32 also contain low noise receive amplifiers, filters and power management modules.
- Lastly, it has a boot button on the board itself, we can come in handy in case of any irregularities regarding the functioning of the wheelchair during testing phase.

4.2.3 Ultrasonic sensor HCSR04

Fig 4.3: Ultrasonic sensor HCSR04

- Ultrasonic sensor is a very useful component which can detect any obstacle inside a particular range the alerts the user about the same.
- The sensor works on a DC voltage of +5V and throws 8 cycle bursts of ultrasound at 40 KHz frequency [7].
- The range of HCSR04 ultrasonic sensor is between 2cm – 4m which is perfect for our application [7].
- If there is any object in its path, then an echo is received by the sensor.
- The time period between the release of ultrasound and the detection of echo is noted. Using this we can find the distance of the obstacle from the ultrasonic sensor.
- Distance of object = velocity (340 m/s^2) * (time/2) [7].
- Hence, avoiding or stopping action can be performed depending on the distance calculated by the above formula.
- 1^{st} and 4^{th} pin of the sensor are obviously the supply voltage (+5V) and ground respectively.
- The 2^{nd} pin, which is the trigger pin, is the one which controls the ultrasound signal emitted by the sensor.
- Pin 3, which is the echo pin, receives back the signal emitted and keeps track of the time taken to do the same, which can then be used to calculate the distance from the obstacle.

4.2.4 Surface EMG Electrodes

There are three major types of electrodes which can be used for EMG signal acquisition:

1) Needle Electrodes
2) Fine Wire Electrodes
3) Surface EMG Electrodes

Needle Electrodes

They provide an invasive technique for measurement and detection of EMG signals. Here, Tip of the needle electrodes, which is bare, is used as a detection surface [1]. However these electrodes are generally painful for the user and a medical supervisor is required in case of any difficulties [1]. They are widely used in clinical procedures in the evaluation of neuromuscular issues [1].

Fine Wire Electrodes

Fine wire Electrodes are very useful for accuracy whenever muscles are located deeper in the body or are covered by other superficial muscles. It also provides an invasive form of detection of EMG signals. Surface Electrodes are not preferred when deep muscles are concerned due to crosstalk from neighboring muscle layers. Fine wire technique is strongly recommended for prolonged investigation of muscle fibre movement.

Surface EMG Electrodes

In these types of electrodes, a chemical equilibrium is formed between the skin and the electrode, hence current is able to pass through a conducting electrolyte [1]. This is a non-invasive way of EMG signal detection and they do not require any medical help on standby and are very simple to implement. However, they do have limitations, as in, they are used for superficial muscles only and crosstalk can become an issue.

There are two types of surface EMG electrodes:

Gelled EMG Electrodes: They contain a gelled electrolytic substance, mostly Silver – Silver Chloride (Ag –AgCl) and can be both disposable as well as reusable.

Dry EMG Electrodes: They do not require a gel interface between skin and electrode. Bar electrodes and array electrodes are two types of dry electrodes. The electrode must be attached with stability on the skin.

Gelled electrodes have provision for employing pre – amplification circuits. Also, dry electrodes are much heavier and have increased inertial mass which may cause electrode fixation problems. For stability, gelled electrodes are preferred over dry electrodes.

After considering the costs involved, the effect of the electrodes on the human body and the location where the electrodes will be placed, we determined that **Gelled Surface EMG Electrodes** would be the best choice with the point of view of this project. These electrodes are available at any chemist's shop and provide good accuracy in muscle sensing for a non – invasive sensor.

4.4: Gelled Surface EMG Electrodes

4.2.4 Other Components

Fig 4.5: Lithium Ion polymer battery

There are two batteries which we have used to power our apparatus. The bigger one shown in Fig 4.8 is Lithium Ion (Li) polymer battery. It is connected in a 2S configuration and has a rating of 8V, 16Ah. It is used in our circuit to operate the motor. The smaller one depicted in fig 4.9 is the Lithium Iron Phospate ($LiFePO_4$) battery. It is connected in a 4S configuration and has a rating of 12V, 4Ah. Two of these batteries are used to power the signal acquisition circuit for each hand. Two different types of batteries are used due to the different voltage requirements for different subsystems.

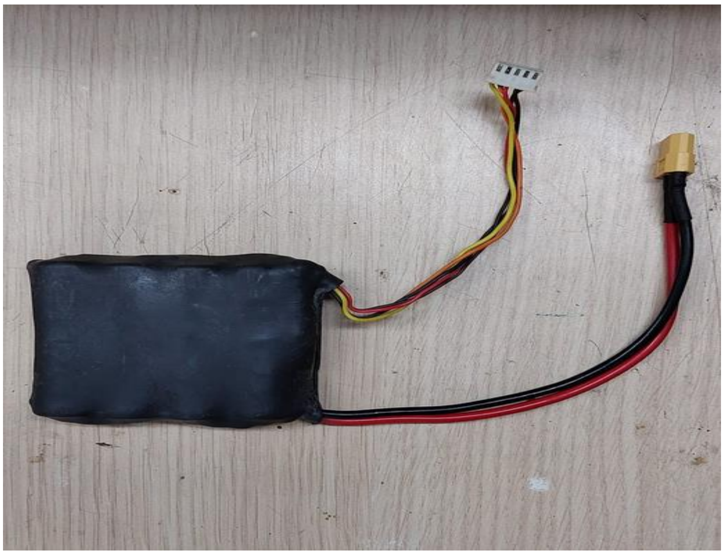


Fig 4.6: Lithium Iron Phosphate battery

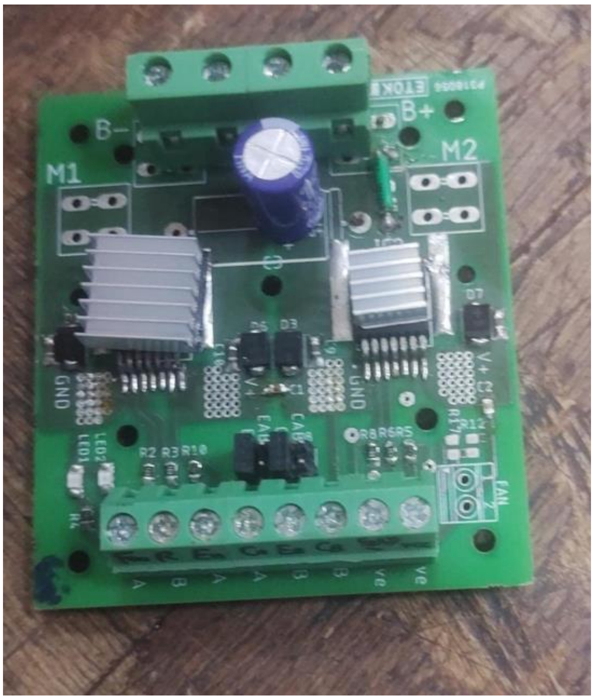


Fig 4.7: BTN 7960 Motor Driver

We can see from fig 4.10, the driver used to operate the motors. We are using two BTN 7960 drivers to drive both the motors independently. This driver is completely capable of carrying the load of the wheelchair as it has a maximum current capacity of 40A.

Also, bicycle motor MY 1016Z2 were used to facilitate left and right motion respectively. They were selected on the basis of torque calculation having rated torque on 24 Nm, 250 W of power capacity and 360 rpm speed.

4.3 Battery Life Calculation

Battery life = Capacity / Consumption × (1 - Discharge safety) [11]

Where, Capacity = battery capacity in Ampere-hour (Ah) [11]

Consumption = Average current drawn by device(s) in amperes (A) [11]

Discharge safety = Percentage of battery capacity that is never used to ensure safety of the battery [11]

For Li – Ion Polymer (LiPo) battery

Capacity = 16Ah

Consumption = 14A – for both motors

Assuming Discharge safety = 30%

Battery life = (16 / 14) × (1 – 0.3) = 0.8 hrs = 48 minutes

Battery life for the bigger Li – Ion Polymer battery will be 48 minutes if the battery is used continuously and sufficient discharged safety is kept.

For Lithium Iron Phosphate ($LiFePO_4$) battery

Capacity = 4Ah

Consumption = 1A – for electronic circuitry

Assuming Discharge safety = 30%

Battery life = (4 / 1) × (1 – 0.3) = 2.8 hrs = 2 hrs 48 minutes

Battery life for both Lithium Iron Phosphate batteries will be 2hr 48 minutes if the batteries are used continuously and sufficient discharged safety is kept.

4.4 Results

Fig 4.8: The prototype of the designed wheelchair

After completing literary research and simulation, we started to customize the wheelchair out of wood. A back wheel of 12 inches was chosen along with a support wheel of 3 inches to reduce the torque, hence preventing wheelchair from toppling. A low center of gravity was chosen and the front wheels were kept as free wheels for manual manoeuvrability.

Simultaneously, we built and started testing our acquisition circuit with muscle sensor module and dummy motors. We got the output successfully as shown in fig 4.12

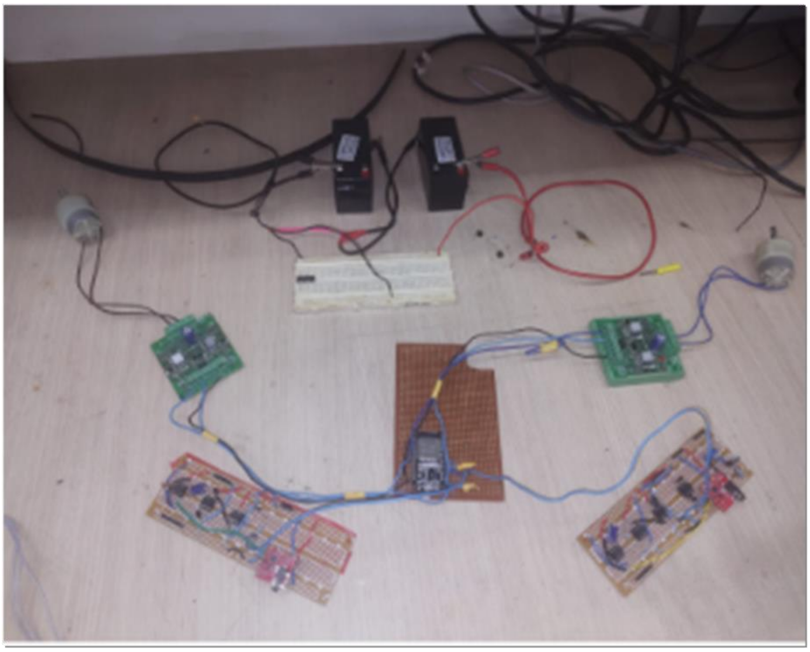


Fig 4.9: Testing the signal acquisition circuit with dummy motors

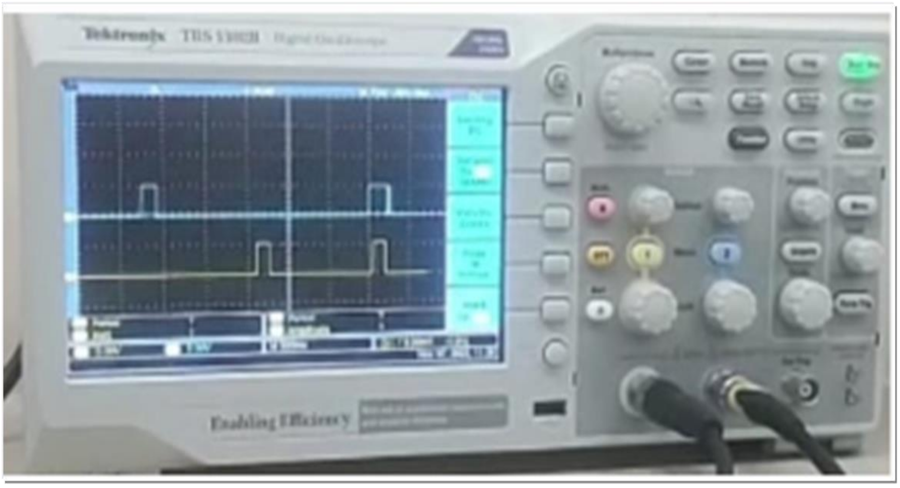


Fig 4.10: Electric pulse output obtained from the EMG module

Fig 4.11: Motor hosted inside the wheelchair

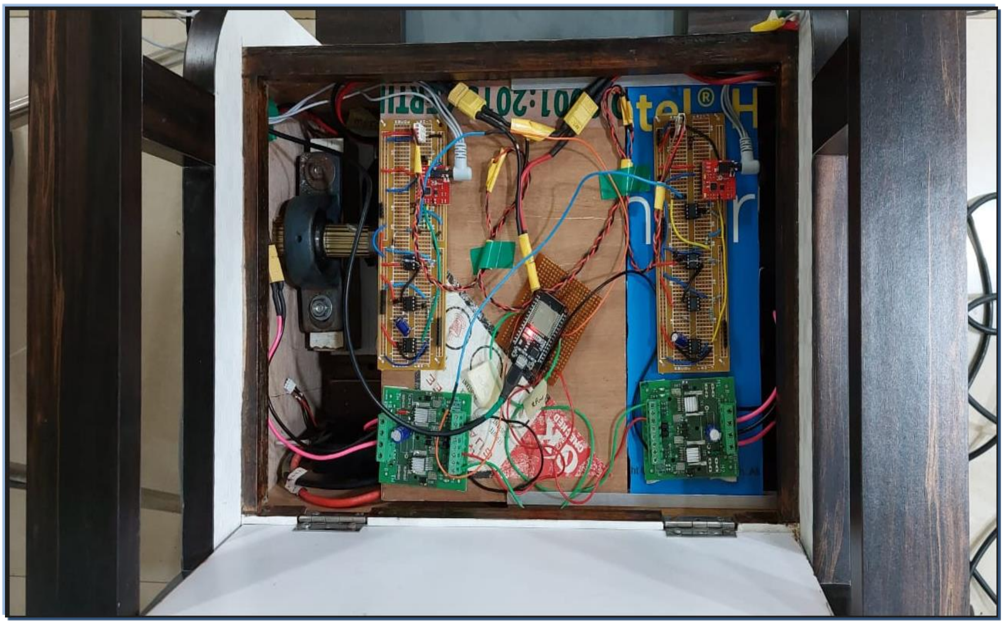


Fig 4.12: Electronic Circuitry present inside the wheelchair

Fig 4.14 shows how the bicycle motors were fitted inside the wheelchair enclosure with the help of wooden shafts. Fig 4.15 shows the perfectly working electronic circuitry and its placement inside the wheelchair. We have made a makeshift wire arrangement where one wire is split into two and connected with end connectors for the microcontroller to command the motors to move.

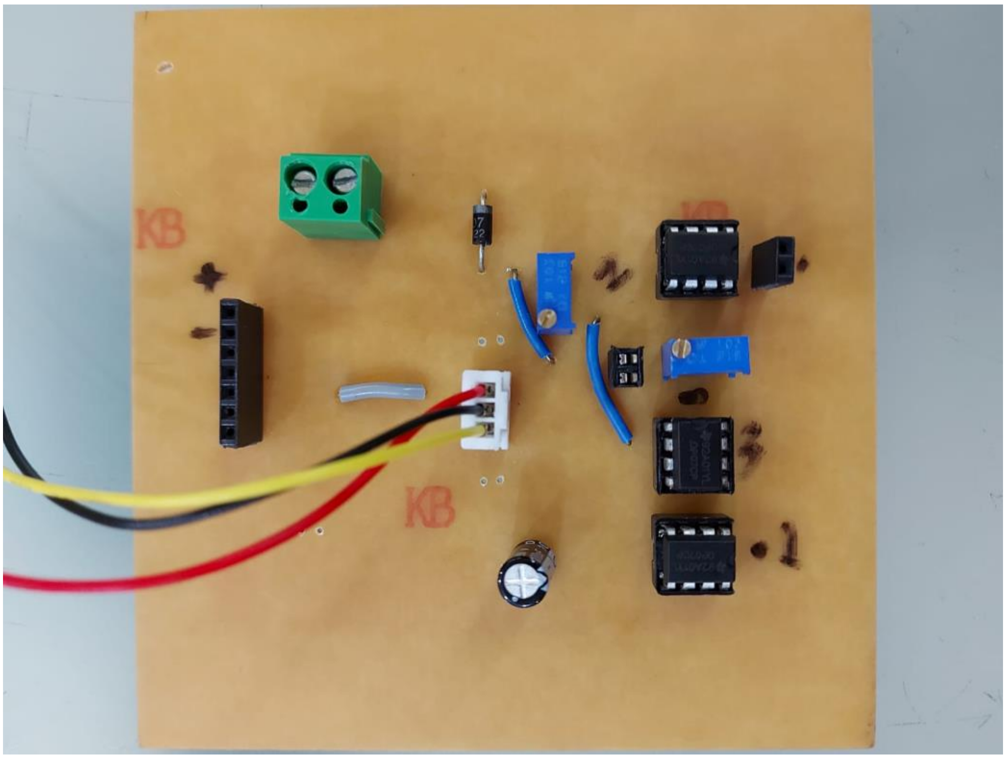


Fig 4.13: Incorporating Signal Acquisition circuit on a Printed Circuit board

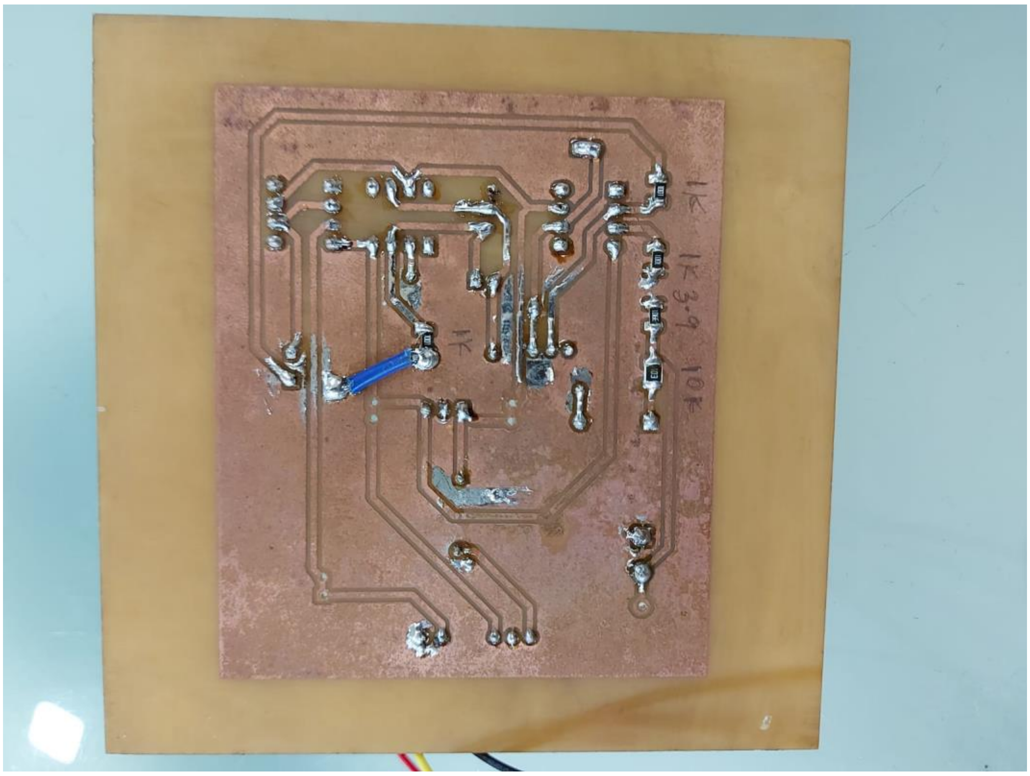


Fig 4.14: The routing and soldering part of the PCB

Though alright for initial testing phase, we found out that the arrangement in Fig 4.15 has major crosstalk issues and hard reset problem. To fix that, we decided to reduce the wiring and hence designed a self-made PCB of the signal acquisition circuit.

This self-made PCB was checked first by providing sinusoidal signal by the DSO. This provided a clean output and accurate as depicted by fig 4.18. After this success, we tested the PCB with the muscle sensor v3 module and saw a largely accurate wave whenever the muscle twitch was measured above the threshold level as shown in fig 4.19 and 4.20.

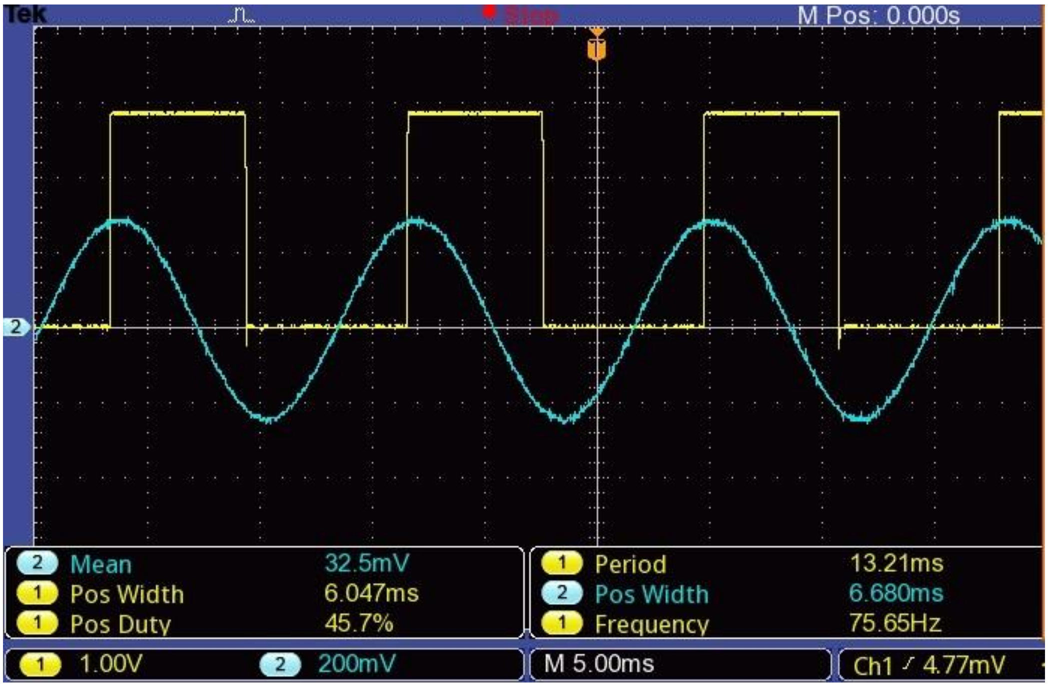


Fig 4.15: The output signal of signal acquisition circuit when sinusoidal wave is given as input

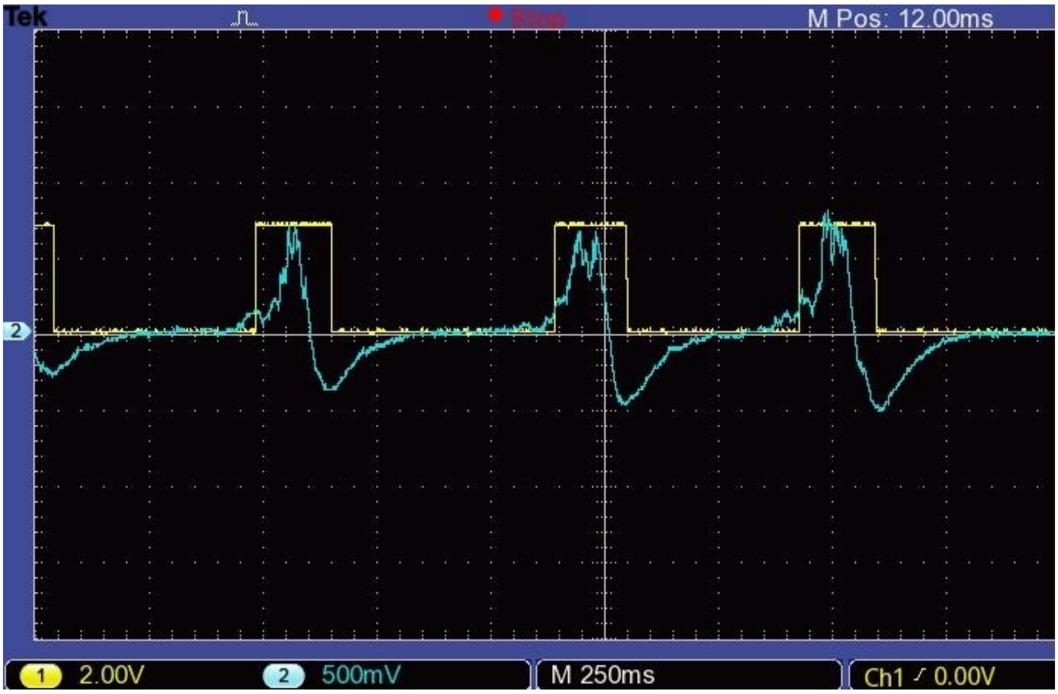


Fig 4.16: The output signal of signal acquisition circuit with muscle input to EMG module

Fig 4.17: Another scale for fig 4.16

After the basic functionality was completed with expected results, we put our efforts in making the wheelchair more fool-proof and safe of the user and hence, this switch was drilled into the side of the wheelchair as seen in fig 4.21. This switch is basically to turn on and off the wheelchair. So, basically, the wheelchair will take the muscle signal from the user only when this switch is on.

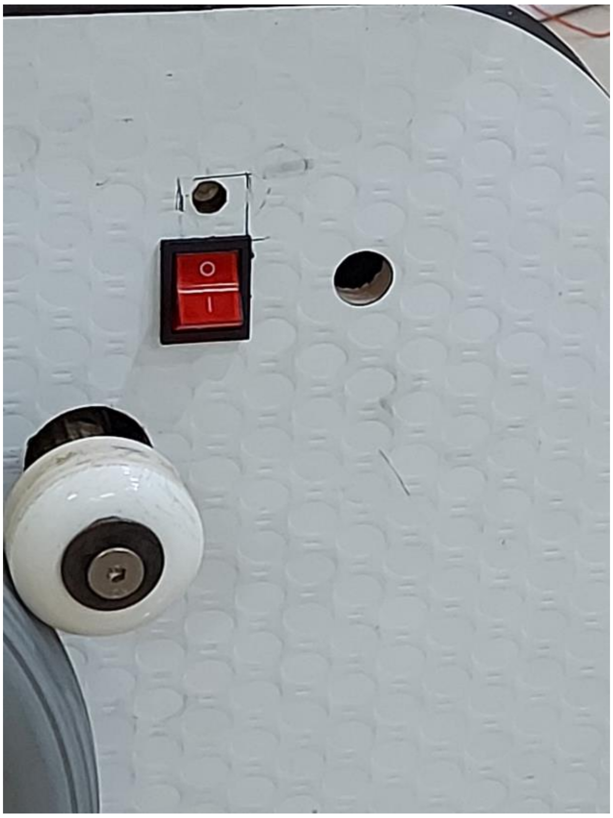


Fig 4.18: Switch added for on – off function

A push button has been screwed into the front of the wheelchair as shown in fig 4.22 for the purpose of emergency stop. This immediately ceases of the power supply to the motors. This button can be pushed by the user if possible, or by an external companion or caretaker. Lastly, we have fitted an ultrasonic sensor also, at the front of the wheelchair as can be seen in fig 4.23. This sensor checks for any obstacle and hindrance and warns the microcontroller which stops the wheelchair if the obstacle is near enough.

Fig 4.19: Push button for emergency stop function

Fig 4.20: Ultrasonic sensor for collision prevention

CHAPTER – 5

CONCLUSION AND FUTURE SCOPE

5.1 Conclusion

When we decided to build an EMG Controlled wheelchair, we referred to a bunch of research papers so as to find some ideas on how to approach our objective. Based on that, a signal acquisition circuit was designed on LTSpice simulation software. After verifying the output of this virtual system, the components required for the circuitry were assembled. This also included the motor drivers, DC motors as well as the batteries. Sufficient torque and current calculation was carried out regarding the same.

The wheelchair was customized and made completely out of wood which allows scope for modifications to the wheelchair if required. The signal acquisition circuitry was designed and tested practically and its connection was made to the motor and its drivers through the microcontroller ESP32. A simple code of operation was fed to the microcontroller and the wheelchair was checked successfully for workability. A soft start circuit and a voltage regulator were also created by us but we decided against using them in our circuit.

We had some issues with accuracy of detecting the EMG signals which we tried to minimize as much as possible. Also, provisions were made to include kill switches and stop buttons in case of emergencies. Ultrasonic sensor was also easily incorporated into the wheelchair for the function of collision detection. All of these features were necessary to improve the overall quality and precision of our wheelchair as much as possible.

From the above mentioned activities we can conclude that:

- EMG signal controlled wheelchair has been able to alleviate the problems faced by people with physical disabilities.
- Testing of the signal acquisition circuit and the wheelchair connections as a whole should be performed regularly to detect any errors at the initial stage only.
- Due to the difference in the ability to twitch muscles in every patient, the threshold set for detecting EMG signals should be as low as possible.
- Self-designed PCBs are needed to operate as signal acquisition circuitry due to the fact that the original circuitry had many clustered components and wire which lead to noise interference and inaccuracy in acquisition of signal.

- Safety measures like push buttons and ultrasonic sensors are necessary to combat the physical shortcomings of the user.
- There can be some people who do not have any functionality in either their upper limb or lower limb and are paralyzed. Such users cannot be accommodated in an EMG Controlled wheelchair.
- Even though we have done our utmost to create a fully operable wheelchair prototype, there can still be some additions or improvements which can be incorporated into the wheelchair in the future.

5.2 Future Scope

As mentioned before, this EMG Controlled Wheelchair has much scope for improvement in the future. Some of the ideas that can be feasibly implemented are listed below:

- Signal processing can be applied to be able to control the wheelchair with the fingers of a single hand. This increases the target audience or people who can use the wheelchair.
- Our wheelchair cannot be driven on a rough surface or on a steep incline. However, this can be possible with powerful motors and customized wheels.
- It can also be possible in the next stage to try to get the wheelchair to climb up and down the stairs on the discretion of the user.
- We have found that the best location to place the electrodes is on the forearm but for some people with, let's say, neck-down paralysis, this might not work. Hence, recording EMG signals from the neck movement can be explored.
- Lastly, the weight of the wheelchair is on the higher side due to it being made up of wood. This can be tried to solve by using a lighter material. Also, in such a case, even the cost of the wheelchair will decrease.

CHAPTER – 6

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CHAPTER - 7

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Also, a big round of applause must go to all the **lab assistants** and **non-teaching faculty** of the Electronics department for helping us procure any material if needed, from college and giving us ample space and freedom to do our work.

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Neel Karia

Rohit Joshi

Yash Khanolkar

CHAPTER – 8
PLAGIARISM REPORT

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